ENGINEERING CONSULTANCY 49

DRAINAGE DESIGN STATEMENT

Project:

Sunset Park Homes,
Whitfield Road,
Brackley,
NN13 5TD

On behalf of:

GROUNDWATER DYNAMICS

EC49-23-18-01

18 MONTROSE AVENUE DARTON BARNSLEY SOUTH YORKSHIRE S75 5LS

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Version	Written By	Checked By	Date
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APPENDICES

1. INTRODUCTION

1.1 EC49 has been appointed by Groundwater Dynamics (GWD) to undertake calculations to demonstrate the level of drainage that may be realised by sustainable means through the use of the GWD Energy-Passive Groundwater Recharge Pump (ECO-90) system for dispersing surface water into ground with low infiltration properties at the natural ground surface.

1.2 Falling head test results have been provided for a test drilling exercise on the site. The results from this testing have been used to provide the data needed to determine design infiltration rates that can be used to calculate the volume of surface water that can be removed from the site by infiltration to ground using the GWD ECO-90 system.

2. METHODOLOGY

2.1 The infiltration rates taken from the supplied results have been used to generate an ECO-90 “cluster” design with an associated infiltration rate for comparison with the rainfall data for the Whitfeld Road, Brackley (NN13 5TD) area.

2.2 The calculated infiltration rates have been used in conjunction with the simulation capabilities of Micro Drainage to establish the volume of storage required to attenuate a range of storm events. By balancing the inflow (rainfall) and outflow (infiltration to ground) with the impermeable area and the available space on the site, a system of micro boreholes and associated attenuation facility has been designed.

2.3 A “cluster” of ECO-90 is determined by iteration to arrive at a solution that limits the installation of ECO-90 whilst ensuring that the attenuation volume required can be provided on site. The cluster make up is generated from the calculated infiltration rates to establish an equivalent square metre rate to use for the Micro Drainage simulations. This allows the calculation to be scalable which assists the iteration of the design.

2.4 The output of the Micro Drainage simulations shows the maximum volume of attenuation required for the impermeable area considered and the proposed ECO-90 installation. The volume of attenuation can be provided in any practical way as long as it is located directly adjacent (over or alongside) the ECO-90 installation. This allows the infiltration trench design in Micro Drainage to be left with a cover level of 100m and an invert level of 95m for simplicity and ease of calculation.

3.0 RESULTS

3.1 The calculations in Appendix B show how the site testing results have been converted to infiltration rates and then to a cluster design.

3.2 The Micro Drainage results in Appendix C show that for an installation of 20 clusters, the system will need a maximum volume of 11.7 cubic metres of attenuation for the worst case 100-year return period storm event with an additional 40% allowance for climate change to drain each 200 square metres of impermeable area. This solution is scalable for changes in impermeable area but partial clusters determined by such scaling of the solution should be rounded up.

3.3 The volume of attenuation may be provided as a porous base to permeably paved areas, or other preferred method of providing below ground voids that works with the proposed layout and cost plan. The calculations have been based upon the test result values for the 6m deep boreholes in Test Drill Area 2 as these were the lowest of the 6m results (by a small margin) which allows the proposed solution to be applied across the site subject to the basic mathematical increase/reduction depending upon the actual impermeable area to be treated.

3.4 This system is capable of attenuating and infiltrating to ground the run-off anticipated from the 200 square metres of impermeable area. This has been provided to allow a site wide solution that is scalable to the area that is proposed to be treated.

3.5 The proposed ECO-90 and attenuation system has been assessed against the anticipated rainfall for storm events up to 100-year return period (storms ranging from 15 minutes to 7 days duration) with a further 40% allowance for climate change.

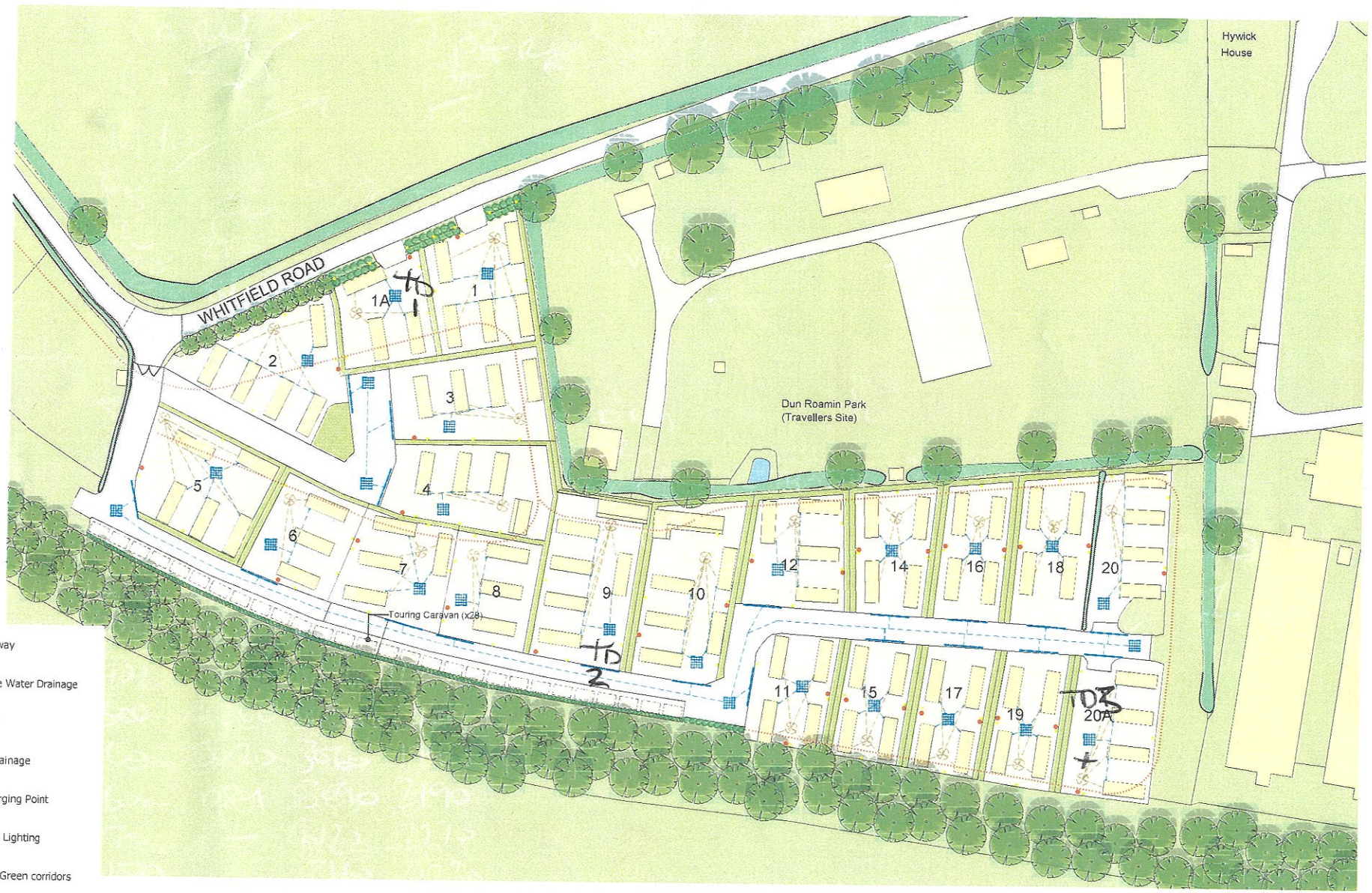
3.6 The required storage volume has been calculated by reducing the total volume required by the volume of storage provided in the micro boreholes, as shown in Appendix B.

3.7 The calculated half drain time for the proposed system is 1131 minutes for the worst case 100-year storm event with an additional allowance of 40% for climate change.

Appendices

Appendix A

NN13 5TD



Key:

- Soakaway
- Surface Water Drainage
- Cesspit
- Foul Drainage
- EV Charging Point
- Outside Lighting
- Shrubs/Green corridors
- Mains Water

As Proposed Site Development Scheme Masterplan

SCALE 1:500

Date	February 2023
Scale	1:500@A1
Drawn	TRT
Checked	SW
Client	Mr A Smith
Project	Sunset Park Homes, Whitfield Road, Brackley, NN13 5TD
Title	As Proposed Site Development Scheme Masterplan
Drawing No.	3004023-TD-00
Rev.	

Eco90 Field Trial - Borehole Log and Infiltration Testing Datasheet

Project Name	Sunset Park Homes	**Drill method**	Rotary auger	**Logger**	Matt Dale	
Client	Integrated Designs & Associates Ltd	**Drill rig**	Comachio 205	**Weather**	Warm/Cloudy 13°C	
Test drill area	TD3	**Drill diameter**	89 mm	**Ground**		
Date	15/05/23.					

Borehole Reference						
BH1	**BH2**	**BH3**	**BH4**	-	-	-

Drilling Details

Target drill depth (mm)	1.5m	3m	6m	12m	-	-	-
Final drill depth (mm)	1.5m	3m	6m	9m			
Time to drill (mins)	2	5	20	45			

Soil / Drilling Conditions

Description	3m Soft clay with sand with traces of stone. 4.5m Hard layer (No spoil). 6m very dry chalk with stone and gravel 7.5m very dry stone/ gravel. 9m very soft chalk/clay/water.

Groundwater Conditions

Depth to damp rods (mm)							
Water level after 0 mins (mm)	Dry	Dry	5630	4630			
Water level after 20 mins (mm)			5180	4630			

Test Conditions

Depth of hole pre-test (mm)							
Water level pre-test (mm)							
Pipework or open cavity?							

Test Results

Mins	*Secs*	*Mins*	*Secs*	*Depth to water (mm bgl)*						
1	60			15	100	2620	85			
2	120			30	210	2680	180			
3	180			50	320	2730	250			
4	240			70	390	2780	330			
5	300			80	500	2880	430			
6	360			80	700	2900	530			
7	420			80	910	3000	620			
8	480			90	1110	3010	740			
9	540			90	1300	3015	810			
10	600			100	1420	3020	940			
15	900			130	2150	3040	1510			
20	1200			140	2580	3050	1680			
25	1500			150	2860	3050	1860			
30	1800			160	3020	3060	1990			
40	2400			160	Dry	3090	2190			
50	3000			170	Dry	3120	2220			
60	3600			180	Dry	3160	2230			
Re-tested 16/05/23 @ 10am				430	Dry	3630	3530			

Notes

1 *All depths below ground level (bgl) unless stated*

2

Eco90 Field Trial - Borehole Log and Infiltration Testing Datasheet

Project Name	Sunset Park Homes	**Drill method**	Rotary auger	**Logger**	Matt Dale	
Client	Integrated Designs & Associates Ltd	**Drill rig**	Comachio 205	**Weather**	Warm/Cloudy 13°C	
Test drill area	TD1	**Drill diameter**	89 mm	**Ground**		
Date	16/05/23.					

Borehole Reference						
BH1	**BH2**	**BH3**	**BH4**	-	-	-

Drilling Details

Target drill depth (mm)	1.5m	3m	6m	12m	-	-	-
Final drill depth (mm)	1.5m	3m	6m	7.5m			
Time to drill (mins)	2	5	20	45			

Soil / Drilling Conditions

Description	3m Soft clay with sand with traces of stone. 4.5m Hard layer (No spoil). 6m very dry chalk with stone and gravel 7.5m very dry stone/ gravel. 9m very soft chalk/clay/water.

Groundwater Conditions

Depth to damp rods (mm)							
Water level after 0 mins (mm)	Dry	Dry	4490	3960			
Water level after 20 mins (mm)			4350	3740			

Test Conditions

Depth of hole pre-test (mm)							
Water level pre-test (mm)							
Pipework or open cavity?							

Test Results

Mins	*Secs*	***Mins***	*Secs*	*Depth to water (mm bgl)*						
1	60			50	250	150	50			
2	120			100	300	300	90			
3	180			150	750	450	150			
4	240			200	1000	600	210			
5	300			260	1170	720	240			
6	360			260	1295	820	280			
7	420			260	1420	900	310			
8	480			260	1545	980	330			
9	540			260	1600	1050	360			
10	600			260	1670	1140	390			
15	900			270	1980	1410	490			
20	1200			270	2140	1620	580			
25	1500			290	2270	1770	640			
30	1800			290	2370	1880	710			
40	2400			300	2510	2060	780			
50	3000			320	2600	2160	850			
60	3600			340	2650	2230	910			

Notes

25ft (7.5m) in 10 mins. Hard Layer encountered at 7.5m.				

1 All depths below ground level (bgl) unless stated

2

Eco90 Field Trial - Borehole Log and Infiltration Testing Datasheet

Project Name	Sunset Park Homes	**Drill method**	Rotary auger	**Logger**	Matt Dale	
Client	Integrated Designs & Associates Ltd	**Drill rig**	Comachio 205	**Weather**	Warm/Cloudy 13°C	
Test drill area	TD2	**Drill diameter**	89 mm	**Ground**		
Date	15/05/23 & 16/05/23.					

Borehole Reference						
BH1	**BH2**	**BH3**	**BH4**	-	-	-

Drilling Details

Target drill depth (mm)	3m	6m	12m	12m	-	-	-
Final drill depth (mm)	3m	6m	7.75m	10m			
Time to drill (mins)	2	5					

Soil / Drilling Conditions

Description	3m Soft clay with sand with traces of stone. 4.5m Hard layer (No spoil). 6m very dry chalk with stone and gravel 7.5m very dry stone/ gravel. 10.5m Hard Layer.

Groundwater Conditions

Depth to damp rods (mm)							
Water level after 0 mins (mm)	Dry	Dry	Dry	Dry			
Water level after 20 mins (mm)			Dry	Dry			

Test Conditions

Depth of hole pre-test (mm)							
Water level pre-test (mm)							
Pipework or open cavity?							

Test Results

Mins	*Secs*	***Mins***	*Secs*	*Depth to water (mm bgl)*						
1	60			30	60	25	35			
2	120			60	120	50	70			
3	180			90	180	80	100			
4	240			110	240	100	140			
5	300			140	330	120	170			
6	360			160	380	130	190			
7	420			180	420	150	210			
8	480			200	470	160	230			
9	540			210	520	170	250			
10	600			230	590	170	270			
15	900			350	680	210	330			
20	1200			420	780	270	400			
25	1500			470	840	310	460			
30	1800			540	920	340	500			
40	2400			670	1000	360	640			
50	3000			780	1120	450	710			
60	3600			880	1220	520	800			
Tested again in the morning 9.45 16/05/2023				Dry	1380	2680				

Notes

1 *All depths below ground level (bgl) unless stated*

2

Key:

- Soakaway
- Surface Water Drainage
- Cesspit
- Foul Drainage
- EV Charging Point
- Outside Lighting
- Shrubs/Green corridors
- Mains Water

As Proposed Site Development Scheme Masterplan

0 5 10 15 20 25 30 35 40 45 50m
SCALE 1:500

These drawings are for Planning and Building Regulations approval only.
Figured dimensions must be taken in preference to scaled.
All dimensions must be checked on site by the contractor
Advise of any discrepancies before commencing work no liability is taken for any deviation or any unreported variations found on site prior or during work in progress.

CDM
It is the clients responsibility to take all necessary steps to fully comply with the CDM Regulations amendment 6 April 2015. The Designer has taken necessary action to avoid injury / incident within the specification, and reasonable and practicable steps in the design of the building.

