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Project				Job Ref.	
Harrison Way, Cheddleton - Drainage System				4040	
Section				Sheet no./rev.	
Stormwater Attenuation Design				1	
Calc. by	Date	Chk'd by	Date	App'd by	Date
CK	10/10/2014				

Contents:

Summary:

Drainage system to account for a greenfield run of rate of 5 l/s/ha, with a maximum storage capacity from all sites of 1120.1m^3. Two separate systems have been designed to accomadate storgae for both the main area and the brewery roof drainage (System 1) and the remote area (System 2). The two systems have been designed separatly to allow each system to work independantly to the other.
For System 1 to obtain the maximum stoarge capacity required for both main site and the brewery roof drainage, a 1.65x17x20m tank will need to be installed.
System 2 has the capacity to store all excess drainage water from the remote area with astorage tank sized at 1.7x15.3x20m.

NOTE:

Pipes – Ø = 300mm (Area; 0.07m^2), drainage pipes must be at a minimum of 750mm below surface level (ground level taken as 1.35m throughout site), continuing at a gradient of 1:200 throughout system. The drainage system will exit and the river.

Manholes – Ø = 1800mm (Area; 2.54m^2), with a 25mm differential across the manhole.

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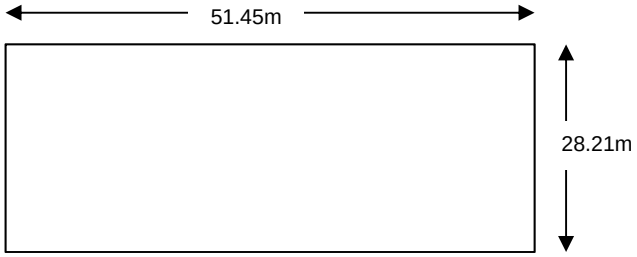
Project				Job Ref.	
Harrison Way, Cheddleton - Drainage System				4040	
Section				Sheet no./rev.	
Stormwater Attenuation Design				2	
Calc. by	Date	Chk'd by	Date	App'd by	Date
CK	10/10/2014				

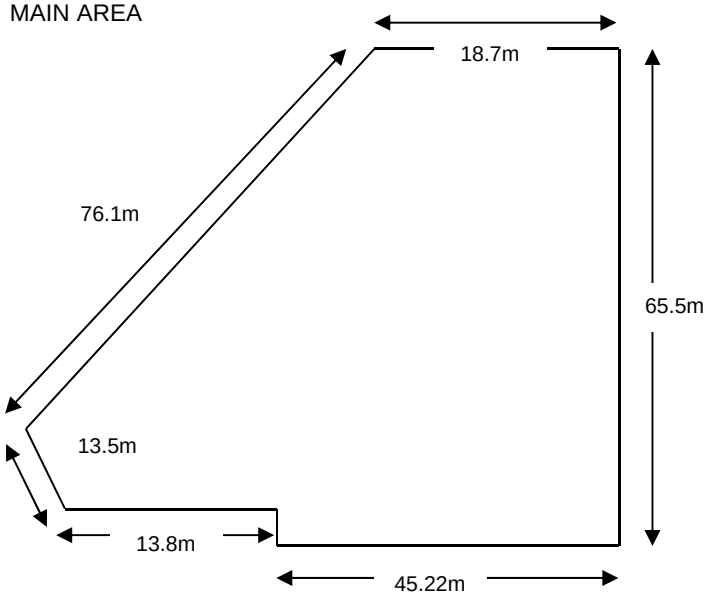
SECTION AREAS

BREWERY ROOF



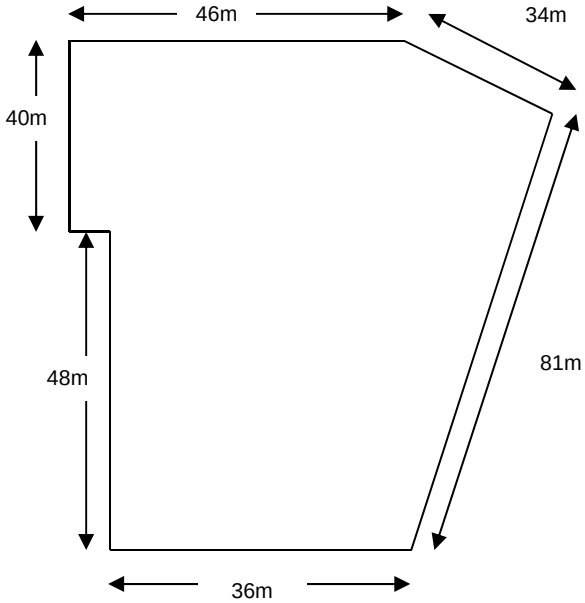
Total Area = 1451m^2
= 0.14ha

MAIN AREA



Total Area = 3236.5m^2
= 0.324ha

REMOTE AREA



Total Area = 4848m^2
= 0.48ha

ATTENUATION DESIGN – CONSIDERING ALL AREAS

In accordance with CIRIA publication C697 - The SUDS Manual

Tedds calculation version 1.0.02

Pre post runoff method

Site characteristics

Location; Stoke

Hydrological region; 4

Soil type (Wallingford Procedure W.R.A.P map); 4

Standard percentage runoff; SPR = **0.47**

Average annual rainfall; SAAR = **720** mm

5 year return period rainfall of 60 minute duration; M5_60min = **18.0** mm

Ratio 60-minute to 2 day rainfalls of 5 year return; r = **0.36**

Rainfall intensity increase due to global warming; $p_{climate}$ = **30**%

Routing coefficient; c_r = **1.30**

Volumetric runoff coefficient; c_v = **0.75**

Catchment details

Subcatchment	Name	Area (ha)	PIMP (%);	Impermeable. area (ha)
1;	Remote site;	0.48;	95.0;	0.46;
2;	Main Site;	0.32;	100.0;	0.32;
3;	Brewery Roof;	0.14;	100.0;	0.14;
Total		0.95;	97.4;	0.92;

Greenfield runoff rates

Catchment area; AREA = **50.00** hectare

Greenfield runoff rate (50 hectare site); $\bar{Q}_{rural} = 0.00108 m^3/s \times (AREA/1km^2)^{0.89} \times (SAAR/1mm)^{1.17} \times SPR^{2.17}$ = **249.5** l / s

Greenfield runoff rate; $\bar{Q} = \bar{Q}_{rural} / AREA \times A$ = **4.7** l / s

Greenfield runoff rate per unit area; $\bar{Q}_A = \bar{Q} / A$ = **5.0** l / s / hectare

Estimated site discharges

FSR growth rate (1 year); FSR_{1yr} = **0.83**

Discharge (1 year); $Q_{1yr} = \bar{Q} \times FSR_{1yr}$ = **3.9** l/s

FSR growth rate (2 year); FSR_{2yr} = **0.96**

Discharge (2 year); $Q_{2yr} = \bar{Q} \times FSR_{2yr}$ = **4.5** l/s

FSR growth rate (10 year); FSR_{10yr} = **1.49**

Discharge (10 year); $Q_{10yr} = \bar{Q} \times FSR_{10yr}$ = **7.0** l/s

FSR growth rate (30 year); FSR_{30yr} = **2.00**

Discharge (30 year); $Q_{30yr} = \bar{Q} \times FSR_{30yr}$ = **9.5** l/s

FSR growth rate (50 year); FSR_{50yr} = **2.20**

Discharge (50 year); $Q_{50yr} = \bar{Q} \times FSR_{50yr}$ = **10.4** l/s

FSR growth rate (100 year); FSR_{100yr} = **2.57**

Discharge (100 year); $Q_{100yr} = \bar{Q} \times FSR_{100yr}$ = **12.2** l/s

Table equations

Peak flow; $Q_{post\_imp} = c_r \times I_{max} \times A_{imp}$

Runoff volume; $V_{post\_imp} = Q_{post\_imp} \times D / c_r$

Post development runoff; $\bar{Q}_{post} = Q_{post\_imp} + Q_{post\_open}$

Permitted discharge; $O_{exist} = Q \times D$

Post development runoff volume; $I_{post} = Q_{post\_open} \times D + V_{post\_imp}$

