Revised Draft Water Resources Management Plan 2024

Appendix 6A – Allowing For Uncertainty

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August 2023

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ALLOWING FOR UNCERTAINTY – EXECUTIVE SUMMARY

As part of our Water Resources Management Plan 2024 (WRMP24) submission, we have calculated the supply-demand balance for our single water resource zone (WRZ) over the 50-year planning period from 2025 to 2075. In accordance with statutory guidelines and industry standard practice, the supply-demand balance includes a margin between supply and demand to allow for uncertainties inherent within the supply and demand forecasts. This margin is known as 'headroom', and the headroom value determined for each year across the planning period, at a defined level of risk, is termed the target headroom allowance.

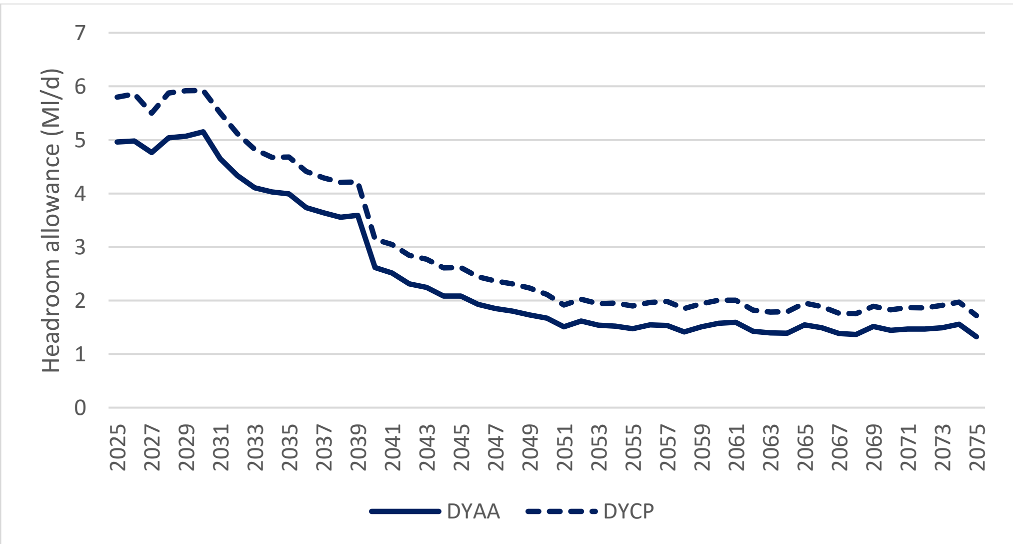
There are a range of factors leading to uncertainty in the calculations of supply and demand over the 50-year planning horizon, including meter accuracy, demand forecast uncertainty, source pollution risks and the uncertain future effects of climate change on supply and demand. We have adopted the recommended methodology (UKWIR, 2002) of using Monte Carlo simulation to statistically combine probability distributions representing each component of uncertainty. The parameters of each distribution are determined from our latest supply and demand forecast data calculated for our WRMP24 submission and other relevant data.

The Monte Carlo simulation process results in an overall probability distribution covering the combined impact of all relevant factors on the supply-demand balance, for each year and planning scenario as required. Target headroom values are then determined from the combined distributions at the required probability percentiles (corresponding to supply-demand risk). Our selected profile of risk is based on a percentile glidepath starting at 90% (10% risk) up to 2030/31, then tapered linearly to a percentile of 70% (30% risk) in 2050/51 and fixed at 70% for the remainder of the planning period.

In alignment with our regional planning group, Water Resources South East (WRSE), for WRMP24 we have adopted an adaptive planning approach to cover some of the key areas of future uncertainty within the supply-demand balance. Our adaptive plan branches into different pathways at key decision points, based on different scenarios relating to demand growth, climate change impacts and environmental licence reductions. We therefore calculated three customised headroom profiles to apply to different pathways through the branches of our adaptive planning framework. This ensures that there is no double-counting of the key uncertainties within each adaptive planning pathway. A hybrid profile of target headroom allowances is applied to our core pathway through the adaptive planning branches, switching between customised profiles as appropriate at the key decision points across the planning period.

The results of the assessment are summarised below. Our company target headroom allowance, for the core pathway for each of the two planning scenarios assessed, is presented for the 50-year planning period based on the selected risk profile as outlined above.

Target headroom profiles for dry year annual average (DYAA) and dry year critical period (DYCP) planning scenarios



Summary of target headroom allowances, 2025 - 2075

Year	Combined Company Target Headroom Allowance, Ml/d	
	Dry Year Annual Average	Dry Year Critical Period
2025/26	4.98	5.86
2030/31	4.65	5.51
2035/36	3.74	4.41
2040/41	2.52	3.05
2045/46	1.93	2.44
2050/51	1.51	1.92
2055/56	1.54	1.97
2060/61	1.59	2.01
2065/66	1.49	1.89
2070/71	1.47	1.87
2074/75	1.32	1.72

1 INTRODUCTION

This report forms part of Portsmouth Water's Water Resources Management Plan 2024 (WRMP24) submission. A key element of our plan is a detailed analysis of the supply-demand balance over a 50-year planning period from 2025 to 2075.

In accordance with statutory guidelines and industry standard practice, the supply-demand balance includes a margin between supply and demand to allow for uncertainties inherent within the supply and demand forecasts. This margin is known as 'headroom'; available headroom is defined as the difference between supply and demand and is required to be positive, indicating that available supply exceeds demand. Portsmouth Water must calculate appropriate values of headroom for each planning scenario considered in WRMP24, to ensure that headroom is adequate to cover potential future variations in supply and demand from the baseline forecasts. The required headroom value determined for each year across the planning horizon is termed the target headroom allowance.

There are a range of factors leading to uncertainty in the forecasts of supply and demand over the 50-year planning horizon. These include accuracy of meters measuring abstractions and distribution input, uncertainties in the data and analysis used to prepare supply forecasts, variation in the company's future demand forecasts, uncertainty in the future impacts of climate change, risks of future pollution impact on supply availability, and risks of changes to the company's abstraction licences for sustainability or other reasons. The aim of calculating a target headroom allowance is to provide a reasonable margin to cover the statistically combined impact of these factors on the supply-demand balance, at a defined level of risk.

The inclusion of target headroom allowances in the supply-demand balance is not the sole approach by which water companies can account for future uncertainty in water resources planning. Companies may also adopt a risk-based planning approach directly within their supply-demand balance analysis, and/or adopt an adaptive planning approach by testing alternative pathways based on key areas of uncertainty in their plans. For WRMP24 we are adopting an adaptive planning approach to test significant areas of uncertainty, in line with our regional group Water Resources South East (WRSE), however an assessment of target headroom allowances is still required to cover uncertainty within our core pathway.

This report presents the methodology, data sources and key assumptions utilised in our target headroom assessment for WRMP24.

2 BACKGROUND

This section presents an overview of our supply system, comprising a single water resource zone (WRZ), the previous target headroom assessments carried out for our 2019 Water Resources Management Plan and the planning and regulatory context which underpins our updated assessments for the 2024 plan.

2.1 Overview of supply system

We supply water to a single water resource zone in the south of England, which includes the towns of Gosport, Fareham, Havant, Chichester and Bognor Regis, in the counties of Hampshire and West Sussex. All of our water comes from chalk-based sources, including a number of groundwater sources (boreholes, wells and springs), along with a single surface water abstraction from the River Itchen.

Figure 1 shows our area of supply and water treatment works locations.

Figure 1: Company area of supply

2.2 Previous target headroom assessment

Our assessment of target headroom allowances builds on previous work undertaken for our Water Resources Management Plan 2019 submission (WRMP19). Table 1 provides a summary of the target headroom allowances calculated for WRMP19. For WRMP24 we have undertaken a full review of the potential areas of uncertainty for our plan and updated our target headroom analysis with revised supply and demand forecasts as well as amending other key data and assumptions where appropriate.

Table 1: Target headroom allowances - WRMP19 assessment

	Target Headroom Allowance (Ml/d) for year:					
Scenario	**2020/21**	**2025/26**	**2030/31**	**2035/36**	**2040/41**	**2044/45**
Dry Year Annual Average	5.34	4.99	5.14	6.02	6.82	7.58
Dry Year Critical Period	7.10	6.93	7.75	8.72	9.73	10.66

2.3 Planning scenarios

Our WRMP24 needs to ensure reliable water supplies both over the whole of a dry year, as well as during shorter critical periods that can put strain on our systems (for example, summer heatwaves when demand for water is high and available water is low, or freeze-thaw events when frozen ground leads to burst pipes and a sudden increase in leakage). We therefore prepare our supply-demand balance analysis for a dry year annual average (DYAA) and a dry year critical period (DYCP) scenario. A profile of target headroom allowances is required for each of these planning scenarios.

2.4 Regional planning context

In March 2020 Defra published their National Framework for Water Resources which confirmed the requirement for regional Water Resources Plans to be produced, to address the need for resilient and sustainable water supplies in a growing economy and changing climate. There are currently five regional groups across the UK, consisting of water companies, water industry regulators and stakeholders, working to address the requirement for regional plans to be developed in line with the National Framework.

Portsmouth Water is a member of Water Resources South East (WRSE), the regional group established to oversee water resources planning for the south east of England. The other core members of the group are Affinity Water, SES Water, South East Water, Southern Water and Thames Water, with key regulators and stakeholders acting to provide support on direction and decisions in an advisory capacity.

Through WRSE, the companies of the south east have developed common methodologies, shared data sets and a regional adaptive planning approach to meet future water resource challenges. This collaborative work has supported regional plan submissions including the draft of the Regional Water Resources Plan published in November 2022, as well as Water Resources Management Plans (WRMPs) for individual companies.

2.5 Regulatory context

Our target headroom assessments have been undertaken in line with the guidance set out by the Environment Agency in their Water Resources Planning Guideline (December 2021). The guidance emphasises the need for water companies to consider key uncertainties in the supply-demand balance through an adaptive planning approach, in which alternative future scenarios may be triggered in future years by significant variation of factors such as demand forecasts and/or climate change impacts.

The EA guidance also indicates that the level of risk adopted within the headroom component is expected to follow a reducing profile across the planning period, reflecting the expectation that the later years allow more time to adapt to variations of key uncertainty factors. This, combined with the increasing use of adaptive plans to cover future uncertainties, is a consideration when selecting risk profiles to determine the target headroom allowances to apply within the company's supply-demand balance (see Section 6 for more details).

3 METHODOLOGY

As for our previous (2019) Water Resources Management Plan, we have adopted the industry standard method for the calculation of our company target headroom allowance. The method is outlined in An Improved Methodology for Assessing Headroom (UKWIR, 2002) and referred to by the Environment Agency (EA) in their Water Resources Planning Guideline (December 2021).

In this approach, a probability distribution is assigned to each individual risk or uncertainty factor within the supply-demand balance, based on known data and other relevant information. All probability distributions are then combined using the statistical technique of Monte Carlo simulation, which iteratively takes random samples from each distribution and sums them according to specified rules. The summed result of each iteration then forms a point on the curve of the combined distribution; by sampling the distributions over many iterations it is then possible to build up a probability distribution to represent the overall risk or uncertainty of all factors taken together.

Typical types of probability distribution used to represent uncertainty factors in supply-demand balance analysis are shown in Table 2 below.

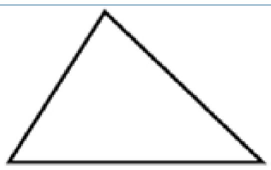
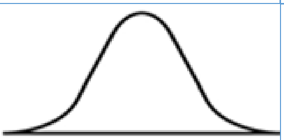
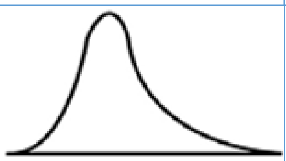
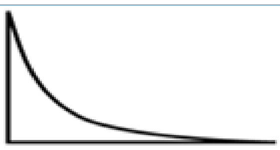
Our model input data and assumptions have been collated in a Microsoft Excel spreadsheet, and we have developed an application using the open-source coding language Python to read in the data and apply the Monte Carlo simulation.

Due to the random nature of the Monte Carlo simulation technique, it is not possible to guarantee that identical results will be generated each time the same simulation is run. However, by selecting a suitably large number of iterations for the simulation, to give an acceptable mean standard error for the simulation results, it should be possible to obtain repeatable results to an acceptable level of accuracy. The 2002 UKWIR methodology suggests using 5,000 as a typical number of iterations. However, in practice it has been found that more consistent results can be obtained using 10,000 iterations. All Monte Carlo simulations undertaken for the 2024 Water Resources Management Plan target headroom assessment have therefore been run for 10,000 iterations.

The target headroom allowances for each resource zone, in megalitres per day or Ml/d, are read off the selected probability point on each combined headroom distribution produced from the Monte Carlo simulation as outlined above. To determine a single profile of target headroom allowance across the 50-year planning period, for each planning scenario, it is necessary to select the appropriate level of risk on which to base the target headroom allowance for each year. This defines the probability point on the headroom distribution at which to take the headroom value. For example, if a low level of risk is preferred, to reflect a low resilience to the uncertainty factors inherent within a company's supply and demand forecasts, then a percentile of 95% may be selected. This corresponds to a 95% probability that the selected target headroom allowance will be adequate to cover the range of simulated uncertainties, or a 5% risk that it will not.

The resulting profile of target headroom allowances for each resource zone is then incorporated within the supply-demand balance analysis for each year across the planning horizon.

