Appendix:
Adjusted storm overflows PCL

YKY-PR24-DDR-58-Adjusted-PCL-Storm-overflows

Yorkshire Water

Contents

Test 3 Compelling Factors Affecting Storm Overflow Performance

Ofwat has challenged that there is insufficient compelling evidence to justify a different PCL AMP8 starting point. Table 1 summarises the main factors which affect storm overflow performance, most of which are beyond our control. The following subsections discuss these factors in more detail, how they are shared with other water companies, and how we compare.

It is important ***to consider these factors collectively, as they influence our AMP8 PCL starting point,*** and the scale of investment required to meet the AMP8 exit PCL. Combined sewers and their corresponding contributing areas of impermeability, along with other significant regional factors such as rainfall, result in a higher starting position compared to a water company for example in the South and East of England.

Table 1: Factors Affecting Storm Overflow Performance

Factor	Narrative	Exogenous Factor not in control of Yorkshire Water
Historical Starting Position & Permit Setting	The scale of intervention required to meet new statutory drivers, such as the Environment Act and SODRP, for storm overflows is significantly influenced by their historical context, including design approach when first built (or added to the network), discharge frequency, previous legislation, policies, and past investments. Consequently, the starting position for storm overflow discharges varies by region, reflecting historical environmental needs, modelling, and assessments, as well as the regulatory stance during successive Asset Management Periods (AMPs) which were primarily aimed at preventing ecological harm. In addition, permits and pass forward flows have typically been set as a function of the population and base flow which may include for example: a multiple of dry weather flow, Formula A calculation, simulated rainfall design events and not by how much water must be managed and controlled. Development and application of these permits and associated hydraulic controls has varied across England and Wales. From AMP3 to AMP6, over £700 million was invested in storm overflow management, including significant programmes to install new screens to prevent solids discharge. Ecological impact modelling took into account the available dilution in receiving watercourses, with regional variations in rainfall influencing the modelled harm of those discharges and the corresponding discharge frequency.	Yes – it cannot be reasonably expected of Yorkshire Water to undo many years of historical industry practice at the start of AMP8 given the relative differences in starting position given our unique regional circumstances.
Combined Sewer Legacy & Asset Health	Combined sewers will have more hydraulic capacity than foul sewers at times of heavy rainfall and therefore increase the risk of storm overflow activation as they have to convey significantly more rainfall than a foul sewer (which in theory, should have no storm water conveyed, but is sometimes not the case). The proportion of combined sewers define how	Yes – combined sewer legacy is a historical planning

	much surface water you are managing as a volume, and partially separate systems may add to this volume to be manged in a combined system. Some surface water networks do connect into combined sewer systems but in our experience, this is not significant. These older, combined sewer systems are often not constructed to modern design standards and are at more risk of sewer deterioration and collapse, which can lead to reduced hydraulic capacity and blockages. Some overflows can block, especially those with small pass forward pipes, for example. Additionally, combined sewers carry more silts as a direct result of highway runoff and associated maintenance regimes of the separated surface water network which can count towards increased maintenance costs. In a separate surface water system, the silt goes straight to the watercourse. In our region we have one of the highest combined sewer percentages of all water companies at 52.4% and one of the highest combined sewers to foul sewers ratios of 3:1. Proportionally the number of combined storm overflows and the length of combined sewers should bear a relationship and a water company's performance will be related to the impermeable area which drains into its combined sewer.	decision that was not in the control of Yorkshire Water. Separating the combined sewer network remains an aspirational long-term ambition.
High Urban Rainfall	Rainfall falls onto impermeable surfaces in urban areas taking up capacity in combined sewers. The regional differences in rainfall, the runoff generated and the percentage of combined sewers capturing the runoff significantly changes the volume of water presented to each overflow on average. The number of days where there is rainfall is also likely to influence the historical number of discharges. These factors typically drive higher number of discharges per overflow per company.	Yes – the degree of urbanisation and climatic rainfall events are outside the control of Yorkshire Water.
Blockages	Blockages tend to form in small diameter pipes with small defects (typically at pipe joints) causing the backing up of flows and exacerbation of the original defect. Other causes may be where there is a throttling down of flows in small diameter systems (e.g. narrowing from 225mm to 100mm). Yorkshire Water proactively detects the formation of blockages at storm overflows and intervenes with proactive blockage remediation. Since the middle of 2021, Yorkshire water has been proactively managing storm overflows using AI to give forewarning of blockages occurring in the network.	No – blockage detection is within its control and that storm overflow activation due to blockages is within the control of Yorkshire Water.

Detailed Data analysis

We analysed EDM data at 5km^2 grid spacings based on the total number of discharges for the years 2021-2023. As can be seen from **Figure 1**, to the south west of our region is the area with the highest density (and hence higher population and urban sprawl) and also the highest total number of discharges, depicted by the darker oranges. This figure in isolation does not give much context as to the factors driving discharge frequency within our region.

By comparing ourselves to other water companies (**Figure 2**) we can see that we rank 3^{rd} consecutively behind United Utilities and South West Water across the 3 years of EDM data (2021-2023) for the average number of discharges measured by the EDM across the period, unadjusted for uptime. The industry average across these 3 years is 28 discharges and we exceeded that industry average in two out of the 3 years of monitoring.

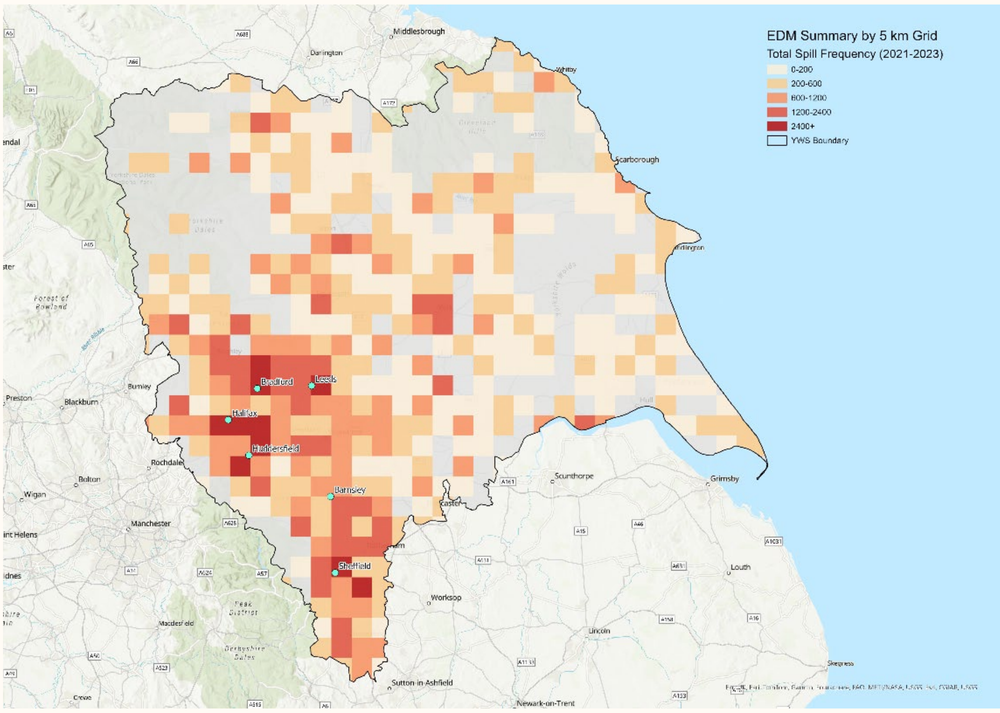


Figure 1 – EDM spill averages per overflow between 2021 and 2023 in the Yorkshire Water Region (at 5km grid squares).