Storage volume required; $S_{post} = I_{post} - O_{exist}$

Required storage for period of 1 year

Discharge per hectare; $Q_{1yr\_area} = Q_{1yr} / A =$ **4.1** l/s/hectare

Greenfield runoff rate post development; $Q_{1yr\_post\_open} = Q_{1yr\_area} \times A_{imp} =$ **3.8** l/s

Duration (min)	1 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	5.2	62.0	0.21	47.7	0.21	1.18	48.84	47.67
10	7.3	44.0	0.15	67.6	0.15	2.35	69.94	67.59
15	9.0	35.9	0.12	82.9	0.12	3.53	86.37	82.84
30	11.7	23.4	0.08	108.2	0.08	7.06	115.10	108.03
60	15.3	15.3	0.05	141.2	0.05	14.13	154.99	140.87
120	19.2	9.6	0.03	177.7	0.04	28.26	205.26	177.00
240	23.9	6.0	0.02	220.4	0.02	56.51	275.49	218.98
360	27.3	4.5	0.02	251.9	0.02	84.77	334.53	249.76
600	31.5	3.2	0.01	291.0	0.01	141.28	428.71	287.43
1440	41.4	1.7	0.01	382.0	0.01	339.07	712.44	373.38

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_1yr} \times p_{hydro} =$ **466.7** m^3

Required storage for period of 2 year

Discharge per hectare; $Q_{2yr\_area} = Q_{2yr} / A =$ **4.8** l/s/hectare

Greenfield runoff rate post development; $Q_{2yr\_post\_open} = Q_{2yr\_area} \times A_{imp} =$ **4.4** l/s

Duration (min)	2 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	6.7	79.9	0.27	61.5	0.27	1.36	62.78	61.42
10	9.5	56.8	0.19	87.5	0.19	2.72	90.14	87.41
15	11.6	46.4	0.15	107.0	0.16	4.09	111.02	106.94
30	14.9	29.8	0.10	137.7	0.10	8.17	145.71	137.54
60	19.1	19.1	0.06	176.5	0.07	16.34	192.41	176.07
120	23.6	11.8	0.04	218.0	0.04	32.68	249.88	217.20
240	28.9	7.2	0.02	266.9	0.03	65.36	330.60	265.24
360	32.8	5.5	0.02	302.8	0.02	98.04	398.32	300.27
600	37.5	3.8	0.01	346.7	0.02	163.41	505.92	342.51
1440	48.4	2.0	0.01	447.2	0.01	392.17	829.40	437.22

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_2yr} \times p_{hydro} =$ **546.5** m^3

Required storage for period of 10 year

Discharge per hectare; $Q_{10yr\_area} = Q_{10yr} / A =$ **7.4** l/s/hectare

Greenfield runoff rate post development; $Q_{10yr\_post\_open} = Q_{10yr\_area} \times A_{imp} =$ **6.9** l/s

Duration (min)	10 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	10.2	122.4	0.41	94.2	0.41	2.11	96.22	94.11
10	14.7	87.9	0.29	135.3	0.30	4.23	139.41	135.19
15	18.0	71.8	0.24	165.9	0.25	6.34	172.03	165.69
30	22.9	45.8	0.15	211.7	0.16	12.68	224.02	211.34
60	29.0	29.0	0.10	267.9	0.10	25.36	292.65	267.29
120	35.0	17.5	0.06	323.1	0.07	50.72	372.57	321.84
240	41.8	10.4	0.03	385.7	0.04	101.45	484.56	383.11
360	46.6	7.8	0.03	430.4	0.03	152.17	578.69	426.52
600	52.5	5.3	0.02	484.9	0.02	253.62	732.03	478.41
1440	65.8	2.7	0.01	607.6	0.02	608.69	1200.78	592.09

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_10yr} \times p_{hydro} =$ **740.1** m^3

Required storage for period of 30 year

Discharge per hectare; $Q_{30yr\_area} = Q_{30yr} / A =$ **10.0** l/s/hectare

Greenfield runoff rate post development; $Q_{30yr\_post\_open} = Q_{30yr\_area} \times A_{imp} =$ **9.2** l/s

Duration (min)	30 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	12.4	148.6	0.50	114.4	0.50	2.84	117.11	114.28
10	18.0	107.7	0.36	165.8	0.37	5.67	171.29	165.61
15	22.1	88.4	0.29	204.0	0.30	8.51	212.33	203.82
30	28.4	56.9	0.19	262.6	0.20	17.02	279.17	262.15
60	36.0	36.0	0.12	332.0	0.13	34.04	365.18	331.14
120	43.4	21.7	0.07	400.5	0.08	68.09	466.81	398.73
240	51.7	12.9	0.04	477.0	0.05	136.17	609.73	473.56
360	57.5	9.6	0.03	530.8	0.04	204.26	729.83	525.58
600	64.3	6.4	0.02	593.6	0.03	340.43	925.32	584.89
1440	79.3	3.3	0.01	731.9	0.02	817.03	1528.06	711.03

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_30yr} \times p_{hydro} =$ **888.8** m^3

Required storage for period of 50 year

Discharge per hectare; $Q_{50yr\_area} = Q_{50yr} / A =$ **11.0** l/s/hectare

Greenfield runoff rate post development; $Q_{50yr\_post\_open} = Q_{50yr\_area} \times A_{imp} =$ **10.1** l/s

Duration (min)	50 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	13.7	163.9	0.55	126.1	0.56	3.12	129.18	126.06
10	19.9	119.5	0.40	184.0	0.41	6.24	190.04	183.80
15	24.6	98.4	0.33	227.1	0.34	9.36	236.21	226.85
30	31.8	63.6	0.21	293.8	0.22	18.72	312.01	293.28
60	40.3	40.3	0.13	372.3	0.14	37.45	408.83	371.39
120	48.7	24.3	0.08	449.7	0.09	74.89	522.65	447.76
240	57.9	14.5	0.05	534.8	0.06	149.79	680.72	530.93
360	64.3	10.7	0.04	593.8	0.05	224.68	812.73	588.05
600	71.7	7.2	0.02	662.3	0.03	374.47	1027.21	652.74
1440	87.8	3.7	0.01	810.9	0.02	898.73	1686.72	787.99

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_50yr} \times p_{hydro}$ = **985.0** m^3

Required storage for period of 100 year

Discharge per hectare; $Q_{100yr\_area} = Q_{100yr} / A$ = **12.8** l/s/hectare

Greenfield runoff rate post development; $Q_{100yr\_post\_open} = Q_{100yr\_area} \times A_{imp}$ = **11.8** l/s

Duration (min)	100 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	15.8	189.3	0.63	145.6	0.64	3.65	149.18	145.54
10	23.2	139.0	0.46	213.9	0.48	7.29	220.99	213.70
15	28.8	115.0	0.38	265.5	0.40	10.94	276.20	265.26
30	37.3	74.6	0.25	344.5	0.26	21.87	365.77	343.89
60	47.2	47.2	0.16	435.7	0.17	43.75	478.32	434.58
120	56.6	28.3	0.09	522.4	0.11	87.49	607.63	520.14
240	66.9	16.7	0.06	618.1	0.07	174.98	788.65	613.67
360	74.1	12.4	0.04	684.7	0.05	262.47	940.43	677.96
600	82.4	8.2	0.03	761.3	0.04	437.45	1187.56	750.11
1440	99.9	4.2	0.01	922.9	0.03	1049.88	1945.96	896.07

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_100yr} \times p_{hydro}$ = **1120.1** m^3

Interception storage

Interception rainfall depth; d_{int} = **15** mm

Volume of interception storage required; $V_{int\_req} = 0.8 \times A_{imp} \times d_{int}$ = **110.81** m^3

