United Utilities Water

Drainage and Wastewater Management Plan 2023

Technical Appendix 5 - Assessing Future Risk

Document Reference: TA5

May 2023

Water for the North West

Executive Summary

This document sets out United Utilities Water (UUW) approach to assessing future risk as part of producing a long-term drainage and wastewater plan, which will offer best value to customers and deliver robust and resilient wastewater services for the North West. The approach to assessing future risk accounts for key challenges facing the North West over the next 25 years, including climate change and a growing population. This is UUW's first Drainage and Wastewater Management Plan (DWMP) and the first time such plans have been produced by the sector as a whole. Under the guidance of the DWMP Framework, UUW have developed a range of approaches and tools in order to build the plan; these tools will continue to be refined, developed and re-run as new or better information becomes available. These tools include approaches to forecasting demand, application of climate change uplifts, optimisation of solution blends, and modelling across UUW's wastewater network, wastewater treatment sites and the environment.

There is a need to ensure that the impact of current and future risk that arises from challenges such as population growth and climate change are suitably assessed. This enables the planning for, and mitigation of the risk before there is an impact on UUW's wastewater service to customers and the receiving environment. Some risks are within UUW's control, but others are beyond that, so there is a need to plan for and include them where possible in order that the plan can be adapted as required in the future.

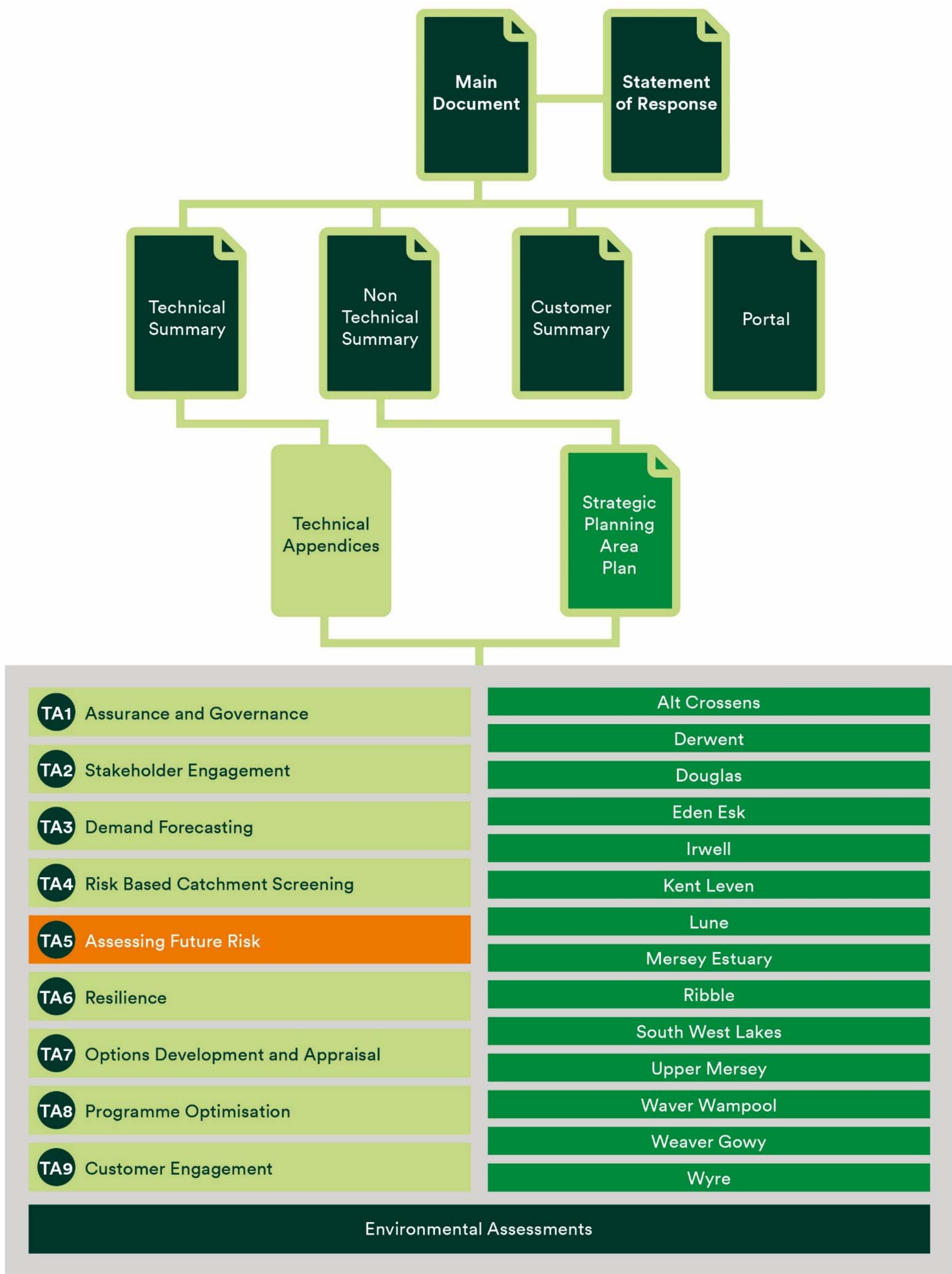
Through the DWMP, a number of assessments have been carried out in order to establish the level and locations of multiple risks; these include sewer flooding, storm overflow activations, wastewater treatment performance and the impact on the receiving environment from these discharges.

The assessment locations are identified using an initial screening exercise as detailed in Technical Appendix 4: Risk based Catchment Screening and the results incorporated into option development and programme appraisal (Technical Appendices 7 and 8). The results are used to understand locations with high numbers of variable risk, or those where a specific risk is likely to require mitigation. Additional horizon scans supplement the understanding of each catchment, to enable a full assessment of potential risk to be undertaken.

The assessments will inform the next UUW business plan (2025–2030) and future long-term delivery strategies in order to ensure that the North West is as best prepared for the future as possible.

This Technical Appendix is one of a suite of documents that provides information used in the development of the Drainage and Wastewater Management Plan as shown in Figure 1.

Figure 1 DWMP document structure



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For a list of glossary, refer to document C003.

1. Introduction

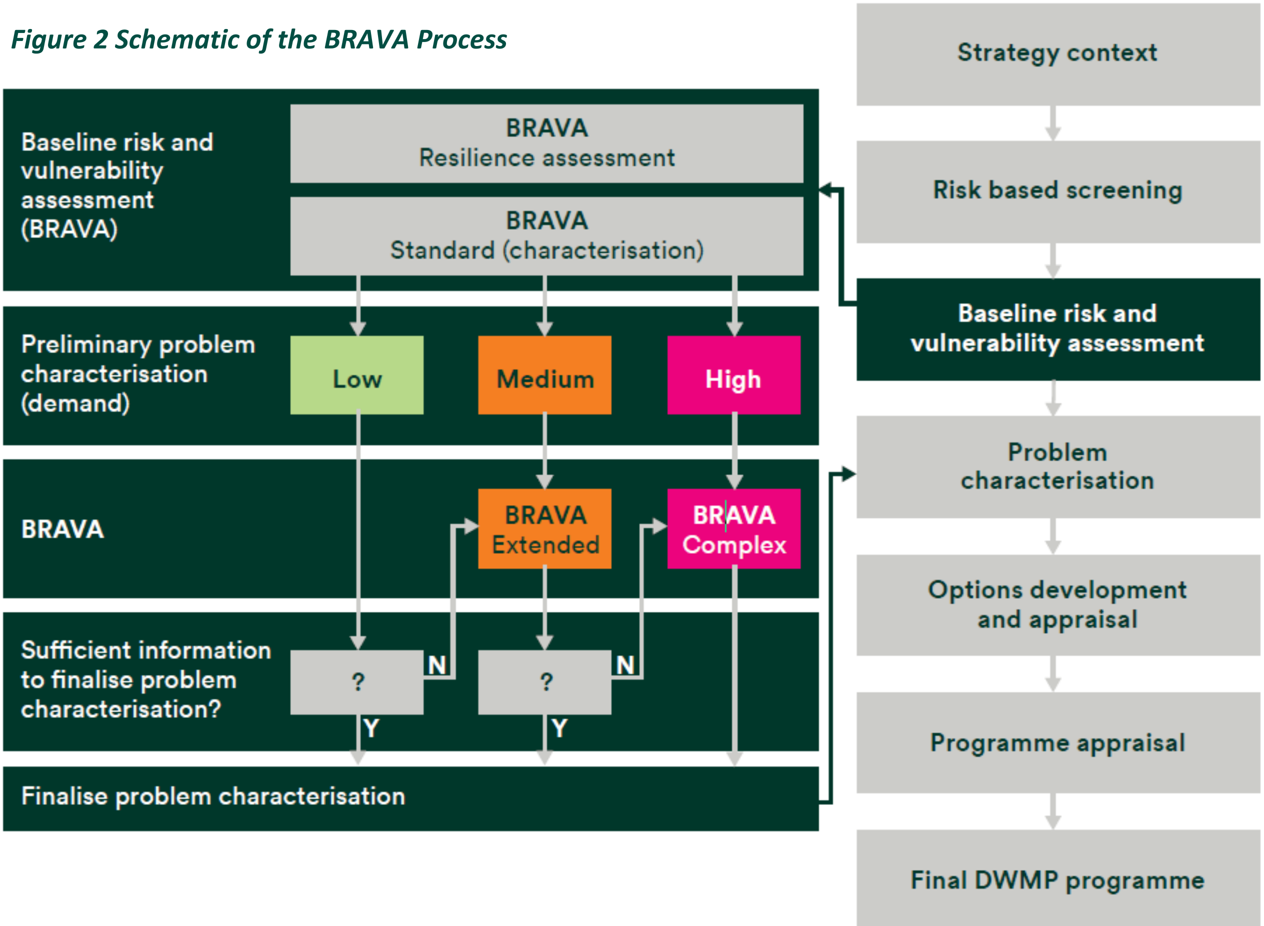
1.1 Overview

1.1.1 This document details the methods and data used to assess future risk within the United Utilities Water (UUW) region. This process was informed by, and closely adhered to, the guidance detailed within 'Appendix C – Baseline risk and vulnerability assessment; and problem characterisation' of the Water UK document 'A framework for the production of Drainage and Wastewater Management Plans' published in September 2018.

1.1.2 A baseline risk and vulnerability assessment (BRAVA) is undertaken to assess the baseline position of system performance and to understand wider resilience issues within each catchment that could impact on maintaining compliance with planning objectives. BRAVA is assessed across a water company's region.

1.1.3 This is part of the overall DWMP planning process shown in Figure 2 taken from 'A framework for the production of Drainage and Wastewater Management Plans', Water UK, September 2018.

Figure 2 Schematic of the BRAVA Process



1.1.4 A BRAVA is designed to develop an understanding of impacts on planning objectives as a function of future changes in a catchment based on an established base year position and to develop an understanding of wider catchment resilience issues that are not directly linked to system characteristics. Problem characterisation identifies the nature and complexity of the interventions required and assigns catchments to different levels of options development and appraisal.

1.1.5 This technical appendix covers all steps associated with BRAVA (including horizon scanning for wider issues) and problem characterisation including a summary of the results and recommendations for future DWMPs.

2. Application of BRAVA following Risk Based Catchment Screening (RBCS)

2.1 Planning areas

2.1.1 As defined within the DWMP framework, BRAVA has been assessed at three levels to maximise the potential for partnership working and for effective engagement between regulators and stakeholders at both company-wide level and more locally. These levels are known as Tactical Planning Units (TPU) and are defined in Figure 3 and Table 1. A TPU comprises the wastewater treatment works and its catchment, while a Strategic Planning Area (SPA) comprises multiple TPUs within the same river basin.

Figure 3 Definitions of Tactical Planning Areas

Table 1 Tactical Planning Areas

Tactical Planning Area Name	Level	Definition	UUW Definition
Company Area	Level 1 (L1)	Overarching area where the company is licensed to provide wastewater services	Regional area
Strategic Planning Area (SPA)	Level 2 (SPA)	An aggregation of TPUs, which align with river catchments and/or administrative boundaries	River Catchment area
Tactical Planning Unit (TPU)	Level 3 (TPU)	A wastewater treatment works, its drainage area and its catchments	Wastewater treatment drainage area
Local Planning Needs	Level 4 (L4)	Sub catchments of wastewater treatment works catchments	Wastewater treatment sub-drainage areas

2.2 Pre-BRAVA

2.2.1 Overview

2.2.1.1 Following Risk Based Catchment Screening (as detailed in Technical Appendix 4 – Risk Based Catchment Screening (TA4) of the same name), verification and data validation is applied to ensure that appropriate assessments are being undertaken for each Tactical Planning Unit including those catchments with known issues that may not have flagged during RBCS. This 'Pre BRAVA' process verifies assumptions for each TPU catchment to be used in assessments, identifies locations where a risk hasn't been highlighted to be assessed, and where the risk is not defined or has been resolved is removed from the process.

2.2.2 Approach

2.2.2.1 A workbook is completed for each Strategic Planning Area with all RBCS scores and horizon scanning information (inland bathing water risk, environmental designation risks and population threshold exceedances under environmental guidance) included.

2.2.2.2 Assumptions on trade effluent discharges, infiltration, population (current and forecast) and dry weather flow are also included for review along with identification of significant new developments and existing projects.

2.2.2.3 The workbook is reviewed by the relevant Asset Managers for each TPU (including those catchments that had not met any screening criteria) and the assumptions and individual BRAVA required agreed. This also enables identification of some locations that require further action or investigations before final agreement on assessments or assumptions.

2.2.3 Outcome

2.2.3.1 A verified summary is produced detailing all BRAVAs required at each TPU confirming the locations to be included in the next stage of risk assessments (BRAVA).

3. Planning tools and modelling methodologies

3.1 Overview

3.1.1 This section provides details on the input data, models and outputs used to assess current and future risk within the UUW region. A number of these tools and models have been developed in-house specifically for the BRAVA process in order for UUW to build as complete a picture as possible of future risk.

3.2 Demand forecast model

3.2.1 A forecast of demand is produced, which then provides inputs for the assessment models detailed within the below section of this document. Technical Appendix 3 – Demand Forecasting (TA3) contains the detail of how this model is produced and definitions of the inputs and outputs it provides. A summary of the inputs, assumptions and how the model data is applied is shown in Table 2.

Table 2 Elements of continuous flow forecast data used to assess future risk

Forecast Element	Source and Summary	Application
Household Population (P)	Based on Local Authority planning information where available, with trend-based forecast beyond the planning timescales	Allocated at TPU along with the assumptions on PCC and infiltration for calculating future flow and load
Per Capita Consumption (PCC)	From UUW Water Resource Management Plan 2019* includes the impact of interventions to reduce PCC by 2050	Allocated to all household population with assumption that 95% of consumption discharges to sewer and included in dry weather flow forecast
Visitor Population (p)	Not included in the forecast, but discharge is included in measured baseline flow	Allocated to TPU. Forecast to be reviewed for next DWMP and will account for any permanent impact of COVID-19 on visitors to drainage areas
Infiltration (I)	New property assumption applied as 55 l/hd and current property assumption dependent on measured flow information. Standard assumption (120 l/hd/day) applied where measured flow is not available for existing properties	Included for all assessments at TPU that use continuous flow. Wastewater treatment works compliance, Dry Weather Flow (DWF) and multiples of flow treated and as an input to the assessment of deterioration. Flows were reconciled to a baseline value
Trade Effluent (E)	Historic trade effluent flow and load data included in baseline and future assumptions unless specific local knowledge on trade increase/decrease is identified	Allocated to TPU and part of wastewater treatment works continuous discharge flow assumptions as above

Forecast Element	Source and Summary	Application
Wastewater Treatment Works Discharge	Baseline DWF from measured (Q80) historic data with future PG+I+E calculation	Allocated to individual wastewater treatment works for multiple BRAVAs (DWF, multiples of flow, compliance, capacity and resilience)

*Note: PCC assumptions were revised during development of the DWMP in line with draft WRMP for Water Resources West timescale. The revised assumptions have been applied to solution development to ensure the change is captured and a review of wastewater treatment works BRAVAs undertaken to identify additional risks from the change in this value. The difference is not significant within network models and associated BRAVAs (due to the relative impact of surface water) so they have not been adjusted.

3.3 Hydraulic network model(s)

3.3.1 Overview

3.3.1.1 The Network Modelling team within UUW Engineering maintain an extensive collection of hydraulic network models. Each hydraulic model represents the network draining to an individual wastewater treatment works and is utilised to assess hydraulic flood performance and overflow activation performance. Where there is a high risk drainage area without a hydraulic model, a new model was built. The starting models (2020 baseline) have been verified against short-term flow surveys and long-term observed wastewater treatment works flow data where available.

3.3.1.2 In order to assess the future 2030 and 2050 planning horizons, these models are uplifted to account for future growth, development and urban creep. Climate change is applied to all rainfall used for these future scenarios.

