

Technical Note - 6155/02

Project Title:	Proposed Residential Development, Mill Road, Bevis Green, Bury				
Client:	Barratt Homes Manchester				
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Title:	Security Screen Design				
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1.0 Introduction

- 1.1 This *Technical Note* has been prepared by Cole Easdon Consultants Limited (CEC) on behalf of Barratt Homes Manchester, to set out the parameters used and the design process followed in relation to the design of a security screen to be located at the upstream end of 2.7m wide and 1.5m high precast concrete culvert at the approved development site. The culvert is to be located at the downstream end of an approved 300m reach of new watercourse within the site.
- 1.2 The design has followed guidance as set out within the document entitled *Culvert, Screen and Outfall Manual (C786)* published by CIRIA in 2019.
- 1.3 This *Technical Note* outlines how the development proposals can be satisfactorily accommodated as per guidance provided within the National Planning Policy Framework (NPPF) and Bury Council's drainage requirements.
- 1.4 Barratt Homes have determined that, whilst a debris screen is not required, a security screen is needed. This Technical Note is therefore based on the security screen design requirements as set out in C786.

2.0 Hydraulic Design Process

- 2.1 The security screen design has followed the process below as set out within C786:
- Step 1 - Initial screen sizing & outline design.
 - Step 2 - Blockage Design.
 - Step 3 - Design for Safety & Maintenance.

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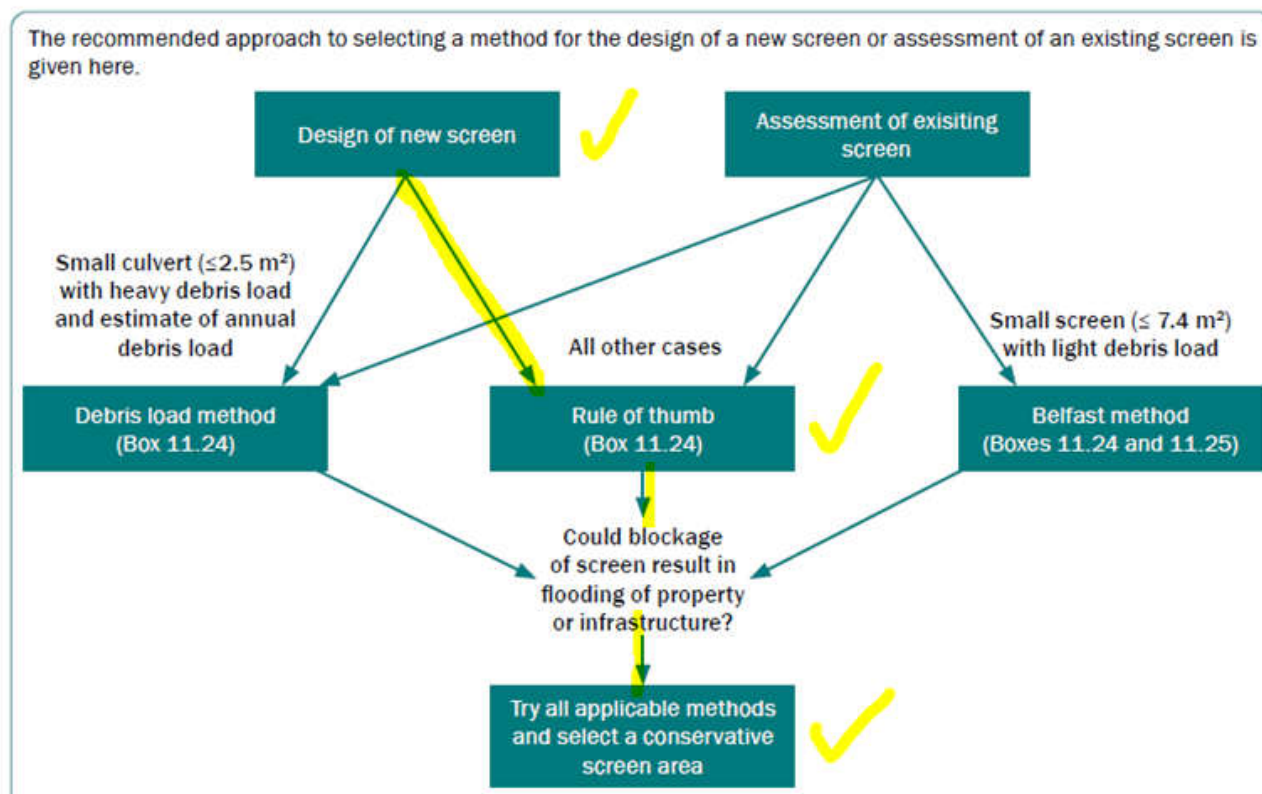
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Initial Screen Sizing & Outline Design

2.2 The design process outlined in Box 11.24 (from C786) has been followed. 'Rule of Thumb' has been used to design the screen. As such the following principles have been used to guide the design:

- Minimum bar spacings and sizes have been considered that are appropriate for a security screen.
- Minimum effective screen area = 4 x culvert cross sectional area (with 150mm bar spacing).
- Blocked Area: If the effective screen area is less than or equal to 4 x culvert cross sectional area then the blocked area should be the larger of 3 x culvert cross sectional area or 75% of the security screen area.

Box 11.24 Effective screen area and blocked area



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Method	Rule of thumb ✓	Debris load method (NRA, 1992)	Belfast method (Wallerstein and Arthur, 2012)
Recommended applications	Design of new screens or assessment of existing screens	Design of new screens or assessment of existing screens Small culverts (up to 2.5 m ²) with heavy debris load and an estimate of annual debris load	Assessment of existing screens only Only for small screens (up to 7.4 m ²) on small watercourses with light debris load (see Box 11.25)
Minimum effective screen area (m ²)	$A_s \geq N A_o$ (11.46) Recommended multiplier N is a minimum of 3 for debris screens with bar centre-to-centre spacing > 150 mm and a minimum of 4 for security screens with 150mm bar spacing.	For debris load < 30 m ³ /year, use the larger of 4 A_o or 6 m ² For debris load 30 to 60 m ³ /year, use the larger of 7 A_o or 9 m ² For debris load > 60 m ³ /year, use the larger of 9 A_o or 12 m ²	Not applicable
Maximum effective screen area (m ²)	$A_s \leq 30 A_o$ (11.47)	$A_s \leq 30 A_o$ (11.47)	Not applicable
Blocked area (m ²)	If effective screen area is less than or equal to the minimum requirement above: $A_{sb} = \text{larger of } 2 A_o \text{ or } 67\% A_s \text{ (debris screen) or larger of } 3 A_o \text{ or } 75\% A_s \text{ (security screen)}$ (11.48) If effective screen area is significantly larger than the minimum requirement above: $A_{sb} = 50\% A_s \text{ (debris screen) or } 67\% A_s \text{ (security screen)}$ (11.49)		For debris or security screen, use $A_{sb(\text{raw})}$ multiplied by a factor of 1 to 4.5 (see Box 11.25). If blocked area is considerably lower than predicted by the rule of thumb, then revert to the rule of thumb.

where

A_s = effective screen area (m²) (excluding areas above water level and working platforms)

A_o = cross-sectional area of culvert or outfall barrel (m²)

A_{sb} = blocked area (m²)

N = multiplier (see above)

Blockage Design

- 2.3 Once the initial sizing had been completed, the selected screen size was tested for the following blockage scenarios:
- Permanent Blockage + Permeable Blockage with the blocked screen area being the larger of 3 x culvert cross sectional area or 75% of the security screen area. Method 1 (C786) was followed.
 - Permanent blockage + a 50% permeable blinding blockage of Screen 1 area (sloping screen). Method 2 (C786) was followed.

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iii) Permanent blockage + a 50% permeable choking blockage of Screen 1 area (sloping screen). Method 3 (C786) was followed.

2.4 Each method calculates the water level upstream of the screen as a result of blockage extent and type. The blockage assessments were undertaken to ensure that the screen does not increase upstream water level to an unacceptable level (ie above 141mAOD top of bank level).

