



HR Wallingford
Working with water

SAM – System Based Analysis and Management of Urban Flood Risks

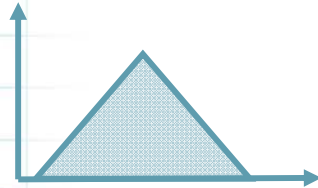
Application of the Risk based Procedure

Dr Yannick Cesses

BERR

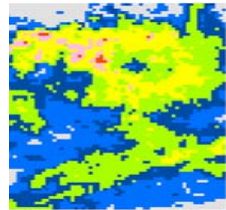
Department for Business
Enterprise & Regulatory Reform

Design storm

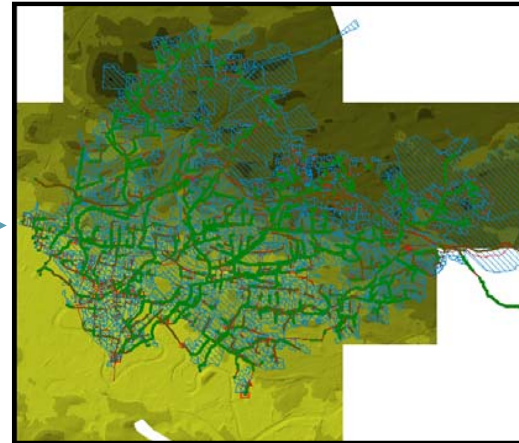


or

Enable Continuous time series

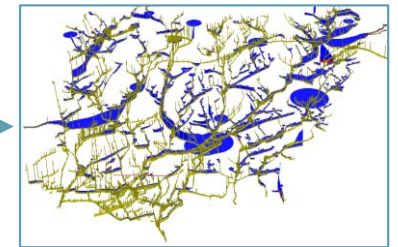


InfoWorks CS Model



incorporate potential blockage or collapse

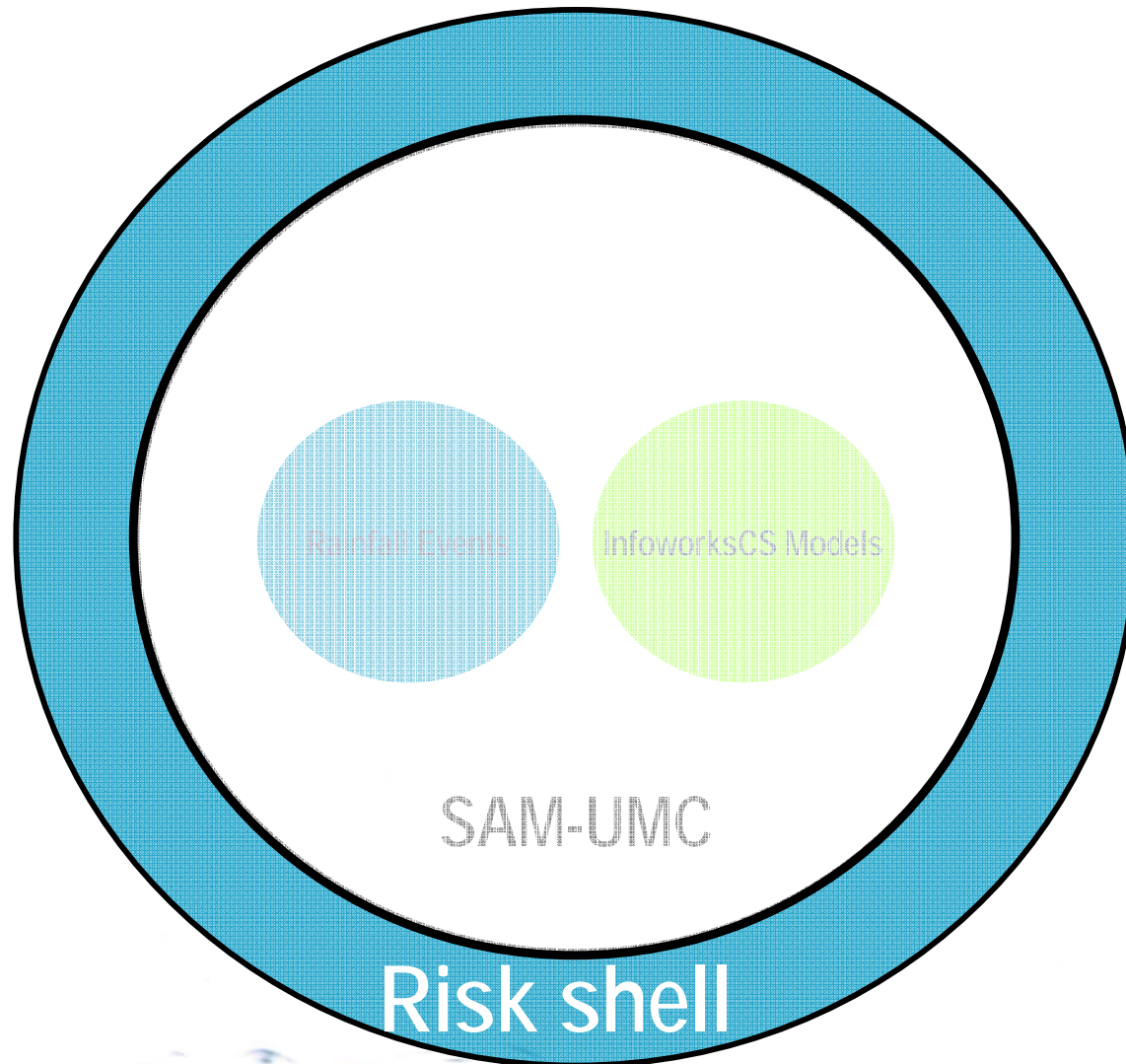
Flood results



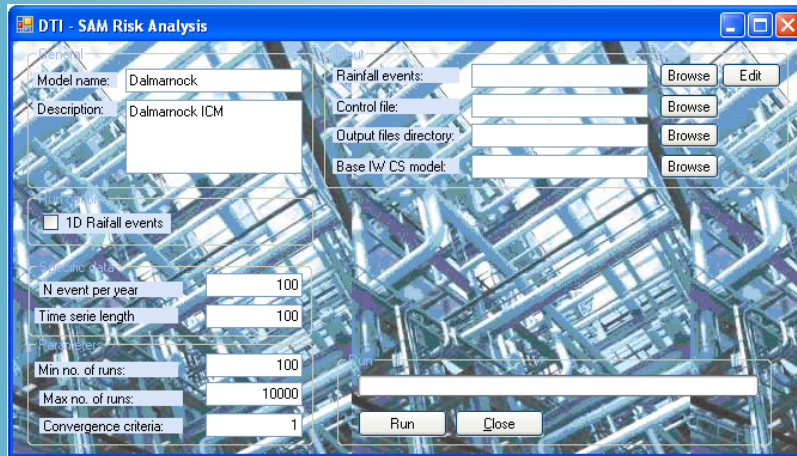
Expected Annual Damage

Enable strategic decision-making to be made
on the basis of consequences instead of level of performance

Risk based tools structure



Risk based tools structure



DTI - SAM Risk Analysis

General

Model name: Dalmarnock
Description: Dalmarnock ICM

Input

Rainfall events: Browse Edit
Control file: Browse
Output files directory: Browse
Base IW CS model: Browse

Options

1D Raifall events

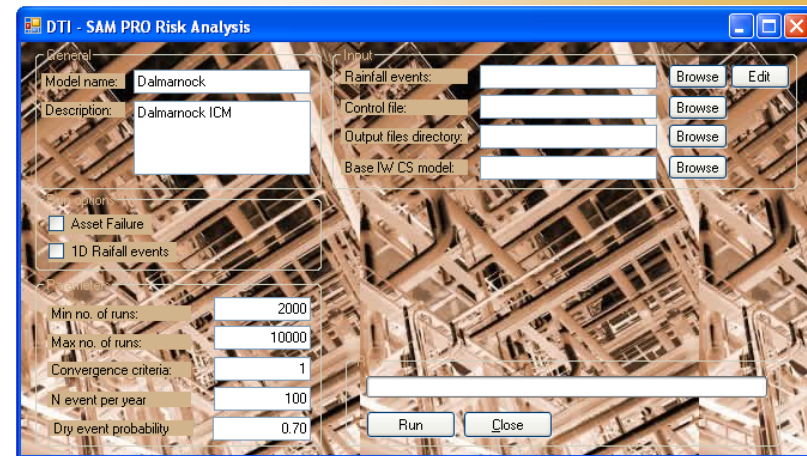
Running Data

N event per year: 100
Time serie length: 100

Iterations

Min no. of runs: 100
Max no. of runs: 10000
Convergence criteria: 1

Run Close



DTI - SAM PRO Risk Analysis

General

Model name: Dalmarnock
Description: Dalmarnock ICM

Input

Rainfall events: Browse Edit
Control file: Browse
Output files directory: Browse
Base IW CS model: Browse

Options

Asset Failure
 1D Raifall events

Running Data

Min no. of runs: 2000
Max no. of runs: 10000
Convergence criteria: 1
N event per year: 100
Dry event probability: 0.70

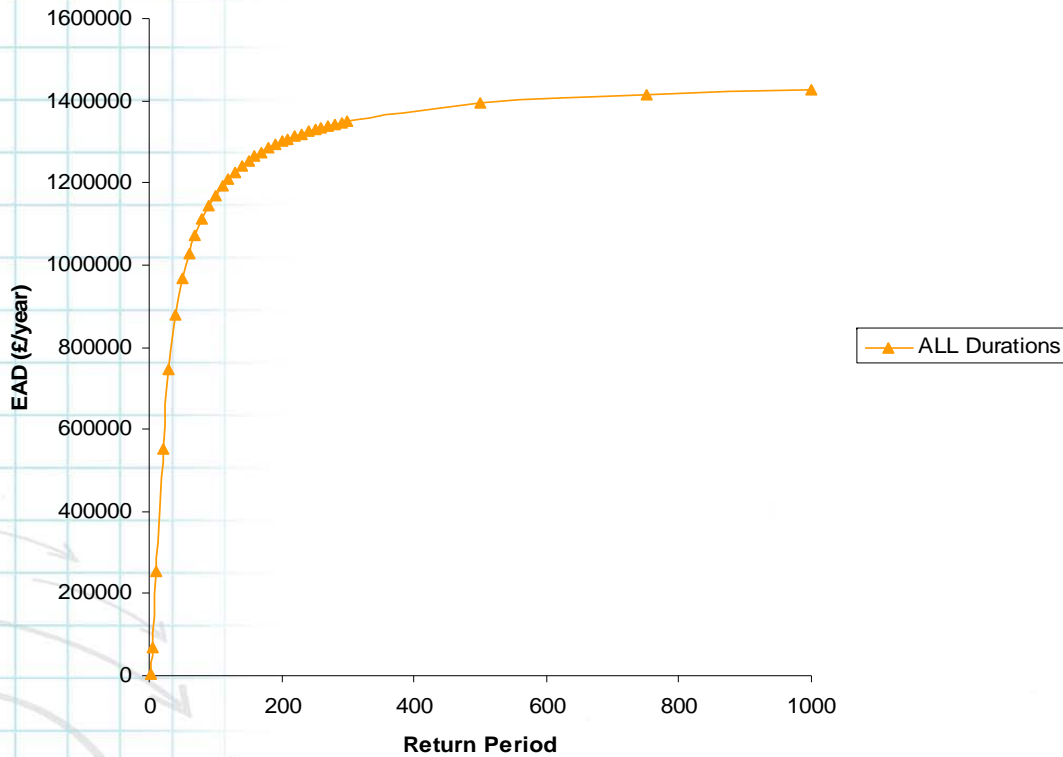
Run Close

Hydraulic failure – Design events

- 700 rainfall events with :
 - 20 Durations from 30 min to 600 min
 - 35 Return Periods from 2 year to 1000 year

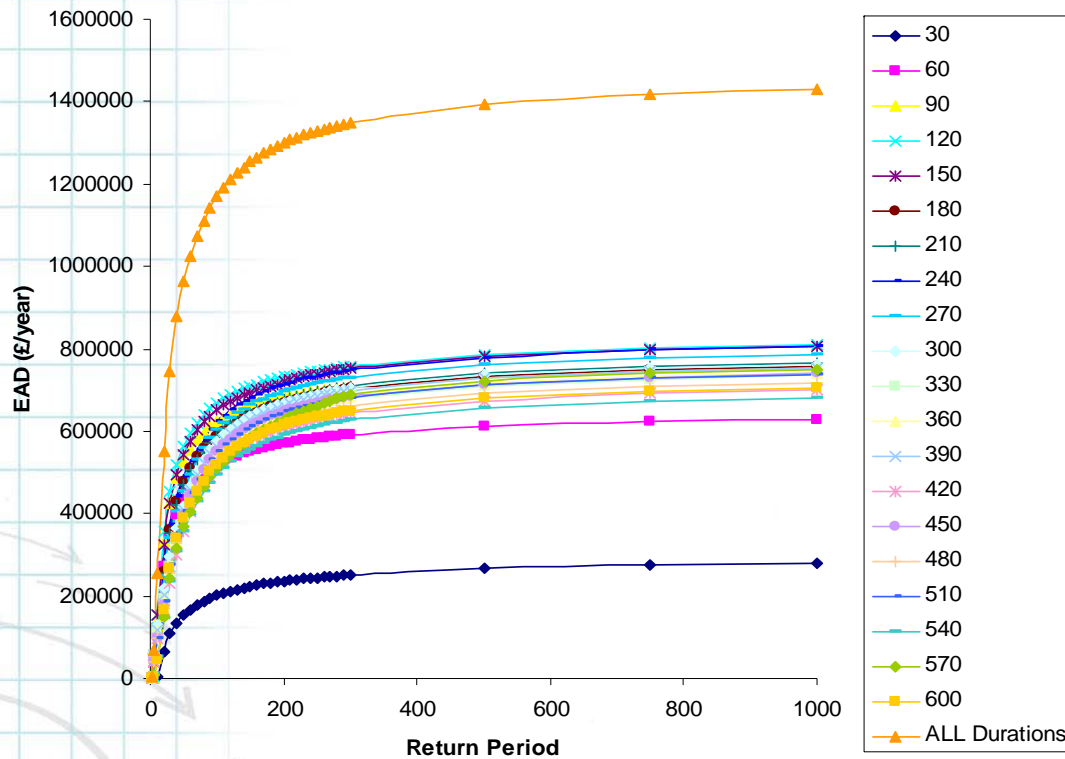
Return Period (RP)	Duration																			
	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	570	600
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
50	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
60	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
70	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
80	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
90	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
100	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
110	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
120	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
130	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
140	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
160	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
170	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
180	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
190	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
200	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
210	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
220	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
230	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
240	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
250	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
260	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
270	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
280	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
290	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
500	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
750	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1000	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Hydraulic failure – Design events



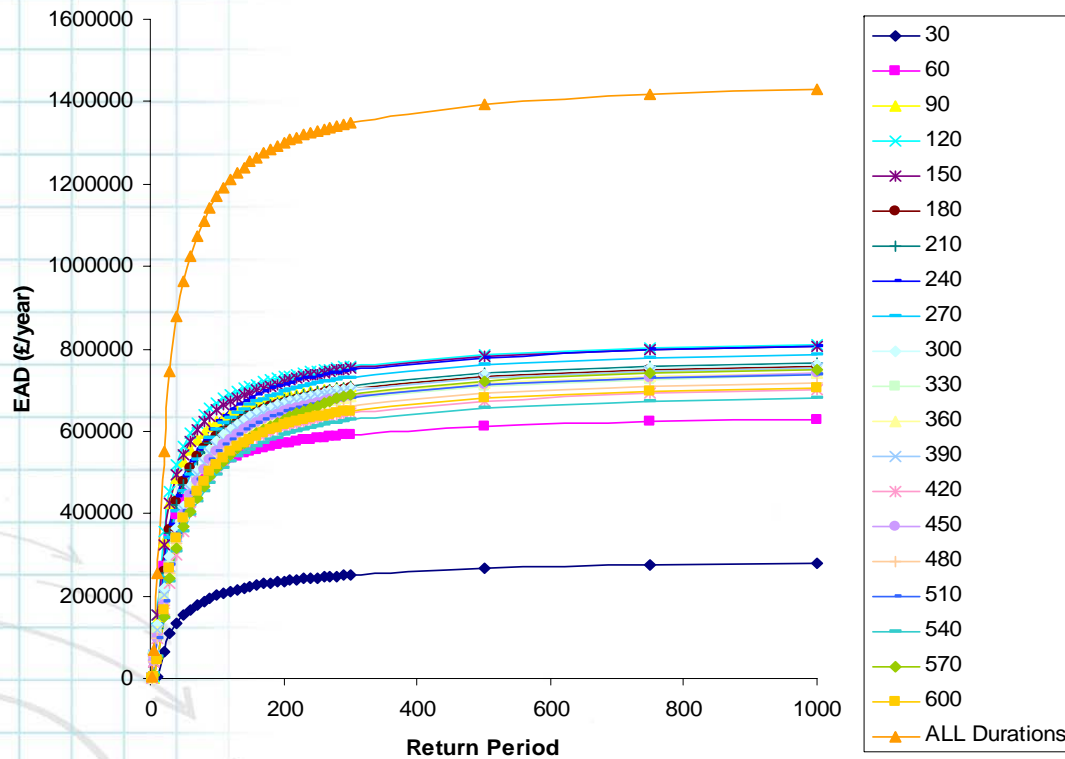
- EAD = £ 1.42M
- Quick convergence of the EAD (200-250 years)

Hydraulic failure – Design events

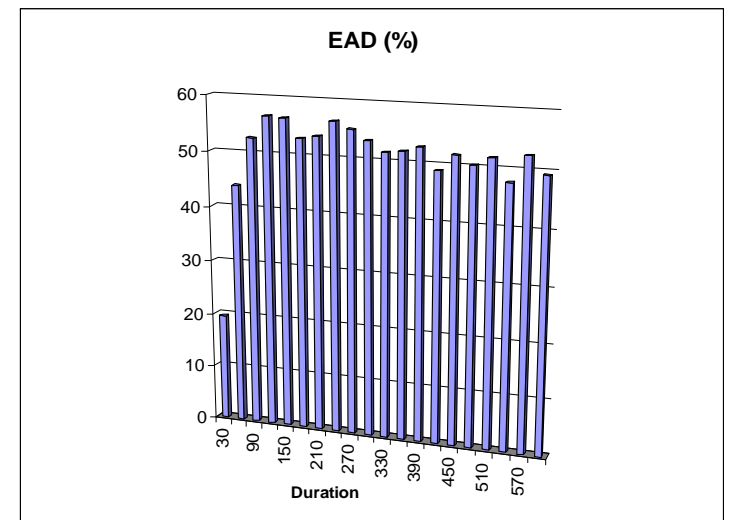


- EAD = £ 1.42M
- Quick convergence of the EAD (200-250 years)
- EAD is dependant on the durations considered

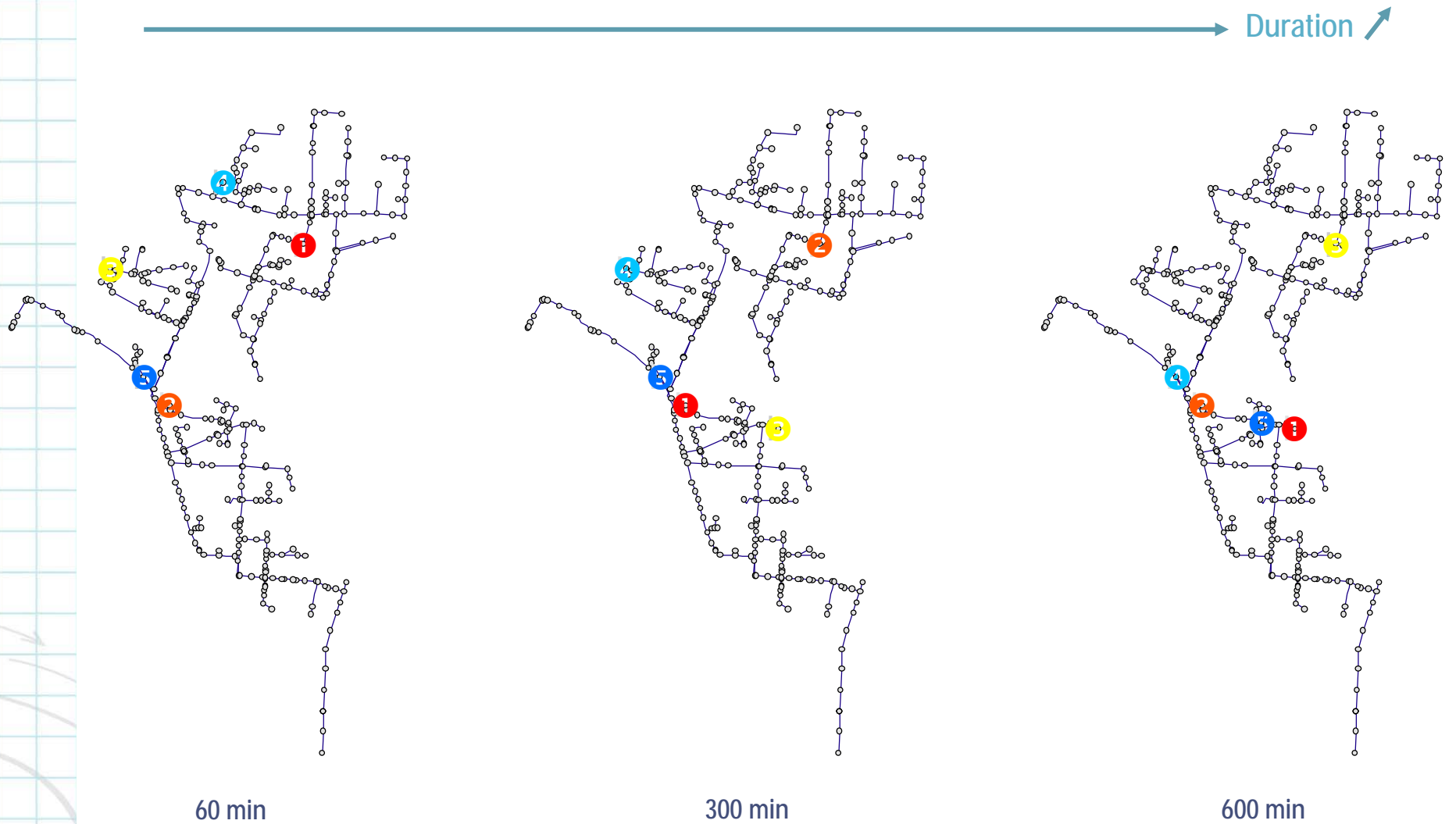
Hydraulic failure – Design events



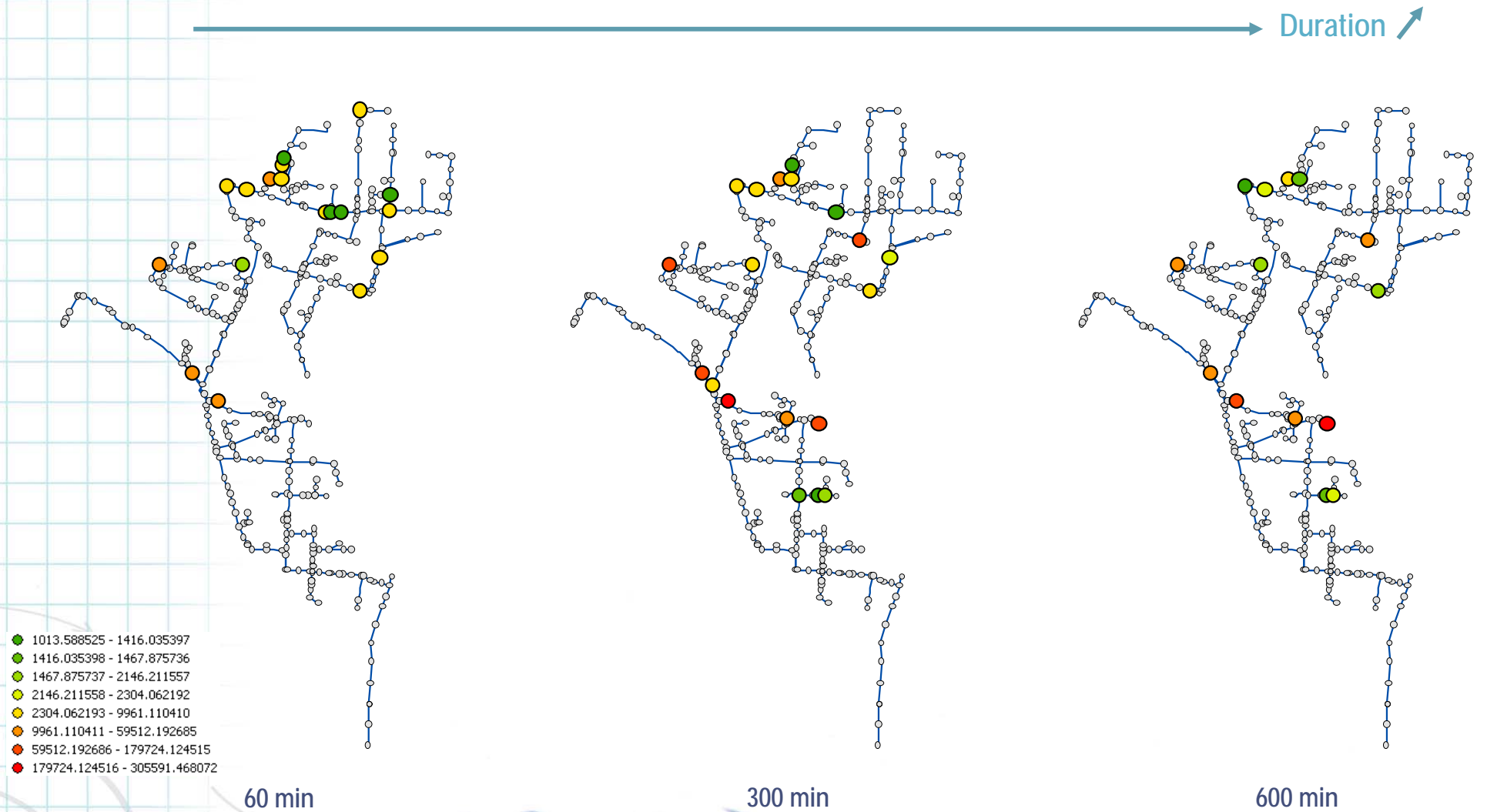
- EAD = £ 1.42M
- Quick convergence of the EAD (200-250 years)
- EAD is dependant on the durations considered
- Range of duration that produces 50% of the total EAD is quite important