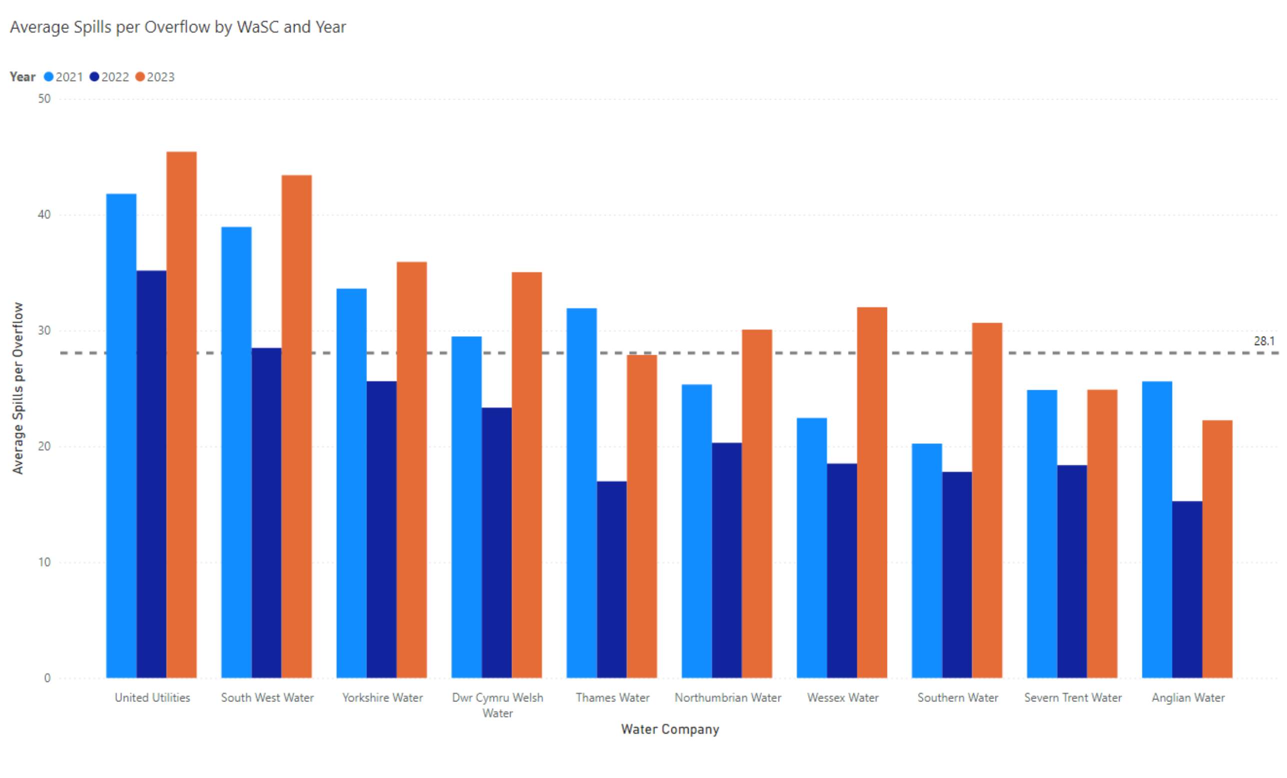


Figure 2 – EDM discharge averages (unadjusted) per water company between 2021 and 2023 and industry average (dotted).

Please note that the source of data for the EDM discharge averages are different to the values now in OUT5.

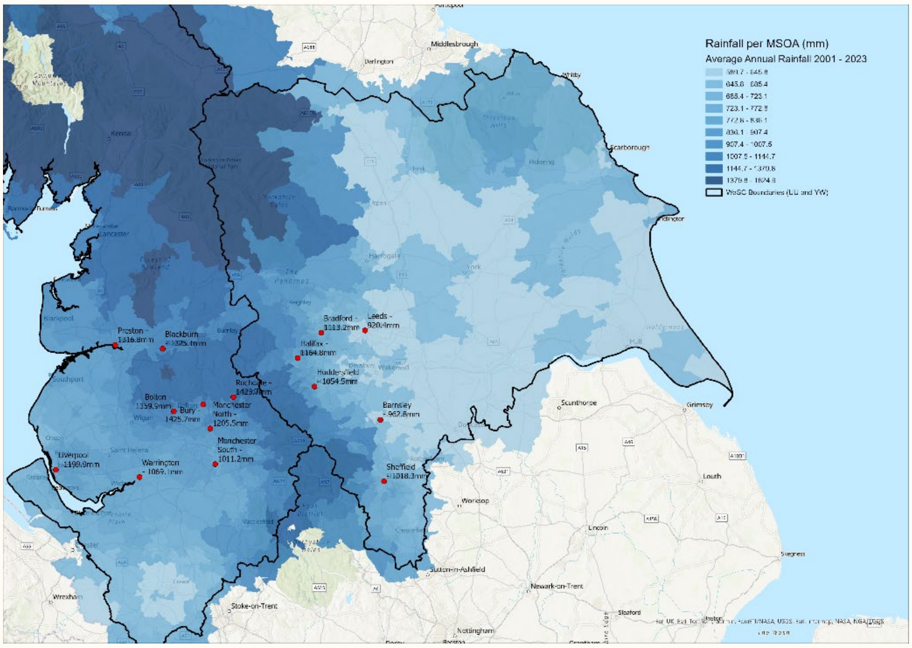
Rainfall

Higher annual rainfall also occurs in the west of our region, where we have the predominance of our population and EDM activation. Rainfall distribution ranges significantly across the Yorkshire Water region as indicated in Table 3 and there is a general trend on the number of "wet days" - whereby the rain is greater than 1mm – as we move from east to west as further highlighted pictorially in Figure 3. Rain gauges to the west and east of Leeds highlight how urban areas to the west have significantly more rainfall than locations to the east.

Table 3: Variation of average rainfall depth (1991-2020) and "wet days" greater than 1mm rain across the Yorkshire Region[1]

Major urban location	Bradford	Huddersfield	Leeds (West of)	Leeds (East of)	Sheffield	York	Hull	Doncaster
Rain gauge distance from urban location (miles)	4	2	13	14	0	9	0	6
Rainfall Average (1991-2020) mm	1057	1041	1057	620	832	634	693	582
Rainfall > 1mm days (1991-2020)	156	Not available	156	116	133	120	125	114

Figure 3: Rainfall averages by MSOA for Yorkshire Water (2001-2023) showing higher rainfall to the west of our region.



In a broader comparison across England and Wales, Yorkshire's average regional rainfall is influenced by the drier areas (which have a lower population density and larger MSOA areas) in the middle and eastern parts.

Figure 4 shows box and whisker analysis of the rainfall data from 2012 to 2022 which indicates, Yorkshire receives typically average rainfall compared with other water companies across its region. It demonstrates, when considering rainfall at a water company regional scale, that those on the west coast receive predominantly more rainfall than companies further east, which broadly becomes progressively less the further east you go.

However, the graph in **Figure 5** plots the number of "wet days" against the annual rainfall data from 1991-2020. Firstly, this shows there is good correlation between the total annual rainfall and the number of "wet days" as would be expected but shows that there is regional variability within all water company regions. For Yorkshire Water, this shows that for our rainfall for the Leeds (using the westerly data point of 1057mm see table 4 below), Bradford, Halifax and Huddersfield areas may have higher rainfall and more wet days (>1mm) than most parts of the country.

By analysing **Figure 3** we can compare ourselves to our nearest westerly neighbour, United Utilities. Their region's total average annual rainfall is likely being influenced upwards by high rainfall totals over the Lake District and Yorkshire Dales. Higher average urban rainfall totals the furthest west in our region are similar to those experienced in south Manchester and to the south and west of United Utilities region showing that we both experience similar depths of annual rainfall across that band. Towards the north of Manchester, towards the Yorkshire Dales, these rainfall depths rise significantly. Although rainfall is an important factor in storm overflow performance, it is not the only factor that needs to be considered, as this analysis highlights that topography plays a role if you are trying to normalise water company performance based on rainfall alone.