Permanent Blockage + Permeable Blockage (Method 1)

2.5 Equations used:

Box 11.27 Head loss due to expansion and contraction

Headwater elevation upstream of the screen is given by:

$$H_s = H_n + h_{ex} \quad (11.52)$$

and

$$h_{ex} = \frac{1.5}{2g} \left(\frac{Q}{W_s y} \right)^2 \left(\frac{1}{s^2} - 1 \right) \quad (11.53)$$

where

H_s = headwater elevation upstream of screen (m)

H_n = water elevation immediately downstream of screen (m) (typically culvert headwater elevation, unless there is a drop in bed level between the screen and culvert inlet)

h_{ex} = head loss due to expansion and contraction (m)

Q = discharge (m³/s)

W_s = total width of screen (m)

y = depth of flow immediately downstream of screen (m) (typically culvert headwater, unless there is a drop in bed level between the screen and culvert inlet)

s = opening ratio (the opening area relative to the screen area (-))

The opening ratio is:

$$s = (1 - r)(1 - b) \quad (11.54)$$

where

r = ratio between bar thickness and centre-to-centre bar spacing (permanent blockage) (%)

b = degree of variable (permeable) blockage (%) (see [Section 11.6.3](#))

An alternative equation for partially blocked screens is available for screens that are triangular in plan with the apex pointing towards the approach flow (Zayed et al, 2018), but note that zero blockage gives zero head loss.

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Permanent blockage + a 50% permeable blinding blockage (Method 2)

2.6 Equations used:

Box 11.22 Weir equation

The depth of flow over an obstruction (embankment or screen blinding/pseudo-weir) for flow type 6 (modular weir flow) and flow type 7 (submerged weir flow) is given by the broad-crested weir equation:

$$y_1 = \left(\frac{Q_w}{C_w B f} \right)^{2/3} \quad (11.41)$$

where

y_1 = upstream flow depth (m)

Q_w = discharge over embankment (m^3/s)

C_w = discharge coefficient for weir flow (-)

B = width of crest (perpendicular to flow direction) (m)

f = submergence correction factor

The discharge coefficient C_w is typically 1.44 to 1.7 for International System of Units (SI) metric units, with lower values for less efficient spills such as embankments with vegetation or uneven crests or where the flow is overflowing the channel banks. It varies with weir geometry and upstream head. Further advice is given in BS 3680:1990. Note that the discharge coefficient is unit-specific and values in guidance written for cusec/feet units need converting.

If the downstream water level exceeds the crest level of the obstruction, a submergence correction factor may be needed. Check for submerged flow by calculating the submergence ratio (see [Figure 11.18](#)):

$$S = \frac{y_2}{y_1} \quad (11.42)$$

where

y_2 = downstream water depth above crest level (m)

y_1 = upstream water depth above crest level (m)

If $S < 0.75$, flow is modular (ie passes through critical depth) and submergence correction factor is 1.0.

If $0.75 < S < 0.95$, the weir is submerged (ie downstream water level exceeds the critical depth over the weir), and submergence correction factor should be calculated (see table).

If $S > 0.95$, the weir is drowned (see [Box 11.23](#)).

Submergence correction factor can be estimated using the equations shown in the table, or [Figure A7.7](#).

Box 11.28 Weir flow plus expansion and contraction

Headwater elevation upstream of a blinded screen (see [Figure 11.21](#)) is:

$$H_s = Z_{bl} + y_{bl} + h_{ex} \quad (11.56)$$

where

H_s = headwater elevation upstream of screen (m)

Z_{bl} = crest elevation of blinding (pseudo-weir) (m)

y_{bl} = depth of flow over blinding (pseudo-weir), calculated for effective width (excluding the width occupied by any bars) (m) (see [Box 11.22](#))

h_{ex} = head loss due to expansion and contraction around permanent blockage (see [Box 11.27](#)), calculated for the flow depth over the blinding (m) ([Box 11.22](#))

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Permanent blockage + a 50% choking blockage (Method 3)

2.7 Equations used:

Box 11.29 Headwater due to orifice flow

Headwater elevation upstream of a screen acting as a free flowing orifice (see Figure 11.22) is:

$$H_s = Z_{or} + h_{or} \quad (11.57)$$

where

H_s = headwater elevation upstream of screen (m)

Z_{or} = elevation of centroid of orifice (m)

h_{or} = head required to drive flow through orifice (m) (see Box 11.21)

Headwater elevation upstream of a screen acting as a submerged orifice (see Figure 11.23) is:

$$H_s = H_h + h_{or} \quad (11.58)$$

where

H_h = water elevation immediately downstream of screen (m)

3.0 Hydraulic Design

Initial Screen Sizing & Outline Design

Design Parameters

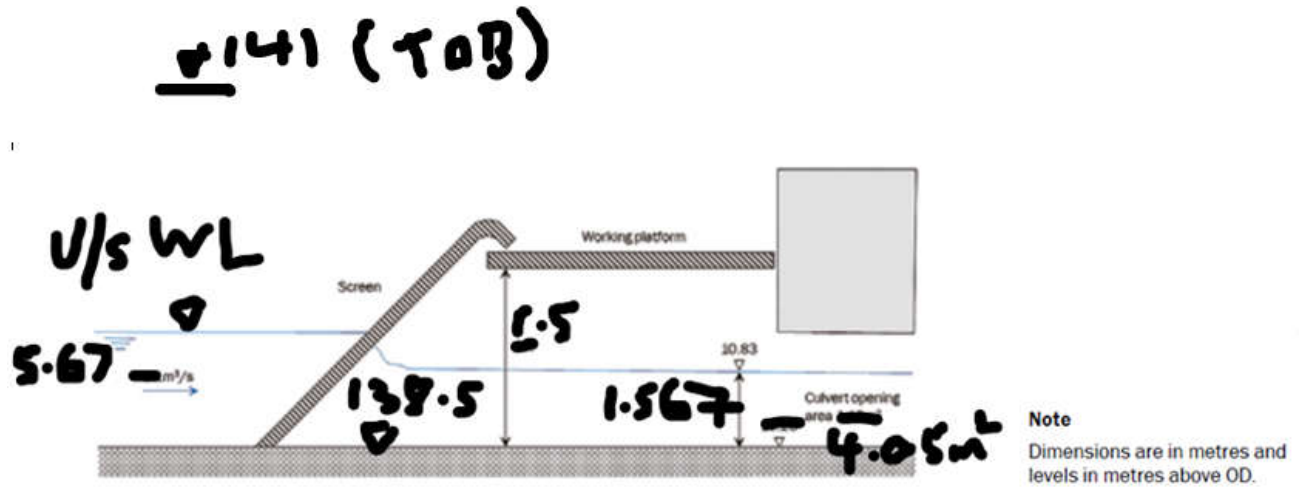
3.1 The following parameters have been used in all design iterations:

Design Parameter	Value
Design Storm	1:100 yr + 35% climate change event
Peak Flowrate	5.67m ³ /s (from hydraulic modelling)
Bed Level	138.5mAOD
Peak Water Depth upstream of screen (w/o screen)	1.567m (from hydraulic modelling)
Top of Bank	141mAOD
Culvert Size	2.7m wide x 1.5m deep
Bar Size	12mm
Bar spacing	150mm

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Screen Size

Design Parameter	Value
Culvert cross sectional area (2.7m x 1.5m)	4.05sqm
4 x Culvert cross sectional area	16.2sqm

Use twin screen arrangement:

Screen 1 (sloping screen at 45 degree to horizontal)

Screen 1 (Sloping Screen)	Value
Width (Av.)	4.45m
Height	1.7m
Screen area	7.57sqm
Sloping screen effective area (45 degrees)	10.70sqm

