Anglian Water

10B. VIVID ECONOMICS ENHANCEMENT GROWTH COST ASSESSMENT AT PR19

Draft Determination Representation, August 2019

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Enhancement growth cost assessment at PR19

Report prepared for Anglian Water

Final report

August 2019

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Executive Summary

This report reviews Ofwat's approach to growth cost assessment at the PR19 draft determination (DD) and makes recommendations on how it can be improved for the final determinations. Building on previous work on enhancement cost modelling submitted to Ofwat after the initial assessment of plans (IAPs), the report seeks to contribute constructively to cost assessment in this important area, recognising the inherent difficulties in modelling growth costs.

Ofwat adopts a 'botex+' approach to growth cost assessment at DD, replacing the use of standalone enhancement models at IAP, which were not fit for purpose. At IAP, Ofwat developed water and wastewater growth models in an inconsistent way, producing models with very wide ranges in unit costs in water and a highly unstable forecast data model in wastewater. At DD, Ofwat took on board industry responses and addressed some issues around cost data reporting, as well as the treatment of enhancement opex and Hafren Dyfrdwy. Given the difficulty in producing robust standalone models for growth, Ofwat resolved to use botex+ models, where base and growth enhancement costs are explained together, to set cost baselines.

However, the botex+ models suffer from severe narrative deficiencies, failing to account for distinct drivers of growth costs. Contrary to Ofwat's claim in the DD, growth-related expenditure is not a 'routine' activity that scales with base costs; rather, it has a distinct set of scale and complexity drivers that are not strongly correlated with the factors that explain base cost. Engineering logic and historical evidence suggests that the efficient unit costs of connecting new properties are significantly greater than those associated with serving existing customers. The botex+ models, which explain growth costs using company-level scale variables, do not recognise this critical distinction: they assume a company that had zero growth would face the same costs as a company of the same size that accommodated very rapid growth. Thus, the models fail to account for basic *scale* drivers of growth, let alone important complexity factors, which affect onsite unit costs and offsite reinforcement requirements.

The use of botex+ modelling has a material and apparently unintended effect of redistributing expenditure from customers and high growth companies towards low growth companies. The effect of using botex+ models on allowances can be decomposed as follows:

- **It greatly reduces allowed growth spending across the sector**. Across the industry, allowed spending on growth in AMP7 falls by £900m relative to the IAP allowances, leading to a gap with company business plans of £1.8bn. The fall in allowances stems from the weak correlation between growth and company scale, meaning coefficients do not reflect average unit costs.
- **It penalises high growth companies**. Almost all companies' growth allowances fall, but those that have relatively high growth relative to existing connections see the steepest declines, as would be expected given the higher unit costs of accommodating new growth than serving existing customers.
- **It moderates the upper quartile (UQ) efficiency challenge applied to all base costs, leading to a net loss to customers.** Both waste and water botex+ models feature greatly reduced UQ challenges relative to comparable botex models used at IAP. Across the sector, the effect of this more than offsets that of reduced growth allowances, *leading to a net loss of £300m to customers*. Ofwat offers no critical appraisal of this fall in the UQ, which is much less exacting than it applied in the IAP.

A new approach to cost assessment is required for the final determinations (FDs), but it is not realistic to rely on econometric modelling for this. Shortcomings identified in both Ofwat's IAP and DD approaches demonstrate the need for a new approach. Previous Vivid modelling work shared with Ofwat explored fully the potential to explain growth costs using drivers familiar to the industry, but did not find any models that were fit for purpose in setting baseline allowances. Challenges in this area relate both to a lack of granular, consistent data and the need to account for distinct drivers of on- and offsite costs.

- Cost data on growth suffers from inconsistent reporting of onsite versus offsite costs and gross versus net spending, while the sample size is limited by the lack of site-level expenditure data.

- Engineering narratives, supported by statistical analysis conducted for this work, suggest that *complexity* drivers are particularly important in determining efficient costs and that these differ for onsite and offsite activities, The mix of connections (flats versus detached houses), the local intensity of development relative to the size of existing settlements, and the remoteness of growth sites are all highly relevant to costs and subject to significant variation between company regions.

Given the severity of the data challenges , the intricacies around drivers and the level of expenditure at stake, it is not considered plausible for Ofwat to devise, consult upon and quality assure new econometric models suitable for setting baselines allowances in this area before it issues FDs.

Against this backdrop, deep dives on company business plans are the most suitable way to assess efficient costs for growth within the available timeframe. Ofwat has used deep dives to assess significant sums in other areas of expenditure, such as resilience, raw water deterioration and large elements of supply-demand balance programmes. Following this established process would allow Ofwat to appropriately challenge company costs, while capturing differences in company operating circumstances, including complexity factors for offsite and onsite work, as well as potential variations in accounting practices

Deep dives could be supported by a modified version of the DSRA mechanism to protect customers against uncertainty over growth rates. There is very considerable uncertainty over the rate of growth in AMP7, as evidenced by variation between official forecasts from ONS and MHCLG. This could affect spending requirements by hundreds of millions of pounds for some companies. The current DSRA mechanism allows variation in the balance between developer services revenue and customer bills to reflect this uncertainty, but makes no adjustment to totex allowances resulting from growth forecasting errors. As a consequence, companies are not fully incentivised to deliver growth. Ofwat can address this shortcoming by extending the DSRA mechanism so that totex allowances vary with outturn growth.

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1 Introduction

1.1 Terms of reference

This report reviews Ofwat's approach to growth cost assessment at the PR19 draft determination (DD) and makes recommendations on how it can be improved for the final determinations. Vivid Economics was engaged by Anglian Water to review cost assessment of growth at the DD and to provide suggestions on how Ofwat can address any shortcomings within the PR19 timeframe. It builds on previous work on enhancement cost modelling submitted to Ofwat after the initial assessment of plans (IAPs), which included a review of different growth models deployed at the IAP. [1] As with earlier work, the intention of this report is to contribute constructively to cost assessment in this important area[2], recognising the inherent difficulties in modelling growth costs.

The review does not consider the cogency of the IAP base cost models that are extended in the DD to cover growth expenditure. When reviewing the DD 'botex+' models, which extend the IAP base cost models, the Vivid team considered solely the effects of adding growth to the IAP models rather than the IAP models themselves, which Vivid was partly involved in developing in previous work for Ofwat. The choice of botex drivers, definition of base costs and use of estimation techniques therefore fall outside the scope of this work, as these are all retained from the earlier botex models.

1.2 Structure

The remainder of this report is structured as follows:

- **Section 1.3 and 1.4** provide relevant context, including an overview of the causal drivers of growth and a brief appraisal of the IAP approach to growth cost assessment;
- **Section 2** assesses the use of models in growth cost assessment in detail, summarising key changes from the IAP models, assessing the narrative support for the botex+ approach, considering the statistical performance of DD botex+ models, and reviewing the implications for company allowances;
- **Section 3**reviews other components of the DD approach to growth cost assessment, including the Developer Services Revenue Adjustment (DSRA) mechanism and company deep dives;
- **Section 4** concludes with key a summary of key challenges for improving growth cost assessment and recommendations for PR19.

Section 5, the Statistical Annex, lays out the statistical evidence produced as part of this review and drawn on in the main report.

1.3 Causal drivers of growth

This section provides an outline of key exogenous drivers of efficient water and wastewater growth costs across the sector. Section 1.3.1 summarises the different types of growth activity and key drivers. Section

[1] Vivid Economics (2019). *Enhancement cost assessment for the PR19 Initial Assessment of Plans.*

[2] See Defra (2017). *The government's strategic priorities for Ofwat.* This sets Ofwat objectives to ensure bills remain affordable and that companies can support national strategies to increase the supply of housing. Effective cost assessment is critical in the attainment of these objectives, as it can set funding allowances at the level required to support growth, but no more.

1.3.2 reviews challenges associated with cost data, before Sections 1.3.3 and 1.3.4 present evidence on drivers of onsite and offsite costs in more depth. Finally, Section 1.3.5 discusses sewer flooding.

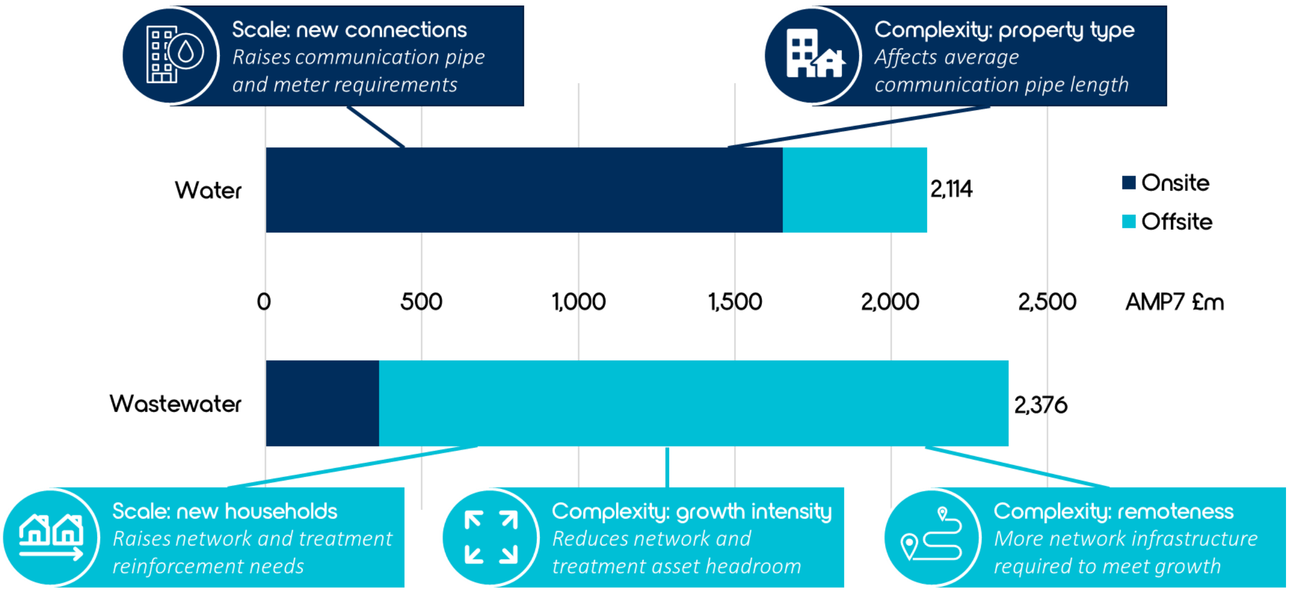
The drivers and narratives set out in this section are based on evidence provided by the industry and interviews with Anglian Water engineers. This section incorporates evidence from the 2018 Ofwat cost assessment modelling consultation and company representations made at IAP. In addition, the Vivid team carried out detailed interviews with Anglian engineers and programme specialists in support.