ATTENUATION DESIGN – BREWERY ROOF

In accordance with CIRIA publication C697 - The SUDS Manual

Tedds calculation version 1.0.02

Pre post runoff method

Site characteristics

Location;	Stoke
Hydrological region;	4
Soil type (Wallingford Procedure W.R.A.P map);	4
Standard percentage runoff;	SPR = **0.47**
Average annual rainfall;	SAAR = **720** mm
5 year return period rainfall of 60 minute duration;	M5_60min = **18.0** mm
Ratio 60-minute to 2 day rainfalls of 5 year return;	r = **0.36**
Rainfall intensity increase due to global warming;	$p_{climate}$ = **30**%
Routing coefficient;	c_r = **1.30**
Volumetric runoff coefficient;	c_v = **0.75**

Catchment details

Subcatchment	Name	Area (ha)	PIMP (%);	Impermeable. area (ha)
1;	Brewery Roof;	0.14;	100.0;	0.14;
	Total	0.14;	100.0;	0.14;

Greenfield runoff rates

Catchment area;	AREA = **50.00** hectare
Greenfield runoff rate (50 hectare site);	$\bar{Q}_{rural} = 0.00108 m^3/s \times (AREA/1km^2)^{0.89} \times (SAAR/1mm)^{1.17} \times SPR^{2.17}$ = **249.5** l / s
Greenfield runoff rate;	$\bar{Q} = \bar{Q}_{rural} / AREA \times A$ = **0.7** l / s
Greenfield runoff rate per unit area;	$\bar{Q}_A = \bar{Q} / A$ = **5.0** l / s / hectare

Estimated site discharges

FSR growth rate (1 year);	FSR_{1yr} = **0.83**
Discharge (1 year);	$Q_{1yr} = \bar{Q} \times FSR_{1yr}$ = **0.6** l/s
FSR growth rate (2 year);	FSR_{2yr} = **0.96**
Discharge (2 year);	$Q_{2yr} = \bar{Q} \times FSR_{2yr}$ = **0.7** l/s
FSR growth rate (10 year);	FSR_{10yr} = **1.49**
Discharge (10 year);	$Q_{10yr} = \bar{Q} \times FSR_{10yr}$ = **1.0** l/s
FSR growth rate (30 year);	FSR_{30yr} = **2.00**
Discharge (30 year);	$Q_{30yr} = \bar{Q} \times FSR_{30yr}$ = **1.4** l/s
FSR growth rate (50 year);	FSR_{50yr} = **2.20**
Discharge (50 year);	$Q_{50yr} = \bar{Q} \times FSR_{50yr}$ = **1.5** l/s
FSR growth rate (100 year);	FSR_{100yr} = **2.57**
Discharge (100 year);	$Q_{100yr} = \bar{Q} \times FSR_{100yr}$ = **1.8** l/s

Table equations

Peak flow;	$Q_{post\_imp} = c_r \times I_{max} \times A_{imp}$
Runoff volume;	$V_{post\_imp} = Q_{post\_imp} \times D / c_r$
Post development runoff;	$\bar{Q}_{post} = Q_{post\_imp} + Q_{post\_open}$
Permitted discharge;	$O_{exist} = Q \times D$
Post development runoff volume;	$I_{post} = Q_{post\_open} \times D + V_{post\_imp}$
Storage volume required;	$S_{post} = I_{post} - O_{exist}$

Required storage for period of 1 year

Discharge per hectare; $Q_{1yr\_area} = Q_{1yr} / A =$ **4.1** l/s/hectare

Greenfield runoff rate post development; $Q_{1yr\_post\_open} = Q_{1yr\_area} \times A_{imp} =$ **0.6** l/s

Duration (min)	1 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	5.2	62.0	0.03	7.2	0.03	0.17	7.41	7.23
10	7.3	44.0	0.02	10.3	0.02	0.35	10.60	10.26
15	9.0	35.9	0.02	12.6	0.02	0.52	13.09	12.57
30	11.7	23.4	0.01	16.4	0.01	1.04	17.45	16.41
60	15.3	15.3	0.01	21.4	0.01	2.09	23.50	21.41
120	19.2	9.6	0.00	26.9	0.01	4.17	31.12	26.95
240	23.9	6.0	0.00	33.4	0.00	8.35	41.77	33.42
360	27.3	4.5	0.00	38.2	0.00	12.52	50.72	38.20
600	31.5	3.2	0.00	44.1	0.00	20.87	65.00	44.13
1440	41.4	1.7	0.00	57.9	0.00	50.09	108.02	57.92

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_1yr} \times p_{hydro} =$ **72.4** m^3

Required storage for period of 2 year

Discharge per hectare; $Q_{2yr\_area} = Q_{2yr} / A =$ **4.8** l/s/hectare

Greenfield runoff rate post development; $Q_{2yr\_post\_open} = Q_{2yr\_area} \times A_{imp} =$ **0.7** l/s

Duration (min)	2 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	6.7	79.9	0.04	9.3	0.04	0.20	9.52	9.32
10	9.5	56.8	0.03	13.3	0.03	0.40	13.67	13.26
15	11.6	46.4	0.02	16.2	0.02	0.60	16.83	16.23
30	14.9	29.8	0.02	20.9	0.02	1.21	22.09	20.88
60	19.1	19.1	0.01	26.8	0.01	2.41	29.17	26.76
120	23.6	11.8	0.01	33.1	0.01	4.83	37.89	33.06
240	28.9	7.2	0.00	40.5	0.00	9.66	50.12	40.47
360	32.8	5.5	0.00	45.9	0.00	14.49	60.39	45.91
600	37.5	3.8	0.00	52.6	0.00	24.14	76.70	52.56
1440	48.4	2.0	0.00	67.8	0.00	57.94	125.75	67.81

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_2yr} \times p_{hydro} =$ **84.8** m^3

Required storage for period of 10 year

Discharge per hectare; $Q_{10yr\_area} = Q_{10yr} / A =$ **7.4** l/s/hectare

Greenfield runoff rate post development; $Q_{10yr\_post\_open} = Q_{10yr\_area} \times A_{imp} =$ **1.0** l/s

Duration (min)	10 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	10.2	122.4	0.06	14.3	0.06	0.31	14.59	14.28
10	14.7	87.9	0.04	20.5	0.05	0.62	21.14	20.51
15	18.0	71.8	0.04	25.1	0.04	0.94	26.08	25.15
30	22.9	45.8	0.02	32.1	0.02	1.87	33.97	32.09
60	29.0	29.0	0.01	40.6	0.02	3.75	44.37	40.62
120	35.0	17.5	0.01	49.0	0.01	7.49	56.49	48.99
240	41.8	10.4	0.01	58.5	0.01	14.99	73.47	58.48
360	46.6	7.8	0.00	65.3	0.00	22.48	87.74	65.26
600	52.5	5.3	0.00	73.5	0.00	37.47	110.99	73.52
1440	65.8	2.7	0.00	92.1	0.00	89.93	182.05	92.13

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_10yr} \times p_{hydro}$ = **115.2** m^3

Required storage for period of 30 year

Discharge per hectare; $Q_{30yr\_area} = Q_{30yr} / A$ = **10.0** l/s/hectare

Greenfield runoff rate post development; $Q_{30yr\_post\_open} = Q_{30yr\_area} \times A_{imp}$ = **1.4** l/s

Duration (min)	30 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	12.4	148.6	0.08	17.3	0.08	0.42	17.76	17.34
10	18.0	107.7	0.05	25.1	0.06	0.84	25.97	25.13
15	22.1	88.4	0.04	30.9	0.05	1.26	32.19	30.94
30	28.4	56.9	0.03	39.8	0.03	2.51	42.33	39.81
60	36.0	36.0	0.02	50.3	0.02	5.03	55.37	50.34
120	43.4	21.7	0.01	60.7	0.01	10.06	70.77	60.72
240	51.7	12.9	0.01	72.3	0.01	20.12	92.44	72.33
360	57.5	9.6	0.00	80.5	0.01	30.18	110.65	80.48
600	64.3	6.4	0.00	90.0	0.00	50.30	140.29	90.00
1440	79.3	3.3	0.00	111.0	0.00	120.71	231.67	110.97

