Appendix

YKY47_Oxera cost adjustment claims analysis

An assessment of Yorkshire Water's cost adjustment claims

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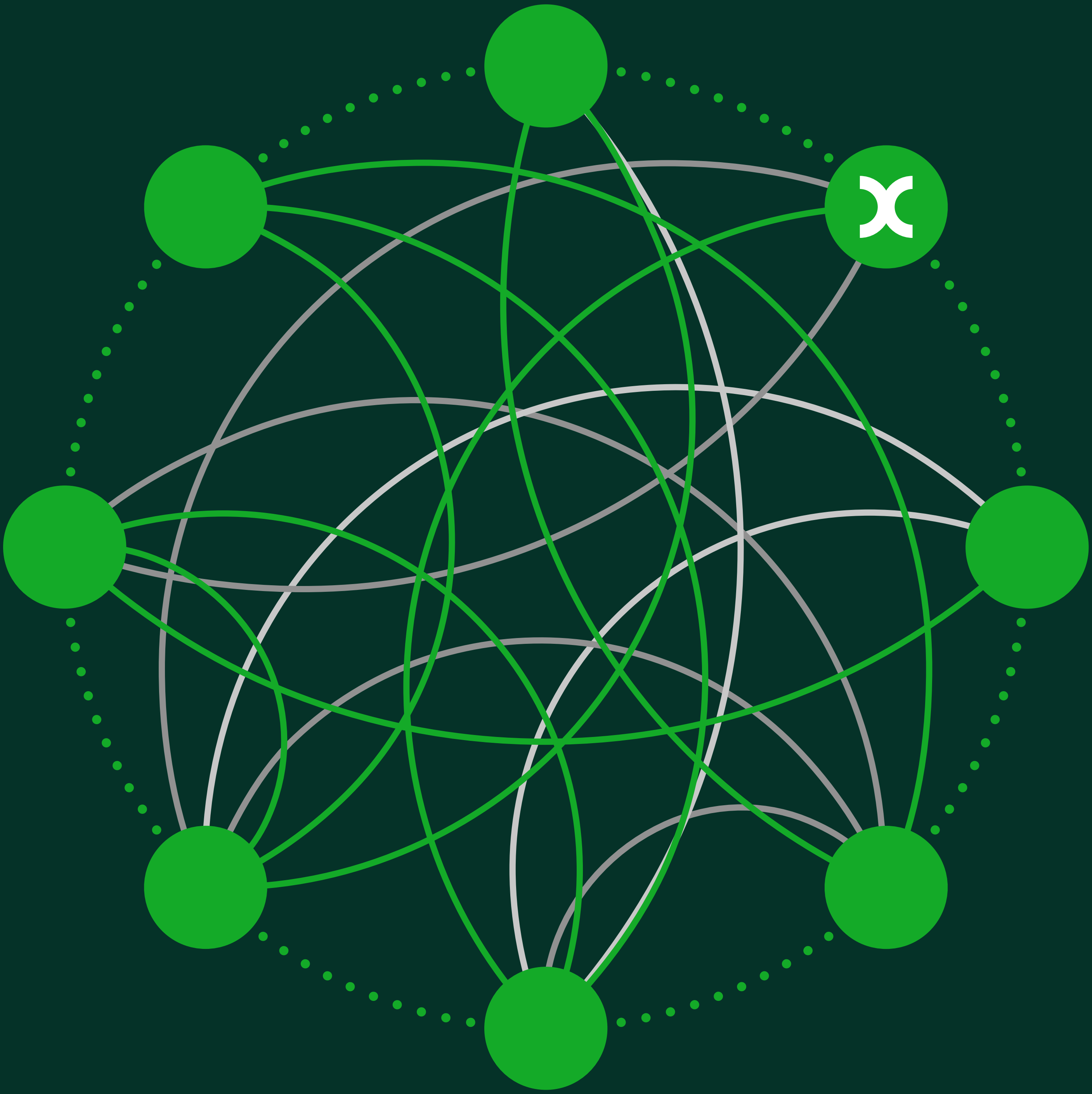
Prepared for Yorkshire Water Services

28 September 2023



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Executive summary

Ofwat uses econometric cost modelling as the principle method for assessing companies' efficient base expenditure requirements. As the econometric models need to explain industry-wide costs in a heterogeneous sector,[1] Ofwat has observed that some company-specific cost pressures may not be adequately reflected in its core models. This could be because, for example: (i) relevant cost drivers are omitted from the cost models; (ii) the cost drivers are 'high-level' and may capture industry-wide cost pressures adequately, but not the specific features of individual companies; or (iii) there is an anticipated step change in activity over AMP8 that is inadequately represented in the outturn data.

To address this, Ofwat allows companies to submit cost adjustment claims (CACs), whereby it can make post-modelling adjustments to companies' estimated efficient expenditure requirements to reflect characteristics that are inadequately captured by the core models. Ofwat has noted that CACs could receive a 'symmetrical' treatment insofar as a CAC affects companies' cost allowances positively and negatively.

Yorkshire Water Services (YWS) has commissioned Oxera to provide top-down evidence to support the CACs that it has submitted on Ofwat's PR24 consultation models in relation to combined sewers and phosphorus removal (P-removal), and to assess the evidence submitted by other companies to support their respective CACs.

Combined sewers

Combined sewers is an operationally relevant cost driver as such sewers require additional maintenance given that they are more prone to sewer flooding than separate sewers for foul and surface water. Its prevalence is also largely outside of management control, since these sewers were installed before privatisation, and it is difficult and costly to change the structure of a company's sewerage network. YWS has the second-highest proportion of combined sewers[2] in the industry and is,

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[1] For example, there are significant differences in the scale of companies in the English and Welsh water sector. In 2023, the smallest company served c. 40 times fewer properties than the largest company.

[2] We note that the company with the highest proportion of combined sewers in the industry (United Utilities) submitted a related claim in the CAC consultation.

therefore, materially affected by Ofwat's decision to not include combined sewers as a cost driver in its PR24 consultation models.

In the PR24 modelling consultation, Ofwat argued that the inclusion of combined sewers in the cost assessment models could 'perversely incentivise companies not to separate sewers into surface water and foul [water]'.[3] Therefore, Ofwat proposed to use urban rainfall as a cost driver instead of combined sewers, arguing that it captures a similar impact while being more exogenous (i.e. outside the companies' control). Ofwat's arguments for the exclusion of combined sewers is poorly motivated as: (i) companies cannot influence their asset base in the short run; and (ii) urban rainfall and combined sewers capture different cost pressures, and should not be considered substitutes.

On the first point, we note that Ofwat has used cost drivers that are measures of assets (and, therefore, can be influenced by companies in the long run) in its cost assessment models for successive price controls, and in the draft models that it presented in the PR24 consultation. In line with Ofwat's modelling principles, it can be appropriate to control for asset-based cost drivers (including combined sewers) providing that they are exogenous in the short term.[4]

To illustrate the short-term exogeneity of combined sewers, one would expect companies to reduce the length of their combined sewers in order to perform better in Ofwat's cost modelling as the cost impact of combined sewers is not accounted for in Ofwat's cost assessment framework. However, the proportion of combined sewers across the industry has been static over the modelling period (2012–23).[5] That is, despite the incentive to reduce the length of combined sewers, companies have been unable to do so, indicating that the risk of endogeneity is limited.[6]

On the second point, Ofwat argues that the inclusion of urban rainfall (which is intended to capture costs associated with increased flooding risk) in some of its PR24 consultation models means that combined

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[3] Ofwat (2023), 'Econometric base cost models for PR24', April, p. 45.

[4] See Ofwat (2021), 'Assessing base costs at PR24', December, section 2.3.

[5] The industry has reduced the proportion of combined sewers by only 0.02–1.60 percentage points, with an industry average reduction of 0.57 percentage points.

[6] In principle, it might be possible to test whether combined sewers are exogenous in a statistical sense. Such analysis requires the identification of an 'instrumental variable'—a variable that is correlated with combined sewers but is known to be exogenous and otherwise has no impact on companies' costs. In principle, the proportion of combined sewers at privatisation would be a valid instrument—it is exogenous to current companies' management and should have a strong correlation with the current level of combined sewers, given that few combined sewers have been installed since privatisation. However, such data is not publicly available.

sewers (which can also capture costs associated with increased flooding risk) is not required. This line of reasoning is incorrect—the observation that the two drivers may capture similar characteristics does not indicate that controlling for one driver negates the need to control for the other. Indeed, this argument is inconsistent with Ofwat's P19 models, where, for example, Ofwat controlled for both population density and STW size in its bioresources models, even though both cost drivers were intended to capture the cost impact of STW-level economies of scale.[7]

Ofwat's argument appears to rest on the assumption that an appropriate approach to model development is to group cost drivers into different categories depending on how the drivers are expected to influence costs (e.g. scale, complexity, topography), and then to select one cost driver from each category to construct a model. In the current context, Ofwat has grouped combined sewers and urban rainfall into the same category (i.e. 'costs associated with flooding'). However, the two cost drivers could equally have been grouped into different cost categories (e.g. 'climate and weather' and 'network complexity'), in which case there would be no reason ex ante to exclude combined sewers from a model that controls for urban rainfall.

On the current dataset, we note that urban rainfall and combined sewers are not strongly correlated with each other.[8] Moreover, the two cost drivers perform well when included in the same model on the current dataset—the cost drivers are both statistically significant and are (directionally) aligned with expectations, and the inclusion of both drivers improves model fit. This provides empirical evidence that the two drivers could capture different aspects of costs and can therefore be included in the same model.

Based on the difference between YWS's predicted costs over AMP8 in Ofwat's consultation models with and without combined sewers, we calculate a claim value of £17.6m p.a.[9]

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[7] See Ofwat (2019), 'PR19 final determinations: Securing cost efficiency technical appendix', December, Table A2.2. Ofwat has presented similar models as part of the PR24 modelling consultation—see Ofwat (2023), 'Econometric base cost models for PR24', April, Table 7.15.

[8] The correlation coefficient is c. 0.4.

[9] This estimate is based on an upper-quartile benchmark. The determination of the appropriate benchmark requires further work, and indeed, the upper-quartile benchmark is the more stringent of the two benchmarks presented in our base modelling report. See Oxera (2023), 'An assessment of Yorkshire Water Services' base cost requirements', section 4.

Phosphorus removal

YWS is facing, and will continue to face, tightening phosphorus-consent (P-consent) levels, due to the Water Industry National Environment Programme (WINEP). This requires a material increase in P-removal activities. The new and different treatment processes necessarily result in higher operating expenditure (OPEX),[10] and the drivers of this increased OPEX are outside of management control. On the basis of bottom-up analysis, YWS has estimated that it will need to increase its annual expenditure by c. £26.3m in order to meet these tighter P-consent levels.

P-removal activity is not explicitly included as a cost driver in Ofwat's PR24 consultation models. Moreover, the industry as a whole has not undertaken a significant amount of P-removal activity in the outturn data. Therefore, P-removal activity may be inadequately funded through the PR24 consultation models. Indeed, Ofwat itself has acknowledged this and is exploring an appropriate cost-modelling adjustment for increased P-removal activity.[11]

The most direct approach to account for the additional expenditure associated with P-removal activities would be to include a P-removal cost driver in Ofwat's proposed models. On the current dataset, as noted above, expenditure relating to P-removal activity accounts for only a small proportion of the modelled costs. As such, it is not feasible to estimate robust models with P-removal activity as an additional cost driver.[12] However, as there has been some (albeit limited) P-removal activity across the industry, the models will implicitly fund a certain level of such activity even if a P-removal cost driver is not included.

We have calculated the implicitly funded level of P-removal activity based on the average P-removal activity observed in the historical data.[13] On the basis of this analysis, c. 16% of YWS's bottom-up estimate (c. £26.3m p.a.) is implicitly funded by the models, and the remaining c. 84% (c. £22m p.a.) is not funded through the models.[14] In other words,

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[10] The increased P-removal activity may also increase base capital expenditure (CAPEX) requirements (e.g. maintenance expenditure) in the medium run.