1.3.1 Overview

Onsite and offsite growth[3] activity cover separate activities and have distinct scale and complexity drivers.[4] Onsite work is on the development site itself, and ensures new properties are metered and connected to requisitioned mains, and through these to the wider network. Offsite reinforcement takes place in the existing network, consisting of either the enhancement of existing pipes or the construction of new pipes to meet higher demand. The number of new connections, development site ground conditions, and type of property affect onsite costs, while offsite costs are driven by population growth, existing available capacity (headroom) and the location of development sites relative to existing infrastructure. These are expected to vary between companies and over time, and evidence on cost drivers set out in this section suggests they do.

Figure 1 summarises the industry split between offsite and onsite activity in the two services and sets out the key drivers of the two types of cost. The drivers highlighted in the figure are those for which, in addition to the narrative evidence presented in Sections 1.3.3 and 1.3.4, there is statistical evidence presented in the Appendix that these have explanatory power over costs.

Figure 1 Water growth is primarily made up of onsite activity, while wastewater is over 80% offsite



Note: Water offsite expenditure based on App28 line 6; wastewater offsite expenditure consists of App28 line 23 for network expenditure and growth at sewage treatment works spend

Source: Vivid Economics

[3] Offsite expenditure refers to infrastructure network reinforcement expenditure for new connections in water (App28 line 6), and infrastructure network reinforcement expenditure for new connections (App28 line 23) and growth at sewage treatment works expenditure for wastewater.

[4] The drivers considered in this section offer more a richer account of the determinants of growth costs than the 'greenfield' vs 'brownfield' description referred to in DD documents.

1.3.2 Cost data

A key barrier to modelling growth costs are limitations in the granularity and consistency of industry data. Issues around cost data include the following:

1. **Lack of existing offsite and onsite models:** the lack of separate offsite and onsite models at IAP and DD means company reporting will not have been scrutinised to the extent that other modelled lines, such as overall enhancement growth expenditure have been. The scope for different interpretations of the offsite vs. onsite boundary means that company data may not be suitable for cost assessment without further data requests or revisions. Though in principle, the fact that on- and offsite costs have different drivers suggests separate modelling of these costs could be attractive, in practice this has not proved fruitful.

2. **Inter-AMP nature of offsite work:** offsite activity is driven by long-run population growth. Companies may efficiently trade-off network and treatment (wastewater only) reinforcement activity between asset management periods as a result. Offsite models which use in-year or within AMP costs will miss these trade-offs, and conflate (in)efficiency with periods of (more)less intense activity.

3. **Self-lay:**

    a. Penetration rates vary between companies and can affect the relationship between onsite costs and scale drivers. As noted by Ofwat, high self-lay penetration rates in a region could either be outside of management control and suggestive of a competitive fringe of providers who drive down company costs, or a result of company inefficiencies. In the former case, efficient company costs would depend on self-lay penetration rates, while in the latter they would not.

    b. Historically, some companies have not undertaken excavation or reinstatement work when laying mains. This represents a hidden onsite cost for developers, which self-lay providers do not include in asset value payments. Ofwat recently determined[5] that this behaviour is not appropriate, but historical onsite costs for companies such as Affinity Water already factor this in and will look misleadingly efficient.

1.3.3 Drivers of onsite costs

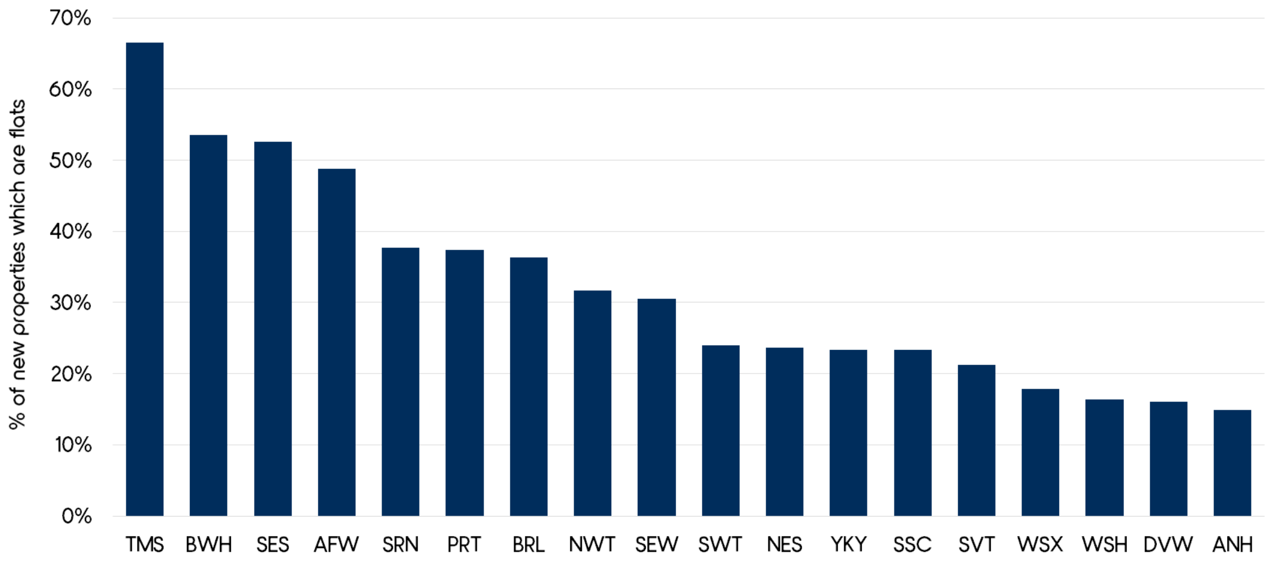
New connections is the preferred scale driver for onsite activity, but may still understate activity in the case of large-scale development sites. Companies have statutory obligations to connect new properties for domestic use, so there is no risk of the driver being under management control. New connections is available across the industry both historically and in business plans, and has regulatory precedence. It has a stronger causal narrative than change in population or number of new households, as it more closely captures company activity. Statistical evidence supports this narrative, with connections outperforming population and households in tested specifications. For large-scale developments, connections may nevertheless misstate costs as companies may lay all supporting onsite infrastructure in one go, while new connections may appear over a number of years, or even AMPs.

Average length of communication pipes affects per connection costs and is found to vary across the sector. Longer average communication pipes increase capital and labour costs. Ofwat's independent review of water supply connection costs in 2017[6] found this to be true, with 2m connection pipes costing £730, 4m pipes £900, and 9m pipes £1,400 on average across surface types. Property type can be used as a proxy for average communication pipe length, as flats are expected to have lower per property requirements than houses, and particularly detached houses. Figure 2 below shows that variation across the industry in the share of new connections which are flats and detached properties is considerable. Thames, Affinity,

[5] SLP1 and Affinity Water: complaint against Affinity Water Limited about the calculation of asset value payments https://www.ofwat.gov.uk/wp-content/uploads/2019/08/OFW0019870-Final-determination_Redacted.pdf
[6] Ofwat independent comparison of monopoly water companies' new water supply connection costs https://www.ofwat.gov.uk/wp-content/uploads/2017/02/IN-1702-New-connections-benchmarking-costs.pdf

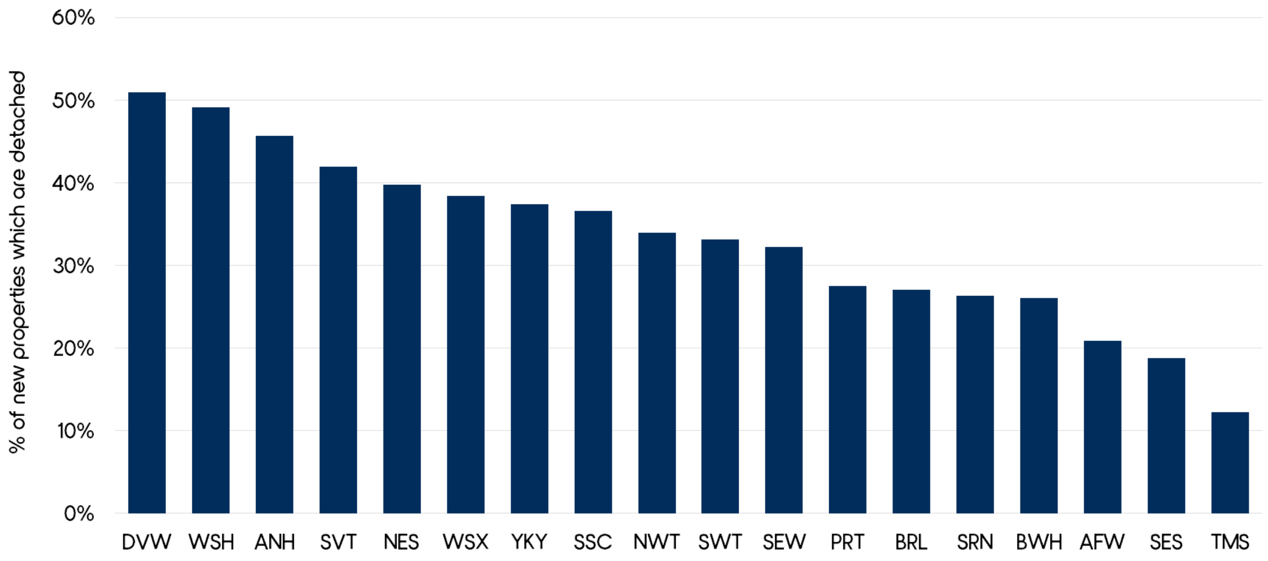
Southern Water and single town WOCs have high proportions of flats, while Wessex, Welsh and Anglian Water have amongst the lowest. For detached homes, the converse is true, with Anglian and Welsh ranking in the top 3, and Thames and Affinity Water near the bottom as shown in Figure 3.