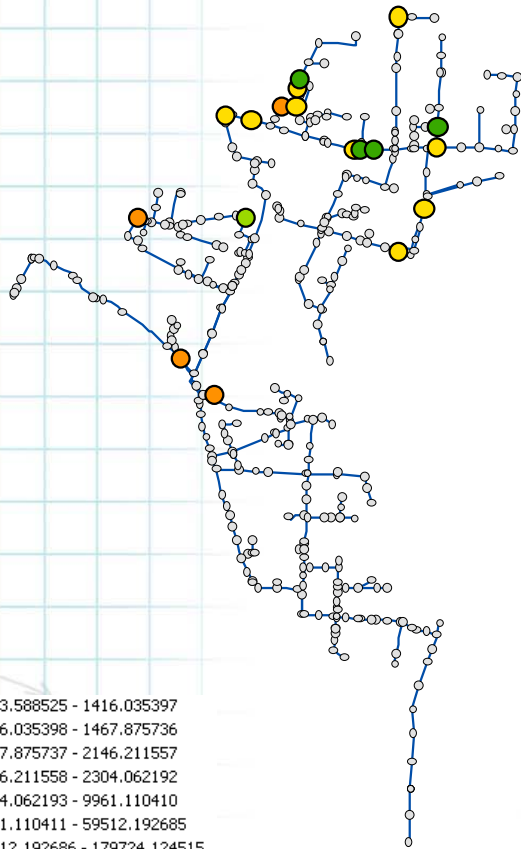
Hydraulic failure – Design events



Hydraulic failure – Design events

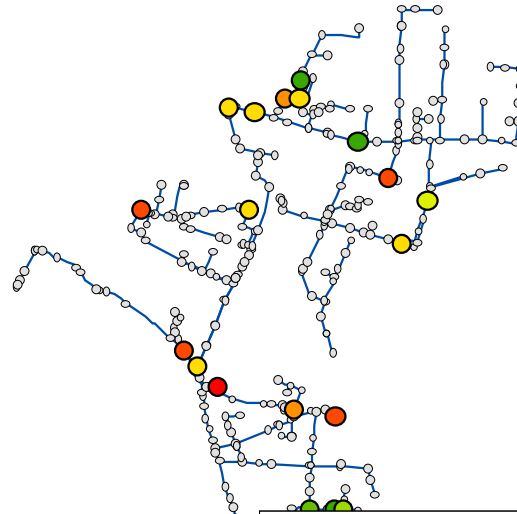


Hydraulic failure – Design events

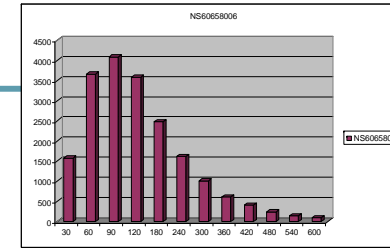


60 min

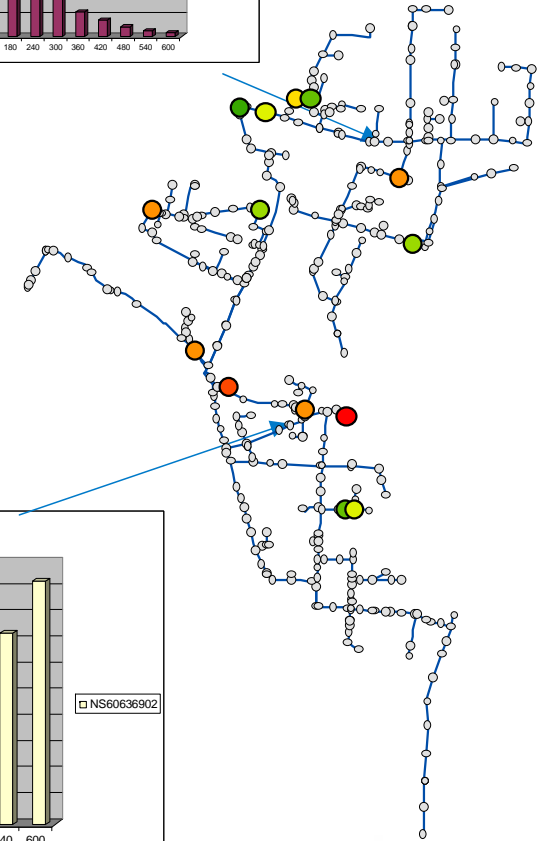
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- 1416.035398 - 1467.875736
- 1467.875737 - 2146.211557
- 2146.211558 - 2304.062192
- 2304.062193 - 9961.110410
- 9961.110411 - 59512.192685
- 59512.192686 - 179724.124515
- 179724.124516 - 305591.468072



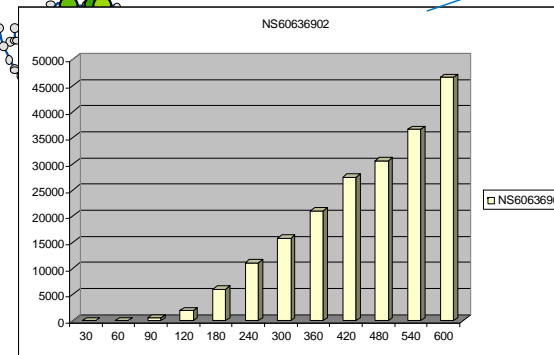
300 min



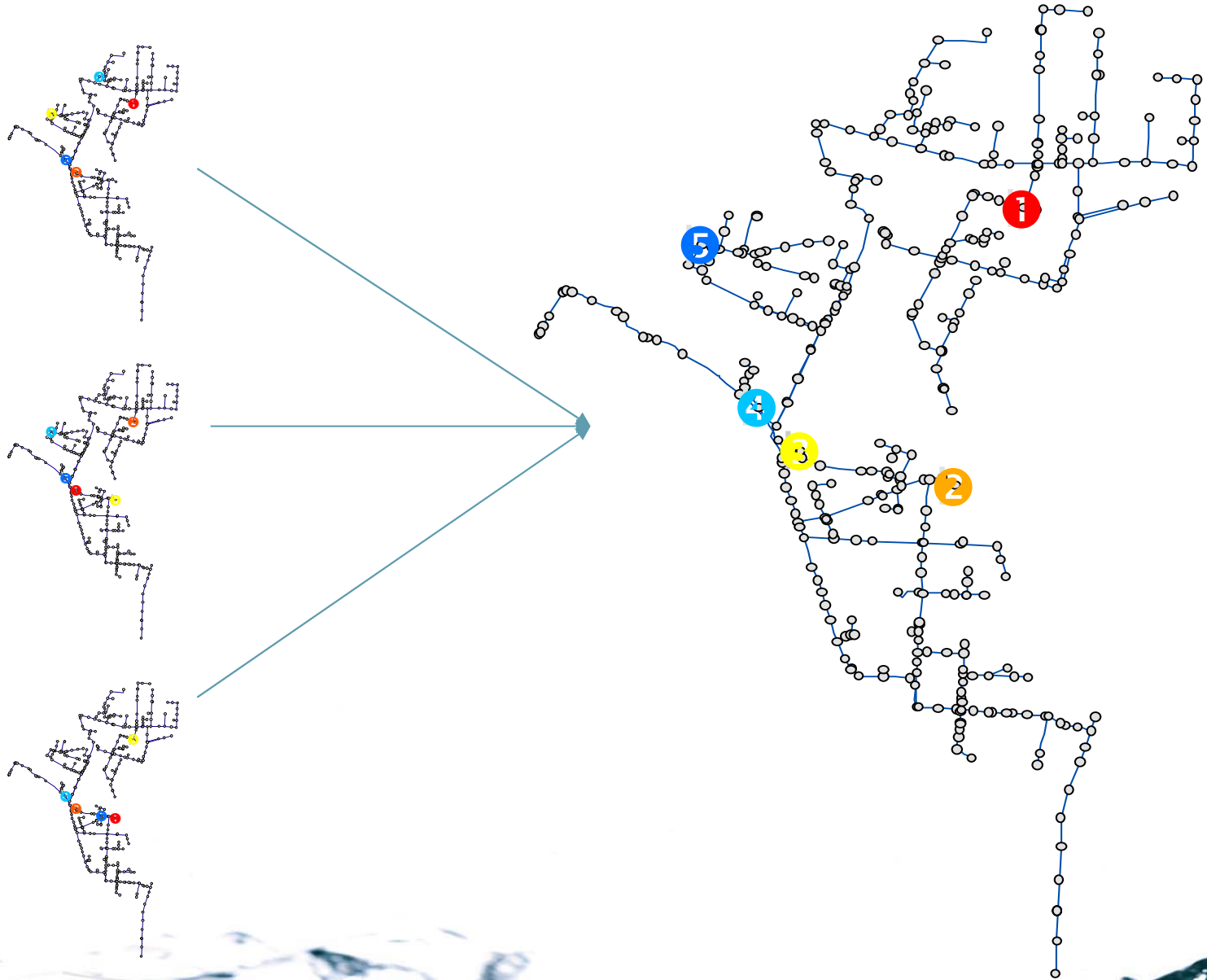
Duration ↗



600 min



Hydraulic failure – Design events



Hydraulic failure – Design events

RP	Reference	5 50		5 10 50		5 10 20 50 100
Durations		60 240	90 240	60 240	90 240	90 240
£ per year	1428076	1401899	1420904	1206171	1216133	1281719
%	100	98.2	99.5	84.5	85.2	89.8

✓ EAD at the catchment scale quite easy to reproduce

Hydraulic failure – Design events

RP	Reference	5 50		5 10 50		5 10 20 50 100
Durations		60 240	90 240	60 240	90 240	90 240
£ per year	1428076	1401899	1420904	1206171	1216133	1281719
%	100	98.2	99.5	84.5	85.2	89.8

✓ EAD at the catchment scale quite easy to reproduce

NodeID	£ per year	%					
		2 RP		3 RP		5 RP	
		60 240	90 240	60 240	90 240	90 240	90 240
NS60649802	474717.63	79	82	82	84	89	
NS60637916	306232.53	0	0	0	0	7	
NS60643003	282697.19	225	225	210	210	213	
NS60641102	89406.83	140	140	107	107	110	
NS59649705	83846.69	143	143	67	67	78	
NS60636902	61582.37	0	0	0	0	6	
NS60655104	39592.2	148	154	70	73	73	

✓ EAD at the node scale more complex to reproduce

Hydraulic failure – Design events

	Duration																			
	30	60	90	120	150	180	210	240	270	300	330	360	390	420	450	480	510	540	570	600
2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
40	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
50	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
60	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
70	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
80	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
90	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
100	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
110	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
120	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
130	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
140	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
160	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
170	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
180	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
190	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
200	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
210	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
220	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
230	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
240	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
250	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
260	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
270	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
280	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
290	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
500	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
750	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1000	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Hydraulic failure – Design events

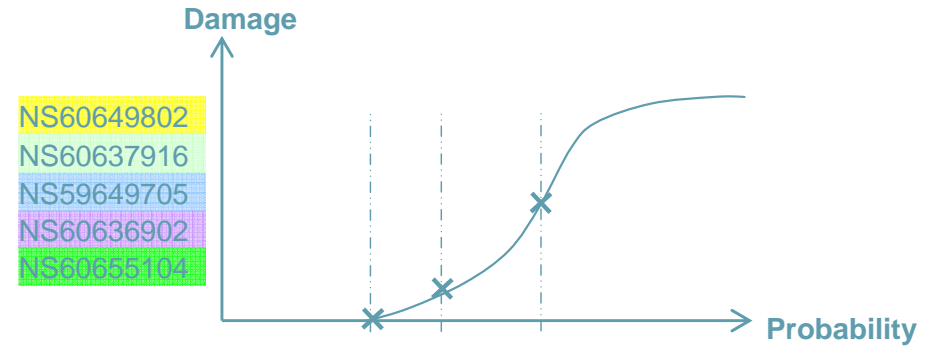
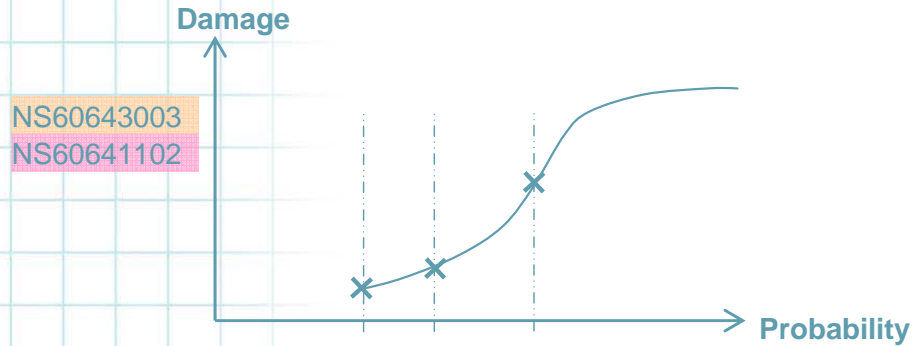
NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902		
Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546
50	270	1066610.55	330	2151805.345	150	4833444.79	150	783330.279	240	1488671.69	480	5370243.3	600	1382639.34
60	240	1083547.627	300	2149947.019	150	4929808.07	150	868662.227	240	1528853.33	480	5370243.3	600	1477930.069
70	210	1071290.73	270	2167385.558	150	4996568.2	240	915028.4	240	1557015.87	600	7065944.731	570	1481626.398
80	210	1088491.075	270	2162842.219	150	5037433.13	270	969367.817	240	1587095.3	600	8415410.527	510	1442449.958
90	180	1071522.917	270	2147297.687	180	5092644.1	300	978651.338	270	1606810.18	600	9093841.418	450	1408058.622
100	180	1063702.827	240	2136028.283	180	5136822.49	360	1012617.418	240	1626801.36	600	9395654.985	420	1396965.778
110	180	1049394.124	240	2141141.349	180	5205024.5	390	1040157.107	240	1641610	600	9619768.661	390	1400966.975
120	150	1051101.856	210	2094353.158	210	5297216.5	420	1048444.405	300	1660620.38	600	10118121.64	360	1358094.24
130	150	1060929.822	210	2105070.184	240	5371805.03	450	1071955.564	270	1674070.91	600	10504008.29	360	1414933.772
140	150	1079335.577	210	2088017.026	240	5421510.64	510	1094431.575	270	1686163.19	600	10685001.9	330	1349061.272
150	150	1057986.205	180	2121974.471	270	5443740.77	480	1107363.396	270	1701804.3	600	10785936.88	330	1419068.05
160	150	1035427.001	180	2089464.251	270	5494868.58	540	1112728.297	300	1715041.33	600	10851025.24	330	1447982.989
170	120	1030011.536	180	2017285.013	270	5516206.75	600	1126453.413	300	1726536.47	600	10900230.69	300	1385598.406
180	120	1037054.546	180	2020231.268	300	5557479.19	600	1148777.733	300	1739143.75	600	10927991.14	300	1449342.737
190	120	1037243.244	150	2036024.889	300	5597183.61	570	1157635.161	300	1749439.01	600	10946770.35	270	1362403.006
200	120	1049007.324	150	2050948.099	300	5625818.1	600	1161036.711	300	1758087.07	600	10955727.06	270	1406658.505
210	120	1057834.737	150	2063807.041	300	5637189.94	600	1152471.19	300	1764532.91	600	10967536.97	270	1427310.403
220	120	1057433.178	150	2066032.935	300	5660201.77	600	1163931.06	300	1774089.12	600	10971903.87	270	1447136.573
230	120	1050574.141	150	1996239.413	330	5684155.46	570	1156103.75	300	1781502.55	600	11046482.2	270	1445163.544
240	120	1042642.63	120	1929022.21	330	5715074.37	600	1168830.13	300	1789378.81	600	11065197.49	240	1388919.33
250	120	1035206.149	120	1937684.962	360	5731621.03	600	1171222.55	300	1796373.14	600	11076855.23	240	1411617.09
260	90	1028195.202	120	1947568.79	360	5766171.09	570	1164696.77	390	1803558.68	600	11090870.27	240	1454872.19
270	90	1034708.957	120	1951541.969	360	5796210.43	600	1175653.55	390	1809594.94	600	11095223.42	240	1468310.934
280	90	1038207.135	120	1960680.492	360	5812152.23	570	1154002.42	300	1815840.76	600	11108493.39	240	1479949.956
290	90	1046797.962	120	1968697.722	390	5843726.24	600	1169387.11	390	1823733.51	600	11108508.81	240	1456777.249
300	90	1055447.761	120	1969319.187	390	5876019.97	600	1165544.52	390	1830200.26	600	11118153.48	210	1364240.015
500	90	1124131.936	90	1829521.184	510	6127205.09	570	1111457.3	510	1935198.01	480	11104801.18	180	1442895.326
750	90	1096121.178	90	1679559.144	600	6281311.05	600	1070832.48	600	2018550.693	390	11002448.85	150	1442308.812
1000	60	1142504.763	60	1663186.523	600	6302453.6	570	1023552.4	600	2071612.562	600	11392009.2	120	1388312.488

Hydraulic failure – Design events

RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546

Hydraulic failure – Design events

RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546



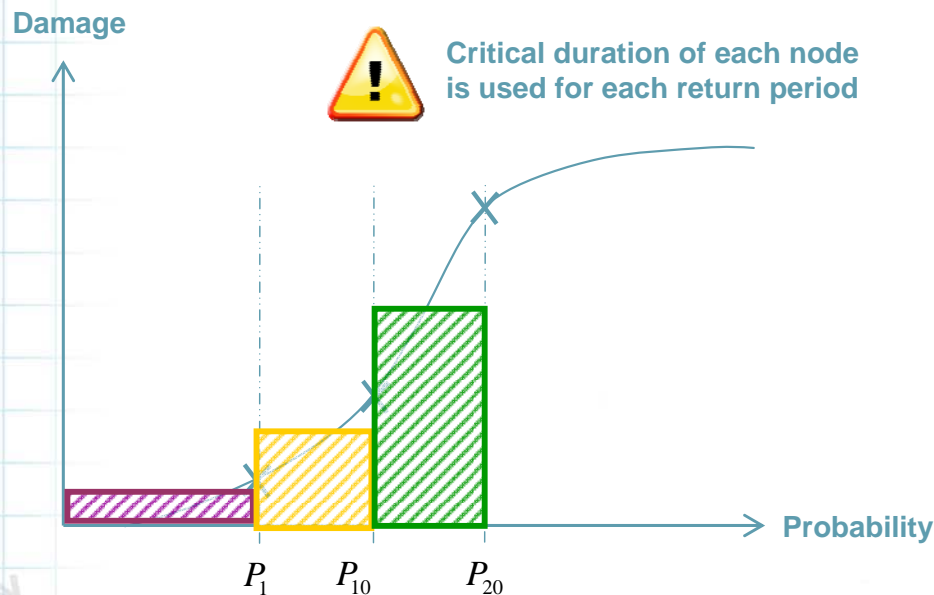
Design storm - Hydraulic failure

$EPY \times RP_i = \text{Total number of events in } RP_i \text{ period}$

$\frac{1}{EPY \times RP_i} = \text{Probability of exceedance of each event in } RP_i \text{ period}$

$1 - \frac{1}{EPY \times RP_i} = \text{Probability of NON-exceedance of EACH event in } RP_i \text{ period}$