[11] Ofwat (2023), 'Econometric base cost models for PR24', April, p. 41.

[12] This might change once forecast data for AMP8 becomes available.

[13] Specifically, we have constructed a weighted average P-removal activity variable, based on the assumption that P-removal at a consent level below 0.5mg/l is three times as expensive as P-removal at a consent level above 0.5mg/l. This assumption is supported by YWS's operational evidence. The industry average is calculated over the last five years (2019–23), aligned with how Ofwat estimated the benchmark at PR19.

[14] A key assumption of this analysis is that P-removal activity is not captured by the cost drivers included in the PR24 consultation models.

the net CAC value on the basis of YWS's bottom-up estimate is c. £22.03m p.a. based on this analysis.

To assess the efficiency of YWS's bottom-up estimate of the incremental costs associated with P-removal activity, we have considered two sources of evidence.

1. **Modelling at the level of sewage treatment works (STW).** Companies are required to report data at the treatment plant level regarding the expected incremental costs (OPEX) associated with increasing P-removal activity for affected treatment plants in table 7F of the annual performance reports (APRs). This data can be used to estimate the relationship between costs and P-removal activity at the treatment plant level, which can be aggregated to a company-level adjustment.
2. **Amendments to the PR24 consultation models.** As noted above, P-removal activity cannot be robustly captured in Ofwat's PR24 consultation models as a separate cost driver. In order to account for P-removal activity, we have replaced Ofwat's current complexity variable (ammonia-removal, N-removal) with a composite complexity variable that also accounts for P-removal activity.[15]

Regarding the second source of evidence, the construction of a composite complexity variable requires assumptions regarding the relative cost impact of P-removal and N-removal activity. We understand from YWS that the cost of P-removal activity (at a consent level below 0.5mg/l) is approximately half the cost of N-removal activity (at a consent level below 3mg/l). This observation is supported by evidence from STW-level modelling of large treatment works. Therefore, we have constructed the composite complexity variable as the weighted sum of P-removal and N-removal activity, with P-removal receiving half the weight of N-removal.

The table below compares the net CAC under each of these modelling approaches with YWS's bottom-up estimate.

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[15] Such composite measures are commonly used in regulatory applications to mitigate the practical challenges associated with modelling a large number of cost drivers. For example, Ofwat's weighted average complexity variable can be seen as a composite complexity variable, as can Ofgem's modern equivalent asset value (MEAV) cost driver and its composite scale variables (CSVs). Each of these examples require an aggregation of different variables into a single metric through relative weighting which involves some assumptions regarding each driver's relative impact on costs.

Claim value relating to P-removal by estimation method

	Net claim value (£m p.a.)
YWS's bottom-up estimate (excluding implicit allowance)	22.03
STW-level modelling	19.76
Amendments to the PR24 consultation models	48.82

Note: Expenditure is expressed in 2022/23 prices.
Source: Oxera analysis.

The table shows that YWS's bottom-up estimate of £22.0m falls towards the lower range of our top-down estimates of £19.7m–£48.8m. Therefore, YWS's CAC (which is derived from bottom-up analysis) can be considered to be broadly aligned with the results from our analysis.

As this CAC relates to an increase in activity in AMP8 relative to outturn activity, the analysis presented here can be further validated and refined once the PR24 business plans are published.

Review of other companies' CACs

Given Ofwat's intention for the CAC process to be more symmetrical at PR24, CACs submitted by other companies may affect YWS's efficient cost allowance if they are approved by Ofwat. In the absence of companies' final CAC submissions, which could be published as part of the business plans, we have reviewed the draft CACs submitted by companies in the April 2023 consultation.[16]

From our review of the draft CACs that we have focused on as part of this report, we consider that they fall into one or more of the three categories set out below.

- **Overlap with YWS's own CACs.** For some CACs, there is significant overlap with YWS's own CAC submissions. If Ofwat were to adjust YWS's efficient cost allowance on the basis of both YWS's CAC and these other companies' CACs, it may double-count the impact of the issues.

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[16] See Ofwat (2023), 'Cost adjustment claims – June 2023', June, available at: https://www.ofwat.gov.uk/regulated-companies/price-review/2024-price-review/data-tables-and-models/cost-adjustment-claims-june-2023/.

- **Forward-looking adjustments.** Some CACs relate to expected increases in expenditure in AMP8, such as on network reinforcement or growth enhancement. These are forward-looking expenditures, and the extent to which they should be considered symmetrical will depend on the activity that other companies' propose in their business plans. Without sight of others' business plans, it is not possible to state whether the CACs will be symmetrical.
- **Does not meet evidentiary standards.** These CACs do not, at this stage, present robust evidence that a cost adjustment is required, or that it has been robustly quantified. For example, the econometric models submitted by companies to support their claims might have weak operational or statistical evidence, or the bottom-up evidence to support the claims might have no external challenge, thereby requiring further development.

Therefore, at this stage we consider that YWS's allowance should not be adjusted on the basis of the draft CACs that we have reviewed. However, the allowance will need to be reviewed in light of new evidence that may be presented by companies in their business plan submissions.

Overall view of CACs

The table below summarises the necessary adjustments to YWS's efficient baseline expenditure if Ofwat maintains its PR24 consultation models.

Summary of CACs

	Net claim value (£m p.a.)	Net claim value (£m AMP8)[1]
Combined sewers	17.62	88.11
P-removal—YWS's bottom-up estimate	22.03	110.13

Note: [1] The AMP8 values may not amount to exactly five times the corresponding p.a. values due to rounding. Expenditure is expressed in 2022/23 prices.
Source: Oxera analysis.

1 Introduction

Ofwat uses econometric modelling of costs as the principal instrument to assess companies' efficient base expenditure requirements. The wholesale cost models that Ofwat has developed as part of the PR24 base cost modelling consultation seek to account for the heterogeneity across the industry primarily with respect to scale, treatment complexity, pumping requirements and population density. However, it is well understood that some specific drivers (recurring ones, as well as new drivers) of companies' expenditure may not be sufficiently accounted for in these cost assessment models—a company could appear to be inefficient (or efficient) on the basis that it suffers (or benefits) from a characteristic that is not properly accounted for. As such, Ofwat has a cost adjustment claim (CAC) process whereby it can make post-modelling adjustments to companies' estimated efficient expenditure requirements to reflect well-evidenced characteristics that are omitted or inappropriately reflected in the models.

Ofwat has provided some guidance on how it will assess CACs at PR24, as well as the type of evidence that companies need to support their claims. The first stage in the process of submitting CACs was for companies to respond to the CAC consultation by 9 June 2023, and Ofwat shared via its website the CACs that companies submitted.[17]

Yorkshire Water Services (YWS) has commissioned Oxera to provide additional top-down evidence to two of the CACs that it submitted as part of the consultation. These CACs relate to the relative prevalence of combined sewers on YWS's sewerage network and (separately) the anticipated increase in phosphorus removal (P-removal) activity in AMP8. YWS has further asked Oxera to assess whether YWS's allowances may need to be adjusted (upwards or downwards) to account for the impact of the CACs submitted by other companies as part of the consultation.

The report is structured as follows.

- Section 2 analyses evidence on YWS's CAC relating to combined sewers.

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[17] See Ofwat (2023), 'Cost adjustment claims – June 2023', June, available at: https://www.ofwat.gov.uk/regulated-companies/price-review/2024-price-review/cost-adjustment-claims-june-2023/.

- Section 3 analyses evidence for YWS's CAC relating to P-removal.
- Section 4 evaluates the CACs submitted by other companies that may have a material impact on YWS.

2 Combined sewers

The sewerage network is designed to transport both surface water (e.g. water from rainfall) and wastewater (or 'foul'). The network can have either separate sewers for surface water and foul, or one network comprising of combined sewers. Historically (i.e. pre-privatisation), combined sewers were often installed because combined sewers in principle require less space (given that only one pipe is required as opposed to two separate pipes for surface water and foul).

However, during high rainfall events, the combined sewers can exceed their design capacity, leading to blockages, partial collapses and flooding incidents. In order to prevent such incidents, additional infrastructure can be required (such as storage tanks) to store and divert excess flows, which increases the complexity and associated costs of the sewerage network. Given the additional costs of combined sewers, it is now more common for companies to install separate networks for surface water and foul water.

At PR19, Oxera proposed models that accounted for combined sewers.[18] Several companies also submitted models that control for combined sewers as a cost driver in the PR24 modelling consultation.[19] This indicates that there is at least some support from across the industry for accounting for combined sewers in the assessment of companies' costs.

However, in the PR24 modelling consultation, Ofwat argued that the inclusion of combined sewers in the cost assessment models could 'perversely incentivise companies not to separate sewers into surface water and foul [water]'.[20] Therefore, Ofwat proposed to use urban rainfall as a cost driver instead of combined sewers, arguing that it captures a similar impact while being more exogenous (i.e. outside the companies' control). Ofwat's arguments for the exclusion of combined sewers are poorly motivated as: (i) companies cannot influence their asset base in the short run; (ii) urban rainfall and combined sewers

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[18] For example, see Oxera (2018), 'Independent assessment of Yorkshire Water's historical cost performance and consideration of its AMP7 cost adjustment claims in this context', August, section 2.3.2 and appendix A2.
[19] Defined as 'km, Length of combined public sewers' divided by 'km, Total length of legacy public sewers as at 31 March'.
[20] Ofwat (2023), 'Econometric base cost models for PR24', April, p. 45.

capture different cost pressures, and should not be considered substitutes.

On the first point, Ofwat uses 'asset-based' cost drivers across its modelling suite, where companies have some control of the driver in the long run but not in the short run, including:

- the length of the water network in Ofwat's treated water distribution (TWD) models;
- the length of the sewer network in Ofwat's sewage collection costs (SWC) and wastewater network plus (WWNP) models;
- the size of treatment works in Ofwat's sewage water treatment (SWT), WWNP and bioresources (BR) models;
- the number of booster pumping stations in Ofwat's TWD and WW models.

Note that the use of asset-based cost drivers is not limited to the water sector in England and Wales. For example, Ofgem makes extensive use of asset-based cost drivers in its cost assessment models for energy distribution networks.[21] Indeed, it is common-place across sectors and jurisdictions for regulators to incorporate asset-based cost drivers into their cost assessment models.[22] Therefore, there is extensive precedent for using asset-based cost drivers both within the English and Welsh water sector and in other sectors and jurisdictions.