Table 2: Typical probability distributions used to represent supply-demand uncertainty

Type	Shape	Description	Application
Triangular		Most easily defined continuous distribution. Defined by a least likely, most likely and maximum likely value. Can be skewed either way.	Forecasting situations where the supply or demand value can be any value within a range and the most likely value can be estimated. May not be appropriate if highly skewed.
Normal		Symmetrical continuous distribution defined by a mean and standard deviation.	Most commonly applied to random uncertainties (known unknowns).
Log-Normal		Skewed continuous distribution defined by a mean and standard deviation.	Forecasting situations where there is a large difference between the maximum and the most likely values such that a triangular distribution is considered unsuitable.
Exponential		Continuous distribution defined by rate. Minimum value always equals zero.	Forecasting situations where the most likely and minimum values are zero, but there is a possibility of a large positive value.
Discrete/ Custom		Non-continuous distribution defined by values and probabilities.	Forecasting situations where specific values apply and values between do not. For example, chance events where the outcome is a particular value or zero.

3.1 Summary of uncertainty components

Table 3 lists the key components of uncertainty which the UKWIR methodology recommends for inclusion in a water company's target headroom assessment. However, it should be noted that factor S7 (single source dominance) was included in a previous headroom methodology but excluded from the latest UKWIR methodology on the grounds that this factor is an outage issue and any related uncertainty or risk should therefore be incorporated in a company's outage allowance assessment, if applicable. It is included in the table for completeness only.

In addition, there are three factors below (S1, S2 and S3) which have been excluded from the WRMP24 target headroom assessment in line with Environment Agency guidance in the final published Water Resources Planning Guideline (December 2021). Further details are provided in Sections 4.1, 4.2 and 4.3 of this report.

Table 3: Summary of supply-demand balance uncertainty factors

Factor	Name	Description
S1	Vulnerable Surface water licences	Risk of future loss of deployable output due to sustainability changes to surface water abstraction licences for environmental reasons
S2	Vulnerable Groundwater licences	Risk of future loss of deployable output due to sustainability changes to groundwater abstraction licences for environmental reasons
S3	Time Limited Licences	Risk of future loss of deployable output due to non-renewal of time limited abstraction licences
S4	Bulk Imports	Risk of future loss of deployable output due to changes in bulk supply agreements (imports only)
S5	Gradual Pollution	Risk of future loss of deployable output due to pollution and/or water quality issues which cannot be mitigated or recovered
S6	Accuracy of Supply-Side Data	Uncertainty surrounding the accuracy of supply side data e.g. percentage accuracy of abstraction meters
S7	Single Source Dominance	(This factor is no longer used in the headroom methodology)
S8	Impact of Climate Change on Deployable Output	Uncertainty surrounding the future impact of climate change on deployable output (varying estimates of loss depending on scenario)
S9	New Sources	Uncertainty surrounding the available yield of major new resource developments included in the final planning supply-demand balance
D1	Accuracy of Sub-component Demand Data	Uncertainty surrounding the accuracy of demand side data i.e. percentage accuracy of distribution input meters (generally located at service reservoirs)
D2	Demand Forecast Variation	Uncertainty surrounding future demand forecasts which may be higher or lower than assumed in the baseline supply-demand balance

Factor	Name	Description
D3	Impact of Climate Change on Demand	Risk of future increases in demand due to climate change impacts (varying estimates of demand effects depending on scenario)
D4	Demand Management Measures	Uncertainty surrounding the impact on future demand of demand management measures including leakage reduction, metering strategy and water efficiency activities.

Note that each of the above uncertainties may be represented as a single annual probability distribution within the Monte Carlo simulation, or alternatively may be divided into a number of subcomponents. For example, typically the uncertainties in the demand forecast variation component (factor D2) are included as individual probability distributions for each factor which has been identified as leading to uncertainty in the demand forecasts.

Sections 4 and 5 provide an overview of the assumptions adopted for each of the uncertainty factors or components within the headroom model. Graphs of the probability distributions representing each individual uncertainty component are included in Appendix 1.

4 REVIEW OF SUPPLY-SIDE UNCERTAINTY FACTORS

We have reviewed the data, assumptions and probability distributions used in our target headroom assessment for our 2019 Water Resources Management Plan, for each of the supply-related uncertainty factors. Where the approach to determining the associated probability distribution is still applicable, we have retained this but updated the parameters as appropriate based on latest data from our 2024 plan (e.g. updated source deployable output assessments). For other factors, a full update of both the methodology and data used to derive the probability distributions has been undertaken (for example we have adopted new distribution types for climate change impacts).

An overview of the review and any updates for each supply-side uncertainty factor is provided in this section.

4.1 S1 Vulnerable surface water licences

The Environment Agency's (EA's) water resource planning guideline states that water companies "should not include any allowance for uncertainty related to sustainability changes to permanent licences" and should work with the EA to discuss how to consider possible future sustainability changes in their Water Resources Management Plans. We have therefore excluded this factor from our target headroom assessment.

Work will take place in two phases over the first 10 years of our plan, under the Water Industry National Environmental Programme (WINEP), to undertake environmental assessments for all the river catchments in our supply area. Working with the EA, the aim is to ascertain the extent of any capping of our abstraction licenses necessary to deliver improvements for the environment. This is our long-term environmental destination, and in our main Water Resources Management Plan report we have set out how a range of environmental destination scenarios have been incorporated into our supply-demand balance analysis and our adaptive planning pathways, to ensure that this key area of uncertainty is addressed within the plan.

4.2 S2 Vulnerable groundwater licences

As for vulnerable surface water licences, we have excluded this uncertainty factor from our target headroom assessments in line with the EA water resource planning guideline referred to above. We have worked with the EA to identify potential impacts on our groundwater abstraction licences through WINEP or other environmental investigations, and we have incorporated a range of environmental scenarios within our baseline supply-demand balance and adaptive planning pathways to account for the uncertainty surrounding the potential impact of these changes.

4.3 S3 Time limited licences

The Environment Agency's water resource planning guideline also states that water companies "should not include uncertainty related to non-replacement of time-limited licences on current terms" but should "address this uncertainty…..through investigations and planning alternative supplies as necessary". We have therefore excluded this factor from our target headroom assessments for our 2024 Water Resources Management Plan.

4.4 S4 Bulk imports

Currently there are no bulk imports into our supply system, therefore this factor has been excluded from the target headroom assessment.

4.5 S5 Gradual pollution of sources

In previous (WRMP19) headroom assessments this factor included an allowance for the risk of source deployable output loss due to oil spillage events, however this risk has now been reviewed and is considered more appropriate to include in the outage component of the supply-demand balance.

Other gradual pollution risks include deteriorating water quality due to rising levels of nitrates and pesticides. However, these issues are being addressed through blending schemes and therefore have not been identified as a significant risk of loss of deployable output. We are also active in developing catchment management and nature-based schemes which will help to mitigate deteriorating water quality, as well as delivering wider benefits such as river enhancement and habitat creation. For example, we are part of the Arun and Western Streams Catchment partnership on the River Ems to create and develop the River Ems Chalk Restoration Scheme.

This factor has therefore been excluded from the WRMP24 target headroom assessment.

4.6 S6 Accuracy of supply-side data

We have represented the uncertainty of supply-side data accuracy by a triangular distribution with the minimum and maximum parameters being determined as +/- 5% of the baseline company deployable output. This is based on accuracy of abstraction meters, source yield assessments and infrastructure constraints combined into a single company uncertainty range.

4.7 S8 Impact of climate change on supply

The impact on deployable output (DO) was assessed for 28 WRSE climate scenarios (1 in 500-year return period) with the EA scaling factors applied. The median value of the 28 deployable output impacts, in Ml/d, was included as the best estimate of climate change impacts in the baseline supply forecast. The uncertainty range was defined as a triangular distribution, with the minimum and maximum parameters being defined by the difference of the minimum and maximum values of the 28 DO impacts, from the median value. This was applied across each year of the planning period.

4.8 S9 New sources

Our baseline supply-demand balance includes the benefits of future schemes that have already been identified/agreed in previous planning cycles, for delivery before or during the WRMP24 planning period (2025 – 2075). However, until these schemes have been implemented there is a degree of uncertainty over the deployable output benefit to be delivered by each scheme. The S9 uncertainty factor has been subdivided into two components, one for Havant Thicket Reservoir and one for two new groundwater schemes planned for the 2020-25 period (AMP7).

Havant Thicket Reservoir has received planning permission and is therefore included as part of our baseline supply forecast from 2029/30 onwards, when it is programmed to have been constructed and filled. Therefore, no uncertainty allowance has been included in headroom prior to 2029/30. The operational assumptions that underpinned the headroom uncertainty ranges for our WRMP19 assessment are no longer valid. As a result, the default WRSE option yield uncertainty range for reservoir development has been adopted, i.e. a triangular distribution with the minimum and maximum parameters determined as +/- 5% of the scheme yield (1 in 500-year return period) assumed in the baseline.

Risks associated with the planned implementation date of Havant Thicket Reservoir have not been included in the headroom assessment, however a 2-year delay in delivery is being sensitivity tested within the investment model and the results will be reported in the revised draft WRMP24.

Both new groundwater schemes are assumed to be delivered by 2024/25, therefore no uncertainty allowance is included prior to this year. The baseline yields for the two schemes are 3.2 Ml/d and 4.8 Ml/d (1 in 500-year return period). The uncertainty ranges are represented by triangular distributions with the minimum and maximum parameters determined as +/- 5% of the combined baseline yield values; this is based on the standard WRSE uncertainty ranges for groundwater sources.

5 REVIEW OF DEMAND-SIDE UNCERTAINTY FACTORS

We have reviewed the data, assumptions and probability distributions used in our target headroom assessment for our 2019 Water Resources Management Plan, for each of the demand-related uncertainty factors. Where the approach to determining the associated probability distribution is still applicable, we have retained this but updated the parameters as appropriate based on the latest set of demand forecasts from our 2024 plan. For some components, in particular the demand forecast variation factor (D2), we have introduced subcomponents to reflect the different sources of variation within our demand forecasts.

Sections 5.1 to 5.4 present an overview of the data and assumptions used to define the demand-side uncertainty components for our WRMP24 target headroom assessment.

5.1 D1 Accuracy of sub-component demand data

This factor has been subdivided into two subcomponents representing two key areas of uncertainty in base year demand data. The first is the accuracy of distribution input (DI) meters, which has been assumed to be in the range +/- 2% aligned to the assumption adopted in the annual MLE (Maximum Likelihood Estimate) water balance reconciliation process. This is applied to the baseline dry year annual average demand (1 in 10-year return period).

The second subcomponent is uncertainty in the magnitude of the dry year uplift percentage, applied to the outturn distribution input to uplift this to the equivalent dry year (1 in 10-year return period) DI. The demand model assumed an uplift factor derived from the WRSE/WRc stochastic DI series. Two versions of the stochastic data were created, Series 1 and Series 2. The central case assumes Series 3. In addition to the stochastic series, there is also a DI series based on the historic record which has been de-trended to the base year, produced internally by Portsmouth Water. The upper and lower bands of the uncertainty range were determined from the difference between the minimum and maximum values from either the WRc/WRSE stochastic DI (Series 2) or the rebased historic outturn data around the central case (stochastic Series 3).

As there is no upside risk associated with the critical period scenario, a half normal distribution is used so as not to put too much weight on the most extreme value. The maximum value was used to define the Q_{95} value of the normal distribution.

5.2 D2 Demand forecast variation

For our draft WRMP24 headroom assessment, the uncertainty in demand forecast variation was represented by four separate subcomponents: population growth, non-household consumption, natural water efficiency and covid impacts on demand. However, this has been reduced to three subcomponents for the revised draft assessment, as explained below.

5.2.1 Population Growth

Population growth uncertainty was initially represented by a triangular distribution with the minimum and maximum parameters taken from the low and high demand forecasts (difference from 'central' forecast) in each year. However, as the Environment Agency guidelines specify that the core or central forecast should be based on local authority plans, this results in the baseline forecast being very close to the maximum or high forecast, whilst there is a large negative skew to the significantly lower, ONS trend-based low forecast. This leads to very skewed uncertainty distributions, with negative impacts on the headroom allowance of sufficient magnitude to outweigh the uncertainty contributions of all other components. This is clearly not appropriate, as negative target headroom does not align with the purpose of this allowance to provide a buffer between supply and demand.

Having reviewed the final set of forecasts for the revised draft plan and undertaken benchmarking reviews of approaches adopted by other water companies with similar issues in their forecast ranges, we therefore decided to exclude the population growth subcomponent for the revised draft plan headroom assessment. Note that this exclusion only impacts the FTHR scenario as this subcomponent is dropped at the first adaptive planning branch point (see section 7).

5.2.2 Non-household consumption

Variation in forecasts of non-household consumption is represented by triangular distributions, with the minimum and maximum parameters taken from the annual differences in the range of non-household volume forecast scenarios compared to the central or baseline forecast adopted. The non-household forecasts were produced by Artesia for WRMP24, and the scenario ranges are taken from the company's demand model. The distributions are the same for the DYAA and DYCP scenarios.

5.2.3 Natural water efficiency

This component reflects the uncertainty associated with hands-off water efficiency and customer behaviour. Households are expected to become more efficient over time as older, less water efficient devices are replaced. However, Portsmouth Water has seen a recent trend in increasing per capita consumption (PCC) which is likely to be driven by changes in customer behaviour. In the central forecast, customer water use is assumed to be constant over the planning period, apart from those changes driven by changes in occupancy. The range of uncertainty around this central forecast is represented by triangular distributions with the minimum and maximum parameters based on a range of +0.1 to -0.2 l/h/d (per year). These changes are assumed to be driven by day-to-day usage rather than summer demands, therefore the assumptions for the DYAA scenario are also carried into the DYCP.