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_30yr} \times p_{hydro}$ = **138.7** m^3

Required storage for period of 50 year

Discharge per hectare; $Q_{50yr\_area} = Q_{50yr} / A$ = **11.0** l/s/hectare

Greenfield runoff rate post development; $Q_{50yr\_post\_open} = Q_{50yr\_area} \times A_{imp}$ = **1.5** l/s

Duration (min)	50 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	13.7	163.9	0.08	19.1	0.08	0.46	19.59	19.12
10	19.9	119.5	0.06	27.9	0.06	0.92	28.81	27.89
15	24.6	98.4	0.05	34.4	0.05	1.38	35.81	34.43
30	31.8	63.6	0.03	44.5	0.03	2.77	47.30	44.54
60	40.3	40.3	0.02	56.5	0.02	5.53	61.98	56.45
120	48.7	24.3	0.01	68.2	0.01	11.07	79.24	68.18
240	57.9	14.5	0.01	81.1	0.01	22.13	103.21	81.08
360	64.3	10.7	0.01	90.0	0.01	33.20	123.22	90.03
600	71.7	7.2	0.00	100.4	0.01	55.33	155.74	100.41
1440	87.8	3.7	0.00	122.9	0.00	132.78	255.73	122.95

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_50yr} \times p_{hydro}$ = **153.7** m^3

Required storage for period of 100 year

Discharge per hectare; $Q_{100yr\_area} = Q_{100yr} / A$ = **12.8** l/s/hectare

Greenfield runoff rate post development; $Q_{100yr\_post\_open} = Q_{100yr\_area} \times A_{imp}$ = **1.8** l/s

Duration (min)	100 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	15.8	189.3	0.10	22.1	0.10	0.54	22.62	22.08
10	23.2	139.0	0.07	32.4	0.07	1.08	33.51	32.43
15	28.8	115.0	0.06	40.3	0.06	1.62	41.88	40.26
30	37.3	74.6	0.04	52.2	0.04	3.23	55.46	52.22
60	47.2	47.2	0.02	66.1	0.03	6.46	72.52	66.06
120	56.6	28.3	0.01	79.2	0.02	12.93	92.13	79.20
240	66.9	16.7	0.01	93.7	0.01	25.85	119.57	93.72
360	74.1	12.4	0.01	103.8	0.01	38.78	142.58	103.80
600	82.4	8.2	0.00	115.4	0.01	64.63	180.05	115.42
1440	99.9	4.2	0.00	139.9	0.00	155.11	295.03	139.92

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_100yr} \times p_{hydro}$ = **174.9** m^3

Interception storage

Interception rainfall depth; d_{int} = **5** mm

Volume of interception storage required; $V_{int\_req} = 0.8 \times A_{imp} \times d_{int}$ = **5.60** m^3

ATTENUATION DESIGN – MAIN AREA

In accordance with CIRIA publication C697 - The SUDS Manual

Tedds calculation version 1.0.02

Pre post runoff method

Site characteristics

Location; Stoke

Hydrological region; 4

Soil type (Wallingford Procedure W.R.A.P map); 4

Standard percentage runoff; SPR = **0.47**

Average annual rainfall; SAAR = **720** mm

5 year return period rainfall of 60 minute duration; M5_60min = **18.0** mm

Ratio 60-minute to 2 day rainfalls of 5 year return; r = **0.36**

Rainfall intensity increase due to global warming; $p_{climate}$ = **30**%

Routing coefficient; c_r = **1.30**

Volumetric runoff coefficient; c_v = **0.75**

Catchment details

Subcatchment	Name	Area (ha)	PIMP (%);	Impermeable. area (ha)
1;	Main Area;	0.32;	100.0;	0.32;
Total		0.32;	100.0;	0.32;

Greenfield runoff rates

Catchment area; AREA = **50.00** hectare

Greenfield runoff rate (50 hectare site); $\bar{Q}_{rural} = 0.00108 m^3/s \times (AREA/1km^2)^{0.89} \times (SAAR/1mm)^{1.17} \times SPR^{2.17}$ = **249.5** l / s

Greenfield runoff rate; $\bar{Q} = \bar{Q}_{rural} / AREA \times A$ = **1.6** l / s

Greenfield runoff rate per unit area; $\bar{Q}_A = \bar{Q} / A$ = **5.0** l / s / hectare

Estimated site discharges

FSR growth rate (1 year); FSR_{1yr} = **0.83**

Discharge (1 year); $Q_{1yr} = \bar{Q} \times FSR_{1yr}$ = **1.3** l/s

FSR growth rate (2 year); FSR_{2yr} = **0.96**

Discharge (2 year); $Q_{2yr} = \bar{Q} \times FSR_{2yr}$ = **1.6** l/s

FSR growth rate (10 year); FSR_{10yr} = **1.49**

Discharge (10 year); $Q_{10yr} = \bar{Q} \times FSR_{10yr}$ = **2.4** l/s

FSR growth rate (30 year); FSR_{30yr} = **2.00**

Discharge (30 year); $Q_{30yr} = \bar{Q} \times FSR_{30yr}$ = **3.2** l/s

FSR growth rate (50 year); FSR_{50yr} = **2.20**

Discharge (50 year); $Q_{50yr} = \bar{Q} \times FSR_{50yr}$ = **3.6** l/s

FSR growth rate (100 year); FSR_{100yr} = **2.57**

Discharge (100 year); $Q_{100yr} = \bar{Q} \times FSR_{100yr}$ = **4.1** l/s

Table equations

Peak flow; $Q_{post\_imp} = c_r \times I_{max} \times A_{imp}$

Runoff volume; $V_{post\_imp} = Q_{post\_imp} \times D / c_r$

Post development runoff; $\bar{Q}_{post} = Q_{post\_imp} + Q_{post\_open}$

Permitted discharge; $O_{exist} = Q \times D$

Post development runoff volume; $I_{post} = Q_{post\_open} \times D + V_{post\_imp}$

Storage volume required; $S_{post} = I_{post} - O_{exist}$

Required storage for period of 1 year

Discharge per hectare; $Q_{1yr\_area} = Q_{1yr} / A =$ **4.1** l/s/hectare

Greenfield runoff rate post development; $Q_{1yr\_post\_open} = Q_{1yr\_area} \times A_{imp} =$ **1.3** l/s

Duration (min)	1 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	5.2	62.0	0.07	16.7	0.07	0.40	17.12	16.71
10	7.3	44.0	0.05	23.7	0.05	0.80	24.51	23.71
15	9.0	35.9	0.04	29.1	0.04	1.21	30.27	29.06
30	11.7	23.4	0.03	37.9	0.03	2.41	40.34	37.92
60	15.3	15.3	0.02	49.5	0.02	4.82	54.32	49.49
120	19.2	9.6	0.01	62.3	0.01	9.65	71.93	62.28
240	23.9	6.0	0.01	77.2	0.01	19.30	96.54	77.25
360	27.3	4.5	0.01	88.3	0.01	28.95	117.23	88.29
600	31.5	3.2	0.00	102.0	0.01	48.25	150.24	101.99
1440	41.4	1.7	0.00	133.9	0.00	115.79	249.67	133.88

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_1yr} \times p_{hydro} =$ **167.4** m^3

Required storage for period of 2 year

Discharge per hectare; $Q_{2yr\_area} = Q_{2yr} / A =$ **4.8** l/s/hectare

Greenfield runoff rate post development; $Q_{2yr\_post\_open} = Q_{2yr\_area} \times A_{imp} =$ **1.6** l/s