We consider Ofwat's argument—that companies may be incentivised to invest in combined sewers to receive higher cost allowances—to be unrealistic. In the current context, combined sewers are associated with higher costs, yet these high costs are not reflected when setting cost allowances. Indeed, replacing combined sewers with separate sewers for foul and surface water could increase the total length of the network, thereby leading to higher cost allowances in Ofwat's cost modelling. Therefore, if combined sewers were indeed endogenous in the short run, companies would have had strong incentives to reduce their number of combined sewers (e.g. by replacing them with separate surface water and foul water sewers) in order to perform better in the cost assessment models and achieve higher returns. The figure below

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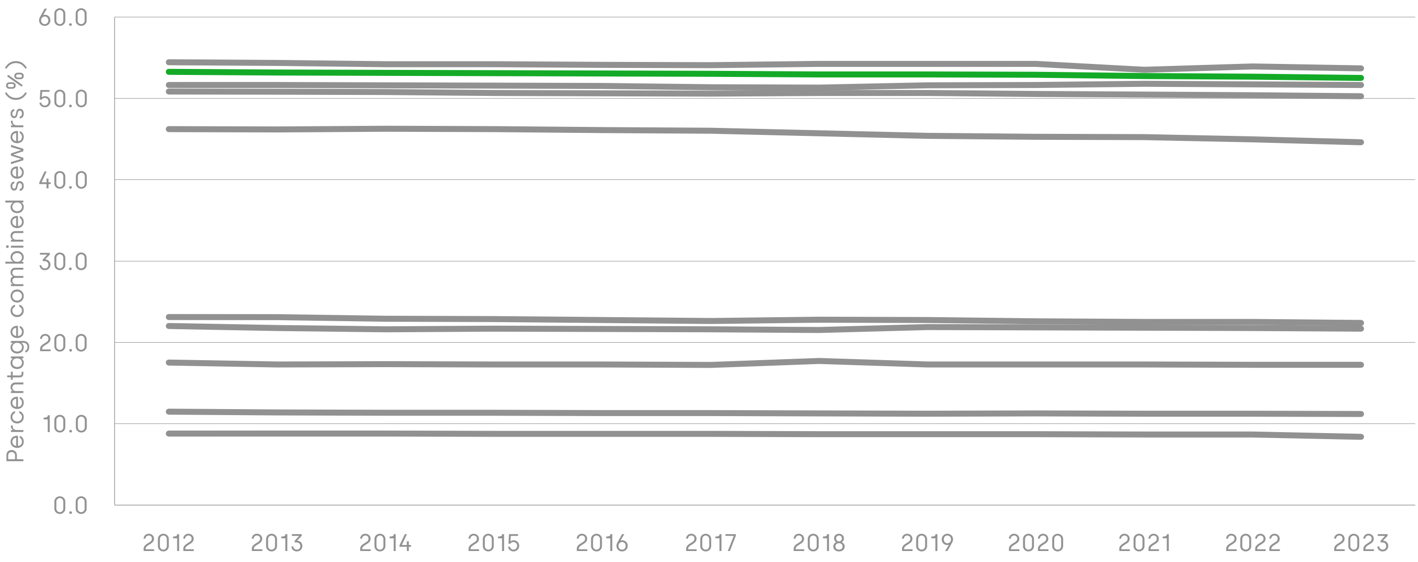
[21] For example, Ofgem uses Modern Equivalent Asset Value (MEAV) as one of the cost drivers in its cost models. MEAV is defined as the weighted sum of assets, where the weights are based on the replacement value of that asset category. See Ofgem (2022), 'RIIO-ED2 Final Determinations Core Methodology Document', December, table 20.

[22] For example, the Danish Energy Agency uses NormGrid (a weighted sum of assets) as a cost driver in its cost assessment models (see Benchmarking Expert Group (2017), 'Benchmarkingrapport', February).

shows how the proportion of combined sewers has evolved over the modelling period (2012–23).

Figure 2.1 Evolution of combined sewers over time (2012–23)



Note: YWS is shown in green.
Source: Oxera analysis.

The chart shows that the percentage of combined sewers has not materially changed for any company over the last 11 years, indicating that the extent to which companies have any substantial control over this variable is limited. Indeed, they have reduced the proportion of combined sewers by only 0.02–1.60 percentage points, with an industry average reduction of 0.57 percentage points.

This demonstrates that, in the short and medium run, the percentage of combined sewers should be considered exogenous[23] and, by implication, its inclusion in the models would not lead to perverse incentives.

Second, Ofwat argues that the inclusion of other cost drivers, such as urban rainfall, has an impact similar to that of including the percentage

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[23] In principle, it might be possible to test statistically whether combined sewers are exogenous in a statistical sense. Such analysis requires the identification of an 'instrumental variable'—a variable that is correlated with combined sewers but is known to be exogenous and otherwise has no impact on companies' costs. In principle, the proportion of combined sewers at privatisation would be a valid instrument—it is exogenous to current companies' management and should have a strong correlation with the current level of combined sewers, given that few combined sewers have been installed since privatisation. However, such data is not publicly available.

of combined sewers.[24] The rationale behind Ofwat's argument is not clear, but we consider that it may have applied the following logic.

1. Combined sewers are more prone to sewer flooding. As such, the costs associated with having combined sewers are typically related to dealing with sewer flooding.
2. Urban rainfall is also intended to capture the costs relating to sewer flooding.
3. As there is already a cost driver that captures a characteristic that leads to increased sewer flooding (urban rainfall), there is no need to include another cost driver that also captures costs associated with increased sewer flooding (combined sewers).

This line of reasoning is incorrect. The observation that urban rainfall increases sewer flooding says nothing about whether combined sewers also increase sewer flooding—the two cost drivers are not intrinsically related to each other nor can they be treated as proxies or substitutes. For example, at PR19 Ofwat controlled for both population density and STW size in its BR models, even though both cost drivers were intended to capture the cost impact of STW-level economies of scale.[25]

Moreover, we note that all of the cost drivers included in Ofwat's models are 'high-level' and may capture a range of characteristics. For example, controlling for length of mains or sewers as a scale variable may partially capture some of the additional costs associated with operating in a sparsely populated area—for two companies of a similar 'size', one that operates in a sparser region is likely to have greater mains length in total. However, it would be wrong to conclude that population density is not also required in the cost models, simply because part of the cost impact of density/sparsity is already reflected in the scale variable.

Ofwat's argument rests on the assumption that an appropriate approach to model development is to group cost drivers into different categories depending on how the drivers are expected to influence costs (e.g. scale, complexity, topography), and then to select one (and only one) cost driver from each category to construct a model. In the

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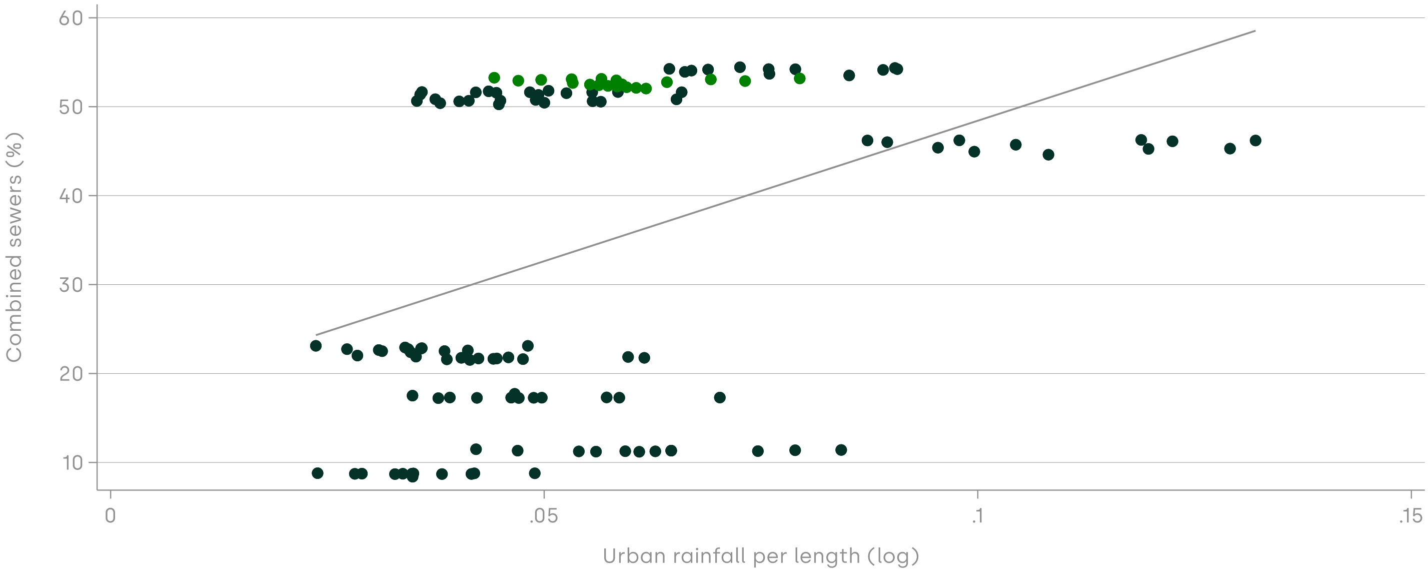
[24] Ofwat (2023), 'Econometric base cost models for PR24', April, p. 45, available at https://www.ofwat.gov.uk/wp-content/uploads/2023/04/Econometric_base_cost_models_for_PR24_final.pdf. Formatted to be consistent with the other reports.

[25] See Ofwat (2019), 'PR19 final determinations: Securing cost efficiency technical appendix', December, Table A2.2. Ofwat has presented similar models as part of the PR24 modelling consultation—see Ofwat (2023), 'Econometric base cost models for PR24', April, Table 7.15.

current context, Ofwat has grouped combined sewers and urban rainfall into the same category (i.e. 'costs associated with flooding'). However, the two cost drivers could equally have been grouped into different cost categories (e.g. 'climate and weather' and 'network complexity'), in which case there would be no reason (ex ante) to exclude combined sewers from a model that controls for urban rainfall. Indeed, the categorisation problem is a fundamental problem with this approach to modelling.

For Ofwat's argument to have some merit, urban rainfall must be (nearly) perfectly correlated with combined sewers. The figure below shows the correlation between urban rainfall and combined sewers.

Figure 2.2 Relationship between urban rainfall and combined sewers (2012–23)



Note: YWS is shown in green.
Source: Oxera analysis.

The figure shows that, although there is some correlation between the urban rainfall and combined sewers, urban rainfall does not capture the variability present in combined sewers across companies.[26] Therefore, urban rainfall cannot be considered as a 'substitute' or a 'proxy' for combined sewers. In the case of YWS, the percentage of combined

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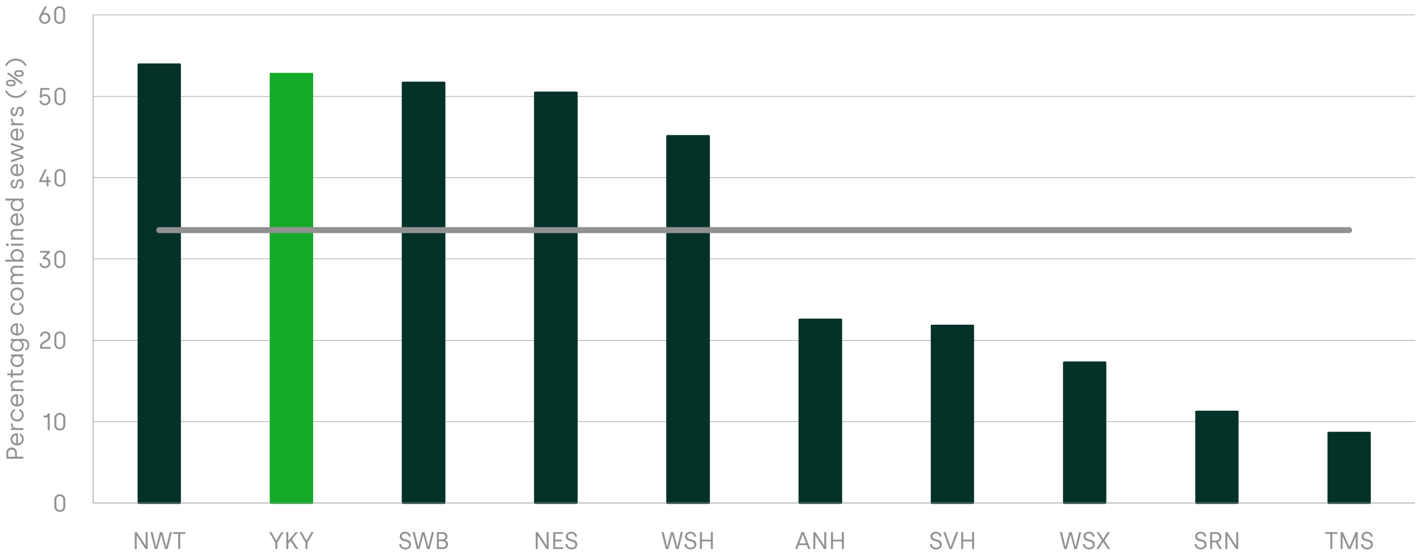
[26] The correlation coefficient is c. 0.4.