5.2.4 Covid impact

In our draft WRMP24, our demand forecast base year was 2019/20 and therefore did not include the significant impact of business closures and increased levels of homeworking which occurred during the covid-19 pandemic from March 2020 onwards. We included the potential impacts of this factor as a one-sided risk within the headroom assessment for the draft plan. However, for our revised draft plan we have rebased our demand forecasts from 2021/22, a year which reflects the 'new normal' with some legacy or ongoing effects of the pandemic still impacting patterns of household and non-household consumption. In effect, the data from 2021/22 still shows an uplift on household consumption due to increased levels of hybrid or home working, relative to pre-pandemic levels, with a corresponding decrease in non-household consumption.

We have analysed the average monthly and annual percentage impacts of covid on household and non-household consumption and reported on the findings in our annual water resources review reports for 2020/21 and 2021/22 (summarised in Table 4). The percentage impacts were higher in the main 'lockdown' year of 2020/21, and therefore we have used the differences between these impacts and those of 2021/22, to define the minimum and maximum parameters of symmetrical triangular distributions representing the range of uncertainty around the percentages reflected in our baseline forecasts. We have chosen this approach rather than assuming a minimum impact of zero, on the basis that patterns of home versus office working are unlikely to return to pre-pandemic levels in the foreseeable future. Using the 2020/21 levels to define the maximum impact effectively also allows for the possibility of future significant lockdowns due to covid-19 or other similar pandemics.

The percentages shown in Table 4 below are based on annual average impacts analysed for 2020/21 and 2021/22 for the annual average headroom assessment. For the critical period, the uncertainty range has been calculated for household consumption using the monthly values for August. However, the seasonal pattern for non-household consumption is very variable and less dependent on weather effects, therefore the non-household uncertainty range adopted for the annual average has also been applied for the critical period.

Table 4: Summary of covid impacts in 2020/21 and 2021/22

Scenario	Percentage impact of covid on:	2020/21	2021/22	Uncertainty range
Annual Average	Household consumption	12%	8%	+/- 4%
	Non-household consumption	-16%	-13%	+/- 3%
Critical Period	Household consumption	13%	12%	+/- 1%
	Non-household consumption	Varies	Varies	+/- 3%

The bounds of the household and non-household impacts are calculated in Ml/d by applying the percentages to baseline forecast volumes for each year. These are then summed together to form a single annual input distribution to the headroom analysis. This effectively assumes that the impacts are fully correlated, i.e. when non-household demands decrease, the household demands proportionally increase. The range of uncertainty of covid impacts therefore vary over time and are proportional to household and non-household forecasts in each year. This approach also means that the household covid uncertainty increase in the headroom allowance is in part mitigated by a reduction due to the non-household consumption covid uncertainty.

5.3 D3 Impact of climate change on demand

We have assessed the impacts of climate change on our company demand forecasts, using the methodology and data from the study 'Impact of climate change on water demand' (UKWIR, 2013). This presents the impacts of climate change as percentage changes in household demand, for five quantiles (10%, 25%, 50%, 75% and 90%) and for different UK river basins/regions. The impacts for each river basin, and for annual average and critical period demand, are presented in this study as look-up tables of percentage increases to apply to household consumption forecasts for each year across the planning period.

Our baseline demand forecasts include the median or 50th percentile impacts of climate change for the South East England data set applied to our household consumption forecasts. We have applied the lowest and highest percentile impacts from the look-up tables to household consumption to give a range of uncertainty around the baseline in Ml/d; these form the minimum and maximum parameters for triangular distributions adopted in our target headroom assessments for both the dry year annual average and dry year critical period scenarios.

5.4 D4 Demand management measures

Our baseline demand forecasts include the effects of water efficiency schemes which are planned for delivery during our 2020-25 (AMP7) business plan period. Triangular distributions have been adopted to represent the range of uncertainty around the forecast savings in demand which will be achieved from these schemes. All schemes are assumed to be delivered by the end of 2024/25, and therefore the profile of uncertainty parameters remains flat from 2025/26 onwards.

6 SELECTION OF RISK PROFILES

As outlined in Section **Error! Reference source not found.**, having reviewed and updated the probability distributions for the required uncertainty components, we then ran the updated Monte Carlo simulation model at 10,000 iterations. The simulations combined all components into an overall probability distribution representing the supply-demand balance uncertainty for Portsmouth Water for each year across the planning period.

To derive a profile of target headroom values across the planning period, for each planning scenario, it was necessary to select an annual level of risk and then take the headroom value from the relevant distribution at the percentile point corresponding to that level. The water resources planning guideline does not specify the level of risk which water companies should select to determine profiles of target headroom. However, the guidelines do state: "You should consider the appropriate level of risk for your plan. If target headroom is too large it may drive unnecessary expenditure. If it is too small, you may not be able to meet your planned level of service. You should accept a higher level of risk further into the future. This is because as time progresses the uncertainties will reduce and you have time to adapt to any changes." (EA, Water Resources Planning Guideline, 2021).

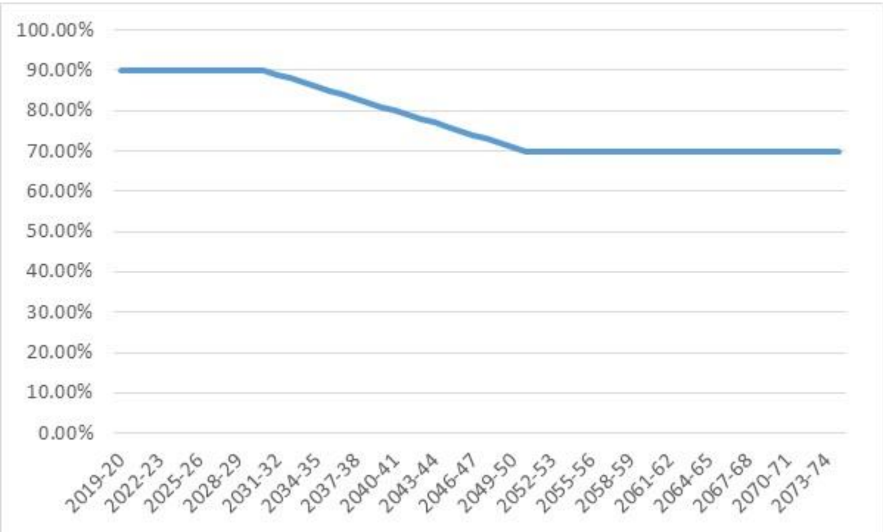
Considering the above, we have given careful thought to the selection of appropriate risk profiles to adopt in determining our target headroom allowances. We have benchmarked this against the risk profiles adopted by other water companies in their draft WRMP24 submissions, and our risk profile is broadly in line with those adopted by other companies.

Table 5 summarises our selected profiles of headroom percentile and corresponding risk at five-yearly intervals across our 50-year planning period (percentile glidepath also shown in Figure 2).

Table 5: Selected headroom risk/probability profiles

Year	2025/26	2030/31	2035/36	2040/41	2045/46	2050/51	2055/56	2060/61	2065/66	2070/71	2074/75
Risk of supply-demand balance variation (reduced surplus / increased deficit)	10%	10%	15%	20%	25%	30%	30%	30%	30%	30%	30%
Headroom distribution probability	90%	90%	85%	80%	75%	70%	70%	70%	70%	70%	70%

Figure 2: Selected headroom percentile glidepath



7 ADAPTIVE PLANNING APPROACH

WRSE's document, Target headroom approach for an adaptive plan (February 2022), sets out how the existing UKWIR target headroom methodology can be utilised within WRMP24 to ensure that uncertainties are not double counted within adaptive planning pathways.

In summary, there are two key decision points at which the plan branches depending on key uncertainties: in 2035 there are three branches selected according to high, medium, or low population growth. In 2040 each of these three paths branches again into three alternative pathways according to high, medium, or low climate change and environmental destination scenarios. Therefore, there are a total of nine alternative pathways over the full planning period from 2025 to 2075.

Three customised target headroom profiles have been calculated for both DYAA and DYCP and the final adopted profile is a hybrid of the three, switching from one profile to another at the key decision points within the adaptive plan:

- Full target headroom (FTHR) – includes all relevant components as well as environmental destination and growth forecasts. Applies from 2025 to 2035.
- Environmental Destination and Growth (EDG) – removes growth related components from D2 of the headroom forecast. Applies from 2035 to 2040.
- Environmental Destination, Growth and Climate Change (EDGC) – excludes growth related components, as well as climate change related components. Applies from 2040 to the end of the planning period.

Table 6 summarises which headroom uncertainty factors are included in each of the three customised profiles specified above. Note that subcomponent D2_1 (population growth uncertainty) is now excluded from all three scenarios as detailed in Section 5.2.

Table 6: Summary of components included in customised headroom profiles

Factor	Name	Full target Headroom profile (FTHR)	Environmental destination and Growth target headroom profile (EDG)	Environmental destination, Growth, and climate changes target headroom profile (EDGC)
S1	Vulnerable Surface water licences	×	×	×
S2	Vulnerable Groundwater licences	×	×	×
S3	Time Limited Licences	×	×	×
S4	Bulk Imports	×	×	×
S5	Gradual Pollution	×	×	×
S6	Accuracy of Supply-Side Data	✓	✓	✓
S7	(Not used)	N/A	N/A	N/A

Factor	Name	Full target Headroom profile (FTHR)	Environmental destination and Growth target headroom profile (EDG)	Environmental destination, Growth, and climate changes target headroom profile (EDGC)
S8	Impact of Climate Change on Deployable Output	✓	✓	×
S9	New Sources	✓	✓	✓
D1	Accuracy of Sub-component Demand Data	✓	✓	✓
D2 #	Demand Forecast Variation	✓	✓	✓
D3	Impact of Climate Change on Demand	✓	✓	×
D4	Demand Management Measures	✓	✓	✓

excluding population growth uncertainty

8 RESULTS

Table 7 and Table 8 provide a summary of each of the three customised target headroom profiles outlined in the previous section, along with the hybrid target headroom profile which is applicable to the core pathway (switching from FTHR to EDG in 2035, and from EDG to EDGC in 2040). These profiles are also shown in Figure 3 and Figure 4; note that due to the exclusion of the D2 population growth factor, in this assessment the FTHR and EDG profiles are effectively the same and therefore the lines are not both visible on the graphs. (Note that environmental destination uncertainty is also excluded from the headroom assessment in line with Environment Agency guidelines).

All these profiles correspond to the selected glidepath of risk/headroom probability shown in Figure 2. Graphs showing the combined probability distributions of each calculated profile are included in Appendix 2.

Table 7: Profiles of target headroom allowances (Ml/d) – dry year annual average scenario

Profile	2025/26	2030/31	2035/36	2040/41	2045/46	2050/51	2055/56	2060/61	2065/66	2070/71	2074/75
FTHR	4.98	4.65	3.74	3.23	2.55	1.96	2.05	2.18	2.13	2.18	2.08
EDG	4.98	4.65	3.74	3.23	2.55	1.96	2.05	2.18	2.13	2.18	2.08
EDGC	4.53	3.95	3.00	2.52	1.93	1.51	1.54	1.59	1.49	1.47	1.32
Hybrid profile for core pathway	4.98	4.65	3.74	2.52	1.93	1.51	1.54	1.59	1.49	1.47	1.32

Table 8: Profiles of target headroom allowances (Ml/d) – dry year critical period scenario

Profile	2025/26	2030/31	2035/36	2040/41	2045/46	2050/51	2055/56	2060/61	2065/66	2070/71	2074/75

FTHR	5.86	5.51	4.41	3.89	3.21	2.64	2.77	2.93	2.91	2.99	2.98
EDG	5.86	5.51	4.41	3.89	3.21	2.64	2.77	2.93	2.91	2.99	2.98
EDGC	5.23	4.67	3.57	3.05	2.44	1.92	1.97	2.01	1.89	1.87	1.72
Hybrid profile for core pathway	5.86	5.51	4.41	3.05	2.44	1.92	1.97	2.01	1.89	1.87	1.72

Figure 3: Profiles of target headroom allowances - dry year annual average scenario

