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FINAL REPORT

Performance Evaluations: Caskade High Capacity Gutter System

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CASKADE HYDRA

The University of Sheffield Report

Contents

		Page No
1.0	Introduction	3
2.0	Details of the roof gutter arrangement	3
3.0	Programme of Tests	3
4.0	Results and Discussion	4
5.0	Conclusion	4

Figures

Figure 1 Flow depth relationship at inlet 1
Figure 2 Flow depth relationship at inlet 2
Figure 3 Flow depth relationship at inlet 3
Figure 4 Flow depth relationship at inlet 4
Figure 5 Flow depth relationship at inlet 5

Plates

Plate1 Test system
Plate 2 Anti vortex device fitted to inlet
Plate 3 Typical flow pattern to inlet
Plate 4 Inlet at near capacity

Addendum index

Index 1 Flow test graph layout
Index 2 Analytical design layout - calculations
Index 3 Anti vortex device detailed drawing

Plate 1 Pumps at University of Sheffield for calibration flow.
Plate 2 Test rig Facility University of Sheffield
Plate 3 Computer equipment for flow calibration

1.0 Introduction

The University of Sheffield has tested the performance of the Caskade high capacity gutter system. The primary aim of the study was to assess the hydraulic performance of the system, in the form of a depth discharge relationships, and hence, to establish the hydraulic capacity of the system. Tests were completed on the prototype system with 5 inlets, equally spaced along the gutter length. Subsequently the results will provide the opportunity to calibrate and verify a mathematical model that describes the design performance of the Caskade system for use by practicing engineers.

2.0 Details of the Caskade Products Inlet and Roof Gutter Arrangement

The system was designed by Mr John Smith and was tested in the unique roof gutter test rig, located on the flat roof area above the Structures Laboratory of the Department of Civil and Structural Engineering at the University of Sheffield. This system is shown in Plate 1. The system is 35m long and has a roof width of 1.2 m inclined at an angle 12 degrees to the horizontal. The roof area is supplied with water from the sump in the Water Engineering Laboratory at the University of Sheffield via 3no 110mm diameter pipes to a channel that runs the full length of the rig. This channel, located at the upstream end of the roof incorporates a horizontal thin plate overflow weir that allows the water to spill onto the roof and to create a uniform flow depth over the complete length of the roof. The inflow to this channel was computer controlled to the required flowrate.

The water was drained from the roof area into the Caskade high capacity gutter system that has a unique in-built channel below the gutter sole. The cross sectional area of channel is increased with distance downstream to accommodate the increase in flow that enters into the channel through each inlet. The flow through this outlet was returned to the Water Engineering Laboratory where each individual flowrate was measured volumetrically.

The inlets to the high capacity gutter system used in the tests were placed centrally in the base of the gutter. Each inlet incorporates a circular anti-vortex device, as shown in Plate 2. At each flowrate the depth of flow in the gutter was measured along the length of the gutter both upstream and downstream of each inlet with the measurement recorded at the centreline of the gutter base. All depth measurements were referenced to the elevation of the base of the gutter at the measurement point.

3.0 Programme of Tests

Three tests were completed to measure the hydraulic performance of the new design of system. In each test a series of flowrates were used and, following a period of time that allowed the flow conditions to become steady (constant depth with time), the depth profile along the gutter length was recorded both upstream and downstream of each inlet. The performance of the system was tested up to system capacity.

The test programme recorded the flowrate-depth relationship at each of the 5 inlets.

4.0 Results and Discussion

The results from the study have been plotted to give the flow depth relationship to each inlet, as shown in Figures 1 to 5. Typical flow conditions are shown in Plates 3 and 4.

The results highlight that the flow depth to each outlet generally increased towards the downstream end of the gutter and that the capacity of the system with 5 inlets, was approximately 25 litres/s.

This report presents a series of results that may subsequently be used for the calibration and verification of a mathematical model that predicts the performance of the system for design purposes.

These results highlight that the new system had a similar performance to that of other siphonic systems as reported in the references. The system has therefore considerable potential and it is recommended that further work is completed to enhance the understanding of system performance using a bespoke manufactured unit.

5.0 Conclusion

Tests have been completed on the Caskade high capacity gutter system at the University of Sheffield.

The hydraulic performance of the Caskade high capacity gutter system was good and compared favourably to the results from previously published work.

The results of the report are specific to the configuration of the test facility used but will provide valuable information for the calibration and verification of a mathematical model that describes the hydraulic performance of the Caskade high capacity gutter system.