Duration (min)	2 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	6.7	79.9	0.09	21.5	0.09	0.47	22.00	21.54
10	9.5	56.8	0.07	30.7	0.07	0.93	31.59	30.66
15	11.6	46.4	0.05	37.5	0.06	1.40	38.91	37.51
30	14.9	29.8	0.03	48.3	0.04	2.79	51.06	48.27
60	19.1	19.1	0.02	61.9	0.02	5.58	67.43	61.85
120	23.6	11.8	0.01	76.4	0.02	11.16	87.57	76.41
240	28.9	7.2	0.01	93.5	0.01	22.32	115.86	93.54
360	32.8	5.5	0.01	106.1	0.01	33.48	139.59	106.11
600	37.5	3.8	0.00	121.5	0.01	55.80	177.30	121.49
1440	48.4	2.0	0.00	156.7	0.00	133.93	290.66	156.73

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_2yr} \times p_{hydro} =$ **195.9** m^3

Required storage for period of 10 year

Discharge per hectare; $Q_{10yr\_area} = Q_{10yr} / A =$ **7.4** l/s/hectare

Greenfield runoff rate post development; $Q_{10yr\_post\_open} = Q_{10yr\_area} \times A_{imp} =$ **2.4** l/s

Duration (min)	10 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	10.2	122.4	0.14	33.0	0.15	0.72	33.72	33.00
10	14.7	87.9	0.10	47.4	0.11	1.44	48.86	47.41
15	18.0	71.8	0.08	58.1	0.09	2.17	60.29	58.12
30	22.9	45.8	0.05	74.2	0.06	4.33	78.51	74.18
60	29.0	29.0	0.03	93.9	0.04	8.66	102.56	93.90
120	35.0	17.5	0.02	113.2	0.02	17.32	130.56	113.24
240	41.8	10.4	0.01	135.2	0.01	34.64	169.81	135.17
360	46.6	7.8	0.01	150.8	0.01	51.97	202.80	150.83
600	52.5	5.3	0.01	169.9	0.01	86.61	256.53	169.93
1440	65.8	2.7	0.00	212.9	0.01	207.86	420.81	212.94

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_10yr} \times p_{hydro}$ = **266.2** m^3

Required storage for period of 30 year

Discharge per hectare; $Q_{30yr\_area} = Q_{30yr} / A$ = **10.0** l/s/hectare

Greenfield runoff rate post development; $Q_{30yr\_post\_open} = Q_{30yr\_area} \times A_{imp}$ = **3.2** l/s

Duration (min)	30 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	12.4	148.6	0.17	40.1	0.18	0.97	41.04	40.07
10	18.0	107.7	0.13	58.1	0.13	1.94	60.03	58.09
15	22.1	88.4	0.10	71.5	0.11	2.91	74.41	71.50
30	28.4	56.9	0.07	92.0	0.07	5.81	97.83	92.02
60	36.0	36.0	0.04	116.3	0.05	11.63	127.98	116.35
120	43.4	21.7	0.03	140.3	0.03	23.25	163.59	140.34
240	51.7	12.9	0.02	167.2	0.02	46.50	213.68	167.18
360	57.5	9.6	0.01	186.0	0.01	69.75	255.77	186.01
600	64.3	6.4	0.01	208.0	0.01	116.25	324.27	208.02
1440	79.3	3.3	0.00	256.5	0.01	279.01	535.50	256.49

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_30yr} \times p_{hydro}$ = **320.6** m^3

Required storage for period of 50 year

Discharge per hectare; $Q_{50yr\_area} = Q_{50yr} / A$ = **11.0** l/s/hectare

Greenfield runoff rate post development; $Q_{50yr\_post\_open} = Q_{50yr\_area} \times A_{imp}$ = **3.6** l/s

Duration (min)	50 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	13.7	163.9	0.19	44.2	0.20	1.07	45.27	44.21
10	19.9	119.5	0.14	64.5	0.14	2.13	66.60	64.47
15	24.6	98.4	0.11	79.6	0.12	3.20	82.78	79.58
30	31.8	63.6	0.07	102.9	0.08	6.39	109.34	102.95
60	40.3	40.3	0.05	130.5	0.05	12.79	143.27	130.48
120	48.7	24.3	0.03	157.6	0.03	25.58	183.16	157.58
240	57.9	14.5	0.02	187.4	0.02	51.15	238.55	187.40
360	64.3	10.7	0.01	208.1	0.02	76.73	284.82	208.09
600	71.7	7.2	0.01	232.1	0.01	127.88	359.98	232.10
1440	87.8	3.7	0.00	284.2	0.01	306.91	591.10	284.19

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_50yr} \times p_{hydro}$ = **355.2** m^3

Required storage for period of 100 year

Discharge per hectare; $Q_{100yr\_area} = Q_{100yr} / A$ = **12.8** l/s/hectare

Greenfield runoff rate post development; $Q_{100yr\_post\_open} = Q_{100yr\_area} \times A_{imp}$ = **4.1** l/s

Duration (min)	100 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	15.8	189.3	0.22	51.0	0.23	1.24	52.28	51.04
10	23.2	139.0	0.16	75.0	0.17	2.49	77.45	74.96
15	28.8	115.0	0.13	93.1	0.14	3.73	96.79	93.06
30	37.3	74.6	0.09	120.7	0.09	7.47	128.18	120.71
60	47.2	47.2	0.06	152.7	0.06	14.94	167.63	152.69
120	56.6	28.3	0.03	183.1	0.04	29.88	212.94	183.06
240	66.9	16.7	0.02	216.6	0.02	59.75	276.38	216.62
360	74.1	12.4	0.01	239.9	0.02	89.63	329.57	239.94
600	82.4	8.2	0.01	266.8	0.01	149.39	416.17	266.79
1440	99.9	4.2	0.00	323.4	0.01	358.53	681.95	323.42

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_100yr} \times p_{hydro}$ = **404.3** m^3

Interception storage

Interception rainfall depth; d_{int} = **5** mm

Volume of interception storage required; $V_{int\_req} = 0.8 \times A_{imp} \times d_{int}$ = **12.94** m^3

ATTENUATION DESIGN – SYSTEM 1 (MAIN AREA & BREWERY ROOF)

In accordance with CIRIA publication C697 - The SUDS Manual

Tedds calculation version 1.0.02

Pre post runoff method

Site characteristics

Location;	Stoke
Hydrological region;	4
Soil type (Wallingford Procedure W.R.A.P map);	4
Standard percentage runoff;	SPR = **0.47**
Average annual rainfall;	SAAR = **720** mm
5 year return period rainfall of 60 minute duration;	M5_60min = **18.0** mm
Ratio 60-minute to 2 day rainfalls of 5 year return;	r = **0.36**
Rainfall intensity increase due to global warming;	$p_{climate}$ = **30**%
Routing coefficient;	c_r = **1.30**
Volumetric runoff coefficient;	c_v = **0.75**

Catchment details

Subcatchment	Name	Area (ha)	PIMP (%);	Impermeable. area (ha)
1;	Brewery Roof;	0.14;	100.0;	0.14;
2;	Main Area;	0.32;	100.0;	0.32;
	Total	0.46;	100.0;	0.46;

Greenfield runoff rates

Catchment area;	AREA = **50.00** hectare
Greenfield runoff rate (50 hectare site);	$\bar{Q}_{rural} = 0.00108 m^3/s \times (AREA/1km^2)^{0.89} \times (SAAR/1mm)^{1.17} \times SPR^{2.17}$ = **249.5** l / s
Greenfield runoff rate;	$\bar{Q} = \bar{Q}_{rural} / AREA \times A$ = **2.3** l / s
Greenfield runoff rate per unit area;	$\bar{Q}_A = \bar{Q} / A$ = **5.0** l / s / hectare