Figure 2 New flats account for 15% of new properties in Anglian Water's region, while the figure is over 65% for Thames Water



Note: % of new properties which are flats between 2011/12 – 2017/18
Source: Vivid Economics analysis of Land Registry postcode-level data

Figure 3 The share of detached properties in companies' new connections varies significantly between companies



Note: % of new connections which are detached properties between 2011/12 – 2017/18
Source: Vivid Economics analysis of Land Registry postcode-level data

Onsite costs may also be affected by self-lay penetration rates, which varies across companies. Developers may undertake some or all contestable work if they can deliver at lower costs than incumbent water companies. The causal direction of this relationship is unclear – a competitive market for contestable work may drive down company unit costs, or high company unit cost could be driving high rates of self-lay penetration. Inconsistent company reporting has made further analysis challenging, although Ofwat's Draft Determinations developer services data request offers an opportunity to improve understanding in this area.

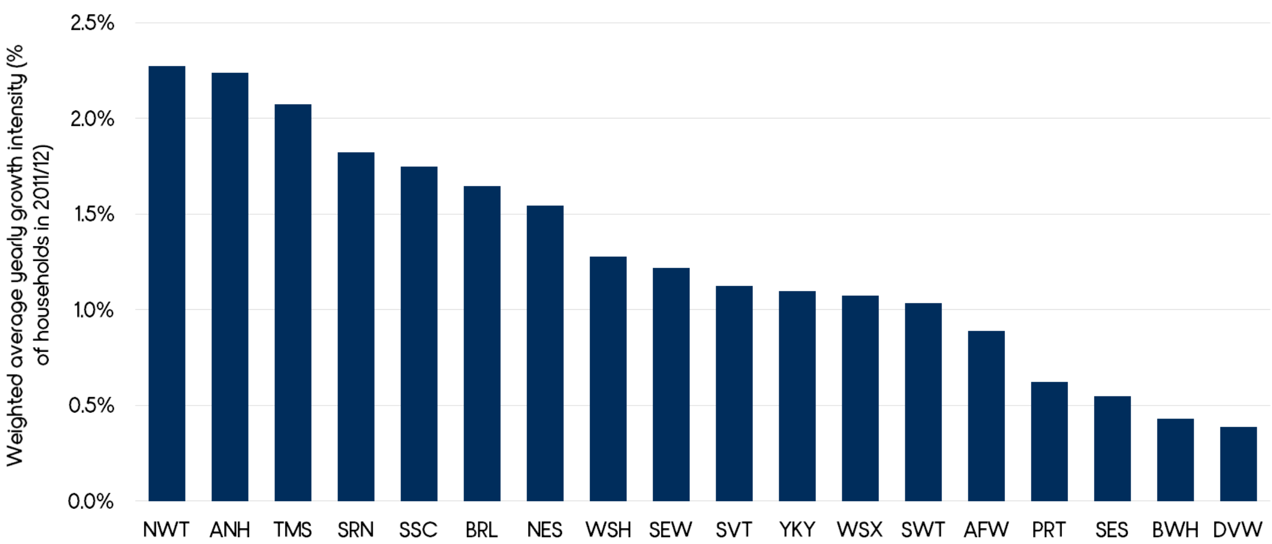
Development site ground surface types affects onsite unit costs, but evidence on variation across the sector is unclear. Hard surfaces increase the cost of fitting new connections, while pre-dug communication pipe trenches would clearly reduce company unit costs. Suitable metrics on how these factors differ across the sector are not currently available, but would be expected to drive efficient onsite costs. There is no evidence of inter-company variation in surface type.

1.3.4 Drivers of offsite costs

Population growth is the preferred scale driver for offsite costs, but the relationship between it and costs may be weak in the short run. Offsite activity requirements are determined by the volume of additional treated water, or additional wastewater resulting from growth and developments. This is related to population growth rather than the number of new connections in-year. This is supported by the models set out in Section 5.2, where population growth outperforms number of new connections and households. However, overall model fit remains weak across tested specifications, consistent with a narrative that the relationship between population growth and offsite expenditure stronger in the long-run. Companies trade-off offsite activity across AMPs, and may intentionally build excess capacity when enhancing their networks to prepare for future growth. This may represent efficient behaviour, but could appear as inefficiency in offsite models which model in-year or AMP-level costs against population growth.

The intensity of growth is a key driver of offsite reinforcement requirements. A company may be able to rely on existing headroom to accommodate new connections where local growth is modest relative to the size of the receiving network (wastewater catchment or water distribution zone). By contrast, companies that experience locally *intense* growth are much more likely to require additional offsite assets. To understand the extent to which this varies in the DD modelling horizon variation, a measure of growth intensity, defined as a weighted average of postcode-level % growth in households, was developed. Figure 4 shows that historically growth intensity has varied significantly: from around 2.3% (United Utilities and Anglian Water), down to less than 0.5% (Bournemouth Water and Dee Valley Water).

Figure 4 Historically, United Utilities, Anglian and Thames Water have the highest postcode-level intensity of growth



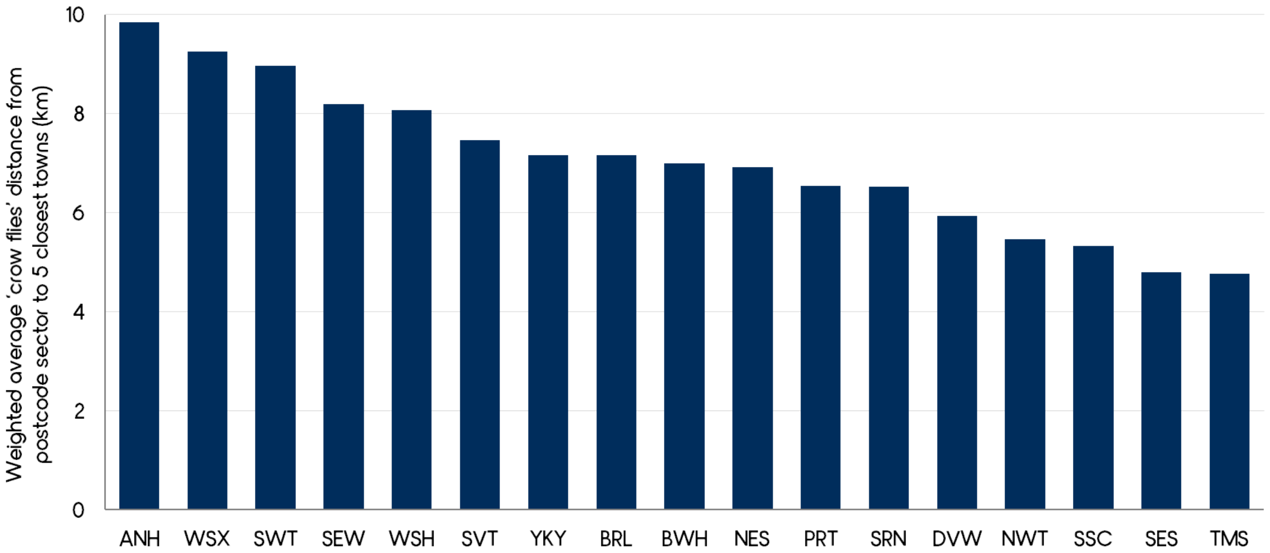
Note: % growth in households from 2011/12 to 2017/18 calculated at the postcode-level and aggregated to a weighted average based on the distribution of household growth across postcodes

Source: Vivid Economics analysis of Land Registry postcode-level data

The remoteness or sparsity of development sites raises costs as it raises infrastructure costs. A development site located further away from existing infrastructure will require more new mains, sewers and potentially even new sewage treatment works. Figure 5 shows a proxy for the remoteness of growth, calculated as the population growth weighted average 'crow flies' distance from each postcode sector to the closest 5 town.

This captures where each company's growth is situated relative to sizeable urban developments. Companies with high scores on this metric have more remote growth and may need to build out more infrastructure to meet their growth. This metric is fairly robust to the choice of historical and forecast data, and from switching from the nearest 5 towns to the nearest town.

Figure 5 Remoteness of growth in households varies across the sector, and is highest for Anglian and Welsh Water



Note: Average 'crow flies' distance to closest 5 town calculated at the postcode-level and aggregated to a weighted average based on the distribution of household growth across postcodes

Source: Vivid Economics analysis of Land Registry postcode-level data

1.3.5 Sewer flooding

Sewer flooding is a separate area of enhancement activity with drivers that do not relate directly to growth or those discussed in Sections 1.3.2 and 1.3.4. Allowances under the new developments and growth enhancement area already fund companies for no detriment to existing service quality levels for current customers. To avoid double counting spend, any funding companies receive under the sewer flooding enhancement area should therefore not be linked directly to growth.

Climate change is an important non-growth related driver of sewer flooding activity. Climate change will increase the prevalence and intensity of extreme weather events, including storms and related flooding events. Sewerage systems may have to be enhanced to increase capacity and reduce the risk of infiltration and sewer flooding incidents relating to climate change. Flood risk maps developed by insurers or the UK government could be used to estimate the spatial distribution of future flood risk, and how this relates to existing sewerage company network infrastructure.

It is therefore inappropriate to include sewer flooding in models of growth enhancement spend, and also in botex+ models. The distinct drivers of sewer flooding activity mean there are unlikely to be trade-offs or cost accounting issues with respects to base costs or new developments and growth and growth at STWs spend. Companies may also receive funding in the area of sewer flooding through the Outcome Delivery Incentives (ODI) mechanism.

1.4 IAP enhancement models

This section summarises the PR19 Initial Assessment of Plans (IAP) growth modelling approach. As part of previous work for Anglian Water, Vivid conducted a more detailed review of the IAP enhancement modelling approach, including growth[7].