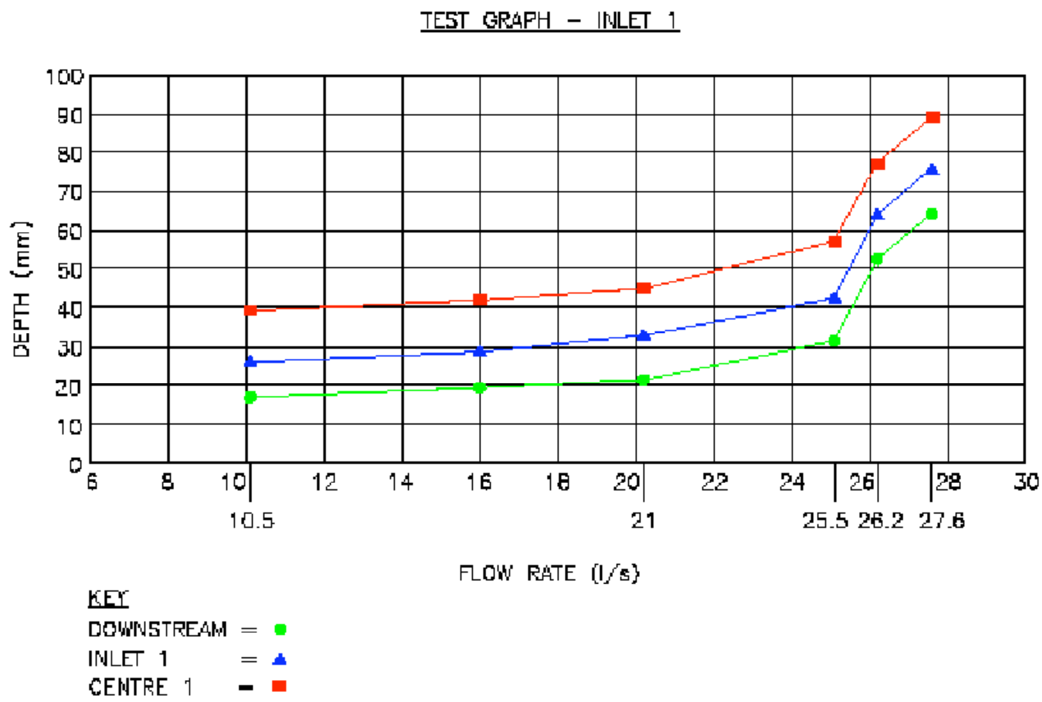


Figure 1 Flow depth relationship at inlet 1

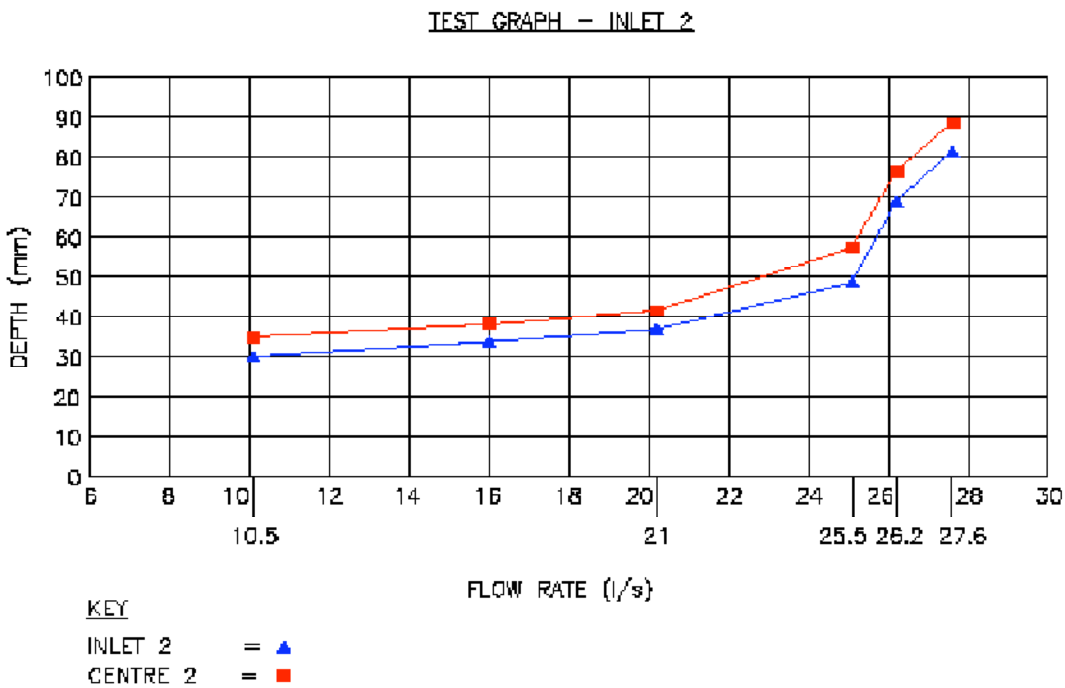


Figure 2 Flow depth relationship at inlet 2

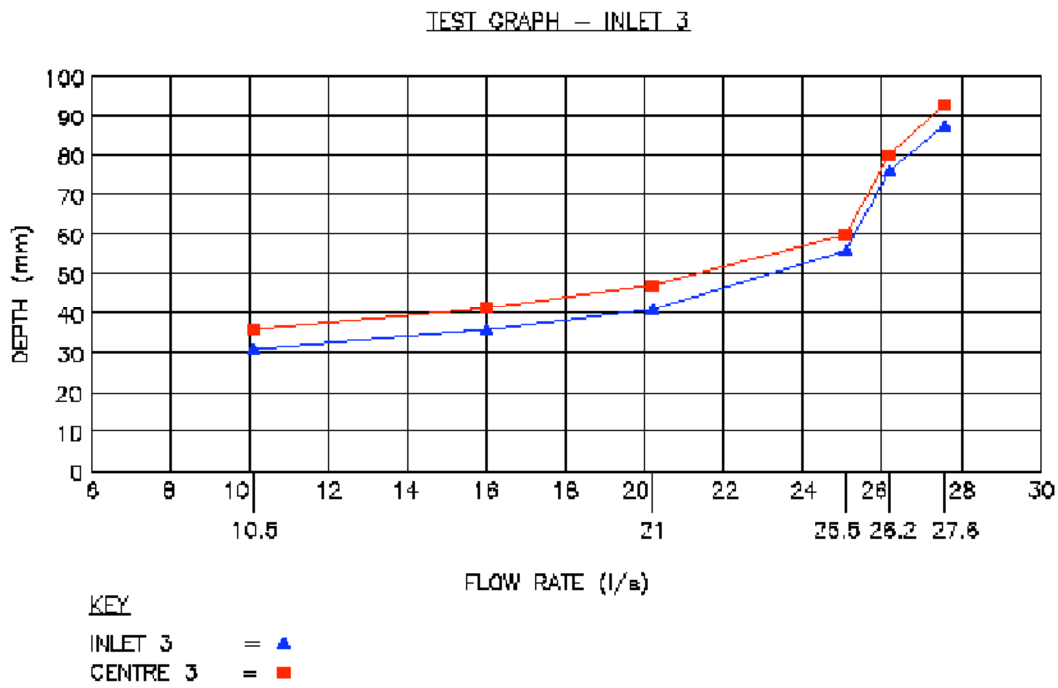


Figure 3 Flow depth relationship at inlet 3

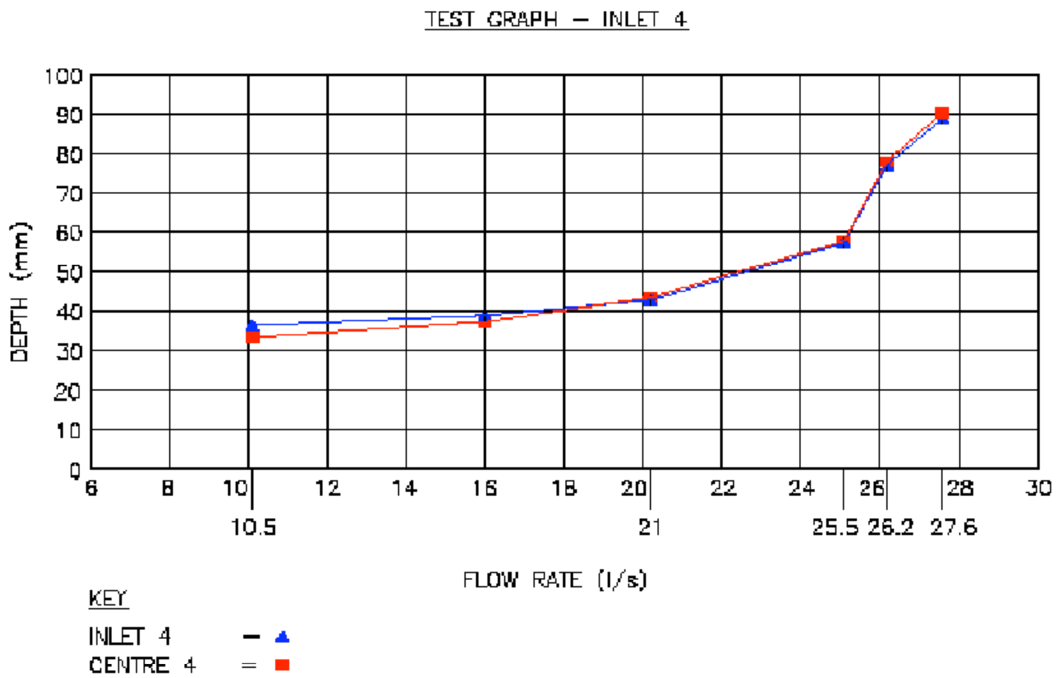


Figure 4 Flow depth relationship at inlet 4

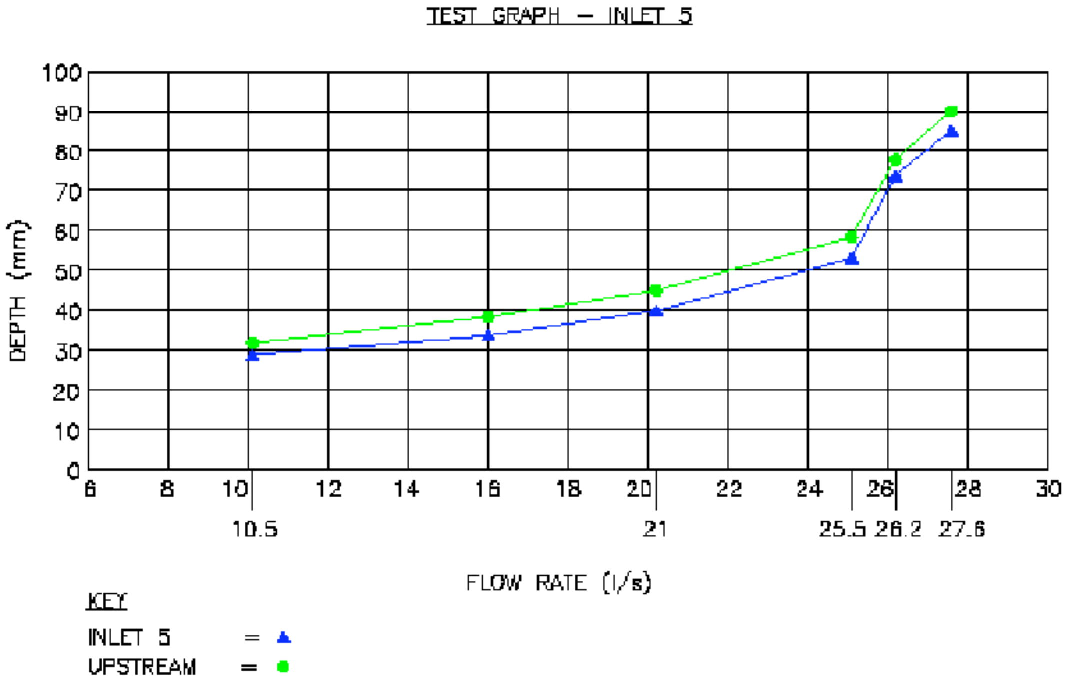


Figure 5 Flow depth relationship at inlet 5

Plate 1 Test system

Plate 2 Anti vortex device fitted to inlet

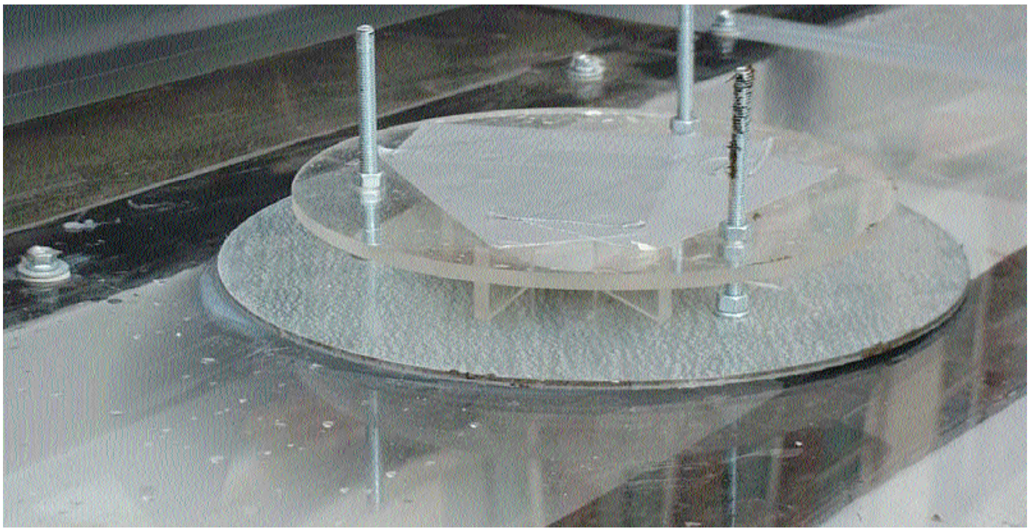


Plate 3 Typical Flow Pattern to inlet

Plate 4 Inlet at near capacity

3.0 Addendum Index

1. Flow Test graph layout
2. Analytical design layout - Calculations
3. Anti vortex device detailed drawing
4. Plates

Plate 1 Pumps at University of Sheffield for calibration

Plate 2 Test rig Facility University of Sheffield

Plate 3 Computer equipment for flow calibration