Party Wall 1996
The client is the Building owner and as such should take the necessary steps to comply with the Act where applicable.

rev.	description	date	initial

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Title: Drainage Areas

Project: Sunset Park Homes
Brackley
NN13 5TD

Scale: 1:500 @ A1
Drawing No. ANS/345/01
Date 19/05/23

Appendix B

Infiltration Test Drilling	Location	Sunset Park	Date 16/05/2023	MPD
Area	1	Augers		
BH Depth (m)	1.5	3	6	7.5
	Dip to water (mm)			
1	50	250	150	50
2	100	300	300	90
3	150	750	450	150
4	200	1000	600	210
5	260	1170	720	240
6	260	1295	820	280
7	260	1420	900	310
8	260	1545	980	330
9	260	1600	1050	360
10	260	1670	1140	390
15	270	1980	1410	490
20	270	2140	1620	580
25	290	2270	1770	640
30	290	2370	1880	710
40	300	2510	2060	780
50	320	2600	2160	850
60	340	2650	2230	910

Max - Min	Max - Min	290	2400	2080	860	mm
Max - Min * 0.25	25%	72.5	600	520	215	mm
Max - Min * 0.75	75%	217.5	1800	1560	645	mm
75% - 25%	Delta Z	145	1200	1040	430	mm
water drop per minute		12.83	87.08	56.46	18.45	mm/min
Time taken to 25	t25%	2.45	3.4	4.58	5.625	min
Time taken to 75	t75%	13.75	17.18	23	28.93	min
	t75-25	11.3	13.78	18.42	23.305	min
wetted area =pi D x delta Z						
		3.6488E-01	4.3338E-01	1.3449E+00	1.9628E+00	sq.m
	discharge vol	9.0207E-04	7.4654E-03	6.4700E-03	2.6751E-03	cu.m
	dis per min	7.9829E-05	5.4175E-04	3.5125E-04	1.1479E-04	cu.m
	dis per hr	4.7897E-03	3.2505E-02	2.1075E-02	6.8872E-03	cu.m
	infil rate	**1.3127E-02**	**7.5004E-02**	**1.5670E-02**	**3.5088E-03**	**m/hr**
BH infil rate						
Surface Area		0.4236	0.8473	1.6946	2.1182	sq.m
infiltration rate per bh		5.561106E-03	6.354954E-02	2.655466E-02	7.432490E-03	**m/hr**

Area 1 Infiltration Rate Calculation

Infiltration Test Drilling	Location	Sunset Park	Date 16/05/2023	MPD

Area	1	Augers		
BH Depth (m)	3	6	7.75	10
	Dip to water (mm)			
1	30	60	25	35
2	60	120	50	70
3	90	180	80	100
4	110	240	100	140
5	140	330	120	170
6	160	380	130	190
7	180	420	150	210
8	200	470	160	230
9	210	520	170	250
10	230	590	170	270
15	350	680	210	330
20	420	780	270	400
25	470	840	310	460
30	540	920	340	500
40	670	1000	360	640
50	780	1120	450	710
60	880	1220	520	800

Max - Min	Max - Min	850	1160	495	765	mm
Max - Min * 0.25	25%	212.5	290	123.75	191.25	mm
Max - Min * 0.75	75%	637.5	870	371.25	573.75	mm
75% - 25%	Delta Z	425	580	247.5	382.5	mm
water drop per minute		37.61	42.09	13.44	16.41	mm/min
Time taken to 25	t25%	2.45	3.4	4.58	5.625	min
Time taken to 75	t75%	13.75	17.18	23	28.93	min
	t75-25	11.3	13.78	18.42	23.305	min
wetted area =pi D x delta Z						
		7.1159E-01	1.4987E+00	2.0907E+00	2.6793E+00	sq.m
	discharge vol	2.6440E-03	3.6083E-03	1.5397E-03	2.3796E-03	cu.m
	dis per min	2.3398E-04	2.6185E-04	8.3590E-05	1.0211E-04	cu.m
	dis per hr	1.4039E-02	1.5711E-02	5.0154E-03	6.1264E-03	cu.m
	infil rate	**1.9729E-02**	**1.0483E-02**	**2.3989E-03**	**2.2866E-03**	**m/hr**
BH infil rate						
Surface Area		0.8473	1.6946	2.1888	2.8243	sq.m
infiltration rate per bh		1.671609E-02	1.776463E-02	5.250754E-03	6.457945E-03	**m/hr**

Area 2 Infiltration Rate Calculation

Infiltration Test Drilling	Location	Sunset Park	Date 16/05/2023	MPD
Area	1	Augers		
BH Depth (m)	1.5	3	6	9
	Dip to water (mm)			
1	50	250	150	50
2	100	300	300	90
3	150	750	450	150
4	200	1000	600	210
5	260	1170	720	240
6	260	1295	820	280
7	260	1420	900	310
8	260	1545	980	330
9	260	1600	1050	360
10	260	1670	1140	390
15	270	1980	1410	490
20	270	2140	1620	580
25	290	2270	1770	640
30	290	2370	1880	710
40	300	2510	2060	780
50	320	2600	2160	850
60	340	2650	2230	910

Max - Min	Max - Min	290	2400	2080	860	mm
Max - Min * 0.25	25%	72.5	600	520	215	mm
Max - Min * 0.75	75%	217.5	1800	1560	645	mm
75% - 25%	Delta Z	145	1200	1040	430	mm
water drop per minute		12.83	87.08	56.46	18.45	mm/min
Time taken to 25	t25%	2.45	3.4	4.58	5.625	min
Time taken to 75	t75%	13.75	17.18	23	28.93	min
	t75-25	11.3	13.78	18.42	23.305	min
wetted area =pi D x delta Z						
		3.6488E-01	4.3338E-01	1.3449E+00	2.3822E+00	sq.m
	discharge vol	9.0207E-04	7.4654E-03	6.4700E-03	2.6751E-03	cu.m
	dis per min	7.9829E-05	5.4175E-04	3.5125E-04	1.1479E-04	cu.m
	dis per hr	4.7897E-03	3.2505E-02	2.1075E-02	6.8872E-03	cu.m
	infil rate	**1.3127E-02**	**7.5004E-02**	**1.5670E-02**	**2.8911E-03**	**m/hr**
BH infil rate						
Surface Area		0.4236	0.8473	1.6946	2.5419	sq.m
infiltration rate per bh		5.561106E-03	6.354954E-02	2.655466E-02	7.348744E-03	**m/hr**

Area 3 Infiltration Rate Calculation

Cluster Calculation

Micro BH Depth (m)	1.5	3	6	7.5	7.75	9	10		
Area 1	0.013127	0.075004	0.015670	0.003509				m/hr	
Area 2		0.019729	0.010483		0.002399		0.002287	m/hr	
Area 3	0.013127	0.075004	0.015670			0.002891		m/hr	
Averages	0.013127	0.056579	0.013941	0.003509	0.002399	0.002891	0.002287	m/hr/sq.m	
Taken forward			0.010483						
Surface Area	0.4236	0.8473	1.6946	2.1182	2.1888	2.5419	2.8243	sq.m	
BH infil rate	0.0000	0.0000	0.0178	0.0000	0.0000	0.0000	0.0000	m/hr	
Cluster	0	0	4	0	0	0	0		
Equiv. rate for calc.	0	0	0.071059	0	0	0	0	0.071059	m/hr/cluster
Equiv. rate per sq.m								**0.035529**	m/hr/plan sq.m
ECO-90 Length	1.525	3.050	6.100	7.625	7.879	9.150	10.167	m	
Drilling Depth	1.8	3.3	6.3	7.8	8.1	9.3	10.3	m	
Volume	0.009	0.019	0.038	0.047	0.049	0.057	0.063	cu.m	

Cluster dimensions		
Length	1	m
Width	1	m
Cluster area	1	sq.m

Infiltration and Attenuation System Summary

100 year storm events +40% Climate Change Allowance

Max. Storage Vol. m^3	Infiltration Facility Dimensions			No. of clusters	Length of boreholes m	Length of ECO-90 m	Storage in Boreholes m^3	Net Storage Volume m^3
	Length	Width	Depth					
13.2	5	4	0.61	20	252	244.00	1.52	11.68

This is based on an imperemable area of 200sq.m and should be adjusted to suit the actual imperemable area to be treated in each instance.

This is based upon a voids ratio of 0.95

Half Drain Time 1131 minutes

ECO-90 devices 4 x 3m devices per sq.m

A 50% reduction has been applied to the 6m rate on the basis that the upper 3m will be taken up by cover to attenuation and the attenuation depth itself, etc.

Drilling depth and ECO-90 length have also been adjusted to suit 3m (nominal) devices.

From the recorded results, infiltration potential reduces as depth increases for the depths tested. It is recommended that installations are kept as shallow as possible to ensure that the infiltration potential is maximised.

The solution provided in this summary is based on an impermeable area of 200sq.m and should be pro-rated to the actual impermeable area to be treated. It is also noted that the impermeable areas for the development parcels comprise roof areas only. The areas between the residential units have not been considered in this solution and will need to be considered separately.

Appendix C

Summary of Results for 100 year Return Period (+40%)

Half Drain Time : 1131 minutes.

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
15 min Summer	95.287	0.287	0.1	5.5	O K
30 min Summer	95.370	0.370	0.1	7.0	O K
60 min Summer	95.449	0.449	0.1	8.5	O K
120 min Summer	95.522	0.522	0.1	9.9	O K
180 min Summer	95.557	0.557	0.1	10.6	O K
240 min Summer	95.576	0.576	0.1	10.9	O K
360 min Summer	95.596	0.596	0.1	11.3	O K
480 min Summer	95.604	0.604	0.1	11.5	O K
600 min Summer	95.603	0.603	0.1	11.5	O K
720 min Summer	95.598	0.598	0.1	11.4	O K
960 min Summer	95.579	0.579	0.1	11.0	O K
1440 min Summer	95.543	0.543	0.1	10.3	O K
2160 min Summer	95.496	0.496	0.1	9.4	O K
2880 min Summer	95.453	0.453	0.1	8.6	O K
4320 min Summer	95.376	0.376	0.1	7.2	O K
5760 min Summer	95.308	0.308	0.1	5.9	O K
7200 min Summer	95.248	0.248	0.1	4.7	O K
8640 min Summer	95.196	0.196	0.1	3.7	O K
10080 min Summer	95.153	0.153	0.1	2.9	O K
15 min Winter	95.322	0.322	0.1	6.1	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
15 min Summer	147.659	0.0	19
30 min Summer	95.740	0.0	34
60 min Summer	59.033	0.0	64
120 min Summer	35.144	0.0	124
180 min Summer	25.604	0.0	182
240 min Summer	20.334	0.0	242
360 min Summer	14.690	0.0	362
480 min Summer	11.655	0.0	482
600 min Summer	9.733	0.0	600
720 min Summer	8.397	0.0	720
960 min Summer	6.647	0.0	894
1440 min Summer	4.776	0.0	1112
2160 min Summer	3.426	0.0	1496
2880 min Summer	2.704	0.0	1904
4320 min Summer	1.935	0.0	2720
5760 min Summer	1.525	0.0	3464
7200 min Summer	1.267	0.0	4248
8640 min Summer	1.089	0.0	4928
10080 min Summer	0.957	0.0	5640
15 min Winter	147.659	0.0	19

Summary of Results for 100 year Return Period (+40%)

Storm Event	Max Level (m)	Max Depth (m)	Max Infiltration (l/s)	Max Volume (m³)	Status
30 min Winter	95.415	0.415	0.1	7.9	O K
60 min Winter	95.505	0.505	0.1	9.6	O K
120 min Winter	95.589	0.589	0.1	11.2	O K
180 min Winter	95.630	0.630	0.1	12.0	O K
240 min Winter	95.653	0.653	0.1	12.4	O K
360 min Winter	95.681	0.681	0.1	12.9	O K
480 min Winter	95.693	0.693	0.1	13.2	O K
600 min Winter	95.697	0.697	0.1	13.2	O K
720 min Winter	95.695	0.695	0.1	13.2	O K
960 min Winter	95.681	0.681	0.1	12.9	O K
1440 min Winter	95.635	0.635	0.1	12.1	O K
2160 min Winter	95.574	0.574	0.1	10.9	O K
2880 min Winter	95.513	0.513	0.1	9.7	O K
4320 min Winter	95.397	0.397	0.1	7.6	O K
5760 min Winter	95.294	0.294	0.1	5.6	O K
7200 min Winter	95.206	0.206	0.1	3.9	O K
8640 min Winter	95.135	0.135	0.1	2.6	O K
10080 min Winter	95.081	0.081	0.1	1.5	O K

Storm Event	Rain (mm/hr)	Flooded Volume (m³)	Time-Peak (mins)
30 min Winter	95.740	0.0	33
60 min Winter	59.033	0.0	62
120 min Winter	35.144	0.0	122
180 min Winter	25.604	0.0	180
240 min Winter	20.334	0.0	240
360 min Winter	14.690	0.0	356
480 min Winter	11.655	0.0	472
600 min Winter	9.733	0.0	586
720 min Winter	8.397	0.0	700
960 min Winter	6.647	0.0	922
1440 min Winter	4.776	0.0	1296
2160 min Winter	3.426	0.0	1624
2880 min Winter	2.704	0.0	2076
4320 min Winter	1.935	0.0	2936
5760 min Winter	1.525	0.0	3696
7200 min Winter	1.267	0.0	4464
8640 min Winter	1.089	0.0	5096
10080 min Winter	0.957	0.0	5648

Rainfall Details

Rainfall Model	FSR	Winter Storms	Yes
Return Period (years)	100	Cv (Summer)	0.750
Region	England and Wales	Cv (Winter)	0.840
M5-60 (mm)	20.800	Shortest Storm (mins)	15
Ratio R	0.428	Longest Storm (mins)	10080
Summer Storms	Yes	Climate Change %	+40