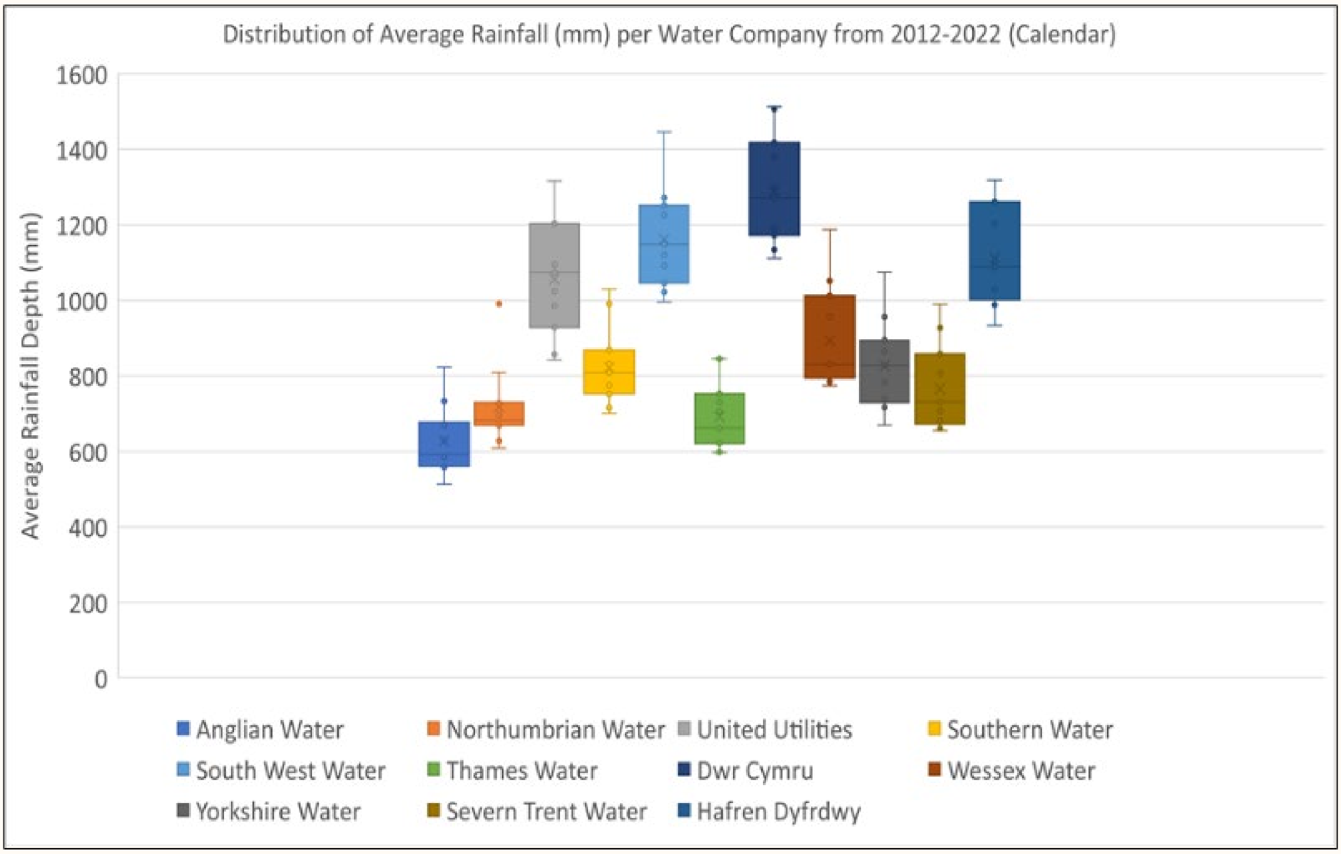


Figure 4: Average rainfall across the water companies

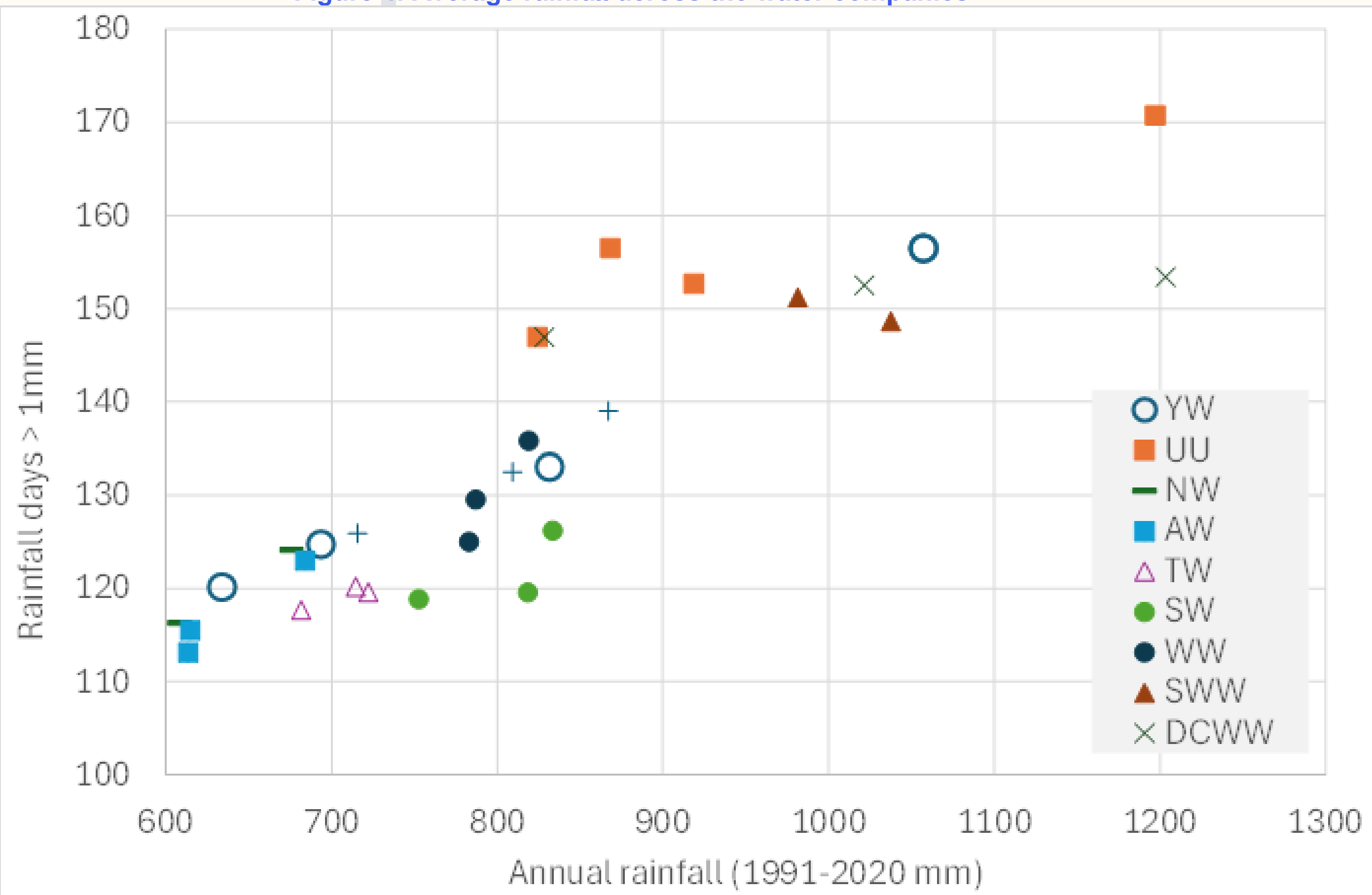


Figure 5 rainfall variability within towns for each water company region

Further comparison of Yorkshire Water against the two "wettest" water company regions in **Figure 6** – Welsh Water and South West Water - explores whether rainfall is the primary driver of storm overflow performance in isolation.

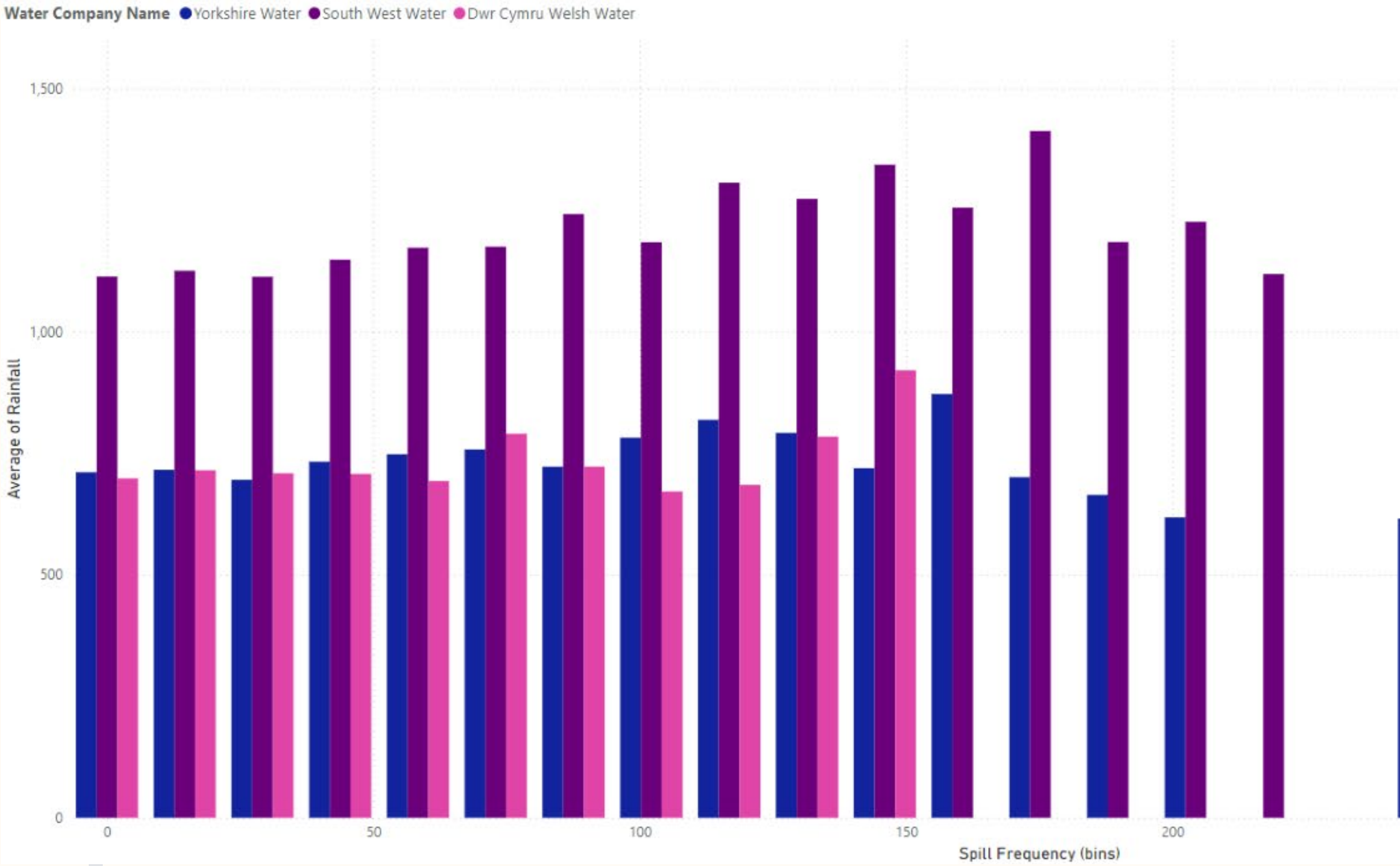


Figure 6: EDM Discharge Frequencies and Water Company Regional Rainfall averages for period 2021-2023 for Yorkshire Water (Blue), South West Water (Purple) and Dwr Cymru (Pink)

Using EDM data from 2021-2023 and MSOA regional rainfall averages across that period you would expect to see a consistent pattern that higher discharge frequencies due to higher rainfall in that water company region.