3.3.1.3 Since a significant proportion of the North West sewer network is combined, the increase in risk of sewer flooding by 2050 is mainly being driven by additional surface water resulting from climate change, a factor which far surpasses the impacts of growth and urban creep. This characteristic means that drainage systems in the North West are more vulnerable to climate change impacts than areas with lower proportions of combined systems and lower rainfall. Table 3, below, defines the modelling inputs.

Table 3 Input data to hydraulic network models

Forecast element	Source and summary	Application
Population	Based on Local Authority planning information where available, with trend-based forecast beyond the planning timescales; Population, Household and property Forecast: Demographic evidence for Water Resources Management Plans, Edge Analytics 2017	Allocated at TPU
Per Capita Consumption	From WRMP 2019 includes the impact of interventions to reduce PCC by 2050	Allocated to all household population with assumption that 95% of consumption discharges to sewer
Trade and Commercial Flows	Consent Data	Consented flows less than 1 l/s are summed and applied at TPU level. Consented flows greater than 1 l/s are applied to discharge manhole

Forecast element	Source and summary	Application
Infiltration	New property assumption applied as 55l/hd and current property assumption dependent on measured flow information	Applied at site of development for new properties. Applied at TPU level unless source confirmed through flow survey
Development	Developer Impact Assessment Programme	Applied to known discharge manhole (otherwise assumed based on location and existing assets)
Urban Creep	Impact of Urban Creep on Sewerage Systems, Allitt (2010)	Allocated at TPU level
Climate Change	Rainfall Intensity for Sewer Design, UKWIR 2017, 17/CL/10/17	Applied at TPU level via rainfall uplifts or modification

3.3.2 Model output and evaluation

3.3.2.1 Ten-year time series rainfall simulation outputs are used to calculate annual overflow activation performance at the baseline 2020 scenario and then the change over time due to growth and climate change.

3.3.2.2 Risk of hydraulic flooding is assessed through simulating all network models for a range of return periods (1, 10, 20 and 50 years) using 2D models and design rainfall. The 2D flood extents are used within geo-spatial queries to calculate, for each property in the region, the minimum return period (of the subset of simulations), at which each property is affected by overland flow. This return period is converted to an annualised flood risk for each property. (For example, a property flooding in a ten-year event would have an annual flood risk of 1 in 10, or 0.1).

3.4 PIONEER model(s)

3.4.1 Overview

3.4.1.1 A regional asset deterioration model (PIONEER) is used to calculate annualised risk across all wastewater network assets for internal and external flooding ('other causes' flooding rather than hydraulic overload of the sewer system), blockage, collapse and pollution. The individual asset annualised risk is summed by TPU.

3.4.1.2 Three different scenarios are simulated that each represent a different level of capital investment into the asset base over time. All three scenarios are assessed for the present day (2020) plus each of the 2030 and 2050 planning horizons. The investment strategies simulated are:

- **Fix on fail**
  - For this scenario, we simulate a more reactive approach to maintenance than we would typically deploy in our normal business operation. This means that we would react to faults and failures across our system, rather than proactively intervene to ensure that assets are in a suitable condition to provide the expected service level. This scenario results in a gradual deterioration in predicted service levels as the asset base ages and becomes less and less reliable. This scenario provides a 'worst case' planning approach to help us understand how quickly our assets, system and overall service levels could deteriorate without proactive investment.
- **Stable performance**
  - For stable performance, we look to simulate maintaining a broadly stable service, in line with our recent historical experience. This means that we select the most cost effective, proactive work to refurbish or replace those assets that present the largest predicted risk to service. This scenario helps us to identify; underlying trends in expected deterioration, future risk hotspots,

overall investment needed as well as relative levels of investment between different types of assets in order to provide a stable long-term service. As this sort of scenario is financially unconstrained, it may lead to an unaffordable programme of work, so we would always look to challenge and further optimise the simulated programme by looking for synergies across other investment needs, over and above simply maintaining our existing assets.

- **AMP7 committed spend**
  - This scenario looks at the expected long-term impact of maintaining the current level of investment into the future. This scenario is often very similar to the stable performance scenario, but as it is financially constrained it will typically show some increase in service risk. We, therefore, aim to identify other work that could help to stabilise and even reduce the risk, often through changing operational processes and procedures or through more efficient use of new technology.

3.4.2 Model output and evaluation

3.4.2.1 BRAVA utilises results from the stable performance scenario as this most closely aligns to the existing long-term objective of stabilising the health of the asset base by the end of AMP9. The two remaining scenarios are used for sensitivity analysis and to inform the optioneering and solution development stages of DWMP.

3.5 Wastewater treatment model(s)

3.5.1 Overview

3.5.1.1 Individual wastewater treatment capacity models have been developed to understand the risk of future demand on the current process capacity.

3.5.1.2 Models use forecast flow and load and apply it to existing wastewater treatment works process unit sizing information to understand the risk of capacity exceedance.

3.5.1.3 The models can be adapted with different future scenarios (including future final effluent permits) but for the purpose of BRAVA, capacity is assessed against current final effluent permit requirements.

3.5.2 Model input

3.5.2.1 Most of the inputs into individual wastewater treatment works models (baseline and future) are taken from the Demand Forecast model for consistency and collated in an individual ‘input sheet’ to be used within the treatment capacity model. Details on the assumptions within this forecast are given in Technical Appendix 3 – Demand Forecasting (TA3) and included in Table 4, along with additional assumptions required for a complete model to be developed.

3.5.2.2 Assessments are provided at five-year intervals from 2020 to 2040 with an additional assessment at 2050.

Table 4 Input to wastewater treatment works capacity assessment models

Input	Units	Source
Domestic population	PE	Demand forecast assumptions 2020 baseline
Population equivalent	PE	Demand forecast assumptions 2020 baseline
Incoming Flow	m^3/day (DWF and multiples of)	Demand forecast assumptions: Three years measured if available
Wastewater treatment works Compliance limits	mg/l 95%ile or average	Demand forecast assumptions (existing or AMP7)

Input	Units	Source
Forecast future flow(s)	m^3/day (DWF and multiples of)	Demand forecast assumptions applied using PG + I + E where P = population, I = infiltration and E = trade effluent
Crude effluent values	mg/l 95%ile or average	Measured sample data over three years (baseline) or standard assumption per p.e. if not available
Liquor return	m^3/day	Bespoke calculation for sites with sludge treatment
Biochemical Oxygen Demand (BOD): Chemical Oxygen Demand (COD) ratio		Standard assumption
Future load (BOD; Ammonia; Alkalinity; phosphorous)	mg/l 95%ile or average	Calculation using historic flow and load ratio (or base assumption where information is not available)
Process Unit Type (existing)		Referenced Engineering sources specific to each site
Process Unit size (existing)		Referenced Engineering sources specific to each site
Assumption on performance (load removal) by process type		Standard engineering assumptions based on treatment type and size
Process unit size required (future)		Current asset standard assumptions

3.5.3 Model output

3.5.3.1 A calculation of asset standard size (using future flow and load forecasts) is compared to existing process unit size to understand if capacity is likely to be exceeded. Each process unit is assessed individually, and a weighted score applied depending on the criticality of sizing and importance of the process to overall performance. A risk summary as shown in Figure 4 is produced for each planning horizon.

Figure 4 Example of a wastewater treatment works model output showing elements of the treatment process of process assessed for risk (with standard weighting assumption)

Risk summary

	Individual Asset Standard criteria	Individual criteria rating	Weighting factor	Weighted Headroom Score (Value)	Overall Asset Score %	Unit Score (Value)	Maximum Unit Score (Value)
Primary Settlement	Retention Time	Compliant	1.2	120	85%	290	340
	Max Surface Loading Rate	Compliant	1.2	120			
	Max Surface Loading Rate (n-1)	Compliant	0.5	50			
	Weir Loading Rate	at risk	0.5	0			
Mineral Trickling Filters	BOD Loading rate	Compliant	1.4	140	69%	320	460
	Ammonia loading rate	at risk	1.4	0			
	Minimum (DWF) Wetting Rate	Compliant	1	100			
	Maximum Wetting Rate	Compliant	0.8	80			
COUF	Minimum Upflow Rate	at risk	1	100	93%	380	410
	Solids Loading rate (n-1)	Compliant	1.3	130			
	Maximum Upflow Rate (n-1)	Compliant	1	92			
	Maximum Upflow Rate	at risk	0.8	58			
Humus tank	Minimum retention time	Compliant	1.2	120	90%	243	270
	Max Surface Loading Rate (n-1) UV sites only	N/A					
	Max Surface Loading Rate	at risk	1.5	123			
Storm Storage	Total Storm Tank Volume	Compliant	1	100	100%	100	100
Sludge storage	Days Retention Time (Total)	at risk	0.5	44	88%	44	50
Coagulant dosing	Ferric sulphate storage volume	at risk	1	0	0%	0	100
Alkalinity dosing	Required alkalinity storage volume	Compliant	1	0	0%	0	100
AT RISK UNIT COUNT		7			66%	1376	1830
COMPLIANT COUNT		11					
					*For reference only, final scoring on 'Output Summary' Sheet		

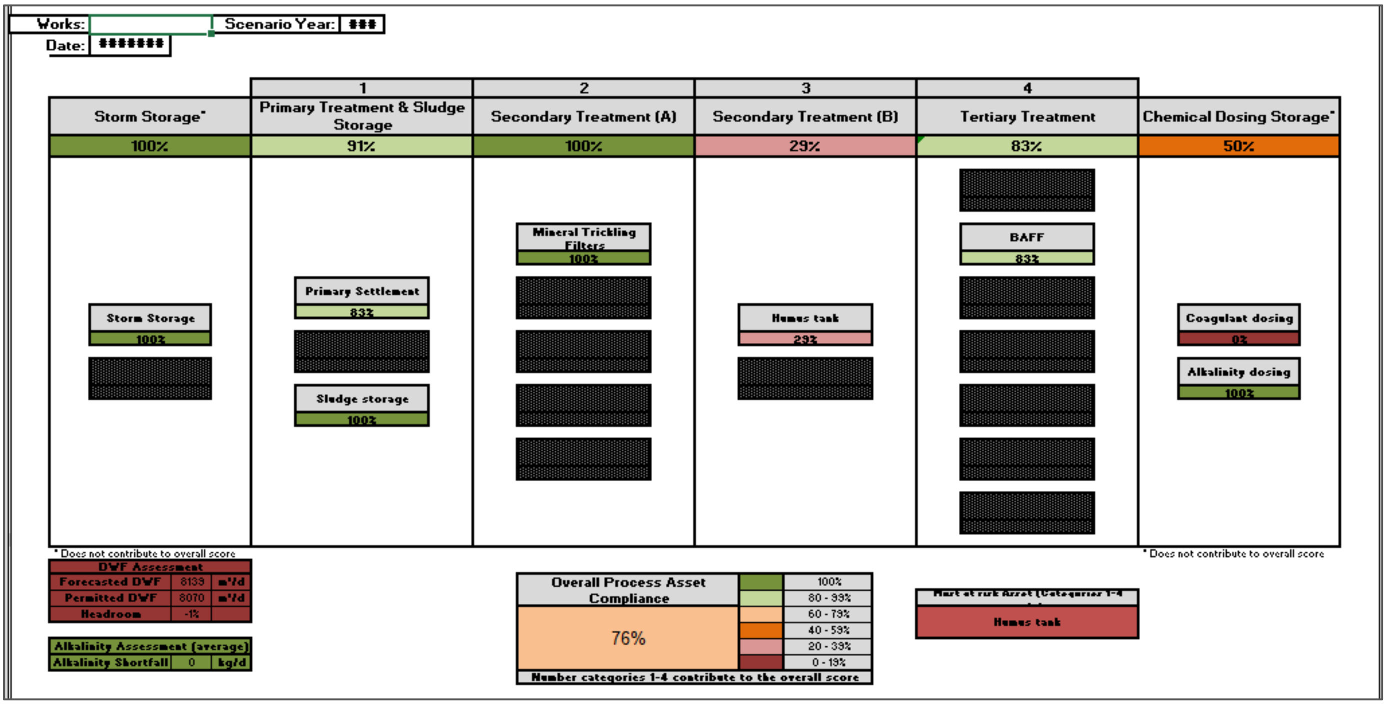
3.5.3.2 The overall risk is then calculated as a percentage likelihood to achieve compliance, with 100% being fully compliant and 10% very likely that future demand would result in non-compliance (based on the existing process unit type and size).

3.5.3.3 An additional output from the assessment illustrating the result is a process flow diagram (Figure 5) to demonstrate which elements of the process are driving the risk.

3.5.3.4 The model outputs are used for BRAVA but can also be adapted to include different future scenarios during options development.

3.5.3.5 Updates to individual models are made when a significant change in input is recorded (crude flow and load increase/decrease) or projects on site alter the process size or type.

Figure 5 Example of a wastewater treatment works model output as a process flow diagram with a distribution of process unit assessment results



3.5.4 Evaluation

3.5.4.1 The models use standard process unit assumptions so unusual or uncommon processes cannot be evaluated. Where the process is more complicated or bespoke or includes multiple different treatment units for different streams of effluent (at six locations), a review of the most recent project design sheet is undertaken to assess the design capacity against future flow and load. Historic (measured) data cannot be used as a baseline where a recent transfer to a wastewater treatment works has been delivered. Assumptions are made on the current and future flow and load but are less reliable. A design sheet is produced for transfer solutions so is used to verify the capacity for the future flow and load instead.

3.6 Environmental river model(s)

3.6.1 Overview

3.6.1.1 A Microsoft Excel based regional model is used to assess the impact that increasing final effluent (FE) flows from United Utilities Water's wastewater treatment works would have on water quality in the receiving water courses, specifically for BOD, ammonia and phosphorous. The increases are assessed relative to the modelled water quality for the base planning horizon of 2020.

3.6.2 Model input

Table 5 Excel River model – inputs

Input	Source
River Stretch	2012 SIMCAT models
WFD Standards for BOD, Ammonia and Phosphate	2012 SIMCAT models
River Flow (mean and 5%ile)	2012 SIMCAT models
River concentration of BOD, Ammonia and Phosphate (mean and 90%ile)	2012 SIMCAT models

Input	Source
Wastewater treatment works FE Flow (mean)	UUW measured flow or theoretical values
Wastewater treatment works concentration of BOD, Ammonia and Phosphate (mean and standard deviation)	UUW measured data or theoretical values
Forecast flow change (from 2020) at five-year intervals (up to 2050)	Demand Forecast Model

3.6.3 Methodology

3.6.3.1 For each wastewater treatment works, mass balance equations are used to calculate the concentration of each determinant in the downstream river:

3.6.3.2 Load Upstream (US) of the FE discharge = Load Downstream (DS) of the FE discharge

3.6.3.3 US River Load + wastewater treatment works Load = DS River Load

3.6.3.4 Given Load to be the product of Flow and Concentration (Conc), this equation can be written as follows:

- US River Flow x US River Conc + wastewater treatment works Flow x wastewater treatment works Conc = DS River Flow x DS River Conc

3.6.3.5 The flows and concentrations in bold are all known, so the DS river concentration is calculated by re-arranging the equation. The downstream river concentration is then translated directly into a Water Framework Directive status. Assessments were provided at five-year intervals from 2020 to 2050. Each continuous discharge was assessed independently and did not account for changes in impact from upstream discharges.

3.6.4 Model output

3.6.4.1 The results provide an indication of whether a significant deterioration of BOD, ammonia or phosphorous is likely in the receiving watercourse and if this would alter the existing quality standard. The model outputs are used to highlight locations at risk through BRAVA but also to indicate which wastewater treatment works require a more detailed review of final effluent permits to prevent deterioration. Updates are required when a significant change in input is recorded (crude flow and load increase/decrease) or a change in final effluent permit limits.

3.7 Sludge model (RIAP)

3.7.1 Overview

3.7.1.1 The UUW Regional Integrated Asset Planning (RIAP) model is a Microsoft Excel based model used to evaluate scenarios of operating the regional bioresources sludge treatment system. For the purposes of the BRAVA assessment, the RIAP model is used to determine the capacity to treat sludge given the forecasted sludge production and to provide a projection of the volume and composition of liquor returns from bioresources thickening/dewatering activity to Network+ for input into the wastewater treatment capacity models.

3.7.2 Model input

Table 6 Excel sludge model inputs

Input	Units	Source
Wastewater Population Equivalent (PE) forecast	PE	Demand forecast assumptions 2020 baseline

Input	Units	Source
Indigenous sludge production	tonnes Dry Solids (tDS) & m^3	Measured data from regulatory reporting
Asset standard sludge production by wastewater treatment type	g/hd/day	UUW Asset Standards
Wastewater future Phosphorous (P) Scheme Information	Type (e.g. ferric dosing), permit limit mg/l, implementation date	Water Industry National Environmental Programme (WINEP)
Current wastewater treatment works classification and information	Classification (e.g. Activated Sludge Process (ASP), filter works), permit level mg/l	Water Environment Federation (WEF)
Historical sludge transport	Sludge volumes m^3, dry solids %DS, routes	Proof of Delivery system (PoDFather)
Asset standard sludge dry solids by process (e.g. Surplus Activated Sludge (SAS) thickening, thickening, dewatering)	%DS	UUW Asset Standards
Sludge liquor composition	BOD mg/l, COD mg/l, Ammonia mg/l	UUW Measured Data
Sludge treatment capacity	m^3/day, tDS	Bioresources and Network+ service level agreement (SLA)

3.7.3 Methodology

3.7.3.1 A regional sludge forecast is produced by taking the indigenous sludge production for each wastewater treatment works determined in the regulatory reporting and projecting this forward based on population growth and incorporating changes to treatment type and environmental permits based on asset standards (e.g. tighter Phosphorus consents could lead to increased ferric dosing, which results in increased sludge production).