Time Area Diagram

Total Area (ha) 0.020

Time (mins) From:	To:	Area (ha)
0	4	0.020

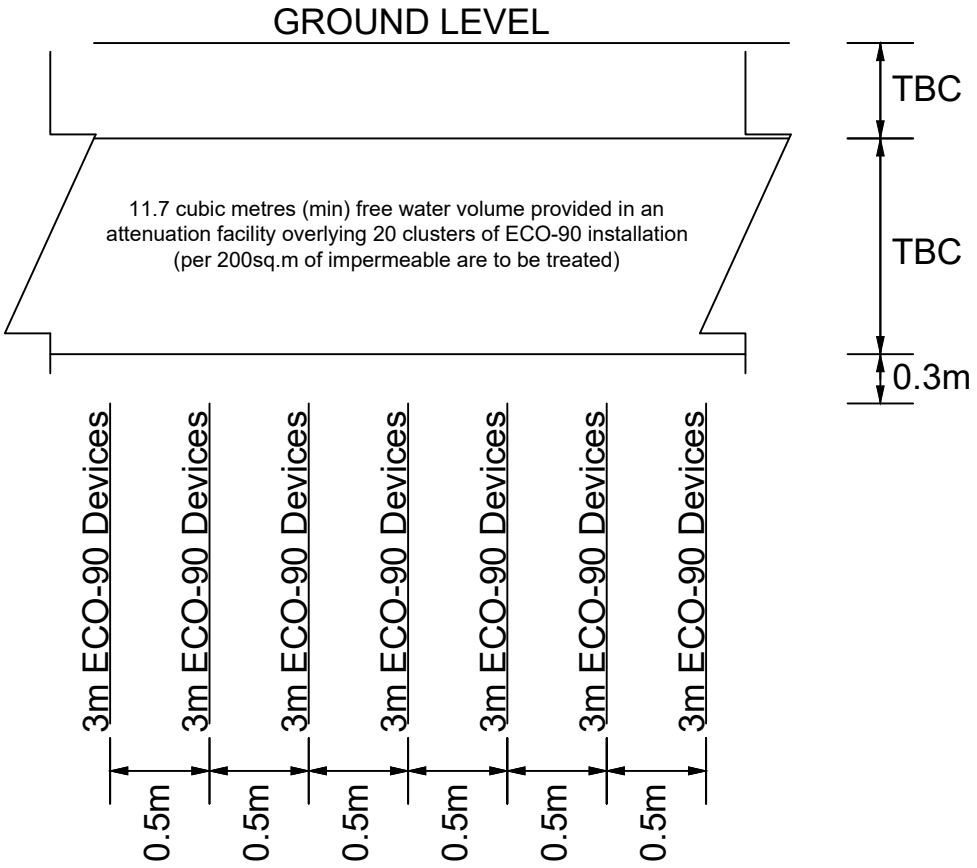
Model Details

Storage is Online Cover Level (m) 100.000

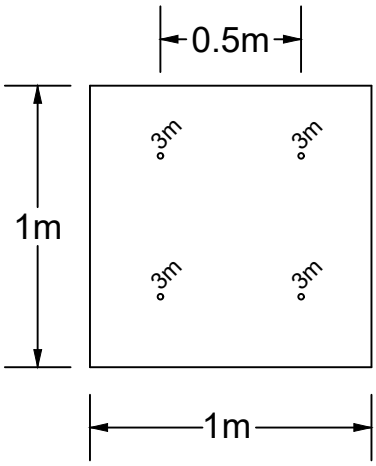
Infiltration Trench Structure

Infiltration Coefficient Base (m/hr)	0.03553	Trench Width (m)	5.0
Infiltration Coefficient Side (m/hr)	0.00000	Trench Length (m)	4.0
Safety Factor	2.0	Slope (1:X)	0.0
Porosity	0.95	Cap Volume Depth (m)	0.000
Invert Level (m)	95.000	Cap Infiltration Depth (m)	0.000

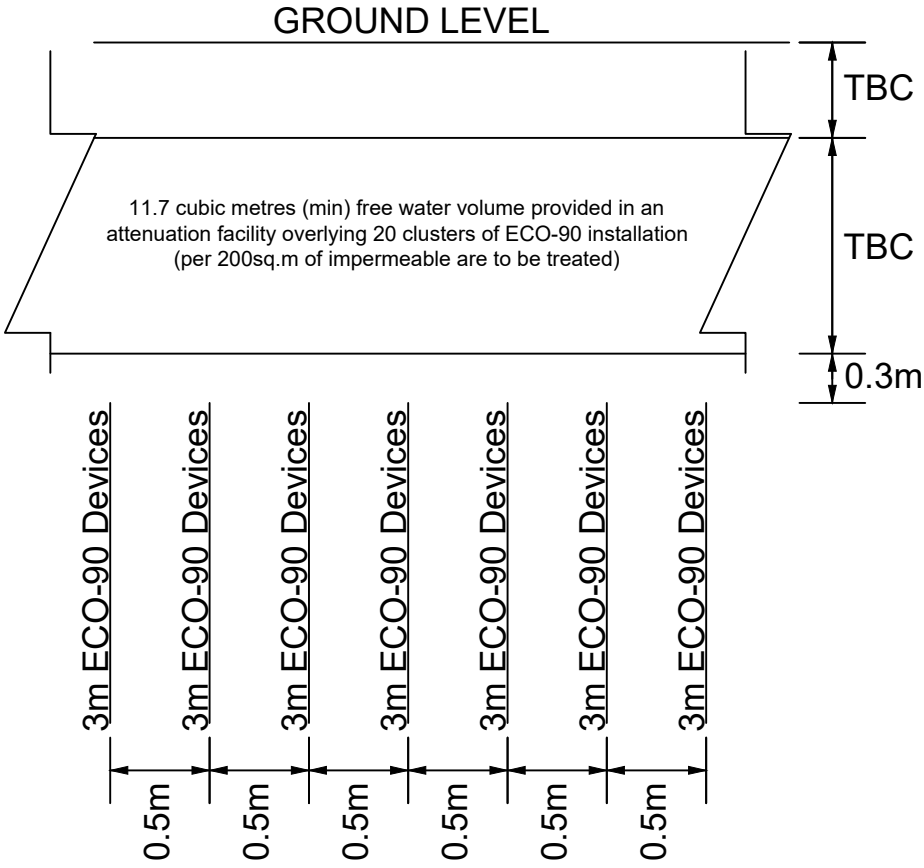
Appendix D



Typical section through attenuation and ECO-90



Typical ECO-90 cluster composition



Long section through attenuation and ECO-90

Appendix D
Schematic ECO-90 Installation

Appendix G

SUDS Technical Specification

&

Datasheet

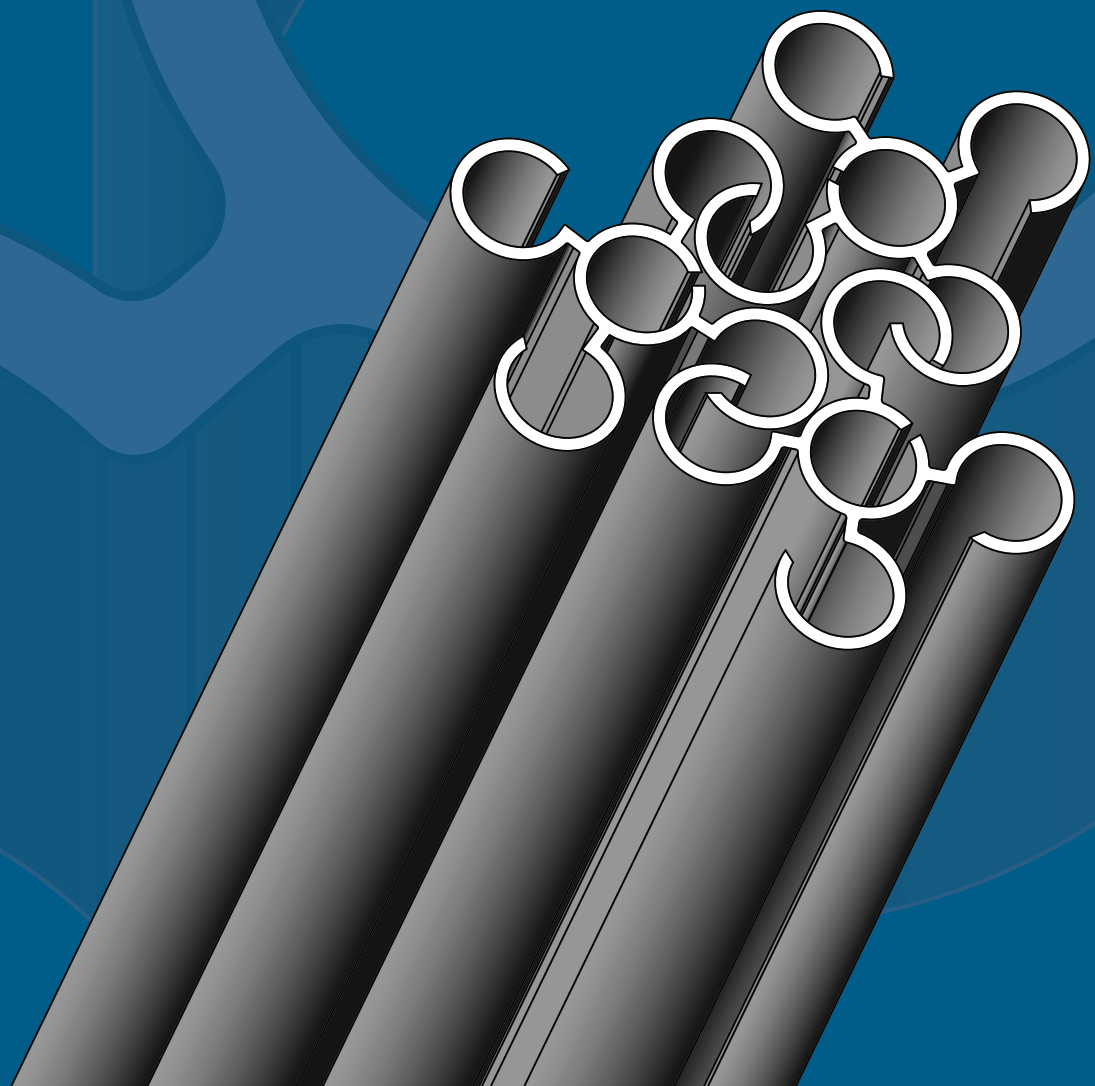
ECO-90™

GROUND WATER DYNAMICS

A GUIDE TO THE ECO-90™ DRAINAGE SYSTEM

DESIGN, INSTALLATION & OPERATION. ECOLOGICAL & ENVIRONMENTAL STANDING.

Including a synopsis of an independent scientific analysis paper covering the efficacy of the ECO-90™ system.



Contents

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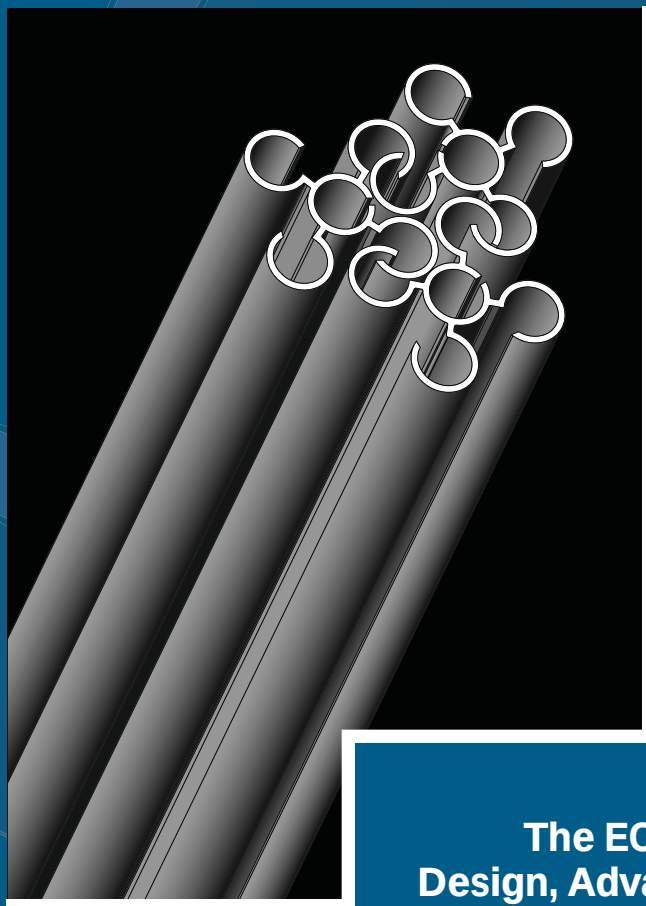


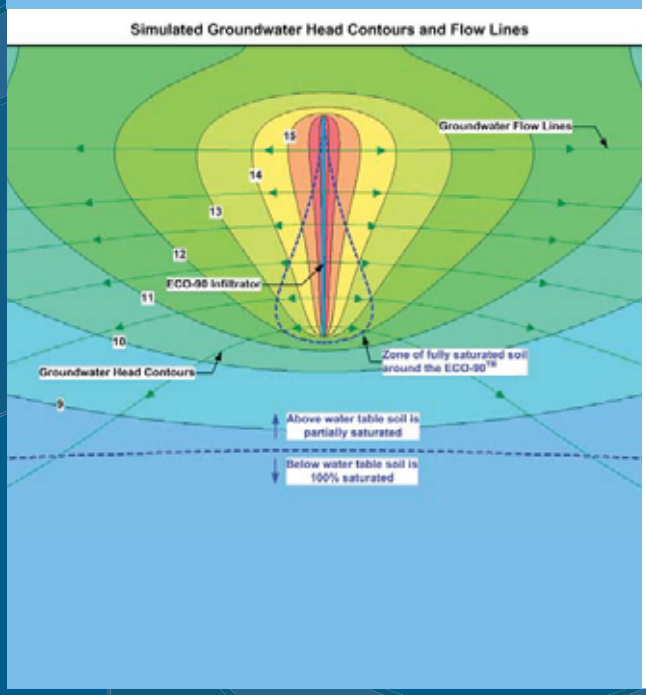
£500,000

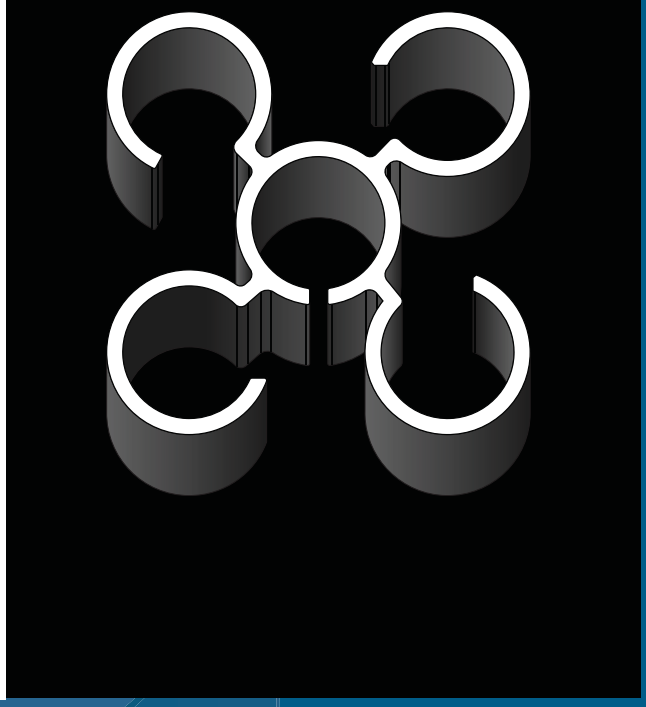
PROFESSIONAL INDEMNITY COVER

Where we supply and install an ECO-90™ engineered drainage solution we offer an insured warranty, covered by up to £500,000 Professional Indemnity cover. Higher cover is available as required.

In some instances, such as natural turf where we offer our own ECO-90™ drainage design solution and install, we offer a two year defect warranty. This means we will return to site to remedy any problems at our expense.

The ECO-90™ Design, Advantages over Traditional Drainage & Sector Applications





Background

Extreme rainfall events have created growing problems for natural turf reliant businesses and organisations, from golf courses to school playing fields and multiple other examples.

Increased property development has resulted in a larger proportion of land with impermeable surfaces which, when combined with prolonged periods of rainfall, can give rise to nuisance groundwater and flooding.

For new builds there is now fast-growing resistance from planning authorities and water boards to developments that cannot deal with storm water and even effluent discharge at source (on site).

In addition, if a development collects storm water and then moves it into a storm drain that takes it to wherever, the land that the development stands on has lost water it used to have. This negatively impacts the ecology and environment of the catchment area and can also undermine the aquifer and the drought resistance of ditches, streams and rivers. Public opinion, particularly amongst the demographic of house buyers, is shifting to growing intolerance of property developers who show little concern for the ecology and environment in which they have developed housing.