$\left(1 - \frac{1}{EPY \times RP_i}\right)^{EPY} = \text{Probability of NON-exceedance per year in } RP_i \text{ period}$



$$\text{[Purple bar]} = D_1 \times P_1$$

+

$$\text{[Yellow bar]} = \frac{D_1 + D_{10}}{2} \times (P_{10} - P_1)$$

+

$$\text{[Green bar]} = \frac{D_{10} + D_{20}}{2} \times (P_{20} - P_{10})$$

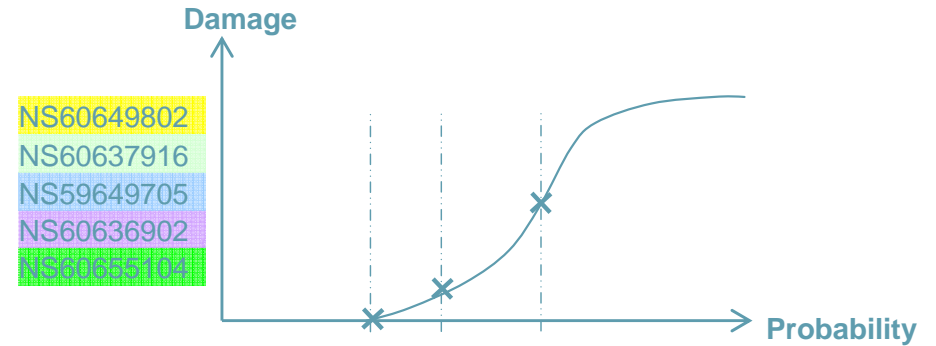
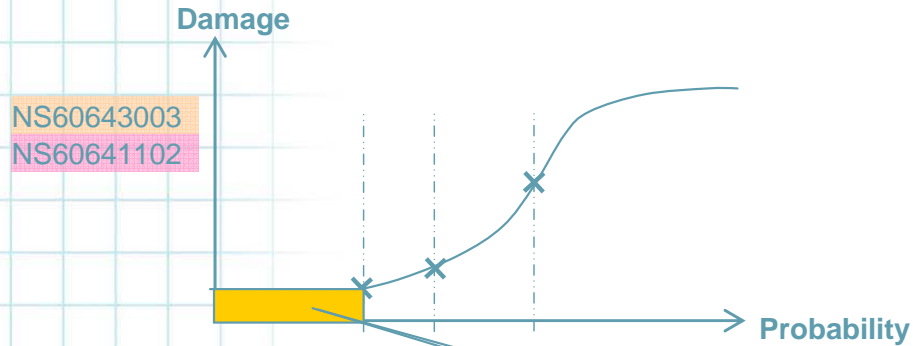
⋮

$$\text{[Ellipsis bar]} = \frac{D_{RP_{i-1}} + D_{RP_i}}{2} \times (P_{RP_i} - P_{RP_{i-1}})$$

$$EAD = D_1 \times P_1 + \sum_i \frac{D_{RP_{i-1}} + D_{RP_i}}{2} \times (P_{RP_i} - P_{RP_{i-1}})$$

Hydraulic failure – Design events

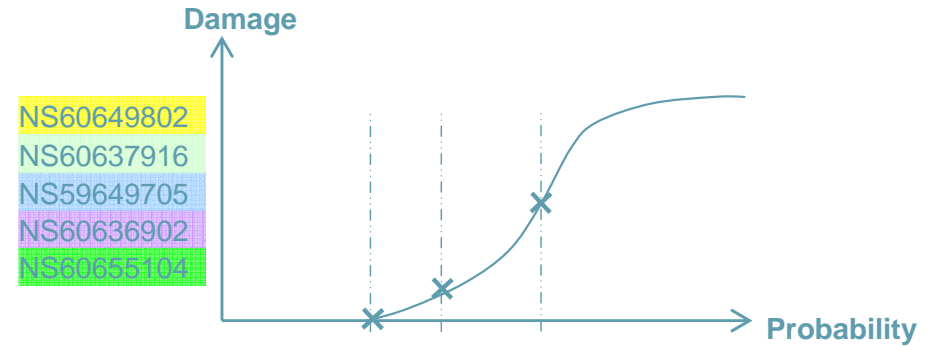
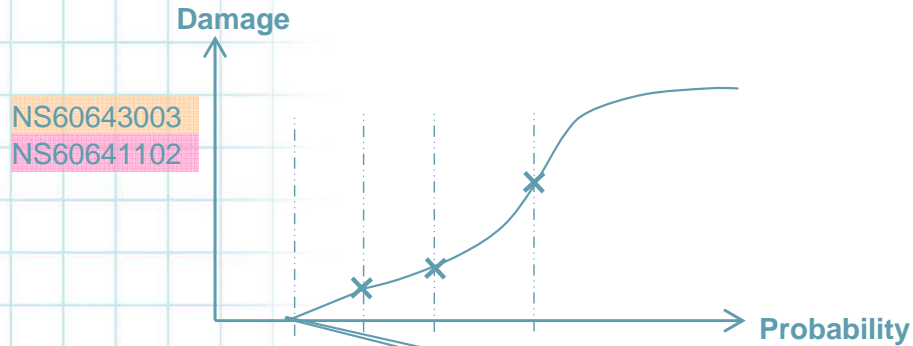
RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546



NodeID	£ per year	%					
		2 RP		3 RP		5 RP	
		60	240	60	240	90	240
NS60649802	474717.63	79	82	82	84	89	
NS60637916	306232.53	0	0	0	0	7	
NS60643003	282697.19	225	225	210	210	213	
NS60641102	89406.83	140	140	107	107	110	
NS59649705	83846.69	143	143	67	67	78	
NS60636902	61582.37	0	0	0	0	6	
NS60655104	39592.2	148	154	70	73	73	

Hydraulic failure – Design events

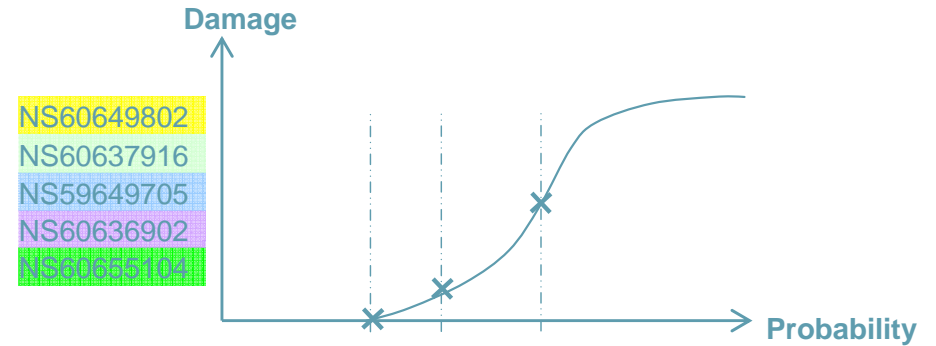
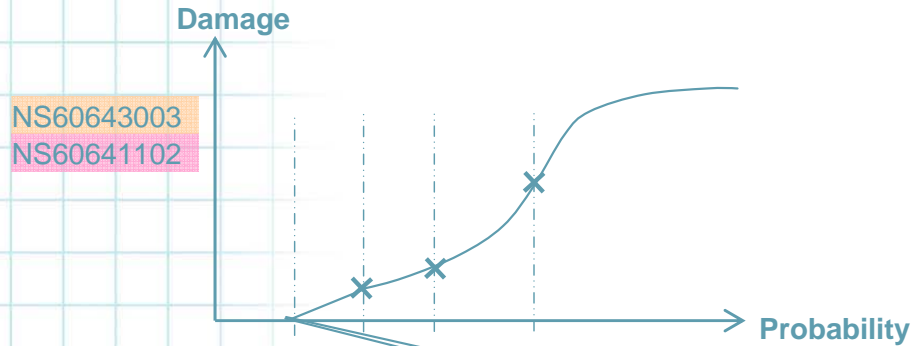
RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546



NodeID	£ per year	2 Year Return Period Added					
		2 RP		3 RP		5 RP	6 RP
		60 240	90 240	60 240	90 240	90 240	90 240
NS60649802	474717.63	79	82	82	84	89	89
NS60637916	306232.53	0	0	0	0	7	7
NS60643003	282697.19	225	225	210	210	213	76
NS60641102	89406.83	140	140	107	107	110	75
NS59649705	83846.69	143	143	67	67	78	78
NS60636902	61582.37	0	0	0	0	6	6
NS60655104	39592.2	148	154	70	73	73	73

Hydraulic failure – Design events

RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546

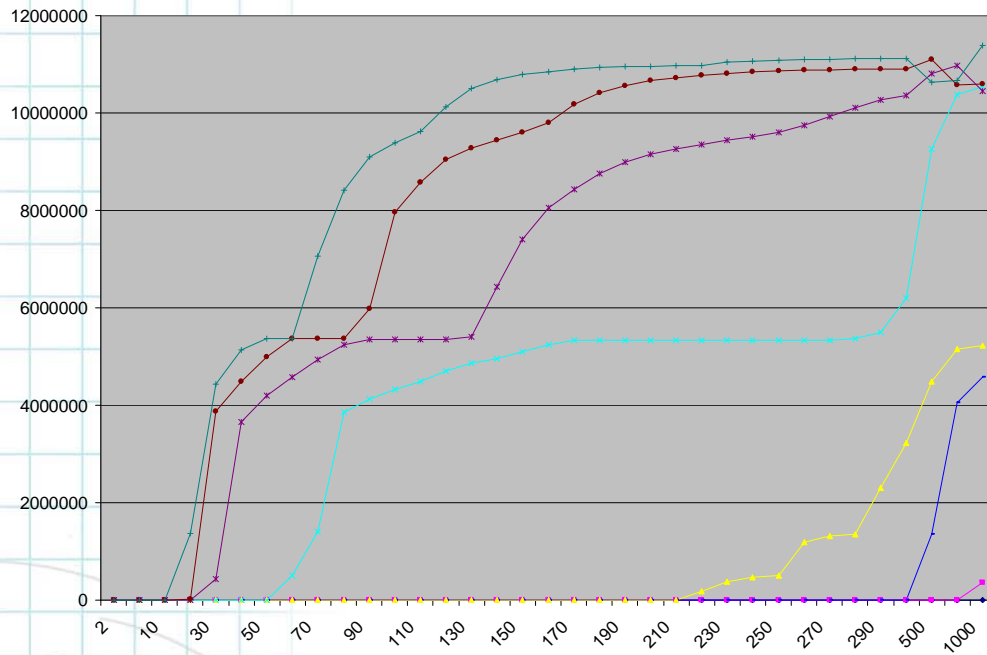


NodeID	£ per year	2 Year Return Period Added					
		2 RP		3 RP		5 RP	6 RP
		60 240	90 240	60 240	90 240	90 240	90 240
NS60649802	474717.63	79	82	82	84	89	89
NS60637916	306232.53	0	0	0	0	7	7
NS60643003	282697.19	225	225	210	210	213	76
NS60641102	89406.83	140	140	107	107	110	75
NS59649705	83846.69	143	143	67	67	78	78
NS60636902	61582.37	0	0	0	0	6	6
NS60655104	39592.2	148	154	70	73	73	73

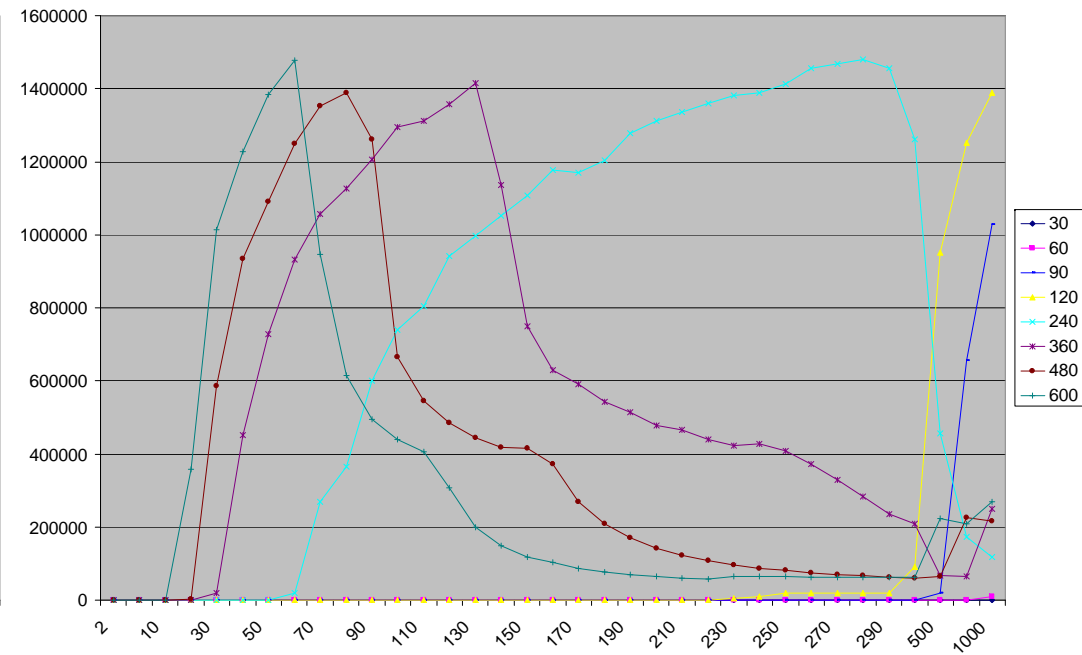
Hydraulic failure – Design events

RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546

NS60637916



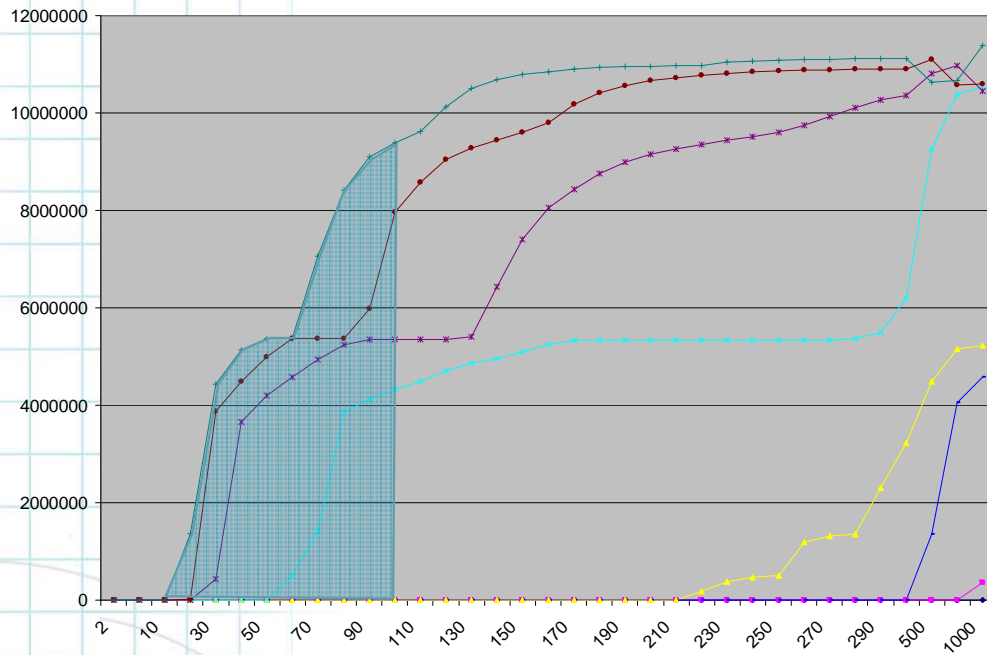
NS60636902



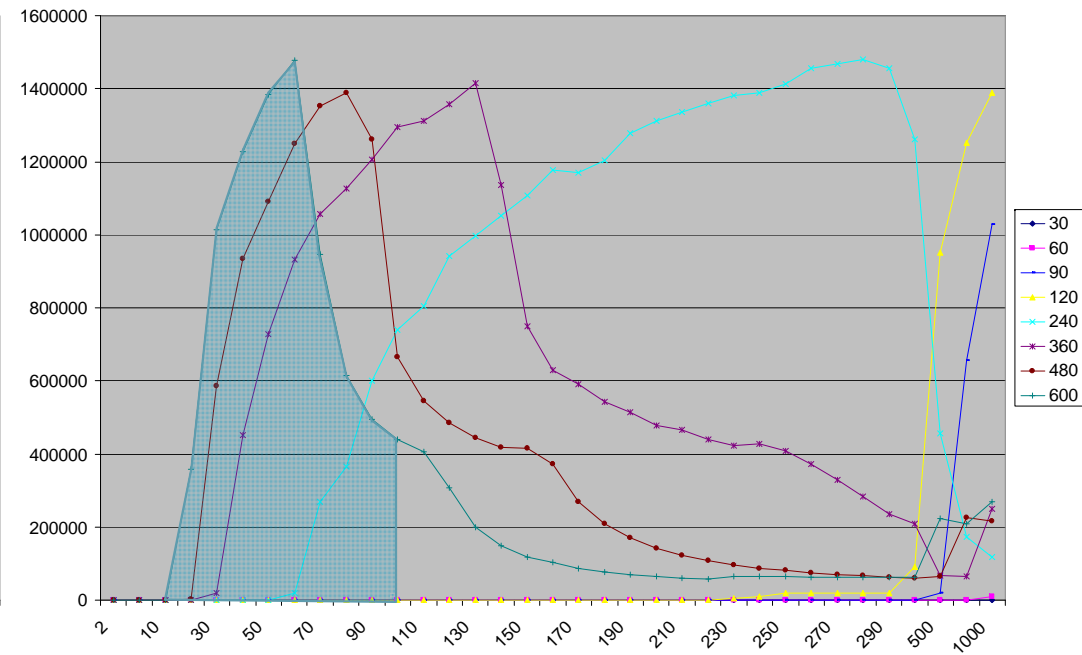
Hydraulic failure – Design events

RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546

NS60637916



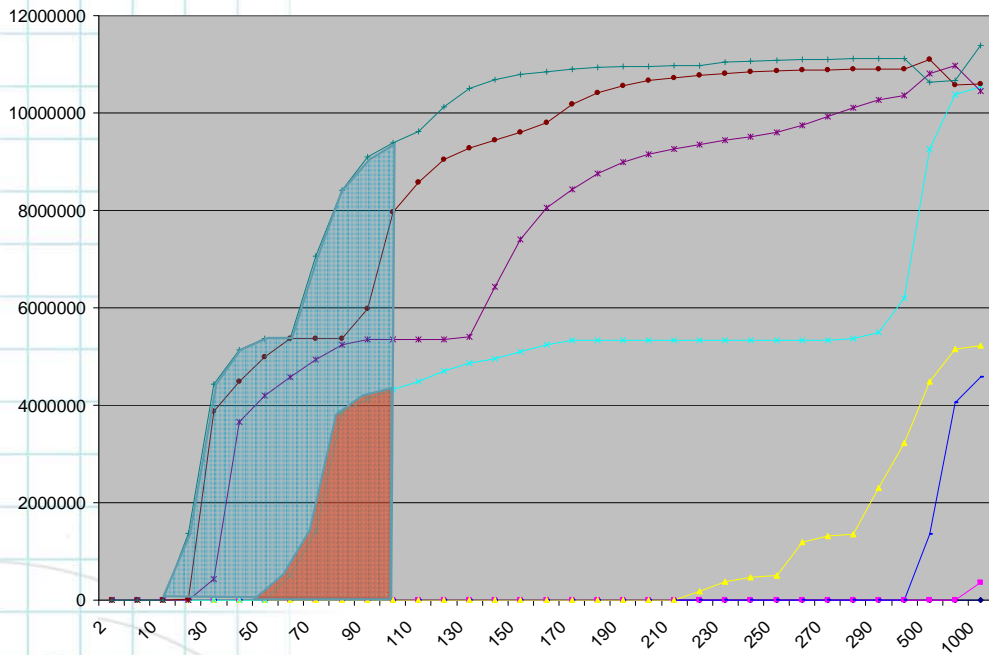
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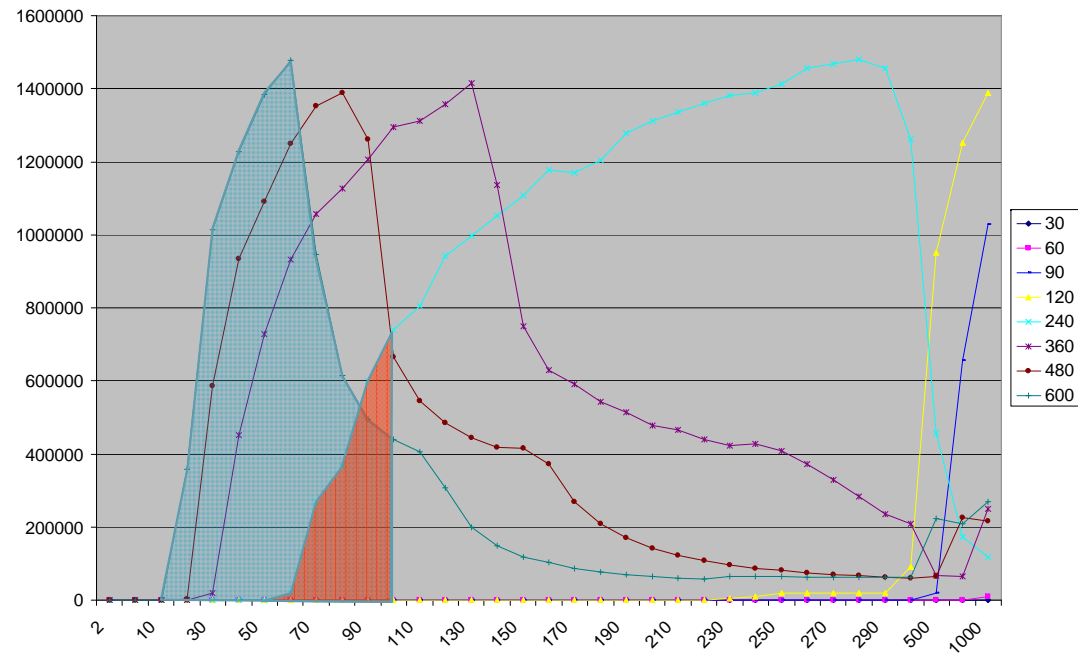
Hydraulic failure – Design events

RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546

NS60637916



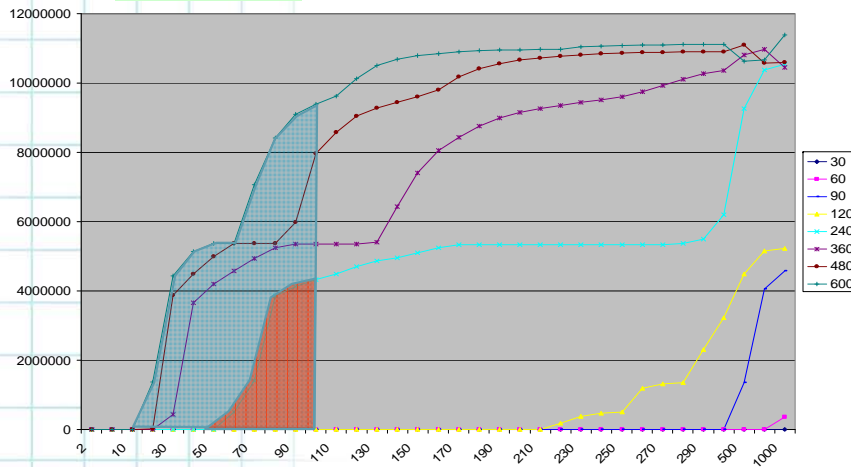
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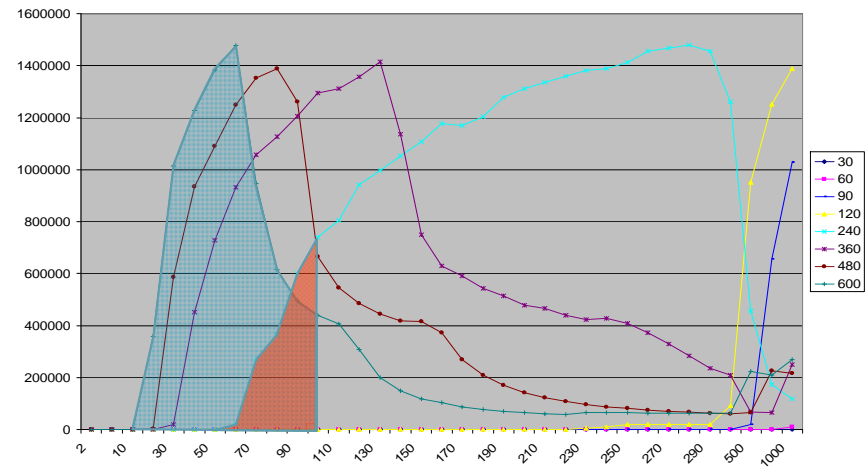
Hydraulic failure – Design events