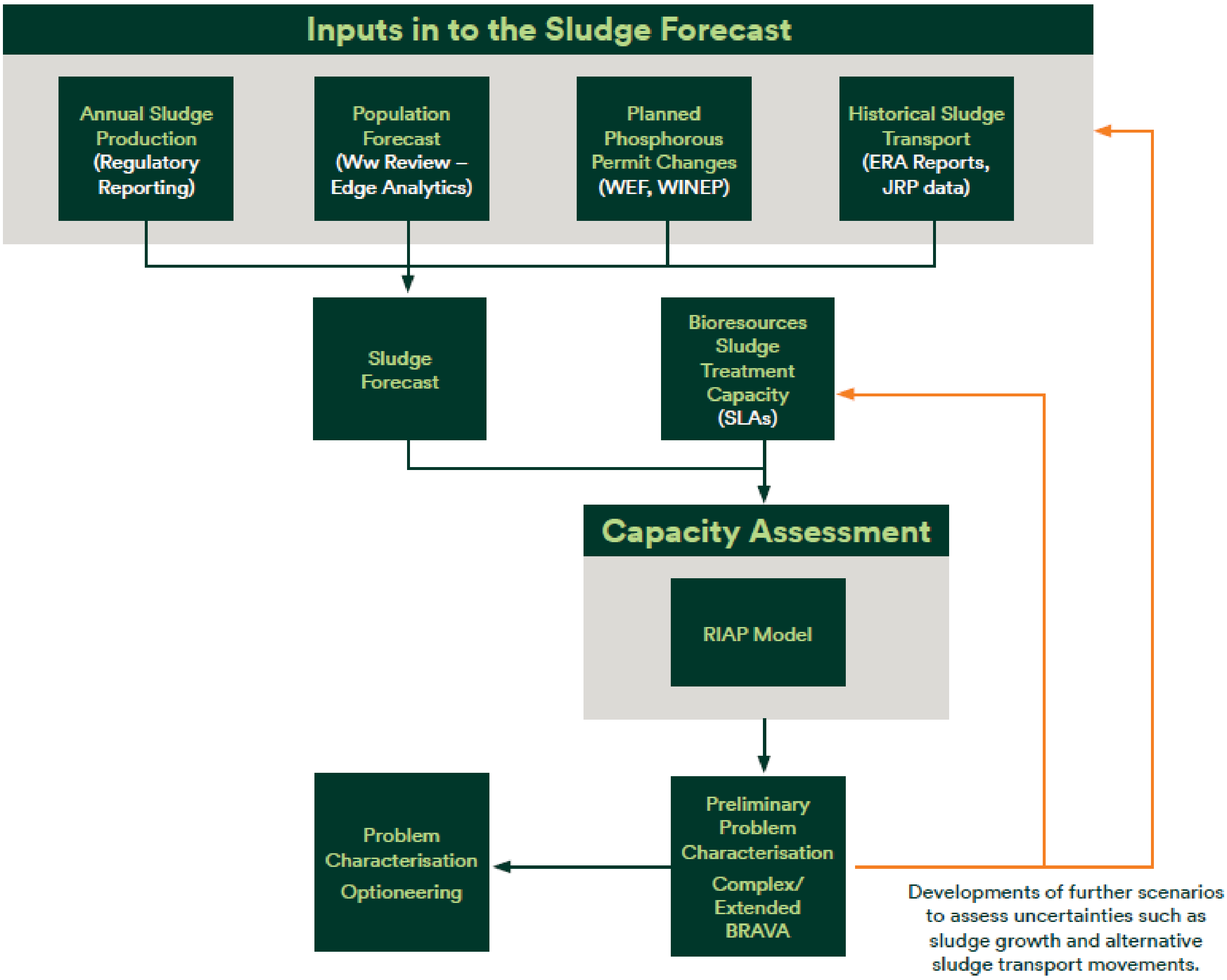
3.7.3.2 Historical sludge transport data is used to determine the allocation of sludge from each wastewater treatment works to bioresources facilities as per typical operation, with adjustments made to accommodate any future proposed changes to the regional bioresources system.

3.7.3.3 The RIAP model computes a mass/energy balance across all bioresources facilities to calculate the sludge throughput volumes through each process and any resulting liquor volumes produced through thickening/dewatering activity. Liquor composition/strength is taken from measurements captured in OMS as part of the regulatory reporting.

3.7.3.4 Sludge treatment capacity is defined at a site level based on the service level agreements between the Network+ and bioresources price controls. The RIAP model compares the sludge throughput volumes against the site capacity to assess the available treatment headroom on an annual basis.

3.7.3.5 Figure 6 demonstrates how the RIAP model is set up.

Figure 6 Sludge model inputs and outputs



3.7.4 Model output and evaluation

3.7.4.1 The model outputs are used to highlight bioresources sludge treatment facilities at risk through BRAVA when they reach their maximum throughput capacity under current operation. Note that sludge treatment operates as a regional system with raw or thickened/dewatered sludge transported by road, and as such, sludge can be diverted from its usual site of treatment to another bioresources facility (or out of region to a third party) when the bioresources facility reaches its maximum capacity. Total liquor production at each bioresources facility is given as an output to feed into the wastewater treatment capacity models.

3.8 How we use the model outputs

3.8.1 The outputs from the models listed in sections 3.2 to 3.7 are initially used to produce a detailed picture of current and future risk within the UUW operating area at both a Strategic Planning Area and Tactical Planning Unit basis. The process of how that regional picture of risk is developed is detailed in the next sections of this document. Within the DWMP process, these results are then used for Problem Characterisation scoring (Section 8 of this document) before feeding into the Optioneering and Solution Development phases of DWMP, which are discussed in UUW documents Technical Appendix 7 – Option Identification and Appraisal, and Technical Appendix 8 – Programme Optimisation, respectively.

4. Inputs to the assessments

4.1 Overview

4.1.1 This section defines the background and source of the model input data detailed within Section 3 that are used to undertake BRAVA and establish the level of risk.

4.2 Growth and development

4.2.1 Residential population

4.2.1.1 In line with Environment Agency guidance and the Water Resources Management Plan, a local housing plan trajectory forecast is used. This forecast was updated for the draft WRMP after BRAVA had been published, so a review of the differences at a Tactical Planning Unit level was completed and additional risk-based screening (based on population increase) applied to identify locations where additional assessments are required. Plan-based assumptions on housing growth (instead of ONS trend-based population) is expected to be more representative of growth as they take into account known approved future developments in specific locations. In addition to this, more detailed assessments of local planning data and applications is completed for drainage areas to understand specific impacts. This approach is shared with all Local Planning Authorities. A limitation of this methodology is that the assumptions on location, timing and extent of new properties can change over time.

4.2.2 Non-residential population

4.2.2.1 Trade effluent forecasts (by trader type) are used to understand likely regional trends but are not reliable at TPU level due to individual trader characteristics. Historic trade discharge values are used, and this is verified with trade effluent teams to understand if there is likelihood of a significant change in the future (from discussion with individual traders). Where there is certainty that a trade volume or composition will change, this is included in the forecast. Likewise, non-household consumption (business premises with a discharge that don't require a trade permit) are assumed to be stable and, therefore, the volumes and composition are within the baseline assumption.

4.3 Urban creep, infiltration, per capita consumption changes and climate change

4.3.1 In 2019, UUW commissioned a piece of work to investigate best practice within the UK water industry of the calculation and application of urban creep to urban drainage models. The findings were that the methods detailed within the UKWIR Research document 'Impact of Urban Creep on Sewerage Systems' Allitt (2010) are the most widely used and are considered a sound evidence-based approach. This was in line with UUWs existing approach to the application of urban creep to its sewer models.

4.3.2 Infiltration is applied using standard assumptions for future developments (55 l/hd/day).

4.3.3 Per Capita Consumption (PCC) is applied in line with the most recent WRMP as 95% of the average value (2019 figure for BRAVA but updated with more recent figure for option development).

4.3.4 The UKWIR 2017 report 'Rainfall Intensity for Sewer Design, 17/CL/10/17' is the basis of all climate change uplifts applied to the hydraulic network models for BRAVA. Therefore, the basis for both the 2030 and 2050 planning horizons is the RCP8.5 high emissions scenario. The projections are based on the UKCP09 models and additionally, the REDUP tool associated with the UKWIR paper was used to perturb long time series rainfall.

4.3.5 UKCP18 outputs were not available within the timescales of BRAVA, however, this data will be used in the future for subsequent DWMP cycles.

4.4 Continuous and intermittent discharges and receiving water quality

4.4.1 Assumptions are made where there are confirmed environmental drivers that will be mitigated by 2025 (AMP7 WINEP programme). The no deterioration model identifies locations where the increase in wastewater treatment works discharge could lead to tighter environmental permits and locations identified as requiring environmental permit improvements that have not been included in the current planning cycle (AMP7) have been identified through horizon scanning and highlighted for option development.

4.4.2 Existing water body status and discharges that impact on Sites of Special Scientific Interest (SSSI) and Special Area of Conservation (SACs) are highlighted through the horizon scanning process along with potential inland bathing waters.

4.4.3 Since the analysis pre-dates the outputs from the bathing and shellfish water investigations, activation frequencies were assessed in-line with Water UK's BRAVA planning objectives publication[1].

4.4.4 At the time of the analysis, WINEP guidance on activation frequency for storm overflows had not been released, so an assumption on activation frequency and volume thresholds that generate risk was applied.

4.4.5 Option development at all locations (including newly identified TPUs at risk from the environmental requirements) was driven by WINEP guidance.

[1] https://www.water.org.uk/wp-content/uploads/2020/07/BRAVA-planning-objectives-for-the-first-cycle-of-DWMPs.pdf

5. Baseline Risk and Vulnerability Assessments (BRAVA)

5.1 BRAVA process summary

5.1.1 Overview

5.1.1.1 BRAVA allow UUW to model baseline and future performance, taking into account factors such as climate change and population growth, to understand where we are likely to see a deficit in achieving our long-term planning objectives. By assessing the impact of current and future risk, we can understand the challenges that arise from uncertainties such as population growth and climate change. This enables us to plan for and mitigate the risk before there is an impact on our wastewater service to customers and the receiving environment. Some risks are within our control, but others are beyond that, so we account and plan for these to enable us to adapt, mitigate risk and identify where shortfalls require new knowledge or approaches.

5.1.1.2 Figure 7 identifies how the assessments undertaken relate to UUWs long-term planning objectives.

Figure 7 DWMP planning objective targets

5.1.2 Base year

5.1.2.1 To understand the current system a base year is determined, for the purpose of this plan it is 2020. This reflects existing demand (flow and load) from foul and surface water and is used to define current performance against all planning objectives; available constraints and capacity within the system; and appropriate thresholds to assess the risk. All committed capital schemes for AMP7 are taken into consideration so as not to forecast a problem that is already being resolved. The thresholds for all assessments are included in Table A1 BRAVA thresholds.

5.1.3 Future risk

5.1.3.1 Assessments are undertaken for multiple planning horizons. Planning within a ten-year horizon (up to 2030) the risk is defined, but has lower levels of uncertainty on the demand than long term (2050). This planning horizon provides an opportunity to identify risk to be included in AMP8, either as a partial or full intervention to address long-term risk. Planning within a 30-year horizon the risk has higher uncertainty, but it can be used to drive best value investment. This current, medium and long-term analysis enables risks to be prioritised and a long-term adaptive plan to be developed.

5.1.4 Standard BRAVA

5.1.4.1 These assessments are applied at a Tactical Planning Unit level in order to understand the primary drivers for failing to meet planning objectives. The assessments use a central (i.e. most likely) estimate of growth and climate change. The outputs from each assessment provide an indication of the severity of the consequence and the timing. A demand assessment on population growth is undertaken for all TPUs identified as requiring a BRAVA. Supply assessments are undertaken at locations identified through RBCS, or through additional risk identification processes. The demand assessment results in a score that is added to the supply assessment score to provide a strategic needs score that defines how big the problem is. This is used with the growth uncertainty to understand if a more complex or extended BRAVA is required.

5.1.5 Extended BRAVA

5.1.5.1 Sensitivity testing of uncertainties is required to understand the extent of risk. An uplift on growth or rainfall projections is applied to understand potential variations in risk and if there is confidence that the risk could be mitigated despite uncertainties.

5.1.6 Complex BRAVA

5.1.6.1 Complex scenarios are applied to assess a wide range of uncertainties, these include variations in growth, consumption and rainfall events dependent on the catchment characteristics.

5.1.6.2 More detail on how complex and extended assessments are completed is included in Section 7 Extended and Complex BRAVA.

5.1.7 Scenarios for problem characterisation

5.1.7.1 Engagement with Strategic Planning Groups led us to develop a central estimate of demand for BRAVA as a most likely case for which to assess risk against. Problem characterisation provides additional detail for each TPU, to decide if Extended or Complex BRAVAs are required. The scenarios applied for these additional assessments are included in Section 7.

5.1.8 Outputs of the assessments

5.1.8.1 The outputs provide an indication of risk against planning objectives, the primary drivers and the timing of the exceedances. The assessments will provide a standardised evidence base for future planning. A score of 0, 1 or 2 is generated for both 2030 and 2050 planning horizons with a risk of 0 classed as no concern, 1 as potential area of focus, and 2 as an area of focus.

5.2 Baseline Risk and Vulnerability Assessment methodologies and results

5.2.1 Growth assessment to understand the demand risk

5.2.1.1 As part of preliminary problem characterisation, a growth assessment (demand risk) is used to generate a strategic needs score, which is combined with individual BRAVA strategic needs scores to understand how big a problem is. An assessment of the population growth (and uncertainty) is undertaken for every TPU.

5.2.1.2 Population forecasts have been determined in line with the guidance indicated in Appendix C of the DWMP Framework (C.2.4.2 Growth and use Local Authority Planning data where available. Population forecast is included in the demand forecast model; a separate methodology has been produced for this model, including assumptions used and is detailed in Technical Appendix 3 – Demand Forecasting (TA3). The results from this assessment are shown in Table 7.

Table 7 Results of growth assessment for all TPU drainage areas (number of TPU catchments)

	Growth Assessment		
	0	1	2
2020	N/A	N/A	N/A
2030	288	137	138
2050	282	146	135

5.2.2 Assessments to understand the risk of sewer flooding

- **Overview**
  - Due to the complexity and importance of sewer flooding, a number of assessments are run to fully understand this risk. This includes assessments to understand the risk of: Internal flooding; Flooding of open spaces; Risk of flooding in a storm (in a 1 in 50-year event); Sewer collapses; External flooding (curtilage); and blockages.
  - 332 individual Tactical Planning Units were assessed covering 99.8% of UUW population equivalent (2020). This covered all TPUs that met Risk Based Catchment Screening criteria for flooding, growth or overflow performance.
  - There are two main mechanisms for flooding; Hydraulic Overload and Flooding Other Causes, and we have considered both in our assessments. This requires combining the outputs from two different types of model: hydraulic network models and PIONEER (our common asset deterioration framework tool). Table 8 details which models are used as inputs for each assessment.

Table 8 Models used for network risk assessments

Assessment	Input model	
	Hydraulic	PIONEER
Internal sewer flooding*	⍰	⍰
External (curtilage) sewer flooding	⍰	⍰
External (open spaces) sewer flooding	⍰	⍰
Risk of sewer flooding in a storm (1 in 50)*	⍰	⍰
Sewer Collapses*	⍰	⍰
Sewer Blockages	⍰	⍰
Pollution*^$	⍰	⍰

*DWMP Framework common performance measure.

^Assessment includes non-network assets

$Assessment does not include permitted storm overflow activations

- **Internal Sewer Flood Risk**
  - The extent of the risk is calculated for each TPU and is made up of:
    - Hydraulic risk from hydraulic models; and
    - Flooding Other Causes (FOC) risk from PIONEER.
  - Risk of hydraulic flooding is assessed through simulating all network models for a range of return periods (1, 10, 20 and 50 years) using 2D models and design rainfall. The 2D flood extents are used within geo-spatial queries to calculate for each property in the region the minimum return

period (of the subset of simulations) at which each property is affected by overland flow. This return period is converted to an annualised flood risk for each property. (For example, a property flooding in a ten-year event would have an annual flood risk of 1 in 10, or 0.1). For each TPU, individual property annualised risk values are summed for all properties within the TPU to provide a total catchment annualised risk.