Whilst traditional piped drainage systems require an outflow to storm drains, the ECO-90™ system deals with rainfall at source, cost effectively, environmentally and with minimal disruption. For sites with poor infiltration rates, soakaways will struggle but the ECO-90™ system, as a deep drainage system, in most cases will work.

THE ECO-90™
A unique approach to drainage design

Deals with storm water at source, a game changer in below the ground SuDS (Sustainable Drainage Systems)

Solves surface saturation, standing water and localised flooding for municipal and recreational facilities

Moves storm water into multiple soil stratas to a depth of 12 metres, bringing into play major additional volume of soil for drainage

For new build sites no connection needed to storm drains or combined sewers

For residential new build where ECO-90™ is preferred to soakaways, the reduced drainage footprint can create space for more houses and a higher GDV

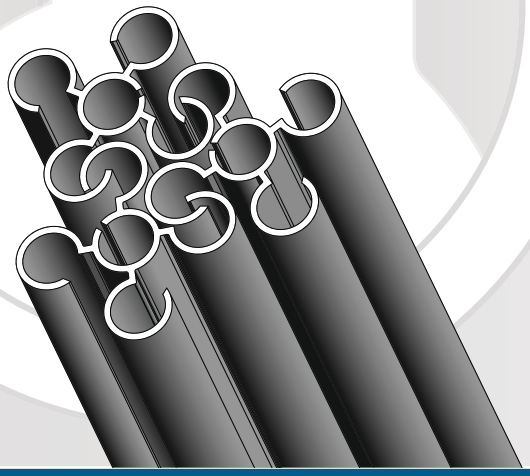
Resolves basement and ground floor flooding

No moving parts, no external power source required, a self-cleaning sealed system

A CARBON NEGATIVE drainage system

£500,000 professional indemnity cover for all installations

Over 300 successful UK installations since 2012.



The future of 'at source' drainage - a cluster of ECO-90s™

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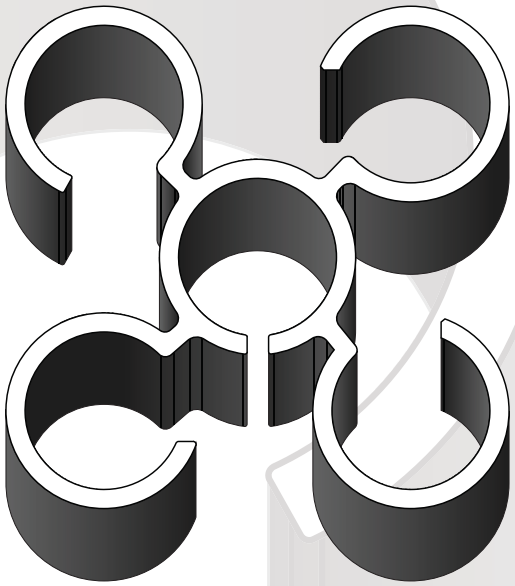


The ECO-90™

The ECO-90™ is a worldwide patented technology, that enhances and accelerates multiple soil stratas ability to absorb water. We introduced it into the UK in 2012, the system was originally used to deal with natural turf drainage issues: flood; saturated ground; and standing water. High profile customers included Edgbaston Cricket Club, Gleneagles Golf Course, Royal Ascot and Silverstone F1.

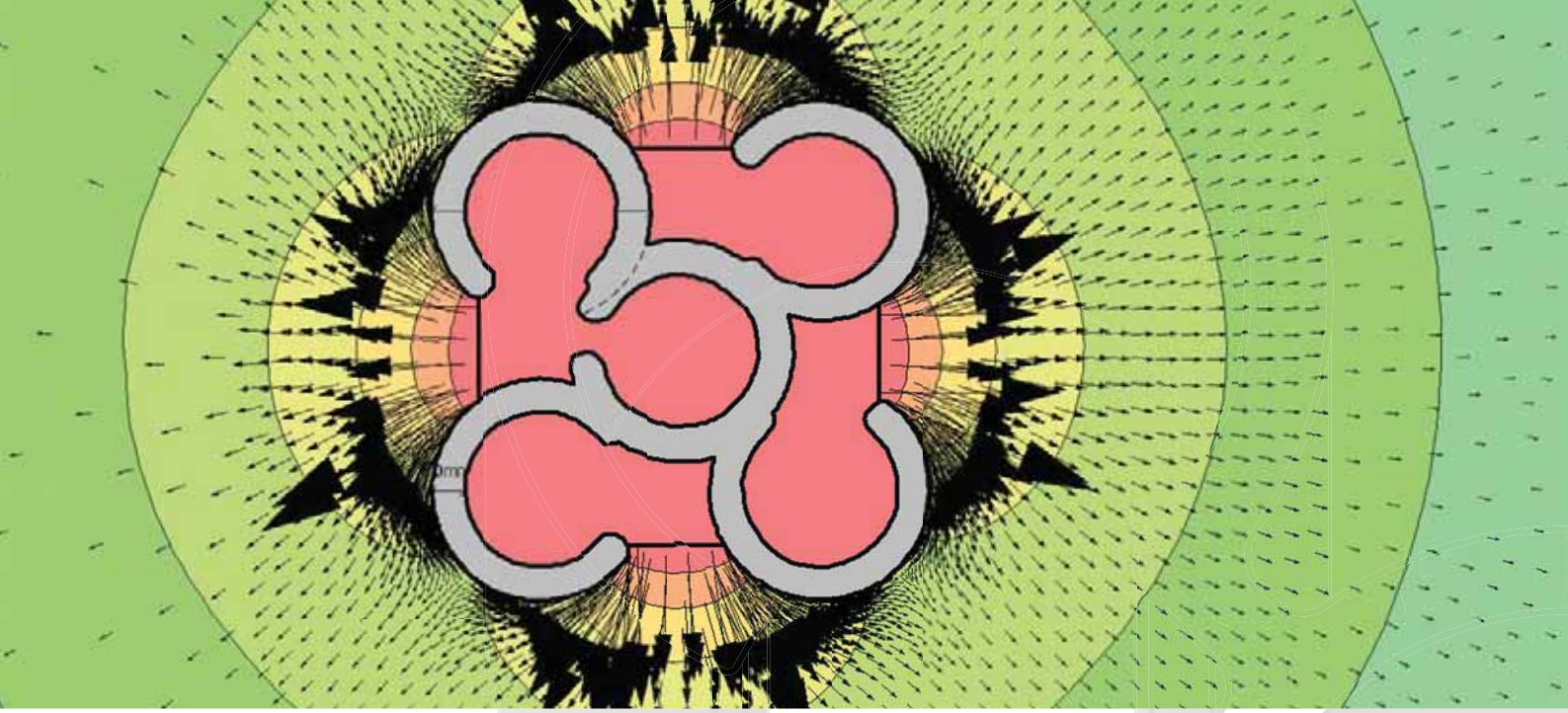
These installations attracted the attention of Architects and Drainage Engineers who were interested in using the system to satisfy Sustainable Drainage System (SuDS) requirements in planning. Increasingly the system is being used as a SuDS solution in new build schemes, particularly given an escalating planning and water board requirement to deal with storm water at source, allied to growing focus on the ecological and environmental impact of such developments.

The ECO-90™ design

The ECO-90™ is a cut length, with a cross section consisting of five open chambers (see above). It is a drainage extrusion made from standard HDPE (High-density Polyethylene), a thermoplastic. With a high strength-to-density ratio, HDPE material is often used for corrosion-resistant piping and is deemed more eco-friendly than other materials used within the industry as it does not deteriorate in the soil. HDPE is commonly re-cycled, it has a Class 2 resin identification.

It is important to understand that the ECO-90™ is not a pipe, the open chambers are a key reason why it works. The ECO-90™ has no moving parts, requires no external energy source and is self-cleaning, requiring no ongoing maintenance.

> “ The ECO-90™ is a Tier 1 below ground SuDS system, designed to engineered industry standards using WinDes micro-drainage positive outflow that half-drains down within 24 hours.



How the ECO-90™ works

The ECO-90™ come in lengths of up to 12 metres.

It is installed vertically into a pre-drilled hole:

(i) that for natural turf installations (such as golf courses, sports pitches etc.) is 30cm deeper than the ECO-90™ length and, therefore the ECO-90™ stands 30cm below the surface. This prevents surface water entering the ECO-90™. Once installed the ECO-90™ is also capped, preventing any pollutants from directly entering the chambers

(ii) that for construction drainage purposes, in conjunction with an infiltration trench, the pre-drilled hole is at the base of the trench and the trench has a geotextile lining to deal with pollutants (hydrocarbons – oil).

Given (i) and (ii) above, the ECO-90™ drainage system is therefore not a borehole drain.

Water held in the soil surrounding the open chambers moves into them and then descends, its natural propensity. Soil around the ECO-90s™ becomes saturated and this creates two key results:

(iii) as the water enters the ECO-90™ chambers and moves to the bottom of the ECO-90™ to a depth of 12 metres, the head of water in the chambers is now exerting significant pressure throughout the length (depth) of the ECO-90™, creating a differential hydraulic head. This head forces water out of the chambers into surrounding unsaturated soil stratas (see Discharge Velocity Modelling above)

(iv) in addition, unsaturated soils start drawing water out of the saturated soils, that now surround the ECO-90s™. This can happen laterally and even upwards. In certain soil structures this discharge can be far greater laterally than vertically, particularly in laminated (layered) soils and is another key advantage of the open chamber design of the ECO-90™ system.

As water is forced out of the chambers due to (iii) and (iv) above, the soil surrounding the ECO-90™ starts to reduce saturation, enabling more surface or trench water to now enter the chambers. The result is a virtuous cycle of nuisance surface or storm water being drawn into the chambers and then being discharged into deeper unsaturated soil stratas. Essentially the ECO-90™ system has created a deep drain, utilizing soil stratas between 2 metres to 12 metres below ground level.

By technical definition, a designed and installed array of ECO-90s™ form a Passive Groundwater Recharge Based Drainage System.

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ECO-90™ replacing traditional drainage

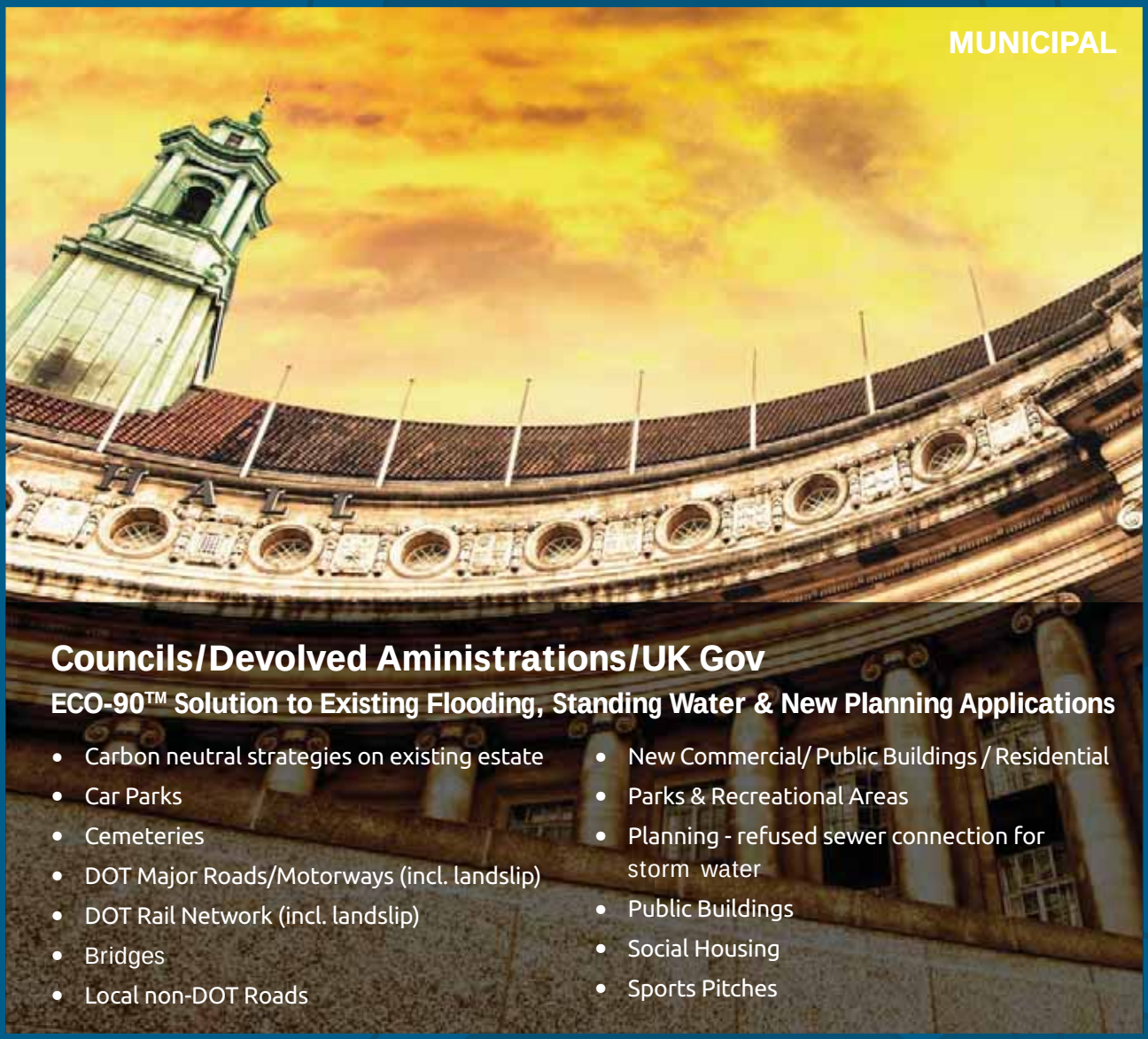
An ECO-90™ system is a multiple install of ECO-90s™ and is a clear design option against traditional drainage systems. As previously stated, by technical definition it is a Passive Groundwater Recharge Based Drainage System.

It scores above these traditional systems over six scales:

- At the scale of the full drainage field the ECO-90™ system, as a deep drainage system increases the surface area to volume ratio, making more soil available for drainage as well as increasing the likelihood of intercepting more permeable soils. This has the benefit of reducing risk of drainage failure, with multiple ECO-90™ forming the system and increasing the likelihood of discharging into soil stratas to a depth of over 12 metres
- Against soakaways an ECO-90™ system can also have the effect of reducing drainage allocation footprint to any new build site, driving GDV higher. This can be further enhanced by using ECO-90™ clusters beneath permeable paving, reducing the volume of water to the point where large scale attenuation is not required
- At the scale of the individual wells the ECO-90™ system improves the drainage and storage potential of soils, allowing them to develop through use
- At the micro or mineralogical scale, soil moisture transfer (shrink-swell) is promoted in otherwise low permeability soils, such as clays and silts
- At the carbon scale, the ECO-90™ creates healthier soils that were formerly saturated; and surface soil suffering drought to be rehydrated from water held in hydrated soils below. By creating more balanced hydration of soils across the seasons, shrub and tree growth are accelerated and are also more drought resistant. This results in removing or securing the removal of carbon from the atmosphere faster and thereby making the system operationally CARBON NEGATIVE
- At the ecological and environmental scale, the ECO-90™ system design can allow storm water to infiltrate naturally across a construction development site, replicating as best as possible the former operation of the catchment area that the site is now building on. This increases the probability of recharging aquifers, ditches, streams and rivers and reducing drought risk with attendant CARBON NEGATIVE benefits.