At IAP, growth enhancement capex models which combined offsite and onsite expenditure were used to estimate efficient company allowances. In water, the industry median unit cost (capex per new connection) was calculated across historical (2011/12 – 17/18) and forecast (2020/21 – 24/25) datasets and multiplied by company's forecasts of new connections. These were then triangulated with equal weights to estimate company allowances. In wastewater, historical (2013/14 – 17/18) and forecast data (2020/21 – 24/25) random effects models of log capex against log new connections were triangulated with equal weights to produce allowances. The cost variable consisted of new connections and development capex in water, and new developments and growth, growth at sewage treatment works and sewer flooding capex in wastewater. Spend was taken as gross of grants and contributions in both services, with expenditure and new connections smoothed over the last 3 years in wastewater.

The single explanatory variable does not account for variation in unit costs driven by factors presented above. As set out in Section 1.3, offsite spend is driven by long-run population growth, intensity and remoteness, with requirements varying with the spatial distribution of growth. Onsite activity also depends on features such as property and potentially surface type. None of these drivers is accounted for in the IAP models.

Water and wastewater IAP growth specifications are unstable and suggestive of an inconsistent model selection process. While coefficients are significant in wastewater forecast random effects models and R^2 is high (0.91), the model is highly unstable – the exclusion of Hafren Dyfrdwy, by far the smallest company, leads to the reallocation of £0.9bn across the industry, and changes the average efficiency score by 42 percentage points. The different water and wastewater specification choices also suggest an inconsistent model selection process: the median unit cost approach is used in water, while random effects log-log models were used in waste. No statistical or engineering evidence was provided to support the different approaches – in fact, water random effects models produced more stable coefficients across historical and forecast data than the chosen wastewater models.

Both sets of growth models have implausibly wide ranges of efficiency scores and unit costs. For water, company business plan unit costs range from around £370 per connection (Yorkshire) to over £3,050 (South East). There is also a 28% difference between the median historical (£890) and forecast unit cost (£1,140) for water which is not explored in detail. For wastewater models, efficiency scores range from 0.05 (Hafren Dyfrdwy) to 1.98 (Northumbrian). In both cases, ranges cannot represent efficiency differences between companies and are suggestive of omitted variable bias. Inconsistent reporting around gross vs. net expenditure data may also have affected IAP model results.

IAP models represented an implicit efficiency challenge to the sector worth over £930m across the sector. The models themselves allowed companies £700m less than Business Plan spend, of which £300m was in water and £400m in wastewater. A further £230m was disallowed through a 'clawback' mechanism under which each company is allowed the minimum of business plan capex and its modelled allowance. Despite the absence of an explicit efficiency challenge in growth, growth models imposed an effective 22% challenge on the sector through modelling shortfalls and the clawback. Given data quality issues, model instability, and the paucity of suitable cost drivers, IAP growth allowances placed too much weight on modelling evidence, and imposed an overly stringent efficiency challenge.

[7] Enhancement cost assessment modelling for the PR19 Initial Assessment of Plans, ,Vivid Economics http://www.vivideconomics.com/publications/enhancement-cost-assessment-modelling-for-the-pr19-initial-assessment-of-plans

2 DD botex+ models

This section reviews the DD approach to growth modelling. Section 2.1 summarises the botex+ modelling approach taken by Ofwat. Section 2.2 considers the narrative case for including growth enhancement in base cost models, while Section 2.3 appraises the statistical performance of the DD models. Section 2.4 sets out the implications of the modelling approach for allowances.

2.1 Modelling approach

Ofwat chose 'botex+' modelling at DD ahead of enhancement totex models, a major departure from the IAP approach. In an attempt to address concerns raised about the IAP models, stand-alone totex growth models, with Hafren Dyfrdwy and Severn Trent England merged in wastewater, were tested but failed to improve upon IAP models. By comparison, botex+ models' performance was found to be unaffected, as well as addressing issues related to cost allocation and self-lay penetration[8]. Other enhancement areas were tested for inclusion in botex+, but ultimately rejected either because conditions for inclusion were not met, or stand-alone models performed well.

The botex+ models use dependent variables that combine base and growth costs. For both water and wastewater, botex (including capital maintenance smoothed over three years) was combined with growth enhancement expenditure lines to form 'botex+' dependent variables. For water the growth enhancement lines were unsmoothed new connections and new developments capex; for waste, the lines were historically averaged (2011/12 – 17/18) new developments and growth, growth at sewage treatment works (STWs) and sewer flooding capex in wastewater. Water botex+ models also include enhancement expenditure on addressing low pressure, but this is less material at £33m across the sector between 2011/12 and 2017/18. Enhancement opex related to these lines is already included as part of historical base opex.

No growth specific drivers have been included in either water or wastewater botex+ models. The underlying specifications are unchanged from the IAP botex models, aside from bioresources model 1, to which % load in bands 1 – 3 was added to capture higher bioresources transport costs associated with small STWs. As with IAP botex models, DD botex+ models use historical data (2011/12 – 17/18), random effects estimation and logged dependent and driver variables.

Unlike at IAP, property forecasts are based on Office of National Statistics (ONS) household projections data. Historical properties data and ONS projections of growth in properties are combined to produce cost driver forecasts for properties. By contrast, at IAP Ofwat applied a linear time trend to forecast properties in botex, and used company new connection forecasts in stand-alone growth models.

2.2 Narrative assessment

Botex+ models might be expected to outperform standalone models under two conditions, but Ofwat does not offer compelling evidence that these hold. These conditions are: first, cost allocation issues between base and enhancement costs and, second, significant substitutability between base and enhancement activities. Under either of these conditions, separate base and enhancement are ill suited to identifying efficient costs. However, Ofwat does not offer direct evidence to show that either of these conditions applies to enhancement growth.

Potential cost allocation issues are confined to offsite growth and base costs. There is no scope for accounting inconsistencies between botex and onsite growth costs which represent 78% of business plan spend in water, and 15% in wastewater. For offsite growth, companies may have some discretion around reporting programme elements against base costs or offsite growth, mostly for unusually large and multi-faceted

[8] PR19 Draft Determinations: Securing cost efficiency technical appendix https://www.ofwat.gov.uk/publication/pr19-draft-determinations-securing-cost-efficiency-technical-appendix/

programmes. Different practices across the sector could lead to inconsistent cost accounting between these areas. Even if this were the case, it is unclear why Ofwat cannot address the issue by reallocating Business Plan spend between botex and offsite growth based on its interpretation of plans and cost lines as it has done in other enhancement areas. Ofwat provides no evidence of the materiality of this.

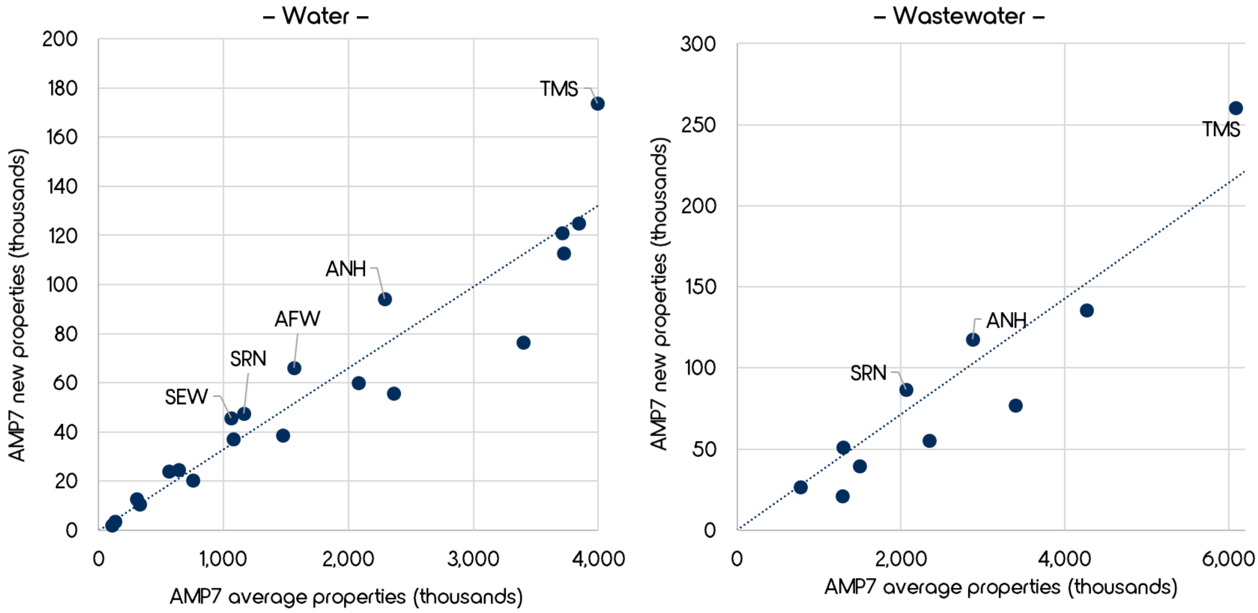
Activity trade-offs may exist between botex and some elements of offsite, but no evidence is provided at DD to support this. There are unlikely to be any trade-offs between botex and onsite growth activity.