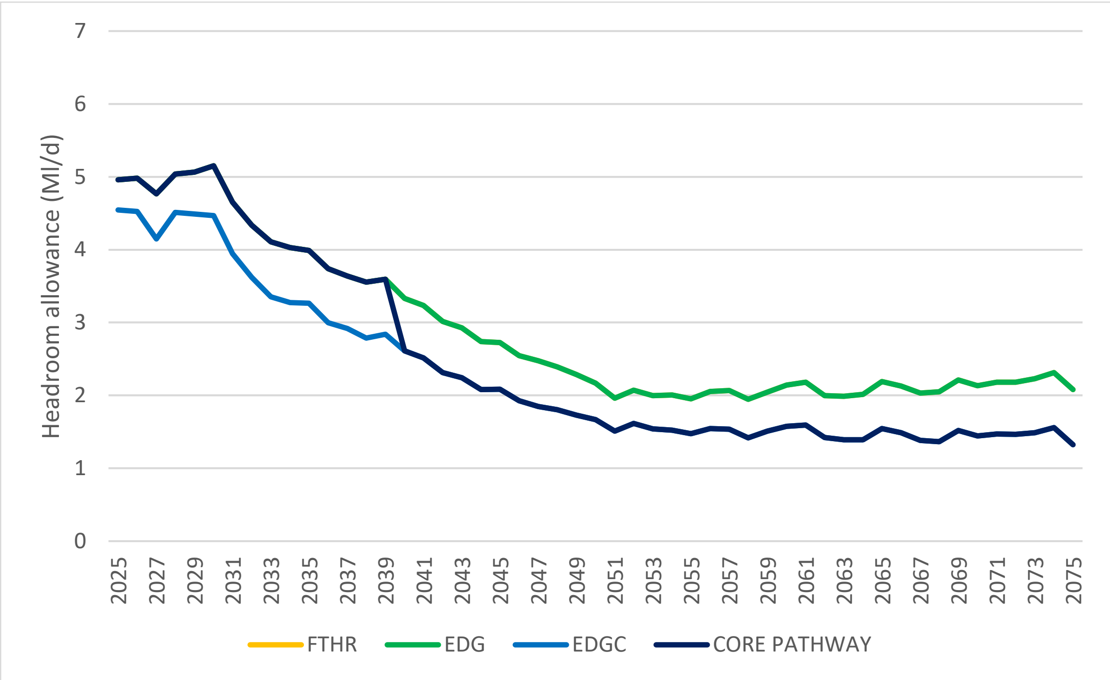
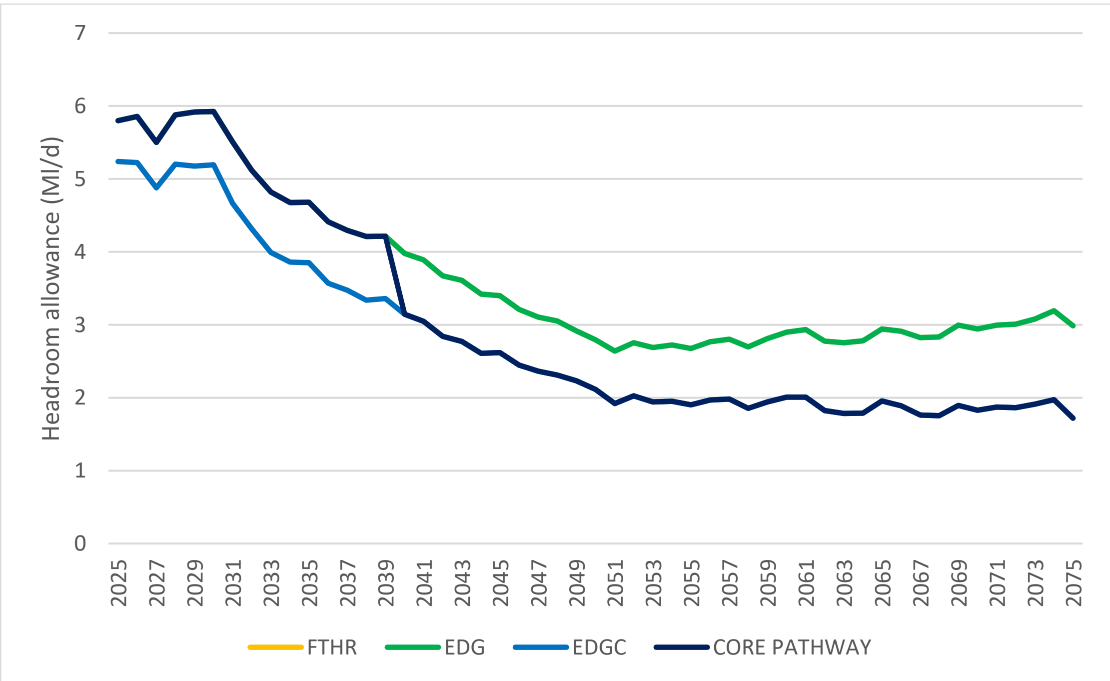


Figure 4: Profiles of target headroom allowances - dry year critical period scenario



8.1 Relative contribution of climate change components

Due to the way in which individual components have been summed, by combining probability distributions using Monte Carlo simulation as described in Section 3, it is not possible to determine the magnitude of uncertainty in Ml/d for each factor which contributes to the overall target headroom allowance. However, by comparing the profiles for the EDG and EDGC scenarios, for which the only difference is the removal of the climate change uncertainty components (S8 and D3), it is possible to estimate the modelled proportion of the EDG target headroom allowances due to the climate change factors. The breakdown of the EDG profile of target headroom allowances by climate change components and all other (non-climate change related) components is shown in Figure 5 and

Figure 6, for the dry year annual average and dry year critical period scenarios respectively.

From 2040 onwards, the hybrid or core pathway target headroom profile is based on the EDGC profile, which excludes the climate change uncertainty components. The contribution of climate change uncertainty to the overall target headroom profile is therefore zero from 2040 onwards. The breakdown of the core pathway target headroom allowances by climate change components and all other (non-climate change related) components is shown in Figure 7 and

Figure 8, for the dry year annual average and dry year critical period scenarios respectively.

Figure 5: Relative contribution of climate change - Dry year annual average scenario (EDG)

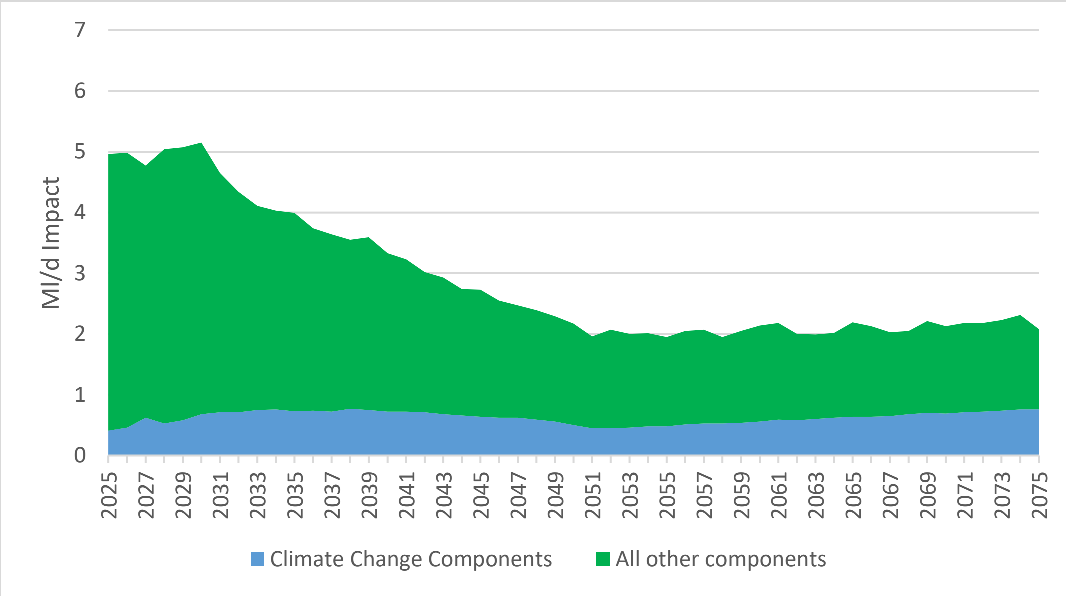
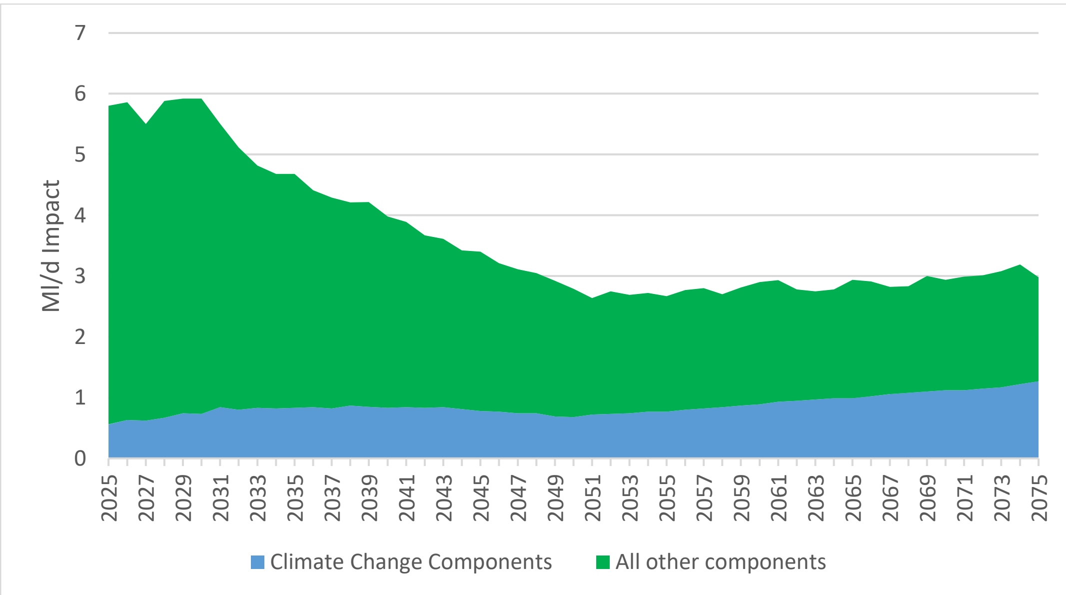


Figure 6: Relative contribution of climate change - Dry year critical period scenario (EDG)



As illustrated by these graphs, the proportion of the DYAA headroom allowance due to climate change impacts on both supply and demand ranges from about 9% in 2025 to about 38% in 2075 (the latter for EDGC profile only). For the DYCP scenario, this proportion ranges from about 11% in 2025 to about 46% in 2075. This reflects the growing influence of climate change effects on the supply-demand balance over time.

Figure 7: Relative contribution of climate change - Dry year annual average scenario (Core pathway headroom)

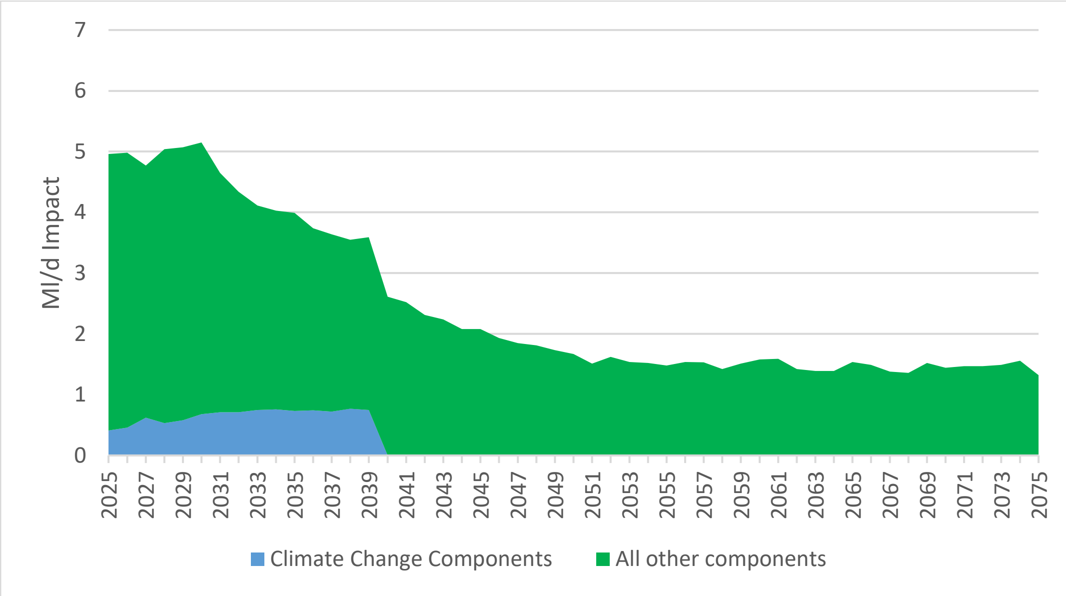
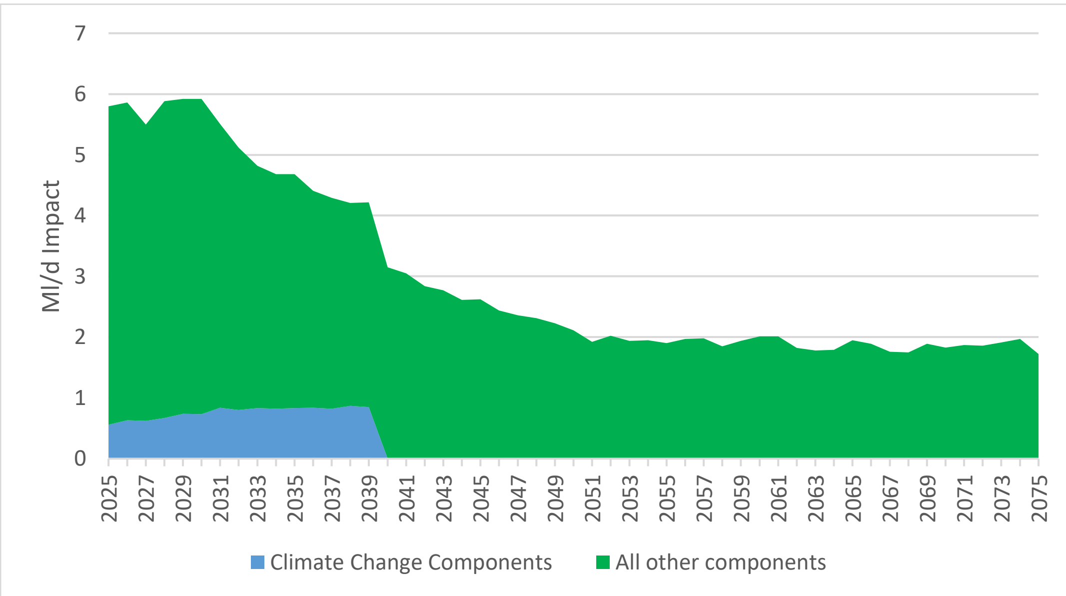


Figure 8: Relative contribution of climate change - Dry year critical period scenario (Core pathway headroom)



8.2 Comparison with previous assessment

Table 9 presents a summary comparison of company headroom allowances calculated for the previous (WRMP19) assessment, and this assessment (WRMP24), for each of the two planning scenarios.

The magnitude of the headroom allowance profile in Ml/d has reduced in comparison to the previous assessment, particularly in the later years of the planning period. This partly reflects the adoption of the EDGC headroom profile from 2040 onwards, which excludes climate change uncertainty to align with the core pathway which follows the 'high climate change' branch from the 2040 decision point.