RP	NS60641102		NS60643003		NS60649802		NS60655104		NS59649705		NS60637916		NS60636902	
	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage	Duration	Damage
2	30	0	30	0	30	0	30	0	30	0	30	0	30	0
5	240	44011.878	270	564562	30	0	30	0	30	0	30	0	30	0
10	300	232880.079	600	781611.628	90	2674795.97	120	3655.972	30	0	30	0	30	0
20	450	822489.205	600	1991267.916	90	3354292.81	90	245060.974	240	759083.87	600	1367003.1	600	358581.693
30	390	1009308.733	450	2146631.41	90	4255681.79	150	545128.955	240	1342280.849	600	4438800.7	600	1012664.779
40	330	1050874.827	480	2156960.295	90	4641699.09	150	684131.856	240	1420744.02	600	5138525.3	600	1228806.546

NS60637916



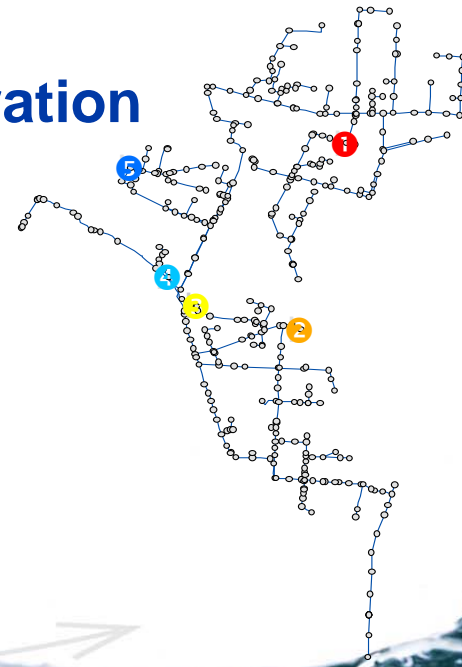
NS60636902



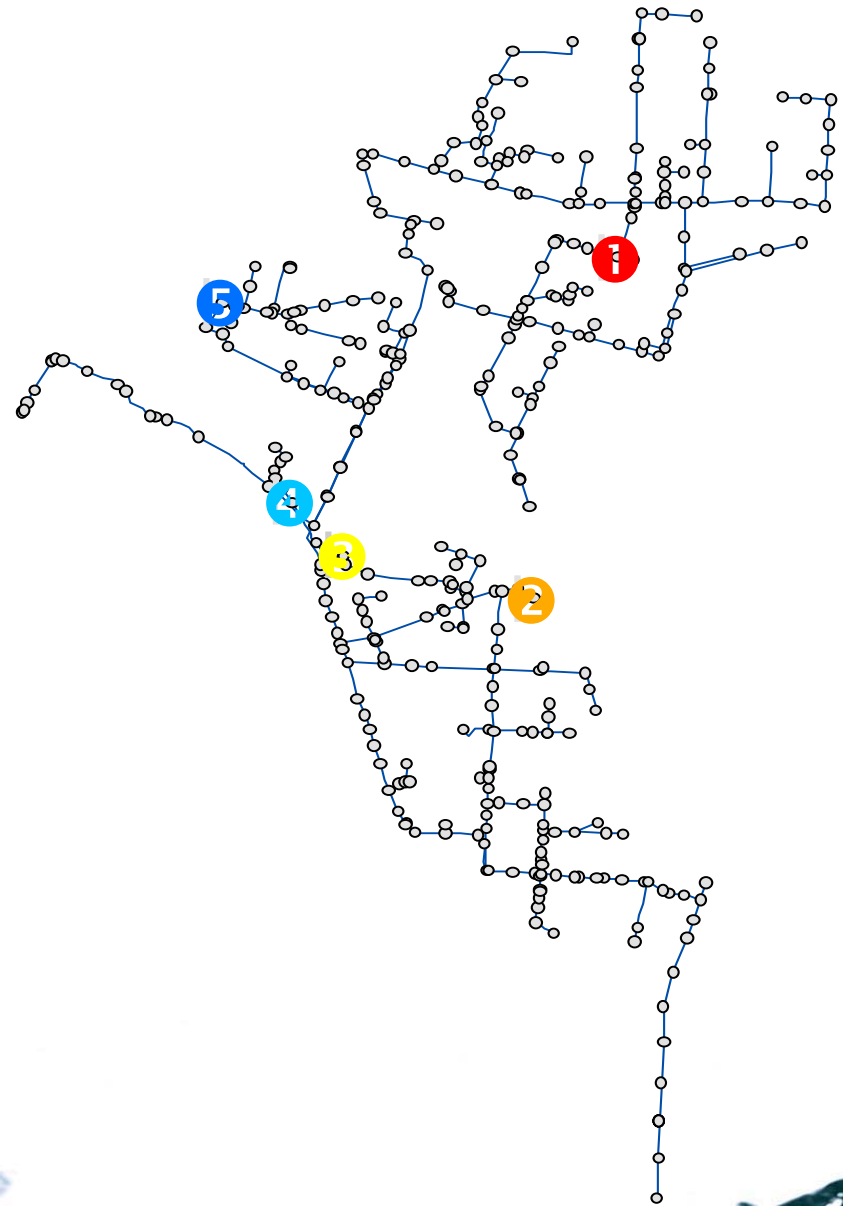
nodeID	£ per year	%								
		2 RP		3 RP		5 RP	6 RP	6 RP		
		60 240	90 240	60 240	90 240	90 240	90 240	90 240	600	
NS60649802	474717.63	79	82	82	84	89			89	89
NS60637916	306232.53	0	0	0	0	7		7	66	
NS60643003	282697.19	225	225	210	210	213		76	90	
NS60641102	89406.83	140	140	107	107	110		75	80	
NS59649705	83846.69	143	143	67	67	78		78	78	
NS60636902	61582.37	0	0	0	0	6		6	71	
NS60655104	39592.2	148	154	70	73	73		73	73	

In order to reduce the number of RP/Duration required to study EAD for set of selected nodes you have to :

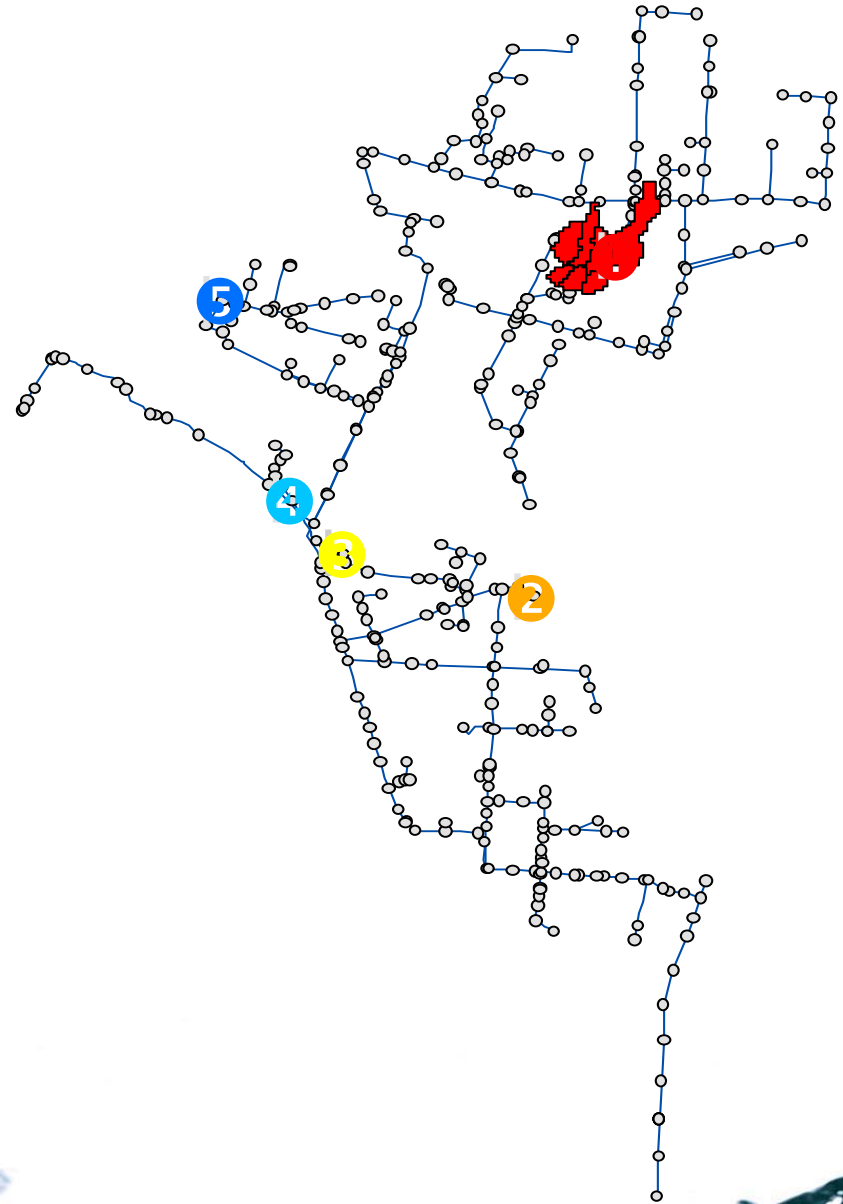
- **Found the threshold of flooding for each manhole**
- **Make sure of capturing the critical duration**