> “Through my understanding of the ground and the principles of groundwater movement, the technical basis of the ECO-90™ system was easily understood.
>
> At its simplest, it is a catalyst that optimises the drainage potential of the ground.
>
> **Russell Bowman**
> Geo & Hydrogeologist, Soils & Structures

Applications of the ECO-90™ system across specific sectors



Councils/Devolved Aministrations/UK Gov

ECO-90™ Solution to Existing Flooding, Standing Water & New Planning Applications

- Carbon neutral strategies on existing estate
- Car Parks
- Cemeteries
- DOT Major Roads/Motorways (incl. landslip)
- DOT Rail Network (incl. landslip)
- Bridges
- Local non-DOT Roads
- New Commercial/ Public Buildings / Residential
- Parks & Recreational Areas
- Planning - refused sewer connection for storm water
- Public Buildings
- Social Housing
- Sports Pitches

ECO-90™ Solution to Existing Problem Flooding, Standing Water & New Planning Applications

- Basement Flooding
- Ground Floor Flooding
- Car Parks
- New Build (SuDS)
- Saturated Landscapes
- Nuisance Standing Water
- Refused Connection - storm water/effluent

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ECO-90™ Solution to Flooding & Standing Water

- Bowling Greens
- Cricket Grounds
- Golf & Horse Racing Courses
- Racing Circuits
- Pitches – Football, Hockey, Lawn Tennis, Polo, Rugby et al.

ECO-90™ Solution to Existing Problem Flooding, Standing Water & New Planning Applications

- Basement flooding
- Flood alleviation
- New Build with greater GDV
- Saturated Landscape/Gardens
- Refused connection -storm water/effluent

ECO-90™ Solution to Flooding & Standing Water

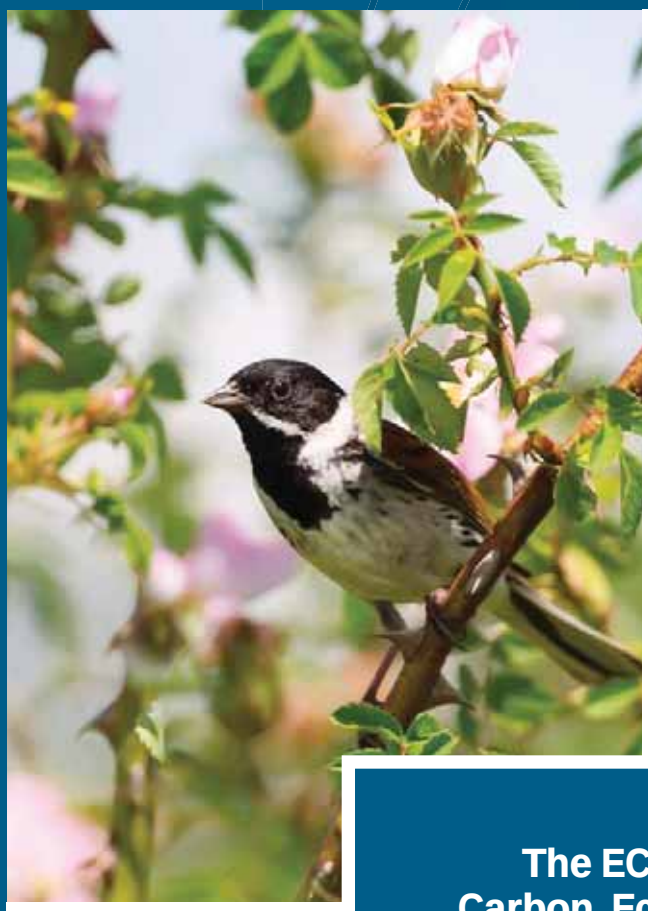
- Airport Runways
- Construction Phase (Temporary) Drainage
- Infrastructure Permanent Drainage
- Railways
- Roads
- Brownfield Urban Regeneration

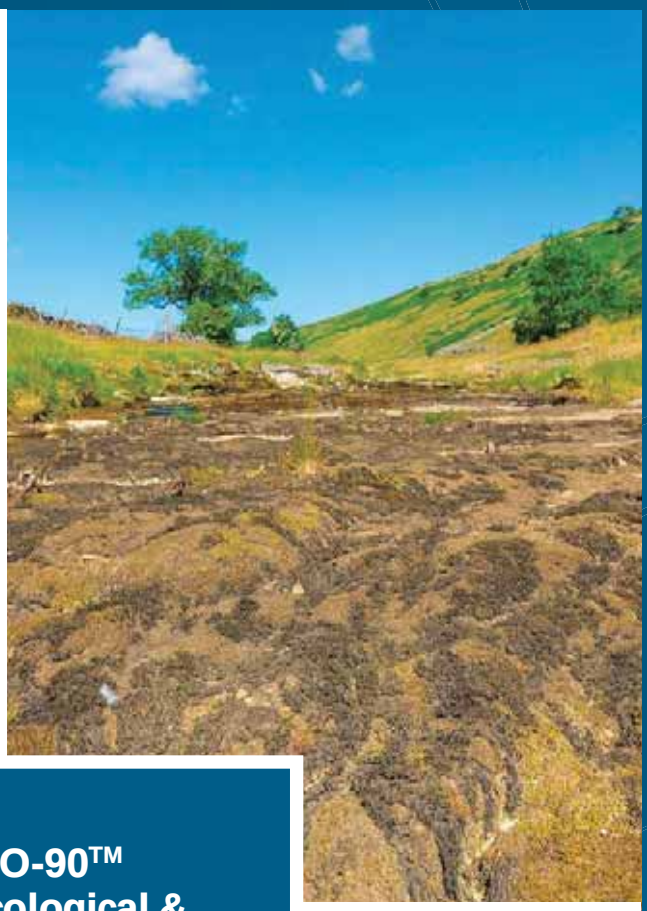
£500,000

PROFESSIONAL INDEMNITY COVER

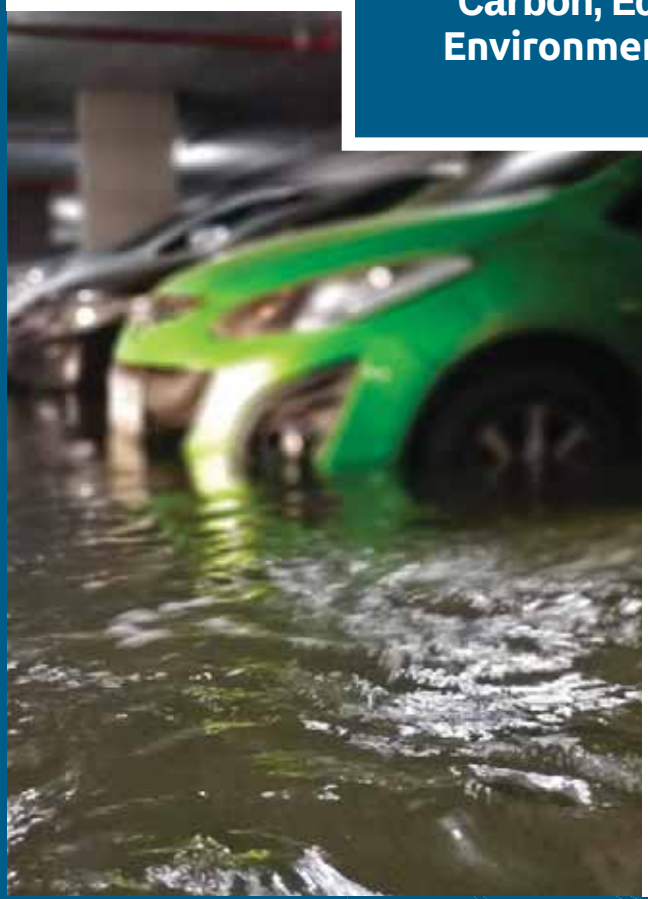
Where we supply and install an ECO-90™ engineered drainage solution we offer an insured warranty, covered by up to £500,000 Professional Indemnity cover. Higher cover is available as required.

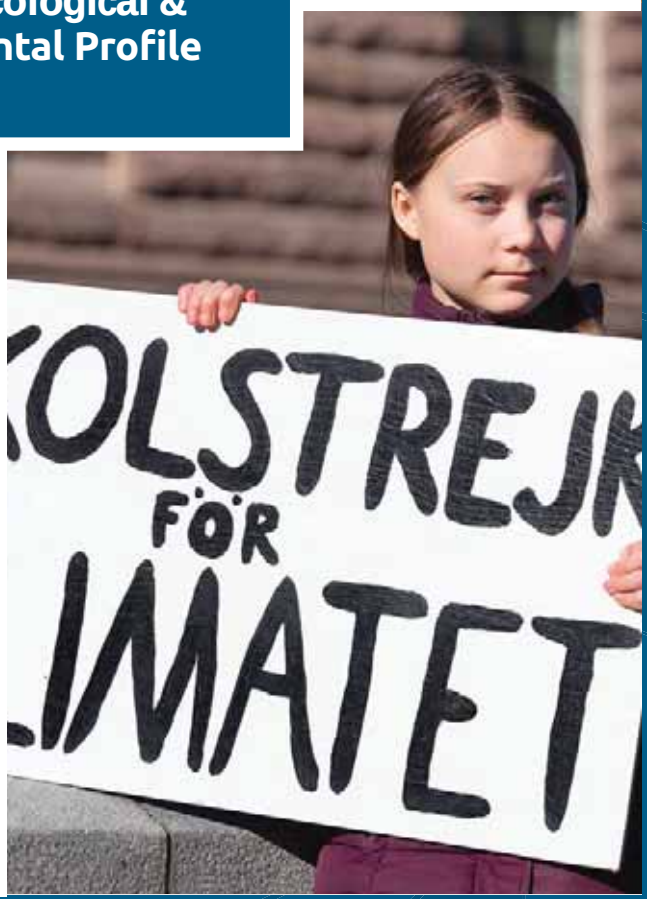
In some instances, such as natural turf where we offer our own ECO-90™ drainage design solution and install, we offer a two year defect warranty. This means we will return to site to remedy any problems at our expense.





The ECO-90™ Carbon, Ecological & Environmental Profile





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Introduction

The ECO-90™ system deals with storm water at source, allowing catchment storm water to infiltrate the soil on either a construction or natural turf site, helping water to move below ground much as it did prior to the land being developed. This is at the heart of the ECO-90™ ecological and environmental profile and is best seen through how it impacts two key issues: drought and flood.

For instance, because the ECO-90™ system does not follow traditional drainage design that moves large amounts of storm water from A to B in conventional horizontal pipes creating problems down the line, it does not contribute, as they do, to the flooding of water treatment facilities that then discharge into critical stream, river and marine ecosystems.

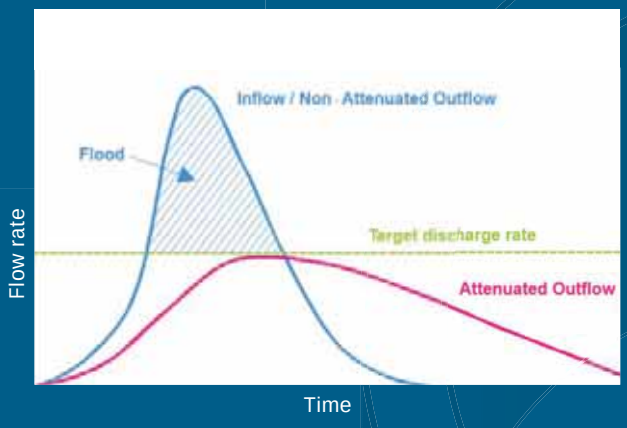
Furthermore, on larger construction sites, 'clusters' of ECO-90™ can be installed strategically around the site, allowing for a decentralised approach to drainage and assisting highly localised storm water infiltration. This has the dual benefit of reducing the amount of attenuation (trench(es)) required and more fully replicating pre-development catchment storm water infiltration.

On the issue of carbon, the ECO-90™ system is operationally CARBON NEGATIVE, a real plus point for any land-owner or developer in their pursuit of ever lower carbon footprints.

> "The closer any site gets to letting rainfall infiltrate and percolate as it always has, the better the ecological and environmental result.

How ECO-90™ reduces flood risk

Although the most preferable SuDS is a passive infiltration system where storm water is first attenuated using volumetric storage facilities, followed by the slow release of the stored water back into the ground, in many locations it is often the case that the ground is not considered suitable for surface infiltration systems due to the clay/silt ground being insufficiently permeable. This means that the storm water either has to be discharged to a sewer or a local watercourse, which can lead to flooding.



However, if the design of an attenuation trench, comprising large storage, is enhanced with a large number of drilled ECO-90™ infiltrators installed from the base of the trench, the pressure head of collected stormwater provides the pressure to force the water into the ground via the ECO-90™ array. Furthermore, by installing these highly permeable ECO-90s™ to depth, more permeable ground strata are encountered, particularly highly anisotropic ground where the horizontal permeability is much higher than the vertical permeability. By enabling infiltration at depth into silt or sand lenses within clay soils, the ECO-90™ system helps to prevent local surface water flooding.

For construction sites an ECO-90™ system helps to mitigate the peak water levels in local rivers following storm events, as shown by the hydrograph opposite. This is because surface water takes time to move through the ECO-90™ system, so providing for more gradual increase in river levels during heavy rainfall and slower reduction in river levels once the rain has passed.

> “
>
> For construction sites an ECO-90™ system helps to mitigate the peak water levels in local rivers following storm events, reducing flood risk.

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How ECO-90™ reduces drought risk

Whilst a lot is made of the impact of new build developments on flooding, little is made of the ecological and environmental damage from drought that these developments can cause. Connecting to storm drains might be the easy way out for developers but in most cases such connections take storm water off to wherever, resulting in the land that the development stands on losing water it used to have. This negatively impacts the catchment area and can also undermine the aquifer and the drought resistance of ditches, streams and rivers.

The ECO-90™ system deals with storm water at source, allowing catchment storm water to infiltrate the soil on either a construction or natural turf site, helping water to move below ground much as it did prior to the land being developed. This provides significant ongoing support for the local ecology.

Former fruit trees killed by drought.

> “ It is most likely that with climate change causing extreme weather events, drought will become more frequent and potent. This will be exacerbated by water from any new development being routed elsewhere.

ECO-90™ carbon credentials

As the ECO-90™ system uses no external energy source, it is operationally carbon neutral, with zero carbon run costs and no ongoing maintenance. It can improve the drainage carbon footprint of any site by wiping out external energy requirements to deal with storm water, with no need for pumps moving water or the energy requirements of treatment works. The system simply becomes part of the soil structure, facilitating the movement of water through multiple soil stratas.

In addition, the ECO-90™ system is positive for bush, plant and tree growth. It can deal with saturated soils, resulting in a root system no longer rotting in the ground, enabling it to perform its vital role in providing water and nutrients to its above ground host. This was the case at Royal Ascot (see picture opposite) where the Parade Ring is encircled by a bush hedge. The bushes were failing because of saturated ground but once an ECO-90™ system was installed the nuisance water was infiltrated into deeper unsaturated ground and the bushes returned to health.

Equally, the ECO-90™ system is a conduit to transfer surface water to the water table, thereby recharging aquifers and other natural water courses, such as streams and rivers. This helps provide greater drought resistance, enabling plant life to see out spells of drought and thrive again. Where plant life dies, carbon is released into the atmosphere.

By supporting plant growth and survival, the ECO-90™ system helps remove carbon dioxide from the atmosphere and any system or device that facilitates this, combined with zero external energy demand to operate, is described as carbon negative, the highest accolade available in the global drive for a carbon neutral world.