Another key change is reduced demand forecast variation, due to the adoption of the local authority plan-based forecast in line with the guidelines, which is close to the maximum range of forecasts. The population growth element of demand forecast uncertainty has therefore been excluded as it would result in negative impact on the headroom uncertainty (see Section 5.2.1). This leads to a significant reduction compared to the previous assessment, which is not outweighed by the inclusion of new subcomponents such as demand uplift uncertainty, covid impact uncertainty and non-household forecast variation.

Table 9: Comparison of target headroom allowances with previous assessment

Target Headroom Allowance (Ml/d) for year:							
Scenario	**Plan**	**2025/26**	**2030/31**	**2035/36**	**2040/41**	**2044/45**	**2049/50**
Dry Year Annual Average	WRMP19	4.99	5.14	6.02	6.82	7.58	N/A
	WRMP24	4.98	4.65	3.74	2.52	1.93	1.51
Dry Year Critical Period	WRMP19	6.93	7.75	8.72	9.73	10.66	N/A
	WRMP24	5.86	5.51	4.41	3.05	2.44	1.92

9 CONCLUSIONS

All uncertainty components in the UKWIR methodology have been reviewed for the WRMP24 target headroom assessment. Some components have been excluded from the assessment, whilst some of the factors included have been split into subcomponents. All component and subcomponent probability distributions have been updated as appropriate, using WRMP24 supply and demand forecasts and other relevant data to determine suitable parameters for each distribution.

Using the Monte Carlo simulation approach as set out in the UKWIR methodology, customised headroom profiles have been determined for each of three different adaptive planning scenarios (based on the selected risk glidepath of 90% to 70% percentile probability). This aligns with the approach to target headroom assessments for adaptive planning set out by WRSE. The overall company target headroom allowance is based on a hybrid of these profiles, switching between them at the appropriate branch points in the adaptive plan, to avoid double-counting of key uncertainty factors in the core pathway through the adaptive plan branches.

From this assessment we have produced core pathway profiles of target headroom for both the dry year annual average and the dry year critical period scenarios, and these are incorporated into the supply-demand balance analysis for each scenario within our WRMP24.

10 REFERENCES

Meeting our future water needs: a national framework for water resources (Environment Agency, March 2020).

Target headroom approach for an adaptive plan (Water Resources South East, February 2022).

Water Resources Planning Guideline Version 10 (Environment Agency, Ofwat and Natural Resources Wales, December 2021).

An Improved Methodology for Assessing Headroom (UKWIR, 2002).

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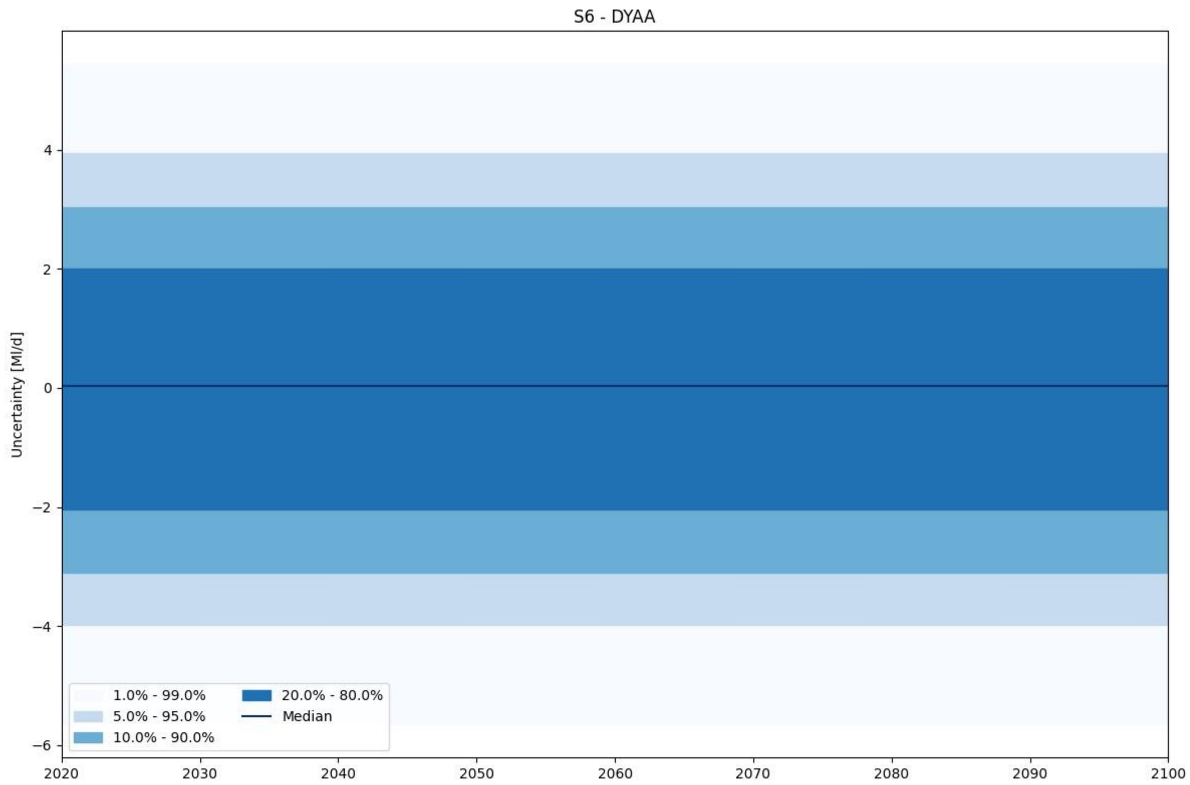
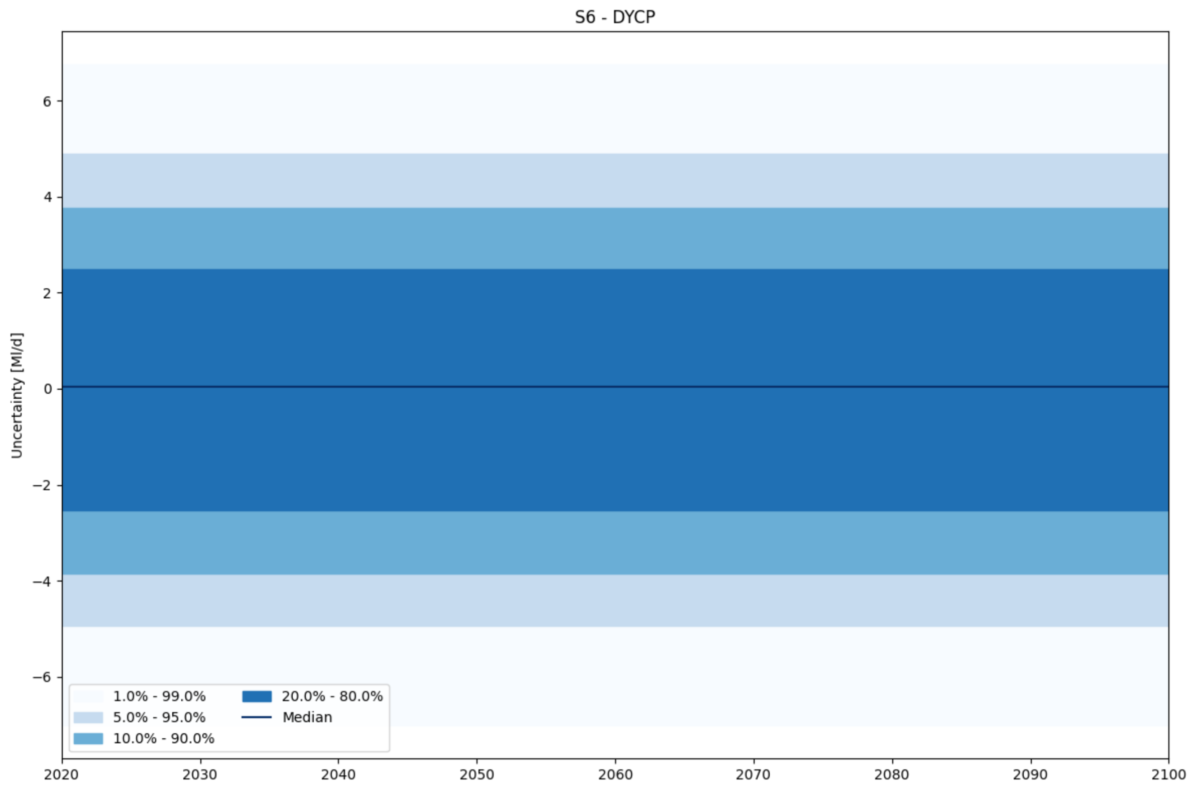
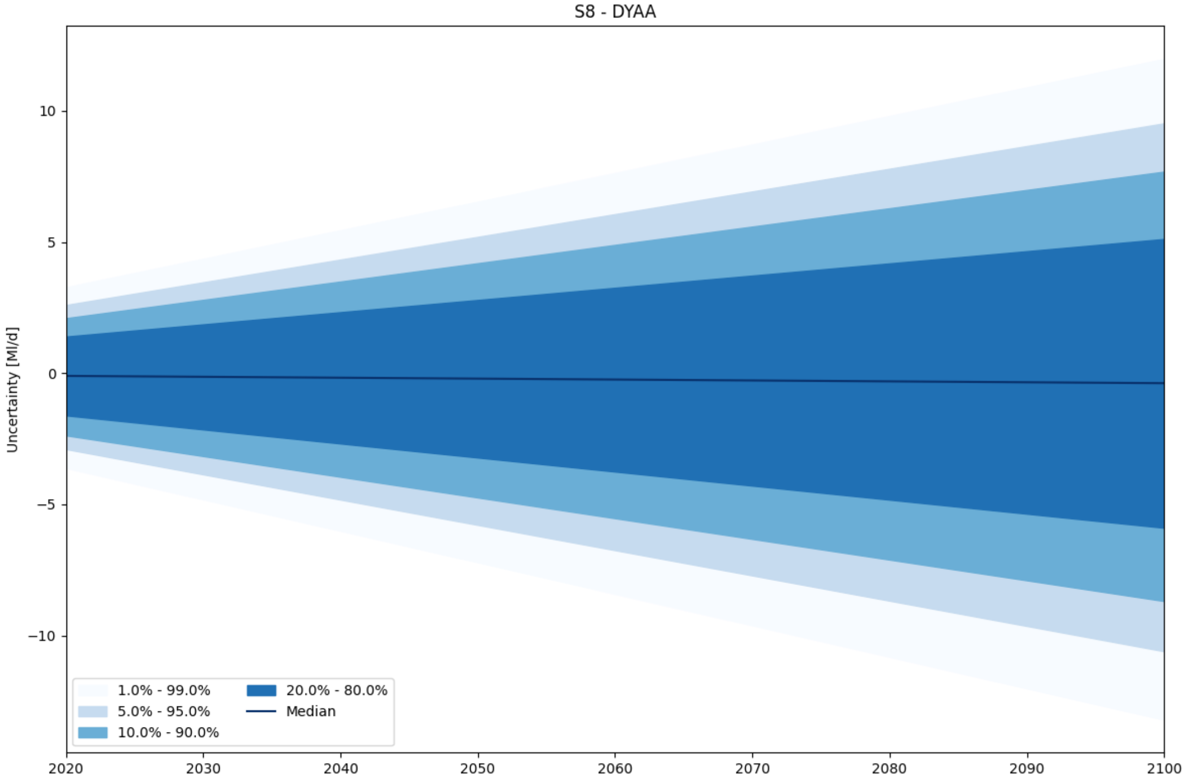
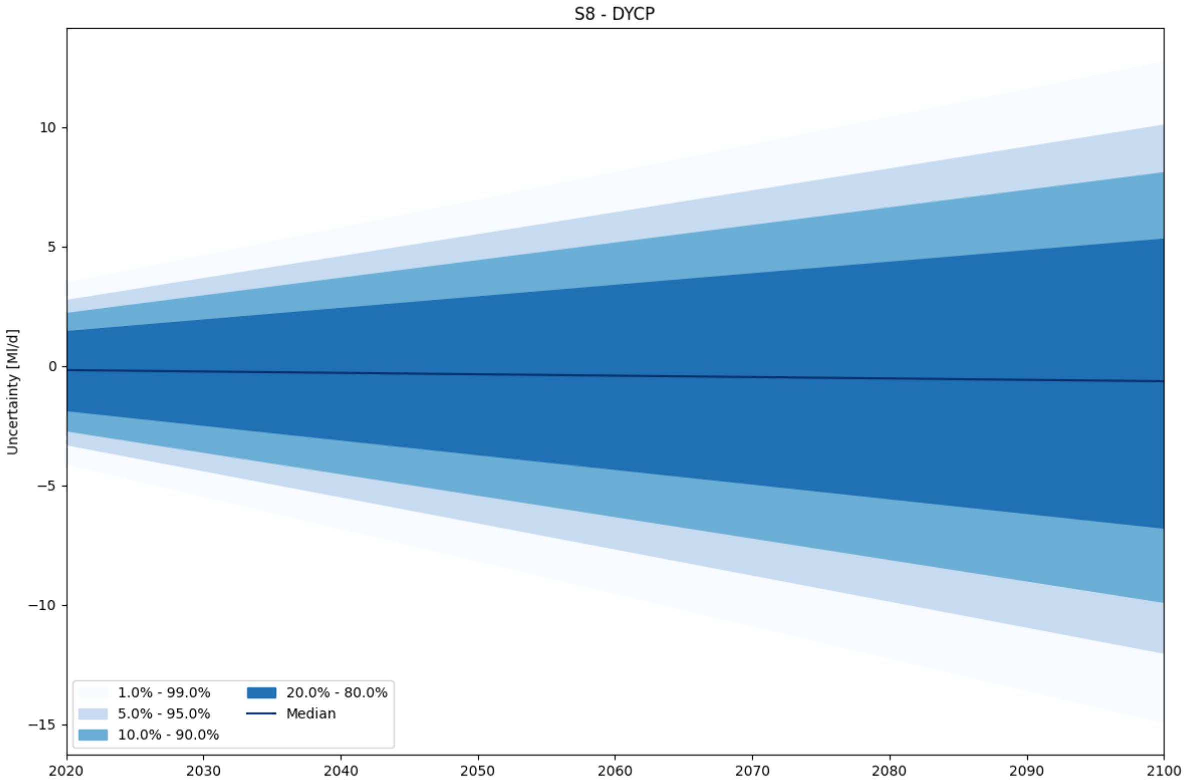
Water Resources Management Plan Annual Review 2022 (Portsmouth Water, December 2022)