- FOC risk is assessed using PIONEER. Annualised risk for all assets within a TPU is again summed to provide a total catchment annualised risk.
- Total internal sewer flood risk per TPU is derived by adding together the hydraulic and FOC annualised risk numbers. This overall score is assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance. Table 9 summarises the total number of TPUs falling within each risk classification per planning horizon.

Table 9 Internal flooding BRAVA results (number of TPUs per classification)

	Internal Sewer Flooding		
	0	1	2
2020	21	148	163
2030	18	123	191
2050	14	106	212

- **External sewer flood risk**
  - External sewer flood risk is assessed at both a property (curtilage) level and for open spaces. The assessment of open space flood risk was the result of feedback from stakeholders who cited it as a cause for concern. Further detail on this feedback is contained within Technical Appendix 2 – Stakeholder Engagement (TA2).
  - The approach for calculating external sewer annualised risk per TPU is the same as for internal sewer flooding.
  - This overall score is assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance. Table 10 and Table 11 summarise the total number of TPUs falling within each risk classification per planning horizon.

Table 10 External (Curtilage) flooding BRAVA results (number of TPUs per classification)

	External (Curtilage) Sewer Flooding		
	0	1	2
2020	81	62	189
2030	71	25	236
2050	43	5	284

Table 11 External (open spaces) flooding BRAVA results (number of TPUs per classification)

	External (Open Space) Sewer Flooding		
	0	1	2
2020	108	18	206
2030	100	5	227
2050	70	9	253

- **Risk of sewer flooding in a (1 in 50-year) storm**
  - As per the Ofwat measure 'Risk of Sewer Flooding in a Storm', this is a measure of the percentage population within the UUW operating area at risk of flooding in a 1 in 50-year storm.
  - Risk of internal hydraulic flooding is assessed through simulating all network models using 2D models and 1 in 50-year design rainfall. The 2D flood extents are used within geo-spatial queries to calculate for each property in the operating area whether or not it is predicted to be affected by overland flow.
  - It should be noted that unlike the Ofwat measure, this assessment included TPUs with less than 2,000 population equivalent.
  - The percentage of properties at risk within each TPU is assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance. Table 12 summarises the total number of TPUs falling within each risk classification per planning horizon.

Table 12 Risk of sewer flooding in a (1 in 50-year) storm BRAVA results (number of TPUs per classification)

	Risk of Sewer Flooding (1 in 50-year)		
	0	1	2
2020	196	45	91
2030	159	60	113
2050	164	7	161

- **Risk of sewer collapse**
  - This is an assessment that does not assess hydraulic risk and as such is calculated based solely on outputs from PIONEER. The approach, as described above, for internal sewer flood risk is utilised; annualised risk of collapse for all assets within a TPU is summed and assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance. Table 13 summarises the total number of TPUs falling within each risk classification per planning horizon.

Table 13 Sewer collapse BRAVA results (number of TPUs per classification)

	Risk of Sewer Collapse		
	0	1	2
2020	87	54	256
2030	69	16	312
2050	36	3	358

- **Risk of sewer blockage**
  - This is an assessment that does not assess hydraulic risk and as such is calculated based solely on outputs from PIONEER. The approach, as described above, for internal sewer flood risk is utilised; annualised risk of blockage for all assets within a TPU is summed and assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance. Table 14 summarises the total number of TPUs falling within each risk classification per planning horizon.

Table 14 Sewer blockage BRAVA results (number of TPUs per classification)

	Risk of Sewer Blockages		
	0	1	2
2020	107	94	130
2030	82	39	210
2050	26	6	299

5.2.3 Assessments to understand the risk of wastewater treatment non-compliance

- **Overview**
  - A combination of assessments is used to understand the overall risk to compliance at UUW wastewater treatment works. Wastewater treatment works can have permit requirements for dry weather flow (DWF), multiples of flow treated and multiple final effluent concentration limits. There are also standard treatment requirements for a number of population thresholds, which are dependent on the receiving environment. To understand the full risk at an individual wastewater treatment works, the results are reviewed as a whole, as well as independently for specific driver types such as flow.
  - This section includes assessments to review dry weather flow, multiples of flow treated, wastewater treatment works compliance, and sludge treatment capacity.
- **Dry Weather Flow (DWF) assessment**
  - A dry weather flow assessment is completed for all wastewater treatment works that have permit requirements to measure and report on DWF.
  - Five years of measured flow data is used to baseline the DWF. Theoretical calculations are applied based on additional population growth using PG + I + E. These assumptions and further details are defined in Technical Appendix 3 – Demand Forecasting (TA3).
  - The assessment provides an indication of where future dry weather flow may exceed the permit; verified non-compliance is only when the Q90 of measured flow exceeds the permit for three of

five years and cannot be forecast. The data is assessed against thresholds (detailed in Appendix A, Table A1 BRAVA thresholds) to understand the significance. Table 15 summarises the total number of TPUs falling within each risk classification per planning horizon.

Table 15 Dry weather flow BRAVA results (number of TPUs per classification)

	Dry Weather Flow		
	0	1	2
2020	207	17	41
2030	180	20	65
2050	180	37	48

– In addition to this, a review is carried out of locations without flow measurement where an increase in flow would potentially lead to a need for measurement in the future. These locations are included as an issue to be resolved through option development.

– Following initial BRAVA work, a revised household consumption value was developed as part of the draft Water Resources Management Plan (WRMP). The above assessments were repeated with this altered assumption to understand locations with significant change in risk. Results are shown in Table 16.

Table 16 Updated dry weather flow BRAVA results following update to household consumption assumption

	0	1	2
2020	N/A	N/A	N/A
2030	164	19	76
2050	157	37	65

- **Multiples of Flow Treated Assessment**
  - This is not an assessment of compliance with current permits. True non-compliance in relation to this assessment is when an inlet or storm tank overflow activates before the permitted volume to be treated is exceeded and can only be assessed historically/currently.
  - This BRAVA is completed for all wastewater treatment works with a treated flow permit. The assessment provides an indication of where the future theoretical treated flow requirement is greater than the current permitted volume that must receive full wastewater treatment (and hence there may be a requirement for a future permit change to increase the maximum flow treated).
  - The calculation of required future treated flow is assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance. Table 17 summarises the total number of TPUs falling within each risk classification per planning horizon.

Table 17 Multiples of flow treated BRAVA results (number of TPUs per classification)

	Multiples of Flow Treated (wastewater treatment works)		
	0	1	2
2020	185	12	54
2030	176	15	60
2050	175	13	63

– Following initial BRAVA work, a revised household consumption value was developed as part of the draft Water Resources Management Plan (WRMP). The above assessments were repeated with this altered assumption to understand locations with significant change in risk. Results are shown in Table 18.

Table 18 Updated multiples of flow treated BRAVA results following update to household consumption assumption

	Multiples of Flow Treated (wastewater treatment works)		
	0	1	2
2020	N/A	N/A	N/A
2030	159	9	62
2050	102	11	59

- **Risk of future final effluent compliance at wastewater treatment works assessment**
  – Wastewater treatment works compliance risk is assessed only at those locations identified through Risk Based Catchment Screening for the relevant screening criteria.
  – BRAVA uses bespoke wastewater treatment works models to review the future flow and load against the sizing of the process units in accordance with asset standard. Detail of this is included in Section 3.5 Wastewater treatment model(s). An overall percentage likelihood of achieving compliance with current permit is calculated (with different weightings to assess more critical process units) and thresholds applied (detailed in Appendix A Table A1 BRAVA thresholds) to assess the level of risk across the wastewater treatment works. Individual process units that have capacity risk are highlighted to identify specific process risks that may need enhancement and to enable more targeted verification and/or option development.
  – Where there have been recent changes to a treatment process, the project design sheet is used to assess the design against future demand. The future compliance assessment is verified against performance results and asset health data to understand if it is representative of the situation and performance before the results are used to develop options.
  – The results of this assessment are shown in Table 19.

Table 19 Risk of wastewater treatment works final effluent compliance BRAVA results (number of TPUs per classification)

	Wastewater treatment works final effluent compliance		
	0	1	2
2020	150	110	16
2030	142	114	20
2050	126	129	21

- In addition to compliance related to wastewater treatment works capacity risk, a review of treatment works that are likely to exceed thresholds for Urban Wastewater Treatment Directive (UWWTD) where population is at risk of exceeding the following:
  - >2,000, for inland and estuary discharges, therefore, secondary treatment is required;
  - >10,000 for coastal discharges, therefore, secondary treatment is required;
  - >10,000 for sensitive and eutrophic receiving watercourse, therefore, 2mg/l (annual average) P removal is required; and
  - >100,000 for sensitive and eutrophic receiving watercourse, therefore, 1mg/l (annual average) P removal is required.
- Where these thresholds are likely to be exceeded, the requirement is included as a risk to be resolved through option development.
- Sludge storage volume is also identified through the process, this is reviewed in a similar way to storm tank volumes and included in potential option requirements following verification.

- **Risk of future compliance with sludge permit requirements**
  - The Sludge Treatment Capacity Assessment BRAVA is run on all TPUs with bioresource price control sludge treatment assets. The assessment considers only sites with bioresource sludge treatment assets (digestion and dewatering) and does not include sludge holding or thickening capacity. The purpose is to understand where there may be a risk of insufficient sludge treatment capacity due to an increase in regional sludge production arising from population growth and removal of phosphorous. Phosphorous removal can lead to increased sludge production (with high phosphorous content), which has to be stored and removed.
  - For the purposes of this assessment, sludge treatment capacity is defined by the high, low and mid-point of the Service Level Agreement (SLA) throughput for each digestion and dewatering facility. The SLA's have been chosen as a measure of capacity over the theoretical maximum design of the digesters/centrifuges as they reflect capacity restrictions on the whole sludge train and also any operational restrictions, which limit sludge throughput. Sludge is measured in both volume (m3) and tonnes of dry solids (tDS).
  - A score is determined based on the proximity to the SLA's. The results of this assessment are shown in Table 20.

Table 20 Risk of sludge treatment compliance BRAVA results (number of TPUs per classification)

	Risk of Sludge treatment compliance		
	0	1	2
2020	14	8	5
2030	9	6	12
2050	6	4	17

- In addition to the sludge BRAVA, an output from the wastewater treatment capacity models is a review of available sludge storage and if this is likely to be exceeded using outputs from the sludge forecast. This is considered as a potential risk to be addressed as part of solution development.
- All wastewater treatment BRAVA results are combined to understand the full potential risk to compliance for flow and final effluent permits. The results are reviewed alongside assumptions on future permit requirements to either improve (WINEP) or protect (deterioration under WFD or bathing/shellfish) the receiving environment.
- Additional assessments at specific locations may be undertaken as additional drivers are identified through the process.

5.2.4 Assessments to understand requirements to prevent deterioration, improve or restore the natural environment

- **Overview**
  - This section includes assessments to review pollution, deterioration of inland water bodies due to continuous discharges, activation frequency and volumes, bathing and shellfish activations. AMP7 bathing water investigations and habitats risk will form future assessment when more information is available, however, this is outside the timescale for this DWMP cycle.
- **Risk of pollution**
  - The annualised risk for each TPU catchment is made up of three components:
    - Risk from hydraulic overload (this relates to the overload of gravity sewers due to excess rainfall intensity beyond the capacity of the sewer to carry);
    - Risk from linear assets – (this relates to the other causes side of flooding, including issues such as structural and customer misuse. Includes sewers, rising mains and storm overflows) from PIONEER; and
    - Risk from point assets (this relates to mechanical, electrical or structural failure at point sites and facilities, pumping stations and wastewater treatment works) from PIONEER.
  - Risk of hydraulic overload is assessed through simulating all network models for a range of return periods (1, 10, 20 and 50 years) using 2D models and design rainfall. The 2D flood extents are used within geo-spatial queries to calculate, for all watercourses in the region, the minimum return period (of the simulation subset) they are affected by overland flow stemming from the wastewater network. This return period is converted to an annualised risk for each watercourse. For each TPU, individual annualised risk values are summed for all watercourses within the TPU to provide a total catchment annualised risk.
  - Point and Linear risks are assessed using PIONEER. Annualised risk for all assets within a TPU is again summed to provide a total catchment annualised risk.

- Total pollution risk per TPU is derived by adding together the hydraulic and FOC annualised risk numbers. This overall score is assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance. Table 21 summarises the total number of TPUs falling within each risk classification per planning horizon.
- All category one to three pollution incidents are included within this measure. Category 4 pollution incidents are recognised as having no impact on the receiving water course and these are not included within historic or forecast pollution figures.

Table 21 Pollution BRAVA results (number of TPUs per classification)

	Pollution		
	0	1	2
2020	65	49	283
2030	10	60	327
2050	0	0	397

- It should be noted that by 2050, the threshold target of zero incidents results in the significant shift of all TPU catchments to have a risk score of 2, due to the pivotal impacts of any risk against our stretching risk reduction ambition.

- **Deterioration of watercourses**
  - The No Deterioration BRAVA is completed for all wastewater treatment works with a final effluent discharge to a river stretch in the Environment Agency SIMCAT models. Its purpose is to understand where there may be deterioration in the receiving watercourse under the Water Framework Directive, due to population growth discharging to the treatment works, and whether this will lead to a change in final effluent permit requirements.
  - For each wastewater treatment works, a river deterioration risk score is calculated for the forecasted increase in final effluent discharge using the river system's mass balance equations. Each continuous discharge is assessed independently and does not account for changes in impact from upstream discharges.
  - The forecast flow assumptions are aligned with the Dry Weather Flow increase from the demand forecast applied to average flows. The concentration of the determinants (mg/l) is assumed to remain as per the baseline measured values and applied to the increase in flow discharged. Further details including the assumptions used are included in section 3.6 Environmental river model(s).
  - Scoring thresholds relating to percentage deterioration or a drop in water quality class (detailed in Appendix A Table A1 BRAVA thresholds) were applied to the following determinants:
    - BOD;
    - Ammonia; and
    - Phosphorous.
  - The maximum of these risk scores (0–2) returns the result for each planning horizon. The regional results are shown in Table 22.

Table 22 No deterioration at wastewater treatment works BRAVA results (number of TPUs per classification)

	Risk of Deterioration to inland water bodies		
	0	1	2
2020	NA	NA	NA
2030	375	44	26
2050	383	31	31

- This assessment does not account for changes to external inputs to the watercourse such as agricultural runoff or storm overflows as the data for this is not included in the SIMCAT model base data. A separate analysis on this topic is included in Technical Appendix 6 – Resilience (TA6). Where a risk is identified, further SIMCAT analysis is undertaken to understand what the future permit limits are likely to be. This accounts for the impact due to growth of all continuous discharges until 2050.

- **Storm overflow activation assessment**
  - This assessment pre-dates the Government's Storm Overflow Discharge Reduction Plan that was published in August 2022.
  - This assessment is applied to all TPUs that meet the screening criteria for growth, the Capacity Assessment Framework or storm overflow performance.
  - The relevant hydraulic network sewer model for each TPU to be assessed is simulated for ten years using continuous time series rainfall. As described in earlier sections of this report; growth, creep and climate change are applied to the 2030 and 2050 scenarios. Annual average activation frequency (based upon the Environment Agency's 12/24 counting method) is then generated for each overflow within each TPU for each planning horizon. The baseline (2020) performance is determined by using the worst of the modelled annual activation frequency or the average event duration monitor (EDM) activation data if available. The 2030 and 2050 planning horizons use the modelled annual activation frequency only.
  - The annual activation frequency of each overflow is assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance. If an overflow is listed on the AMP7 WINEP it is given a risk score of zero for all planning horizons as these investigations constitute an intervention. Using the national DWMP guidance, risk scores for all overflows are then aggregated per TPU catchment by using a weighted points score:
    - Weighted points score = (total number of points scored by storm overflows x 100)/ (total number of storm overflows x 2)
  - The results are then aggregated further (aligning to the Capacity Assessment Framework aggregation) to determine the final BRAVA score for each TPU as per Table 23.

Table 23 Aggregation of scores to determine TPU results

BRAVA Score	CAF Risk Score	% range
0	1	0–15
1	2 and 3	15–45
2	4 and 5	45–100

- The results of the storm overflows Baseline Risk and Vulnerability Assessment are shown in Table 24.

Table 24 Storm overflow BRAVA results (number of TPUs per classification)

	Storm Overflows		
	0	1	2
2020	74	90	131
2030	79	94	122
2050	77	92	126

- The use of EDM data for the 2020 assessment has the impact that slightly more TPUs are scored with a value of '2' than if the data had been purely based on modelled performance. These discrepancies between EDM and modelled data are an ongoing challenge of the AMP7 Sewer Overflow Assessment Framework programme of works across the water industry. The impact of growth, urban creep and climate change can, however, be more clearly seen in Figure 8 and Figure 9, which demonstrate a clear increase of both the average activation frequency and activation volume over time.