1. Flow Test Graph Layout

The flow test graph layout assimilates a full scale working model with an indicative roof area of 35m in length by 15m deep, subject to a rainfall intensity of 175mm/hr into one cavity section. It is assumed that in practice approximately 100mm/hr will be the design norm for a primary cavity section, with the remainder of the design intensity being catered for in a secondary cavity section, therefore the tests at the University of Sheffield represent higher than normal conditions for a single cavity section.

Index: - a) Rainfall Calculations

b) Rainfall Intensity Calculation Sheet

c) Indicative Flow Test Roof Area showing Flow Test Graph Layout Points

Rainfall Intensity

The test and rig configuration was representative of a roof area of 35m x 15m with a rainfall intensity of 175mm/hr discharged by the test cavity channel section.

Calculations as follows:

Calculation to BSEN 12056-3:2000

Rainfall Intensity = 175mm/hr – 0.486 l/s per m sq

Location = Sheffield

Life of Building = 25 years

Category of Protection = 2

Return Period = 37.5 years

Rainfall Intensity Calculation Sheet

Project Title: University Test Rig Location: Sheffield

The calculation for the design rate of rainfall on the above project, based upon BS EN 12056-3:2000

[Rainfall amount (mm) in 2 min, occuring on average once in 5 years (2 min M5)]

3.5 From N.B. 6

[M5 rainfall for different durations as a fraction of the 2 min M5 rainfall] = 1.0

Therefore 2 min M5 rainfall = 1.0 x 3.5 = 3.5

Return period = Life of building (period for which contents need to be protected) x category of protection

Life of Building = 25

Category of Protection = 2 1.5 Category of design rate

Therefore return period = 37.5

(Estimation of the return period or intensity of rainfall)