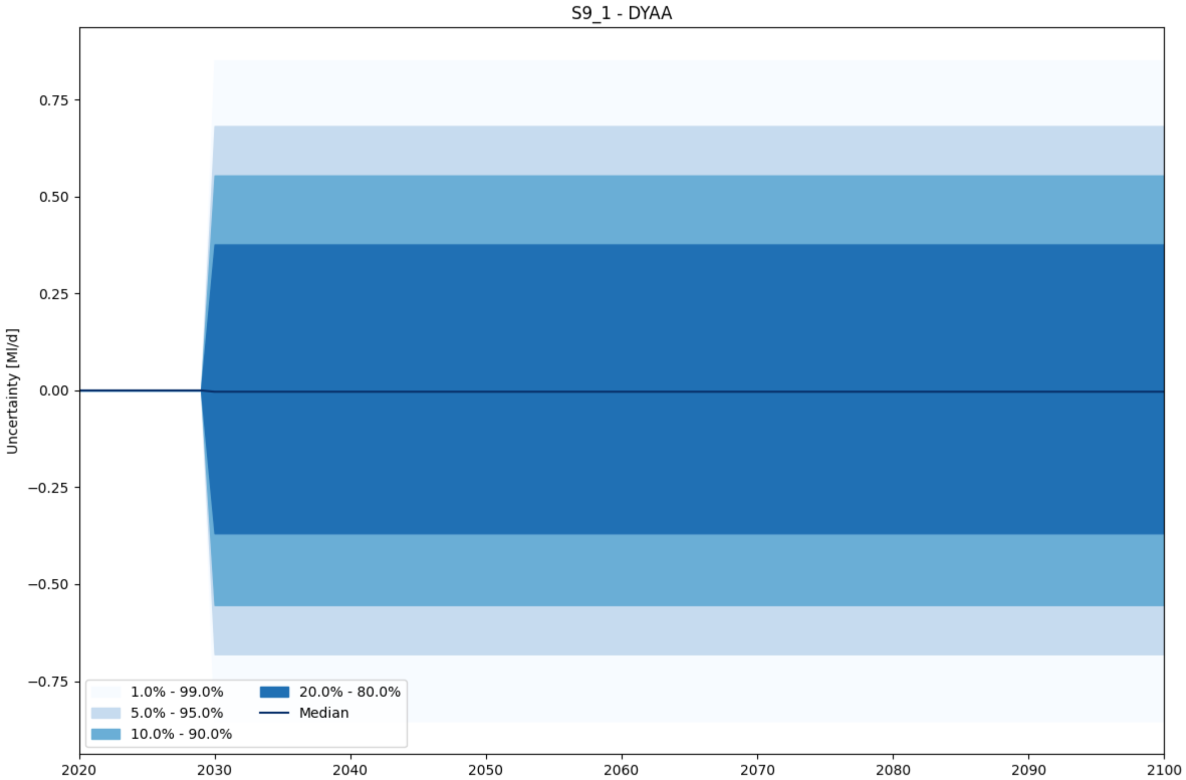
APPENDIX 1 – COMPONENT DISTRIBUTIONS

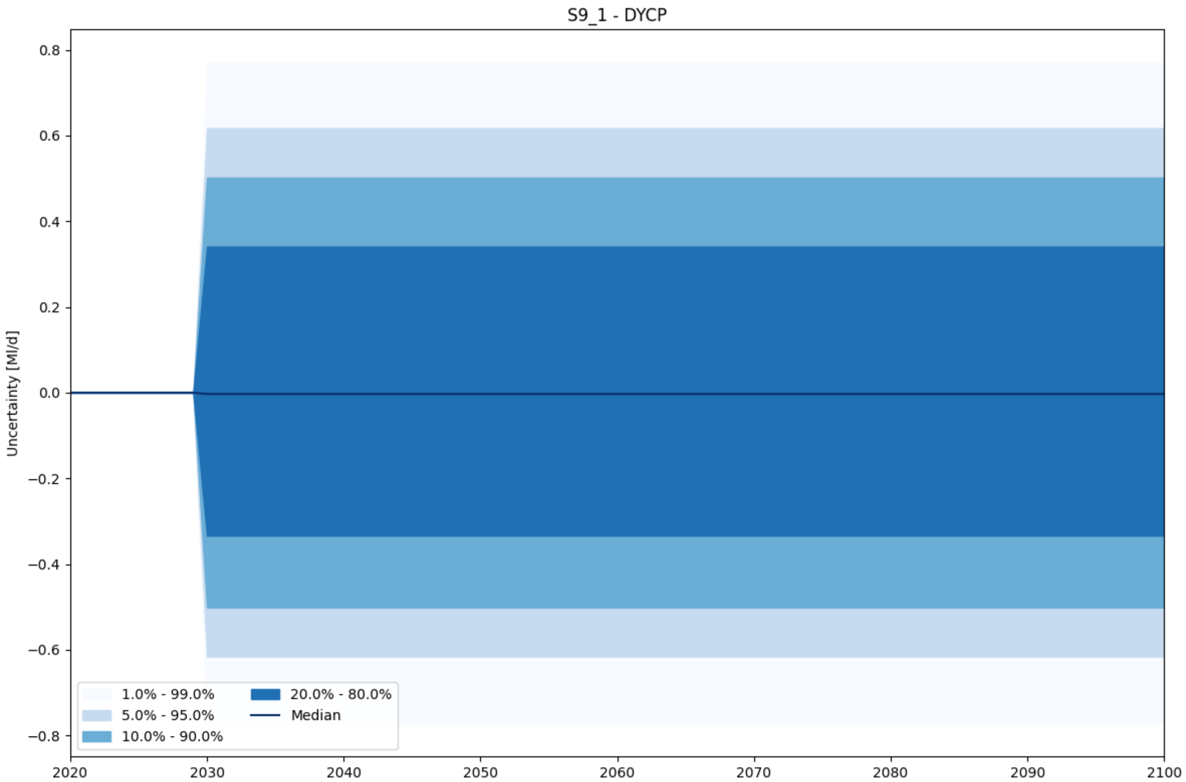


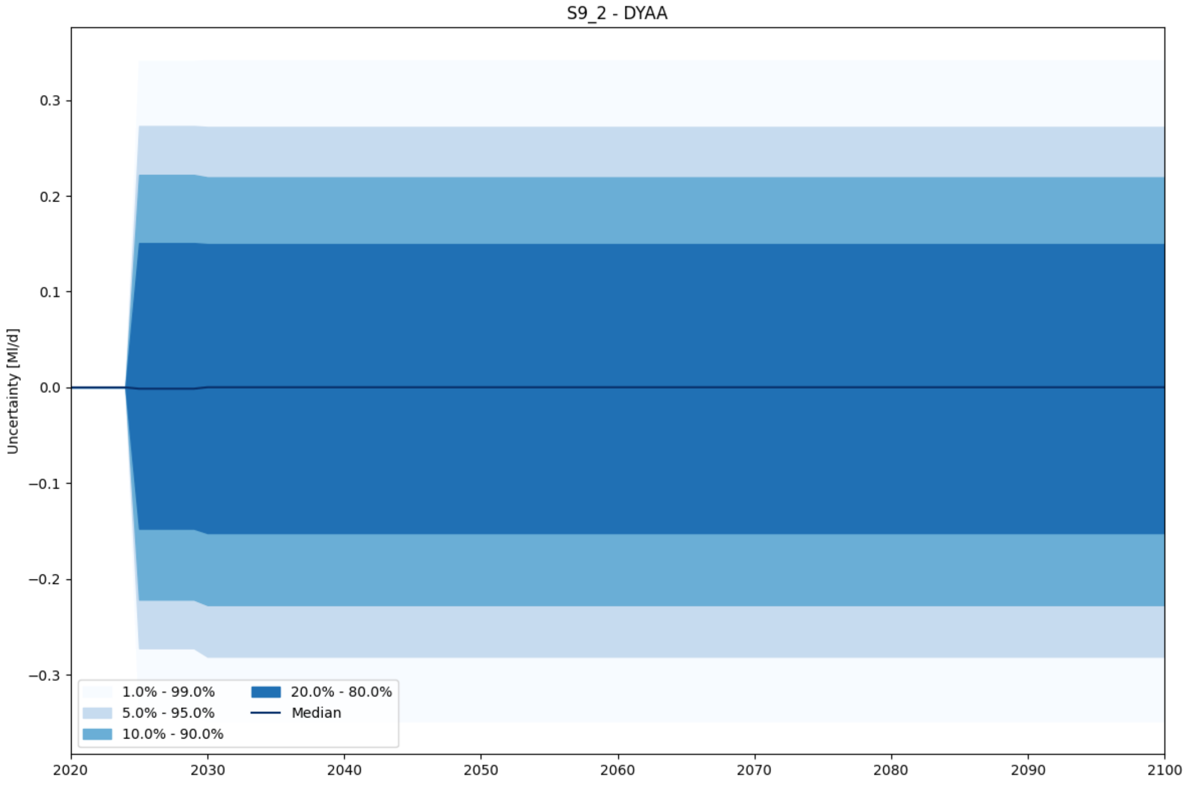


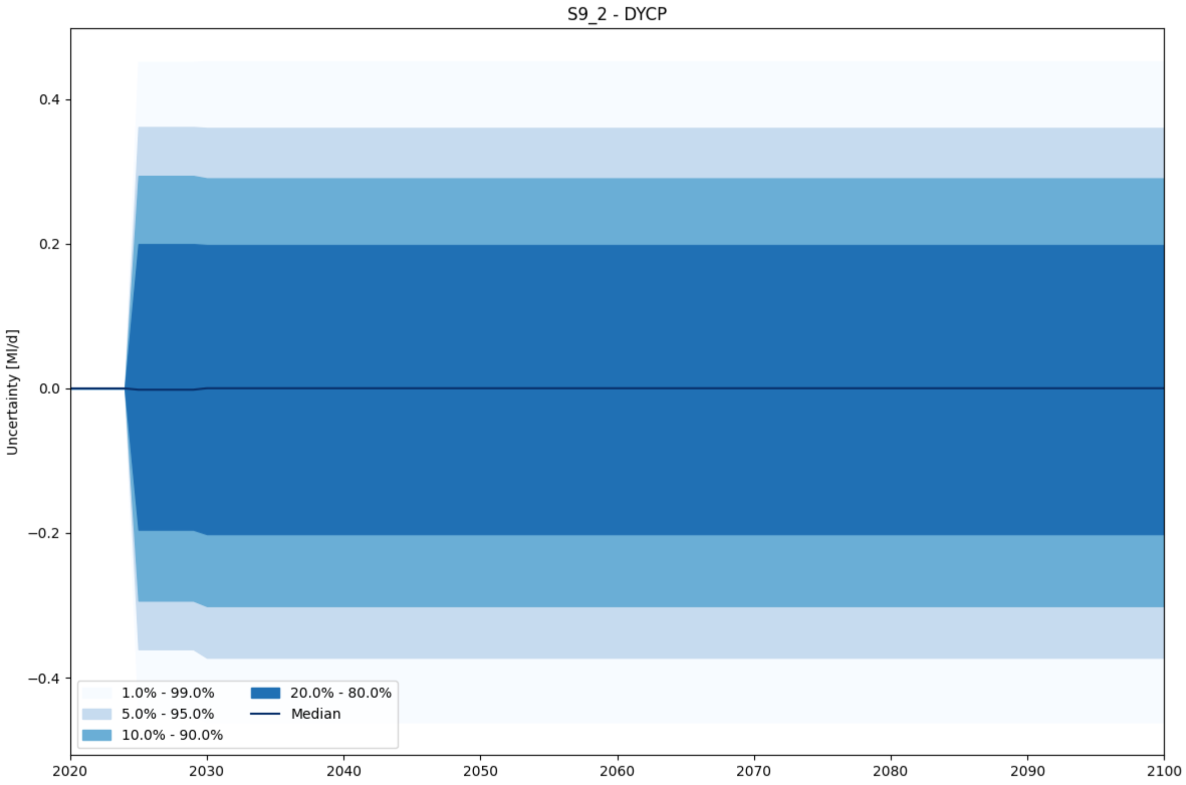

S8 - DYAA
Uncertainty [Ml/d]
10
5
0
−5
−10
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median
2020
2030
2040
2050
2060
2070
2080
2090
2100