The figure highlights that for discharge frequencies up to 150 discharges, there is very little variance in rainfall depth (~100 to 150mm) between the discharge "bins" for Yorkshire Water and Welsh Water. South West Water experience much more rainfall for similar discharge frequencies, highlighting that rainfall (or the granularity of the rainfall) is not the only primary cause of storm overflow activation. For those asset discharging beyond 150 times, it can be seen that there is no clear trend. For Yorkshire Water the rainfall depth actually decreases slightly and for South West Water it is highly variable.

Observation Station	Bingley SAMOS	Church Fenton	Linton on Ouse
Locality to Leeds	West	East	East
Distance from Leeds (miles)	13	14	21
Altitude (m above mean sea level)	262	8	14
Rainfall Av (1991-2020) mm	1057	620	634
Rainfall > 1mm days (1991-2020)	156	116	120

Table 4: Met Office rainfall variation within a 20-mile radius of Leeds

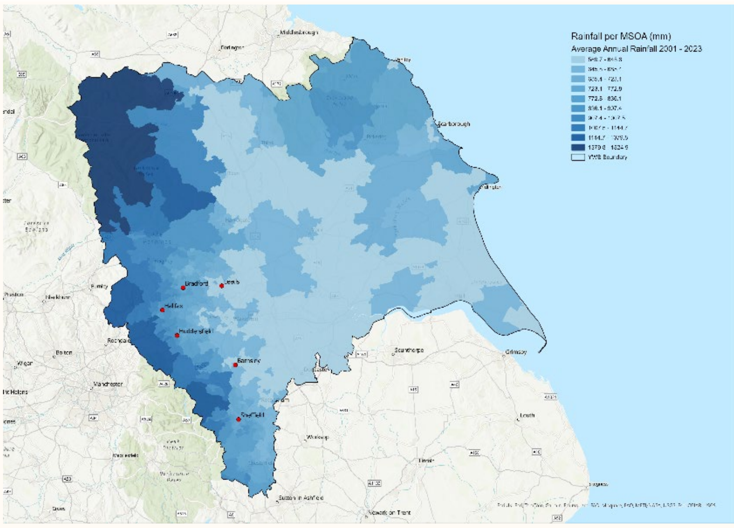
Using MSOA rainfall as a sole driver of storm overflow performance does not fully demonstrate the variability that may occur spatially within our region at a highly localised scale using *observed* Met Office data.

By analysing data around Leeds, using an approximate 20-mile radius, there are 3 Met Office observation stations - one to the west of Leeds and two to the east as shown in **Table 4**. This suggests that altitude and rainfall are likely co-dependent factors when considering rainfall in isolation as Bingley SAMOS station is over 250m higher above sea level than the nearest station directly to the east; Church Fenton. There is also over 400mm of annual average rainfall difference between these two stations which are both less than 15 miles from Leeds. Linton on Ouse is slightly more to the northeast and the rainfall is slightly greater than Church Fenton but not overly significantly. It is also at a slightly higher altitude.

This analysis further highlights that storm overflow discharges need to be considered at a more granular scale when analysing rainfall, as their activation depends on the rainfall that falls in that EDM sub catchment. Using rainfall at a water company regional level, or at an MSOA level, will not fully capture the in-region rainfall variation that occurs in storm overflow sub-catchments. Additionally, further consideration needs to be given to other exogenous factors, other than rainfall, that contribute to storm overflow activation and performance.

Combined Sewer Legacy

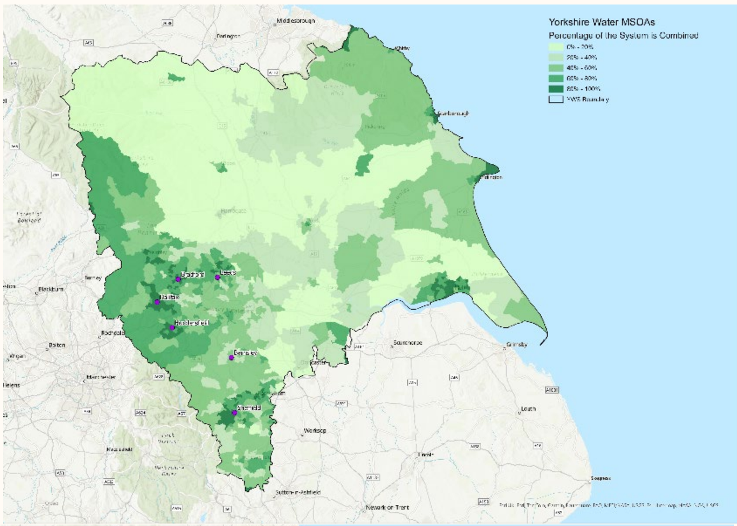
Figure 7: Yorkshire Water Rainfall Depths (2001-2023), Percentage of Combined Sewers and EDM spill frequencies (2021 – 2023)

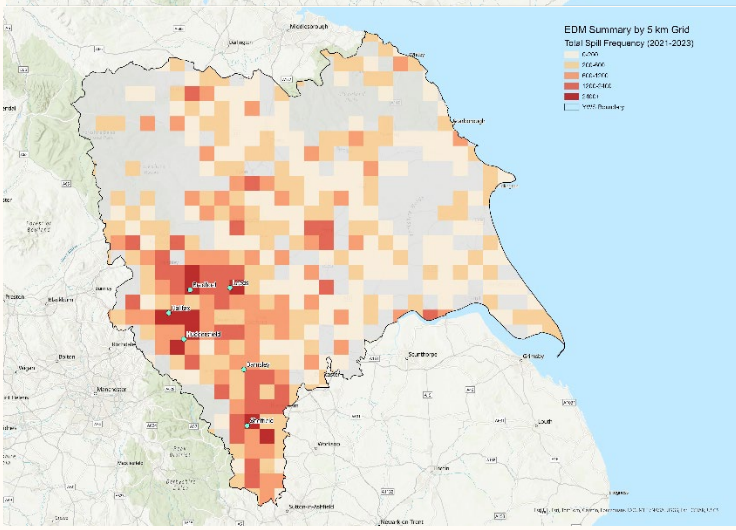


When we overlay rainfall and EDM discharge frequency datasets with the percentage of combined sewers in our region **Figure 7**, a clear picture of the combinatory effects emerges. These effects narrate a logical story about the factors influencing storm overflow performance. Rainfall in areas with high surface water runoff and impermeability significantly impacts storm overflow performance, particularly in regions with a high percentage of combined sewers. This is because there is no nearby surface water network to channel runoff to the nearest watercourse, leaving the combined sewer overflow as the primary relief. These were historically assessed based on ecological harm rather than prescribed discharge frequencies.

Our analysis and visual inspection reveal a notable pattern: towards the west of our region, where population density is higher (hence a greater density of MSOA boundaries), there is also a higher density of combined sewers and larger rainfall depth. This correlates with increased activation of storm overflows, illustrating the impact of these combined factors on our storm overflow performance.

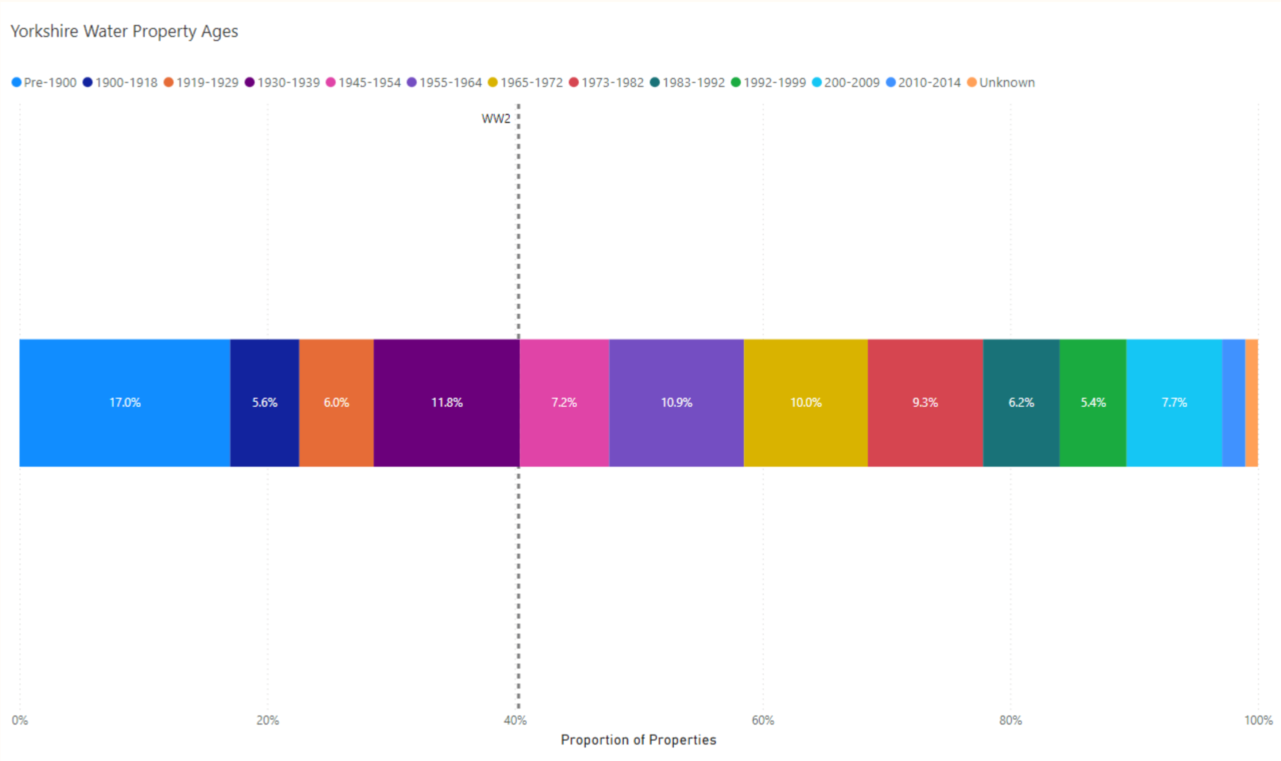
We will further explore what this means for Yorkshire Water in terms of the volume we must manage within our sewer network per overflow and how this translates to discharges. This analysis underscores that rainfall alone is not the only exogenous factor affecting storm overflow performance. Our historical reliance on combined sewers,





coupled with rainfall, positions us as an industry outlier.