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Climate Change

A seismic shift in public opinion and buying behaviour

Climate Change has become a catch-all term for our concern about our impact on nature. The realisation about the effect that humans have on the natural environment is most obvious when looked at through the lense of carbon emissions. This is, however, part of a wider public concern about what we are doing to ecosystems through: relentless building development; plastics; drought; flood; and the extinction of countless species.

Public opinion, particularly amongst the demographic of house buyers, is shifting to growing concerns about property developments that show little care for the ecology and environment and are 'green washing'. Such house buyers are wary of any implied association to 'green washing' and associated 'profit at all costs' motives. Moving forward, developers who put profit ahead of the natural environment will find increasing reputational issues with house buyers and sites will struggle to sell down.

Children are influencing parents' opinions

Much of adult concerns regarding climate change relates to the climate and nature legacy they will leave for our children. What children think therefore does matter.

In March 2020 BBC Newsround worked with Savanata-ComRes, a specialist survey company who asked 2,000 eight to sixteen year olds to answer a series of questions about climate change.

- Four out of five of children (80%) said the problem of climate change was important to them, with over a third saying it was very important
- Just three out of every 100 said that the environment wasn't important to them
- Nearly three quarters (73%) said they are worried about the state of the planet right now - including 22% who say they are very worried
- When asked about their futures, almost three in five (58%) children said they're worried about the impact that climate change will have on their lives
- More than half (59%) of them don't think their voices are being heard on climate change
- Nearly two thirds (64%) don't believe people in power are listening to them enough when they do talk about it
- But when asked about the action being taken by grown-ups to tackle the problem, more than two in five (41%) said they don't trust adults to tackle the challenges that climate change presents.

Sustainable Drainage Systems (SuDS) will become far more dominant in planning decisions

Water features in Climate Change as a threat due to drought or flood, but is not necessarily appreciated as a highly precious commodity in our daily lives. The UK currently has a water surplus of 12% but population growth will see that become a water deficit of between 8% – 22% within the next 30 years (DEFRA, March 2017). This makes the case for SuDS enforcement all the more important because developments discharging storm water into sewers, including water courses, that in the end lose the water to the sea is irrational and unsustainable.

The ECO-90™ drainage system stands up to robust ecological and environmental interrogation and whilst most house buyers don't stop to think about climate change and drainage systems, it is only a matter of telling them before they understand what's on site and where it fits into SuDS.

Wild water swimming, pollution and SuDS

With many people forced to stay close to home due to COVID lockdown there was a surge in river swimming. This resulted in many swimmers confronting river pollution and a barrage of questions aimed at water companies followed. Storm drains taking storm water to combined treatment works have become overrun in major rainfall events and either the sewage is discharged into a watercourse or sent back up into homeowners toilets, so the watercourse gets it. As of February 2021 a private members bill is now looking to address this matter and the result is most likely that water companies will either refuse new connections to their storm drains or to allow it at a restricted rate. Again, SuDS will be seen as an answer and ECO-90™ as a 'go-to' system within the Tier 1 hierachy of SuDS solutions.

> "Water will increasingly be understood as a precious resource. Run out of it and watch the mayhem.

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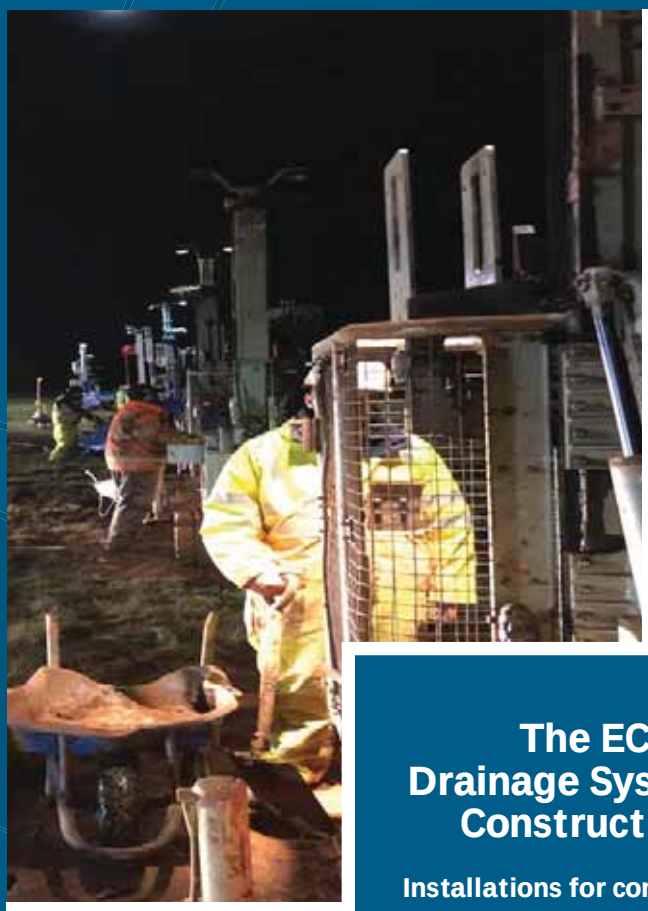

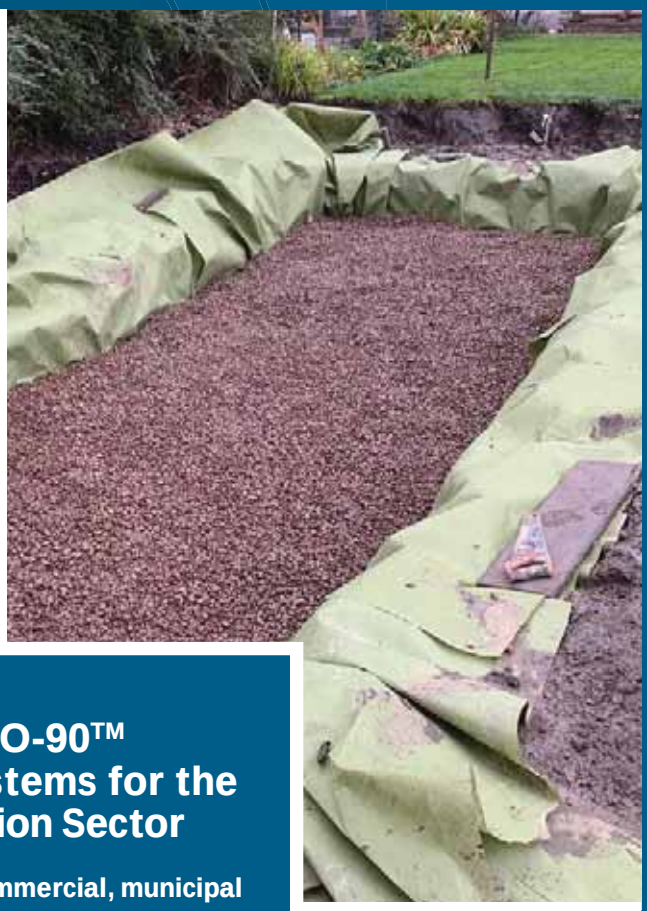

The ECO-90™ Drainage Systems for the Construction Sector

Installations for commercial, municipal and residential developments

Flood prevention to existing buildings, including basements and groundfloor

Retrofitting drainage systems

Designing an Engineered ECO-90™ system

It is vital to investigate any site where an ECO-90™ system is being considered. The system requires an understanding of soil stratas of any site to a depth of 12 metres and to know the height of the water table.

We follow a three-stage approach to designing an ECO-90™ system:

Stage 1 We produce a desk based geo and hydrogeological report, using British Geological Survey records. This is a good indication of what soils and rock stratas are likely to be encountered on site and also the probable height of the water table.

Stage 2 Provided the Stage 1 report is positive for an ECO-90™ system, we move to test-drilling to a depth of 12 metres or to the ground water level if higher. We conduct a minimum of four clusters of four drilled holes across a site. The clusters are drilled holes to a range of depths: 1.5m, 3m, 6m and 12m. For this we use a geo-hydraulics falling head test to a range of depths from which we extract infiltration rates.

Stage 3 The test-drilling results are then provided to a Consulting Drainage Engineer who uses micro-drainage software to perform calculations regarding required storage capacity (attenuation), ECO-90™ outflow rate and half drain-down time. From this the Engineer produces a Drainage Design Statement (summarised in the example table below) showing the required size of:

- the infiltration trench (soakaway) – this is needed to buffer storm water from major rainfall events
- the ECO-90™ array(s) – these are located at the base of the infiltration trench.

To err on the side of caution, the Engineer applies a safety factor against infiltration rates and also assumes no lateral infiltration as this takes time to establish and cannot be recorded at test-drilling stage. The maximum storage volume is based on required parameters, typically a 1 in 100 year event plus 40% climate change allowance.

Max. Storage Vol m^3	Infiltration Trench Dimensions			No. of clusters	Length of boreholes	Length of ECO-90™	Storage in Boreholes m^3	Storage in Trench m^3
	Length	Width	Depth					
79	80m	3m	0.91m	240	2,450m	2,190m	13.7	65.3

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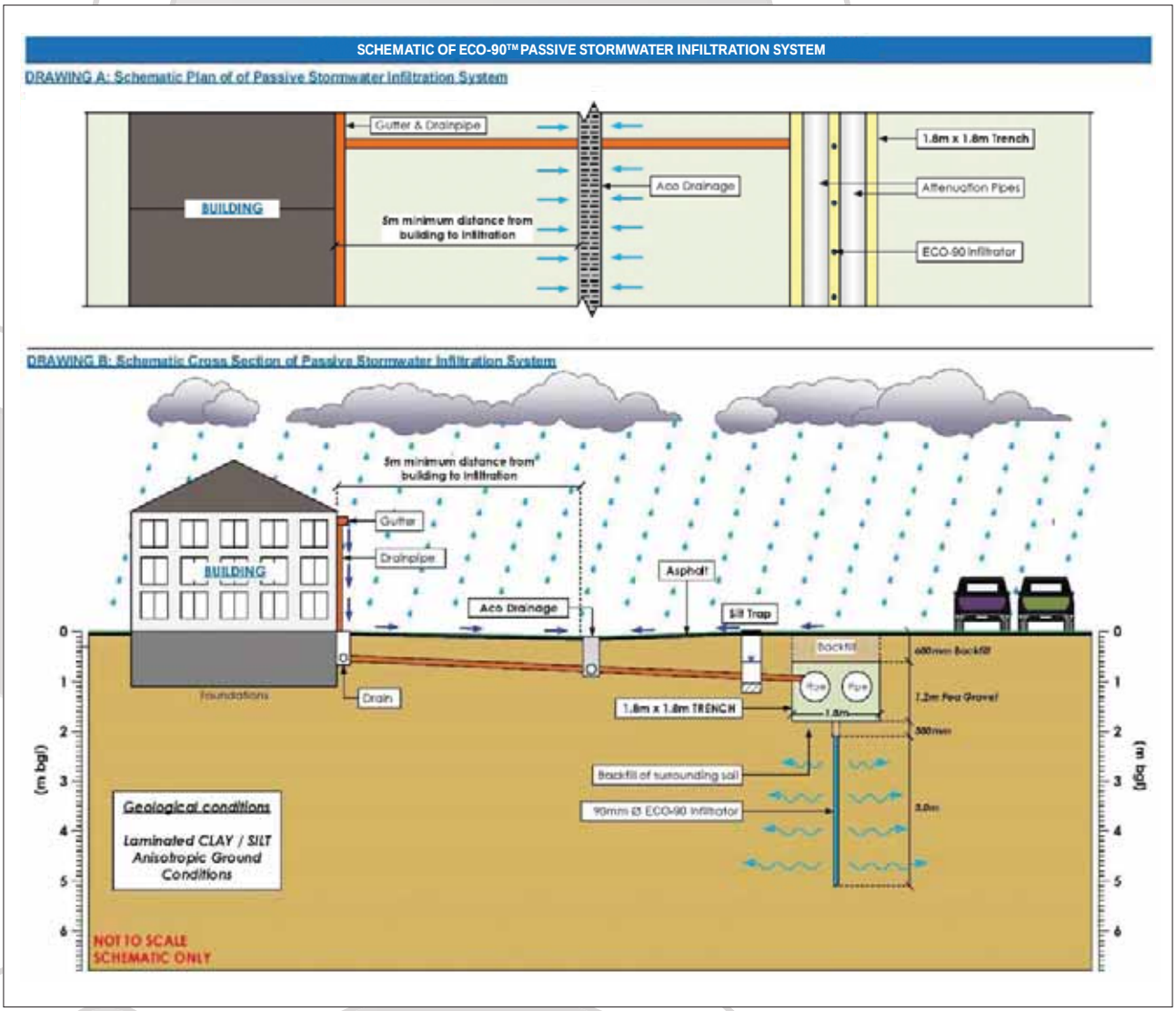
Installing ECO-90s™ to form a complete drainage system



When ECO-90s™ are installed as an array beneath an infiltration trench they form an unrivalled natural storm water drain up to 12 metres deep, dealing with storm water at source.

For construction projects, including satisfying a Drainage Design Statement and Sustainable Drainage System (SuDS) regulations, the system design will incorporate an infiltration (storm water) trench to deal with any required sudden storm water storage, with the ECO-90s™ then draining down the trench to unsaturated soil stratas (as shown in the above illustration). To deal with silt and pollutants the storm water moves through a silt trap and then enters the trench. The trench has a geotextile filter, Inbitex that encourages the formation of microbes that in turn degrade hydrocarbons (oils).

The Drainage Design Statements, including the size and location of the infiltration trench are completed by an independent firm of Consulting Drainage Engineers as a turn-key solution. However, they can also act in a consulting capacity to Architects and other Consulting Engineers, with no need to engage with their client.

ECO-90™ Construction at Scale

Newcastle High School

Construction: Drainage system for Astro Pitch

Impermeable area: 11,000 m^2

Storm water storage requirement: 512 m^3

Edinburgh University

Construction: Drainage system for New Build, Avian research Centre

Impermeable area: 10,000 m^2

Storm water storage requirement: 360 m^3

Motor Point

Construction: Drainage system for New Showroom and Forecourt

Impermeable area: 5,811 m^2

Storm water storage requirement: 155 m^3

“As a drainage designer I used to dread looking at sites that needed drainage but without access to an outflow. The ECO-90™ changed that and for the last six years I have enjoyed working with GWD and seeing how many water and drainage issues can be solved by an ECO-90™ system.”

Steve Bowles, Consulting Drainage Engineer, EC49

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The ECO-90™ Drainage Systems for Natural Turf Installations

Storm water troubles growing

Major rainfall events, many associated with climate change can play havoc with recreational facilities and many businesses or organisations that rely on a good dry surface for its facilities to successfully operate can be severely affected.

From cemeteries, golf courses, horse racing, parks and pitches, nuisance water is a growing problem.

The very inception of the introduction of the ECO-90™ system in 2012 was aimed at dealing with the debilitating effect of localised flooding, saturated ground and standing surface water on recreational facilities. From Edgbaston Cricket Ground, Gleneagles Golf Course, Royal Ascot Parade Ring, Silverstone F1 we quickly established our Hall of Fame. Times move on and from Stanton Cemetery to Wandsworth Common and countless other installations, we have proved the efficacy of the ECO-90™ drainage system to solve these problems.