M (c) Rainfall in a given duration

M5 Rainfall in the same duration

37.5 = 1.67 From N.B. 7

Therefore 2 min M (c) 37.5 Rainfall = 3.5 x 1.665

= 5.8275 mm for a 2 min duration x 30 mins

= 174.825 mm/hr = 0.049 l/s per m^2

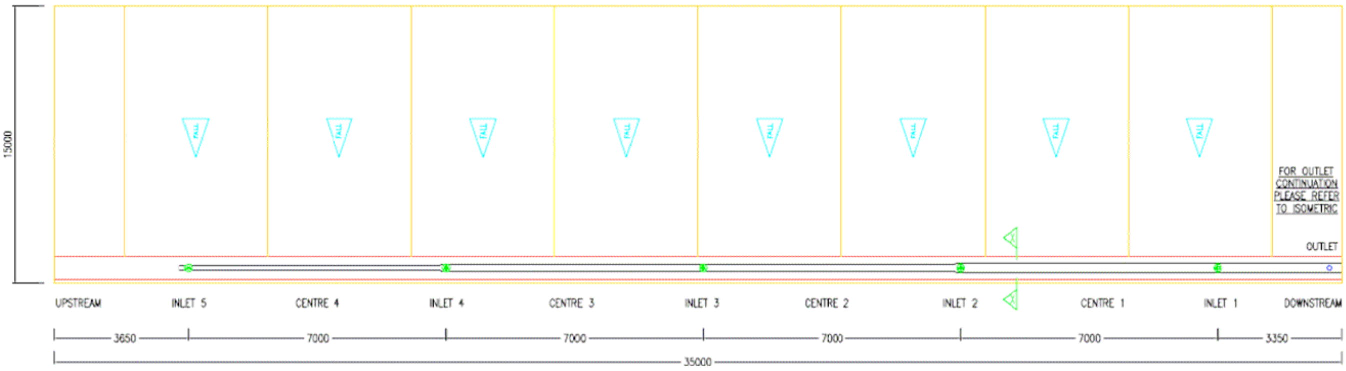
SUMMARY

Rainfall Intensity = 175 = 0.049 l/s per m^2

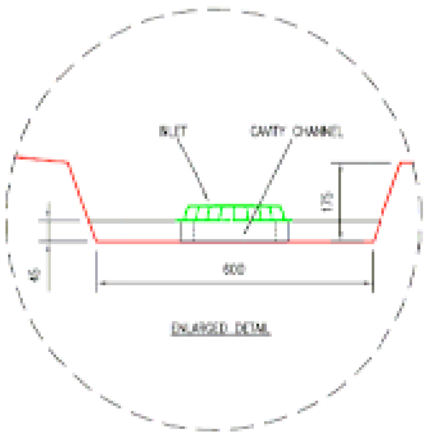
Life of Building = 25 years

Category of Protection = 2

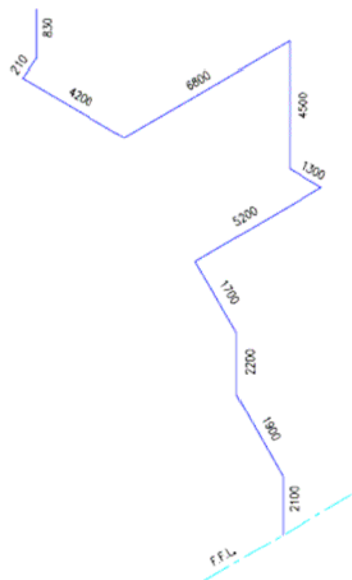
Return Period = 37.5 years



ROOF PLAN



ENLARGED DETAIL



OUTLET ISOMETRIC

1. Analytical Design Layout - Calculations

This section includes for: -

Analytical Software Program version 2.0.1 Isometric of the Test Facility

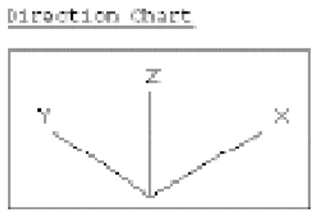
Dimension Calculation Report

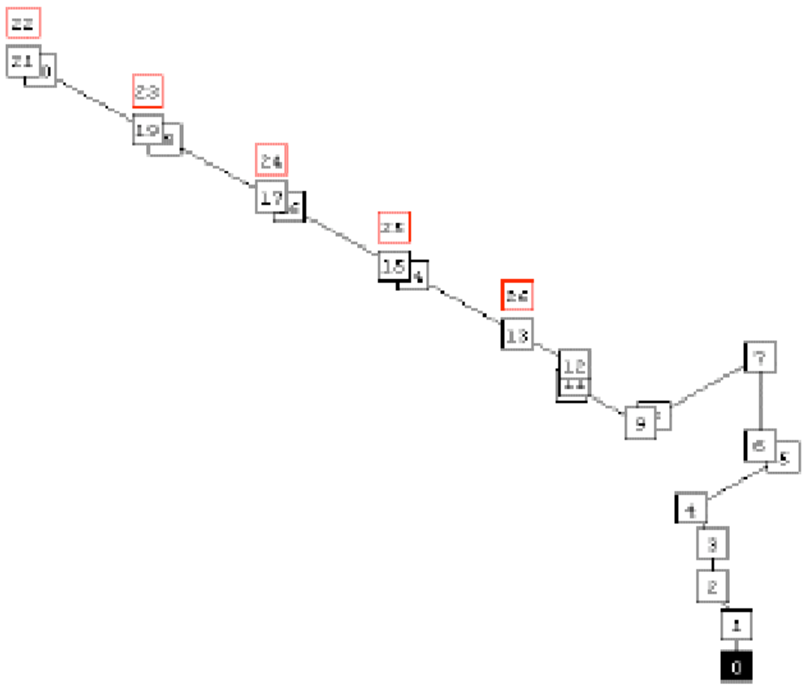
Channel (Cavity) Inlet / Outlet reference chart