A significant factor contributing to the proportion of combined sewers is the number of properties in our region constructed before and after World War II. This period is pivotal as it estimates the UK's transition from Victorian combined sewers to separate surface water networks. Figure 8 shows that approximately 40% of our properties were built before World War II, placing us fourth among our industry peers in this regard.



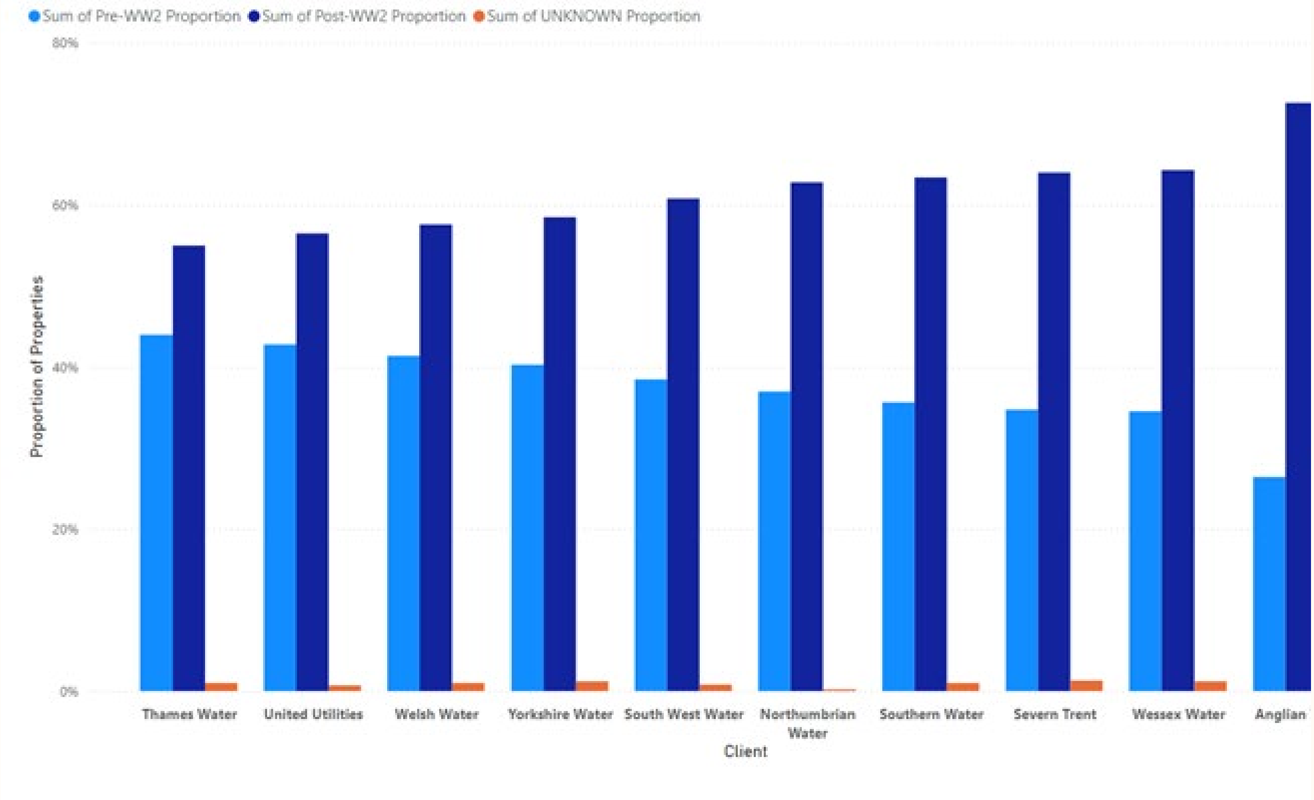


Figure 8: Percentage of property share constructed pre and post WW2

By the 1960s, new developments increasingly adopted separate systems and by the middle of this decade approximately 58% of our network was estimated to have likely been on a combined network. The full transition has been slow, and even today, a significant proportion of England's sewer infrastructure, particularly in older cities, remains combined. As a result, the volume of water our sewer network must manage per overflow is significantly higher than in regions with more modern infrastructure. This further explains the increased frequency of discharges in our region and the rationale behind our requested AMP8 starting position.

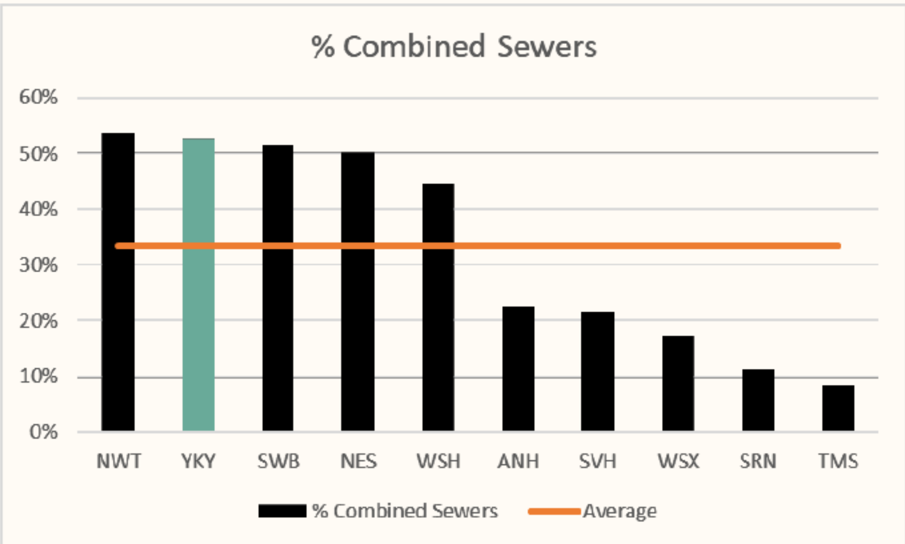
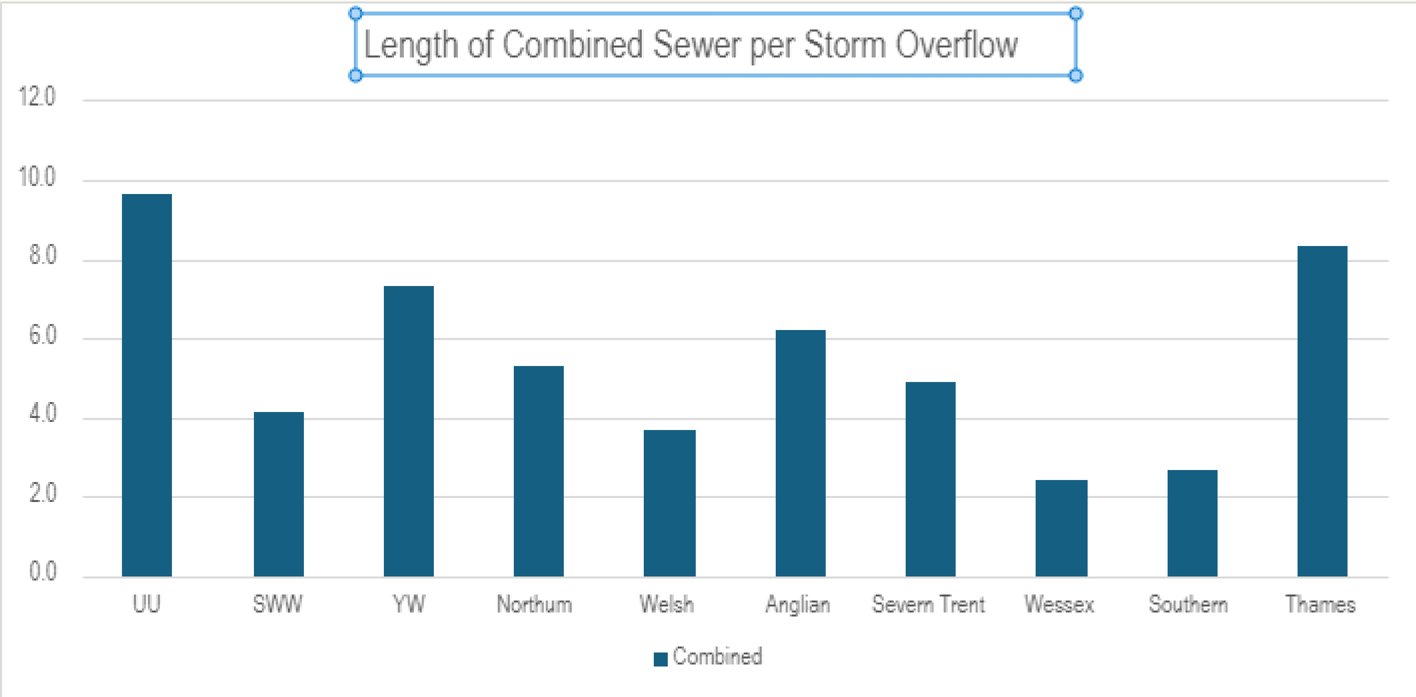


Figure 9: Percentage of combined sewers across water companies

When we consider the current day, with over 16,000km of combined sewer, we have approximately 52% of combined sewers within our network. This is close to the percentage estimated due to our property age showing that historic factors beyond our control play a factor in storm overflow performance. When we analyse industry APR returns, we have the second longest length of combined sewers of all the water companies and are over 1.5 times the industry average in terms of the percentage of our network that is combined.