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 would lead to biased outcomes for YWS.

2.1 Why is an adjustment required?

The figure below shows the proportion of combined sewers for each WaSC, as well as the industry average.

Figure 2.3 Percentage of combined sewers (2019–23)



Note: The grey horizontal line represents the industry average. YWS is shown in light green.

Source: Oxera analysis.

YWS has the second-highest proportion of combined sewers in the industry (c. 53%), behind United Utilities (NWT).[27] This is c. 19 percentage points above the industry average. Therefore, the observation that combined sewers are not accounted for in the cost models is likely to lead to a downward-biased estimate of YWS's efficiency.

As this CAC relates to an omission in Ofwat's cost models, the most direct approach to addressing this issue would be to include combined sewers as an additional cost driver in Ofwat's cost models. The inclusion

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[27] NWT has also submitted a claim relating to drainage costs, which includes the cost impact of combined sewers and urban rainfall. See section 4.7.

of combined sewers as an additional cost driver in the models will affect all companies' estimated efficient cost predictions.

2.2 Empirical analysis

As noted above, the most direct approach for estimating the cost impact of combined sewers is to include this cost driver explicitly in the PR24 cost models. The table below shows how Ofwat's SWC models perform when combined sewers is included as an additional cost driver.

Table 2.1 SWC models with combined sewers

	SWC1	SWC2	SWC3	SWC4	SWC5	SWC6
Sewer length (log)	0.855***	0.956***	0.932***	0.863***	0.942***	0.919***
Pumping capacity per sewer length (log)	0.418***	0.700***	0.651***	0.404***	0.657***	0.604***
Properties per sewer length (log)	1.124***			1.088***		
Weighted average density—LAD to MSOA (log)		0.273***			0.290***	
Weighted average density—MSOA (log)			0.445***			0.469***
Urban rainfall per sewer length (log)				0.0918***	0.133***	0.129***
Combined sewers (%)	0.291***	0.530***	0.560***	0.202[1]	0.403[1]	0.437*
Constant	-8.936***	-8.007***	-9.294***	-8.582***	-7.529***	-8.889***
R-squared	0.923	0.914	0.916	0.920	0.920	0.920
RESET test	0	0.000486	0.000217	0	5.33e-05	1.92e-05
VIF	3.038	2.274	2.326	3.039	2.322	2.364

Note: [1] The P-values on the coefficient on combined sewers are 0.14 and 0.12 in models SWC4 and SWC5, respectively.
Source: Oxera analysis.

The inclusion of combined sewers as a cost driver leads to an improved model fit in all SWC models, with the improvement ranging from 0.2 percentage points in SWC4 to 2.2 percentage points in SWC3. Moreover, the coefficient on combined sewers is positive (directionally in line with operational expectations) in all specifications and statistically significant in four of the six specifications. Where the coefficient is statistically insignificant, the p-value on the coefficient is close to the 10% level.

Note that models SWC4–SWC6 include urban rainfall, which Ofwat argues capture a similar effect in the models. Nevertheless, the coefficient on combined sewers is still statistically significant (or close to) in all three of the models. Moreover, the VIF statistic (Ofwat's preferred measure of multicollinearity) for these models is always materially below Ofwat's threshold of 10, pointing to little collinearity among the independent variables. The observation that both urban rainfall and combined sewers are positive and statistically significant (or close to), and that the models do not suffer from strong multicollinearity concerns, suggests that the two cost drivers capture different operational characteristics.

The table below shows the equivalent analysis for the WWNP models.

Table 2.2 WWNP models with combined sewers

	WWNP1	**WWNP2**	**WWNP3**	**WWNP4**	**WWNP5**	**WWNP6**	**WWNP7**	**WWNP8**
Load (log)	0.720***	0.814***	0.838***	0.772***	0.706***	0.799***	0.828***	0.761***
Pumping capacity per sewer length (log)	0.470***	0.505***	0.493***	0.400***	0.438***	0.475***	0.460***	0.358***
Proportion of load treated in size bands 1–3 (%)		0.0233***				0.0236***		
Proportion of load treated with ammonia consents <3mg/l (%)	0.00475***	0.00441***	0.00460***	0.00505***	0.00497***	0.00469***	0.00487***	0.00534***
Proportion of load treated at STWs serving >100k people (%)			-0.00496***				-0.00527***	
Weighted average treatment plant size (log)				-0.0838***				-0.0933***
Urban rainfall per sewer length (log)					0.0560**	0.0493**	0.0565**	0.0647**
Combined sewers (%)	0.332***	0.357***	0.437***	0.306***	0.261**	0.292***	0.368***	0.221**
Constant	-4.055***	-5.352***	-5.327***	-3.878***	-3.677***	-4.991***	-4.990***	-3.422***
R-squared	0.952	0.959	0.960	0.959	0.951	0.959	0.960	0.960
RESET test	0.213	0.0462	0.00939	0.0514	0.0188	0.00741	0.000991	0.00192
VIF	4.755	6.204	6.718	4.937	5.152	6.526	6.896	5.220

Source: Oxera analysis.

The coefficient on combined sewers is positive and statistically significant in all WWNP specifications. Moreover, the inclusion of combined sewers leads to an improvement in model fit relative to

Ofwat's models, of between 0.3 percentage points (in WWNP8) and 1.6 percentage points (in WWNP3). The coefficient on combined sewers remains statistically significant even in models that already control for urban rainfall, and the VIF remains below Ofwat's threshold of 10. This indicates that these models do not suffer from strong multicollinearity and that urban rainfall and combined sewers may be capturing different effects in the model.

The table below shows how YWS's allowance is affected by the inclusion of combined sewers in the cost assessment models. We have applied an upper-quartile benchmark to the predicted costs in each suite of models.[28] Therefore, the cost predictions and CAC value can be considered efficient.

Table 2.3 Combined sewers CAC value (£m)

	PR24 models	**PR24 models with combined sewers**	**Difference**
YWS's estimated allowances	1,765.14	1,853.25	88.1

Note: The allowances, presented in 2022/23 prices and estimated using the PR24 models with the inclusion of combined sewers, constitute the gross value of the claim. The allowances associated with the PR24 models yield the implicit allowances. Finally, the difference corresponds to the net value of the claim.
Source: Oxera analysis.

The table shows that the net CAC value relating to combined sewers is c. £88m over AMP8. This is above Ofwat's 1% materiality thresholds for WWNP CACs.

Aligned with Ofwat's modelling guidelines, the implicit allowance is the efficient cost prediction under the PR24 cost models and the gross CAC value is the efficient cost prediction under models that control for combined sewers.

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[28] In our separate report on base cost modelling, we demonstrate that there is significant uncertainty in the models such that a benchmark more stringent than the upper quartile could not be supported by the evidence. Indeed, we identify that less stringent benchmarks (such as the upper tercile and average) may be more appropriate. Therefore, we present these CACs at an upper-quartile benchmark, aligned with precedent from the PR19 redetermination. See Oxera (2023), 'An assessment of Yorkshire Water's base cost requirements', September.

3 Phosphorus removal

YWS is facing, and will continue to face, tightening phosphorus-consent (P-consent) levels, due to the Water Industry National Environment Programme (WINEP). This requires a material increase in P-removal activities. The new and different treatment processes necessarily result in higher operating expenditure (OPEX), and the drivers of this increased OPEX are outside of management control.

This section sets out the rationale for a CAC relating to P-removal (section 3.1), how it can be empirically estimated (section 3.2), and what conclusion can be drawn for the AMP8 base cost assessment from this analysis (section 3.3).

3.1 Why is an adjustment required?

P-consent levels are neither directly included as cost drivers in the modelling suite nor are they sufficiently captured by existing cost drivers. Therefore, companies that are anticipating significant increases in P-removal activity in AMP8 may require an additional cost allowance above that predicted by the PR24 models in order to fund their efficient operations. Indeed, Ofwat highlighted this in its April 2023 consultation on base cost assessment for PR24.

> the additional ongoing cost associated with more stringent phosphorus removal programmes across the sector may not be fully captured in our proposed base cost models.
>
> **Ofwat (2023), 'Econometric base cost models for PR24', April, p. 41.**

To assess the extent to which the models might implicitly capture P-removal activity, we have examined the correlation between P-removal activities and other relevant cost drivers.[29] The table below shows the correlation of the proportion of load treated at P-consent levels below or equal to 0.5mg/l with the cost drivers included in the

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[29] Correlation analysis between an omitted driver and cost drivers included in a cost model cannot provide conclusive evidence on the need for including or excluding the omitted driver, and additional analysis is required in order to reach a definitive conclusion.

relevant SWT and WWNP models developed by Ofwat as part of the PR24 modelling consultation.[30]

Table 3.1 Correlation of proportion of load treated at P-consent levels ≤ 0.5mg/l with relevant cost drivers

Cost driver	**Correlation coefficient**
Load (log)	0.0145
Pumping capacity per sewer length (log)	0.0429
Load treated with ammonia consent ≤ 3mg/l	0.2378***
Load treated in size bands 1 to 3 (%)	-0.1586*
Load treated in STWs ≥ 100,000 people (%)	0.1458
Weighted average treatment size (log)	-0.0455
Urban rainfall per sewer length (log)	0.0062

Note: *** and * show statistical significance at the 1% and 10% levels, respectively.
Source: Oxera analysis of PR24 Cost Assessment Master Dataset, Wholesale Wastewater Base Costs v4, published 5 April 2023, and 2023 Annual Performance Report (APR) tables.

Only the correlations with the cost drivers load treated with ammonia consent ≤ 3mg/l and load treated in size bands 1 to 3 (%) are statistically significant. In addition, the correlation coefficients of 0.2378 and -0.1586 are low in magnitude. All other correlation coefficients have smaller magnitudes and are not statistically significant. Overall, Table 3.1 indicates that the cost drivers in Ofwat's proposed models capture P-removal activities to a limited extent only.[31] This supports Ofwat's statement that the PR24 consultation models do not adequately capture the costs associated with P-removal activity.

Given that P-removal activity is an omitted cost driver, it can be argued that the models implicitly fund companies to deliver average P-removal activity in the industry. As the industry has historically treated a low percentage of load at the stringent P-consent levels, the implicitly funded level is low.

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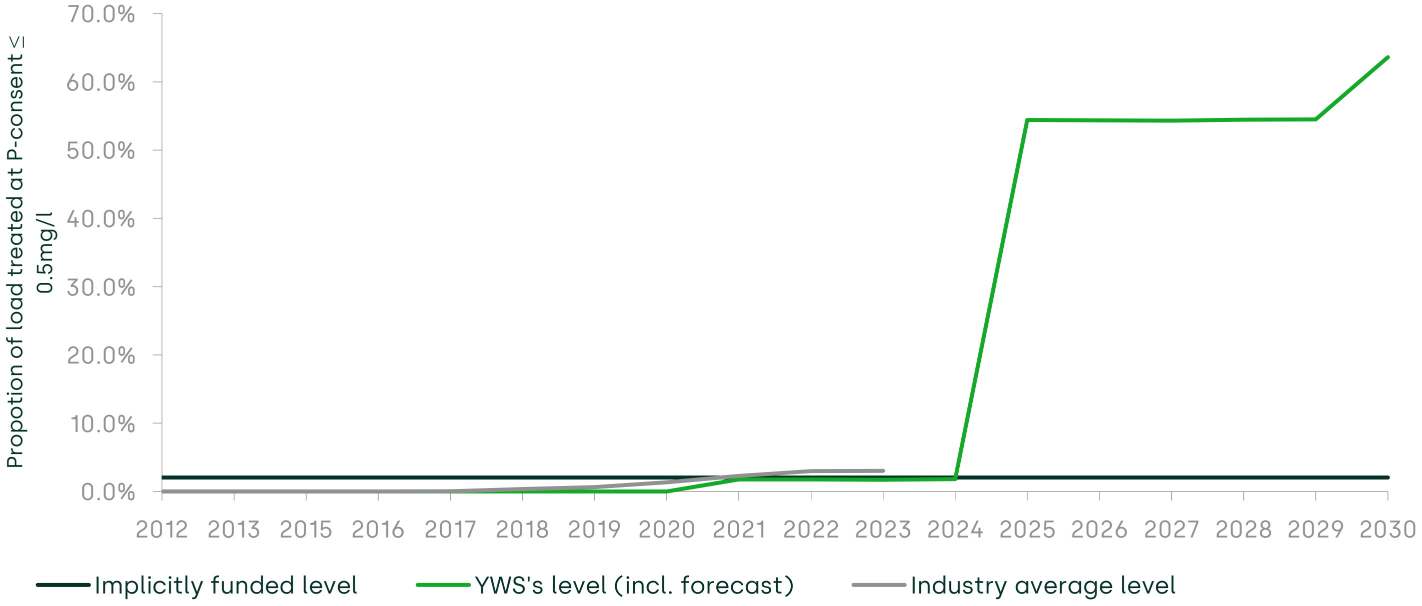
[30] Ofwat (2023), 'Econometric base cost models for PR24', April.