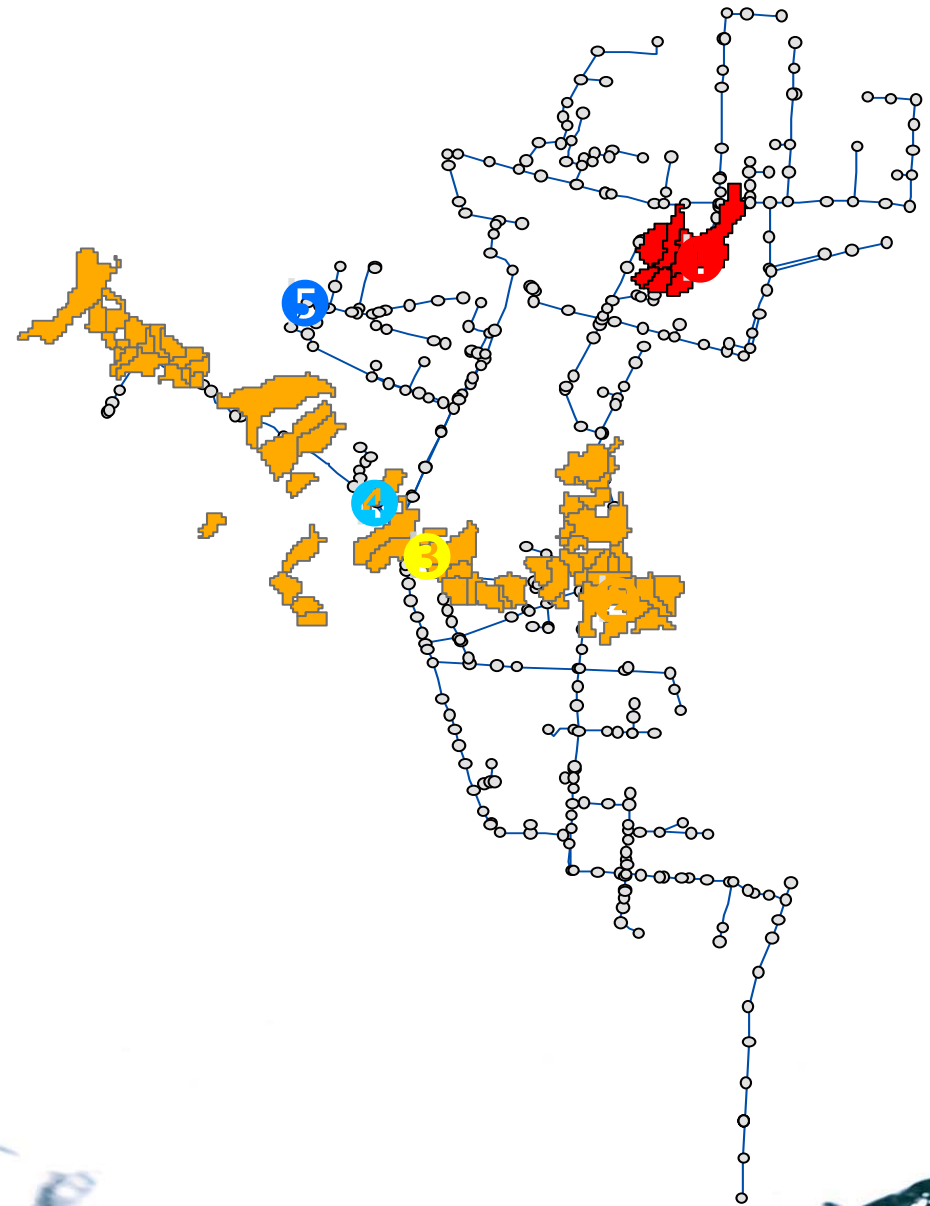
Hydraulic failure – Design events



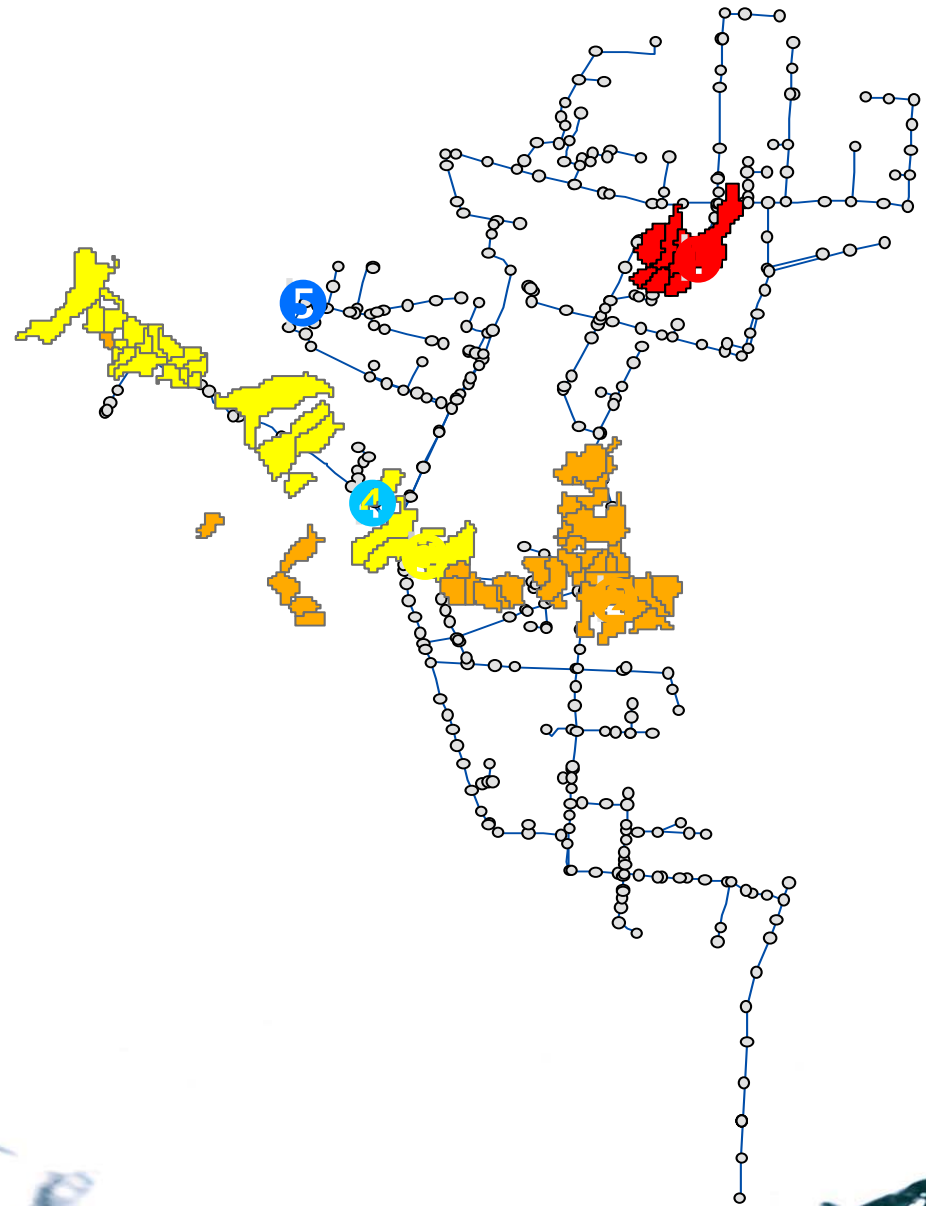
Hydraulic failure – Design events



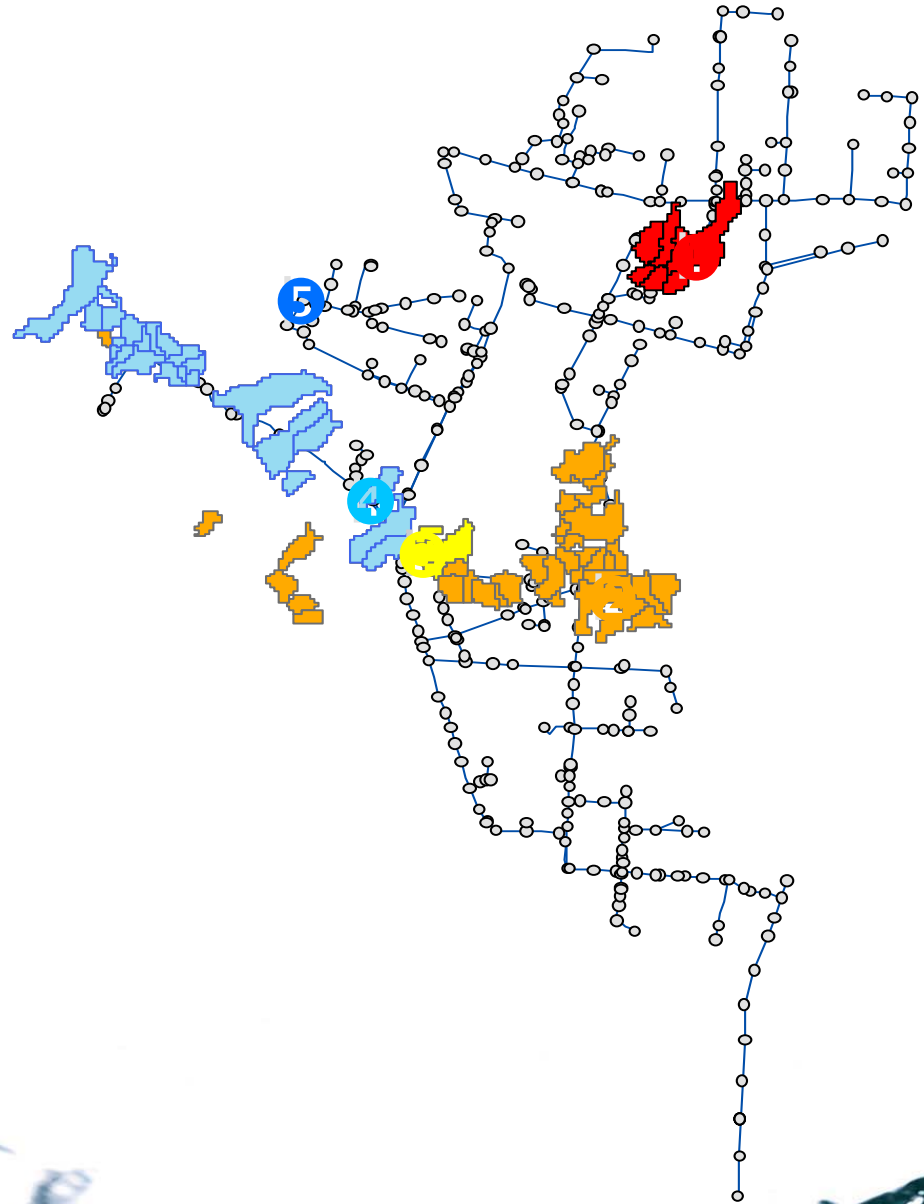
Hydraulic failure – Design events



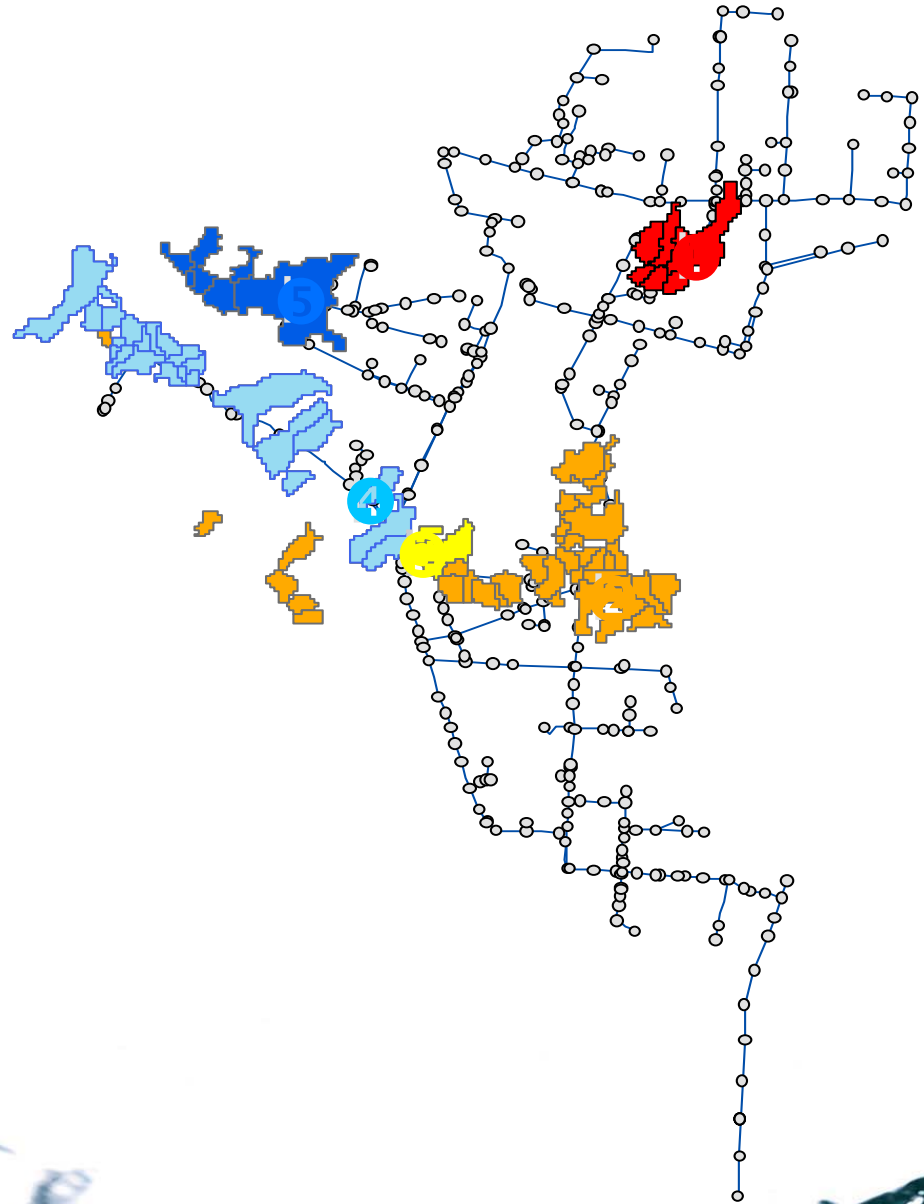
Hydraulic failure – Design events



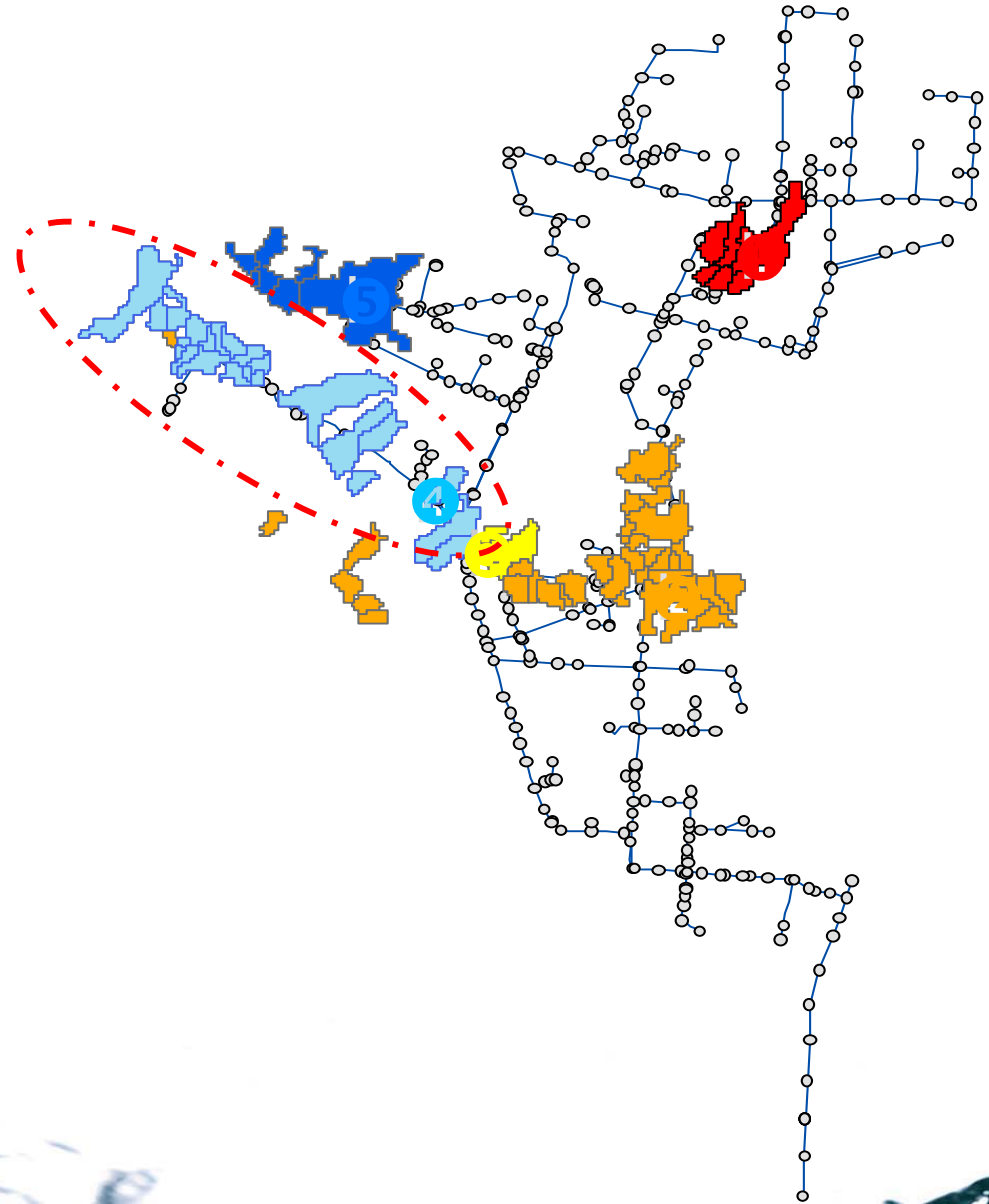
Hydraulic failure – Design events



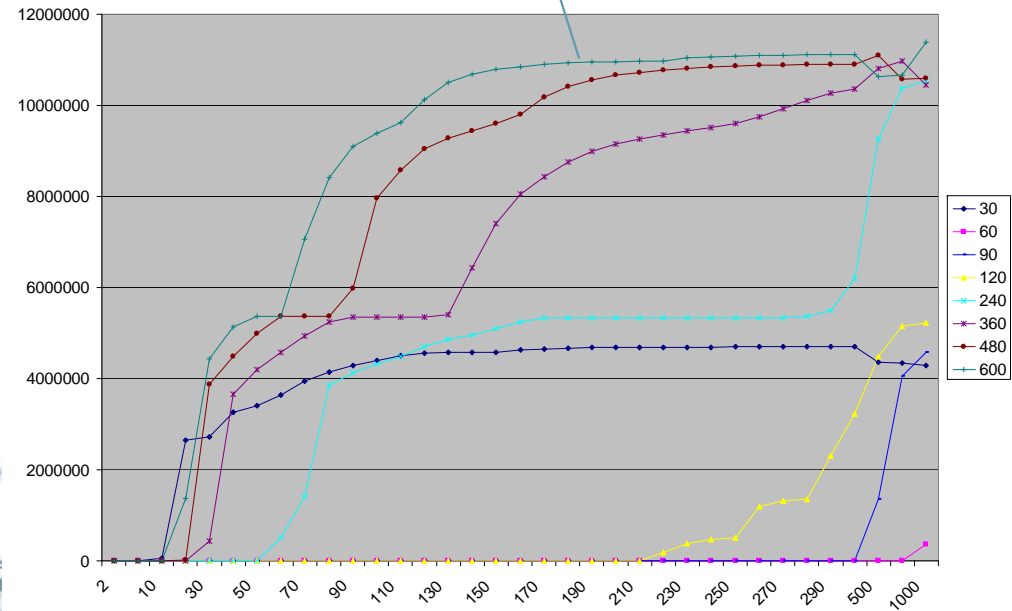
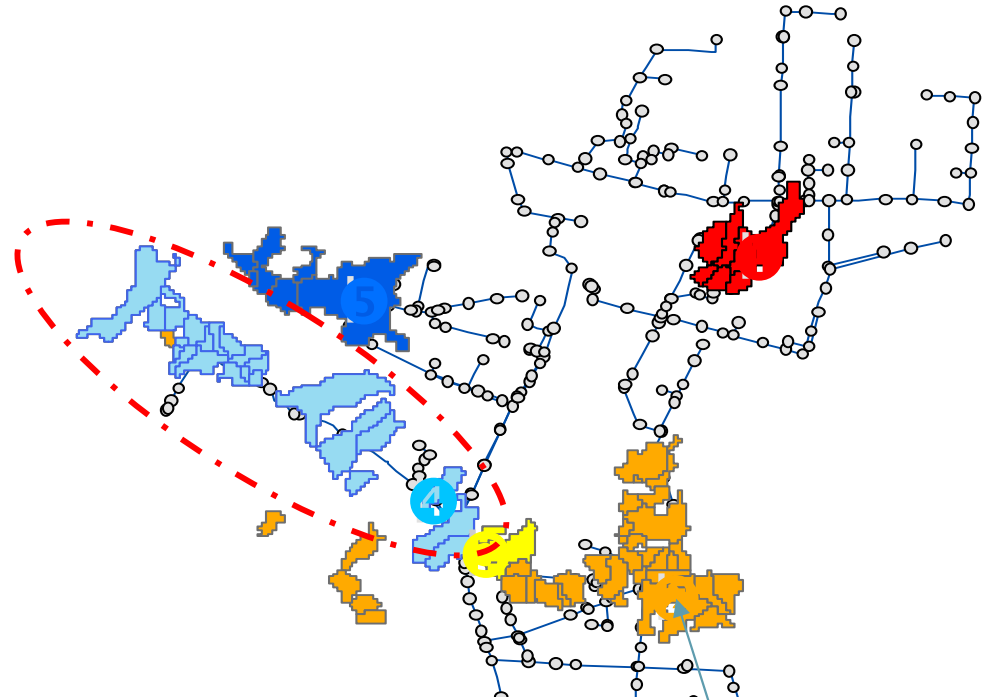
Hydraulic failure – Design events



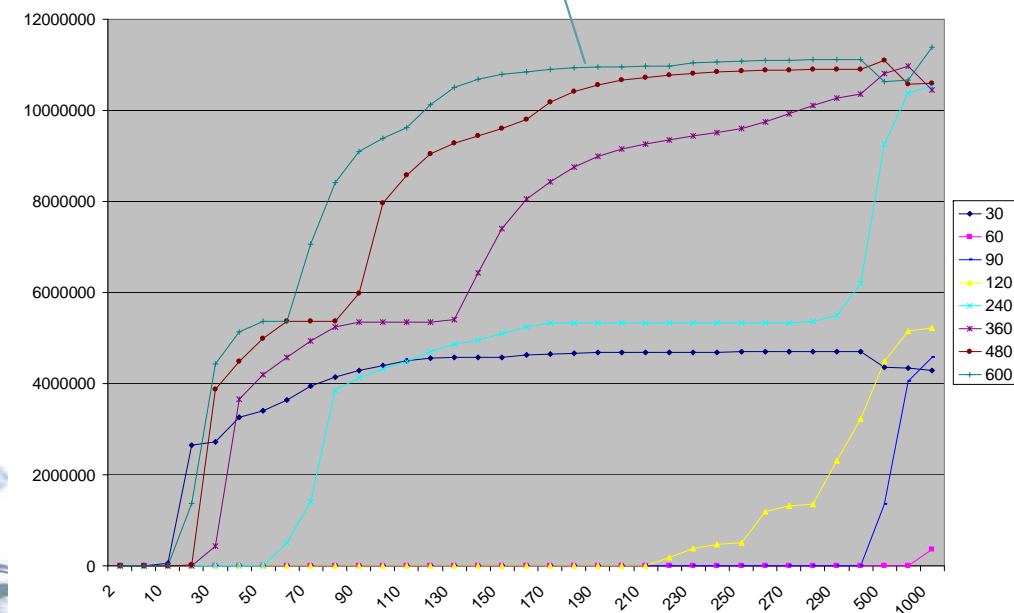
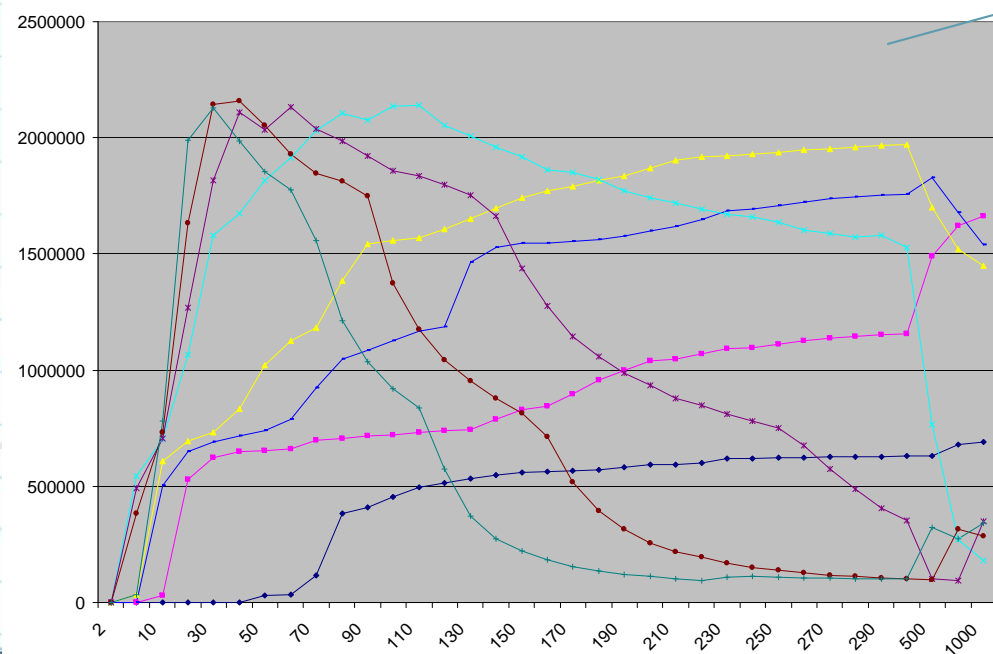
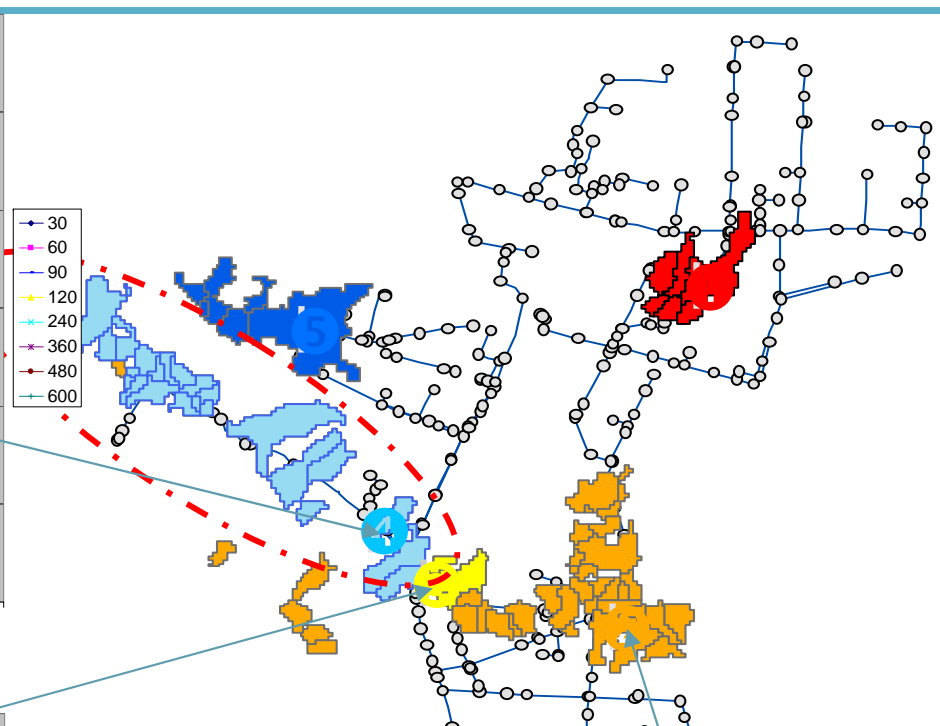
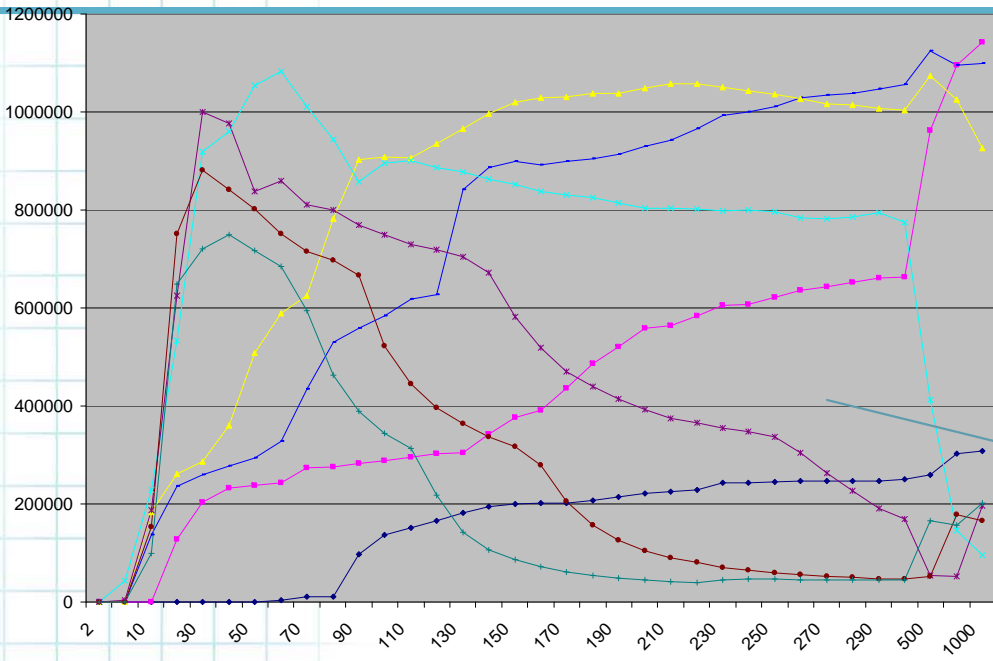
Hydraulic failure – Design events