Consistent with the percentage of combined sewers you would expect the length of combined sewer per storm overflow to be consistent amongst water companies. **Figure 10** below highlights that Yorkshire Water are within the top 3 companies for this metric (behind United Utilities and Thames Water), averaging 7.3km of combined sewer per storm overflow and associated impermeable area draining to it.

However, the water conveyed to storm overflows are also generated through foul networks, and more significantly when considering partially separate networks that carry foul and a proportion of surface water in an urban area. To approximate the runoff that each company may be managing it is appropriate to consider the proportion of foul sewers and an estimate of the runoff. We have sensitivity tested run-off generated through these areas using 25% and 50% allowances of the foul sewer connected assuming that this is mainly from roofed areas as opposed to roads (50% assumption). Typically, the amount of area draining to a foul sewer will be less and a standard modelling allowance is 5%. The results of this sensitivity test are shown below. The sensitivity test shows that there is a 4% increase in the length of combined sewer and the associated impermeable runoff to manage for Yorkshire Water. Thames Water and Southern Water are particularly sensitive to this assumption and test.



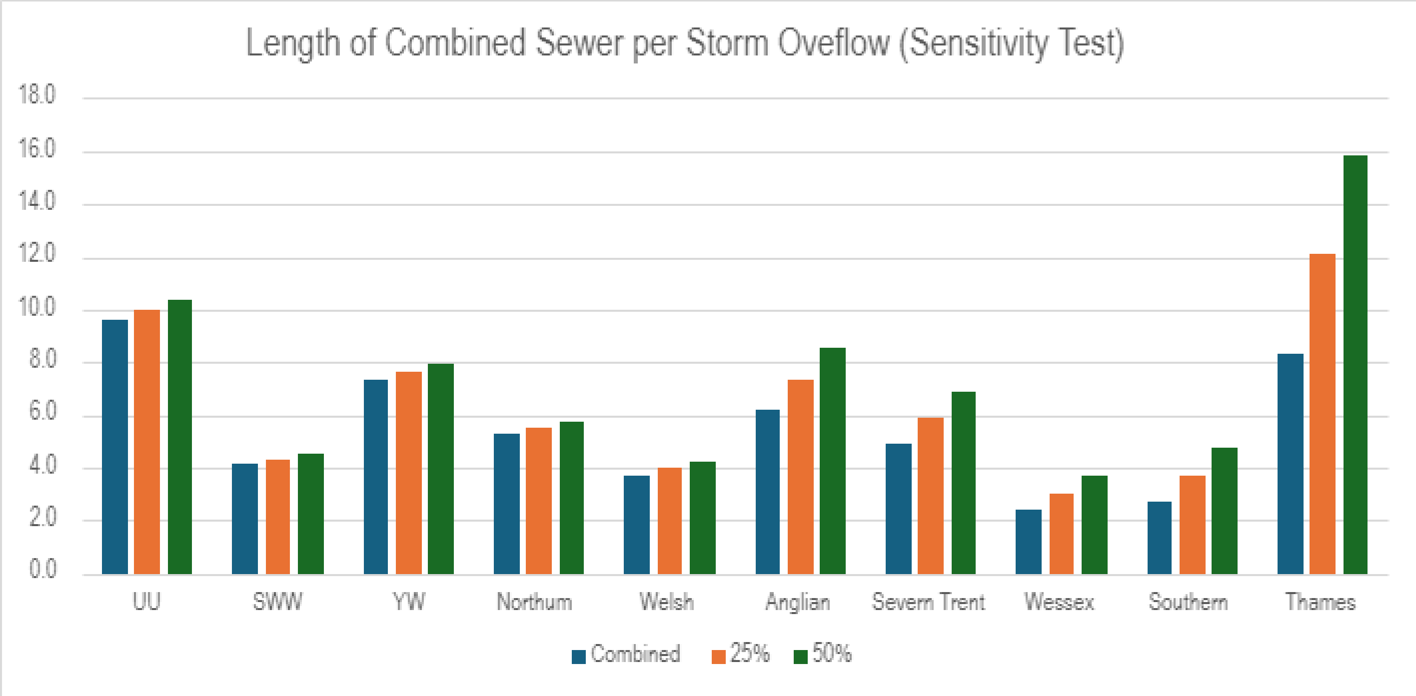
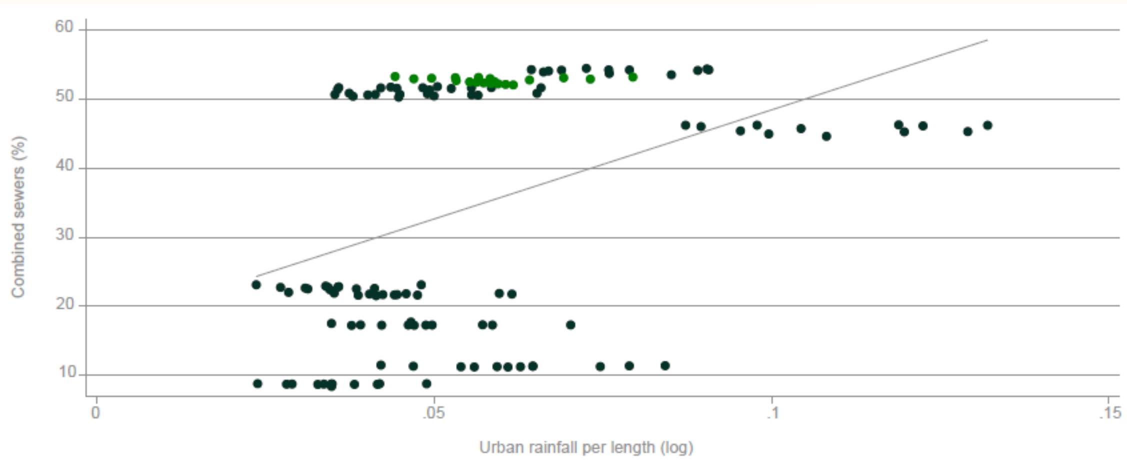


Figure 10: Length of combined sewer per storm overflow (top) and sensitivity test (bottom) assuming a percentage of the foul network generates surface water runoff in the combined sewer.

Rainfall Runoff Generated within Combined Sewer Areas

Figure 11: Relationship between percentage of combined sewers and urban rainfall (2012-23).

Note: The dots represent each company's average for the last 11 years of data. YWS is shown in green. The trendline is shown in a dotted grey line.



The response to date has highlighted that rainfall, in isolation, is not the sole driver of storm overflow performance and that a combination of all factors discussed so far must be considered. Figure 11 shows that there is some, albeit weak, correlation between urban rainfall and combined sewers. It also shows that urban rainfall does not capture the variability present in combined sewers and cannot be used as a 'substitute' for combined sewers. In the case of Yorkshire Water, the percentage of combined sewers is significantly higher than its level of urban rainfall would suggest (i.e. it is above the regression line). Therefore, failing to account for combined sewers will lead to biased and unrepresentative outcomes for Yorkshire Water in the beginning of AMP8 as we are dealing with significant legacy issues.

We believe that Ofwat's urban rainfall driver could be modified to be more granular to capture where the rainfall occurs, and to effectively account for the size of impermeable surface connected to each storm overflow. The runoff in each Middle Super Output Area (MSOA) can be estimated based on the rainfall in the area, using Ofwat's methodology for urban runoff. By multiplying the runoff volumes by the percentage of public sewers that are combined, we can estimate the volume that drains to storm overflows.

Understanding the managed volume allows us to assess the performance of each storm overflow on average. While volume does not directly translate to the average number of discharges, it serves **as a stronger proxy for storm overflow performance than using regional water company rainfall.** It also bears a stronger relationship as to why **different water companies have a different baseline position on discharge frequency**.

Analysis was carried out for years 2021-2023 using EDM returns to understand the rainfall runoff entering the combined system at an EDM level, as opposed to a water company regional level, during that period. The steps that were followed in the methodology adopted is set out at the end of this section.