[31] A regression of P-removal activity against the PR24 cost drivers yields a model fit of c. 0.34. That is, the PR24 cost drivers can predict only c. 34% of the historical levels of P-removal activity.

While the models' inability to reflect the costs associated with P-removal is a general modelling issue that could (in principle) affect all companies, YWS, in particular, is materially affected by the omission of P-removal cost drivers, given that it is expecting a significant increase in P-removal activity in AMP8. The figure below shows how YWS's P-removal activity (specifically, the proportion of load treated at P-consent below 0.5mg/l) is forecast to increase in AMP8, relative to the rest of the industry.

Figure 3.1 Historical and forecast P-removal activity



Note: The implicitly funded level reflects implicitly funded P-removal activity based on the five-year industry average for the years 2019 to 2023.
Source: Oxera analysis of PR24 Cost Assessment Master Dataset, Wholesale Wastewater Base Costs v4, published 5 April 2023, 2023 APR tables and YWS forecast data.

Figure 3.1 shows that historical P-removal activity across the industry is low. This means that estimating the cost of P-removal activities using econometric analysis using historical data is difficult because P-removal activities account for only a small share of the relevant cost areas on an outturn basis. In addition, Figure 3.1 shows that YWS expects to materially increase the percentage of load treated at strict P-consent levels from 2024 to 2025, substantially above the implicitly funded level (the dark green line).

YWS's gross claim relates to the forecast additional OPEX that will be incurred due to tightening P-consent levels. Currently, however, YWS's

P-removal activities are below the industry average (as shown in Figure 3.1). We have therefore calculated an implicit allowance based on the proportion of additional P-removal activities that relate to YWS catching up with the implicitly funded industry average. Consequently, the remaining additional OPEX (the proportion going beyond the implicitly funded level) constitutes the net claim.

One method to calculate the implicit allowances and net CAC values is simply to use information provided in Figure 3.1 above. However, this may underestimate the magnitude of the implicit allowance, given that other companies may have been undertaking P-removal activity at less stringent thresholds. We understand from YWS's internal analysis that the cost associated with P-removal activity at a consent level below 0.5mg/l (the most stringent band, included in Figure 3.1 above), is approximately three times as costly as P-removal activity at less stringent thresholds. Therefore, to account for P-removal activity at different thresholds when calculating the implicit allowance, we have constructed a weighted average P-removal variable, where the proportion of load treated with P-consent below 0.5mg/l is given three times the weight as the proportion of load treated at the least stringent P-consent levels.

The table below shows the shares of load treated at P-consent levels below 0.5mg/l and above 0.5mg/l, respectively (during the past five years and as a forecast for AMP8). It also shows the weighted average of these and the calculation of the implicit allowance.

Table 3.2 Calculation of share of claim beyond implicit allowance

Proportion of load treated corresponding to P-consent levels:	**≤0.5mg/l**	**>0.5mg/l**	**Weighted average**
Weights (relative costs based on operational evidence)	3	1	
YWS's current level of P-removal activity	1.0%	2.5%	1.4%
Industry average level of P-removal activity	2.0%	29.8%	9.0%
YWS's AMP8 forecast level of P-removal activity	54.4%	21.3%	47.5%
% of claim relating to meeting implicit allowance			16.4%
% of claim going beyond implicit allowance			83.6%

Note: Current level refers to the average for the years 2019 to 2023. AMP8 forecast refers to the average of YWS's forecast for the years 2026 to 2030. The category >0.5mg/l includes P-removal activity at consent levels above 1mg/l.

Source: Oxera analysis of PR24 Cost Assessment Master Dataset, Wholesale Wastewater Base Costs v4, published 5 April 2023, and 2023 APR tables.

Table 3.2 shows that the weighted average of YWS's load treated at P-consent levels is currently 1.4%, which is expected to increase to 47.5% in AMP8. Given that the industry average of 9% is implicitly funded through the models, c. 16.4% of YWS's gross claim relates to meeting the implicit allowance, while the remaining 83.6% goes beyond it.[32] We have used this insight to calculate a net claim value from YWS's bottom-up estimate of the gross claim value. The result is shown in the table below.

Table 3.3 Claim value based on calculation method

YWS's bottom-up estimate	**Claim value (£m p.a.)**
Gross, before deducting implicit allowance	26.34
Net, after deducting implicit allowance	22.03

Source: Oxera analysis.

The net claim value based on YWS's bottom-up estimate of the gross claim value amounts to 22.0m.

3.2 Empirical analysis

The CAC estimates provided in the preceding section are based on YWS's own bottom-up estimates. However, these estimates (as with all bottom-up estimates) may include an element of inefficiency. Therefore, in this section we explore top-down models to assess whether YWS's proposed costs are efficient when compared with those of the rest of the industry.

A direct method to calculate the CAC using top-down models would be to include a cost driver reflecting P-removal activities in Ofwat's PR24 consultation models. However, as Ofwat noted in the consultation, cost drivers that can account for P-removal activity do not perform well in the cost models—the cost drivers are typically statistically insignificant.

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[32] The exact calculation of the implicit allowance is as follows:

$$(industry\ average\ level - YWS's\ current\ level) : (YWS'sforecast\ level - YWS's\ current\ level)$$

$= (9.0\% - 1.4\%) : (47.5\% - 1.4\%) = 16.4\%.$

As indicated above, this is likely to be due to the lack of historical variation in P-removal activity across the industry.[33]

Given the limitations of the current base modelling dataset, we have considered the following alternative methods in order to estimate the P-removal CAC.

1. **STW-level modelling based on table 7F in the APRs.** Companies are required to report data at the treatment plant level regarding the expected incremental costs (OPEX) associated with increasing P-removal activity for affected treatment plants. This data can be used to estimate the relationship between costs and P-removal activity at the treatment plant level, which can then be aggregated to a company-level adjustment.
2. **STW-level modelling based on APR tables 7B.** Companies are required to report data at the treatment plant level relating to costs, scale (load) and treatment complexity for large treatment plants. Unlike the dataset referred to in method 1 above (which captures only those STWs that are experiencing increases in P-removal activity), this dataset can be used to confirm operational insights into the relative costs of P-removal and ammonia removal (N-removal) (and other complexity measures).
3. **Company-level modelling.** The insights from method 2 above can also be used to construct a composite complexity variable, defined as the weighted sum of P-removal and ammonia-removal complexity, where the weights are determined through the relative cost impact of different complexity variables.

These three methods are discussed in more detail below.

3.2.1 STW-level modelling based on table 7F in the APRs

In table 7F of companies' APRs, companies are required to report cost, load and treatment complexity data for treatment works that are experiencing an increase in P-removal activity.[34] Therefore, this dataset can be used to model the relationship between anticipated expenditure and anticipated P-removal activity.

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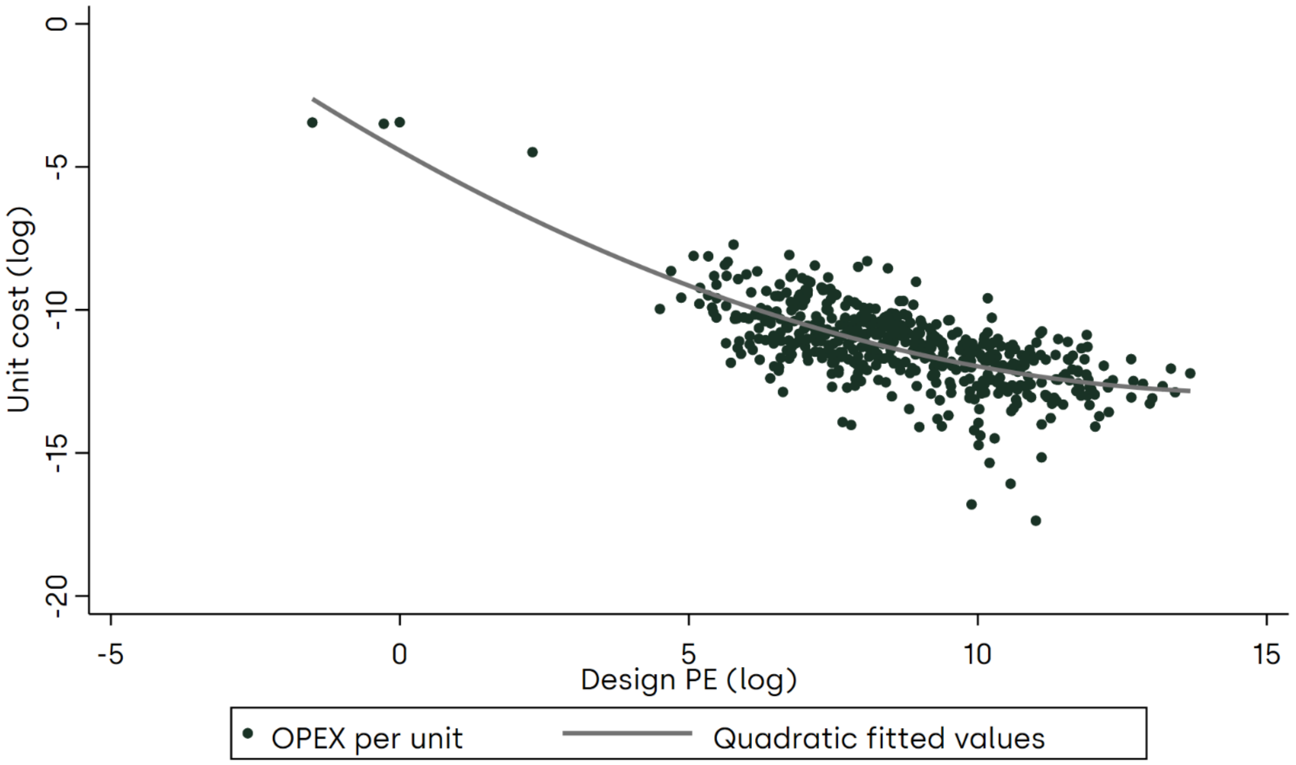
[33] The inability of the models to account for P-removal activity is an empirical problem based on the limitations of the current dataset. These limitations of the dataset may be mitigated once new outturn and business plan data become available at the PR24 determination.

[34] See table 7F in companies' 2023 APRs.

To estimate the cost of P-removal for time periods relevant for PR24, we have used the forecast OPEX for 2026 onwards. In addition, we have included only the 521 observations that are associated with positive OPEX values. The figure below shows a scatter plot of the unit costs by STW against the size of the STW, as measured by design population equivalent (PE).[35]

Figure 3.2 Economies of scale at the STW level



Note: Unit cost in £ / design PE. Both variables are plotted as natural logarithms.
Source: Oxera analysis of table 7F in companies' 2023 APRs.