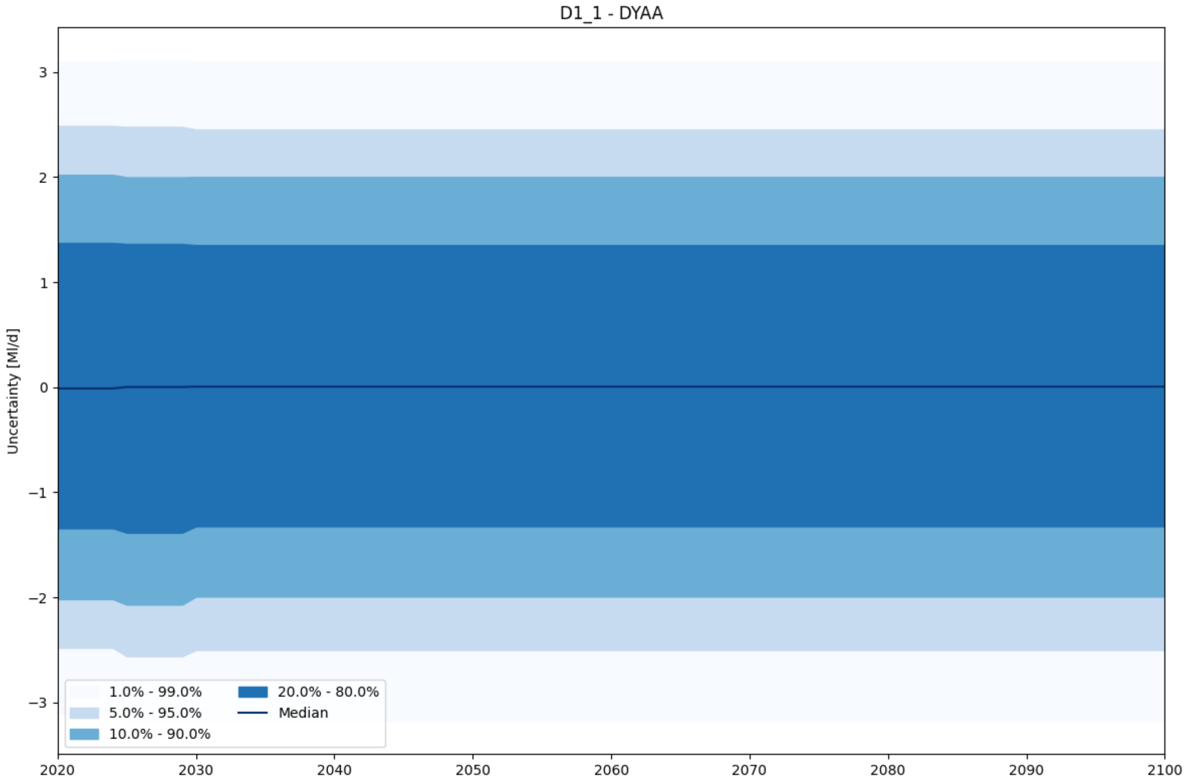

S8 - DYCP
Uncertainty [Ml/d]
10
5
0
−5
−10
−15
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median
2020
2030
2040
2050
2060
2070
2080
2090
2100

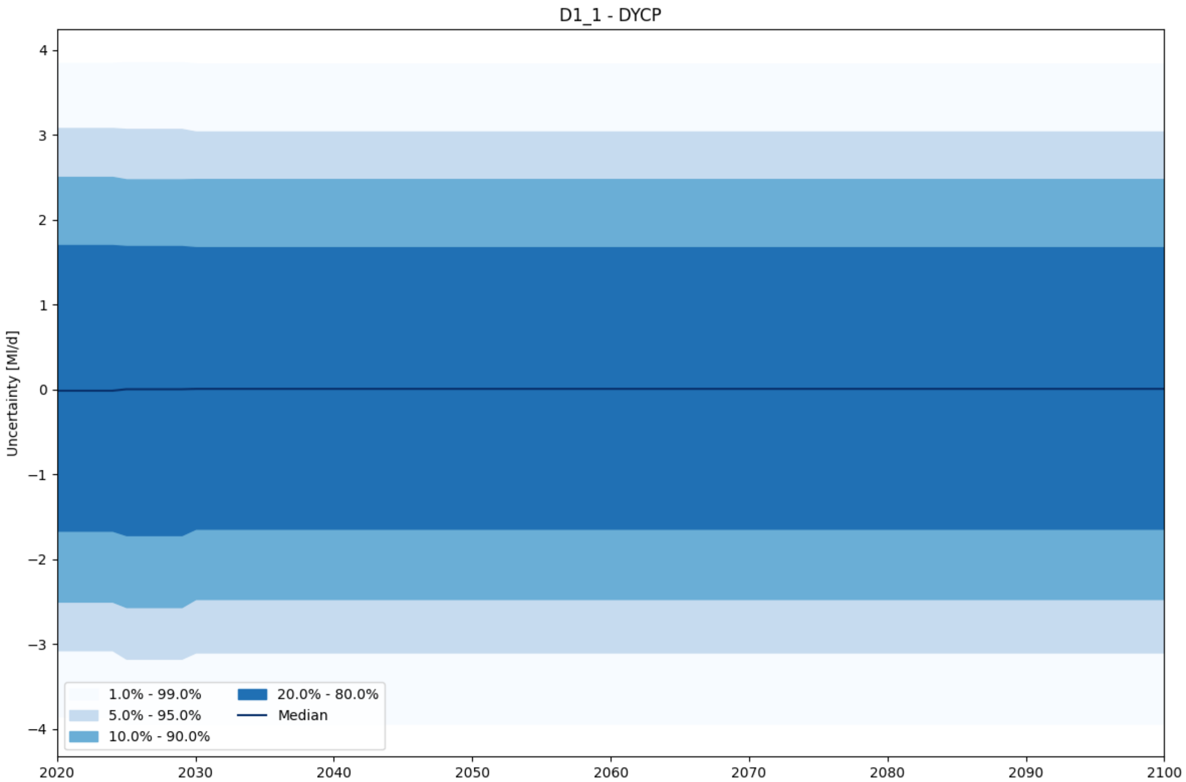

S9_1 - DYAA
Uncertainty [Ml/d]
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

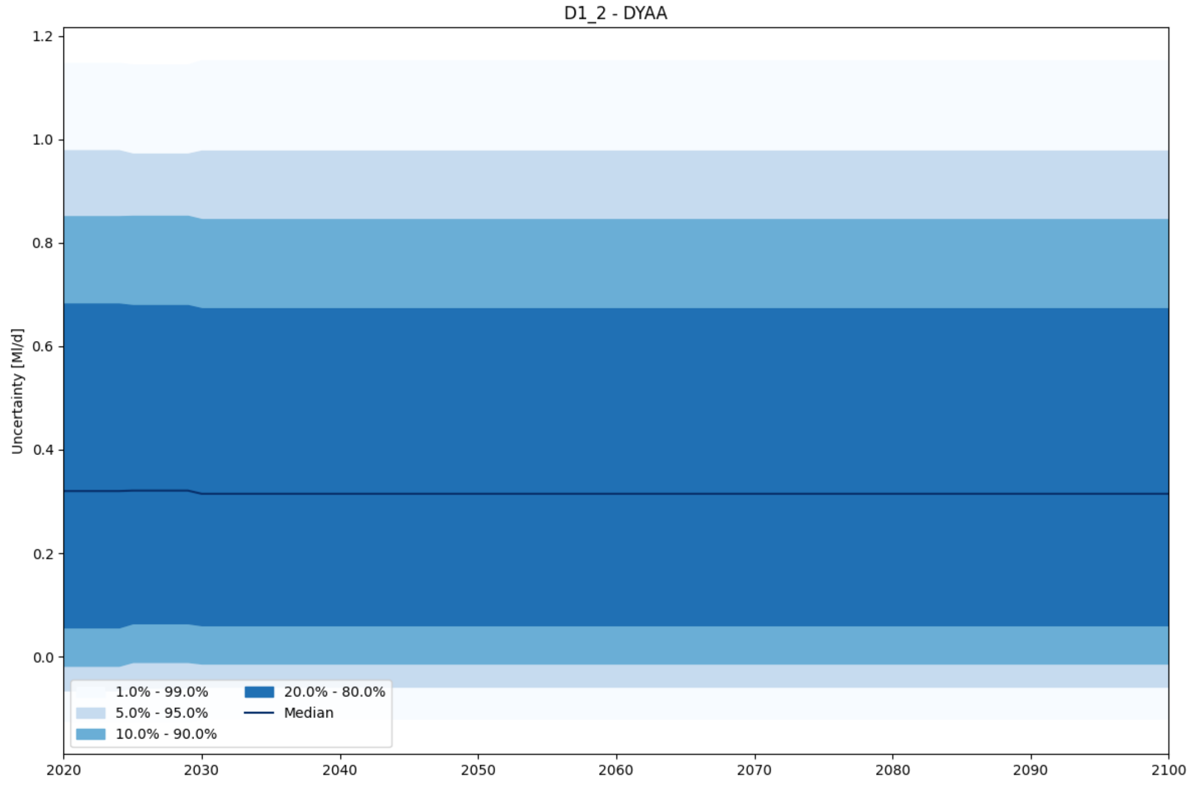

S9_1 - DYCP
Uncertainty [Ml/d]
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

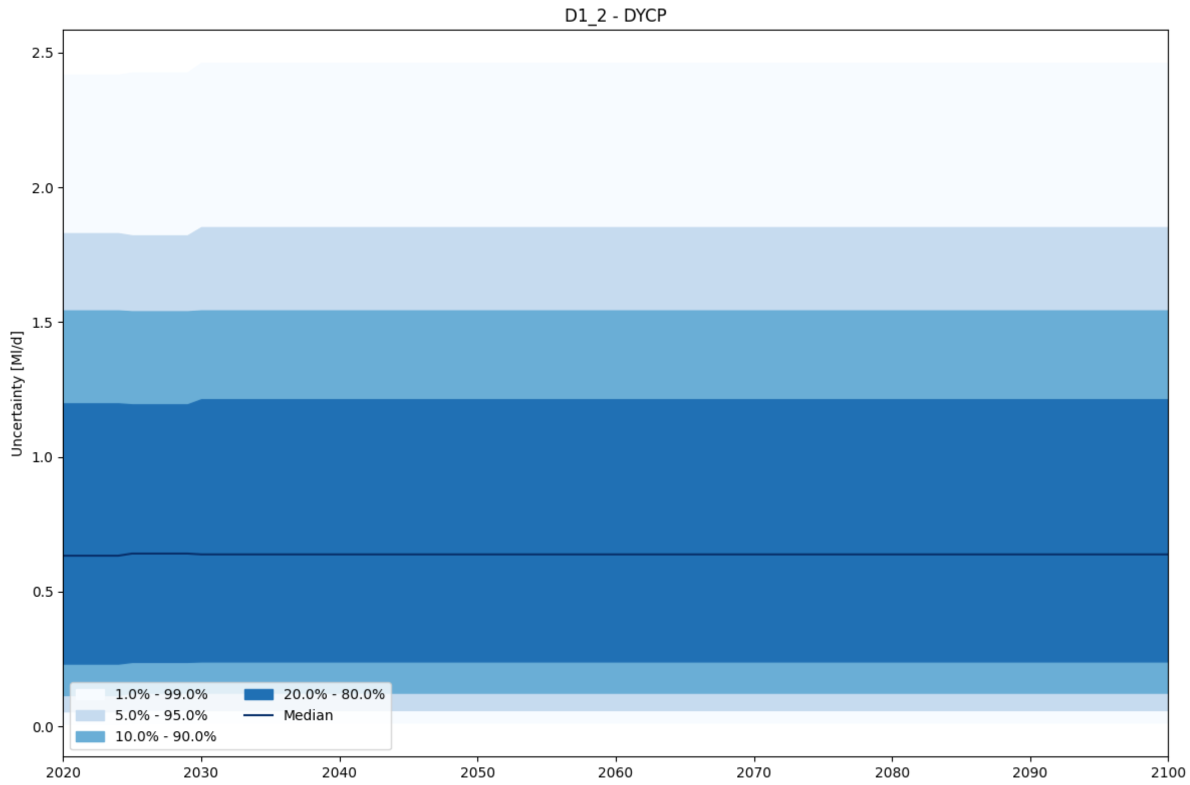

S9_2 - DYAA
Uncertainty [Ml/d]
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median
2020
2030
2040
2050
2060
2070
2080
2090
2100

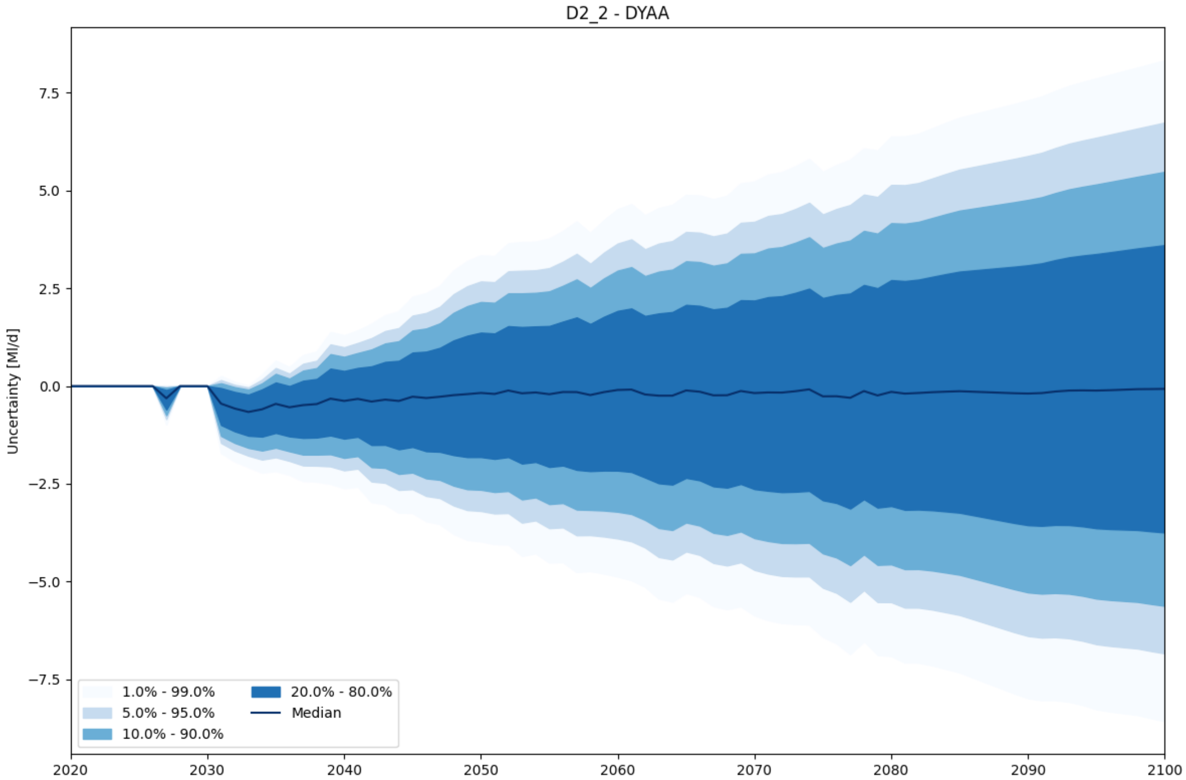

S9_2 - DYCP
Uncertainty [Ml/d]
0.4
0.2
0.0
−0.2
−0.4
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median
2020
2030
2040
2050
2060
2070
2080
2090
2100