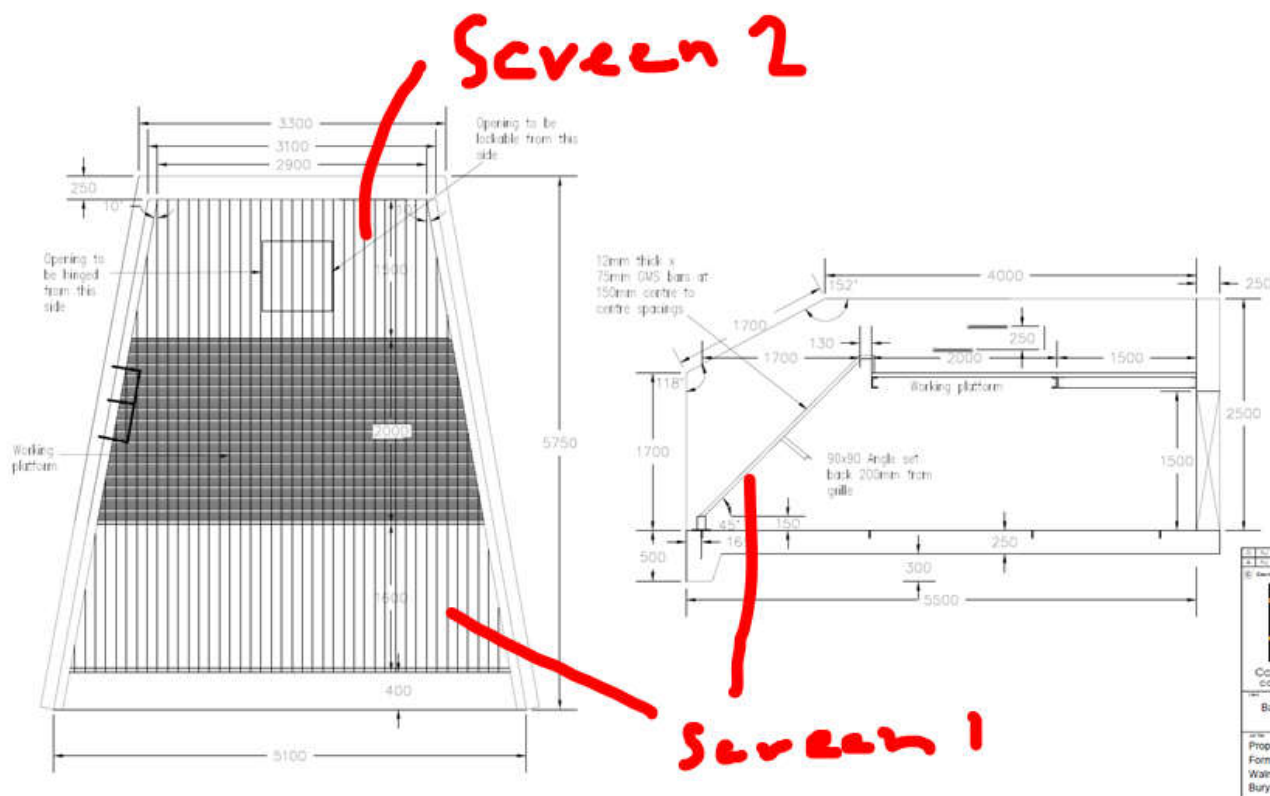
Screen 2 (Horizontal Screen)	Value
Width (Av.)	3.15m
Height	1.5m
Effective Screen area	4.73sqm

Total effective Screen Area = 10.70 + 4.73 = 15.42sqm (<4 x Culvert cross sectional area)

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Blockage Design

- 3.2 The effective screen area (15.42sqm) is less than 4 x culvert cross sectional area (16.2sqm) so the blocked area should be the larger of 3 x culvert cross sectional area or 75% of the security screen area:

3 x culvert cross section area:	$3 \times 4.05 = 12.15\text{sqm}$
75% of security screen area:	$0.75 \times 15.42 = 11.57\text{sqm}$
Blocked area = 12.15sqm = 79% of total effective screen area	

Permanent Blockage + Permeable Blockage (Method 1)

% Permeable Blockage	Blocked Screen 1 & 2 Area	Upstream Water Level due to Blocked Screen
0	0	140.070mAOD
50	7.71sqm	140.122mAOD
79	12.18sqm	140.447mAOD
85	13.11sqm	140.83mAOD

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- 3.3 For Method 1, all upstream water levels are less than top of bank level (141mAOD) so screen size and design is ok. Refer to Spreadsheet calculations enclosed with this *Technical Note*. For the 79% design blockage, flow is throttled as the remaining clear screen area (3.24sqm) is less than the culvert cross sectional area (4.05sqm) but despite this flooding does not occur.

Permanent blockage + a 50% permeable blinding blockage (Method 2)

% Permeable Blockage	Blocked Screen 1 Area (sqm)	Upstream Water Level due to Blocked Screen
50	5.35	140.421mAOD
75	8.03	140.846mAOD

- 3.4 Using Method 2, for blockages of Screen 1 up to 75%, no flooding occurs. For blockages greater than 75% flooding upstream of the screen may occur. However, in this situation the horizontal screen (Screen 2) will provide an alternative discharge point that will be adequate as the horizontal screen area is greater than the culvert cross sectional area (4.72sqm > 4.05sqm) so in reality throttling of flow and flooding will not occur. This is corroborated by the Method 1 results which demonstrate that for twin screens, no flooding will occur for up to 85% permeable blockage of the twin screen area.

Permanent blockage + a 50% choking blockage (Method 3)

% Permeable Blockage	Blocked Screen 1 Area (sqm)	Upstream Water Level due to Blocked Screen
50	5.35	141.075mAOD

- 3.5 For 50% choking of Screen 1 (sloping screen) some flooding upstream of the screen may occur. However, in this situation the horizontal screen (Screen 2) will provide an alternative discharge point that will be adequate as the horizontal screen area is greater than the culvert cross sectional area (4.72sqm > 4.05sqm) so throttling of flow and flooding will not occur. This is corroborated by the Method 1 results which demonstrate that for twin screens, no flooding will occur for up to 85% permeable blockage of the twin screen area. Furthermore, this type of blockage is not anticipated at the site.

4.0 Design For Safety & Maintenance

- 4.1 Screen design guidance for safety and maintenance is summarised in Tables 12.11 (Design Features to be considered), Table 12.12 (Design of Screen Bars) and Table 12.13 ('Safe by Design' Principles for Screen Maintenance) within C786. These are reproduced below and annotated accordingly. A tick besides each box indicates that the item has been considered or incorporated in the screen design.

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Table 12.11 Design features to be considered (after Environment Agency, 2016c)

List	Measure	Notes
Avoid these features	Horizontal bracing members	Can catch the tines of the rake and affect clearance of screen.
	Vertical bars	Vertical bars should generally be avoided on all screens, especially inlet screens as they reduce flow area and are difficult to clear of debris.
	Gaps between working platform and adjacent structure	Foot entrapment hazard for operatives.
	Vertical stanchions supporting structure (centrally placed)	Reduces channel capacity and creates debris-snagging point behind screen, which is difficult to clear.
Assess pros and cons of these features	Vertical stanchions supporting structure (non-central)	Reduces channel capacity and creates debris-snagging point behind screen, which is difficult to clear, but to a lesser degree than centrally-placed stanchions.
	Bottom of screen elevated above bed level	A site-specific design decision. Unless bracing is designed to be recessed, the bracing bar can catch the tines of the rake and makes clearance of screen difficult. Debris also catches on base plates.
	Screen bars tight to channel side	Reduces effective bar spacing at channel edge, also debris snags at channel edge and is difficult to rake.
	Ladder access into channel	Increased risk of slip, trips and falls from height, also unsafe to access during flood event. Consider provision of steps.
	Kickboards or bar returns (adjacent to working platform)	Trip hazard for operatives. Bar returns however can help with removal of debris.
Preferred features	Wider bar spacing	Maximises flow while maintaining protection from large debris, and reduces operational demand for clearance.
	Concrete access steps with handrail and anti-slip treads	Safer access to clear large items of debris and for maintenance. Reduces risk of slips, trips and falls from height. Aids safe access and egress if rescue of operatives or members of public required.
	Fixing screen flush to channel bed	Allows unimpeded raking, but prevents small debris being washed through the screen at low flows.
	Removable mid-guard rail on working platform	Allows safe removal of large items of debris while working from the platform.
	Chain link mid-rail	Allows safe removal of large items of debris while working from the platform.
	Twist-grip serrated working platform	Increases grip for safe operation in wet and slippery conditions.
	Two-stage screen	Allows screen length to be less than 2 m, making clearance easier. Increases screen area giving it greater capacity and easing operational demand.