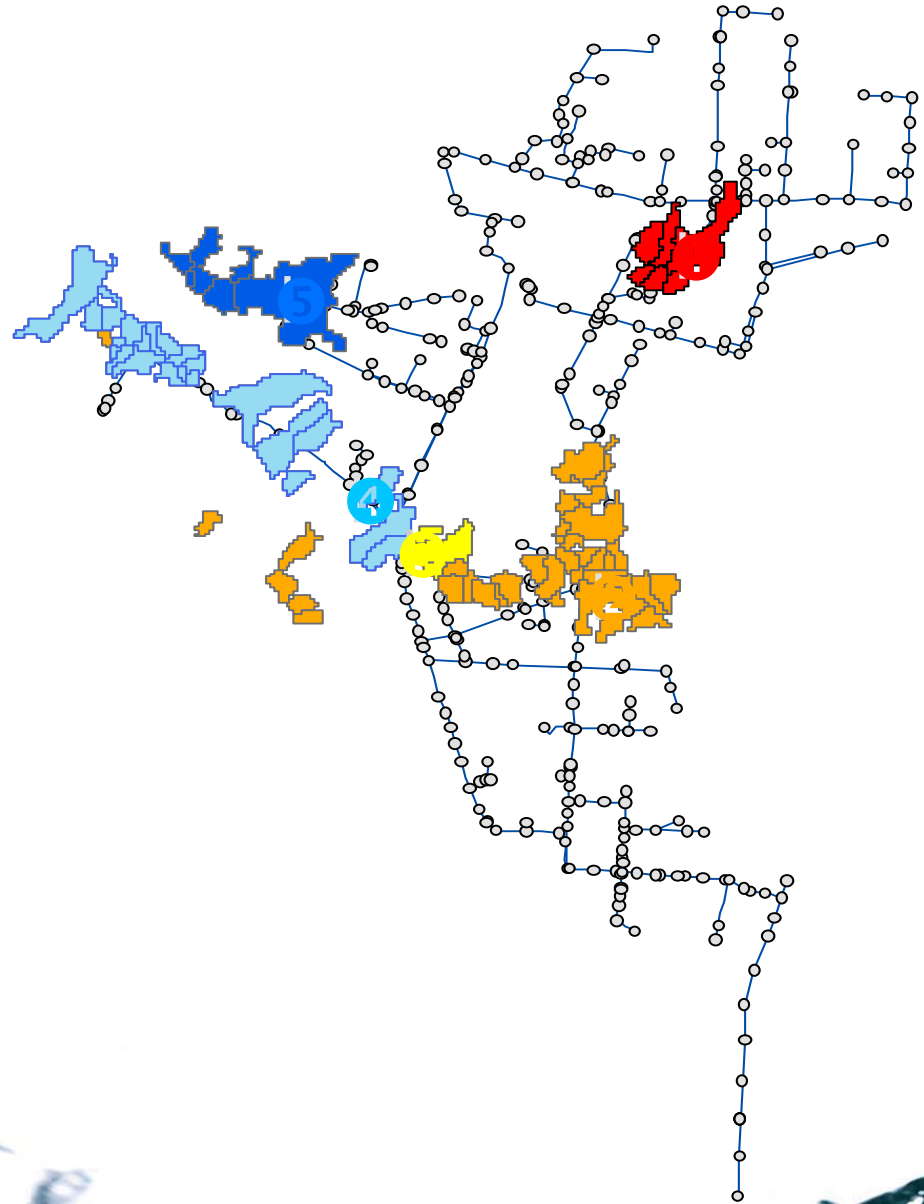
Hydraulic failure – Design events



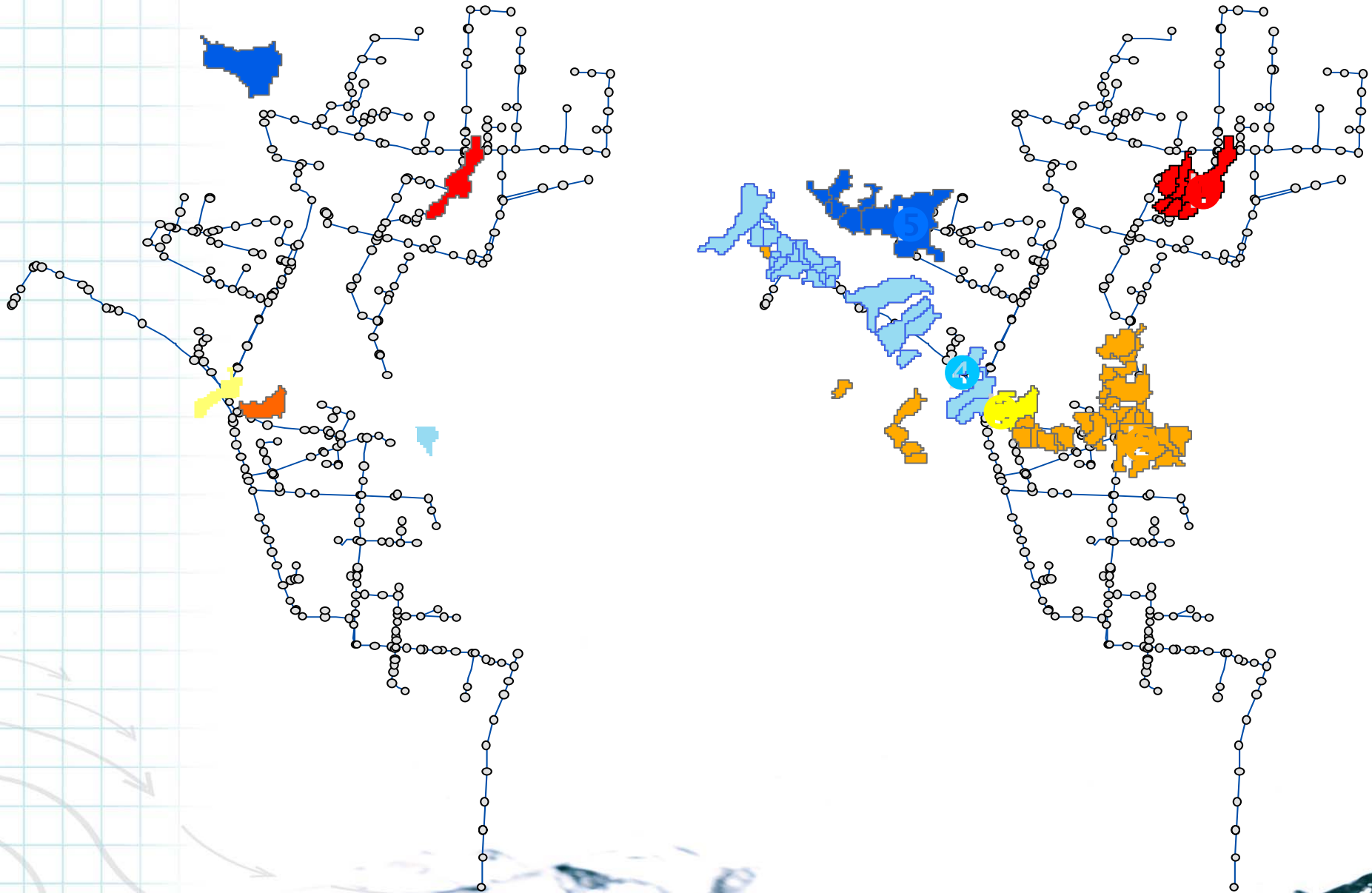
Hydraulic failure – Design events



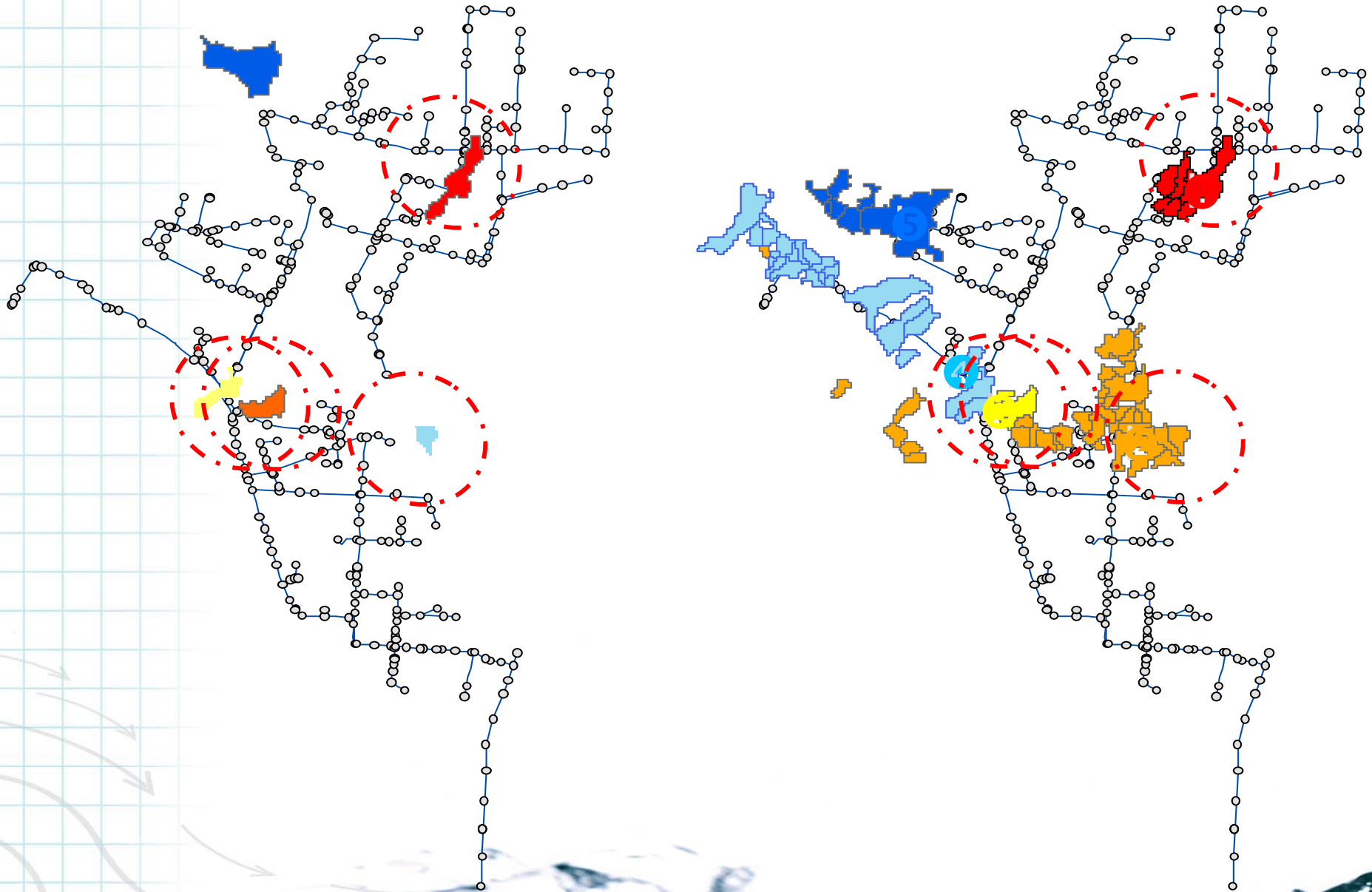
Hydraulic failure – Design events



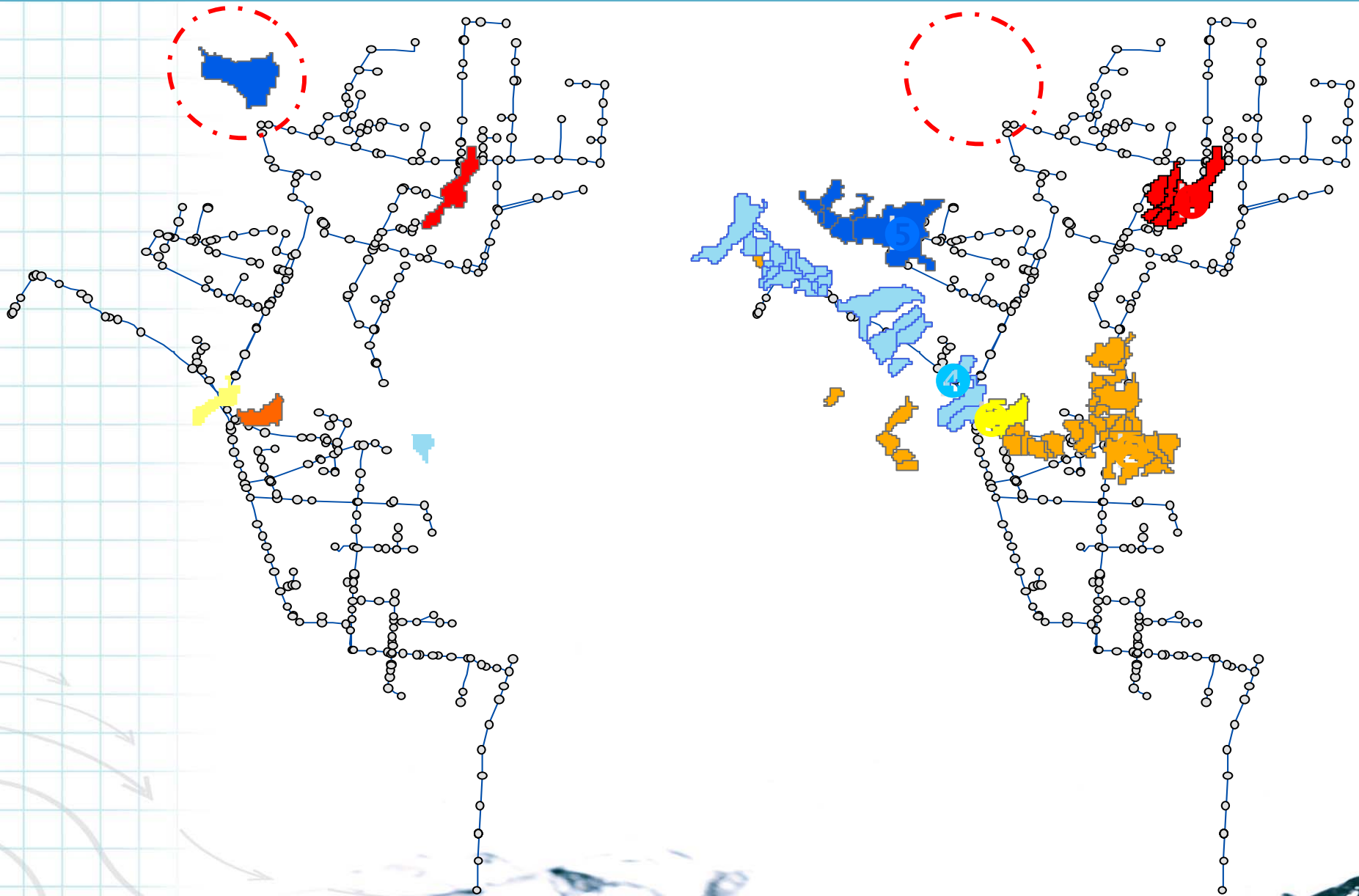
Hydraulic failure – Design events



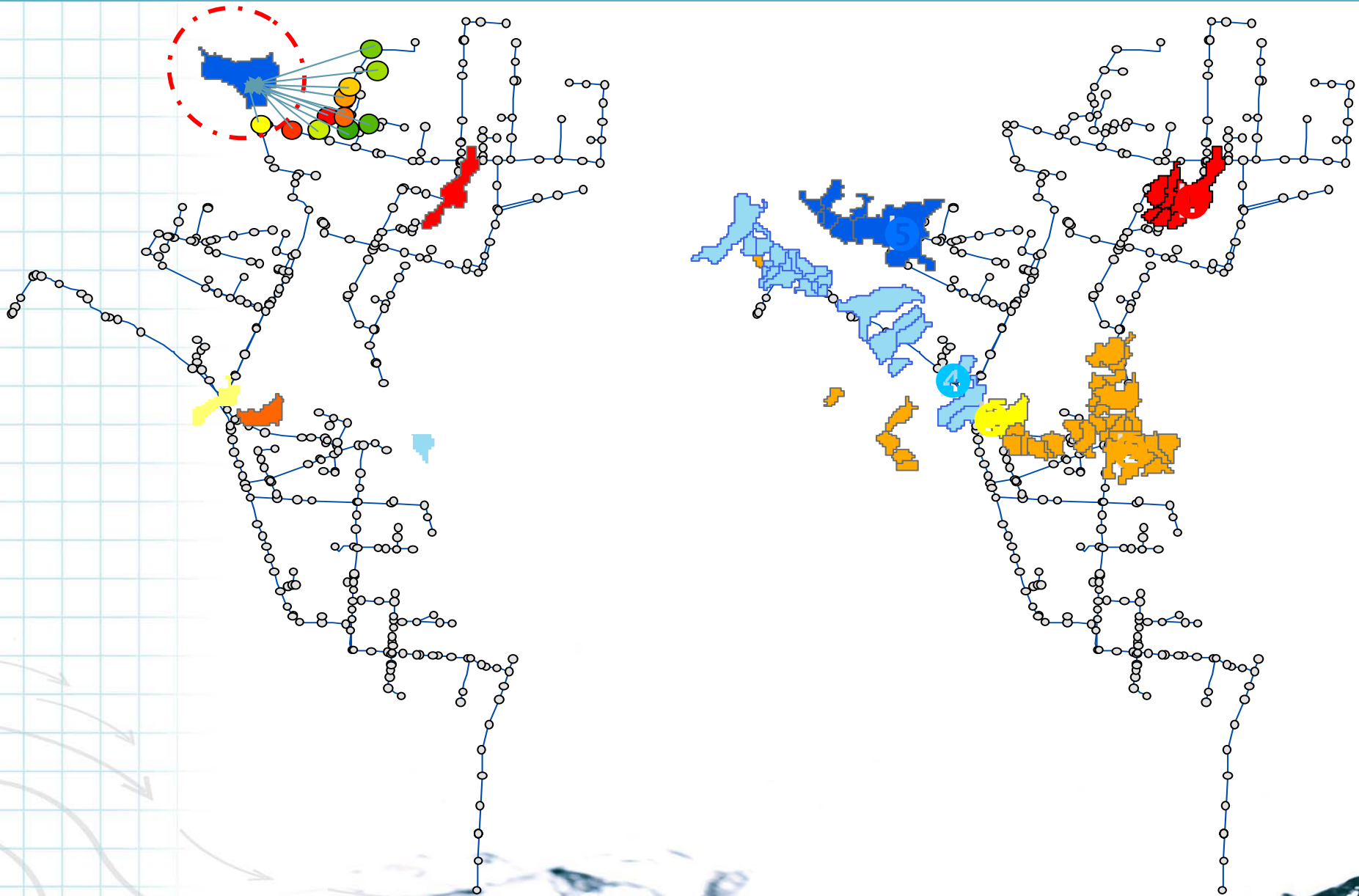
Hydraulic failure – Design events



Hydraulic failure – Design events



Hydraulic failure – Design events

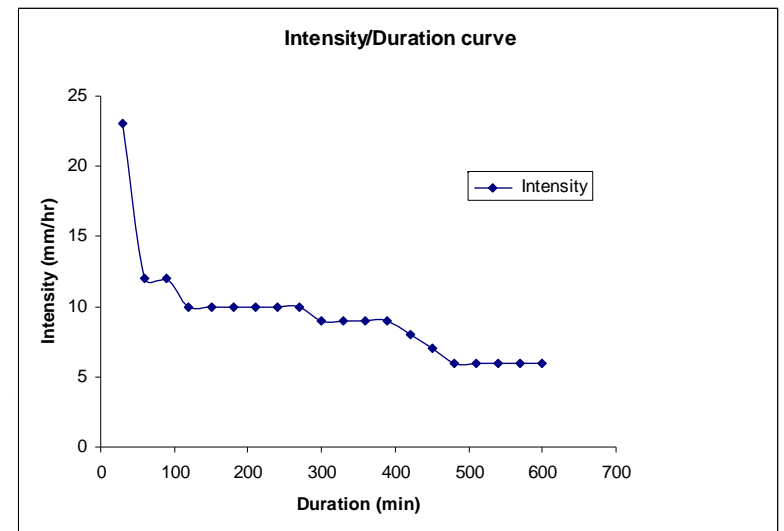


Hydraulic failure - Time series Rainfall

	2001-2071
Events	14286

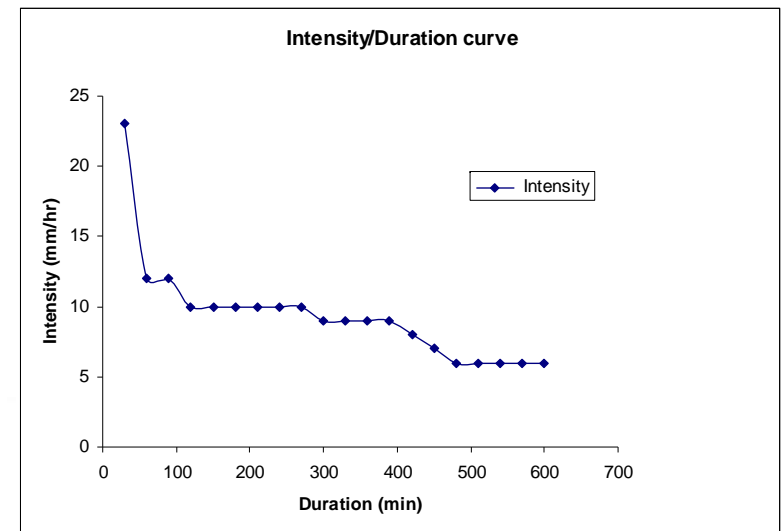
Hydraulic failure - Time series Rainfall

	2001-2071
Events	14286

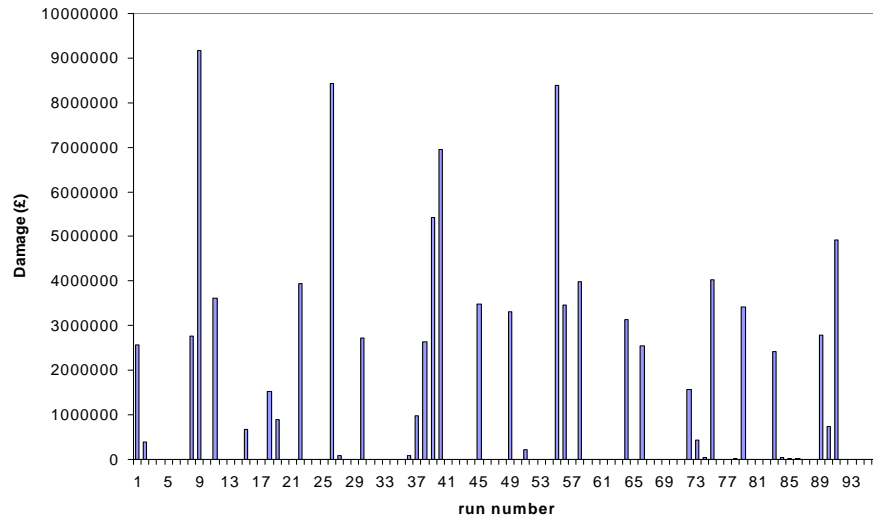


Hydraulic failure - Time series Rainfall

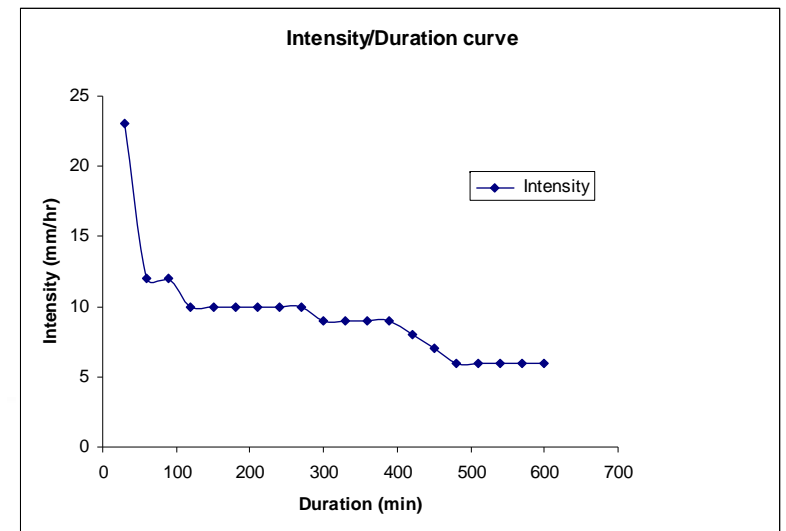
	2001-2071
Events	14286
Frequents	14189
Extremes	97



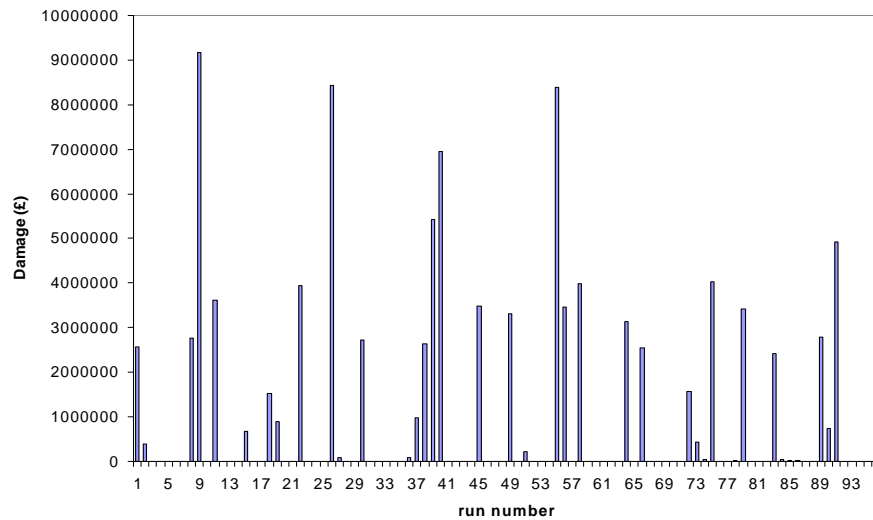
Hydraulic failure - Time series Rainfall



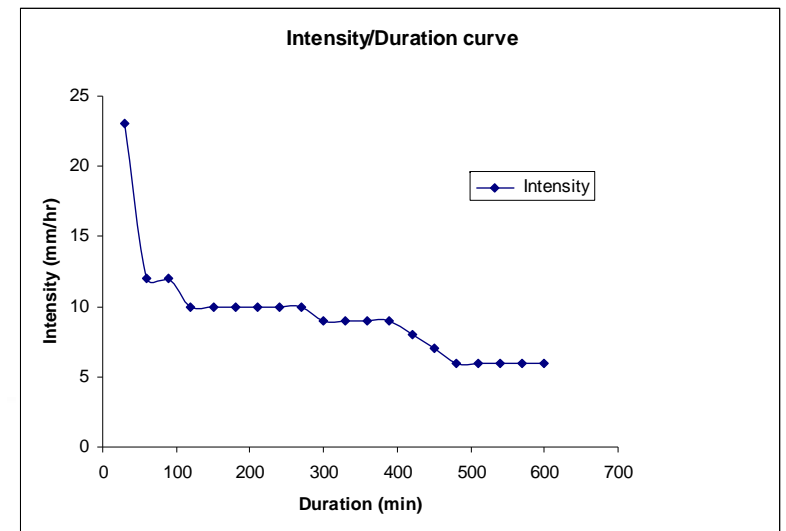
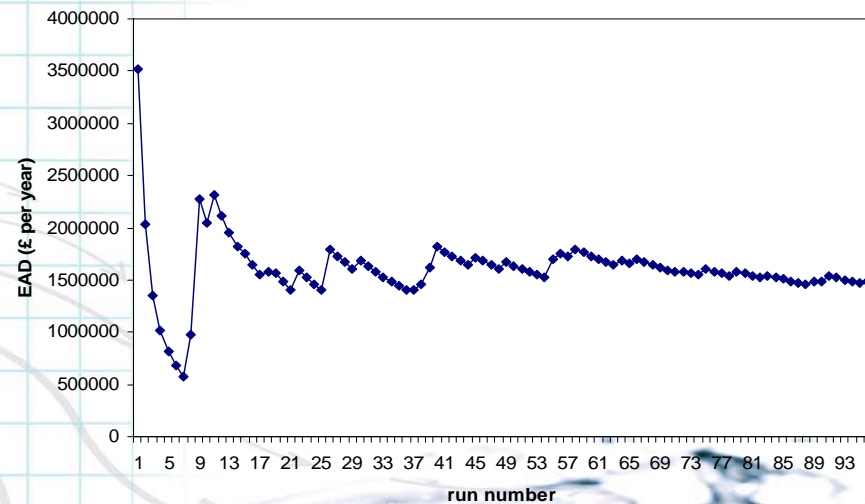
2001-2071	
Events	14286
Frequents	14189
Extremes	97
Flood events	41



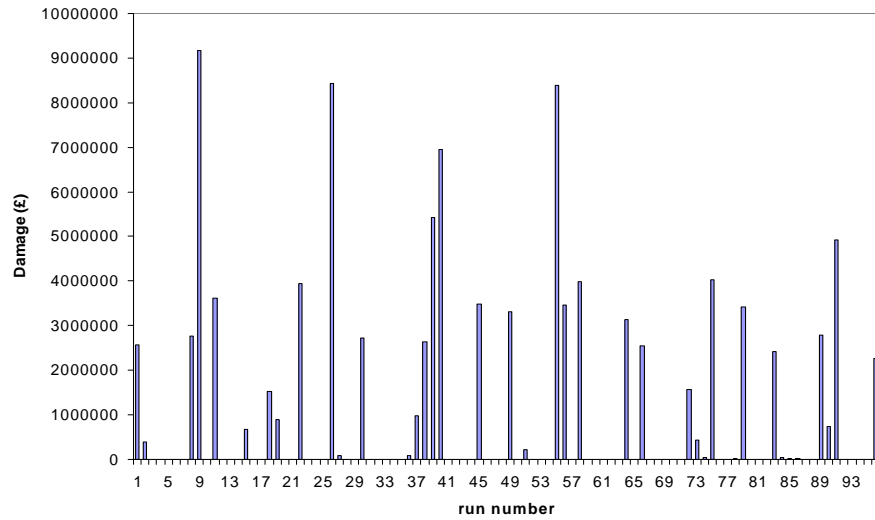
Hydraulic failure - Time series Rainfall