The analysis uplifted the annual regional water company rainfall averages by a factor which accounted for the rainfall that fell in MSOAs that have EDMs present. This is to be more representative of the rainfall and associated runoff that fell in EDM catchments. This is so that, for example, rain that fell in less urbanised areas were not skewing regional water company annual rainfall statistics e.g. areas with high topography. By using company statistics on the proportion of combined sewers allowed for cross company comparison.

The runoff volumes generated in these combined sewered areas are then normalised based on data in APR24 returns as follows and illustrated in the figures that follow:

- Rainfall runoff entering the combined system - per storm overflow (m^3/storm overflow)
- Rainfall runoff entering the combined system - per discharge that occurred (m^3/discharge)[2]
- Rainfall runoff entering the combined system - per storm overflow – sensitivity tested with 25% and 50% foul sewer connected (m^3/storm overflow)
- Rainfall runoff entering the combined system per discharge that occurred - sensitivity tested with 25% and 50% foul sewer connected (m^3/discharge)

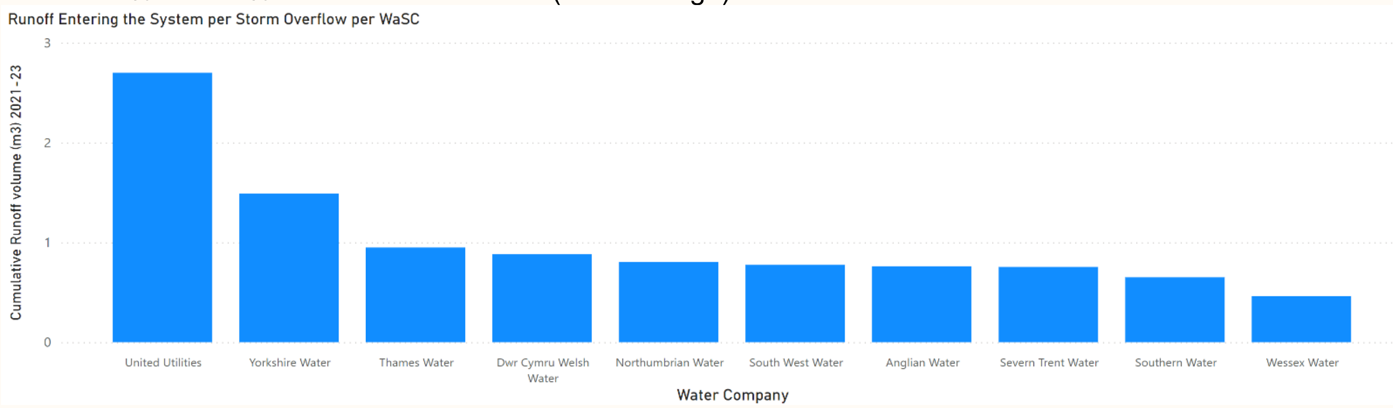


Figure 12: Comparative analysis of cumulative runoff entering combined sewers in EDM MSOA catchment areas per storm overflow (2021-23)

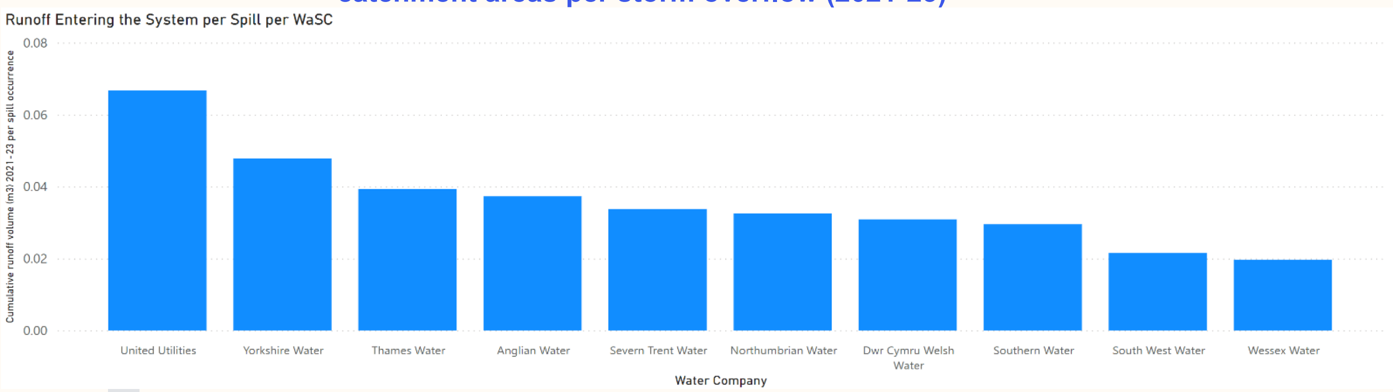


Figure 13: Comparative analysis of cumulative runoff entering combined sewers in EDM MSOA catchment areas per discharge that occurred (2021-23)

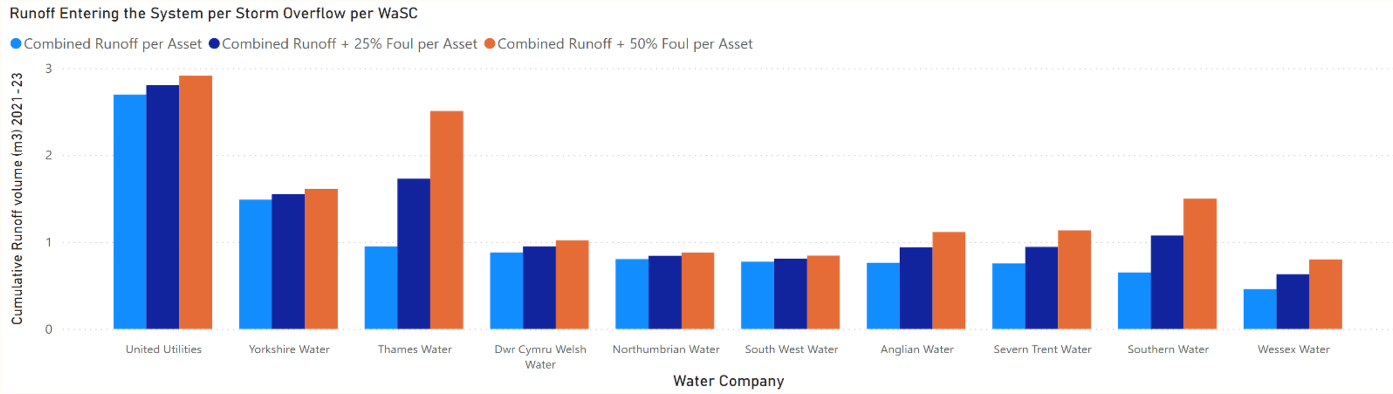


Figure 14: Runoff entering combined sewers from EDM MSOA rainfall areas per storm overflow – sensitivity test (2021-23)

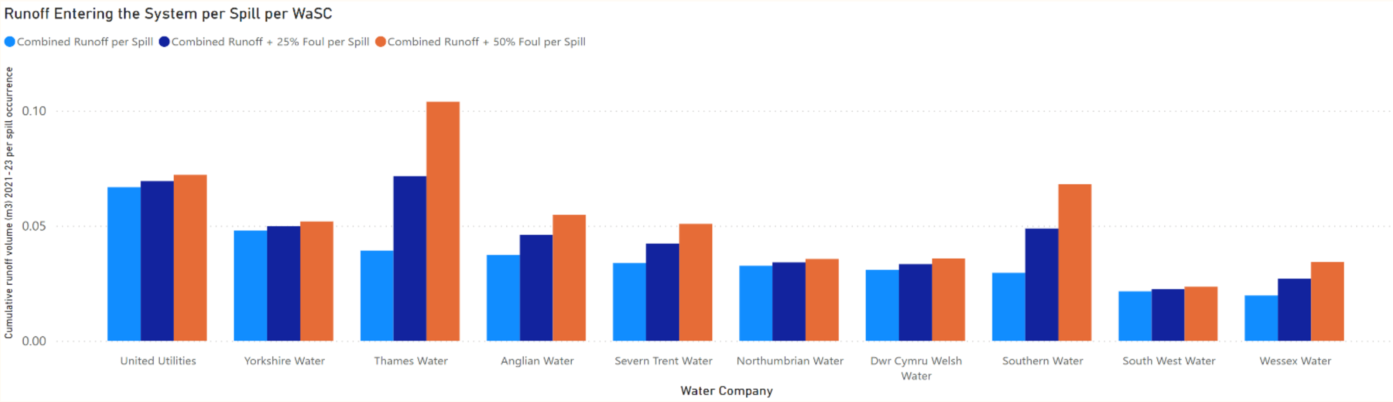


Figure 15: Comparative analysis of cumulative runoff entering combined sewers in EDM MSOA catchment areas per discharge that occurred – sensitivity test (2021-23)

The results show that Yorkshire Water are placed second in the industry in terms of the volume that must be managed within our combined sewer networks taking account of where the rainfall falls in our region. These factors are compounded by our combined sewer legacy and housing stock age and are valid reason for seeking a higher AMP8 entry point due to these historic and exogenous factors. Taking this analysis a step further, by using our sewer records within each MSOA to calculate the percentage of combined sewer, (as opposed to a regional company level percentage of combined sewers) a more granular analysis can be observed. Figure 16 shows that by using more catchment specific datasets that the total discharge frequency during the period 2021-23 directly correlates with the volume of runoff which must be managed.