Figure 8 Modelled annual average activation frequency across 2020, 2030 and 2050

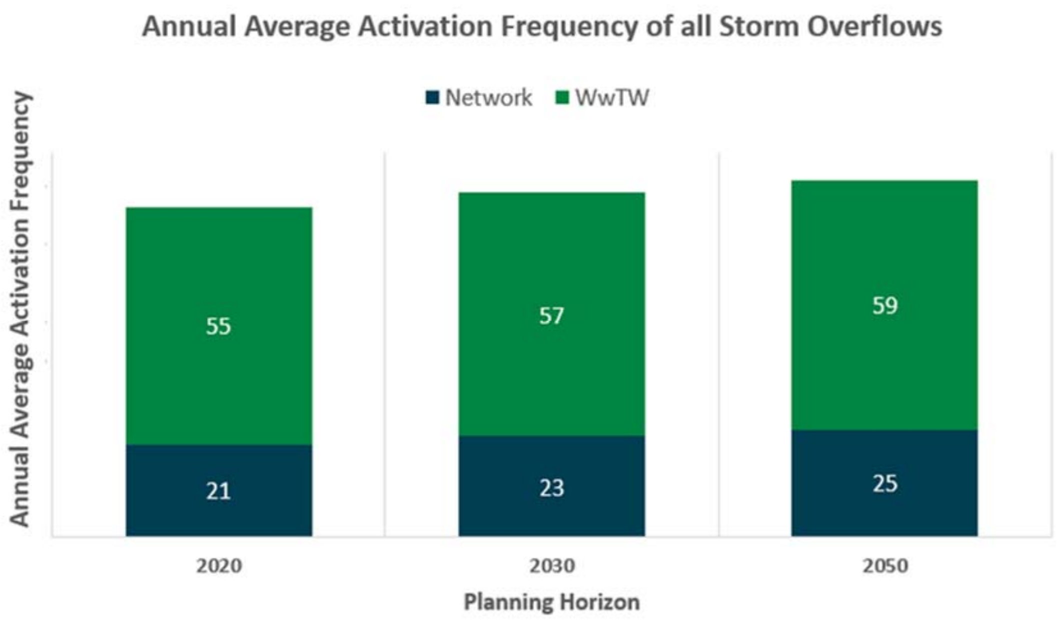
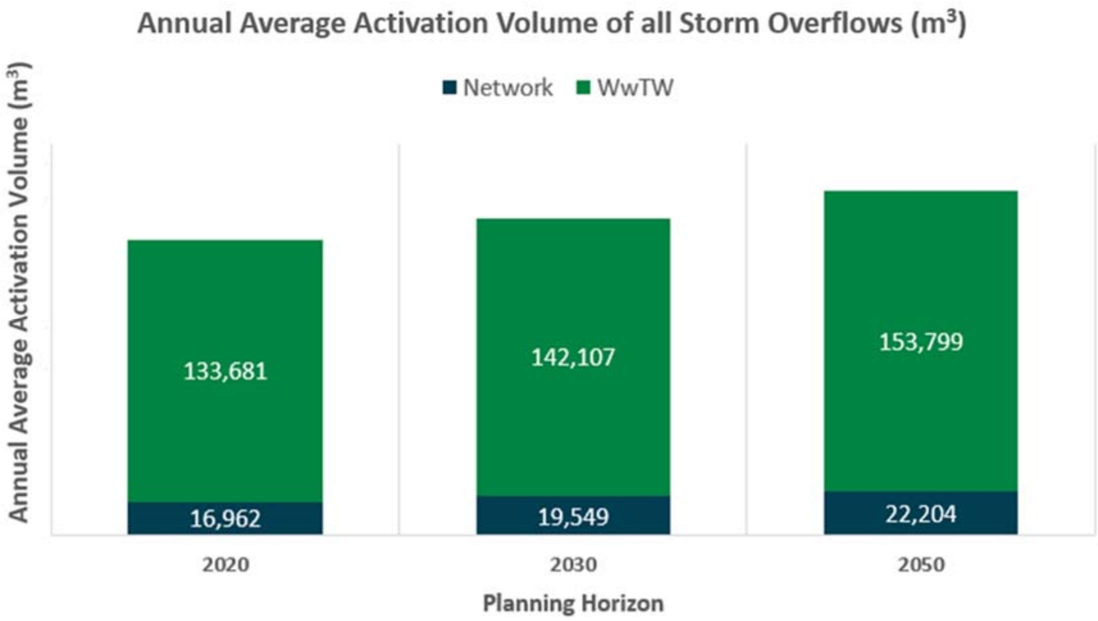


Figure 9 Modelled annual average activation volume across 2020, 2030 and 2050



– All storm overflows are assessed against the criteria below to determine which intervention path they should follow post BRAVA.

Recommendation	Criteria
Activation Investigation	If the sum of the 2020, 2030 and 2050 BRAVA scores >3 and there was a significant difference between the 2020 modelled annual activation frequency and the EDM data
Optioneering	If the sum of the 2020, 2030 and 2050 BRAVA scores >1 and there was not a significant difference between the 2020 modelled annual activation frequency and the EDM data

- **Bathing and shellfish waters activation assessment**
  - Storm overflows previously designated as discharging to, or impacting on, bathing and/or shellfish waters are separately assessed again in order to further summarise their risk to the environment. The approach is as described above for the storm overflows assessment with the notable exception being that activation frequency is only analysed between the 15 May and the 30 September inclusive for bathing waters.
  - The activation frequency of each overflow is assessed against thresholds (detailed in Appendix A Table A1 BRAVA thresholds) to understand the significance.
  - Table 25 and Table 26 summarise the results, however, as per the storm overflows assessment, the use of EDM data for the 2020 assessment has the impact that slightly more TPUs are scored with a value of '2' than if the data had been purely based on modelled performance.

Table 25 Bathing waters BRAVA results (number of TPUs per classification)

	Bathing Waters Activation Assessment		
	0	1	2
2020	6	7	16
2030	11	10	8
2050	10	11	8

Table 26 Shellfish BRAVA results (number of TPUs per classification)

	Shellfish Waters Activation Assessment		
	0	1	2
2020	1	0	33
2030	10	8	16
2050	9	8	17

- **Alignment with WINEP**
  - UUW's WINEP was submitted to the Environment Agency for review in January 2023. In response to updated Environment Agency guidance, UUW's WINEP has evolved significantly since draft DWMP publication in June 2022. Some of the new elements in the programme include first time treatment, nutrient neutrality and the monitoring of emergency overflows. Some additional drivers, which are not yet confirmed, are also being raised.
  - Bathing water investigations have now been completed with outputs incorporated into the WINEP submission where required.
  - Habitats modelling was revised following the release of modelling optimisers by the EA. This has led to a number of changes in required permit standards. A habitats programme has now been proposed based on PR24 models and PR24 optimisers, polluter pays principles and nutrient neutrality requirements. Opportunities for catchment nutrient balancing were submitted in February 2023.
  - A review of potential inland bathing water areas was undertaken with priority locations included for investigation as part of the price review. Implementation schemes have been included in WINEP and the Price Review for locations where applications for designation have been submitted to the local authority with the caveat that delivery will be dependent on the designation being duly made.
  - Chemical investigations (as part of the CIP4 programme) and chemical permit requirements have been included in WINEP proposals along with shellfish water improvement schemes for deteriorated shellfish beds.
  - A detailed review of storm overflows against Environment Act and Bathing and Shellfish Water guidance has been undertaken. The Environment Act guidance was released in the second half of 2022 and provided the water industry with direction on activation frequencies required to fulfil environmental obligations, not only in AMP8, but over the next 25 years to 2050.
  - Any further updates to WINEP following the January 2023 submission will be reflected in UUW's Price Review submission.

5.3 Calculating strategic needs

5.3.1 The key step in the BRAVA process is developing the understanding of how changes in system inputs in the future might impact on system performance against relevant planning objectives. Following BRAVA, the level of concern that planning objectives could be significantly affected by current or future risks, without interventions, is to be assessed with results providing an overall 'strategic needs score'. This forms the initial problem characterisation stage as detailed in the DWMP framework.

5.3.2 The strategic needs score for each assessment is calculated by adding the demand (flow/load) risk to the supply (capacity) risk for each TPU for both the 2030 and 2050 planning horizons to give a maximum score of 8. This is summarised in Table 27.

Table 27 Calculating strategic needs using demand risk and supply risk scores (2030 and 2050)

Strategic needs factors	Not significant (Score = 0)	Moderately significant (Score = 1)	Very significant (Score = 2)	Don't know
Demand (flow/load) risks	2 questions: > Minimum score = 0 (no significant concerns for all planning objectives) > Maximum score = 4 (very significant concerns for all planning objectives)			
Supply (capacity) risks	2 questions: > Minimum score = 0 > Maximum score = 4			
Total	**4 questions:** > **Minimum score = 0** > **Maximum score = 8**			

5.3.3 From 'DWMP Framework Appendix C – Baseline risk and vulnerability assessment; and problem characterisation'.

5.4 Calculating growth uncertainty

5.4.1 Uncertainty is assessed to understand the level of confidence in the growth element and, therefore, the certainty in BRAVA outputs. All TPUs have been given a score depending on the reliability of the planning data used. Where plans have been adopted, the uncertainty is low, if plans are still in the early draft stage, the uncertainty will be high. Where there is more than one local plan associated with a TPU, the scores are combined and normalised depending on the area covered. This score is used to inform the Preliminary Problem Characterisation. Table 28 summarises the number of TPUs falling within each uncertainty bracket.

Table 28 Number of TPUs with high, medium and low uncertainty of growth forecasts

Uncertainty	Number of TPUs*	% Age population (2050)
High	86	12%
Medium	179	48%
Low	298	40%

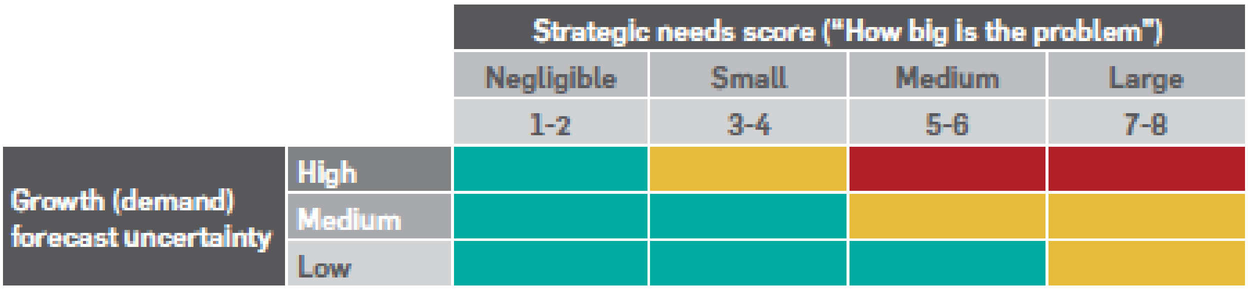
*Five TPUs were not assessed due to being transferred.

5.4.2 Some elements of the local plan are defined with more confidence, this is particularly relevant to specific network locations where a risk has been identified and is reviewed during Pre-BRAVA.

5.5 Preliminary problem characterisation

5.5.1 The preliminary problem characterisation score for each TPU is reviewed against the growth uncertainty to understand what level of BRAVA is appropriate (standard, extended or complex) as per Table 29.

Table 29 Preliminary problem characterisation guide



From 'DWMP Framework Appendix C – Baseline risk and vulnerability assessment; and problem characterisation'.

5.5.2 Where the assessment results for a TPU indicate green in the Table 29 matrix, a standard BRAVA is sufficient; amber requires an extended BRAVA and Red require a complex BRAVA. Specific details of how these additional assessments are applied and the results are included in Section 7.

5.5.3 This stage of the assessment led to the outcomes in Table 30.

Table 30 Number of TPUs requiring extended or complex BRAVA

Assessment	Extended	Complex
Internal sewer flooding*	128	30
Risk of sewer flooding in a storm (1:50-year)*	85	14
Sewer collapses*	151	39
Wastewater treatment works compliance*	37	5
Pollution*	174	36
Storm overflows*	91	13
DWF compliance	41	10
Multiples of flow treated compliance	36	7
External (curtilage) sewer flooding	131	36
Sewer flooding of open spaces	123	20
Sewer blockages	118	31
Sludge treatment capacity	N/A	N/A
No deterioration	35	6
Bathing and Shellfish	8	2

*DWMP Framework common performance measure.

6. Resilience and horizon scanning

6.1 Overview

6.1.1 In addition to BRAVA, a variety of assessments are carried out to develop an understanding of wider catchment resilience issues that are not directly linked to systems characteristics.

6.2 Resilience

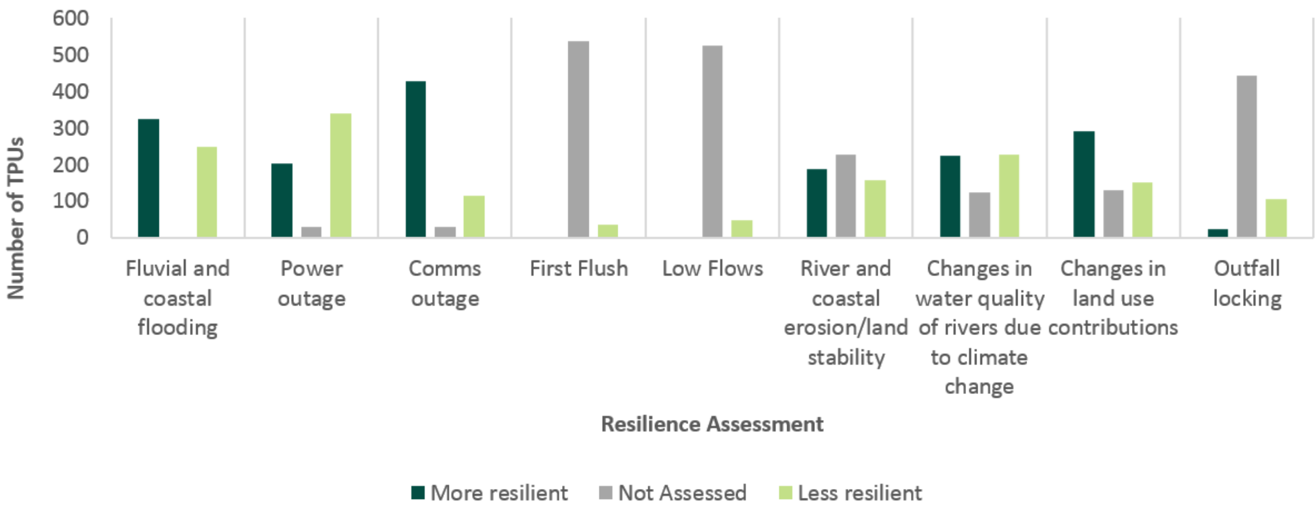
6.2.1 Resilience assessments covering a range of risks from service outages to how climate change might impact the UUW operating area are proposed. The assessments cover the whole of the operating area, irrespective of whether or not the TPU has been identified as requiring BRAVA.

6.2.2 The focus for this DWMP is to assess what are believed to be the most significant risks:

- Fluvial and/or coastal flooding of wastewater treatment works and major pumping stations;
- Power outages;
- Outages to remote communications;
- Response recovery plans;
- First flush and low flows;
- Coastal/river erosion and land stability;
- Changes in the water quality of rivers as a result of climate change;
- Changes in catchment contributions as a result of climate change; and
- Outfall locking.

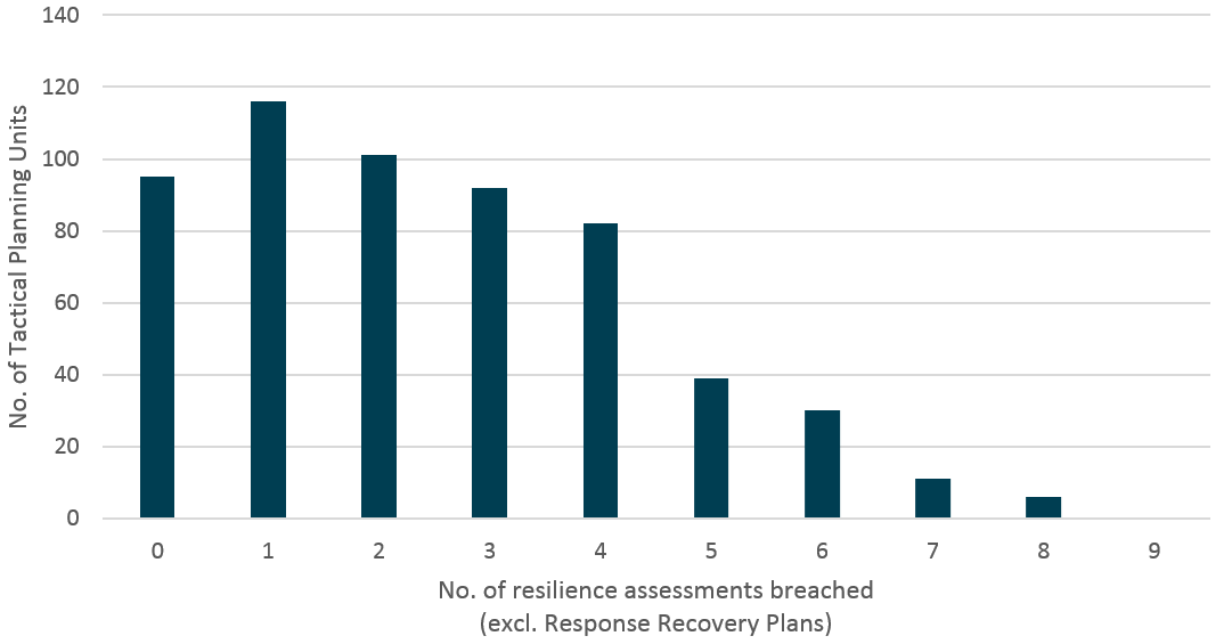
6.2.3 The results from these assessments are reviewed alongside BRAVA results to understand the extent of the potential risk for each planning horizon. The results in Figure 10 show that the North West is least resilient to power outages and most resilient to communications outage.