Estimated site discharges

FSR growth rate (1 year);	FSR_{1yr} = **0.83**
Discharge (1 year);	$Q_{1yr} = \bar{Q} \times FSR_{1yr}$ = **1.9** l/s
FSR growth rate (2 year);	FSR_{2yr} = **0.96**
Discharge (2 year);	$Q_{2yr} = \bar{Q} \times FSR_{2yr}$ = **2.2** l/s
FSR growth rate (10 year);	FSR_{10yr} = **1.49**
Discharge (10 year);	$Q_{10yr} = \bar{Q} \times FSR_{10yr}$ = **3.4** l/s
FSR growth rate (30 year);	FSR_{30yr} = **2.00**
Discharge (30 year);	$Q_{30yr} = \bar{Q} \times FSR_{30yr}$ = **4.6** l/s
FSR growth rate (50 year);	FSR_{50yr} = **2.20**
Discharge (50 year);	$Q_{50yr} = \bar{Q} \times FSR_{50yr}$ = **5.1** l/s
FSR growth rate (100 year);	FSR_{100yr} = **2.57**
Discharge (100 year);	$Q_{100yr} = \bar{Q} \times FSR_{100yr}$ = **5.9** l/s

Table equations

Peak flow;	$Q_{post\_imp} = c_r \times I_{max} \times A_{imp}$
Runoff volume;	$V_{post\_imp} = Q_{post\_imp} \times D / c_r$
Post development runoff;	$\bar{Q}_{post} = Q_{post\_imp} + Q_{post\_open}$
Permitted discharge;	$O_{exist} = Q \times D$
Post development runoff volume;	$I_{post} = Q_{post\_open} \times D + V_{post\_imp}$

Storage volume required; $S_{post} = I_{post} - O_{exist}$

Required storage for period of 1 year

Discharge per hectare; $Q_{1yr\_area} = Q_{1yr} / A =$ **4.1** l/s/hectare

Greenfield runoff rate post development; $Q_{1yr\_post\_open} = Q_{1yr\_area} \times A_{imp} =$ **1.9** l/s

Duration (min)	1 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	5.2	62.0	0.10	23.9	0.11	0.58	24.52	23.95
10	7.3	44.0	0.07	34.0	0.08	1.15	35.11	33.96
15	9.0	35.9	0.06	41.6	0.06	1.73	43.36	41.63
30	11.7	23.4	0.04	54.3	0.04	3.46	57.79	54.33
60	15.3	15.3	0.03	70.9	0.03	6.91	77.82	70.90
120	19.2	9.6	0.02	89.2	0.02	13.82	103.05	89.23
240	23.9	6.0	0.01	110.7	0.01	27.65	138.31	110.66
360	27.3	4.5	0.01	126.5	0.01	41.47	167.95	126.48
600	31.5	3.2	0.01	146.1	0.01	69.12	215.24	146.12
1440	41.4	1.7	0.00	191.8	0.00	165.88	357.69	191.80

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_1yr} \times p_{hydro} =$ **239.8** m^3

Required storage for period of 2 year

Discharge per hectare; $Q_{2yr\_area} = Q_{2yr} / A =$ **4.8** l/s/hectare

Greenfield runoff rate post development; $Q_{2yr\_post\_open} = Q_{2yr\_area} \times A_{imp} =$ **2.2** l/s

Duration (min)	2 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	6.7	79.9	0.13	30.9	0.14	0.67	31.52	30.85
10	9.5	56.8	0.10	43.9	0.10	1.33	45.25	43.92
15	11.6	46.4	0.08	53.7	0.08	2.00	55.74	53.74
30	14.9	29.8	0.05	69.2	0.05	4.00	73.16	69.16
60	19.1	19.1	0.03	88.6	0.03	7.99	96.60	88.61
120	23.6	11.8	0.02	109.5	0.02	15.99	125.45	109.46
240	28.9	7.2	0.01	134.0	0.01	31.98	165.98	134.00
360	32.8	5.5	0.01	152.0	0.01	47.97	199.98	152.01
600	37.5	3.8	0.01	174.1	0.01	79.94	254.00	174.06
1440	48.4	2.0	0.00	224.5	0.01	191.87	416.41	224.54

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_2yr} \times p_{hydro} =$ **280.7** m^3

Required storage for period of 10 year

Discharge per hectare; $Q_{10yr\_area} = Q_{10yr} / A =$ **7.4** l/s/hectare

Greenfield runoff rate post development; $Q_{10yr\_post\_open} = Q_{10yr\_area} \times A_{imp} =$ **3.4** l/s

Duration (min)	10 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	10.2	122.4	0.20	47.3	0.21	1.03	48.31	47.28
10	14.7	87.9	0.15	67.9	0.15	2.07	69.99	67.93
15	18.0	71.8	0.12	83.3	0.12	3.10	86.37	83.27
30	22.9	45.8	0.08	106.3	0.08	6.20	112.47	106.27
60	29.0	29.0	0.05	134.5	0.05	12.41	146.93	134.52
120	35.0	17.5	0.03	162.2	0.03	24.82	187.05	162.23
240	41.8	10.4	0.02	193.6	0.02	49.63	243.28	193.64
360	46.6	7.8	0.01	216.1	0.02	74.45	290.54	216.09
600	52.5	5.3	0.01	243.4	0.01	124.08	367.52	243.44
1440	65.8	2.7	0.00	305.1	0.01	297.79	602.86	305.07

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_10yr} \times p_{hydro} =$ **381.3** m^3

Required storage for period of 30 year

Discharge per hectare; $Q_{30yr\_area} = Q_{30yr} / A =$ **10.0** l/s/hectare

Greenfield runoff rate post development; $Q_{30yr\_post\_open} = Q_{30yr\_area} \times A_{imp} =$ **4.6** l/s

Duration (min)	30 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	12.4	148.6	0.25	57.4	0.25	1.39	58.80	57.41
10	18.0	107.7	0.18	83.2	0.18	2.78	86.00	83.22
15	22.1	88.4	0.15	102.4	0.15	4.16	106.60	102.44
30	28.4	56.9	0.10	131.8	0.10	8.33	140.16	131.83
60	36.0	36.0	0.06	166.7	0.06	16.65	183.34	166.69
120	43.4	21.7	0.04	201.1	0.04	33.31	234.37	201.06
240	51.7	12.9	0.02	239.5	0.03	66.62	306.12	239.50
360	57.5	9.6	0.02	266.5	0.02	99.93	366.42	266.49
600	64.3	6.4	0.01	298.0	0.02	166.55	464.56	298.01
1440	79.3	3.3	0.01	367.5	0.01	399.72	767.17	367.45

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_30yr} \times p_{hydro} =$ **459.3** m^3

Required storage for period of 50 year

Discharge per hectare; $Q_{50yr\_area} = Q_{50yr} / A =$ **11.0** l/s/hectare

Greenfield runoff rate post development; $Q_{50yr\_post\_open} = Q_{50yr\_area} \times A_{imp} =$ **5.1** l/s

Duration (min)	50 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	13.7	163.9	0.27	63.3	0.28	1.53	64.86	63.33
10	19.9	119.5	0.20	92.4	0.21	3.05	95.41	92.36
15	24.6	98.4	0.16	114.0	0.17	4.58	118.59	114.01
30	31.8	63.6	0.11	147.5	0.11	9.16	156.64	147.48
60	40.3	40.3	0.07	186.9	0.07	18.32	205.26	186.94
120	48.7	24.3	0.04	225.8	0.05	36.64	262.40	225.76
240	57.9	14.5	0.02	268.5	0.03	73.28	341.76	268.48
360	64.3	10.7	0.02	298.1	0.02	109.92	408.04	298.11
600	71.7	7.2	0.01	332.5	0.02	183.20	515.72	332.52
1440	87.8	3.7	0.01	407.1	0.01	439.69	846.83	407.14

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_50yr} \times p_{hydro}$ = **508.9** m^3

Required storage for period of 100 year

Discharge per hectare; $Q_{100yr\_area} = Q_{100yr} / A$ = **12.8** l/s/hectare

Greenfield runoff rate post development; $Q_{100yr\_post\_open} = Q_{100yr\_area} \times A_{imp}$ = **5.9** l/s