✓
No vertical bars

No gaps

N/A

N/A

✓

N/A

N/A

150mm

✓ Considered / incorporated in design

✓

✓

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Table 12.12 Design of screen bars

Measure	Description
Bar spacing	Recommended centre-to-centre bar spacing for a screen is: - Maximum of 150 mm for a security screen (this equates to a 140 mm clear spacing between 10 mm bars) - Minimum of 300 mm for debris screens on small culverts, with either height or width up to 1.2 m - Minimum of 450 mm for debris screens on large culverts, with either height or width exceeding 1.2 m and less than 3.0 m For culverts with heights above 3.0 m and widths in excess of 3.0 m, an alternative spacing rule is to use one-quarter (25%) of the culvert width. The spacing should be rounded down to the nearest multiple of 150 mm, eg a 3.4 m wide and 3.0 m high culvert could have centre-to-centre bar spacing of $3.4 \text{ m}/4 = 0.85 \text{ m}$ which would be rounded to 0.75 m or 750 mm). Note that bar spacings of less than 450 mm should prevent man-made debris such as shopping trolleys (600 mm wide) and traffic cones (300 to 1000 mm wide at the base) entering the culvert. This modular approach to bar spacing (at multiples of 150 mm) allows the bar spacing to be increased or decreased by adding or removing bars, for example, in response to operational experience. Also, a security screen that was no longer needed could be modified to be a debris screen by removing every second or third bar (subject to a structural loading check). Conversely, if development became more intense around a culvert inlet and the safety risks to children increased, additional bars could be added to help convert a debris screen into a security screen (but note that additional screen area will probably be required). If screen bars for debris screens are to be more than 50 mm wide consideration should be given to have minimum bar spacing of 450 mm or multiples thereof. For coarse screens, the bar/pole spacing should be based on an assessment of the likely debris that needs to be trapped. The bar/pole spacing would typically be greater than one-quarter (25%) of the downstream culvert/bridge width with a maximum spacing between bars/poles of 3 m. Research shows that a screen with a debris length to bar spacing ratio of 2 will trap about 50% of larger debris pieces – a greater proportion of debris is trapped as the ratio increases (Wallerstein et al, 2013). On a culvert with an outlet screen the inlet screen should have a spacing no larger than the outlet screen spacing to avoid trapping debris that has passed through the inlet screen.
Bar dimensions	Screen bars must be sufficiently robust to withstand routine debris clearing (including by excavator bucket in an emergency) and possible vandalism, although narrow bars are preferable because of the reduced impact on hydraulic performance. Bar dimensions should not be less than 8 mm x 75 mm for flat bars. Generally, thicker bars of 10 mm or 12 mm are advisable to withstand debris loads and where mechanical cleaning is expected. Note that machine cleaning is becoming the norm to reduce manual handling risks and that even a manually raked screen may need to be mechanically raked in extremis. Attempting to save money by making the bars as slender as possible is a false economy.
Bar shape	Flat bars are preferred to round bars because they offer strength with minimal hydraulic impact. Rounding the upstream edges of the bars will improve hydraulic performance slightly 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.
Bar length and bracing	The length of bars should ideally be no more than 1.5 m with a maximum of 2.0 m to allow for manual raking. 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.
Bottom of bars	The bottom of the bar should be fixed to a horizontal member which 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 no more than 150 mm for a security screen. For debris screens a gap between bed and the bottom bars should be a location-specific design decision but should not be less than 150 mm.
Top of bars	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.
Lifting	Consideration needs to be given as to how the screen bars/bar panels (which are likely to be prefabricated off-site) are to be lifted into position (eg use modular components to limit weights, and include lifting eyes, check for stiffness). Consideration should also be given to making at least part of the screen liftable in an emergency (ie if it has become blocked and there is a need to relieve upstream flooding). Component sizes and weights should be recorded in BIM to make it simpler during asset management to create lifting plans and to plan repairs and maintenance.
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).
Vandalism	The screen and any associated equipment should be resistant to vandalism – if necessary the whole of the inlet structure should be fenced off to exclude vandals.

12mm x 75mm
bars specified

Sloping screen
= 2.4m

QMS
specified

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Table 12.13 'Safe by design' principles for screen maintenance

Measure	Description
Access to 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. Access gates and removable panels positioned to provide access to the required sections of the screen and aid debris removal. ✓ Fencing/hand railing provided to increase security and reduce the hazard associated with a potential fall into the channel. ✓ Access ramp, steps or ladder (in order of decreasing preference) to enable access to the main screen and the culvert in order to clear debris from the screen in routine/non-routine events, inspect the culvert, and respond to emergency or safety-related issues. ✓ Ramped access to all stages is preferable, giving wheelbarrow access and minimising manual handling.
Access to culvert	Consider the need for access to the rear (downstream side) of the screen and the culvert for periodic inspection. Provide lifting eyes, hinged access panels (which should be lockable) or access hatches in the working platform. ✓
Working platforms	Working platforms can be permeable to allow drainage and prevent ponding of water and should have a non-slip surface. ✓ If designing for manual raking, working platform depth (the distance between the upstream and downstream edges of the working space) should allow debris to be raked by moving from the front to the back of the working platform in comfort, and allow for some temporary storage of debris. Platform depth should be similar to the rake reach, typically 2.0 m or more. ✓
Storage of debris	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 outside of the main working area. This should be ramped if possible and be above design flood level and should allow for vehicular access for removal from site or to a holding area. Cleared screen debris needs to be stored temporarily in a holding area before transferring off-site. The storage area should be: - remote from the screen so there is no possibility of debris migrating back to the screen or watercourse - above likely flood level - located to make transfer from screen to storage straightforward for operatives. Providing a skip on site will minimise manual handling and allow immediate disposal with no double handling. 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. Ideally, debris should be removed from site as soon as possible, because stored material may be washed back in to the watercourse if water levels rise. A waste transfer licence is likely to apply for removal of the material from site. The capacity of the storage area should reflect the likely volume of debris in a non-routine event. This volume will have been estimated for the evaluation of potential debris load (see Box 11.24). It may be prudent to provide a safety margin, especially if events are frequent and transportation of debris away from the site is difficult.
Screen elevation	It should be possible for operatives to safely rake a screen 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). ✓
Screen width	Provide a sufficiently large screen to accommodate the debris load between cleaning, but avoid over-widening the watercourse as this can result in sedimentation around or behind the screen and deceleration of flow, which will encourage debris build-up. ✓

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Angle of screen	Angle of screen bars on inlet screens should preferably be 45 degrees and no steeper than 60 degrees to the horizontal. Angles shallower than 45 degrees can result in a working platform that becomes submerged in debris and unsafe during high flows. Angles steeper than 60 degrees present a high manual handling risk. Angles can be shallower for coarse screens or outlet screens provided they do not require manual raking.
Lighting	Provide permanent lighting or provision for temporary/mobile lighting as there will always be a need to clean the screen in the hours of darkness. Under no circumstances should operatives be permitted to work on the screen in darkness. 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 these lighting arrangements are not possible, hand-held or cap lamps/head torches must be provided. There may be an environmental impact because of lighting provision (light pollution/disturbance to nearby residents).
Low flow performance	Screens should be designed to allow passage of small debris, and possibly fish and/or mammals during low flow conditions. A gap of at least 150 mm at the bottom of the screen (but designed to allow easy raking) can aid this.
Lifting of parts of screen	Sections of the screen should be designed so they can be removed or lifted in an emergency. This is to allow water through the screen when all other attempts to clear it have failed and to prevent choking of the flow. Consideration may be needed to provide a lifting beam as well as anchor points for lifting cables/chains.

45°



5.0 Summary

- 5.1 The final security screen design is shown on CEC Plans 6155/517 [*Headwall Detail*] & 6155/518 [*Culvert Detail*], enclosed with this *Technical Note*.

Cole Easdon Consultants Limited

May 2021

Enclosures

Calculation Spreadsheet

CEC Plan 6155/517(C) Headwall Detail

CEC Plan 6155/518(B) Culvert Detail

Bristol & Swindon

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Incorporated in UK as Cole Easdon Consultants Ltd No. 0202 7005

Technical Note - 6155/02

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Flood event	1:100 yr + 35%	
Culvert size:	2.7m w x 1.5m h	4.05sqm opening area
Top of Bank:	141mAOD	

Flood event 1:100 yr + 35%

Try 2 screens - 1 sloped & 1 horizontal

PERMANENT BLOCKAGE - Method 1

Discharge rate (m3/s)	5.67
Culvert water level (m)	1.567
Bed Level mAOD:	138.5
Water depth w/o screen (m)	1.567