This is a function of the density of combined sewers at each storm overflow, the rainfall in that area, and are inextricably linked to our historic starting position.

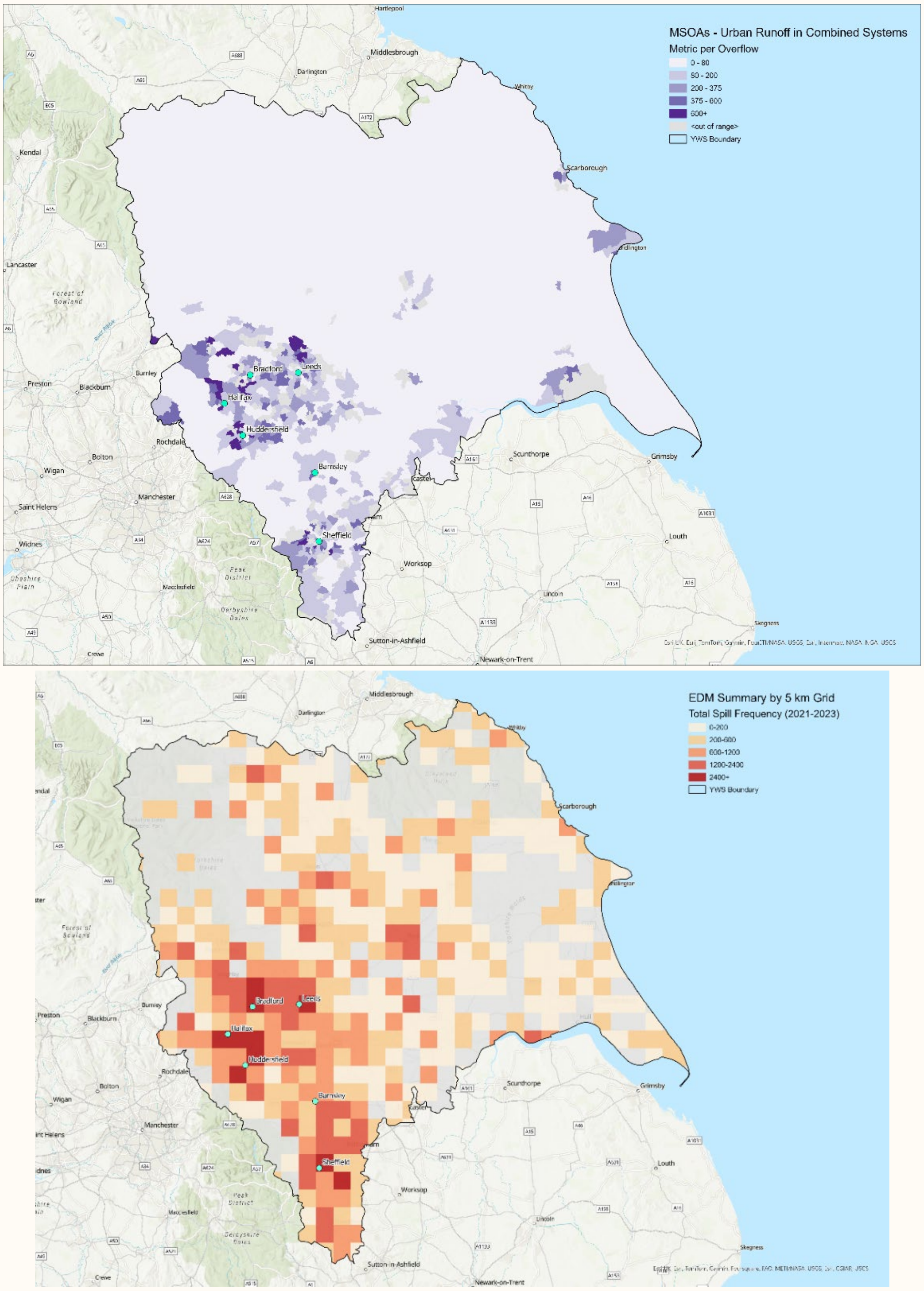


Figure 16: Correlation between combined sewer runoff, using our sewer records for each MSOA, and the total EDM discharge frequency in the period 2021-23.

As we approach AMP8, the existing volume management requirements create a less favourable entry point compared to other regions. This disadvantage necessitates more extensive and costly interventions to meet the new statutory drivers and fixed discharge frequency targets mandated by recent legislation. Consequently, Yorkshire Water must prioritise innovative and efficient solutions to address these challenges and ensure compliance with evolving environmental regulations.

Suggested dependant factors to understand storm overflows

Our analysis indicates that to better understand storm overflow performance and to compare across water company regions, more granular datasets are required to truly understand the reasons discharges occur which are linked to exogenous factors and our respective starting positions. These suggested factors are:

1. rainfall at a higher and more spatially consistent resolution (5km² grid squares or less)
2. the elevation of that area
3. the percentage of combined sewers within that area
4. amount of impermeable area generating runoff.

These factors all help to determine the runoff volume that must be managed. Statistical distributions could then be compared to better understand storm overflow performance for each water company and the extent those exogenous variables contribute to setting targets.

EDM Rainfall Runoff Methodology

1. Using Ofwat's PR24-DD-Urban MSOA rainfall derivation dataset (available at: https://www.ofwat.gov.uk/regulated-companies/price-review/2024-price-review/draft-determinations-models/).
2. To calculate the impermeable area at each MSOA level, Ofwat designate an MSOA as either Fully Urban or Not Urban. This value is then multiplied by the percentage that the MSOA lies within the Water Company Boundary (as many MSOAs overlapped into more than one water company). This area for each MSOA for each water company was aggregated to a give a water company impermeable area value, then multiplied by the yearly rainfall value for each MSOA. This was then averaged over the water company area.
3. This gave a water company share of urban MSOA runoff (million m^3) extracted for the 3 years of EDM returns – 2021, 2022, 2023 from the tab – "Pivot – company urban rainfall".
4. We then applied permeability factors which were supplied from previous work by Arup for OFWAT at a water company regional scale (as opposed to individual MSOA scales). This factor gives an urban rainfall runoff volume (million m^3) that wasn't lost to the ground and contributed to storm overflow rainfall runoff.
5. EDM locations were plotted against MSOAs to ascertain the average rainfall that fell on EDM locations. This was compared against the average rainfall for Yorkshire Water's region each year and a dimensionless uplift factor was applied to the annual rainfall to account for the rainfall that fell in EDM areas.
6. The percentage of combined sewers originated directly from APR24 tables.
7. For sensitivity tests, i.e. the impact of 25% and 50% is calculated as the percentage combined + not combined = (Combined proportion) + (0.5 * Foul proportion * (0.25 or 0.5)).
8. The EDM discharge frequency comes from annual EDM returns. An average discharge frequency is calculated from the total discharge frequency and the annual return. This is then interpolated linearly at the same average discharge frequency for the total number of storm overflows from APR24 to give an approximated equivalent discharge frequency for 100% monitor coverage. This is an adjusted discharge frequency.
9. The graphs are created from the following calculations
    a. Rainfall runoff entering the combined system per storm overflow (m3/storm overflow)
        i. [Urban runoff accounting for permeability and combined systems * EDM location rainfall uplift factor] / Total Number of Storm Overflows
        ii. [Urban runoff accounting for permeability and combined systems with 25% foul uplift * EDM location rainfall uplift factor] / Total Number of Storm Overflows
        iii. [Urban runoff accounting for permeability and combined systems with 50% foul uplift * EDM location rainfall uplift factor]/ Total Number of Storm Overflows
    b. Rainfall runoff entering the combined system per discharge that occurred (m3/discharge)
        i. [Urban runoff accounting for permeability and combined systems * EDM location uplift (more or less rain in EDM regions)]/Number of Total Discharges
        ii. [Urban runoff accounting for permeability and combined systems with 25% foul uplift * EDM location uplift (more or less rain in EDM regions)]/Number of Total Discharges
        iii. [Urban runoff accounting for permeability and combined systems with 50% foul uplift * EDM location uplift (more or less rain in EDM regions)]/Number of Total Discharges

Update to Business Plan Econometric Modelling Target

As set out in our PR24 detailed performance commitment appendix, we previously designed an econometric modelling framework to help determine Yorkshire Water's appropriate PCL targets.[3] YKY-PR24-DDR-58-Adjusted-PCL-Storm-overflows

Specifically, our models estimated the expected performance of a company with our unique regional circumstances.

Our previous analysis suggested that Yorkshire Water should receive a target of between 26.7 and 37.3 discharges per year per storm overflow on average (rather than the common target of 20 discharges).

For our storm overflows econometric model, we have updated the following variables:

- Average number of discharges per storm overflow using the latest EDM storm overflow annual return 2023 data.
- Annual urban rainfall data by using the previous year's growth rate to create a projection for the calendar year 2023.
-

Using our preferred model specification (Model 7, for both OLS and RE), the results indicate Yorkshire Water should receive an adjusted PCL of **between 26.5 and 36.5 discharges per year per storm overflow on average** (relative to 26.7 and 37.5 discharges per storm overflow in our previous analysis). This highlights very little change in our AMP8 starting position utilising the latest updated datasets.

YKY-PR24-DDR-58-Adjusted-PCL-Storm-overflows