Figure 10 Summary per assessment and the associated number of TPUs that are more or less resilient (excluding Response Recovery Plans)



6.2.4 With the exclusion of Response Recovery Plans, across the North West, the majority of TPUs are less resilient to one assessment, which is attributed to the risk of power outage. There are 12 TPUs across the operating area that are less resilient to seven assessments and there are six TPUs, which are less resilient to eight assessments with the majority within the Upper Mersey Strategic Planning Area. There are zero TPUs, which are less resilient to all nine assessments (Figure 11).

Figure 11 The number of TPUs that are deemed to be less resilient across the nine assessments (excluding Response Recovery Plans)



6.2.5 More information on the assessments and the results is available in Technical Appendix 6 – Resilience.

6.3 Horizon scans

6.3.1 Alongside baseline risk and vulnerability assessments, a number of horizon scans were completed to understand additional risk or opportunities that could inform future investment. The scans were developed to include additional risks that were not captured as part of individual BRAVA. The results are also used to identify locations where specific option types would be required or are beneficial, such as surface water removal at locations with high constant infiltration. This information is reviewed alongside BRAVA results to develop options.

6.3.2 A summary of the data collated is given in Table 31.

Table 31 Horizon scans completed regionally to review alongside BRAVA results

Horizon Scan	Summary	Output
Baseline infiltration levels	Assumptions on population, consumption and trade volumes can be used with the dry weather flow equation to back calculate base-flow infiltration arriving at wastewater treatment works based on observed flows. High levels of base-flow infiltration could highlight an opportunity to increase hydraulic capacity through network intervention	Value for all TPUs with reliable measured flow data (l/hd/day)
Private septic tanks and first-time sewerage locations	Un-sewered properties where there could be potential to connect to a sewer network in the future due to environmental drivers, or opportunities as part of option identification in the vicinity to address other needs	GIS layer to be reviewed alongside risks and solutions

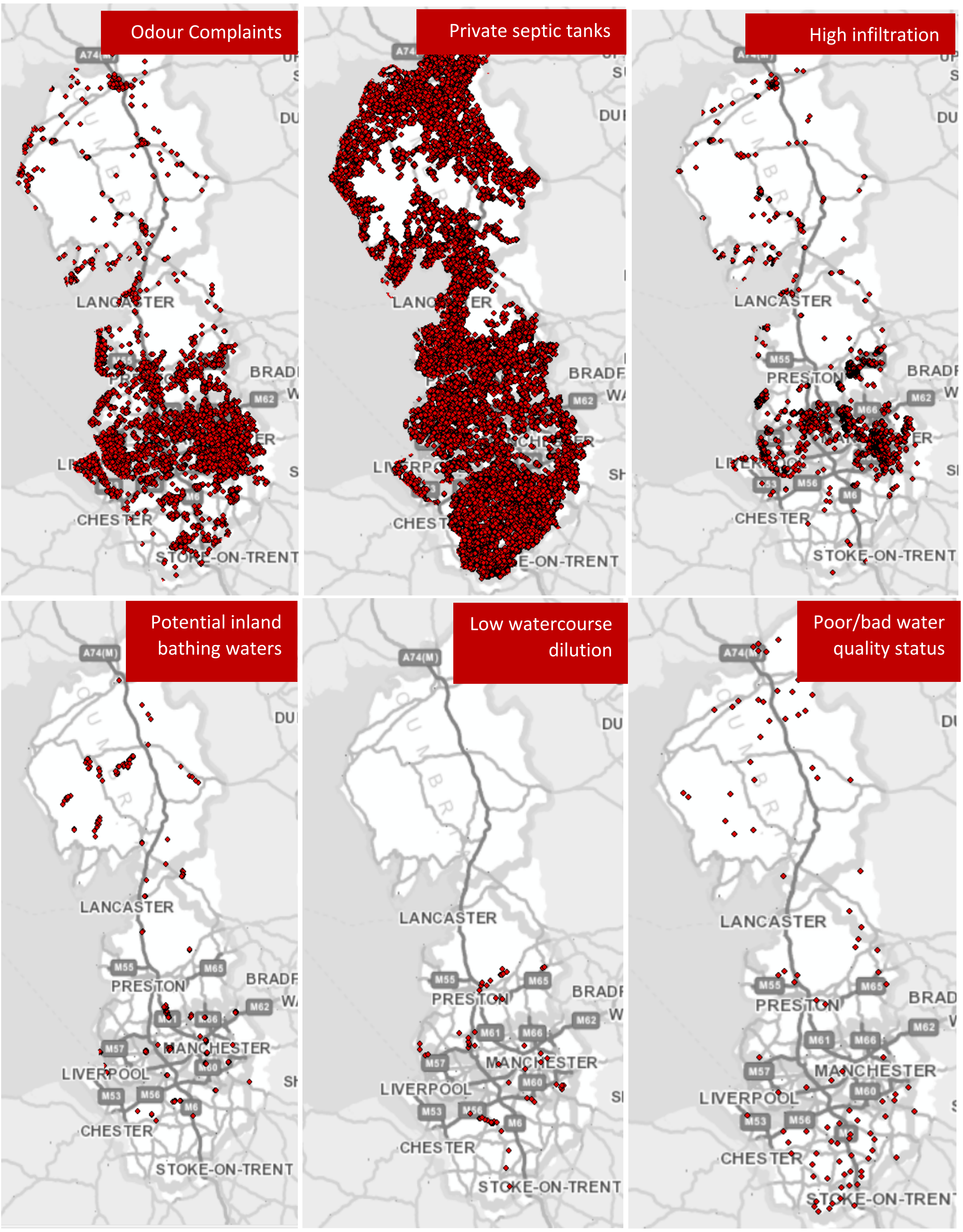
Horizon Scan	Summary	Output
Septic tanks (UUW owned)	Small catchments with septic tanks can be difficult to maintain. If new environmental drivers require investment, connection to an adjacent network may be a feasible solution. These opportunities can be viewed alongside local drivers and option identification for DWMP in the vicinity The risk identified from this horizon scan is superseded by the WINEP driver for all septic tanks to meet a 40 BOD and 60 Suspended solids requirement. All locations at risk will be included on the PR24 improvement programme	Geographic Information System (GIS) layer to be reviewed alongside risks and solutions
River dilution	Low levels of dilution in receiving watercourses can lead to tight final effluent permit requirements, particularly if there is more than one discharge. The information can be viewed alongside option identification and is also part of SIMCAT modelling within option development. The assessment also aids with the understanding of the consequence of future pollution risk	GIS layer to be reviewed alongside risks and solutions
Water quality status	As with river dilution, this information can be used as part of option identification to understand where there is water quality risk that may be impacted by increased flow and load and where options may help provide benefit to the status (or increase risk)	GIS layer to be reviewed alongside risks and solutions
Inland recreational water locations	A list of potential future bathing waters has been identified through a review of open water swimming activities in locations that don't currently have a bathing water designation	List of locations and assets (overflows and wastewater treatment works) that could be impacted with bathing water requirements (UV and activations) in future. To be reviewed alongside other options
Potential environment designation	This gives an indication of where proposed: a) Wetland site designated to be of international importance under the Ramsar convention (Ramsar Site) b) Special Area of Conservation (SAC) c) Special Protection Area (SPA) As with river dilution and water quality status, this information can be used as part of option identification to understand where there is water quality risk that may be impacted by increased flow and load and where options may help provide benefit to the status (or increase risk)	GIS layer to be reviewed alongside risks and solutions
Strategic network locations	Locations identified where a specific development site will have an impact on the sewer network. Most have developer impact assessment results to understand the implications, and some have planned mitigation that could form the first step of adaptive pathways for solutions	List of locations with detail on size and timescale of development to be reviewed alongside option identification

Horizon Scan	Summary	Output
Priority substance risk	AMP7 investigations are underway to understand emerging issues such as micro plastics and antimicrobial resistance as well as monitoring of priority substances (CIP3 WINEP drivers). This gives an indication of where Environmental Quality Status may be at risk and final effluent permit limits may have to be revised to address this	TPU locations (wastewater treatment works) with specific details of substances being investigated to be reviewed alongside option denitrification
WINEP Red Schemes	A scheme is identified as a 'red' scheme where there is evidence to support that water company action is required, however, the solution has been identified as non-cost beneficial. Red schemes may turn amber or green in the future should changes be made that impact the cost benefit analysis or alternative solutions are identified	List of associated assets and permit limits to meet the environmental requirements
Large infrastructure projects	Large infrastructure projects and locations that may impact on solutions is kept up to date	List of locations
Permitted trade discharge	Trade permit limits can be significantly higher than current/historic discharge volumes. This makes it hard to assess future risk as they could increase within permit limits, and this may impact on treatment capacity. Inclusion of this risk is required when developing options	List of permit limits at TPU (wastewater treatment works) and historic volumes to indicate the difference and potential risk. To be reviewed alongside wastewater treatment works interventions
Flooding partnership opportunities	A list of projects that are being delivered to mitigate flood risk has been collated and could be part of short or long-term option development	List of existing flood partnership projects that could be developed as part of option identification
Water quality partnership opportunities	An understanding of: a) Source apportionment (Environment Agency data) b) CaBA Partnership projects that have identified improvements Have been reviewed to understand where partnership interventions may be appropriate and beneficial Information is being developed but can be used alongside option development to include upstream interventions to help reduce risk	Source apportionment values at TPU where available List of CaBA Partnership projects with locations To be reviewed alongside traditional option development

6.3.3 Additional horizon scans are developed through changes in legislation, better understanding of the causes of risk (such as demographic peculiarities), and findings of investigations and can be reviewed throughout the development of the DWMP.

6.3.4 Horizon Scan results are used to understand the complexity within a TPU and the risks included in option development if appropriate. Some of the regional outputs are shown in Figure 12.

Figure 12 Horizon scan results for odour complaints, private septic tanks, high measured infiltration, potential inland bathing waters, low river dilution and bad or poor WFD status



6.4 Additional studies

6.4.1 Overview

6.4.1.1 In addition to assessments carried out specifically for the DWMP, there are a number of other projects that are important to factor into the plan as they have the potential to require substantial investment, further understanding, or can impact upon other risks and solutions development.

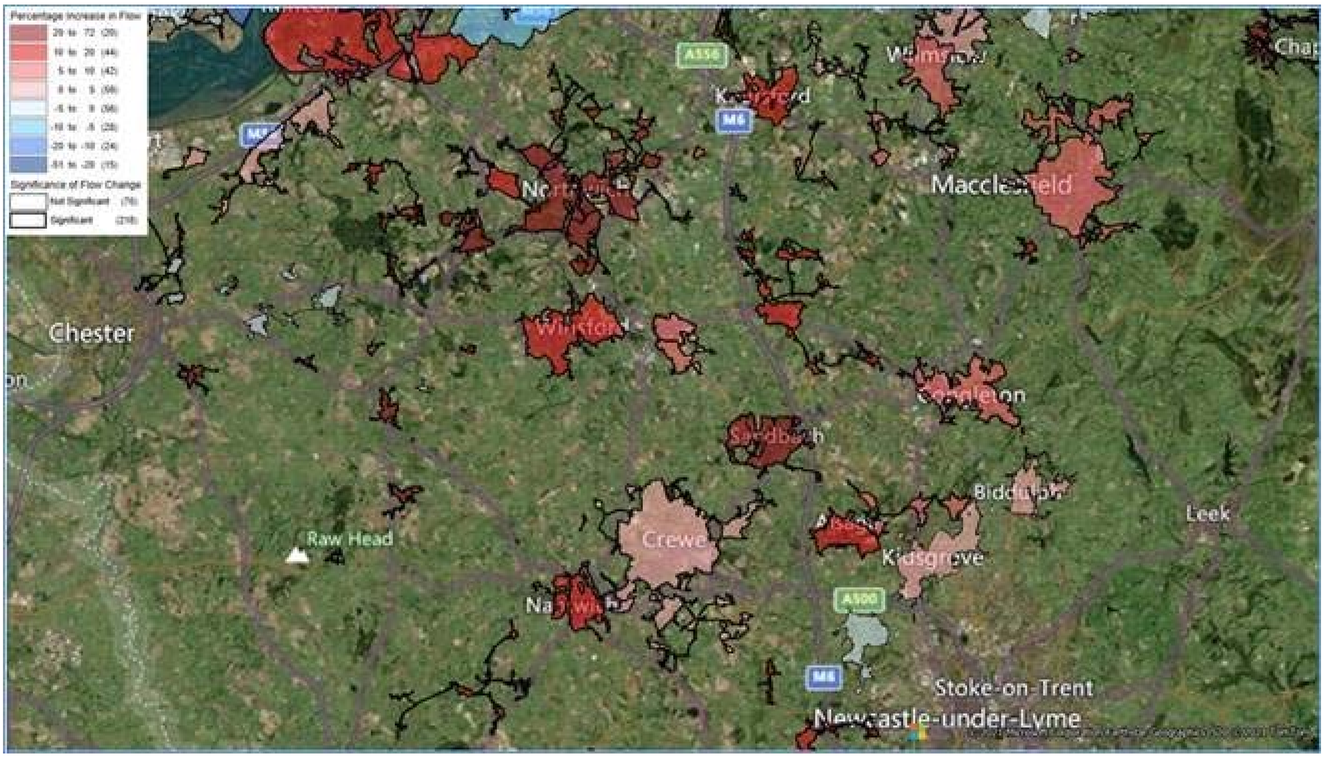
6.4.2 COVID-19 study

6.4.2.1 During the development of the DWMP, the COVID-19 pandemic occurred, which saw much of the population working from home, industries operating at a reduced level, travel restrictions, and enhanced hygiene measures, such as regular hand washing introduced. These changes in normal behaviour could cause fluctuations and changes in wastewater flow rates, volume and loadings, which have the potential to impact on wastewater treatment capabilities and compliance.

6.4.2.2 In order to understand the potential impacts, an assessment was conducted to understand the impacts of COVID-19 restrictions on domestic wastewater discharges across TPUs, and to assess the resilience of wastewater treatment works. The assessment gives an insight into how the behaviours and movements of customers across the North West changed throughout the pandemic, such as changes in tourist populations. This was due to a mixture of local restrictions, restricted international travel and working from home. Figure 13 is an example of how flow changed in the south of the region, typically an increase in flow, which is likely to be attributed to people working from home and reduced numbers of visitors. In contrast to areas of the Lake District, which saw a reduction in flow, likely to be attributed to restricted travel periods.

6.4.2.3 As we move away from the COVID-19 pandemic, it will be important to understand how baseline flow and loadings might have changed. A review of customer consumption following COVID-19 will be undertaken to understand the impact, along with changes in customer behaviour over time. This can then be adopted into demand forecasting tools to provide greater certainty on visitor population, household discharge rate and composition.

Figure 13 Flow changes to wastewater treatment works during the COVID-19 pandemic



7. Extended and complex BRAVA

7.1 Overview

7.1.1 Some Tactical Planning Units require a more detailed or varied review of risk, depending on the complexity and uncertainty of the risk identified. This is defined in the Preliminary Problem Characterisation step within the DWMP framework and the detail on how this is calculated is given in Section 5.5 Preliminary problem characterisation. The number of TPUs that require extended or complex BRAVA (for different strategic needs) are given in Table 30.

7.2 Hydraulic flooding and storm overflow scenarios

7.2.1 Extended BRAVA

7.2.1.1 In order to assess the impact around growth uncertainty on the TPUs flagged as requiring extended BRAVA, existing data from the UUW Developer Impact Assessment (DIA) programme of works is used. The DIA studies assess the impact of significant growth or planned development through use of the 2020 design horizon wastewater network hydraulic models. The planned development is added to the model to reflect the future position, but no account for climate change is made, thus the impact on storm overflow and flood performance can be assessed based on the impact of the development alone.

7.2.1.2 In order to avoid unnecessarily rerunning all hydraulic models, the outcomes of the DIAs are used so that a trend analysis can be undertaken in order to forecast the impact across all affected TPUs.