The scatter plot indicates that the unit costs decrease with the size of the plant, implying positive economies of scale. The grey line, reflecting quadratic fitted values, indicates that the economies of scale are

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[35] For ease of interpretation, we have modelled the logarithm of the unit costs as a function of the STW size.

decreasing with the size of the plant.[36] We have therefore included a linear and a quadratic term of design PE control variables in our models.

We have modelled unit costs as a function of P-consent levels, controlling for economies of scale and the historical P-consent level. The table below shows two alternative models: one controlling for a dummy variable for whether the STW will treat load with P-consent below 0.5mg/l, and one controlling for the P-consent level.

Table 3.4 Results from regressing unit costs (P-removal OPEX/design PE) on P-consent levels (AMP8 and historical) and economies of scale control variables

	STW1	**STW2**
Design PE (log)	-1.2160***	-1.2502***
Design PE squared (log)	0.0411***	.04321***
Historical P-consent—no permit	0.4521	0.3414
P-consent ≤ 0.5mg/l	0.9333***	
P-consent in mg/l		-0.4724***
Constant	-4.7642***	-3.6909***
Observations	519	519
Model fit	0.5971	0.5653

Note: P-consent below 0.5mg/l is a dummy variable, indicating P-consent levels ≤ 0.5mg/l. ***, **, * show statistical significance at the 1%, 5% and 10% level, respectively, based on standard errors clustered at the company level.
Source: Oxera analysis of table 7F in companies' APRs.

The results from regression STW1 indicate that P-consent levels below 0.5mg/l are associated with unit costs that are significantly higher than unit costs for STWs with higher consent levels. The results from regression STW2 indicate that a 1mg/l increase in the P-consent level is associated with a decrease in unit costs of c. 37.6%, this means that a STW treating load with a P-consent level of 0.5mg/l is predicted to have c. 3.25 times the unit costs of an otherwise equivalent STW treating load

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[36] This is shown by the fact that the function is convex.

with a P-consent level of 3.0mg/l.[37] These relationship are statistically significant at the 1% level. In addition, the control variables have the expected sign.[38]

Since table 7F in the APR includes only additional OPEX associated with tightening P-consent levels, we can directly estimate YWS's gross claim by predicting its costs based on the models presented in Table 3.4 above.

Table 3.5 Calculation of claim value

	Value (£m)
YWS's estimated additional OPEX p.a. based on model STW1	25.49
YWS's estimated additional OPEX p.a. based on model STW2	21.95
Gross claim p.a. (average of the estimates based on STW1 and STW2)	23.72
Net claim p.a.	19.83
Net claim over AMP8	99.15

Source: Oxera analysis.

The estimated additional OPEX p.a. corresponds to predicted costs for AMP8 based on models STW1 and STW2, respectively (see Table 3.4). Our central estimate of a gross claim value of c. £23.7m p.a. reflects the average of the two. However, c. 16.4% of this gross claim value reflects costs associated with YWS catching up to the level of P-removal that is currently implicitly funded through the models (see Table 3.2). The net claim p.a. is calculated by multiplying the gross claim value with the share of the claim going beyond the implicit allowance (c. 83.6%). On the basis of this analysis, the net claim amounts to c. £19.8m p.a. or c. £99.2m over a five-year period.

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[37] This is calculated from the coefficient (β_1) for P-consent (x_2), as follows: $\Delta \log(unit\ cost) = \beta_2 \Delta x_2 \iff \Delta unit\ cost = \exp(\beta_2 \Delta x_2) - 1 \Rightarrow$ -37.6% $\cong \exp(-0.4724 * 1) - 1$.

[38] The economies of scale control variables are also statistically significant at the 1% level. The coefficients associated with the variable historical P-consent—no permit have p-values of 0.15 (STW1) and 0.295 (STW2).

3.2.2 STW-level modelling based on APR Table 7B

As explained in section 3.1, the cost of P-removal cannot be directly estimated from the base cost models since P-removal activities account for only a small proportion of the relevant cost areas on an outturn basis.[39] As an alternative, it is possible to include a composite treatment complexity variable in the models, capturing both N-removal and P-removal activities.

To account for treatment complexity in a single composite variable, it is necessary to make assumptions about the relative cost of the treatment activities. We understand from YWS that the unit cost associated with N-removal activity at consent levels below 3mg/l is roughly twice the unit cost associated with P-removal activity at a consent level below 0.5mg/l.[40] This insight can be used to construct a composite complexity variable (defined as the weighted sum of P-removal and N-removal, with P-removal having half the weight of N-removal).

To test YWS's operational insight, we have analysed the relative cost of P-removal and N-removal activities at the STW level. The results have allowed us to construct a composite complexity variable, based on P-consent and ammonia (N-consent) levels. As the basis for our analysis, we compiled a dataset of large STWs, including STW-level costs and pollutant consent levels, from section 7B of all UK wastewater companies' APR tables.[41] The figure below shows a scatter plot of the unit cost by STW against the size of the STW, as measured by the load received.[42]

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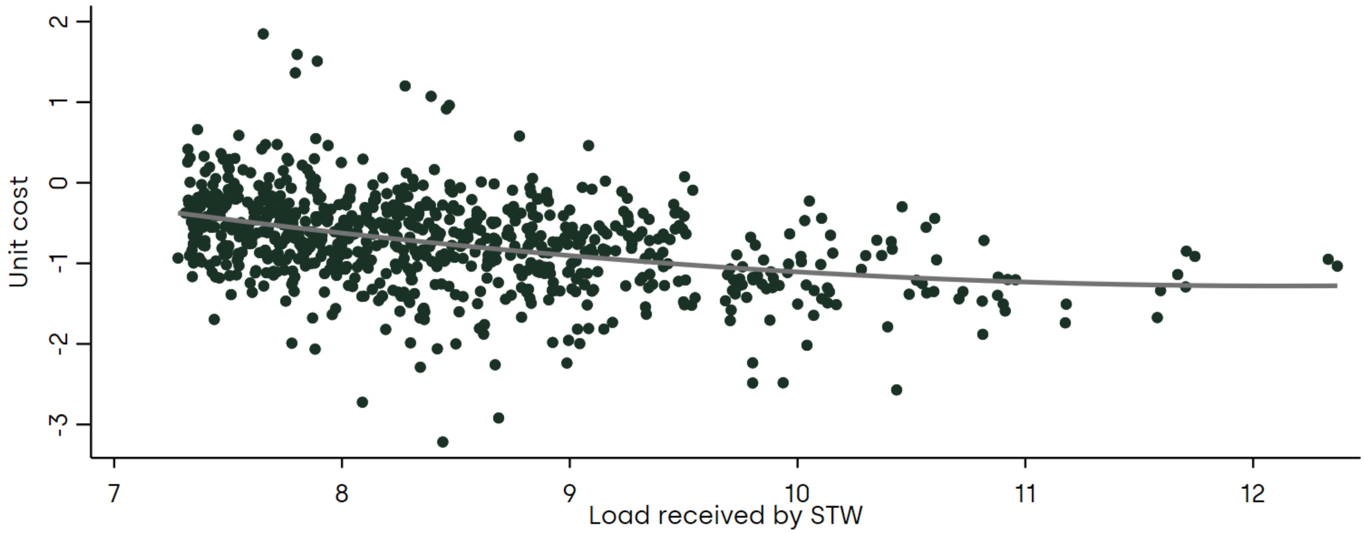
[39] This might change once forecast data becomes available.

[40] 3mg/l corresponds to Ofwat's current treatment complexity relating to N-removal.

[41] 2021–22 and 2022–23 APR tables.

[42] For ease of interpretation, we have modelled the logarithm of the unit costs as a function of the STW size.

Figure 3.3 Economies of scale



Note: Unit cost in £/kg BOD5/day. Load received in kg BOD5/day. Grey line reflects a fitted quadratic function.
Source: Oxera analysis of section 7B of the 2021–22 and 2022–23 APR tables.

The scatter plot suggests that the unit cost decreases with the size of the plant, implying positive economies of scale. The grey line reflects the fitted values of a regression of unit costs on load received, as well as squared load received. It indicates that economies of scale are decreasing with the size of the plant.[43] As in the previous section, we have therefore included a linear and a quadratic term of load received as control variables in our models.[44]

We have used other direct expenditure, and total expenditure, as measures to calculate the relevant unit cost, which we have estimated in our models. Although we would generally expect the cost of P-removal activities to be accounted for under other direct expenditure, we have also used total expenditure since this measure is more closely aligned with Ofwat's definition of modelled base costs. In addition, this

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[43] This is shown by the fact that the function is convex.

[44] Ofwat has proposed controlling for the proportion of load treated at different size bands in the PR24 modelling consultation. There is no equivalent measure of economies of scale when models are estimated at the STW level. See Ofwat (2023), 'Econometric base cost models for PR24', April, appendix A4.

approach may help to prevent potential issues arising from cost misallocation.

Moreover, we have estimated models excluding and including company-specific effects.[45] While such effects can potentially capture some of the effect of varying consent levels, they also capture company-level inefficiencies and other unobserved factors that affect unit costs. This can allow for more precise estimates of the unit costs, thereby potentially improving statistical power.[46] Using a Wald-test, we have tested YWS's operational insight that N-removal is approximately twice as expensive as P-removal at the respective consent levels.

We have explored four specifications, as follows.

- **STW1** reflects a regression of unit costs, measured by other direct expenditure, on a dummy variable for P-consent below 0.5mg/l, a dummy variable for N-consent below 3.0mg/l, and controls for economies of scale.
- **STW2** is equivalent to STW1, but also controls for company-specific effects.
- **STW3** is equivalent to STW1, but uses total expenditure as the dependent variable.
- **STW4** is equivalent to STW3, but also controls for company-specific effects.

The table below shows the results from random effects (RE) regressions based on the models described above.

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[45] Here, company-specific effects are modelled by including company-specific dummy variables (e.g. a dummy variable equal to 1 if the STW belongs to YWS and 0 otherwise, another dummy variable equal to 1 if the STW belongs to Anglian Water and 0 otherwise, etc.).

[46] Some companies have higher average consent levels for certain pollutants than others; the variables are thus correlated.

Table 3.6 Results from RE regression of unit costs on P- and N-consent levels

	STW3	STW4	STW5	STW6
Dependent variable (expenditure)	Other direct	Other direct	Total	Total
Load received by STW	-1.115***	-0.970**	-0.936***	-0.803**
Load received by STW squared	0.0471***	0.0388*	0.0376***	0.0299*
Phosphorus consent ≤ 0.5 mg/l	0.186	0.240**	0.222*	0.232**
Ammonia consent ≤ 3mg/l	0.157*	0.111**	0.129	0.101**
Company-specific effects	No	Yes	No	Yes
Constant	4.356***	3.425*	4.455***	3.576**
Model fit	0.1546	0.2600	0.1748	0.2779
Observations	734	734	734	734
P-value from Wald test	0.4947	0.1389	0.3301	0.1435

Note: All continuous variables enter as natural logarithms. The variables included under 'phosphorus consent' and 'ammonia consent' are dummy variables which indicate that the relevant consent level falls within the specified range. ***, **, * show statistical significance at the 1%, 5% and 10% level, respectively, based on standard errors clustered at the company level.
Source: Oxera analysis of section 7B of companies' 2021–22 and 2022–23 APR tables.

The table shows that tighter P-consent and N-consent levels are associated with higher unit costs in all models and that these relationships are generally statistically significant.[47] The point estimates suggest that P-removal is more expensive than ammonia removal (c. 1.2–2.5 times as expensive). This indicates that YWS's assumption—that P-removal is around half as expensive as N-removal—may be conservative with respect to estimating the cost impact of P-removal. However, we note that these models predict costs with a relatively high degree of uncertainty: the estimated confidence intervals around the coefficients are relatively wide.