Ofwat cites three conditions that botex+ models should meet, but the DD models do not meet all of these. *If* botex+ modelling is to be pursued, Ofwat cites three narrative conditions that these should meet. These conditions are: (i) costs have been incurred in the past; (ii) similar cost drivers explain the base and enhancement spending; and (iii) no significant change in the pattern of costs is expected[9]. Taking each of these in turn:

- **Condition (i)** is met by the DD models as growth costs have been incurred by companies in the past, and are expected to be incurred in the future;
- **Condition (ii):** is not met since:
  - ◊ While the scale drivers included in the base cost models (load, length, properties) may be *correlated* with elements of growth expenditure, they do not directly explain growth costs in an AMP. Rather, as Section 1.3 explains, the number of new connections is a the key scale driver for growth costs, with unit costs influenced by other factors including connection types and the intensity of growth. None of these growth-relevant factors is included.
  - Furthermore, the correlation between base cost scale drivers and growth scale drivers is imperfect. Figure 6 shows that variation in the growth of properties is large across the sector, with growth relative to scale (properties) highest in the South East of England.
  - This means that DD botex+ models based on the historical industry average relationship between growth and company scale are unlikely to suitably fund growth. Botex+ models treat the costs of serving new customers as equivalent to those of serving new customers, when it is widely recognised that the unit cost of serving new properties is higher than that of serving existing properties.
  - ◊ **The consequence of this is that high growth companies are expected to be underfunded and low growth companies overfunded by the botex+ approach.**
- **Condition (iii):** is not met as companies and the sector experience growth at different rates over time, so the relationship between growth spend and botex is unlikely to be stable over time;
  - While Ofwat forecasts have forecast industry average growth at similar levels to historical growth, companies' own and MHCLG forecasts had considerably higher growth as set out in Box 1;
  - If allowances were made based on companies' own or MHCLG forecasts, the expected pattern of growth will be a significant increase in the industrywide growth rate from the historical period to AMP7.
  - **If growth forecasts are closer to company forecasts, the sector as a whole will be significantly underfunded.**

[9] PR19 Econometric Benchmarking Models for Ofwat
https://www.ofwat.gov.uk/wp-content/uploads/2018/03/CEPA-cost-assessment-report.pdf

Figure 6 Companies in the South East are growing faster during AMP7 than the rest of the industry



Note: AMP7 new properties taken as difference between 2019/20 and 2024/25 properties; linear trendlines through the origin shown

Source: Vivid Economics

Box 1 Ofwat's ONS-based properties projections are lower than companies' own and 2014-based Ministry of Housing, Communities and Local Government (MHCLG) forecasts

Service	Historical	Ofwat (ONS)	MHCLG	Companies' own
Water	0.75%	0.68%	0.84%	0.91%
Wastewater	0.65%	0.69%	0.85%	0.91%

- **ONS projections imply a compound annual growth rate of around 0.7% in water and wastewater,** consistent with historical growth rates in both services
- **However, MHCLG projections are closer to 0.85%**, which represents an **additional 345,000 properties in water, and 370,000 properties in wastewater** by 2024/25 across the sector
- Across the sector, **companies' own forecasts** are closer to MHCLG projections, with around **0.9% growth forecast in water and wastewater annually**

2.3 Statistical performance

Against some basic statistical criteria, the DD botex+ models perform similarly to the IAP base cost models. As shown in Statistical Annex Section 5.1, coefficients remain significant when comparing DD botex+ specifications against IAP and DD 'botex only' models. The latter set of models is a useful benchmark as it includes changes from IAP which are unrelated to the inclusion of enhancement costs, such as revisions to booster pumping data and any driver additions. There is little loss of model fit from the inclusion of growth in water botex+ models, and R^2 even rises modestly for certain wastewater models as shown in Table 6.

However, this is unsurprising and does not mean that botex+ models explain growth costs well. As shown in Table 1, the share of growth expenditure lines in historical botex+ is low at around 6% for wholesale water and 9% for wholesale wastewater. In water resources plus and bioresources in particular, growth spend is negligible so models are virtually unchanged from IAP. This suggests that the inclusion of growth costs should have a relatively small impact on models, as the majority of included expenditure is unrelated to growth, and there are no new growth-specific drivers.

Table 1 Growth is a small share of botex+ historically, but grows as a share of botex+ in business plans

Service	Dependent (cost) variable	Historical (2011/12 – 17/18)	Forecast (2020/21 – 24/25)
Water*	Water resources plus (WRP)	0.0%	0.0%
	Treated water distribution (TWD)	9.2%	13.4%
	Wholesale water (WW)	5.6%	8.3%
Wastewater	Sewage collection (SWC)	16.3%	19.3%
	Sewage treatment (SWT)	5.6%	12.4%
	Bioresources (BR)	0.0%	0.0%
	Bioresources plus (BRP)	4.1%	9.6%
	Wholesale wastewater (WWW)	9.0%	13.4%

Note: Growth expenditure as a percentage of botex+ within each subservice, and over the historical and forecast time periods; forecast growth expenditure does not include reallocations made into water and wastewater growth by Ofwat at IAP

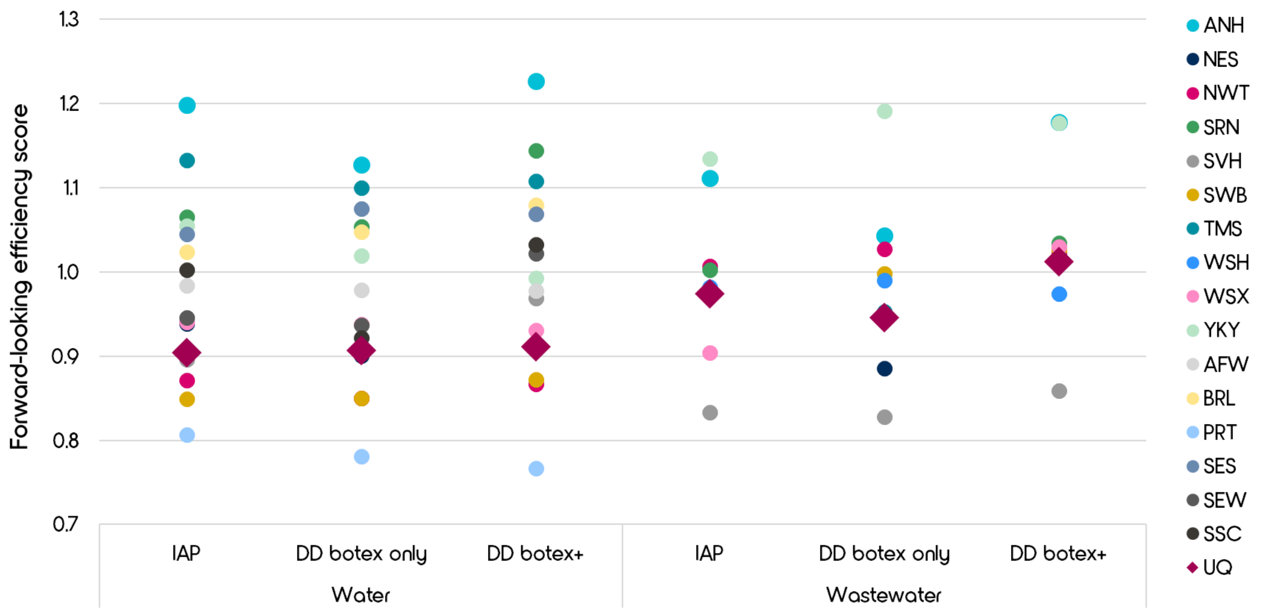
Source: Vivid Economics analysis of Ofwat PR19 Draft Determinations materials

Where basic statistical performance has changed, differences are not always in line with expectations and coefficients are attenuated. If growth were explained by company size, botex+ scale variable coefficients would be expected to be higher than equivalent DD 'botex only' model coefficients. This is not the case for sewage collection models: coefficients on sewer length are lower in DD botex+ than DD 'botex only' for SWC1 (0.82 vs. 0.89) and SWC2 (0.90 vs. 0.98), as shown in Table 6. This suggests that growth expenditure is not explained by existing sewer length in the sewage collection service, and supports the narratives that growth rates differ across the sector, and offsite work is driven by other factors. It also suggests that botex allowance obtains from botex+ models are not robust, as the attenuation bias will apply to both botex and enhancement growth elements of cost. This is particularly significant for wastewater botex+ as the majority of historical growth spend (73%) is in sewage collection.

The adoption of botex+ modelling has a very substantial impact on the base cost efficiency challenge. The upper quartile (UQ) efficiency challenge applied in botex+ models is 0.99 in wastewater and 0.96 in water. Both of these numbers are closer to 1 than at IAP or for DD 'botex only' models, and result in a much more lenient efficiency challenge than at IAP, as discussed in Section 2.4. For DD 'botex only' wastewater models, the UQ efficiency challenge would have been 0.95, close to the IAP score of 0.96. For water, the equivalent scores are 0.91 for DD 'botex only' and 0.95 for IAP models. Ofwat offers no commentary as to why such a significant reduction in the UQ efficiency challenge is considered reasonable.

Across the sector, forward-looking efficiency score changes reflect the size of growth programmes, suggesting growth is not captured well by the models. Business plan, or forward-looking efficiency scores in wastewater botex+ models are highly sensitive to the inclusion of growth spend as shown in Figure 7. In wastewater, high growth companies such as are Northumbrian, Anglian and Wessex Water look relatively inefficient in botex+ as shown in Figure 7. Relative to DD 'botex only', efficiency scores worsen by 12 percentage points for NES, 13 for ANH and 9 for WSX. In water, high growth companies are South Staffordshire and Cambridge, South East, Southern and Anglian Water. Efficiency score changes are 11 percentage points for SSC, 9 for SEW, 9 for SRN and 10 for ANH. By contrast, low growth companies appear efficient in botex+ models: in water, Yorkshire and Southern Water's efficiency scores improve, while in wastewater, Welsh and Yorkshire Water's scores improve. These changes reflect the failure of botex+ models to explain growth spend.

Figure 7 Business plan efficiency scores narrow in wastewater botex+, while the range in water widens



Growth as % of AMP7 botex+	ANH	HDD	NES	NWT	SRN	SVE	SWB	TMS	WSH	WSX	YKY	AFW	BRL	PRT	SES	SEW	SSC
Water	13	6	7	8	13	11	8	7	5	4	3	5	8	4	5	13	16
Wastewater	19	3	21	9	14	13	11	15	8	18	8						

Note: DD 'botex only' efficiency scores are based on business plan spend excluding growth and addressing low pressure spend (water only) and modelled allowances based on 'botex only' model coefficients, that is, the UQ adjustment factor has not been recalculated for DD botex only models

Source: Vivid Economics analysis of Ofwat PR19 Draft Determinations materials

It is unclear why historical average enhancement growth expenditure rather than unsmoothed or 3 year smoothed spend is included in wastewater models. There is a stronger case for smoothing growth enhancement spend in wastewater than in water, because offsite activity is more likely to be subject to temporal trade-offs and represents the majority of spend in wastewater. However, it is unclear why the average value of historical growth enhancement has been included rather than suitably smoothed growth spend. Table 8 and Table 9 in the Statistical Annex show the effects of including 3 year smoothed and unsmoothed enhancement expenditure on wastewater botex+ models. Models are fairly robust to the use of the different smoothing assumptions, and the use of 3 year smoothing does not seem to worsen statistical performance. The latter approach would be more consistent with the enhancement models used for first time sewerage and lead standards, and the IAP wastewater growth models.