7.2.2 Complex BRAVA

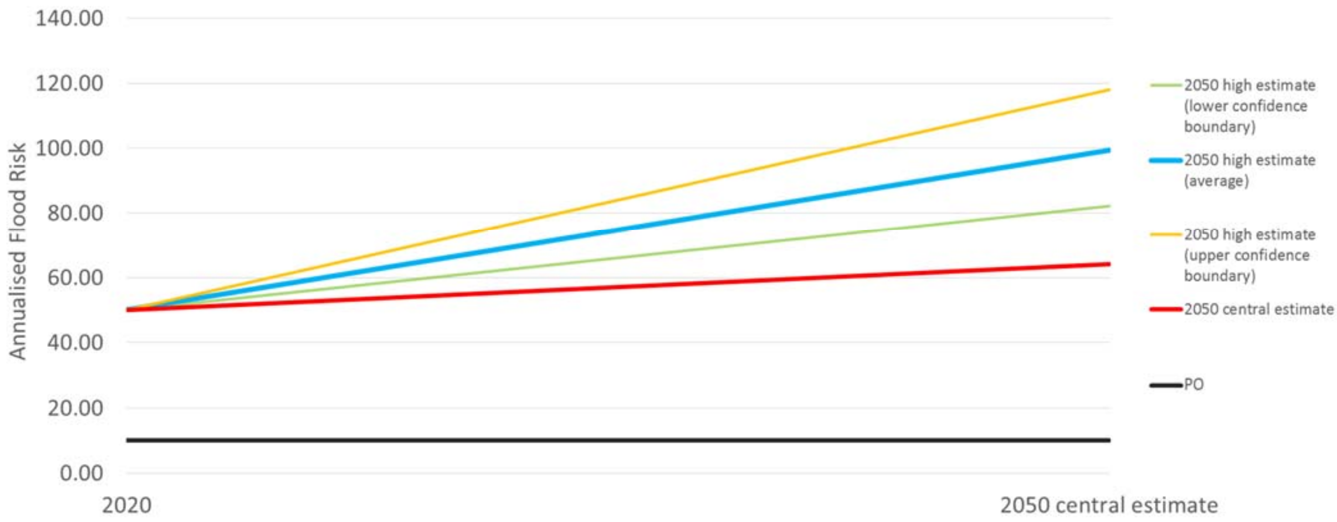
7.2.2.1 In order to assess the impact around the uncertainty of climate change, a number of TPU hydraulic network models are re-assessed for both internal and external property flooding but with a key change; the design rainfall used is modified in order to use both the 2050 high estimate and 2080 central estimate uplifts. The 2050 models are used in order to provide a worst-case scenario for growth. As per the extended BRAVA, to minimise the model runs required, a trend analysis is developed in order to predict the impact across all complex TPUs.

7.2.2.2 Table 32 demonstrates the impact on BRAVA scores of applying the trend analysis derived from extended and complex BRAVA. Figure 14 demonstrates the impact on annualised internal flood risk for an example TPU when using the complex rainfall scenarios.

Table 32 Impacts of extended and complex BRAVA

	Number of Tactical Planning Units		BRAVA Scores							
			Baseline 2050 (Complex Catchments)		Uplift (complex)		Baseline 2050 (Extended Catchments)		Uplift (extended)	
Assessment	Complex	Extended	1	2	1	2	1	2	1	2
Internal Sewer Flooding	30	128	3	27	2	28 (+1)	15	113	5 (1 score 0)	122 (+9)
Risk of flooding in a 1 in 50 year storm	14	85	1	13	0	14 (+1)	2 (5 score 0)	78	0	84 (+6)
External sewer flooding	36	131	0	36	0	36	1	130	0	130
Flooding of open spaces	20	123	0	20	0	20 (3 score 0)	0 (4 score 0)	119	0	120 (+1)

Figure 14 Internal flood risk impact of complex BRAVA rainfall



7.2.2.3 Locations identified as requiring complex or extended bathing or shellfish water BRAVAs were not re-assessed as the bathing water investigation results through AMP7 will provide a more detailed view of the potential risk.

7.3 Flooding other causes (PIONEER) scenarios

7.3.1 The alternative PIONEER scenarios as discussed in Sections 3.4.2 and 3.4.4 above were utilised in order to understand the potential variation in risk. As detailed in those sections, these alternative scenarios provide alternative forecasts on asset risk based on different investment levels.

7.3.2 A number of TPUs were identified as requiring a more complex or extended BRAVA from non-hydraulic flooding or pollution risk, however, as the PIONEER results are available on a regional basis, a more thorough analysis was possible.

7.3.3 In general, little difference was seen between the scenarios, however, the results are summarised in Table 33.

Table 33 Complex and extend BRAVA results using non-hydraulic flooding model (PIONEER)

Assessment	Results
Collapse results	Two extended locations showed increased risk of collapse between the different scenarios, the increase in risk occurred earlier in the fix on fail scenario. No change in the collapse risk was identified for any complex locations
Pollution results	There was no change in risk categorisation for pollution for either extended or complex locations, this is due to all being areas of focus in 2050 using standard BRAVA results

Assessment	Results
Blockage results	No difference in blockage risk categorisation for any extended TPU drainage area between the stable and AMP7 scenarios, with the exception of one Three complex locations showed an increase level of blockage risk with the increase in risk earlier in the Fix on Fail scenario

7.4 Wastewater treatment works compliance model scenarios (including environmental deterioration)

7.4.1 Extended scenario

7.4.1.1 Extended BRAVA results are generated by applying +/- 30% population increase converted to flow for dry weather flow, multiples of treated flow and no deterioration assessments.

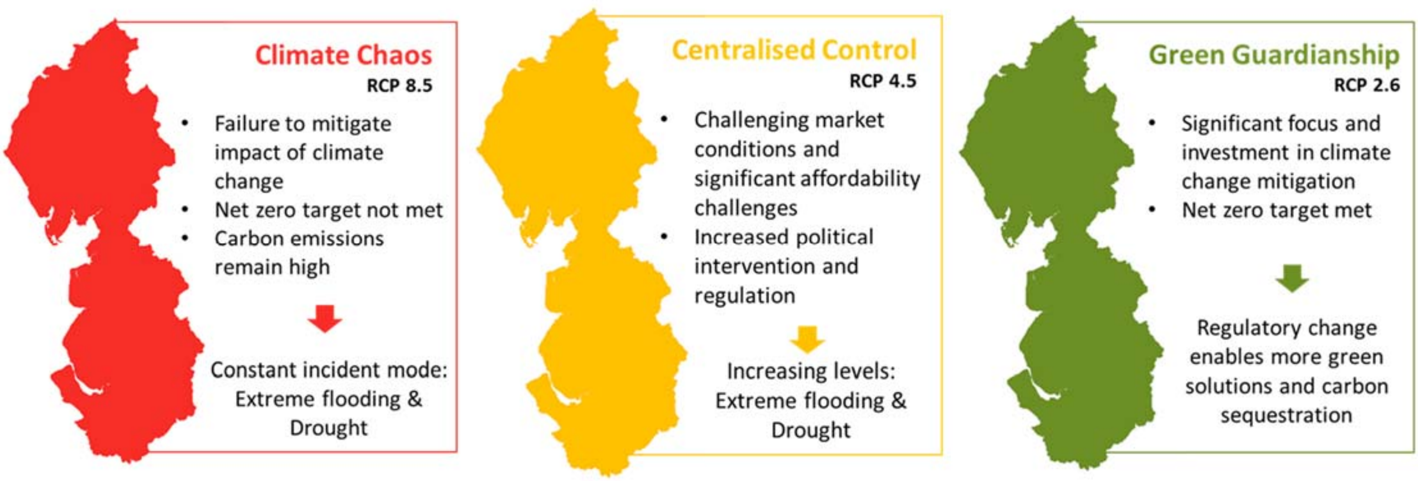
7.4.1.2 For all wastewater treatment works identified as requiring an extended BRAVA, a percentage increase in dry weather flow is applied to the existing compliance model results (as an uplift to the risk score) in order to generate an extended BRAVA score. The same risk thresholds are applied as per standard BRAVA.

7.4.2 Complex scenario

7.4.2.1 Complex BRAVA results are generated using alternative scenarios based on scenarios developed as part of visionary work included in the development of Strategic Context.

7.4.2.2 The scenarios identified are Climate Chaos; Green Guardianship; and Centralised control with a 2050 planning horizon and assumptions on population growth, consumption rates, infiltration and trade effluent applied to dry weather flow, multiples of flow, no deterioration models and were used for sensitivity testing of results.

Figure 15 Visionary scenario descriptions



7.4.2.3 Detail of the assumptions used to generate the demand risk as part of the assessments are given in Technical Appendix 3 – Demand forecasting (TA3).

7.4.2.4 Duplicate compliance assessment models were produced for each wastewater treatment works identified as requiring a complex assessment. Models used the Climate Chaos assumptions and where a local assessment of development had been provided, the associated population from that was applied.

7.4.2.5 Results of Extended and Complex treatment works assessment are given in Table 34.

Table 34 Complex and extended BRAVA results for wastewater treatment works (including deterioration assessment)

Assessment	Results
Wastewater treatment works Compliance Assessment	Extended BRAVA results showed an increase in risk by 2050 with 4 additional extended TPUs at high risk in comparison to baseline Complex assessments showed one TPU at higher risk under the Climate Chaos scenario and two using detailed local authority planning data. All others remain at the same or reduced level of risk
Dry Weather Flow (DWF)	Extended results indicate (+30% population increase) five additional TPU locations at risk (1,2) by 2030. Complex results showed five locations at greater risk in the Climate Chaos scenario with no change under Green Guardianship and two locations at greater risk under Centralised Control
Multiples of Flow Treated	Extended results showed (+30% population increase) six additional TPU locations identified at risk by 2030 Complex results indicate three TPU at greater risk under Climate Chaos scenario, one location at greater risk under Green Guardianship (and one at lesser risk) with similar risk under Centralised Control. The differences do not have an impact until later in the plan timescale
No Deterioration	Extended assessments showed five more TPUs at risk with a +30% population increase Complex assessment showed greater risk for almost all locations identified by 2050 under the Climate Chaos scenario with Green Guardianship showing improvements and Centralised Control a slight increase in risk at some locations

7.4.3 Sludge compliance

7.4.3.1 Complex and Extended assessment of sludge compliance was not undertaken as the detail within the standard assessment is sufficient to understand the level of risk.

7.4.3.2 Options are being developed for all issues identified through the preliminary problem characterisation process.

8. Problem characterisation

8.1 Overview

8.1.1 As stated in the DWMP framework; "The preliminary problem characterisation process was aimed at defining the need for more detailed approaches to understand the nature of any problems as a function of growth uncertainties. The final element of the problem characterisation is aimed at ensuring that the approach to the options development and appraisal process is proportionate to the nature of any problems identified. The problem characterisation step draws heavily from established WRMP processes as detailed in the UKWIR report 'WRMP 2019 Methods – Decision Making Process: Guidelines'".

8.1.2 There are two elements to the problem characterisation assessment:

- Strategic needs ("how big is the problem?") – a high-level assessment of the scale of need for interventions to address near, medium and long-term performance concerns; and
- Complexity factors ("how difficult is the problem to solve?") – an assessment of the complexity of issues that affect investment in a drainage and wastewater planning area.

8.1.3 Strategic needs scoring is calculated as already discussed in Section 5.5 Preliminary problem characterisation.

8.1.4 An assessment of complexity factors is applied to understand the level of optioneering required. The assessment gives a score for demand (flow/load) risk and a score for supply (capacity) risk. The approach to these assessments is discussed further in Section 8.2 and are based on Table 35, which is taken from Appendix C – Baseline risk and vulnerability assessment; and problem characterisation (DWMP framework).

Table 35 Scores to assess complexity factors for TPUs

Complexity factors	Not significant (Score = 0)	Moderately significant (Score = 1)	Very significant (Score = 2)	Don't know
Demand (flow/ load) risks	3 questions: > Minimum score = 0 > Maximum score = 6			
Supply (capacity) risks	5 questions: > Minimum score = 0 (no significant concerns for all planning objectives) > Maximum score = 10 (very significant concerns for all planning objectives)			
Total	**8 questions:** > **Minimum score = 0** > **Maximum score = 16**			

8.2 Complexity factor methodology

8.2.1 All questions in the complexity factors assessment use a scale of significance to characterise the answer. This involves significant elements of engineering judgement. As such, it is important that outputs to the questions are documented. The question set is answered for each planning objective.

8.2.2 Complexity factor scores depend on the nature of the catchment and the assessment to which it is applied. The complexity questions to be answered are detailed in Table 36 and are taken from the DWMP framework document 'Appendix C – Baseline risk and vulnerability assessment; and problem characterisation'.

Table 36 Complexity factors questions and scoring methodology

Demand (flow/load) risks: for clarity, demand refers to the flows and loads that drain to/enter drainage (and hence wastewater) systems

Q1 **Assume 2030**	Are there concerns about **near or medium-term** demand system performance, primarily due to uncertain impacts of: i) climate change; ii) new development and urban creep on vulnerable supply systems, but also including associated deterioration (e.g. increasing flows due to infiltration), impacts of other drainage systems, or poor understanding?; and iii) Infiltration		
Score	**Wastewater treatment works and sludge**	**Flooding, overflow activations and pollution**	**Water quality deterioration (continuous discharge)**
i) Climate change			
Data source	Climate change not included in models	UKWIR 2017 (UKCP09 models) include rainfall uplift. Use flooding, overflow activation and pollution result change from baseline	Temperature and dilution resilience results
0	All	< 5% increase	0 risks
1	N/A	5–10% increase	1 risk
2	N/A	>10% increase	>1 risks
ii) New Development and urban creep			
	RBCS new development assessment results, assumptions is that there is greater certainty of short-term risk from new development	RBCS CAF and new development assessment results	
0		Where other criteria (score 1,2) are not met	
1	<250 population and RBCS risk	CAF assessment score 4 and significant growth	
2	Large know development with uncertainty of drainage area	CAF assessment score 5 and significant growth	
Infiltration			
Data source	Uses back calculated infiltration (TPU) from measured flows where available		
0	Where other criteria (score 1,2) are not met		

Demand (flow/load) risks: for clarity, demand refers to the flows and loads that drain to/enter drainage (and hence wastewater) systems

1	If no measured or unreliable flow data; or an existing project is underway to address high infiltration rates	If infiltration (l/hd/day) is >120	As with wastewater treatment works
2	N/A	If infiltration is in highest 33% of L3s	As with wastewater treatment works

Q2

Assume 2050

Are there concerns about **future** demand system performance, primarily due to uncertain impacts of: i) climate change; ii) new development and urban creep on vulnerable supply systems, but also including associated deterioration (e.g. increasing flows due to infiltration), impacts of other drainage systems, or poor understanding?; and iii) Infiltration

Score	Wastewater treatment works and sludge	Flooding, overflow activations and pollution	Water quality deterioration (continuous discharge)
i) Climate change			
Data source	Climate change not included in models	UKWIR 2017 (UKCP09 models) include rainfall uplift. Use flooding, overflow activation and pollution result change from baseline	Temperature and dilution resilience results
0	All	< 10% increase	0 risks
1	N/A	40–60% increase	1 risk
2	N/A	>60% increase	>1 risks
i) New Development and urban creep			
	Use RBCS new development assessment results and Growth Assessment Results for PPC	RBCS CAF and new development assessment results	
0	Screening has not identified risk or if growth uncertainty is low and growth is moderately or not significant (BRAVA growth criteria)		

Demand (flow/load) risks: for clarity, demand refers to the flows and loads that drain to/enter drainage (and hence wastewater) systems

0	If RBCS results have not identified a risk; *or* Growth forecast uncertainty is low and population growth is moderate or not significant	Where other criteria (score 1,2) are not met	As with wastewater treatment works
1	Low growth uncertainty and significant growth; or Where historic trends are more than 1% (of total pop) per year different to forecast	CAF assessment score 4 and significant growth	As with wastewater treatment works
2	High growth uncertainty and significant growth	CAF assessment score 5 and significant growth	As with wastewater treatment works
ii)	Infiltration		
	Uses back calculated infiltration (TPU) from measured flows where available		
0	Where other criteria (score 1,2) are not met	Where other criteria (score 1,2) are not met	As with wastewater treatment works
1	If infiltration (l/hd/day) is >120	If infiltration (l/hd/day) is >120	As with wastewater treatment works
2	If infiltration (l/hd/day) is >300	If infiltration is in highest 33% of L3s	As with wastewater treatment works

Q3 Does uncertainty associated with forecasts of demographic/economic/behavioural changes over the planning period cause concerns over the level of investment that may be required?