Therefore, instead of relying on the point estimates to validate YWS's assumption, we have statistically tested whether the cost impact of N-removal activity is twice as much as the cost impact of P-removal (the bottom row of the table). The test shows that YWS's assumption that N-

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[47] The coefficients associated with P-consent are statistically significant at the 5% level in models STW4 and STW6 and at the 10% level in STW5. The coefficients associated with N-removal are statistically significant at the 5% level in models STW4 and STW6 and at the 10% level in STW3.

removal is twice as expensive as P-removal is consistent with the data and models presented. Therefore, when generating the composite complexity variable, as a conservative estimate we can assume P-removal to be half as expensive.

3.2.3 Company-level modelling

This section describes the impact of including a composite treatment complexity variable in Ofwat's consultation models, instead of a P-removal variable which is based solely on P-removal, and calculates a claim value based on these results. The composite complexity variable is defined as the sum of the percentage of load treated at P-consent levels below 0.5mg/l divided by two, and the percentage of load treated at N-consent levels below 3mg/l. This reflects the assumption that P-removal is half as expensive as N-removal for the relevant consent levels.

Table 3.7 presents the results for the SWT models, and Table 3.8 and Table 3.9 below present the results for the WWNP models.

Table 3.7 SWT models including composite complexity variable

	SWT1	**SWT2**	**SWT3**
Load (log)	0.641***	0.741***	0.785***
Composite treatment complexity	0.006***	0.006***	0.007***
Load treated in size bands 1 to 3 (%)	0.026		
Load treated in STWs ≥ 100,000 people (%)		-0.009***	
Weighted average treatment size (log)			-0.255***
Constant	-3.561**	-4.229***	-2.838***
R-squared	0.839	0.855	0.900

Note: ***, **, * show statistical significance at the 1%, 5% and 10% level, respectively.
Source: Oxera analysis of PR24 Cost Assessment Master Dataset, Wholesale Wastewater Base Costs v4, published 5 April 2023, and 2023 APR tables.

Table 3.8 WWNP1–4 models including composite complexity variable

	WWNP1	WWNP2	WWNP3	WWNP4
Load (log)	0.643***	0.721***	0.710***	0.714***
Pumping capacity per sewer length (log)	0.374***	0.390***	0.361***	0.299***
Composite treatment complexity	0.005***	0.005***	0.005***	0.006***
Load treated in size bands 1 to 3 (%)		0.023**		
Load treated in STWs ≥ 100,000 people (%)			-0.004*	
Weighted average treatment size (log)				-0.102***
Urban rainfall per sewer length (log)				
Constant	-2.938***	-4.027***	-3.599***	-2.839***
R-squared	0.941	0.947	0.944	0.951

Note: ***, **, * show statistical significance at the 1%, 5% and 10% level, respectively.
Source: Oxera analysis of PR24 Cost Assessment Master Dataset, Wholesale Wastewater Base Costs v4, published 5 April 2023, and 2023 APR tables.

Table 3.9 WWNP5–8 models including composite complexity variable

	WWNP1	WWNP2	WWNP3	WWNP4
Load (log)	0.646***	0.726***	0.726***	0.720***
Pumping capacity per sewer length (log)	0.361***	0.380***	0.350***	0.285***
Composite treatment complexity	0.005***	0.005***	0.005***	0.006***
Load treated in size bands 1 to 3 (%)		0.023**		
Load treated in STWs ≥ 100,000 people (%)			-0.004*	
Weighted average treatment size (log)				-0.105***
Urban rainfall per sewer length (log)	0.074**	0.076**	0.082**	0.086**
Constant	-2.759***	-3.862***	-3.525***	-2.621***
R-squared	0.945	0.952	0.95	0.957

Note: ***, **, * show statistical significance at the 1%, 5% and 10% level, respectively.
Source: Oxera analysis of PR24 Cost Assessment Master Dataset, Wholesale Wastewater Base Costs v4, published 5 April 2023, and 2023 APR tables.

The tables show that the magnitude of coefficients associated with the composite complexity variable is almost the same as the coefficients associated with the N-consent level variable in Ofwat's models. Variables associated with other cost drivers also do not change materially. There are also no material changes in the model fits (R-squared), and the p-values from the RESET tests.

The table below shows how YWS's efficient cost predictions differ between Ofwat's PR24 consultation models and the equivalent models that control for the composite complexity variable.

Table 3.10 Gross claim value calculation based on company-level modelling

	SWT	WWNP	Triangulated
Ofwat proposed models (£m)	893.7	1,845.0	
Models including composite complexity variable (£m)	1,075.0	2,151.6	
Claim value (£m)	181.3	306.6	244.0

Note: All values in 2023 prices.
Source: Oxera analysis of PR24 Cost Assessment Master Dataset, Wholesale Wastewater Base Costs v4, published 5 April 2023, and 2023 APR tables.

From the difference in predicted costs, we calculate a claim value of c. £244.0m over AMP8, corresponding to c. £48.8m p.a. This constitutes a net claim value, since any implicit allowance is already captured by the predicted costs from the models including an N-removal cost driver only, instead of a composite complexity variable.

3.3 Conclusion

The table below shows the net claim value under different modelling approaches.

Table 3.11 Claim value based on calculation method

	Net claim value (£m p.a.)
Analysis based on table 7F in the APRs	19.76
Ofwat proposed models with an added composite treatment complexity variable	48.82
YWS’s bottom-up estimate	22.03

Source: Oxera analysis.

The table shows that the top-down evidence suggests that an efficient CAC for YWS’s expected P-removal activity is c. £19.8m–£48.9m p.a. YWS’s bottom-up estimate (£22m p.a.) is within this range—indeed, it is towards the lower end of the range. Therefore, the top-down evidence suggests that YWS’s bottom-up estimate is broadly efficient.

4 Symmetrical claims submitted by other companies

As noted in the Introduction, Ofwat is proposing to make CACs related to base costs more symmetrical at PR24. In Ofwat's view, if a model is biased against some companies as a result of a particular cost driver, then it could be biased in favour of other companies due to the same driver. In other words, CAC process is generally seen as a 'zero sum game'. A key exception to this symmetrical approach will relate to characteristics that are expected to change in AMP8, such as the expansion of P-removal programmes, where CACs may be more asymmetrical in nature. In addition, it may be the case that a cost driver is relevant for one company, without having a symmetrical impact on other companies.

As part of the initial CAC consultation in June 2023, companies submitted 34 CACs. Oxera has reviewed these to assess whether any are relevant for adjusting YWS's allowance upwards or downwards. We have grouped the CACs into relevant categories, which are discussed below.

4.1 Regional wages

4.1.1 Summary of claims

Affinity Water (AFW) and Southern Water (SRN) submitted CACs relating to regional wages. The argument is that labour costs differ across English and Welsh regions, and that these companies operate in regions with particularly high labour costs. AFW and SRN argue that labour costs are exogenous, given that water companies cannot materially influence the market price of labour within their region.

AFW's primary method of justifying and estimating the CAC is to include a regional wage index as an additional cost driver in Ofwat's TWD PR24 consultation models. The coefficient is statistically significant in most specifications, and AFW argues that this indicates that regional wages are insufficiently accounted for in the cost assessment models.

SRN showed that the correlation between a regional wage index and population density was between 0.42 and 0.58. On the basis of this correlation analysis, SRN concluded that population density does not adequately account for differences in regional wages between companies. To calculate the value of the claim, SRN made a post-modelling adjustment to companies' predicted expenditure on the basis of companies' regional wage index.

4.1.2 Our evaluation of the CAC

According to AFW's analysis, neither AFW nor SRN is uniquely affected by the regional wages issue—AFW is ranked third in the industry with respect to regional wage costs, while SRN is ranked eighth.[48] No other company—including the two companies most affected by regional wages (SES and Thames Water, TMS)—submitted CACs on this issue.

AFW raised a similar claim at PR19. Ofwat ultimately rejected the claim because: (i) AFW's analysis did not account for the higher labour productivity in regions with higher regional wages; (ii) AFW's analysis did not account for the economies of density relating to the supply chain; and (iii) AFW did not consider that wage savings may be under management control.[49] While AFW has partially addressed points (ii) and (iii) in its PR24 submission (see below for details), it has not addressed point (i). Therefore, some of Ofwat's reasoning for rejecting the claim at PR19 remains unaddressed.

Regarding the quality of AFW's models, the estimated coefficient on the regional wage index is c. 0.8–1.3. That is, a 1% increase in regional wages is associated with a 0.8–1.3% increase in expenditure. The magnitude of this coefficient is not robustly justified, and may be too large from an operational perspective.[50] This suggests that the regional wages index may be capturing other factors specific to companies that operate in either high- or low-wage regions, including companies' relative efficiency, or that an inappropriate wage index is used in the analysis.

Moreover, it is not clear from AFW's submission exactly what regional wages index is being used in the adjustment. It appears that AFW has used a general measure of average weekly earnings across the economy, rather than a measure of weekly earnings for sectors more related to the water industry (such as manufacturing). Different regions may have different wages because of a different mix of industries, rather than a genuine difference in input prices. For example, London and the South East may have higher wages than the rest of England and Wales because of a greater abundancy of high-wage professional services jobs, rather than because the wages demanded by water

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[48] See Affinity Water (2023), 'PR24 Cost Adjustment Claims', June, Chart 1.

[49] See Ofwat (2019), 'Cost adjustment claim feeder model Affinity Water', December, available at: https://www.ofwat.gov.uk/wp-content/uploads/2019/12/FM_CAC_AFW_FD.xlsx.

[50] The coefficient on regional wages should be proportional to labour-related costs in the modelled base costs. For example, if it is assumed that labour cannot be substituted and that labour constitutes 50% of TWD base costs, the coefficient on regional wages should be 0.5. If labour can be substituted with other inputs, the coefficient should be less than 0.5. A coefficient above 0.5 would require more economic evidence.

sector workers are higher. If regional wages are to be considered as a basis for a CAC, the regional wages index must accurately reflect the difference in wage rates across regions in the water sector.

SRN's analysis regarding the correlation between density and regional wages is univariate, and does not consider the fact that other drivers may also be associated with regional wages. Moreover, its conclusion on whether regional wages are reflected in the cost models is binary—either the cost models already account for regional wages or they do not. In reality, the models are likely to already (at least) partially account for regional wages, and the post-modelling adjustment proposed by SRN does not account for this.

For these reasons, we do not consider that an adjustment for regional wages has been robustly evidenced by the submissions.

4.2 Network reinforcement

4.2.1 Summary of claims

South East Water (SEW) submitted a CAC relating to increased network reinforcement activity that is not fully accounted for in the cost assessment models. SEW argues that there are no explicit drivers of network reinforcement in the PR24 models, such as localised population growth and existing network capacity. The implicit allowance is calculated by comparing companies' predicted costs in the PR24 cost models (which include network reinforcement costs in the modelled cost definition) to companies' predicted costs in equivalent cost models that remove network reinforcement from the modelled cost base. The gross value of the CAC is SEW's proposed network reinforcement expenditure, under the assumption that SEW's proposed costs are efficient.

4.2.2 Our evaluation of the CAC

We consider that this CAC relates to forward-looking considerations. If the industry as a whole is expecting to increase network reinforcement activity in AMP8 (beyond that implicitly accounted for in the models), then it would be appropriate for all companies to receive an uplift to their allowances.

Given that the CAC is unlikely to be symmetrical, we do not consider that it would be appropriate to adjust YWS's allowance on the basis of this CAC.

4.3 Leakage

4.3.1 Summary of claims

Anglian Water (ANH) and Bristol Water (BRL) argue that they have been at the frontier for performance on reducing leakage, and that this increases the difficulty of continuing to meet stretching performance targets. In the PR19 redetermination, the Competition and Markets Authority (CMA) recognised this link: 'High performing companies would be expected to incur costs that exceed the implicit allowance for leakage costs that is included in the base cost allowance.'[51] BRL states that the current suite of proposed base cost models does not control for rising marginal costs of leakage control as lower leakage levels are achieved.