	Sloping Screen area	7.57
Width (m)	4.45	
Height (m)	1.7	

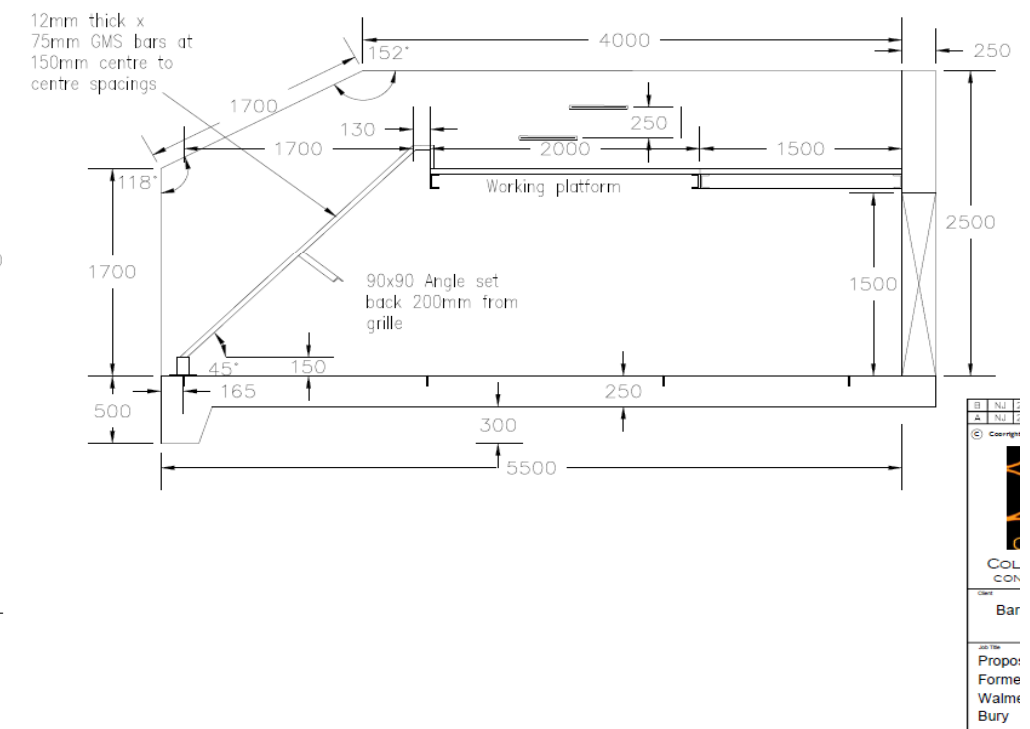
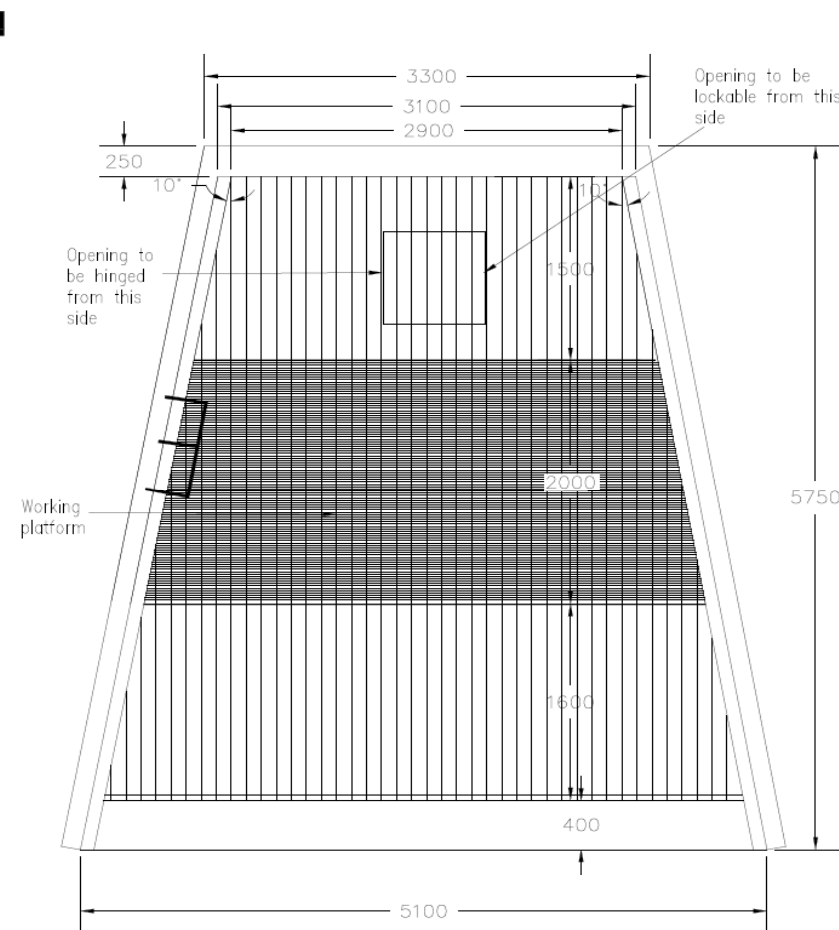
Screen angle	45
Horizontal Screen	
Width (m)	3.15
Length (m)	1.5

Screen Area	4.73
Total Screen effective area	15.424
Total Screen Width	7.6

	Opening ratio (s)	
Blockage %	0	
Bar width	12	
Bar spacing	150	
s		0.92

Headloss (hex)(m)	0.003
-------------------	-------

Water Level u/s of screen = 140.070



PERMANENT + 50% PERMEABLE BLOCKAGE - Method 1

Discharge rate (m3/s)	5.67
Culvert water level (m)	1.567
Bed Level mAOD:	138.5
Water depth w/o screen (m)	1.567

	Sloping Screen area	7.57
Width (m)	4.45	
Height (m)	1.7	

	Sloping Screen effective area	10.70
Screen angle	45	
Horizontal Screen		
Width (m)	3.15	
Length (m)	1.5	

Screen Area	4.73
Total Screen effective area	15.424
Total Screen width	7.6
Opening ratio (s)	

Blockage %	0.5
Bar width	12
Bar spacing	150
s	0.46

Headloss (hex)(m)	0.055
-------------------	-------

Water Level u/s of screen = 140.122 2 screens are ok
140.124 14mm bars

PERMANENT + 75% PERMEABLE BLOCKAGE - Method 1

Discharge rate (m3/s)	5.67
Culvert water level (m)	1.567
Bed Level mAOD:	138.5
Water depth w/o screen (m)	1.567

	Sloping Screen area	7.57
Width (m)	4.45	
Height (m)	1.7	

	Sloping Screen effective area	10.70
Screen angle	45	
Horizontal Screen		
Width (m)	3.15	
Length (m)	1.5	

Screen Area	4.73
Total Screen effective area	15.424
Total Screen width	7.6
Opening ratio (s)	

Blockage %	0.79
Bar width	12
Bar spacing	150
s	0.1932

Headloss (hex)(m)	0.380
-------------------	-------

Water Level u/s of screen = 140.447 2 screens are ok
140.339 14mm bars

PERMANENT + 85% PERMEABLE BLOCKAGE - Method 1 (= 3 x culvert x section area)

Discharge rate (m3/s)	5.67
Culvert water level (m)	1.567
Bed Level mAOD:	138.5
Water depth w/o screen (m)	1.567

	Sloping Screen area	7.57
Width (m)	4.45	
Height (m)	1.7	

	Sloping Screen effective area	10.70
Screen angle	45	
Horizontal Screen		
Width (m)	3.15	
Length (m)	1.5	

Screen Area	4.725
Total Screen effective area	15.424
Total Screen width	7.6
Opening ratio (s)	

Blockage %	0.85
Bar width	12
Bar spacing	150
s	0.138

Headloss (hex)(m)	0.759
-------------------	-------

Water Level u/s of screen = 140.83 2 screens ok (<141)
140.85 14mm bars

Summary:-
79% blocked screens throttles flow as 21% screen area is 3.24m2 which is less than culvert area = 4.05m2
Even so, flow throttling does not flood for up to 85% blockage
The twin screen effective area (15.42m2) is less than 4 x culvert area (16.2m2)
Use 12mm bars

PERMANENT + PERMEABLE BLOCKAGE - Method 2 (Blinding)

Sloping Screen blinded at Bottom Screen (Twin Screen scenario)

Discharge rate (m3/s)	5.67
Culvert water level (m)	1.567
Bed Level mAOD:	138.5
Water depth w/o screen (m)	1.567
Sloping Screen area	7.57
Width (m)	4.45
Height (m)	1.7
Sloping Screen effective area	10.70
Screen angle	45
Horizontal Screen	
Width (m)	3.15
Length (m)	1.5
Screen Area	4.73
Total Screen effective area	15.424

PERMANENT + 50% PERMEABLE BLOCKAGE OF SLOPING SCREEN - Method 2 (Blinding)

Blocked height(m):	0.85
Discharge rate (m3/s)	5.67
C	1.6
B (m):	4.45
f	0.72
y1	1.069
hex	0.003 (12mm bar) (from permanent blockage only - Method 1)
Headwater Elevation (Hs)	140.421 mAOD <141 ok

Weir Equation

Check for submerged flow:

S	0.95 (using f = 1 first iteration)
y2	0.817
y1	0.86 (using f = 1 first iteration)
f	0.72
Discharge rate (m3/s)	5.67
Culvert water level (m)	1.567
Bed Level mAOD:	138.5
Water depth w/o screen (m)	1.567

Sloping Screen area	7.57
Width (m)	4.45
Height (m)	1.7
Sloping Screen effective area	10.70
Screen angle	45
Horizontal Screen	
Width (m)	3.15
Length (m)	1.5
Screen Area	4.73
Total Screen effective area	15.424

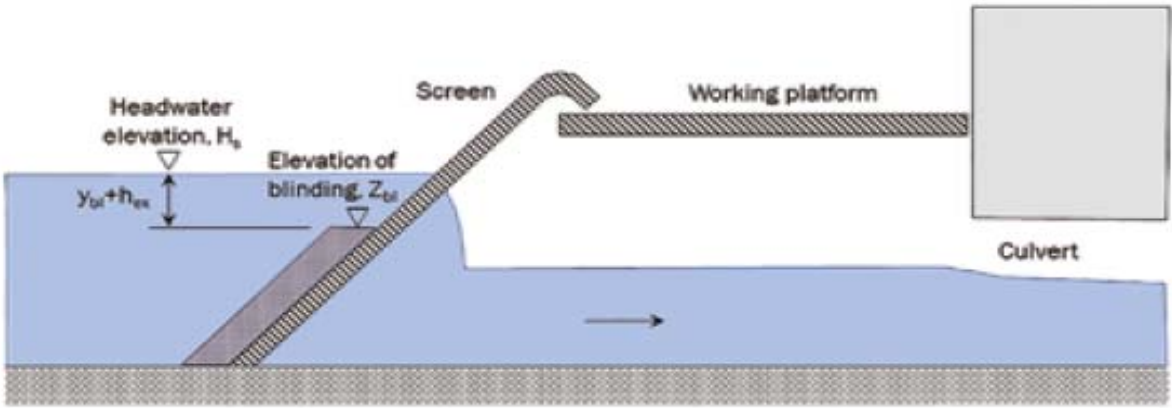


Figure 11.21 Headwater elevation upstream of screen with blinding (pseudo-weir)

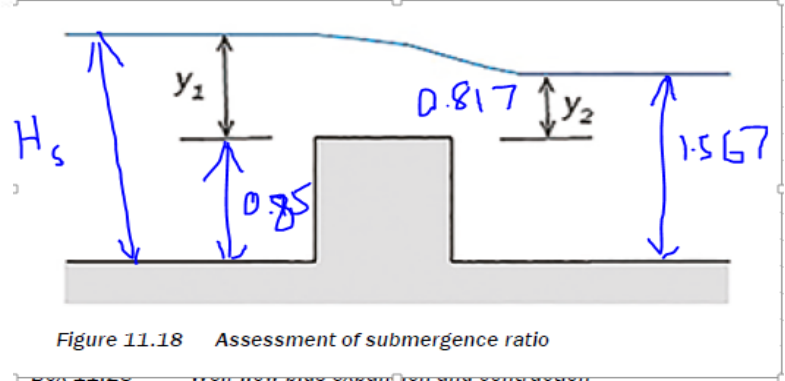


Figure 11.18 Assessment of submergence ratio

Box 11.28 Weir flow plus expansion and contraction

Headwater elevation upstream of a blinded screen (see Figure 11.21) is:

$$H_s = Z_{bl} + y_{bl} + h_{ex} \quad (11.56)$$

where

H_s = headwater elevation upstream of screen (m)

Z_{bl} = crest elevation of blinding (pseudo-weir) (m)

y_{bl} = depth of flow over blinding (pseudo-weir), calculated for effective width (excluding the width occupied by any bars) (m) (see Box 11.22)

h_{ex} = head loss due to expansion and contraction around permanent blockage (see Box 11.27), calculated for the flow depth over the blinding (m) (Box 11.22)

PERMANENT + 75% PERMEABLE BLOCKAGE OF SLOPING SCREEN - Method 2 (Blinding)

Blocked height(m):	1.275
Discharge rate (m3/s)	5.67
C	1.6
B (m):	4.45
f	0.72
y1	1.069
hex (from permanent blockage single screen)	0.003 (12mm bar)
Headwater Elevation (Hs)	140.846 mAOD <141 ok

Check for submerged flow:

S	0.95 (using f = 1 first iteration)
y2	0.817
y1	0.86 (using f = 1 first iteration)
f	0.72

Summary:-

Using Method 2, for Screen 1 blockages up to 75% no flooding occurs. For blockages greater than 75% flooding upstream of the screen may occur. However, in this situation the horizontal screen (Screen 2) will act as a single screen and will provide an alternative discharge point which will be adequate as the horizontal screen area is greater than the culvert cross sectional area (4.72sqm > 4.05sqm) and so throttling of flow and flooding will not occur.

PERMANENT + PERMEABLE BLOCKAGE - Method 3 (Choking)

Sloping Screen choked at Bottom Screen (Twin Screen scenario)

Discharge rate (m3/s)	5.67
Culvert water level (m)	1.567
Bed Level mAOD:	138.5
Water depth w/o screen (m)	1.567

	Sloping Screen area	7.57
Width (m)	4.45	
Height (m)	1.7	

	Sloping Screen effective area	10.70
Screen angle	45	

Horizontal Screen		
Width (m)	3.15	
Length (m)	1.5	
	Screen Area	4.73
	Total Screen effective area	15.424

PERMANENT + 50% PERMEABLE BLOCKAGE OF SLOPING SCREEN - Method 3 (Choking)

Aor (m2)	2.025
C	0.63
hor (m)	1.008

For a free orifice:

Centroid =	0.85
Hs	140.358 No Flooding

For a submerged orifice

Hs	141.075 Flooding
----	------------------

Box 11.22 Weir equation

The depth of flow over an obstruction (embankment or screen blinding/pseudo-weir) for flow type 6 (modular weir flow) and flow type 7 (submerged weir flow) is given by the broad-crested weir equation:

$$y_1 = \left(\frac{Q_w}{C_w B f} \right)^{2/3} \quad (11.41)$$

where

y_1 = upstream flow depth (m)

Q_w = discharge over embankment (m³/s)

C_w = discharge coefficient for weir flow (-)

B = width of crest (perpendicular to flow direction) (m)

f = submergence correction factor

The discharge coefficient C_w is typically 1.44 to 1.7 for International System of Units (SI) metric units, with lower values for less efficient spills such as embankments with vegetation or uneven crests or where the flow is overflowing the channel banks. It varies with weir geometry and upstream head. Further advice is given in BS 3680:1990. Note that the discharge coefficient is unit-specific and values in guidance written for cusec/feet units need converting.

If the downstream water level exceeds the crest level of the obstruction, a submergence correction factor may be needed. Check for submerged flow by calculating the submergence ratio (see Figure 11.18):

--

The discharge coefficient C_w is typically 1.44 to 1.7 for International System of Units (SI) metric units, with lower values for less efficient spills such as embankments with vegetation or uneven crests or where the flow is overflowing the channel banks. It varies with weir geometry and upstream head. Further advice is given in BS 3680:1990. Note that the discharge coefficient is unit-specific and values in guidance written for cusec/feet units need converting.

If the downstream water level exceeds the crest level of the obstruction, a submergence correction factor may be needed. Check for submerged flow by calculating the submergence ratio (see Figure 11.18):

$$S = \frac{y_2}{y_1} \quad (11.42)$$

where

y_2 = downstream water depth above crest level (m)

y_1 = upstream water depth above crest level (m)

If $S < 0.75$, flow is modular (ie passes through critical depth) and submergence correction factor is 1.0.

If $0.75 < S < 0.95$, the weir is submerged (ie downstream water level exceeds the critical depth over the weir), and submergence correction factor should be calculated (see table).

If $S > 0.95$, the weir is drowned (see Box 11.23).

Submergence correction factor can be estimated using the equations shown in the table, or Figure A7.7.