Duration (min)	100 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	15.8	189.3	0.32	73.1	0.32	1.78	74.90	73.12
10	23.2	139.0	0.23	107.4	0.24	3.57	110.95	107.38
15	28.8	115.0	0.19	133.3	0.20	5.35	138.67	133.32
30	37.3	74.6	0.12	172.9	0.13	10.70	183.64	172.94
60	47.2	47.2	0.08	218.7	0.08	21.40	240.15	218.74
120	56.6	28.3	0.05	262.3	0.05	42.80	305.07	262.26
240	66.9	16.7	0.03	310.3	0.03	85.61	395.95	310.34
360	74.1	12.4	0.02	343.7	0.03	128.41	472.15	343.74
600	82.4	8.2	0.01	382.2	0.02	214.02	596.22	382.21
1440	99.9	4.2	0.01	463.3	0.01	513.64	976.98	463.34

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_100yr} \times p_{hydro}$ = **579.2** m^3

Interception storage

Interception rainfall depth; d_{int} = **5** mm

Volume of interception storage required; $V_{int\_req} = 0.8 \times A_{imp} \times d_{int}$ = **18.54** m^3

ATTENUATION DESIGN – SYSTEM 2 (REMOTE AREA)

In accordance with CIRIA publication C697 - The SUDS Manual

Tedds calculation version 1.0.02

Pre post runoff method

Site characteristics

Location;	Stoke
Hydrological region;	4
Soil type (Wallingford Procedure W.R.A.P map);	4
Standard percentage runoff;	SPR = **0.47**
Average annual rainfall;	SAAR = **720** mm
5 year return period rainfall of 60 minute duration;	M5_60min = **18.0** mm
Ratio 60-minute to 2 day rainfalls of 5 year return;	r = **0.36**
Rainfall intensity increase due to global warming;	$p_{climate}$ = **30**%
Routing coefficient;	c_r = **1.30**
Volumetric runoff coefficient;	c_v = **0.75**

Catchment details

Subcatchment	Name	Area (ha)	PIMP (%);	Impermeable. area (ha)
1;	Remote Area;	0.48;	95.0;	0.46;
Total		0.48;	95.0;	0.46;

Greenfield runoff rates

Catchment area;	AREA = **50.00** hectare
Greenfield runoff rate (50 hectare site);	$\bar{Q}_{rural} = 0.00108 m^3/s \times (AREA/1km^2)^{0.89} \times (SAAR/1mm)^{1.17} \times SPR^{2.17}$ = **249.5** l / s
Greenfield runoff rate;	$\bar{Q} = \bar{Q}_{rural} / AREA \times A$ = **2.4** l / s
Greenfield runoff rate per unit area;	$\bar{Q}_A = \bar{Q} / A$ = **5.0** l / s / hectare

Estimated site discharges

FSR growth rate (1 year);	FSR_{1yr} = **0.83**
Discharge (1 year);	$Q_{1yr} = \bar{Q} \times FSR_{1yr}$ = **2.0** l/s
FSR growth rate (2 year);	FSR_{2yr} = **0.96**
Discharge (2 year);	$Q_{2yr} = \bar{Q} \times FSR_{2yr}$ = **2.3** l/s
FSR growth rate (10 year);	FSR_{10yr} = **1.49**
Discharge (10 year);	$Q_{10yr} = \bar{Q} \times FSR_{10yr}$ = **3.6** l/s
FSR growth rate (30 year);	FSR_{30yr} = **2.00**
Discharge (30 year);	$Q_{30yr} = \bar{Q} \times FSR_{30yr}$ = **4.8** l/s
FSR growth rate (50 year);	FSR_{50yr} = **2.20**
Discharge (50 year);	$Q_{50yr} = \bar{Q} \times FSR_{50yr}$ = **5.3** l/s
FSR growth rate (100 year);	FSR_{100yr} = **2.57**
Discharge (100 year);	$Q_{100yr} = \bar{Q} \times FSR_{100yr}$ = **6.2** l/s

Table equations

Peak flow;	$Q_{post\_imp} = c_r \times I_{max} \times A_{imp}$
Runoff volume;	$V_{post\_imp} = Q_{post\_imp} \times D / c_r$
Post development runoff;	$\bar{Q}_{post} = Q_{post\_imp} + Q_{post\_open}$
Permitted discharge;	$O_{exist} = Q \times D$
Post development runoff volume;	$I_{post} = Q_{post\_open} \times D + V_{post\_imp}$
Storage volume required;	$S_{post} = I_{post} - O_{exist}$

Required storage for period of 1 year

Discharge per hectare; $Q_{1yr\_area} = Q_{1yr} / A =$ **4.1** l/s/hectare

Greenfield runoff rate post development; $Q_{1yr\_post\_open} = Q_{1yr\_area} \times A_{imp} =$ **1.9** l/s

Duration (min)	1 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	5.2	62.0	0.10	23.6	0.10	0.60	24.12	23.52
10	7.3	44.0	0.07	33.4	0.07	1.19	34.54	33.35
15	9.0	35.9	0.06	41.0	0.06	1.79	42.65	40.86
30	11.7	23.4	0.04	53.4	0.04	3.58	56.84	53.26
60	15.3	15.3	0.03	69.7	0.03	7.16	76.54	69.38
120	19.2	9.6	0.02	87.8	0.02	14.31	101.36	87.05
240	23.9	6.0	0.01	108.8	0.01	28.63	136.04	107.42
360	27.3	4.5	0.01	124.4	0.01	42.94	165.20	122.26
600	31.5	3.2	0.01	143.7	0.01	71.56	211.71	140.15
1440	41.4	1.7	0.00	188.7	0.00	171.75	351.82	180.07

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_1yr} \times p_{hydro} =$ **225.1** m^3

Required storage for period of 2 year

Discharge per hectare; $Q_{2yr\_area} = Q_{2yr} / A =$ **4.8** l/s/hectare

Greenfield runoff rate post development; $Q_{2yr\_post\_open} = Q_{2yr\_area} \times A_{imp} =$ **2.2** l/s

Duration (min)	2 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	6.7	79.9	0.13	30.3	0.13	0.69	31.00	30.31
10	9.5	56.8	0.09	43.2	0.10	1.38	44.51	43.13
15	11.6	46.4	0.08	52.9	0.08	2.07	54.83	52.76
30	14.9	29.8	0.05	68.0	0.05	4.14	71.96	67.82
60	19.1	19.1	0.03	87.2	0.03	8.28	95.02	86.74
120	23.6	11.8	0.02	107.7	0.02	16.55	123.40	106.84
240	28.9	7.2	0.01	131.8	0.01	33.11	163.26	130.15
360	32.8	5.5	0.01	149.5	0.01	49.66	196.70	147.04
600	37.5	3.8	0.01	171.2	0.01	82.77	249.84	167.07
1440	48.4	2.0	0.00	220.9	0.01	198.65	409.58	210.93

Attenuation storage required

Vol. increase due to head-discharge relationship; $p_{hydro} =$ **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_2yr} \times p_{hydro} =$ **263.7** m^3

Required storage for period of 10 year

Discharge per hectare; $Q_{10yr\_area} = Q_{10yr} / A =$ **7.4** l/s/hectare

Greenfield runoff rate post development; $Q_{10yr\_post\_open} = Q_{10yr\_area} \times A_{imp} =$ **3.4** l/s

Duration (min)	10 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	10.2	122.4	0.20	46.5	0.20	1.07	47.52	46.45
10	14.7	87.9	0.14	66.8	0.15	2.14	68.85	66.71
15	18.0	71.8	0.12	81.9	0.12	3.21	84.95	81.74
30	22.9	45.8	0.08	104.5	0.08	6.42	110.63	104.21
60	29.0	29.0	0.05	132.3	0.05	12.85	144.52	131.67
120	35.0	17.5	0.03	159.6	0.03	25.69	183.98	158.29
240	41.8	10.4	0.02	190.5	0.02	51.39	239.29	187.90
360	46.6	7.8	0.01	212.5	0.02	77.08	285.77	208.69
600	52.5	5.3	0.01	239.4	0.01	128.47	361.49	233.03
1440	65.8	2.7	0.00	300.1	0.01	308.33	592.98	284.65

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_10yr} \times p_{hydro}$ = **355.8** m^3