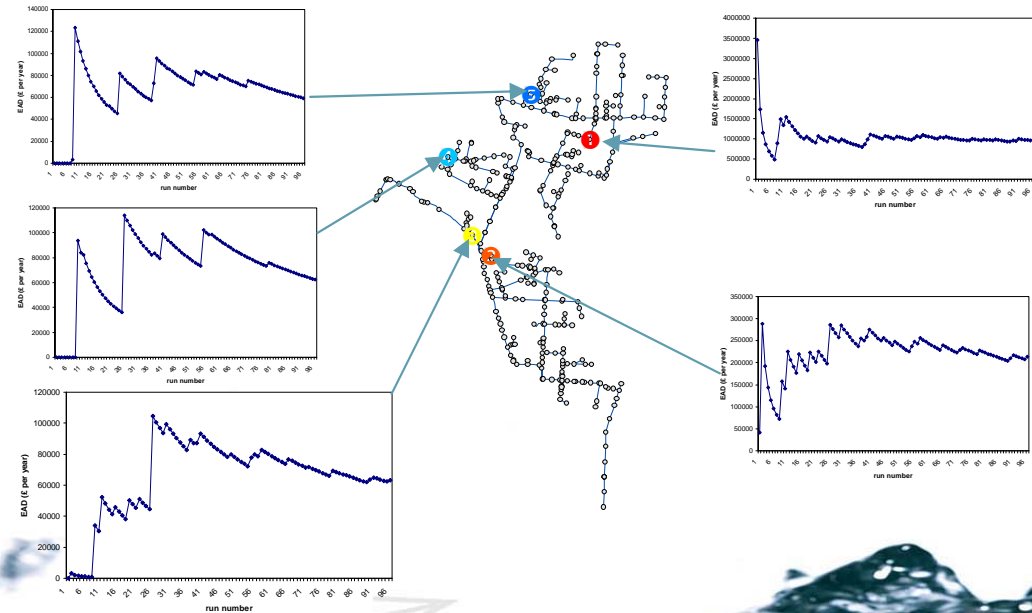
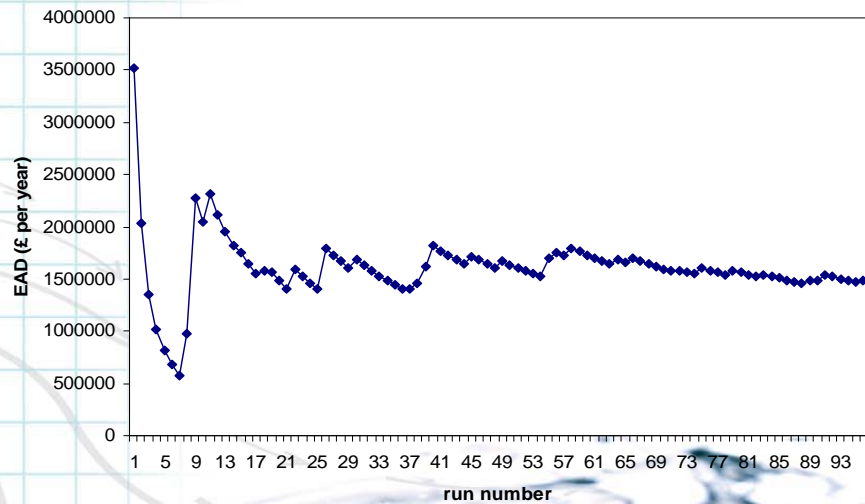
	2001-2071
Events	14286
Frequents	14189
Extremes	97
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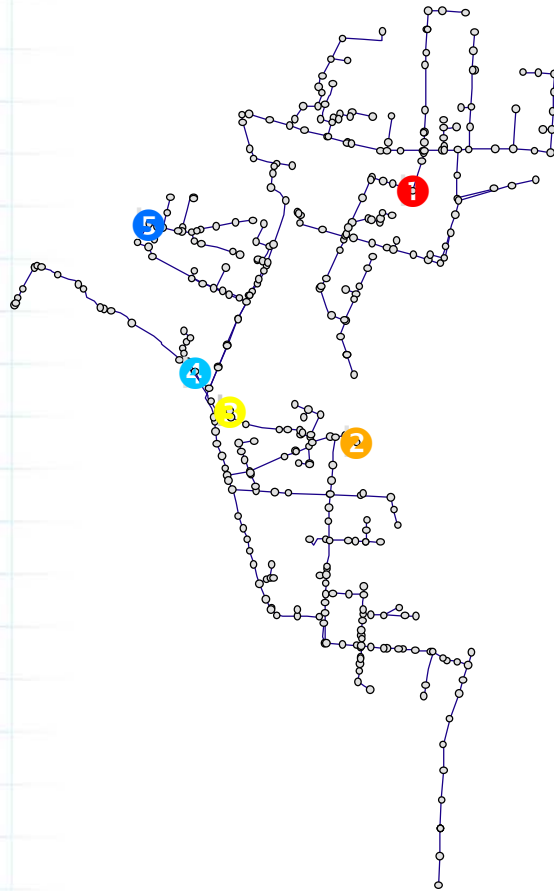
Hydraulic failure - Time series Rainfall



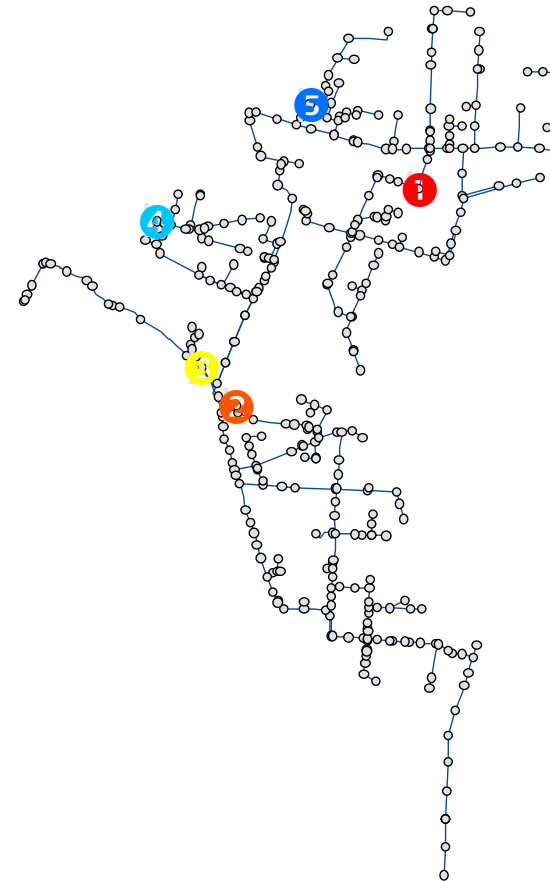
	2001-2071
Events	14286
Frequents	14189
Extremes	97
Flood events	41



Hydraulic failure - Time series Rainfall

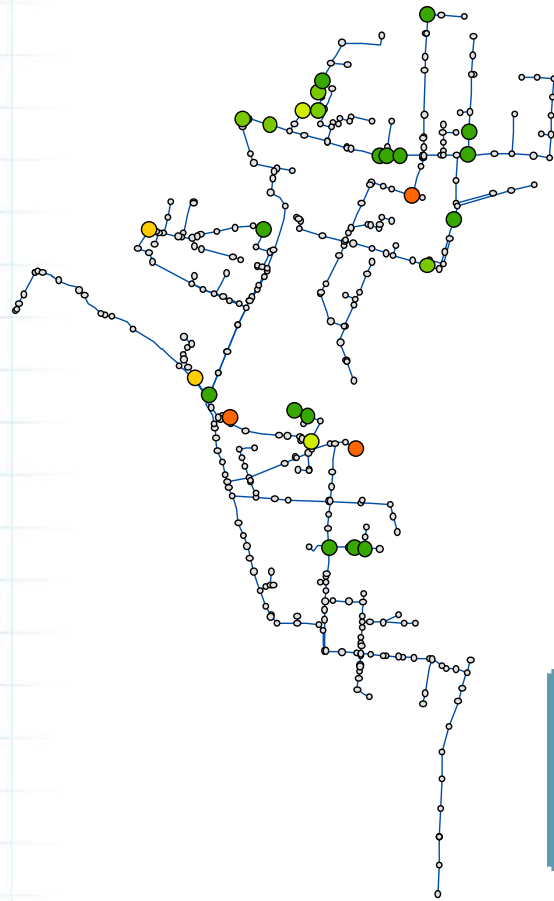


Design storms

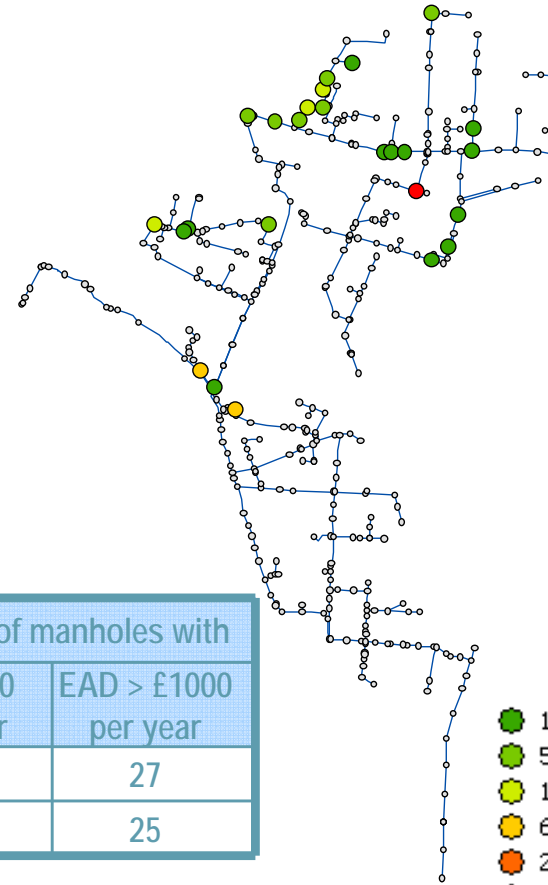


Time series Rainfall

Hydraulic failure - Time series Rainfall

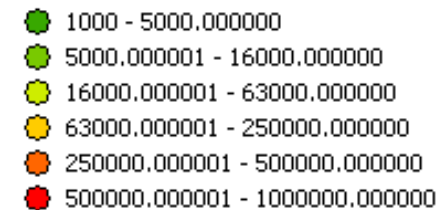


Design storms



Time series Rainfall

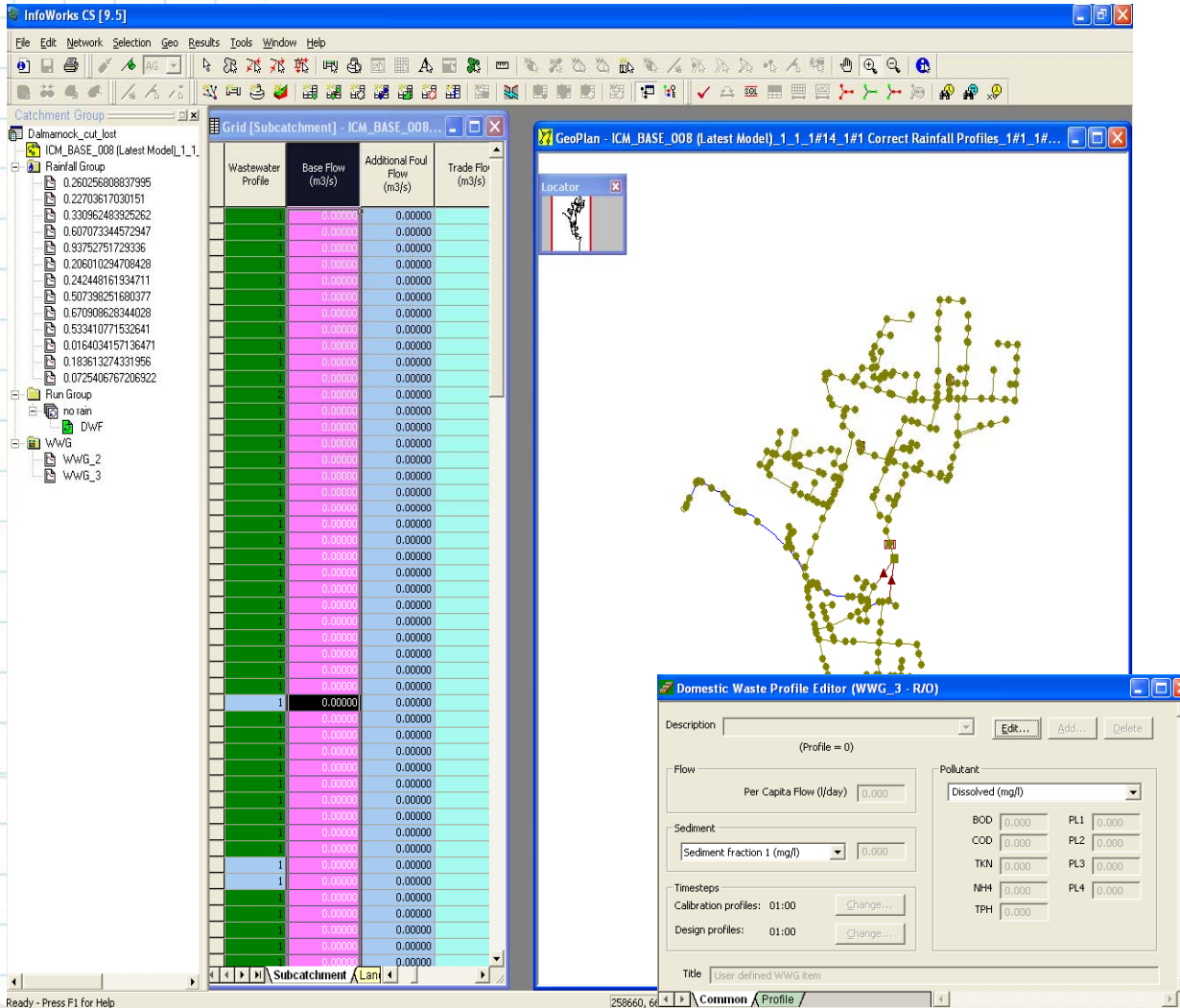
	Number of manholes with	
	EAD > £0 per year	EAD > £1000 per year
Design storms	90	27
Time series	76	25



$$\text{Likelihood of blockage} = \frac{7.5618 \times 10^{-12} \sqrt{N_{con} \times L}}{G^2 \times D^2}$$

$$\text{Likelihood of collapse} = \frac{7.5618 \times 10^{-12} \times Tr \times \sqrt{A \times D \times L}}{D}$$

- L : pipe Length (m)
- D : Diameter (m)
- A : Age (yr)
- Tr : Traffic Load (vehs/hr)
- Nconn : Number of connected properties
- G : Gradient

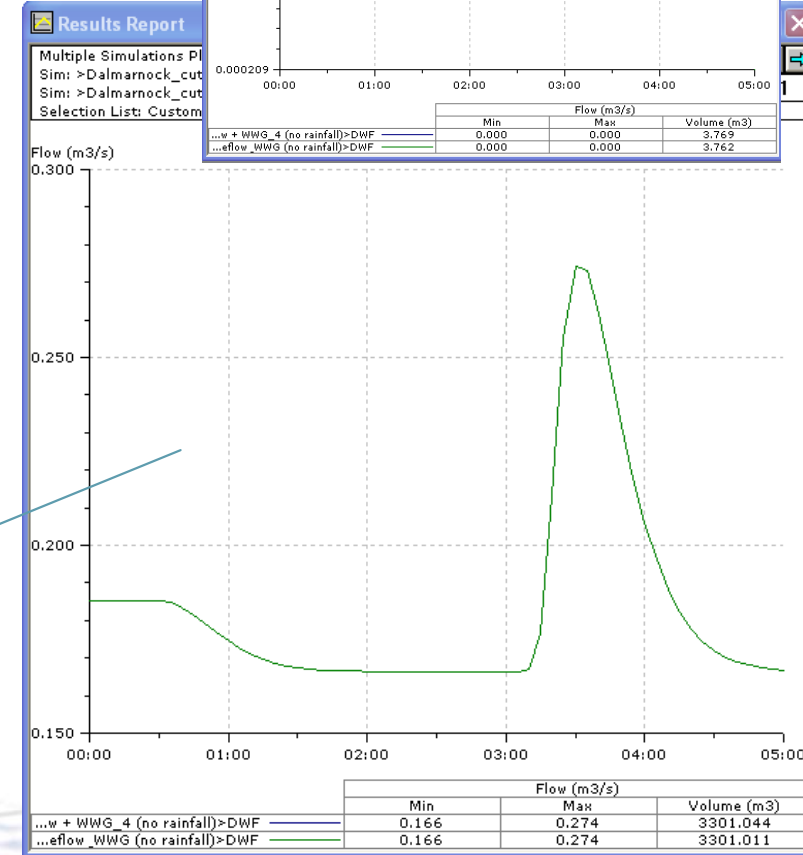
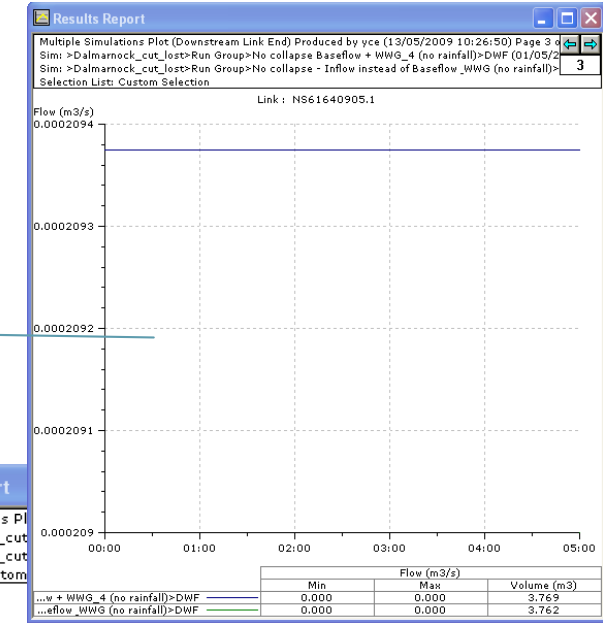
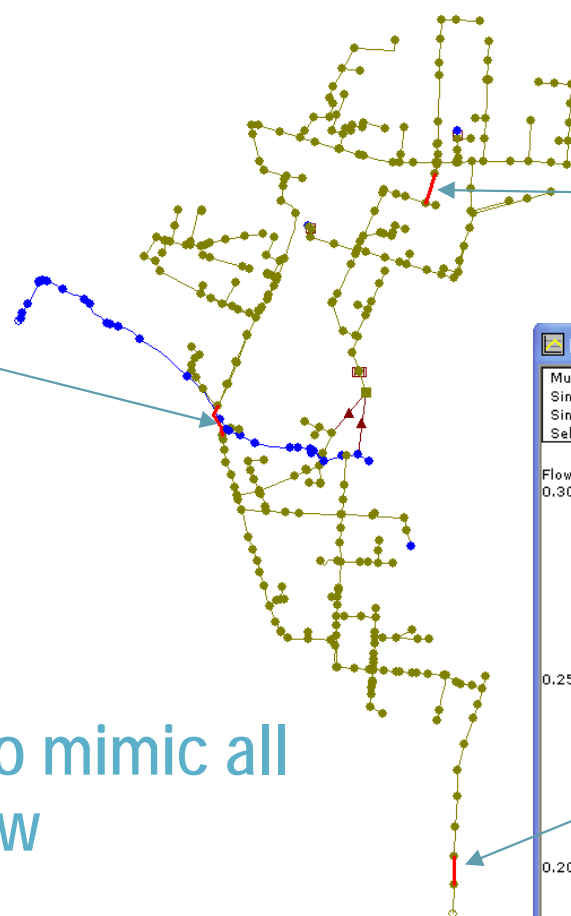
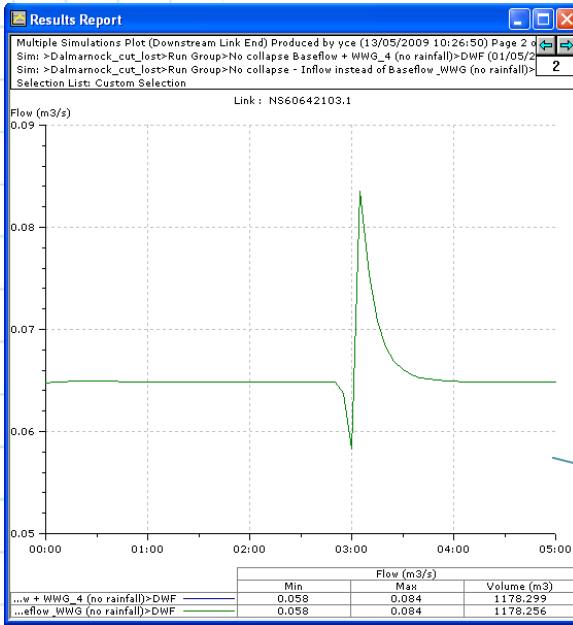


The screenshot displays the InfoWorks CS 9.5 interface. On the left, a tree view shows the project structure including 'Dalmackout_cut_lost', 'ICM_BASE_008 (Latest Model)_1_1', and 'Run Group'. The main window shows a 'Grid [Subcatchment] - ICM_BASE_008...' table with columns for 'Wastewater Profile', 'Base Flow (m3/s)', 'Additional Foul Flow (m3/s)', and 'Trade Flow (m3/s)'. The 'Base Flow' column is highlighted in pink, and the 'Additional Foul Flow' column is highlighted in blue. A 'GeoPlan' window shows a network map of the subcatchment. A 'Domestic Waste Profile Editor (WWG_3 - R/O)' window is open, showing settings for 'Per Capita Flow (l/day)' and 'Pollutant' concentrations (BOD, COD, TKN, NH4, TPH).