In addition, we have helped secure planning permission for new facilities that were blocked by a water company's refusal to take storm water into their sewers. We know how to deal with storm water at source (on site), an increasingly key condition in planning based on the growing enforcement of Sustainable Drainage System (SuDS) regulations that focus on dealing with storm water at source as a condition for planning permission.

FACILITY	PROBLEM
Cemetery	Loved ones cannot access graves; burials
Golf Courses	Closure of holes; falling membership and declining associated spend
Horse Racing	Cancellation of meetings
Parks and Children Play Areas	Council tax levies for unusable facilities
Pitches	Unusable facilities affecting both private and public sector

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Natural Turf Installations

An ECO-90™ system is designed to irradicate surface saturation and ponding enabling natural turf surfaces to drain efficiently. When installing into natural turf an ECO-90™ system causes limited site disruption and as a sealed system, requires no direct maintenance over time.

Designing an ECO-90™ system

It is vital to investigate any site where an ECO-90™ deep drainage system is being considered. The system requires an understanding of soil stratas of any site to a depth of 12 metres and to know the height of the water table.

In addition, many natural turf facilities have been subject to significant compaction from day to day use by customers and by maintenance works. Technically this results in the need to analyse the health of the turf itself, the 'profile', because compaction can create an impossible infiltration scenario for the surface water to infiltrate to below ground soils.

We follow a three-stage approach to designing an ECO-90™ system for natural turf:

Stage 1 We take samples of the 'Profile' and send this for laboratory analysis. This looks at compaction levels and the permeability level. Some Profiles have almost no permeability. This means no matter what we do to increase infiltration below the surface it will be in vain because water cannot even infiltrate through the turf surface. In such cases, remedial action will be advised and we will recommend turf specialists to be engaged to resolve the infiltration quality of the Profile.

Stage 2 We produce a desk-based geo and hydrogeological report, using the British Geological Survey and any recorded trial borehole records. This is a good indication of what soils and rock stratas are likely to be encountered on site and also the probable height of the water table.

Stage 3 Provided the Stage 2 report is positive for an ECO-90™ system, we move to test-drilling to a depth of 12 metres or to the ground water level if higher. We conduct clusters of four drilled holes across a site or problem area. The clusters are drilled holes to a range of depths: 1.5m, 3m, 6m and 12m. For this we use a geo-hydraulics falling head test to a range of depths from which we extract infiltration rates.

The results of Stage 3 provide us with the data we need to create a Drainage Design for the site or problem area. Using our experience of over 300 successful ECO-90™ installs we then set out the ECO-90™ array required to deal with storm water at source (rainfall on site).

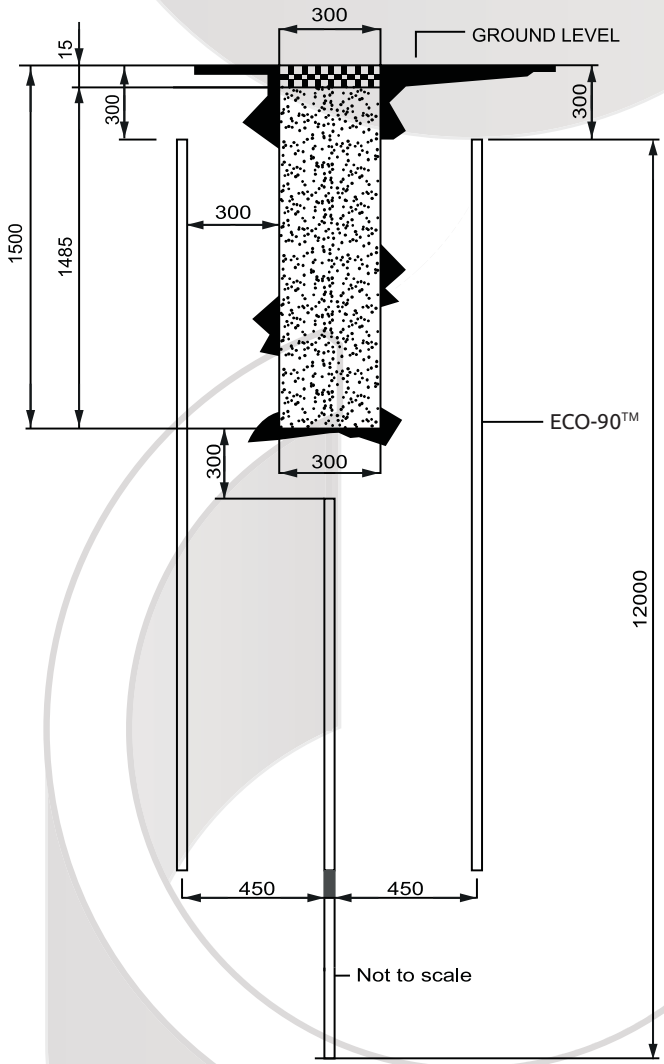
The ECO-90™ supported infiltration trench

For some turf installations, such as pitches and cemeteries, we often install an infiltration storm trench to act as a buffer to deal with heavy rainfall. The trench sometimes has a geotextile filter, Inbitex that encourages the formation of microbes that in turn degrade hydrocarbons (oils). We install ECO-90s™ below the trench to carry the filtered water down from the trench into deeper soil stratas.

The small storm water infiltration trench shown below forms part of a sports field drainage project. Installed in the base of the trench are 6 metre ECO-90s™ at 2 metre spacing and the side walls of the trench respectively have 3 metre ECO-90s™ at 1 metre centres. The cross-sectional sketch shows the positioning of the ECO-90s™ in relation to the trench and ground level. The top of the trench was finally dressed with a RT/Free draining root zone in order to ensure high levels of infiltration during storm events.

An ECO-90™ supported trench design creates a drainage asset capable of significant storm water storage before the ECO-90s™ empty the trench (half drain-down within 24 hours), which in turn creates capacity for the next rainfall event.

In some cases we will incorporate lateral (horizontal) infiltration drainage that takes storm water to a holding trench, with ECO-90™ infiltrators beneath that take the storm water into multiple soil stratas and from there the water will find its natural way to water courses or an aquifer. We have used this approach for cemeteries and grass pitches but it is intrusive to install and in most cases not appropriate for golf courses.



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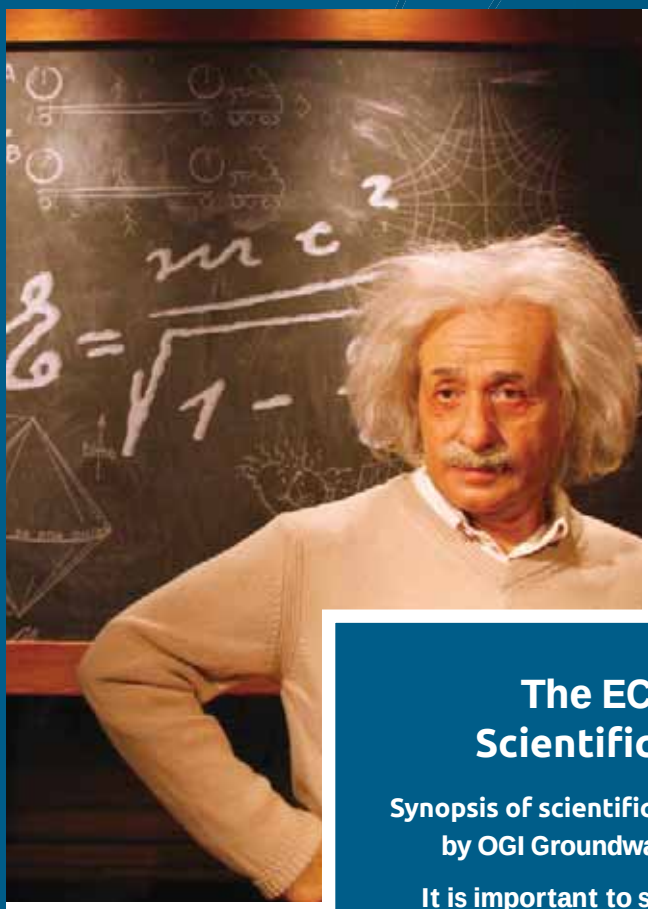
A gentle touch to installation

We take great care when installing an ECO-90™ system. Where a new facility is being constructed, installing an ECO-90™ system is straightforward, we can operate on site along with other ground work firms without concerning ourselves about 'spoiling' the landscape – it is the finished works that matter. However, for an existing recreational facility we are very mindful to ensure that the installation does not damage the facility itself.

The best example of this was the work we did at Gleneagles golf course, as shown in the pictures below. We used track mats for the drill rig to ensure we did not leave traction tracks from the drill rig moving across the fairways and the green. We used green hole cutters prior to drilling the ECO-90™ installation holes and we then set aside these cut turfs, ready for reinserting them once the ECO-90™ is installed. The installation took five days and the hole was closed during this period. However, once we had completed the installation the hole was again playable and was re-opened immediately. It was hard to see we had ever set foot on the Course.



The ECO-90™ Scientific Analysis

Synopsis of scientific analysis undertaken by OGI Groundwater Consultants.

It is important to stress that Newton did not create gravity, he explained it. Einstein did not create energy, he explained it. Likewise OGI did not create the ECO-90™ but has provided a valuable explanation of the underlying science that deals with the 'how' and the 'why'. The science supports over 300 successful installations across the UK, achieved since launch in 2012 – that is the most compelling evidence of all.

GROUND WATER DYNAMICS

OGI
GROUNDWATER SPECIALISTS

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EXECUTIVE SUMMARY

Groundwater Dynamics Ltd has developed the ECO-90 Passive Stormwater Attenuation and Infiltration System to provide an efficient method to collect, attenuate and infiltrate stored water into soils of variable permeability at depth.

The ECO-90 system has been designed to infiltrate water at greater depths (typically in the range of 3 to 12m deep) than conventional soakaway systems (which are typically installed in the upper two metres of ground).

This technical report presents unsaturated groundwater flow computer modelling undertaken by OGI Groundwater Specialists Ltd to demonstrate scientifically how the Groundwater Dynamics ECO-90 infiltration system works in practice.

From prior observations of the ECO-90 infiltrator, Groundwater Dynamics engineers have observed that the unique cross-sectional geometry comprising circular chambers leads to the development of micro-fissures in the surrounding ground that over time radiate outwards from the edge of the ECO-90. OGI's modelling of the ground surrounding the ECO-90 suggests that these micro-fissures may have been created by the large groundwater flow exit velocities that form around the curved edges of the ECO-90 chambers as water flows out of it and into the surrounding soil. This effect, combined with the continuously changing water content of the surrounding soil due to changing rainfall conditions, is likely to be the phenomenon that drives the development of micro-fissures over time.

When the presence of micro-fissures around the ECO-90 are modelled, the infiltration capacity of the ECO-90 is greatly increased. This means that the ECO-90 with micro-fissures behaves like a circular well with a diameter significantly greater than the effective diameter of the ECO-90 itself. The presence of micro-fissures around the ECO-90 increases the available surface area of the surrounding soil that is available for water to infiltrate, therefore increasing the amount of water infiltration capacity.

The ECO-90 is always installed within the unsaturated zone of the soil, typically a few metres above the natural water table. This means the soil around the ECO-90 is partially saturated, and as such the pore-water pressure in the soil is negative. This negative water pressure is called suction because it wants to "suck" more water into the soil to neutralise the negative pressure. When water travels down the ECO-90, the suction in the surrounding soil acts to "pull" the water out of the ECO-90 and into the ground. The cross-sectional modelling of the ECO-90 demonstrated that over time, if there is a continuous stream of water entering the ECO-90, a zone of fully saturated soil forms around the ECO-90. In addition to the suction acting to pull water into the ground, the weight of the water in the ECO-90 from the above infiltration trench acts to "push" the water into the ground. It is these combined forces that are driving water through the infiltration system from the surface and into the ground at depth, so producing an efficient and enhanced Sustainable Drainage System (SuDS) that considerably outperforms a normal crate style soakaway system.

4.3 Model 3: Comparison between a Normal Soakaway and the ECO-90 System.

A third model has been set up in SEEP/W to compare the effectiveness of a normal crate type soakaway system to the ECO-90 infiltration system.

This model is a development of the model presented in Section 4.2. For this model, a layer of lower permeability soil at the ground surface is simulated. It is common within the UK to find low permeability soils within the top two metres of the ground surface, and then soils with higher permeability beneath it.

Often this is due to the presence of horizontal sand and silt lenses within clay soils. This results in a soil of anisotropy, which means the horizontal permeability of the soil is greater than the vertical permeability. It is these layers at depth that the ECO-90 infiltrator targets, and which makes it highly effective. Often soakaway crates are located within the top two metres of the soil, which can hamper the infiltration potential. To simulate this effect, the first 2.0m of the soil is modelled as a silty clay with a horizontal and vertical permeability of 1.0×10^{-7} m/s. Beneath this the soil is simulated with a horizontal permeability of 1.0×10^{-6} m/s and a vertical permeability of 1.0×10^{-7} m/s.

The soakaway crate is simulated as being 1.0m in diameter and 1.0m in height. It is located between 18.8m OD and 19.8m OD. The conceptual model is shown in Figure 11 (a). A fixed head of 19.0m OD is specified in the soakaway crate to simulate a similar scenario to the modelling presented in Section 4.2. For the comparison, the ECO-90 conceptual model is presented in Figure 11 (b).

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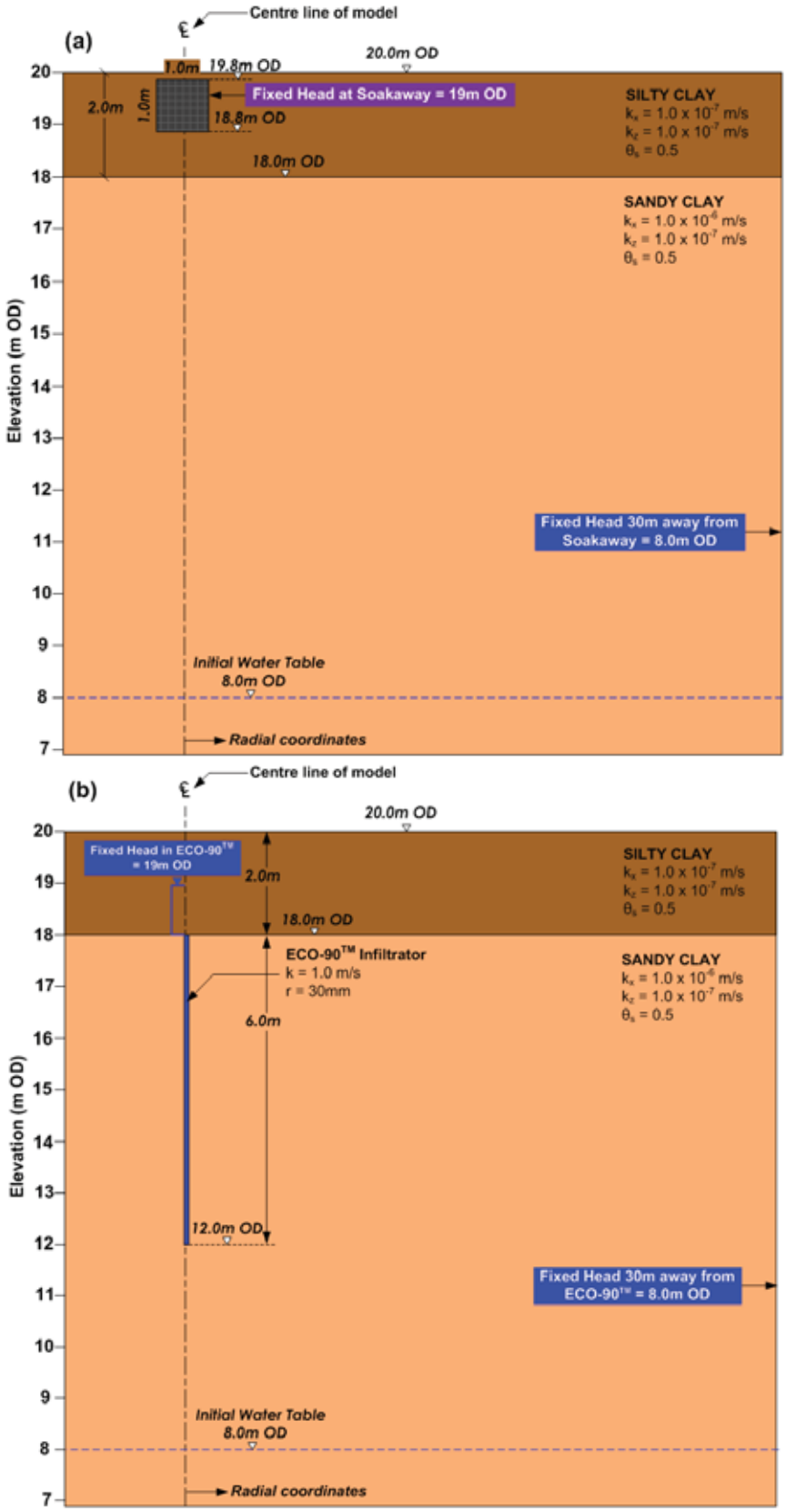

Figure 11: Radial conceptual model drawing for:
(a) the scenario with the soakaway crate in the top 2.0m of soil
(b) the scenario with the ECO-90 installed from 2.0m bgl to 6.0m bgl.