The companies argue that leakage performance is driven by a combination of management decisions to reduce leakage and regional operating circumstances. The latter is evidenced through a regression of leakage performance on company-specific characteristics, such as population density.

Both ANH and BRL quantify the CAC by including leakage performance as an additional cost driver in the PR24 cost assessment models. The coefficient is consistently negative (indicating that lower leakage levels are associated with higher costs), albeit never statistically significantly.

4.3.2 Our evaluation of the CAC

The general case for requiring additional allowances to reflect meeting more stringent performance targets is conceptually strong—an efficient company cannot continuously improve service quality without increasing costs. Indeed, this argument was supported by the CMA at the PR19 inquiry, where it provided additional allowances for ANH, BRL and YWS to account for costs associated with meeting stringent leakage targets.

We note that by regressing leakage against a series of cost drivers, ANH and BRL have presented some evidence that it is more difficult to achieve common leakage targets in some regions than others. For example, ANH shows that leakage performance is determined by companies' population density, soil characteristics, network characteristics, rainfall and metering. Companies that operate in more challenging conditions along these dimensions have a higher predicted

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[51] Competition and Markets Authority (2021), 'Anglian Water Services Limited, Bristol Water plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations', para. 8.59, 17 March.

level of leakage, and therefore it may be more difficult for them to achieve common leakage targets. Such interpretations can also be inferred from Ofwat's cost models—for example, companies that operate in extremely dense regions have higher predicted costs than those that operate in more average conditions, and this is reflected when Ofwat sets cost targets. We note that the same insight—that service performance is partially driven by exogenous characteristics that should be reflected when setting targets—could be applied to other service measures.

The econometric models that ANH and BRL use to support their respective CACs will benefit from further development. While the coefficient is negative (which is directionally intuitive) in all specifications, it is statistically insignificant in all specifications. In part, this could be driven by the fact that the measure of leakage modelled (leakage per length of mains) may not be a direct measure of the managerial effort that companies make to reduce leakage, given that it has not accounted for the exogenous factors that may drive leakage across companies. Indeed, during the PR19 CMA redetermination, we developed robust models that controlled for the volume of leakage above or below the sustainable economic level of leakage (SELL) that explicitly accounted for the difficulty associated with leakage reduction. However, we understand that the data for SELL has been discontinued and therefore alternative leakage measures may need to be adopted.

Finally, the cost models presented assume that the elasticity on leakage reduction is constant across the industry and over time. That is, the models show that all companies face increasing costs associated with reducing leakage, not just those that Ofwat has already classified as strong performers.

For these reasons, we do not consider at this stage that these CACs relating to leakage performance are relevant for adjusting YWS's efficient cost allowance. However, the general premise that improving service quality requires additional expenditure is valid (and widely recognised—e.g. by the CMA in the PR19 Inquiry). Moreover, the observation that leakage (and potentially other service measures) is driven by exogenous characteristics should be explored further and (if appropriate) companies' performance commitments should be adjusted on the basis of their operational environments.

4.4 Population transience

4.4.1 Summary of the claims

AFW and TMS submitted a CAC in residential retail relating to population transience. These companies argue that population transience is a material driver of retail expenditure from an operational perspective, and refer back to the PR19 models that included population transience as a cost driver. Transience, which encompasses population inflow/outflow and total migration, is posited to affect costs through challenges in bad debt collection, account management, and metering expenses. TMS argues that it faces the highest transience rate in the industry, and AFW faces the second-highest, and these companies will therefore be uniquely affected by Ofwat’s decision to exclude this cost driver from the models.

Both companies presented evidence on their own internal data to suggest that population transience is a driver of their own costs. In addition, both companies explored industry-wide cost models that show a statistically significant relationship between population transience and retail expenditure, although we could not find the details of these models in their respective reports.

The top-down evidence supporting the CACs appears to be based on the construction of a new transience measure, derived using forecasts of population transience from the Office for National Statistics dataset.

4.4.2 Our evaluation of the CAC

We recognise that population transience may be an operationally relevant driver of retail expenditure. However, the evidence presented by TMS and AFW is not sufficiently robust for an industry-wide adjustment.

First, the bottom-up evidence presented by AFW and TMS relies solely on internal data. Therefore, there is no external challenge to assess whether: (i) the proposed increase in costs associated with population transience is efficient; or (ii) these are common, industry-wide effects of population transience or just specific to AFW and TMS.

Second, the top-down models rely exclusively on outdated forecast information. Given that the ONS has stopped reporting population transience, it is not possible for Ofwat to validate whether these forecasts are accurate. If the proposed transience measure were to be included, it is possible that companies’ cost allowances are materially influenced by inaccurate forecasting methodologies, rather than genuine differences in population transience between regions. The inclusion of such a cost driver in the econometric models (or applying an industry-wide adjustment on the basis of such models) is therefore inconsistent with Ofwat's aim to incorporate only high-quality data in the cost assessment models.

Third, the models that include population transience perform relatively poorly across model specifications. The estimated coefficient differs materially across specifications; it is negative in two of the 11 models tested and statistically insignificant in seven of them. Therefore, while AFW and TMS might be uniquely affected by population transience, evidence that population transience drives expenditure across the industry is limited.

For these reasons, we do not consider that an adjustment for population transience has been robustly evidenced by the submissions.

4.5 Economies of scale

4.5.1 Summary of claims

SEW submitted a CAC relating to economies of scale at the water treatment works (WTW) level. It argues that it has some of the smallest WTWs in the industry and therefore cannot benefit from the same economies of scale as other companies. SEW further argues that the PR24 models do not sufficiently account for WTW-level economies of scale, given that: (i) there are no explicit drivers of WTW-level economies of scale in the models; and (ii) WTW size is only weakly correlated with the PR24 cost drivers.

SEW presents WTW-level cost models (estimated using its own data) showing the relationship between WTW size and water treatment unit costs. The analysis shows that there is a negative and statistically significant coefficient on WTW size, indicating that there are economies of scale at the WTW level. These models are then used to estimate a CAC value by comparing SEW's cost prediction in the WTW-level models to what the cost prediction would have been if it operated treatment plants at the 'implicitly funded' WTW size.

4.5.2 Our evaluation of the CAC

We acknowledge that economies of scale can be an operationally relevant driver of expenditure. However, from the modelling presented, SEW appears to be uniquely affected by this issue.

We therefore consider that, while additional funding may be justified to optimise SEW's assets or to compensate for the limited scale economies it currently benefits from, this does not necessitate an adjustment to YWS's allowance.

4.6 Wastewater growth enhancement

4.6.1 Summary of the claim

SRN argued that a CAC is required to address the additional costs that it may face in AMP8 in relation to wastewater growth enhancement. Specifically, the CAC is intended to account for: (i) the effect of above-average growth on network reinforcement and growth at STWs in its service area; and (ii) atypical investments in three sites to ensure that there is sufficient capacity for the anticipated exceptional housing growth.

On the former, SRN proposes a mechanism equivalent to Ofwat's post-modelling adjustment for growth enhancement at PR19. The mechanism involves calculating an efficient unit cost for growth enhancement, and multiplying that efficient growth by the difference between a company's expected population growth and the historical population growth rate.

On the latter, SRN has presented bottom-up evidence to support the efficiency of its proposed expenditure at three sites.

4.6.2 Our evaluation of the CAC

We understand that Ofwat is in the process of developing stand-alone econometric models for growth at STWs. Provided that such models are sufficiently robust, we do not consider that a post-modelling adjustment for differentials in population growth across regions will be justified, given that this will already be captured in the econometric models.

We note that the models presented by Arup (Ofwat's consultant) show YWS's growth enhancement expenditure to be efficient (it is ranked second in the industry).

In principle, a CAC could still be required for atypically large investments at specific sites. However, we do not consider that the evidence presented by SRN is sufficiently robust to make a symmetrical adjustment across the industry. First, the bottom-up evidence presented by SRN does not appear to include any external benchmarking—i.e. there is minimal evidence that SRN's proposed costs are efficient when compared to other companies. Indeed, the analysis presented by SRN shows that it has historically had the fourth-highest unit costs in the industry, c. 7.5 times higher than YWS's unit costs. If SRN's proposed costs for these sites are inefficient, then a symmetrical adjustment would overestimate the effect on other companies' allowances.

Second, the analysis presented by SRN does not appear to account for the fact that SRN may have other sites where the costs are atypically low. The sites listed by SRN may incur higher costs because population growth is high and there is limited excess capacity, but equally SRN may have sites where costs are lower if there is any excess capacity that can accommodate the population growth at minimal costs.

Third, the CAC relates to forward-looking considerations. Therefore, the symmetrical adjustment on the basis of historical analysis may neglect the fact that other companies could also propose atypically large investments at PR24. In other words, there is no guarantee that this claim will be fully symmetrical when applied to forecast data.

For these reasons, we do not consider that YWS's efficient cost prediction should be adjusted on the basis of this CAC.

4.7 Drainage

4.7.1 Summary of the claim

NWT argued that Ofwat's PR24 models do not adequately capture the effect of exogenous factors that drive higher costs associated with operating and maintaining a drainage system. In particular, urban rainfall, the proportion of legacy combined sewers, and the interaction between the two are relevant to be considered in the modelling.

NWT presents seven models (modifications of SWC1–SWC3 and WWNP1–WWNP4) which introduce an interaction term between urban rainfall and the percentage of combined sewers. This driver is statistically significant across specifications and the model fit is shown to improve (by roughly 1.8 percentage points) on average.

4.7.2 Our evaluation of the CAC

The operational argument that combined sewers and urban rainfall lead to increased efficient SWC costs is clear. Moreover, the two drivers are exogenous (urban rainfall is exogenous in the long run, while combined sewers are exogenous in the short and medium run), and the cost drivers perform well when included in Ofwat's cost assessment models. Indeed, for these reasons, we include combined sewers and urban rainfall in our cost models (where appropriate), and have developed a CAC relating to combined sewers in case its excluded from Ofwat's models.

Given that combined sewers and urban rainfall are already accounted for in our assessment of YWS's costs, we do not consider that further adjustments to its efficient cost predictions are required.

4.8 Average pumping head

4.8.1 Summary of the claim

ANH, SSC and SVE submitted claims in relation to APH. ANH and SSC argued that APH TWD should be included in all cost assessment models, and calculated the CAC on the basis of a comparison between companies' performance in the PR24 models that account for APH and companies' performance in the PR24 models that do not.

Meanwhile, SVE argued that both APH and booster pumping stations should be included in the same model. SVE further argued that APH (WRP) is an omitted cost driver in Ofwat's model specifications, and seeks to correct for the perceived bias that this generates.

4.8.2 Our evaluation of the CAC

As discussed in our base modelling report,[52] we consider that APH is a legitimate operational driver that performs well on the existing dataset and model specifications. Moreover, APH and booster pumping stations can potentially perform well in the same model, given that the two drivers are largely uncorrelated with each other and could capture different aspects of operational costs. Failing to account for booster pumping stations could lead to biased estimates of companies' costs in the same way that failing to account for APH could.

We note that Ofwat's consultants have highlighted persisting concerns with the quality of the APH data which could require further work.

SVE's argument that the omission of APH (WRP) leads to biased estimates of companies' costs requires further substantiation. We note that APH WRP does not perform well when it is included in the cost assessment models—while the coefficient is positive, the inclusion of APH WRP reduces the significance of the treatment complexity variables, indicating that the cost impact of APH WRP may already be captured through the treatment complexity drivers.

For these reasons, we do not consider that it is appropriate to adjust YWS's allowance on the basis of this CAC.

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[52] Oxera (2003), 'An assessment of Yorkshire Water's base cost requirements', September.

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