2.4 Impacts on allowances

DD botex+ models very substantially underfund companies for growth relative to business plan proposals, with an aggregate gap of £1,850m across the sector, around double that at the IAP. Table 1 shows that the gap between business plan spend and botex+ model growth allowances is large in water and wastewater, representing 42% (£670m) of planned growth spend in water, and 43% (£1,170m) in wastewater. Both materiality gaps have risen considerably since IAP; in water, from £430m to £670m, and in wastewater from £500m to £1,170m.

Growth allowances are calculated straightforwardly using a counterfactual where growth costs are excluded from the base cost models. The growth allowances shown below were calculated by taking the difference between DD botex+ and DD 'botex only' model allowances. This is the most suitable way to calculate growth allowances from botex+ models, as it accounts for *the botex allowance companies would have received* if growth had not been added to botex+.

Table 2 Growth funding shortfalls have grown by over £900m from IAP to DD across water and wastewater

Service	BP growth spend	IAP growth allowance	IAP growth shortfall	DD botex+ allowance	DD 'botex only' allowance	DD growth allowance	DD growth shortfall
Water	1,606	1,168	434	19,036	18,103	933	673
Wastewater	2,706	2,240	503	18,111	16,577	1,534	1,172
Combined	**4,312**	**3,408**	**938**	**37,147**	**34,680**	**2,467**	**1,846**

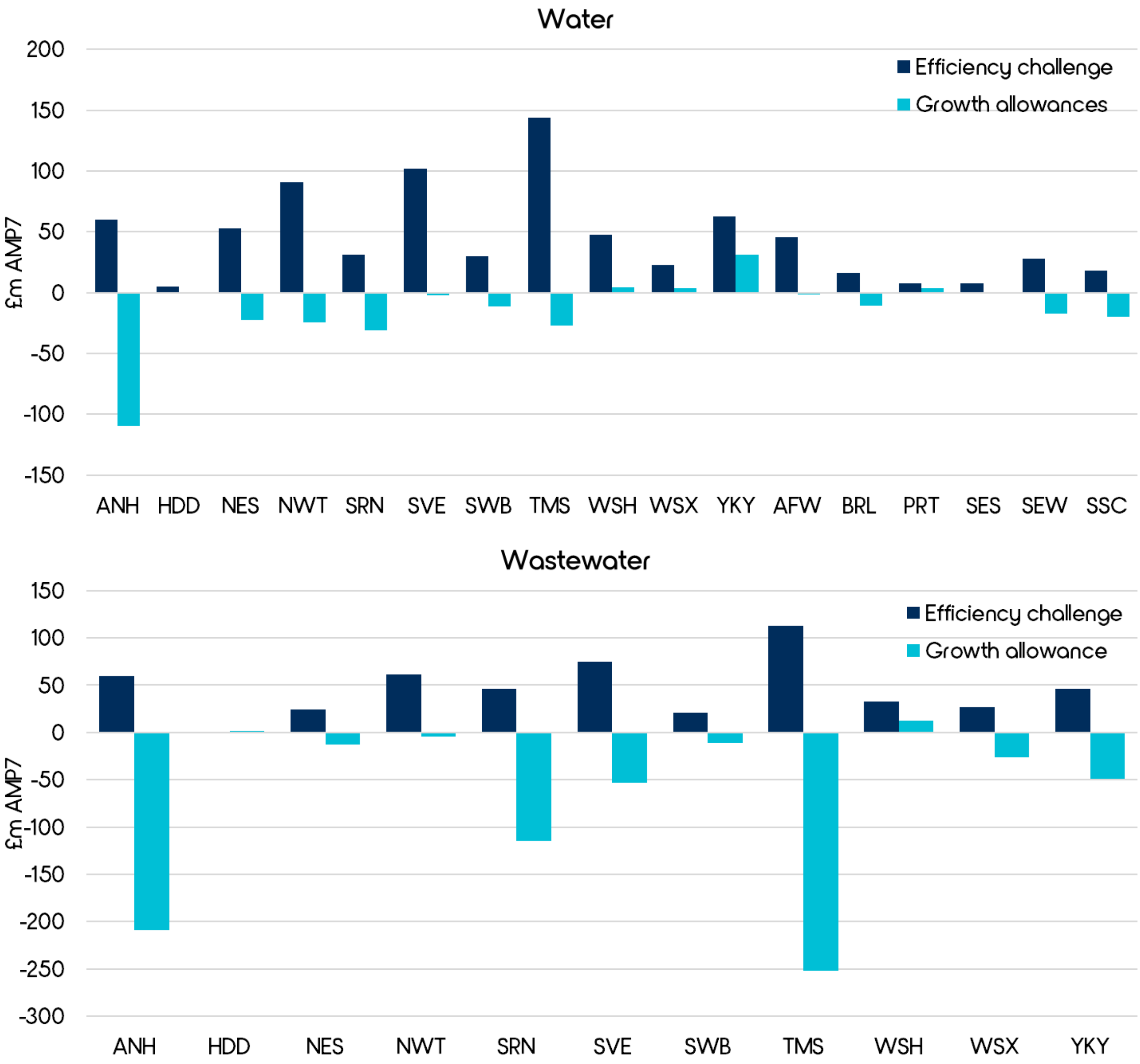
Note: Business plan growth spend based on DD growth lines and IAP growth reallocations
DD botex+ and 'botex only' allowances based on efficient base cost allowances in feeder files; DD growth allowance calculated as difference between botex+ and 'botex only' allowances
IAP shortfall calculated against IAP growth spend

Source: Vivid Economics analysis of Ofwat PR19 Draft Determinations materials

While underfunding growth, botex+ models simultaneously apply a laxer efficiency challenge to all base costs, leading to a net loss to customers. As explained above, the DD botex+ wastewater UQ efficiency challenge is just 1.4%, while the water challenge also fell to 4.2%. Compared to 'botex only' models, the laxer efficiency challenge has raised industry allowances by £770m in water and £507m in wastewater – more in aggregate terms than the reduction in growth allowances.

This means the botex+ effectively redistributes spend away from customers and high growth companies and towards low growth companies as shown in Figure 8.

Figure 8 The efficiency challenge change raises allowances across the sector, while growth allowances are lower



Note: Efficiency challenge impact calculated as difference in allowance from IAP growth + DD 'botex only' model to IAP growth + DD 'botex only' model with botex+ model efficiency challenge
Growth allowance impact calculated as difference in allowance from IAP growth + DD 'botex only' model with botex+ model efficiency challenge to full DD botex+ models

Source: Vivid Economics

The lack of sensitivity of DD botex+ models to growth is evident from Table 3 which shows the industrywide allowance under different scale variable growth rates. The compound annual growth rate of key scale variables is varied from between 0% to 2%, and allowances are re-estimated across the sector. The allowances produced show that growth is not captured within the models, as large differences in projected growth have very little effect on model allowances. The allowances discussed below are for additional botex *and* growth activity resulting from changes in company scale, and are not solely an allowance for additional enhancement growth activity.

Table 3 Allowances from models barely change when the growth rates of key scale drivers are altered

Service	DD botex+	0% growth	0.1% growth	0.5% growth	1% growth	2% growth
Water (£m)	19,036	18,849 (-187)	18,882 (-154)	19,013 (-23)	19,179 (+143)	19,516 (+480)
Wastewater (£m)	18,111	17,979 (-132)	18,008 (-103)	18,127 (+16)	18,276 (+165)	18,578 (+467)
Combined (£m)	37,147	36,828 (-319)	36,890 (-257)	37,140 (-7)	37,455 (+308)	38,094 (+947)

Note: Water variables for which growth rate changes were imposed were properties and mains length
Wastewater variables for which growth rate changes were imposed were properties, sewer length, load and sludge produced
For all other variables in water and wastewater, DD feeder file forecast assumptions were maintained

Source: Vivid Economics analysis of Ofwat PR19 Draft Determinations materials

Box 2 sets out the implications of model coefficients and allowance changes under the different growth rate assumptions.

Box 2 Impacts of different growth rates in scale variables on company allowances

No growth in scale variables:

- **Water:** if there were no growth in properties and length over AMP7, **allowances would be only £187m lower** compared to DD botex+;
- **Wastewater:** if there were no growth in properties, sewer length, load and sludge produced, **allowances would be £132m lower** compared to DD botex+;

2% annual growth in water scale variables:

- 2% growth in properties and mains length leads to an additional 1.5 million properties and 24,000km of water mains in 2024/25 across the sector, compared to DD driver forecasts;
- The additional botex+ allowance for this growth is **£480m**;
- This equates to **£320 per property** to cover the additional costs of offsite and onsite enhancement growth, *and* the base capital and operational expenditure associated with serving the additional customers and operating and maintaining the new assets across AMP7;
- The unit rate for serving the new properties is far lower than the **water growth IAP model's unit historical and forecast unit cost estimates of £890 and £1,140 per connection**, and must also cover additional botex;

2% annual growth in wastewater scale variables:

- 2% scale variable growth over AMP7 results in there being **1.4 million more properties, and 43,000 additional km of sewer length in 2024/25** compared to DD driver forecasts;
- The additional botex+ allowance for this growth is **£467m**
- This is around **£330 per property** to cover both offsite and onsite enhancement growth, and botex associated with new customers and assets;
- By comparison, the **median historical unit cost for serving new properties is £1,810**, far higher than the effective unit rate for new properties in wastewater botex+

The scenarios above show that botex+ does not suitably fund the industry for forecast growth which is different to historical levels, and will not correctly fund companies for differences in growth.

3 Other determinants of allowances

3.1 Driver forecasts and uncertainty mechanisms

DD cost assessment uses lower ONS forecasts (2016-based) than those used at the IAP. Office of National Statistics (ONS) 2016-based projections of the growth rate in households are used to forecast the number of properties in water and wastewater. ONS projections are significantly lower than previous 2014-based projections made by the Ministry of Housing, Communities & Local Government (MHCLG), and companies' own forecasts of AMP7 new connections. The UK government has stated that the '2016-based [ONS] household projections should not be used as a reason to justify lower housing need'[10].