The simulated groundwater head contours and flow lines for this model are shown in Figure 12 (a) for the soakaway crate and (b) for the ECO-90 infiltrator.

As can be seen by the pattern of the groundwater head contours, the normal soakaway system only impacts groundwater conditions within the top 2.0m of soil, which significantly reduces the infiltration capacity of the system.

The ECO-90 system on the other hand has a large impact between 2.0m bgl and 6.0m bgl, with water flowing out horizontally from the ECO-90 over this entire depth range.

From the SEEP/W model output, OGI has calculated the infiltration rate for both the soakaway system and the ECO-90 probe. The results are:

- Soakaway system: Simulated infiltration rate = 0.0013 lit/s (0.08 lit/min)
- ECO-90 infiltrator: Simulated infiltration rate = 0.06 lit/s (3.6 lit/min)

As you can see from the simulated infiltration rates, the ECO-90 is considerably more effective at infiltrating into the ground than the soakaway crate system near the surface.

This is due to the ECO-90 being able to infiltrate water into more permeable horizontal layers such as sand and silt lenses which are found at greater depths below the ground surface.

It must be noted however that the flow rates given here are based on just one set of modelled ground conditions.

Further analysis is required for different arrangements of ECO-90 infiltrators to develop a deeper understanding of the difference in potential infiltration rates between normal soakaway systems and the ECO-90 system as it is installed in practice.

For a copy in full of the OGI scientific analysis please contact us.

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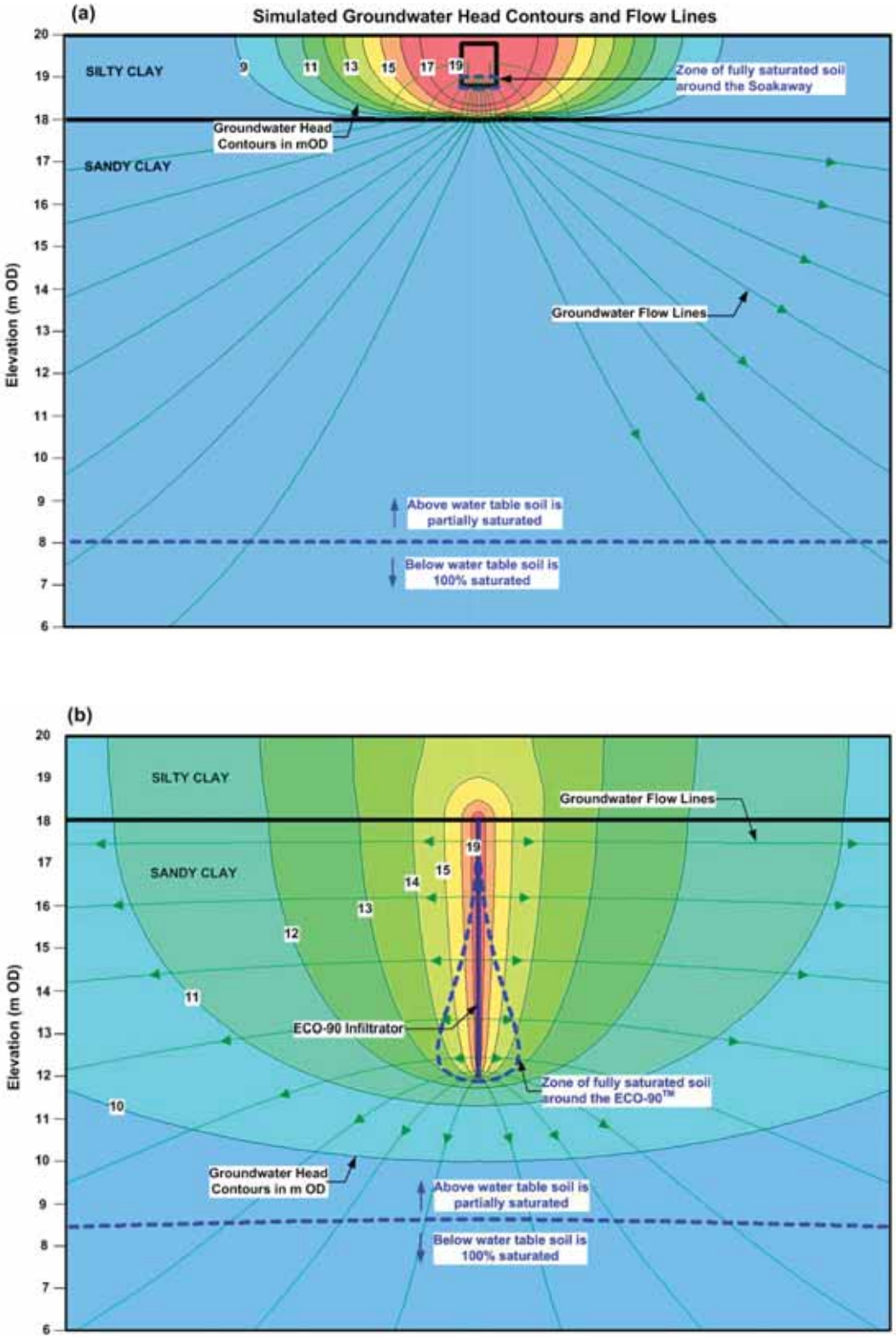

Figure 12: Simulated groundwater head contours and groundwater flow paths for (a) normal soakaway system and (b) a single ECO-90 infiltrator.

Annexe 1: Drilling rig

The Comacchio GEO 205 mini-drill rig

We use the Comacchio GEO 205 mini drill-rig. It can carry out a variety of drilling techniques that makes it a formidable, yet compact, soil investigation rig.

Rig Specification

Tracking width:	1.1 m
Tracking length:	4.5 m
Working width:	2.0 m
Stored height:	2.1 m
Working height:	4.5 m
Weight:	2.0 tonnes

Annexe 2: Drilled hole dimensions & ECO-90™ lengths

Vertical holes are drilled with a diameter of between 63.5mm and 88.9mm using displacement augers to depths up to 14 metres below ground level. Once drilled the ECO-90s™ are capped and then vertically installed, coming to rest 300mm below ground level. If installed in natural turf, such as a golf course, the drilled holes are then dressed with a mixture of native soil and a root zone mix before the original turf core is replaced.

ECO-90s™ are manufactured and stored in 6 metre lengths. Before each installation begins, and with reference to the ECO-90™ system design for the site, some of these lengths are cut into 1.5 and 3 metre lengths and will be installed into the 63.5mm diameter boreholes. For 6 and 12 metre lengths, 3 ECO-90™ devices are interlinked together, before being vertically inserted into the larger 88.9mm diameter boreholes.

The 6 and 12 metre lengths are called 'Primaries'. The 1.5 and 3 metre lengths are called 'Secondaries'. Wherever possible an ECO-90™ system design will comprise an array of Primaries, interspersed with Secondaries that draw water down and find deeper drainage by connecting to a Primary.

Annexe 3: ECO-90™ system maintenance

The ECO-90™ system has no requirement for maintenance.

If it is used below a traditional infiltration trench there will be a need for the trench and silt traps to be maintained.

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Your Notes

Your Notes

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Your Notes

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GROUNDS MANAGEMENT ASSOCIATION

PlanetMark

QMS ISO 9001 REGISTERED

QMS ISO 14001 REGISTERED

QMS ISO 45001 REGISTERED

Polystorm-R Modular Cell

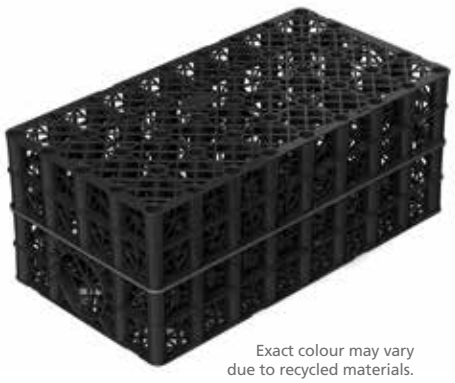
Data Sheet

PRODUCT INFORMATION **P1** **ISSUE 4 - SEPT 2017**

Product code: PSM1A

The Polystorm-R modular cell is ideally suited for loaded applications at greater depths, such as housing, commercial and infrastructure projects and has a compressive strength of up to 61 tonnes/m². It offers all the proven performance of the Polystorm cell, with the added benefits of being manufactured from over 90% recycled material content.

Wherever performance criteria and standards allow, we will always maximise the sustainability of our products by using post consumer plastics in their manufacture. By sourcing and carefully controlling the quality of the recycled material we use our precision injection moulding. Therefore we are able to guarantee consistent quality in our recycled plastic, giving you the confidence and the performance levels you expect from the market leader.



Exact colour may vary due to recycled materials.

Key Benefits

- Made from specially selected and controlled recycled materials
- Environmentally friendly, sustainable solution
- Has undergone stringent testing to ensure product performance
- Compressive strength of 61 tonnes/m²
- Ideal for retention, attenuation and infiltration applications with a suitable geomembrane or geotextile
- BBA approved
- Allow flexibility of shape - ideal for shallow excavation systems, narrow strips or use in restricted areas
- Can be used as part of a value engineered hybrid system with Polystorm, Polystorm Lite and Polystorm Xtra
- Integrated inlet and outlet
- 3D flow throughout the structure
- 95% void ratio
- Light weight yet robust - excellent Health and Safety and installation benefits
- 60 years creep limited life expectancy

Technical Support

Detailed guidance and assistance is available.
For further information, please contact our Technical Team on **+44 (0) 1509 615100** or email **civils@polypipe.com**

BBA BRITISH BOARD OF AGREMENT
CERTIFICATE No. 06/4297

ELEMENT	VALUE
PHYSICAL PROPERTIES	
Length	1m
Width	0.5m
Depth	0.4m
Total volume	0.2m³
Unit weight	9kg (approx)
Unit storage volume	0.19m³ (190 litres)
Void ratio	95%
SHORT TERM COMPRESSIVE STRENGTH	
Vertical	610 kN/m² **
Lateral	63 kN/m² **
SHORT TERM DEFLECTION	
Short-term vertical deflection	60 kN/m² per mm
LONG TERM DEFLECTION	
Estimated long term vertical deflection (creep)	0.2798 Ln (design life in hrs) +0.485 [Based on an applied test load = 162 kN/m²] Creep data limit 60 years
Estimated long term lateral deflection (creep)	1.0192 Ln (design life in hrs) -3.864 [Based on an applied test load = 30.8 kN/m²] Creep data limit 60 years

Note: Polystorm-R is ideal for use in trafficked and pedestrian applications subject to a structural design check and suitable installation conditions

* Each unit includes 4 Clips and 2 Shear Connectors.

** Compressive strength at yield, maximum recommended value for design purposes.

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Polypipe

Polystorm-R Modular Cell

Data Sheet

RECOMMENDED MAXIMUM DEPTH OF INSTALLATION (to cell invert) [m]

TYPICAL SOIL TYPE	TYPICAL ANGLE OF SHEAR RESISTANCE	SOIL WEIGHT kN/m³	WITHOUT GROUNDWATER (below base of cells) NORMAL CASE		WITH GROUNDWATER AT 1M BELOW GROUND LEVEL AND UNITS WRAPPED IN GEOMEMBRANE	
			Pedestrian	Trafficked (cars) <3000kg GVW	Pedestrian	Trafficked (cars) <3000kg GVW
Stiff over consolidated clay e.g. London clay	24	20.0	2.2	1.9	1.8	1.6
Normally consolidated silty sandy clay e.g. alluvium, made ground	26	19.0	2.4	2.2	1.9	1.7
Loose sand and gravel	30	18.0	3.0	2.7	2.0	1.9
Medium dense sand and gravel	33	19.0	3.2	2.9	2.0	1.9
Dense sand and gravel	38	20.0	3.7	3.5	2.1	2.0

Note:
1) Stated depths based on the calculation methodology detailed within CIRIA C680 (2008)
2) Assuming water density = 10.0kN/m³
3) Assumed ultimate limit state (ULS) partial factor of safety applied to: Material = 2.75 Lateral pressure = 1.35

Durability

The polymer material used in the manufacture of the Polystorm-R unit has an adequate resistance to attack from the type and quantities of chemicals that may be expected to naturally occur in uncontaminated soils and rainwater runoff. When installed in accordance with our recommendations, it is expected that the Polystorm-R unit will have a design life in excess of 60 years*. The installer of a proposed geocellular structure should ensure that an appropriate design check has been undertaken, in accordance with the recommended methodology and factors of safety given in CIRIA C680 (2008), Structural Design of Modular Geocellular Drainage Tanks, prior to the commencement of construction activities.

* Derived from long term extrapolated creep testing

Notes

1. Unless stated, all values are nominal and may vary within normal production tolerances.
2. The characteristic unit parameters stated have been based on Polypipe BBA certificate N° 06/4297, sheet 3.
3. Polypipe reserve the right to change product specifications without prior notice.
4. This document is uncontrolled and updates will not be issued automatically.

RECOMMENDED MINIMUM COVER LEVELS [m]

LIVE LOAD CONDITIONS	PEDESTRIAN	LIGHT TRAFFICKED	
		Car park with vehicle mass <GVW	
Minimum cover depth required (m)	0.50	<3000kg 0.50	<9000kg 0.65

Note
1) Stated depths based on the calculation methodology detailed within CIRIA C680 (2008)
2) Assumed serviceability limit state (SLS) partial factor of safety applied to: Material = 1.5 Live load = 1.0 Dead load = 1.0
3) Shallower minimum burial depths may be applicable subject to an assessment of the specific site conditions. For further details please consult our Technical Team on 01509 615100.

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Polypipe