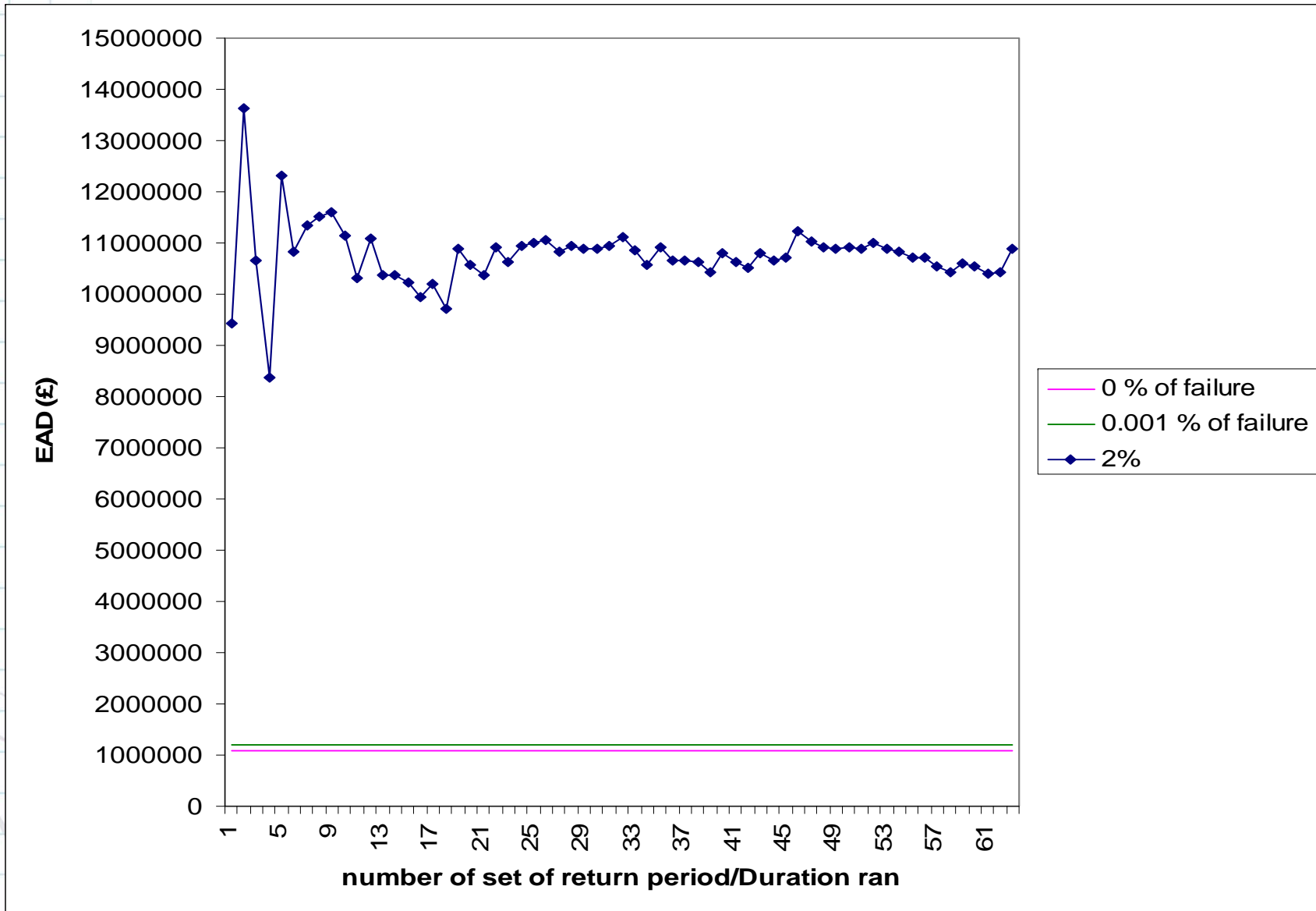
• Network modifications required to allow assets failure simulations

- Removed subcatchment base flows
- Removed Dry weather Flow

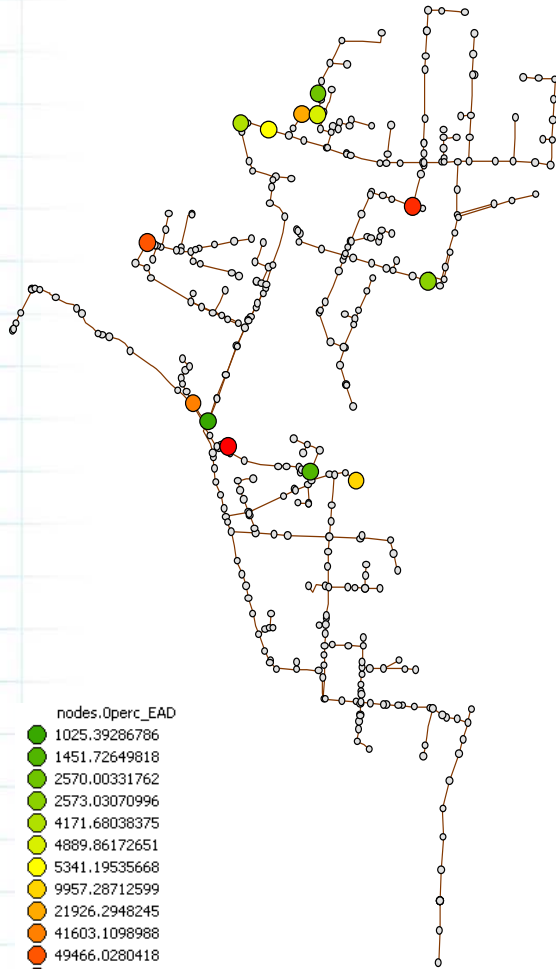
RP	5 - 10 - 20 - 50 - 100	
Durations	90 - 240	
modifications	before	After
£ per year	1281719	1084458
%	100	85



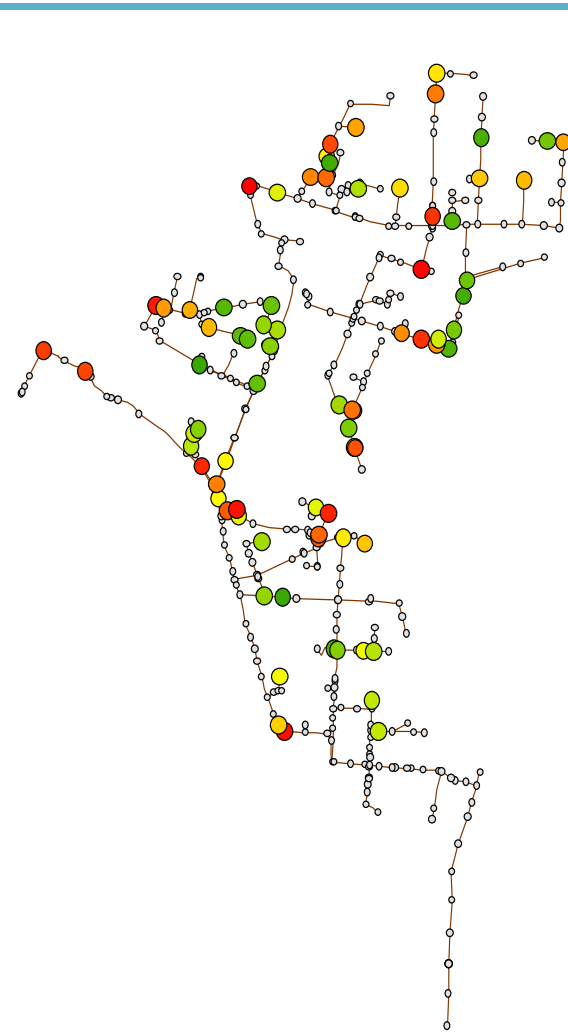
Inflow file can be used to mimic all forms of dry weather flow



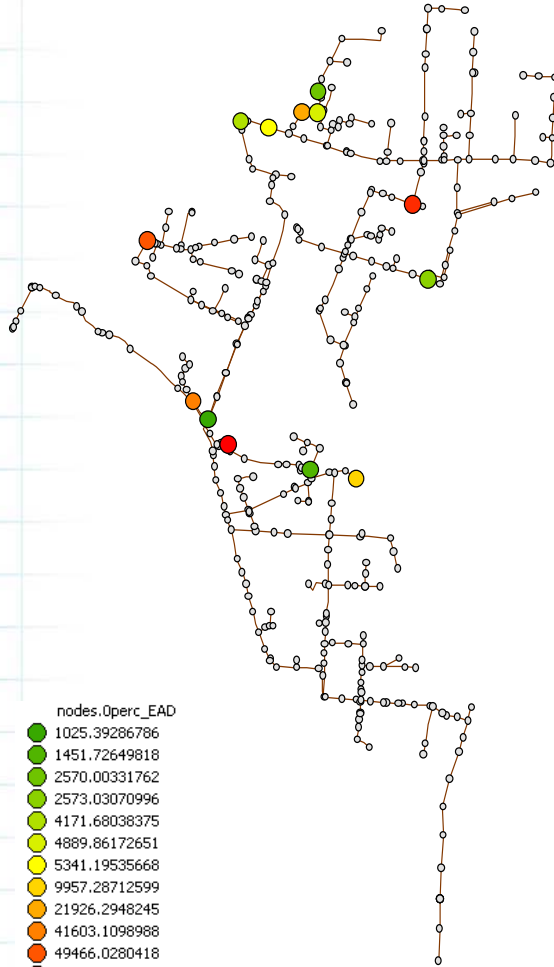
Assets Failure



0% chance of failure



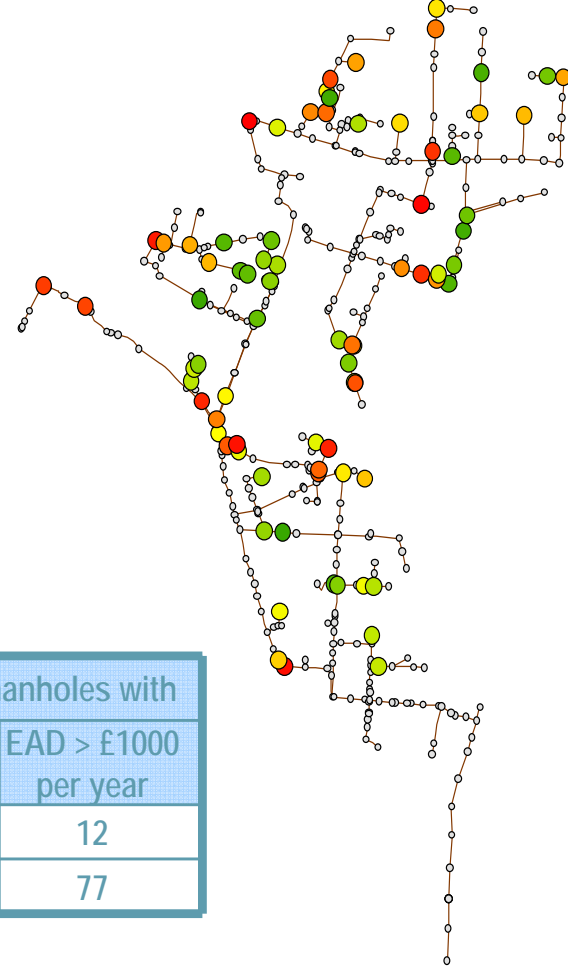
2% chance of failure



- nodes.0perc_EAD
- 1025.39286786
 - 1451.72649818
 - 2570.00331762
 - 2573.03070996
 - 4171.68038375
 - 4889.86172651
 - 5341.19535668
 - 9957.28712599
 - 21926.2948245
 - 41603.1098988
 - 49466.0280418
 - 313042.041841
 - 437910.565999

0% chance of failure

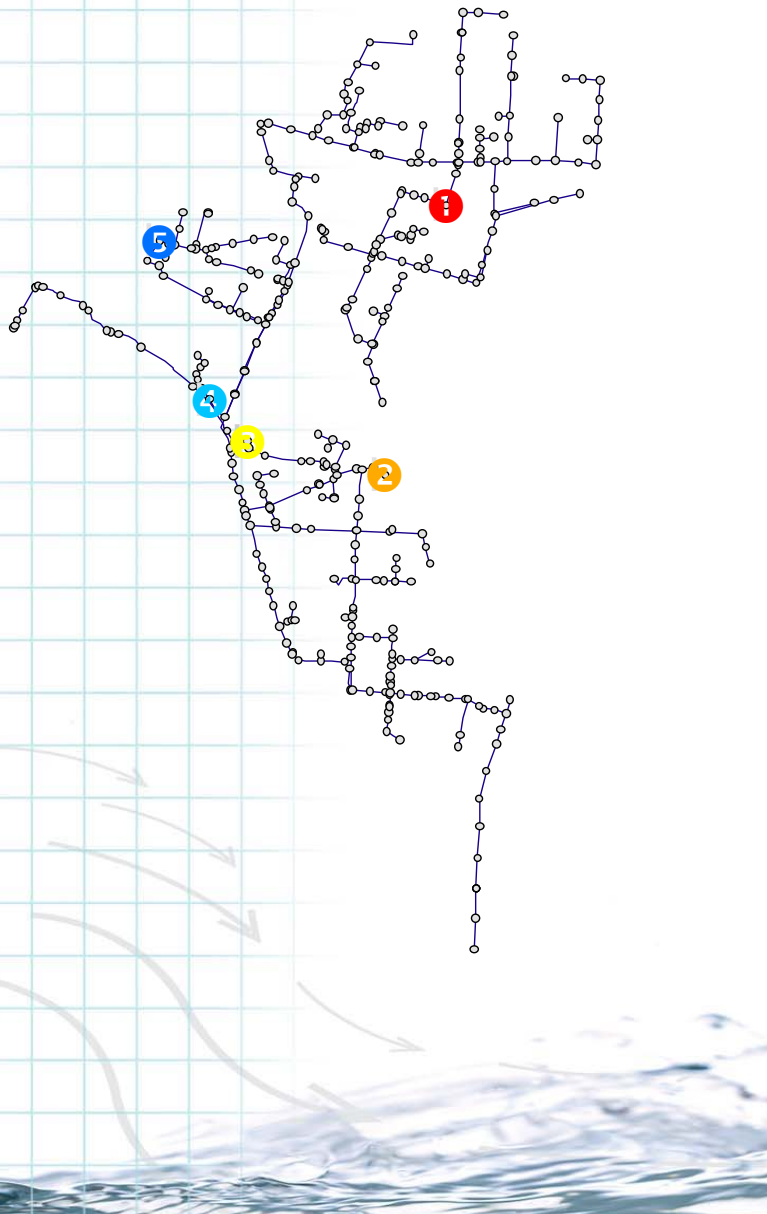
Probability of failure	Number of manholes with	
	EAD > £0 per year	EAD > £1000 per year
0 %	39	12
2 %	195	77



2% chance of failure

- 1142.64492605
- 1198.11437929
- 1260.02993153
- 1321.82263604
- 1373.82142347
- 1585.25477969
- 1639.68384649
- 1748.1062697
- 1768.52387461
- 1799.44525094
- 1900.50332963
- 2054.24190701
- 2073.64812232
- 2114.6227382
- 2122.18155354
- 2176.52666021
- 2372.24336247
- 2535.25369061
- 2680.89977753
- 2783.93107426
- 2953.27610201
- 3042.47162013
- 3089.85754234
- 3223.98767064
- 3353.63816977
- 3394.61285629
- 3484.4165123
- 3635.04820014
- 3924.90516857
- 4046.50625892
- 4185.71714382
- 4644.10517173
- 4736.9772739
- 4986.49608767
- 5003.94499363
- 5246.37882455
- 5891.84433351
- 6006.35584953
- 6082.72183639
- 7381.67480877
- 8521.02757964
- 10662.7406715
- 12021.39581
- 12397.6462473
- 12432.8074381
- 14610.2867574
- 15093.8803141
- 15378.0615315
- 16496.0240222
- 17288.2374859
- 19983.8560084
- 20011.9051181
- 20875.6443731
- 21500.0423434
- 22008.3673234
- 25780.3727502
- 28167.2070444
- 31453.0422386
- 32285.4398648
- 32609.9807965
- 32757.6440657
- 35366.8098631
- 35656.8341446
- 37126.5018261
- 39739.466181
- 53796.4660349
- 65418.8114114
- 68558.5352727
- 78474.8066202
- 87033.2988214
- 121858.913771
- 182976.520918
- 392223.860725
- 526547.997482
- 547832.393926
- 868056.339221
- 1047395.33767

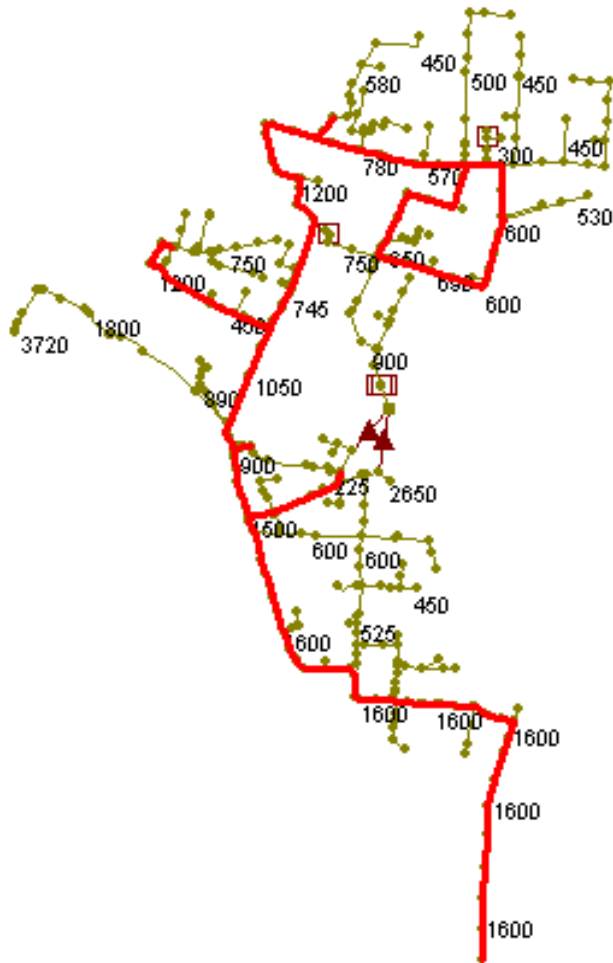
- Selection of optimisable elements



- Selection of optimisable elements

- **Pipes selection and grouping (131 pipes -> 40 Groups)**

- Based upon pipe size
 - Tool developed to identify groups
 - manual editing

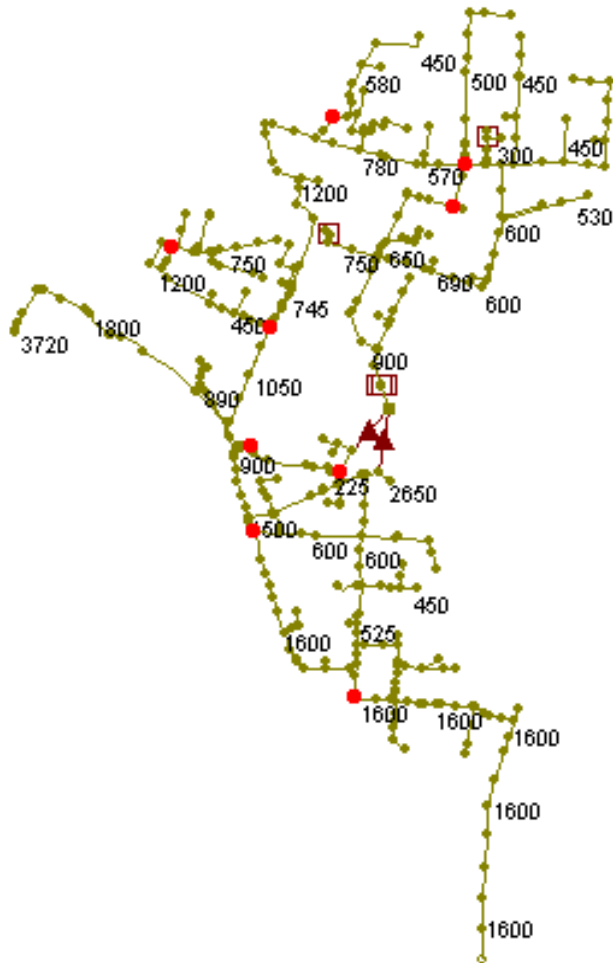


- Selection of optimisable elements

- **Pipes selection and grouping (131 pipes -> 40 Groups)**

- Based upon pipe size
 - Tool developed to identify groups
 - manual editing

- **Tank locations (9 offline tanks)**



- Selection of optimisable elements

- **Pipes selection and grouping (131 pipes -> 40 Groups)**

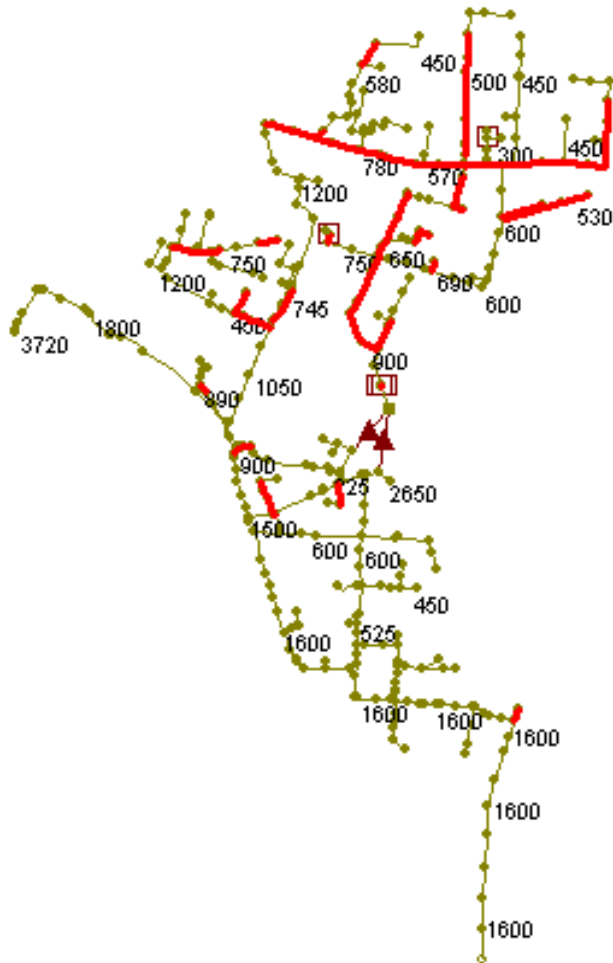
- Based upon pipe size
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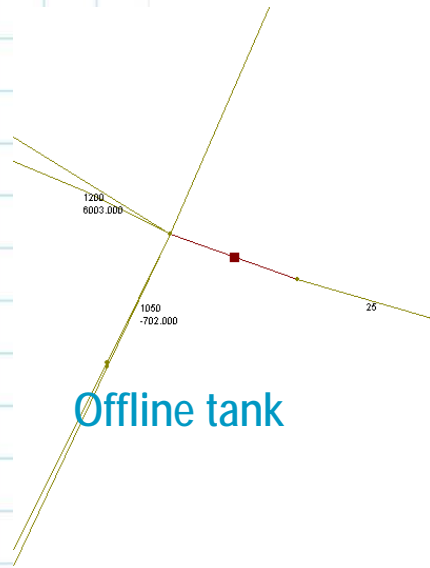
- **Tank locations (9 offline tanks)**

- Network modification

- **To enable grouping**

- Replaced Eggs pipes for circular pipes





- Selection of optimisable elements
 - **Pipes selection and grouping (131 pipes -> 40 Groups)**
 - Based upon pipe size
 - Tool developed to identify groups
 - manual editing
 - **Tank locations (9 offline tanks)**
- Network modification
 - **To enable grouping**
 - Replaced Eggs pipes for circular pipes
 - to allow an optimisation calculation**
 - Insertion of the elements for offline tanks
 - Insertion of orifices at the outfalls to control the outflows



- Selection of optimisable elements
 - **Pipes selection and grouping (131 pipes -> 40 Groups)**
 - Based upon pipe size
 - Tool developed to identify groups
 - manual editing
 - **Tank locations (9 offline tanks)**
- Network modification
 - **To enable grouping**
 - Replaced Eggs pipes for circular pipes
 - **to allow an optimisation calculation**
 - Insertion of the elements for offline tanks
 - Insertion of orifices at the outfalls to control the outflows
- Costs
 - **Volume/Damage curves**
 - **Cost model (offline storage and pipe sizing)**
- Identification of matrix of events to be used