Table 4 ONS household projections lower the industry allowance by around £170m compared to MHCLG forecasts

Service	DD botex+ (ONS properties forecasts)	MHCLG properties forecasts	Company properties forecasts	Company scale variable forecasts
Water	19,036	19,166 (+130)	19,219 (+183)	19,242 (+206)
Wastewater	18,111	18,153 (+42)	18,146 (+35)	18,162 (+51)
Combined	**37,147**	**37,319 (+172)**	**37,365 (+218)**	**37,404 (+257)**

Note: MHCLG properties forecasts use 2014-based household growth rates produced by the Ministry of Housing, Communities & Local Government; company scale variable forecasts cover properties and mains length in water, and properties, load, and sewer mains length in wastewater
MHCLG forecasts were not available for Wales – properties growth rates for Welsh local authority districts are taken from StatsWales

Source: Vivid Economics

The range of projections shows there is substantial uncertainty over the expected level of growth and therefore the allowances. Table 4 shows industrywide allowances under the botex+ models are around £170m higher when using MHCLG properties projections instead of ONS projections. If company properties forecasts are used, the industrywide allowance is about £220m higher than DD botex+ allowances. As shown in Section 2.4, the impact of this uncertainty on allowances would be much greater if unit rates closer to those implied by the IAP models were used.

The proposed developer services revenue adjustment (DSRA) mechanism partially addresses this uncertainty by adjusting developer services revenue to reflect outturn growth The DRSA mechanism seeks to address one potential reason why companies could be under-incentivised to deliver growth above Ofwat's forecast level – that they could be penalised under the wholesale revenue forecasting incentive mechanism (WRFIM). The DRSA mechanism uses a new connection unit rate to adjust developer services revenue for the difference between outturn new connections and Ofwat's new connections forecasts based on ONS projections. If outturn new connections differ from the Ofwat forecast, developer services revenue is adjusted based on company-specific unit rates and the number of additional connections.

However, there is no mechanism to correct company net totex, which means customers companies remain under-incentivised to support growth. Recovery rates for growth costs from developers are generally below 100%, reflecting historical practices due to the need for charging regime stability emphasised within Defra's guidance[11], as well as the fact that companies cannot recover costs for STW upgrades from developers. The

[10] Government response to the technical consultation on updates to national planning policy and guidance, A summary of consultation responses and the Government's view on the way forward https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/779792/LHN_Gov_response.pdf

[11] Water industry: guidance to Ofwat for water and sewerage connections charges https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/575368/ofwat-charging-guidance-sewerage-connection-charges.pdf

consequence of this is that, because allowances rise by less than costs when outturn growth exceeds forecasts, companies remain under-incentivised to deliver growth. A mechanism that adjusts customer contributions towards growth with outturn growth would therefore improve incentives.

Notably, the DRSA mechanism's use of company-specific unit rates based on historical growth costs also appears to be inconsistent with the botex+ approach. Botex+ models fund growth based on company size, and make no adjustment for factors which affect company's unit rates. By contrast, the proposed approach to regulating developer services proposes to use company-specific unit rates to reflect each company's unique characteristics reflected in historical unit cost, which as Section 1.3 and the Statistical Annex shows are explained by factors such as new connections and the local intensity of growth. Box 2 shows the extent to which historical unit costs exceed those allowed in the botex+ models.

3.2 Deep dives

While deep dives have been applied for some companies, it is unclear how these were identified and why deep dives have not been applied in wastewater. Anglian and South East Water were subject to deep dives in water. As set out in Section 2.3, Anglian, Southern, South East, and South Staffordshire and Cambridge Water have large growth programmes and have efficiency scores which worsen by between 9 and 12 percentage points in botex+ models compared to 'botex only'. It is unclear why Southern and South Staffordshire and Cambridge water were not also subject to deep dives. No deep dives were conducted for wastewater, despite several companies seeing large gaps between planned and allowed sending, and the industry growth funding shortfall being similar for water and wastewater as discussed in Section 2.4.

4 Recommendations

A new approach to cost assessment for growth spending is required. Both stand-alone IAP and botex+ DD models have narrative and statistical deficiencies. The IAP approach had model selection inconsistencies between water and wastewater, very wide ranges in unit costs in water, and highly unstable forecast data models in wastewater. Ofwat took on board industry responses and resolved some issues around cost data reporting, enhancement opex and Hafren Dyfrdwy between IAP and DD. However, the DD botex+ modelling approach does not capture the key causal drivers of growth, failing to account for important differences in growth relative to company size. While the approach greatly reduces allowances for growth relative to the IAP models – producing a 'gap' of £1.8bn between industry-wide modelled allowances and company business plans -- the incorporation of growth into botex models *also* leads to a very significant reduction in the UQ efficiency challenge for both water and wastewater services. The net effect is a very large redistribution of expenditure from customers and high growth companies towards low growth companies that is not supported by any evidence.

It is not realistic to improve econometric approaches to an acceptable level before the final determinations. Previous modelling work shared with Ofwat explores fully the potential to explain growth costs using drivers familiar to the industry, but does not find any models that are fit for purpose in setting baseline allowances. This is likely to reflect limitations in data for both costs and drivers.

- Problems with cost data include issues raised by companies at the IAP[12] and noted by Ofwat, such as inconsistent reporting of on- and offsite costs, gross and net spending, and the treatment of self-lay and income offsets – as well as more fundamental limitations, such as the lack of site-level expenditure data.
- Problems with drivers reflect a lack of industry-wide data on complexity factors that cause variation in on- and offsite costs. Work for this report, presented in Section 1.3, shows how publicly available data on housing development can be used to develop such drivers – and finds that these have explanatory power over historical growth costs. However, these models and drivers, unlike others used in cost assessment, have not been subject to widespread industry consultation.

Given the severity of these challenges and the level of expenditure at stake, it is not plausible for Ofwat to devise, consult upon and quality assure new econometric models suitable for setting baselines allowances in this area before it issues FDs.

Deep dives on company business plans are the best way to assess efficient costs for growth. Ofwat has relied on deep dives to allocate significant sums in other areas of expenditure, such as resilience and supply-demand balance. Following this established process would allow Ofwat to capture differences in company accounting, for instance, around cost reporting or self-lay, and operating circumstances, including complexity factors for offsite and onsite work.

Deep dives could be supported by a modified version of the DSRA mechanism to protect customers against uncertainty over growth rates. There is very considerable uncertainty over the rate of growth in AMP7, as evidenced by variation between official forecasts from ONS and MHCLG. This could affect spending requirements by hundreds of millions of pounds for some companies. The current DSRA mechanism allows variation in the balance between developer services revenue and customer bills to reflect this uncertainty, but makes no adjustment to totex allowances resulting from growth forecasting errors. As a consequence, companies are not fully incentivised to deliver growth and customers bear significant forecasting risk. Ofwat can address this shortcoming by extending the DSRA mechanism so that totex allowances vary with outturn growth.

[12] Developer services cost assessment, Jacobs

5 Statistical Annex

5.1 Draft Determinations models

Table 5 Water base cost models at Initial Assessment of Plans, Draft Determinations, and Draft Determinations 'botex only'

Variable	WRP1			WRP2			TWD1			WW1			WW2		
	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+
Connected properties*	1.01 (0.00)	1.01 (0.00)	1.01 (0.00)	1.01 (0.00)	1.01 (0.00)	1.01 (0.00)				0.99 (0.00)	1.03 (0.00)	1.03 (0.00)	0.98 (0.00)	1.02 (0.00)	1.02 (0.00)
Length of mains*							1.01 (0.00)	1.04 (0.00)	1.04 (0.00)						
% water treated at works of complexity levels 3-6	0.008 (0.00)	0.008 (0.00)	0.008 (0.00)							0.003 (0.00)	0.005 (0.00)	0.005 (0.00)			
Weighted average treatment complexity*				0.44 (0.00)	0.44 (0.00)	0.44 (0.00)							0.37 (0.00)	0.52 (0.00)	0.52 (0.00)
Booster pumping stations per mains length*							0.47 (0.00)	0.51 (0.00)	0.47 (0.00)	0.52 (0.00)	0.25 (0.03)	0.24 (0.05)	0.52 (0.00)	0.27 (0.01)	0.26 (0.02)
Weighted average density*	-1.36 (0.01)	-1.39 (0.01)	-1.39 (0.01)	-0.70 (0.20)	-0.73 (0.18)	-0.73 (0.17)	-3.07 (0.00)	-3.06 (0.00)	-2.97 (0.00)	-1.71 (0.00)	-2.07 (0.00)	-2.03 (0.00)	-1.47 (0.00)	-1.66 (0.00)	-1.64 (0.00)
Weighted average density squared*	0.08 (0.03)	0.09 (0.03)	0.09 (0.03)	0.04 (0.37)	0.04 (0.33)	0.04 (0.33)	0.25 (0.00)	0.24 (0.00)	0.24 (0.00)	0.13 (0.00)	0.15 (0.00)	0.14 (0.00)	0.11 (0.00)	0.12 (0.00)	0.11 (0.00)
Constant	-5.32 (0.01)	-5.22 (0.01)	-5.22 (0.01)	-7.61 (0.00)	-7.51 (0.00)	-7.51 (0.00)	5.78 (0.00)	5.68 (0.00)	5.27 (0.00)	-1.27 (0.30)	-1.53 (0.33)	-1.73 (0.27)	-2.27 (0.02)	-3.07 (0.01)	-3.23 (0.01)
Observations	124	124	124	124	124	124	124	124	124	124	124	124	124	124	124
R^2	0.934	0.934	0.934	0.921	0.921	0.921	0.968	0.968	0.970	0.978	0.974	0.975	0.979	0.975	0.977

Note: P-values in parentheses; * denotes that variable is logged
DD 'botex only' models exclude growth enhancement lines from the dependent variable, but include enhancement expenditure on addressing low pressure

Source: Ofwat IAP and DD materials, supplemented with Vivid Economics analysis for DD 'botex only' specifications

Table 6 Sewage collection and sewage treatment base cost models at Initial Assessment of Plans, Draft Determinations, and Draft Determinations 'botex only'