Source	Equation	Notes
White (2001)	$f = 1.045 \left(0.76 - S^{4.2} \right)^{0.0645}$ (11.43)	For $0.75 \leq S < 0.925$
White (2001)	$f = 5.7 - 5.245S$ (11.44)	For $0.925 < S < 0.985$
Environment Agency (2007)	$f = -25S^2 + 42.9S - 17.422$ (11.45)	For $0.85 < S < 0.985$

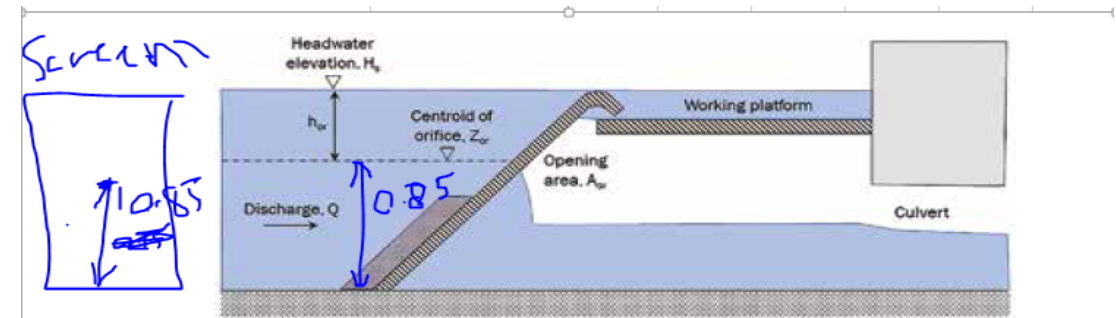


Figure 11.22 Headwater elevation upstream of screen acting as free orifice

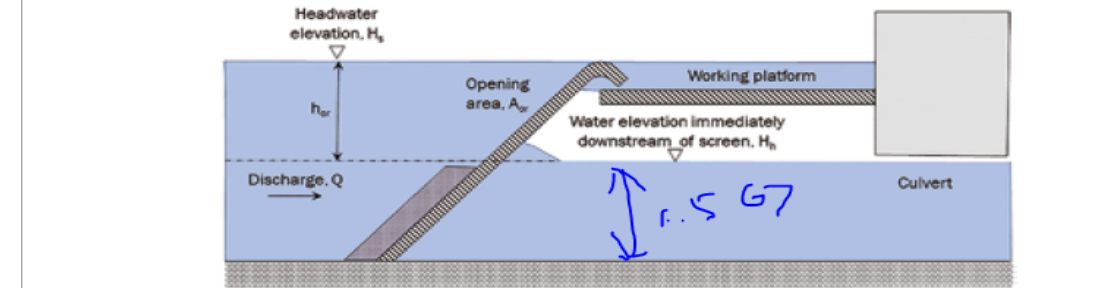


Figure 11.23 Headwater elevation upstream of screen acting as submerged orifice

Box 11.21 Orifice equation

The head required to drive flow through an orifice is given by:

$$h_{or} = \frac{1}{2g} \left(\frac{Q}{C_d A_{or}} \right)^2 \quad (11.40)$$

where

h_{or} = head required to drive flow through an orifice (m)

Q = discharge (m^3/s)

C_d = discharge coefficient for orifice flow (typically 0.63 but depends on the orifice geometry) (-)

A_{or} = cross-sectional area of orifice, the minimum of screen opening and culvert area (m^2)

The head driving flow through an orifice is measured differently depending on whether the orifice is free or submerged. For free flow, the head is measured from the centroid of orifice to the upstream water level. For submerged flow, the head is the difference between upstream and downstream water levels.

Box 11.29 Headwater due to orifice flow

Headwater elevation upstream of a screen acting as a free flowing orifice (see Figure 11.22) is:

$$H_s = Z_{or} + h_{or} \quad (11.57)$$

where

H_s = headwater elevation upstream of screen (m)

Z_{or} = elevation of centroid of orifice (m)

h_{or} = head required to drive flow through orifice (m) (see Box 11.21)

Headwater elevation upstream of a screen acting as a submerged orifice (see Figure 11.23) is:

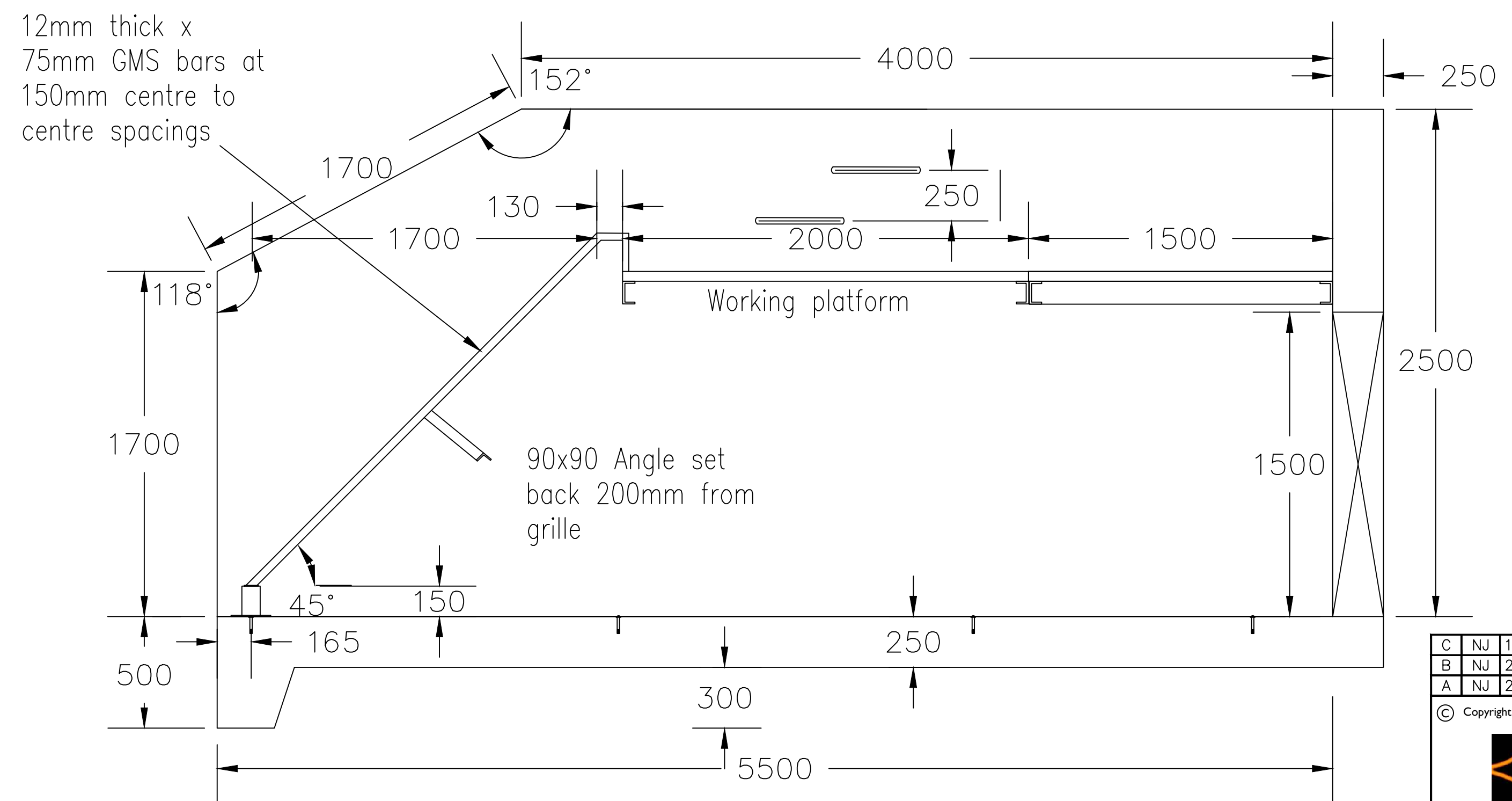
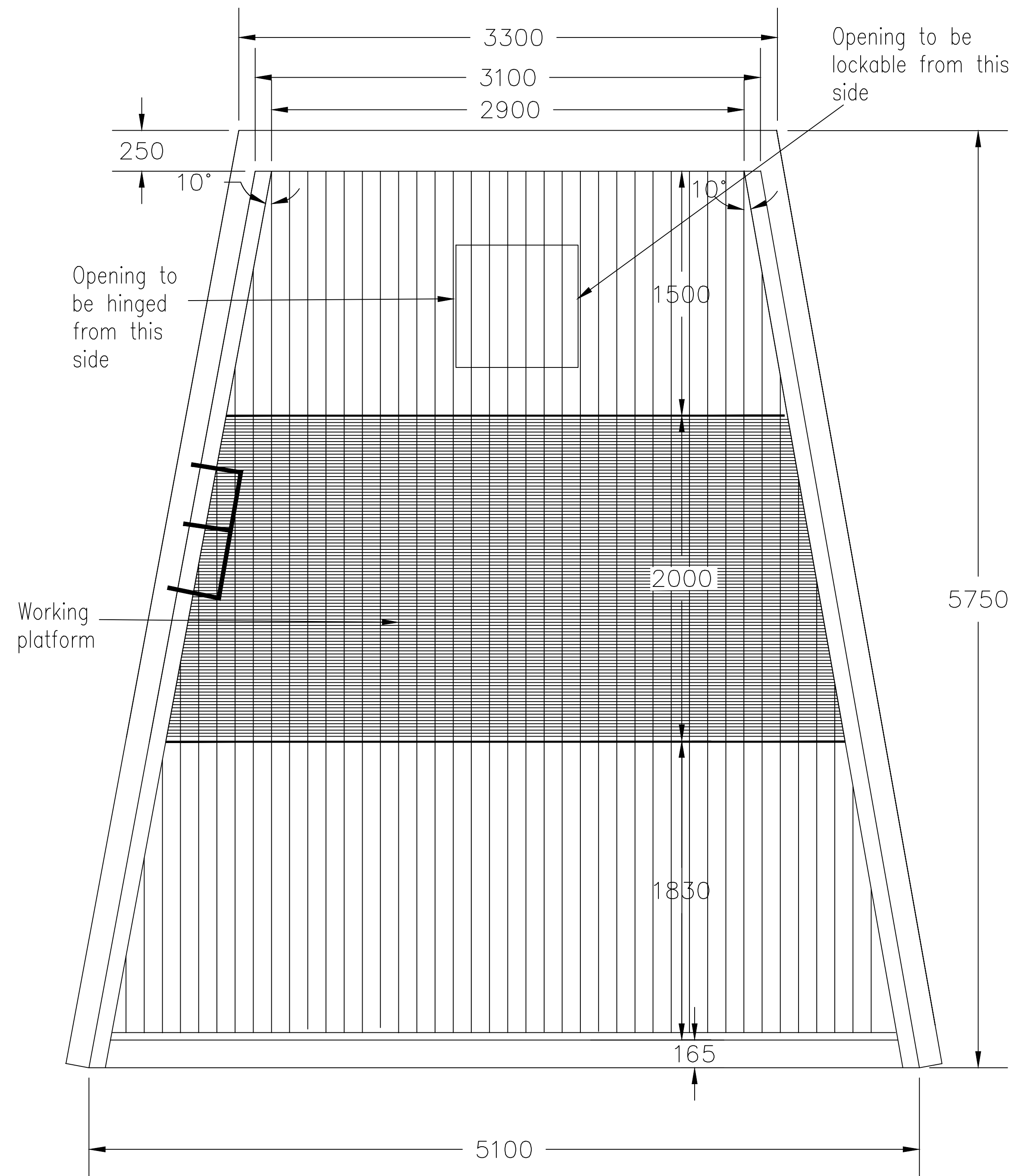
$$H_s = H_h + h_{or} \quad (11.58)$$