Test Facility assimilated roof area showing node points from

Dimension Calculation Report

Analytical Software Program Version 2.0.1





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Analytical Software Program Version 2.0.1

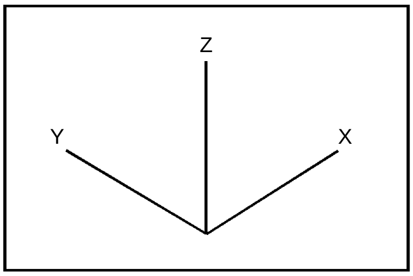
Dimension Calculation Report: 03/01/06

ISO/Direction Node		Length (m)	Channel	Flow (L/sec)	Veloc (m/sec)	Pressure (Bar)
26-13	+Z	Inlet	H	5.10	1.36	- 0.028
26-15	+Z	Inlet	H	5.10	1.36	- 0.028
24-19	+Z	Inlet	H	5.10	1.36	- 0.028
23-19	+Z	Inlet	G	5.10	0.94	- 0.014
22-21	+Z	Inlet	G	5.10	0.94	- 0.007
21-20	+Y	1.00	G	5.10	0.94	- 0.009
20-19	+Y	6.00	G	5.10	0.94	- 0.019
19-18	+Y	1.00	F	10.20	1.27	- 0.025
18-19	+Y	6.00	F	10.20	1.27	- 0.038
17-16	+Y	1.00	F	15.30	1.91	- 0.053
16-15	+Y	6.00	F	15.30	1.91	- 0.082
15-14	+Y	1.00	E	20.40	1.96	- 0.088
14-13	+Y	6.00	E	20.40	1.96	- 0.113
13-12	+Y	3.17	E	25.50	2.46	- 0.165
Nodes below this line are outlet nodes........						
12-11	+Z	0.83	E	25.50	2.46	- 0.099
11-10	+X+Z	0.21	E	25.50	2.46	- 0.105
10-9	+Y	3.90	E	25.50	2.46	- 0.151
9-8	-X	0.80	E	25.50	2.46	- 0.156
8-9	-X	6.00	E	25.50	2.46	- 0.216
7-6	+Z	4.50	E	25.50	2.46	0.184
6-5	+Y	1.30	E	25.50	2.46	0.156
5-4	+X	5.20	E	25.50	2.46	0.101
4-3	+Y+Z	1.70	E	25.50	2.46	0.200
3-2	+Z	2.20	E	25.50	2.46	0.394
2-1	+Y+Z	1.90	E	25.50	2.46	0.505
1-0	+Z	2.10	E	25.50	2.46	0.671

Analytical Software Program Version 2.0.1

Channel (Cavity) / Inlet / Outlet Reference Chart

Direction Chart



Channel (Cavity) Type

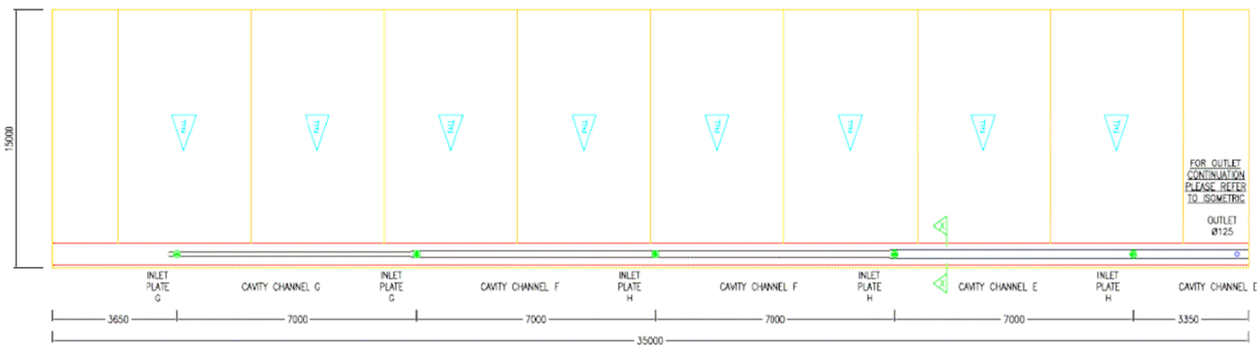
A=685 section	B=431 section	C=276 section	D=171 section
E=104 section	F=80 section	G=54 section	H=37 section
J=25 section	K=15 section		