Variable	SWC1			SWC2			SWT1			SWT2		
	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+
Sewer length*	0.74 (0.00)	0.89 (0.00)	0.82 (0.00)	0.71 (0.00)	0.98 (0.00)	0.90 (0.00)						
Load*							0.80 (0.00)	0.81 (0.00)	0.86 (0.00)	0.78 (0.00)	0.80 (0.00)	0.85 (0.00)
% load treated in bands 1-3							0.05 (0.04)	0.05 (0.03)	0.06 (0.01)			
% load treated in band 6										-0.01 (0.08)	-0.01 (0.08)	-0.02 (0.05)
Pumping capacity per sewer length*	0.17 (0.02)	0.45 (0.01)	0.28 (0.07)	0.35 (0.02)	0.77 (0.00)	0.62 (0.00)						
% load with ammonia consent less than 3mg/l							0.004 (0.00)	0.004 (0.00)	0.004 (0.00)	0.004 (0.00)	0.004 (0.00)	0.004 (0.00)
Number of properties per sewer length*	1.47 (0.00)	1.17 (0.00)	1.19 (0.00)									
Weighted average density*				0.26 (0.02)	0.17 (0.24)	0.19 (0.11)						
Constant	-8.91 (0.00)	-9.57 (0.00)	-8.59 (0.00)	-5.04 (0.00)	-7.45 (0.00)	-6.53 (0.00)	-5.50 (0.00)	-5.71 (0.00)	-6.27 (0.00)	-4.20 (0.00)	-4.35 (0.00)	-4.77 (0.00)
Observations	70	70	70	70	70	70	70	70	70	70	70	70
R^2	0.907	0.905	0.933	0.819	0.851	0.874	0.866	0.865	0.872	0.849	0.845	0.846

Note: P-values in parentheses; * denotes that variable is logged

DD 'botex only' models exclude growth enhancement lines from the dependent variable

Source: Ofwat IAP and DD materials, supplemented with Vivid Economics analysis for DD 'botex only' specifications

Table 7 Bioresources and bioresources plus base cost models at Initial Assessment of Plans, Draft Determinations, and Draft Determinations 'botex only'

Variable	BR1			BR2			BRP1			BRP2		
	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+	IAP	DD 'botex only'	DD botex+
Load*							0.79 (0.00)	0.80 (0.00)	0.84 (0.00)	0.77 (0.00)	0.78 (0.00)	0.81 (0.00)
Sludge produced*	1.06 (0.00)	1.22 (0.00)	1.22 (0.00)	1.18 (0.00)	1.19 (0.00)	1.19 (0.00)						
% load treated in bands 1-3		0.05 (0.03)	0.05 (0.03)				0.04 (0.02)	0.05 (0.00)	0.05 (0.00)			
% load treated in band 6										-0.01 (0.03)	-0.01 (0.02)	-0.01 (0.02)
% load with ammonia consent less than 3mg/l							0.005 (0.00)	0.005 (0.00)	0.005 (0.00)	0.005 (0.00)	0.005 (0.00)	0.005 (0.00)
Weighted average density*	-0.28 (0.12)	-0.24 (0.09)	-0.24 (0.09)									
STWs per property*				0.32 (0.08)	0.33 (0.08)	0.33 (0.08)						
Constant	0.75 (0.33)	-0.54 (0.56)	-0.54 (0.56)	0.75 (0.18)	0.78 (0.18)	0.78 (0.18)	-5.11 (0.00)	-5.31 (0.00)	-5.78 (0.00)	-3.94 (0.00)	-3.97 (0.00)	-4.30 (0.00)
Observations	70	70	70	70	70	70	70	70	70	70	70	70
R^2	0.796	0.823	0.823	0.801	0.800	0.800	0.919	0.920	0.922	0.918	0.918	0.917

Note: P-values in parentheses; * denotes that variable is logged
DD 'botex only' models exclude growth enhancement lines from the dependent variable

Source: Ofwat IAP and DD materials, supplemented with Vivid Economics analysis for DD 'botex only' specifications

Table 8 Sewage collection and sewage treatment base cost models with different smoothing assumptions applied to enhancement spend component

Variable	SWC1			SWC2			SWT1			SWT2		
	DD botex+	Unsmoothed	3yr smoothing	DD botex+	Unsmoothed	3yr smoothing	DD botex+	Unsmoothed	3yr smoothing	DD botex+	Unsmoothed	3yr smoothing
Sewer length*	0.82 (0.00)	0.77 (0.00)	0.77 (0.00)	0.90 (0.00)	0.85 (0.00)	0.85 (0.00)						
Load*							0.86 (0.00)	0.89 (0.00)	0.92 (0.00)	0.85 (0.00)	0.86 (0.00)	0.90 (0.00)
% load treated in bands 1-3							0.06 (0.01)	0.05 (0.01)	0.06 (0.01)			
% load treated in band 6										-0.02 (0.05)	-0.01 (0.07)	-0.01 (0.05)
Pumping capacity per sewer length*	0.28 (0.07)	0.16 (0.12)	0.17 (0.22)	0.62 (0.00)	0.46 (0.00)	0.54 (0.00)						
% load with ammonia consent less than 3mg/l							0.004 (0.00)	0.002 (0.04)	0.001 (0.10)	0.004 (0.00)	0.002 (0.02)	0.002 (0.06)
Number of properties per sewer length*	1.19 (0.00)	1.24 (0.00)	1.37 (0.00)									
Weighted average density*				0.19 (0.11)	0.18 (0.09)	0.23 (0.07)						
Constant	-8.59 (0.00)	-8.25 (0.00)	-8.65 (0.00)	-6.53 (0.00)	-5.87 (0.00)	-6.24 (0.00)	-6.27 (0.00)	-6.66 (0.00)	-6.99 (0.00)	-4.77 (0.00)	-5.11 (0.00)	-5.40 (0.00)
Observations	70	70	70	70	70	70	70	70	70	70	70	70
R^2	0.933	0.921	0.926	0.874	0.870	0.857	0.872	0.867	0.875	0.846	0.843	0.847

Note: P-values in parentheses; * denotes that variable is logged
DD 'botex only' models exclude growth enhancement lines from the dependent variable
3yr smoothing based on average value of enhancement capex over last 3 years, with average over last 2 years used in 2012/13, and in-year value taken in 2011/12

Source: Ofwat DD materials, supplemented with Vivid Economics analysis

Table 9 Bioresources and bioresources plus base cost models with different smoothing assumptions applied to enhancement spend component

Variable	BR1			BR2			BRP1			BRP2		
	DD botex+	Unsmoothed	3yr smoothing	DD botex+	Unsmoothed	3yr smoothing	DD botex+	Unsmoothed	3yr smoothing	DD botex+	Unsmoothed	3yr smoothing
Load*							0.84 (0.00)	0.87 (0.00)	0.88 (0.00)	0.81 (0.00)	0.83 (0.00)	0.85 (0.00)
Sludge produced*	1.22 (0.00)	1.22 (0.00)	1.22 (0.00)	1.19 (0.00)	1.19 (0.00)	1.19 (0.00)						
% load treated in bands 1-3	0.05 (0.03)	0.05 (0.03)	0.05 (0.03)				0.05 (0.00)	0.05 (0.00)	0.05 (0.00)			
% load treated in band 6										-0.01 (0.02)	-0.01 (0.02)	-0.01 (0.01)
% load with ammonia consent less than 3mg/l							0.005 (0.00)	0.004 (0.00)	0.003 (0.00)	0.005 (0.00)	0.004 (0.00)	0.004 (0.00)
Weighted average density*	-0.24 (0.09)	-0.24 (0.09)	-0.24 (0.09)									
STWs per property*				0.33 (0.08)	0.33 (0.08)	0.33 (0.08)						
Constant	-0.54 (0.56)	-0.54 (0.56)	-0.54 (0.56)	0.78 (0.18)	0.78 (0.18)	0.78 (0.18)	-5.78 (0.00)	-6.08 (0.00)	-6.30 (0.00)	-4.30 (0.00)	-4.58 (0.00)	-4.78 (0.00)
Observations	70	70	70	70	70	70	70	70	70	70	70	70
R^2	0.823	0.823	0.823	0.800	0.800	0.800	0.922	0.919	0.924	0.917	0.912	0.916

Note: P-values in parentheses; * denotes that variable is logged
DD 'botex only' models exclude growth enhancement lines from the dependent variable
3yr smoothing based on average value of enhancement capex over last 3 years, with average over last 2 years used in 2012/13, and in-year value taken in 2011/12

Source: Ofwat DD materials, supplemented with Vivid Economics analysis

5.2 Alternative onsite and offsite models

Table 10 Water growth model regression table

Variable	Model
New connections	1.11 (0.01)
% Growth intensity x new connections	16.6 (0.36)
Mean distance x new connections	0.16 (0.00)
Constant	3.18 (0.43)
N	80
R^2	0.75

Note: P-values in parentheses; water growth joint capex and new connections smoothed over last 3 years; % growth intensity and mean distance to the nearest 5 towns are demeaned across the industry; model shown is linear

Source: Vivid Economics analysis based on Ofwat IAP datafiles, company Business Plan data tables and Land Registry new builds data

Table 11 Wastewater growth model regression table

Variable	Model
New connections*	0.90 (0.00)
% Growth intensity x new connections*	66.9 (0.00)
Mean distance x new connections*	0.23 (0.00)
Constant	14.9 (0.00)
N	50
R^2	0.76

Note: P-values in parentheses; wastewater growth joint capex and new connections smoothed over last 3 years; % growth intensity and mean distance to the nearest 5 towns are demeaned across the industry; model shown is linear

Source: Vivid Economics analysis based on Ofwat IAP datafiles, company Business Plan data tables and Land Registry new builds data

Company profile

Vivid Economics is a leading strategic economics consultancy with global reach. We strive to create lasting value for our clients, both in government and the private sector, and for society at large.

We are a premier consultant in the policy-commerce interface and resource- and environment-intensive sectors, where we advise on the most critical and complex policy and commercial questions facing clients around the world. The success we bring to our clients reflects a strong partnership culture, solid foundation of skills and analytical assets, and close cooperation with a large network of contacts across key organisations.

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