where

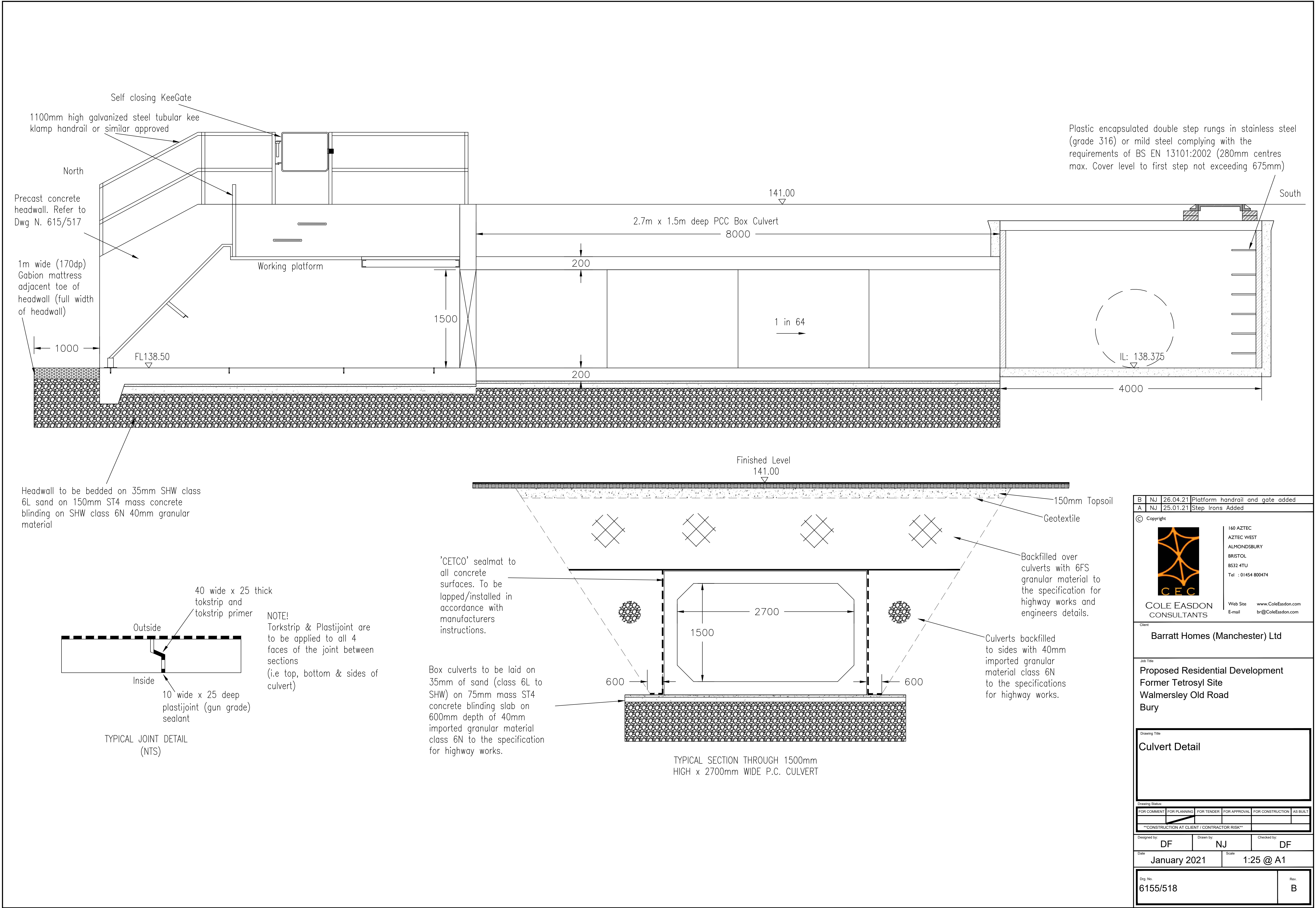
H_h = water elevation immediately downstream of screen (m)

Summary:-

Using Method 3, for 50% choking of Screen 1 some flooding upstream of the screen may occur. However, in this situation the horizontal screen (Screen 2) will act as a single screen and will provide an alternative discharge point which will be adequate as the horizontal screen area is greater than the culvert cross sectional area ($4.72sqm > 4.05sqm$) and so throttling of flow and flooding will not occur.



C	NJ	13.05.21	Plan View Amended
B	NJ	23.04.21	Step irons moved. Rollover added
A	NJ	25.01.21	Screen design updated
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COLE EASDON CONSULTANTS		Web Site www.ColeEasdon.com	E-mail br@ColeEasdon.com
Client Barratt Homes (Manchester) Ltd			
Job Title Proposed Residential Development Former Tetrosyl Site Walmersley Old Road Bury			
Drawing Title Headwall Detail			
Drawing Status			
FOR COMMENT	FOR PLANNING	FOR TENDER	FOR APPROVAL
			FOR CONSTRUCTION
			AS BUILT
CONSTRUCTION AT CLIENT / CONTRACTOR RISK			
Designed by DF		Drawn by NJ	Checked by DF
Date January 2021		Scale 1:20 @ A1	
Dwg. No. 6155/517			Rev. C



B	NJ	26.04.21	Platform handrail and gate added
A	NJ	25.01.21	Step Irons Added
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Client Barratt Homes (Manchester) Ltd			
Job Title Proposed Residential Development Former Tetrosyl Site Walmersley Old Road Bury			
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			FOR CONSTRUCTION
			AS BUILT
CONSTRUCTION AT CLIENT / CONTRACTOR RISK			
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Dwg. No. 6155/518			Rev. B