Inlet Orifice Diameter

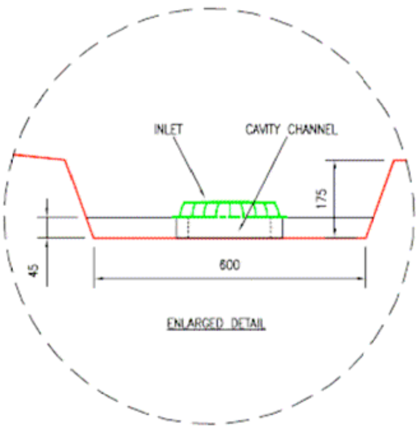
F=101mm	G=83mm	H=69mm	J=57mm

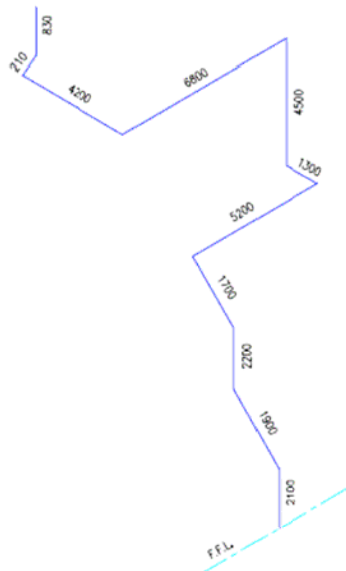
Outlet Internal Diameter

A=295mm	B=234mm	C=187mm	D=147mm
E=115mm	F=101mm	G=83mm	H=69mm
J=57mm			



ROOF PLAN



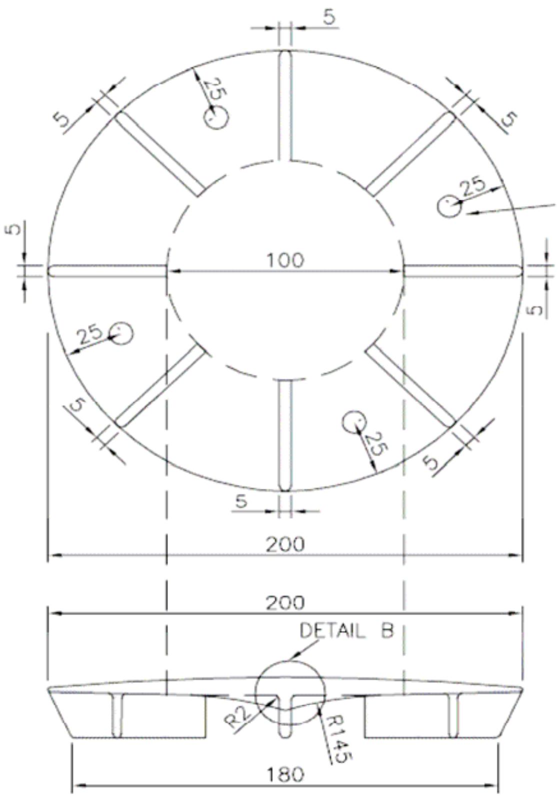


OUTLET ISOMETRIC

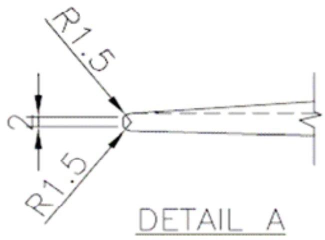
3. Anti vortex device detailed drawing

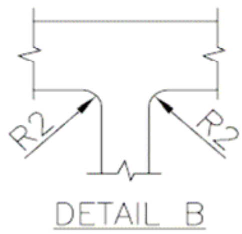
This section indicates the AVD final Design; the device was developed following R & D studies during the cavity channel hydraulic performance tests at the University of Sheffield. Several versions of the device were researched and the optimum performance of the final design was agreed. The unit directs the flow of water to the centre of the orifice inlet via 8 fins. The top plate has been contoured to the centre to alleviate cavitation erosion as the water changes direction into a downward flow pattern. The Edges of the device are designed with subtle radii for a smooth flow. The unit will be manufactured in Aluminium casting alloy to BS 1490:1988 LM24 by high-pressure injection moulding process.