Score	Wastewater treatment works and water quality deterioration	Flooding, overflow activations and pollution
	Review of historic visitor numbers and area demographics including local trade	PIONEER model impact using blockage BRAVA thresholds
0	Where other criteria (score 1,2) are not met	0 impact score

Demand (flow/load) risks: for clarity, demand refers to the flows and loads that drain to/enter drainage (and hence wastewater) systems

1	If tourism population is >10% of population equivalent*; or* Areas with large student population*; or* Areas with large numbers of high-rise buildings (high density); or Significant increase in trade identified	Moderate impact
2		Large impact

Supply (capacity) risks: for clarity, supply refers to the available capacity (both hydraulic and process) within drainage and wastewater systems

Q1 **Assume 2030**	Are there concerns about **near or medium-term** supply system performance, either because of recent level of service failures or because of poor understanding of system reliability/resilience under different circumstances than those contained in the historical record?		
Q2 **Assume 2050**	Are there concerns about **future** supply system performance, either because of recent level of service failures or because of poor understanding of system reliability/resilience under different circumstances than those contained in the historical record?		
Score	**Wastewater treatment works and environment deterioration**	**Sludge**	**Flooding, overflow activations and pollution**
	Availability of wastewater treatment works model, resilience erosion, and flooding assessment results	Size and type of sludge treatment	Modelled activation data vs measured activations
0	Where other criteria (score 1,2) are not met		
1	If a wastewater treatment works model is not available*; or* A wastewater treatment works is at risk of coastal or river erosion*; or* A wastewater treatment works has flooded in the last ten years*; or* Resilience of the system is reliant on third parties	Sludge cake storage sites	Storm overflows consistently activating more frequently than model over one year*; or* Significant difference between the number of mapped nodes and model nodes

Supply (capacity) risks: for clarity, supply refers to the available capacity (both hydraulic and process) within drainage and wastewater systems

2		Large wastewater treatment works integral to sludge treatment (Liverpool and Davyhulme)	Storm overflows consistently activating more frequently than model over multiple years

Q3	Are there concerns about **near**, **medium** or **long-term** system performance, primarily due to uncertain impacts of supply (capacity) issues (chronic and/or acute) on vulnerable systems, due to: i) asset deterioration; ii) the misuse of the system; or iii) poor understanding?	
Score	**Wastewater treatment works, sludge and environment deterioration**	**Flooding, overflow activations and pollution**
i)	Asset deterioration	
0	Used tools that identify asset health; and Assumptions on asset health are included in solutions	Combination of enhanced targeting and high consequence sewer to aid identification and solution development
ii)	Misuse of systems	
0	We consider that we have appropriate training to operate our system well	We have an existing programme aimed at addressing customer misuse of the system
iii)	Poor understanding	
Data source	Measured DWF data (rolling 12 months)	Available model and monitoring data
0	Where other criteria (score 1,2) are not met	If network model*; and* Integrated Drainage Assessment Study (IDAS)*; and* Dynamic network management (DNM) is available*; or* model confidence score is high
1	Between 80% and 90% available DWF data (total daily volumes)	Up to two (of three) of above available data *or*; model confidence score is medium
2	<80% available DWF data (total daily volumes)	None of above available data*; or* model confidence score is low
Q4	Are there concerns about the potential for ‘stepped’ changes in regulation (e.g. pharmaceuticals/microplastics) necessitating a significant change in supply-side approaches to managing demand, in the near or medium term that are currently very uncertain?	
Score	**Wastewater treatment works, sludge and environment deterioration**	**Flooding, overflow activations and pollution**
Data source	Horizon scan information on future environmental drivers including inland bathing waters	
0	No known changes in regulation on the horizon, none of the following examples apply	

Supply (capacity) risks: for clarity, supply refers to the available capacity (both hydraulic and process) within drainage and wastewater systems		
1	Indication that there will be a chemical driver for this catchment in the future; or Indication that there will be a Nitrogen limit in lakes in this catchment in the future; or Indication that new bathing waters will be designated in this area in the future Note: Indication on sludge regulation was unavailable at the time of scoring but will be included in future assessments	
Q5	Are there any opportunities to increase capacity or provide alternative means of addressing flow/load needs, in the near or medium term, that warrant assessment of cross-catchment interventions (that are currently very uncertain)?	
Score	**Wastewater treatment works, sludge and environment deterioration**	**Flooding, overflow activations and pollution**
Data source	Review of rationalisation opportunities, diffuse input and flexible permitting opportunities	
0	Rationalisation, diffuse interventions, Red WINEP requirements* and catchment solutions are all included within option identification and solution development for all locations so this is the default TPU score.	
1	If a Hydraulic Flood Risk Resilience (HFRR)project has been identified but not progressed	
2	N/A	

*where environmental needs are defined but solution is not cost beneficial.

8.3 Problem characterisation outputs

8.3.1 An average problem characterisation score for each question is applied to each TPU to assess against the strategic needs scores.

8.3.2 The detail of how each score was calculated (for each BRAVA per TPU) is also available to enable targeted options to be developed where there are complexities for specific elements of a TPU catchment, such as network flooding, or wastewater treatment. The complexity factor results are summarised in Table 37.

Table 37 Complexity results (high, medium, low) as number of TPUs

		Strategic Needs Score ("How big is the problem")			
		Negligible 1-2	Small 3-4	Medium 5-6	Large 7-8
Complexity factors score ("How difficult it is to solve")	High (8+)	5	20	16	1
	Medium (5-7)	71	73	51	5
	Low (<4)	190	65	59	4

8.3.3 The problem characterisation outputs are applied with strategic needs scores to understand the level of optioneering required for each TPU.

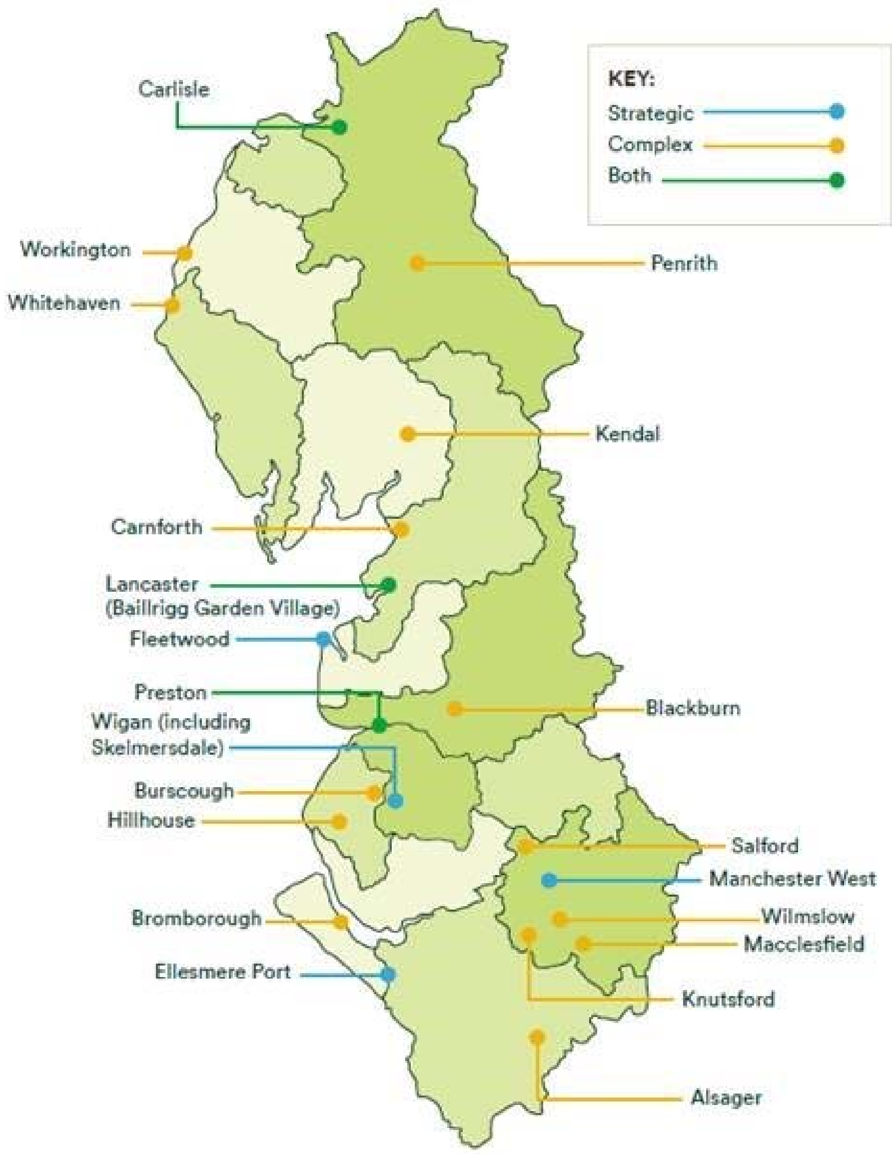
8.3.4 Where a TPU is 'green', or low complexity, the level of concern is low and standard options are developed. For those catchments falling under the yellow category, the level of concern is medium and extended options are developed. Finally, where a TPU is red, the level of concern is high and complex options are developed. The definitions of standard, extended and complex are included in Technical Appendix 7 – Options Identification.

9. Strategic Tactical Planning Units

9.1 Overview

9.1.1 In addition to TPUs identified as requiring further option development. These catchments are those with high growth, a high number of risks and multiple potential scenarios. The locations are not restricted to the TPU level and some involve multiple TPUs where it is uncertain where the risk will be manifested. Some of these catchments include complex TPUs and, therefore, have a greater level of solution detail. The areas considered within strategic optioneering are outlined in Figure 16.

Figure 16 Locations requiring strategic optioneering



9.1.2 Different bespoke scenarios are applied to the catchments based on the needs and drivers of the catchments to understand the variability of risk as a first step for optioneering, so that the range of options developed can mitigate a different range of scenarios. More detail on how options are developed for these locations is in Technical Appendix 7 – Development and Appraisal (TA7).

10. Post-BRAVA verification of risks

10.1 Overview

10.1.1 This aim of this process is two-fold; to account for committed programmes of work that will resolve the risks identified, and to ratify modelled outputs against observed data or local knowledge ahead of optioneering. The outcome of this process is to produce a list of confirmed drivers and locations of risk across the UUW operating area that require optioneering and solution development.

10.2 Clustering network risk

10.2.1 Network risks are clustered to identify locations with common drivers. The methodology for this is as follows:

- All properties with an identified flood risk have a 50m buffer applied through a geo-spatial query. Any intersecting buffers are then combined into clusters in order to identify general areas of risk.
- The annualised flood risk of all properties within a cluster is summed.
- All clusters within the region are then ranked by descending total annualised flood risk in order to identify areas of significance.
- The clusters are ratified by engaging with Asset Managers and Network Operations plus checking against known historical incidents.
- The clusters are then used within the options development process to prioritise investment based upon forecasted risk.

10.3 Development of issue log and verification

10.3.1 All risks and issues identified through BRAVA, resilience and horizon scanning assessments are collated into a central shared location. This enables identification and grouping of risks within tactical planning units and strategic planning areas in order to develop potential solutions by theme or location.

10.3.2 The issues log is reviewed with operational colleagues and through this process a number of issues can either be removed completely or identified as requiring further information before confirming if a solution is required.

10.3.3 Modelled hydraulic network flood risk clusters are verified against historic incident data and local operator knowledge. This process is required as the hydraulic network models are not calibrated for flood performance. Significant inconsistencies between EDM and modelled overflow activation data are flagged for future investigation rather than immediate solution intervention.

10.3.4 Following this process, the remaining risks and issues are collated for the Options Identification phase as detailed in Technical Appendix 7 – Options Development and Appraisal (TA7).

Appendix A

Table A1 BRAVA thresholds

	Growth assessment thresholds		
	No concern	Potential area of focus	Area of focus
2020	N/A	N/A	N/A
2030	<5% population increase	5–10 % population increase	>10% population increase
2050	<10% population increase	10–20% population increase	>20% population increase

	Internal sewer flooding thresholds		
	No concern	Potential area of focus	Area of focus
2020	<1.34 (PO FY25)	4.28 (FY20 Performance)	>4.28 (>FY20 Performance)
2030	<1.34 (PO FY30)	4.28 (PO FY25)	>4.28 (>PO FY25)
2050	<1.34 (PO FY50)	4.28 (PO FY45)	>4.28 (>PO FY45)

	External (Curtilage) Flooding thresholds		
	No concern	Potential area of focus	Area of focus
2020	<17.09 (PO FY25)	20.82 (AMP6 Av)	>20.82 (>AMP6 Av)
2030	<16.30 (PO FY30)	18.53 (AMP7 Av)	>18.53 (>AMP7 Av)
2050	<13.13 (PO FY50)	14.24 (AMP11 Av)	>14.24 (>AMP11 Av)

	External (Open Space) Flooding thresholds		
	No concern	Potential area of focus	Area of focus
2020	<4.31 (PO FY25)	4.98 (AMP6 Av)	>4.98 (>AMP6 Av)
2030	<4.16 (PO FY30)	4.37 (AMP7 Av)	>4.37 (>AMP7 Av)
2050	<3.56 (PO FY50)	3.77 (AMP11 Av)	>3.77 (>AMP11 Av)

	Risk of Flooding (1 in 50) thresholds		
	No concern	Potential area of focus	Area of focus
2020	<14.88 (AMP7 Baseline)	20.65 (FY20 Baseline)	>20.65 (>FY20 Baseline)
2030	<15.02 (FY25 PC)	20.17 (PO FY25)	>20.17 (>PO FY25)
2050	<18.59 (PO FY50)	18.90 (PO FY45)	>18.90 (>PO FY45)

	Risk of Sewer Collapse thresholds		
	No concern	Potential area of focus	Area of focus
2020	<13.07 (PO FY25)	16.04 (FY19 performance)	>16.04 (>FY19 performance)
2030	<12.39 (PO FY30)	13.07 (PO FY25)	10.22 (PO FY45)
2050	<9.67 (PO FY50)	10.22 (PO FY45)	>10.22 (>PO FY45)

	Risk of Sewer Blockage thresholds		
	No concern	Potential area of focus	Area of focus
2020	<247.97 (PO FY25)	298.48 (FY20 performance)	>298.48 (>FY20 performance)
2030	<225. 24 (PO FY30)	247.97 (PO FY25)	>247.97 (PO FY25)
2050	<134.32 (PO FY50)	157.05 (PO FY45)	>157.05 (>PO FY45)

	Dry weather flow thresholds		
	No concern	Potential area of focus	Area of focus
2020	No DWF Exceedance	Forecast DWF up to 5% more than permit	Forecast DWF >5% more than permit
2030	No DWF Exceedance	Forecast DWF up to 5% more than permit	Forecast DWF >5% more than permit
2050	No DWF Exceedance	Forecast DWF up to 10% more than permit	Forecast DWF >10% more than permit

	Multiples of flow treated (wastewater treatment works)		
	No concern	Potential area of focus	Area of focus
2020	<0% above permit	0–10% above permit	>10% above permit
2030	<0% above permit	0–10% above permit	>10% above permit
2050	<0% above permit	0–10% above permit	>10% above permit

	Wastewater treatment works Final Effluent Compliance thresholds		
	No concern	Potential area of focus	Area of focus
2020	>80% likelihood of achieving compliance	40–80% likelihood of achieving compliance	<40% likelihood of achieving compliance
2030	>80% likelihood of achieving compliance	40–80% likelihood of achieving compliance	<40% likelihood of achieving compliance
2050	>80% likelihood of achieving compliance	40–80% likelihood of achieving compliance	<40% likelihood of achieving compliance

	Sludge treatment		
	No concern	Potential area of focus	Area of focus
2020	Sludge forecast is below medium SLA threshold	Sludge forecast is between medium and high SLA thresholds	Sludge forecast is above high SLA threshold
2030			
2050			

	Risk of Pollution thresholds		
	No concern	Potential area of focus	Area of focus
2020	<22.60 (AMP7 Av)	34.00 (EPA Amber)	>34.00 (EPA Amber)
2030	<15.60 (PO 2029)	34.00 (EPA Amber)	>34.00 (EPA Amber)
2050	0.00 (PO 2049)	3.90 (PO 2044)	>3.90 (PO 2044)

	Deterioration of inland water body thresholds		
	No concern	Potential area of focus	Area of focus
2020	N/A	N/A	N/A
2030	<3% deterioration*	>3% deterioration*	>10% or class deterioration
2050	<3% deterioration*	>3% deterioration*	>10% or class deterioration

*BOD; Ammonia; or Phosphorous.

	Individual Overflow Performance		
	No concern	Potential area of focus	Area of focus
Lower	0	20	40
Upper	20	40	–

	Individual Bathing Water Overflow Performance		
	No concern	Potential area of focus	Area of focus
Lower	0	3	10
Upper	3	10	–

	Individual Shellfish Water Overflow Performance		
	No concern	Potential area of focus	Area of focus
Lower	0	11	14
Upper	11	14	–

	Aggregated Points Score per TPU for all Overflows		
	No concern	Potential area of focus	Area of focus
2020	0-15	15-45	45-100
2030	0-15	15-45	45-100
2050	0-15	15-45	45-100

United Utilities Water Limited

Haweswater House
Lingley Mere Business Park
Lingley Green Avenue
Great Sankey
Warrington
WA5 3LP

unitedutilities.com

United Utilities

Water for the North West