Required storage for period of 30 year

Discharge per hectare; $Q_{30yr\_area} = Q_{30yr} / A$ = **10.0** l/s/hectare

Greenfield runoff rate post development; $Q_{30yr\_post\_open} = Q_{30yr\_area} \times A_{imp}$ = **4.6** l/s

Duration (min)	30 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	12.4	148.6	0.24	56.5	0.25	1.44	57.83	56.40
10	18.0	107.7	0.18	81.9	0.18	2.87	84.59	81.71
15	22.1	88.4	0.15	100.8	0.15	4.31	104.86	100.54
30	28.4	56.9	0.09	129.7	0.10	8.62	137.86	129.24
60	36.0	36.0	0.06	164.0	0.06	17.24	180.34	163.09
120	43.4	21.7	0.04	197.8	0.04	34.49	230.52	196.04
240	51.7	12.9	0.02	235.6	0.03	68.98	301.10	232.13
360	57.5	9.6	0.02	262.1	0.02	103.46	360.41	256.95
600	64.3	6.4	0.01	293.1	0.02	172.44	456.95	284.51
1440	79.3	3.3	0.01	361.4	0.01	413.86	754.60	340.74

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_30yr} \times p_{hydro}$ = **425.9** m^3

Required storage for period of 50 year

Discharge per hectare; $Q_{50yr\_area} = Q_{50yr} / A$ = **11.0** l/s/hectare

Greenfield runoff rate post development; $Q_{50yr\_post\_open} = Q_{50yr\_area} \times A_{imp}$ = **5.0** l/s

Duration (min)	50 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	13.7	163.9	0.27	62.3	0.27	1.58	63.79	62.21
10	19.9	119.5	0.20	90.8	0.20	3.16	93.85	90.69
15	24.6	98.4	0.16	112.1	0.17	4.74	116.65	111.90
30	31.8	63.6	0.10	145.1	0.11	9.48	154.08	144.59
60	40.3	40.3	0.07	183.9	0.07	18.97	201.89	182.92
120	48.7	24.3	0.04	222.1	0.05	37.94	258.10	220.16
240	57.9	14.5	0.02	264.1	0.03	75.87	336.16	260.28
360	64.3	10.7	0.02	293.2	0.02	113.81	401.35	287.54
600	71.7	7.2	0.01	327.1	0.02	189.69	507.27	317.58
1440	87.8	3.7	0.01	400.5	0.01	455.25	832.95	377.70

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_50yr} \times p_{hydro}$ = **472.1** m^3

Required storage for period of 100 year

Discharge per hectare; $Q_{100yr\_area} = Q_{100yr} / A$ = **12.8** l/s/hectare

Greenfield runoff rate post development; $Q_{100yr\_post\_open} = Q_{100yr\_area} \times A_{imp}$ = **5.8** l/s

Duration (min)	100 year rainfall (mm)	Rainfall intensity (mm/hr)	Peak flow (m^3/s)	Runoff volume (m^3)	Post dev. runoff (m^3/s)	Permit dischrge (m^3)	Post dev. runoff vol (m^3)	Storage vol. reqd (m^3)
5	15.8	189.3	0.31	71.9	0.32	1.85	73.67	71.82
10	23.2	139.0	0.23	105.6	0.23	3.69	109.13	105.44
15	28.8	115.0	0.19	131.1	0.20	5.54	136.39	130.85
30	37.3	74.6	0.12	170.1	0.13	11.08	180.63	169.55
60	47.2	47.2	0.08	215.2	0.08	22.16	236.21	214.05
120	56.6	28.3	0.05	258.0	0.05	44.32	300.07	255.75
240	66.9	16.7	0.03	305.3	0.03	88.64	389.46	300.82
360	74.1	12.4	0.02	338.1	0.03	132.95	464.41	331.46
600	82.4	8.2	0.01	375.9	0.02	221.59	586.45	364.86
1440	99.9	4.2	0.01	455.7	0.01	531.81	960.97	429.16

Attenuation storage required

Vol. increase due to head-discharge relationship; p_{hydro} = **1.25**

Maximum attenuation storage required; $V_{req\_max} = V_{max\_100yr} \times p_{hydro}$ = **536.4** m^3

Interception storage

Interception rainfall depth; d_{int} = **5** mm

Volume of interception storage required; $V_{int\_req} = 0.8 \times A_{imp} \times d_{int}$ = **18.24** m^3

SYSTEM 1 DESIGN – Main Area and Brewery Roof Drainage

Required Storage: 579.2m^3

Pipe/Manhole	Pipe Entrance Level (m)	Pipe Exit Level (m)	Depth / Length (m)	Storage Capacity (m^3)
S1-P1	99.25	99.10	35	2.45
S1-M1	99.10	99.075	0.925	2.35
S1-P2	99.075	99.00	13.5	0.95
Tank A	99.00	98.91	1.65 x 20*	-
S1-P3	98.91	98.86	11	0.77
S1-M2	98.86	98.83	1.17	3.00
S1-P4	98.83	98.63	40	2.80
S1-M3	98.63	98.605	1.40	3.56
S1-P5	98.605	98.43	34.2	2.40
MA**	98.43	98.13	1.87	4.75
PA**	98.13	98.02	21.5	1.51
			Total Storage Capacity	**25m^3**

*Tank depth taken as invert of lowest pipe, length assumed as 20m to calculate width once storage capacity has been determined.

**Manhole A, point where both systems are combined and defused to the river through Pipe A. Exit level on Manhole A taken from System 2 as lower level needed.

Total storage needed from tank: 579.2- 25 = 554m^3

Therefore as drainage system above specifies a tank of 1.6m deep and 20m long, the width of the tanks should be 17m in width. (1.65 x 17 x 20).

SYSTEM 2 DESIGN – Remote Area Drainage

Required Storage: 536.4m^3

All invert levels taken from ground level at 100

Pipe/Manhole	Pipe Entrance Level (m)	Pipe Exit Level (m)	Depth / Length (m)	Storage Capacity (m^3)
S2-P1	99.25	99.10	30	2.1
S2-M1	99.10	99.075	0.925	2.35
S2-P2	99.075	98.925	30	2.1
Tank B	98.925	98.825	1.65 x 20*	-
S2-P3	98.825	98.70	25	1.75
S2-M2	98.70	98.675	1.33	3.67
S2-P4	98.675	98.52	30	2.1
S2-M3	98.52	98.5	1.5	3.81
S2-P5	98.5	98.35	30	2.1
S2-M4	98.35	98.325	1.675	4.26
S2-P6	98.325	98.154	34.2	2.394
MA	98.154	98.130	2.385	-
PA	98.13	98.02	21.5	-
			Total Storage Capacity	**32.70m^3**

*Tank depth taken as invert of lowest pipe, length assumed as 20m to calculate width once storage capacity has been determined.

Total storage needed from tank: 536.4 – 26.70 = 509.8m^3

Therefore as drainage system above specifies a tank of 1.7m deep and 20m long, the width of the tanks should be 15m in width. (1.7 x 15 x 20).

Orifice Plate Design
System 1

Hydraulic head from invert depth at Pipe to exit at Manhole A = 0.5m
Fluid Pressure = $\Delta P_1 = 4.905kPa$
Fluid Density (ρ) – 9.81kg/m^3
Pipe Diameter (D_1) – 0.3m
Volumetric Flow Rate (Q) – 0.0023m^3/s

$$Q = \sqrt{\frac{1}{1-(\frac{D_1}{D_2})^4}} \quad \frac{\pi D_2^2}{4} \quad \sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

Therefore diameter of orifice plate throat (D_2) = 0.054m

System 2
Hydraulic head from invert depth at Pipe to exit at Manhole A = 0.5m
Fluid Pressure = $\Delta P_1 = 4.905kPa$
Fluid Density (ρ) – 9.81kg/m^3
Pipe Diameter (D_1) – 0.3m
Volumetric Flow Rate (Q) – 0.0024m^3/s

From above equation: Diameter of orifice plate throat (D_2) = 0.055m