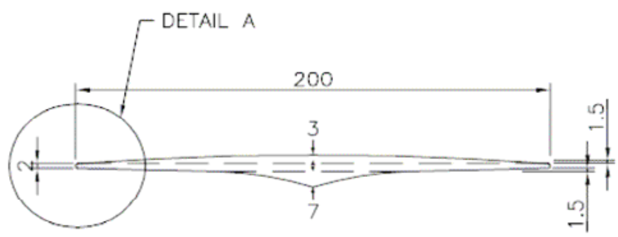
TOP PLATE PLAN SHOWING FIN ARRANGEMENT



TOP PLATE ELEVATION SHOWING FIN ARRANGEMENT







TOP PLATE WITHOUT FINS FOR
DIMENSIONING IDENTIFICATION PURPOSE ONLY

Plate 1 Pumps at University of Sheffield for calibration flow

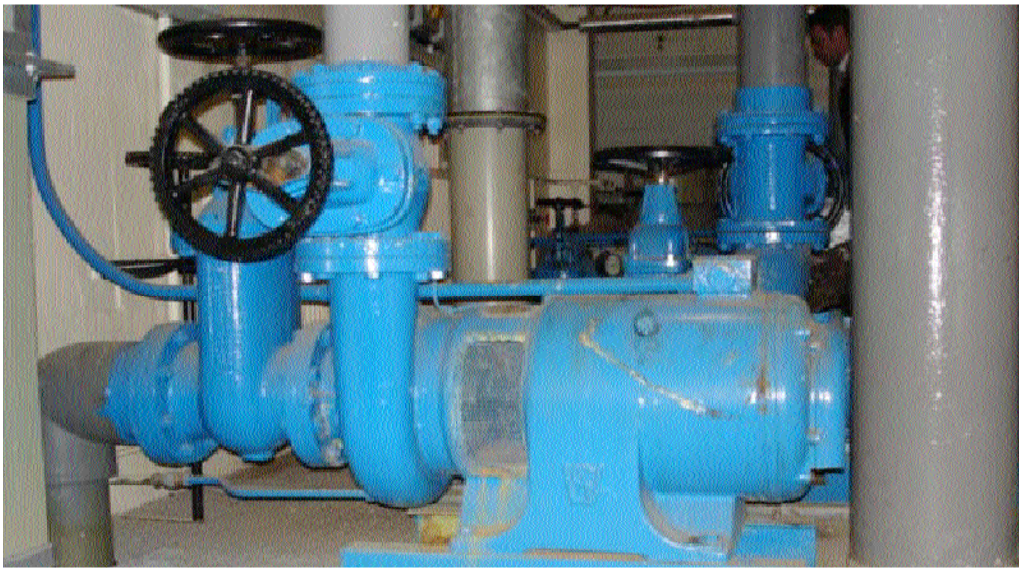
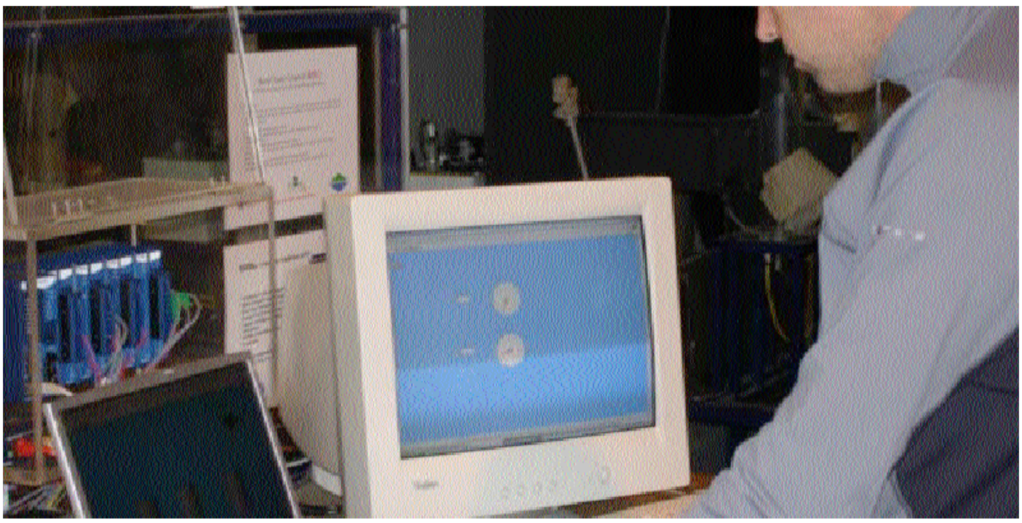


Plate 2 Test Rig Facility University of Sheffield

Plate 3 Computer equipment for flow calibration



Caskade
High Velocity
Gutter System
Conclusion
Report

CASKADE HYDRA

Caskade High Velocity Gutter System Conclusion Report

The conclusions deduced from recent Research & Development studies at the University of Sheffield for the performance of Caskade High Velocity Gutter System are that the system is well engineered and includes favourable benefits when compared to other methods of Rainwater Disposal.

Each inlet orifice is specifically dimensioned for total inflow control, unlike the use of rain-water outlets which have a predetermined discharge diameter. Furthermore the Caskade system allows for total system inflow balance at the inlet position of the inlet orifice, by calibration and sizing at concept design stage. The flow from the surface of the gutter via the inlet orifice into the main collection flow in a Caskade system is instant, as there are no feeder pipes or tail pipes transporting water to the main collection flow. Due to the instant flow from gutter sole to collection flow the system reaches a closed flow condition (plug flow) at a very early stage in the rain storm cycle. In turn this unique operational condition results in a gradual increase in rainwater depth up to optimum design flow, with no surcharging of the gutter before the system becomes operational as with other piped systems and as indicated in the report SR463, a DOE published report September 1996.

Caskade has no intrusive pipework collection systems along the length of the building, and the outlet pipe is connected at the end of a gutter run and can be coordinated to dis-charge in the most suitable location for aesthetic and engineering purposes. The outlet pipe is always manufactured from metal to avoid any material expansion / contraction issues as identified when utilising plastic pipework. The metal outer pipe is also robust and can be coated in any RAL colour, polyester powder coating or finish as required.

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Due to the cavity trays inbound gutter configuration, a further benefit is that the system design will always self balance and regulate itself should there be a joint failure, unlike a piped system outboard of the gutter, whereupon a joint failure would result in:

a) Ingress of water to the building envelope from the joint failure when not in a siphonic mode.

b) Imbalance in the systems design as air would be taken into the system.

c) Possible ingress into the building envelope by gutters topping due to a systems imbalance failure.

CASKADE HYDRA

Benefits of Caskade High Velocity Gutter System

1. Inlet calibration for optimum flow control.
2. Instant and gradual flow condition during storm intensity.
3. No build up of rainwater within gutter prior to designed discharge condition.
4. No intrusive pipework systems within the building.
5. Self balancing system for safe operational discharge.
6. No possible ingress into building from potential gutter sump connections.
7. No possible ingress into building from potential leaking pipework.
8. Clear internal space for racking and storage.
9. No pipework condensation requirements.
10. No noisy inbound pipework.
11. All rainwater controlled outside the building envelope.

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