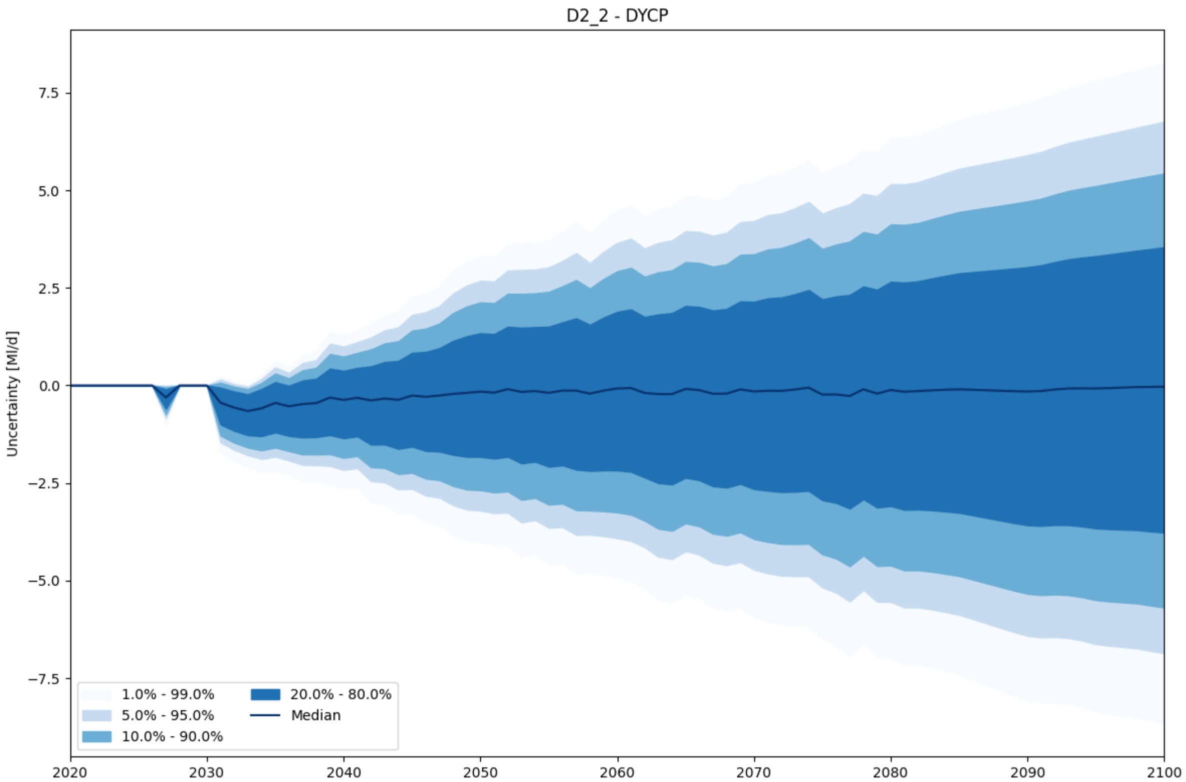

D1_1 - DYAA
Uncertainty [Ml/d]
3
2
1
0
−1
−2
−3
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

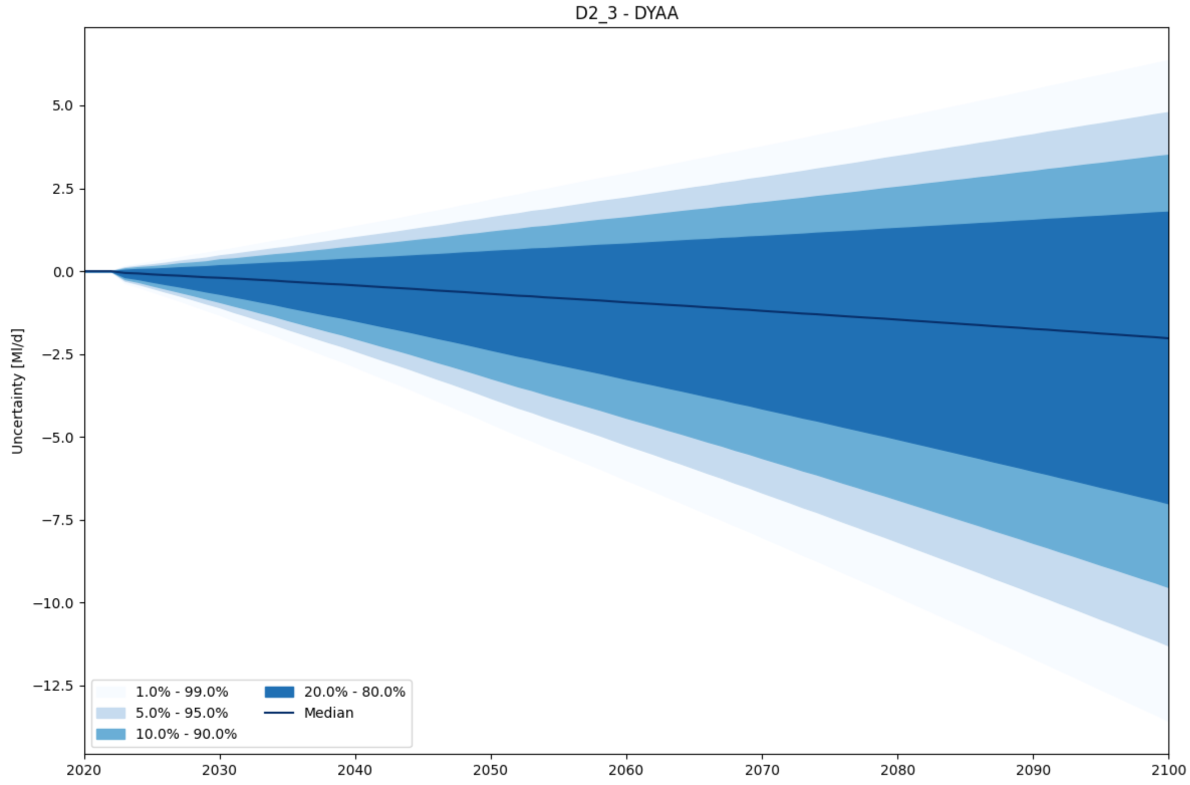

D1_1 - DYCP
Uncertainty [Ml/d]
4
3
2
1
0
−1
−2
−3
−4
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

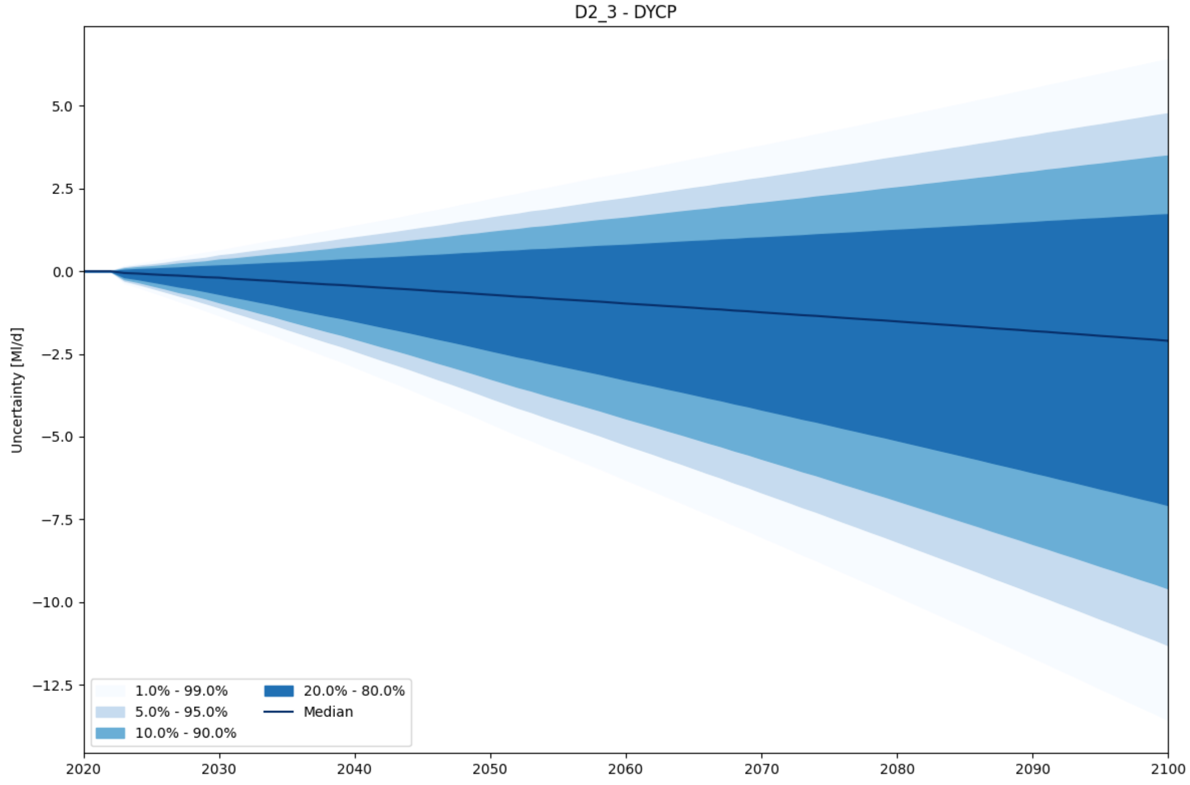

D1_2 - DYAA
Uncertainty [Ml/d]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

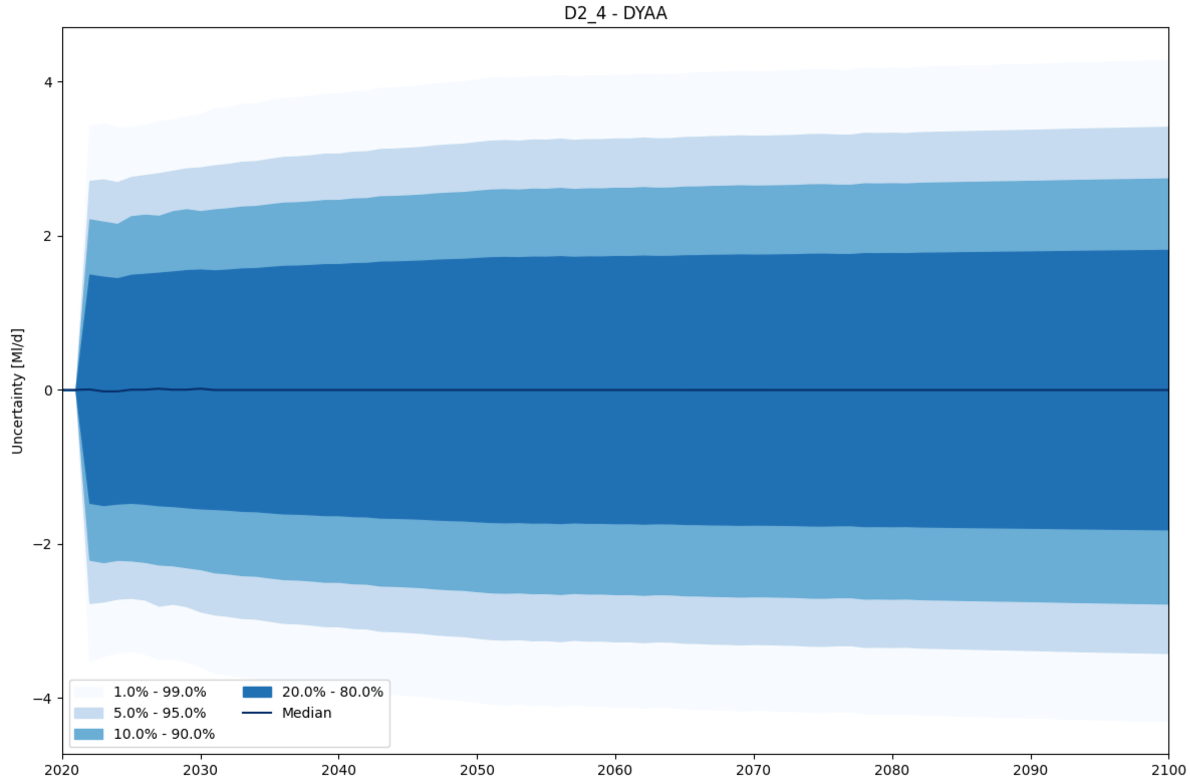

D1_2 - DYCP
Uncertainty [Ml/d]
2.5
2.0
1.5
1.0
0.5
0.0
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

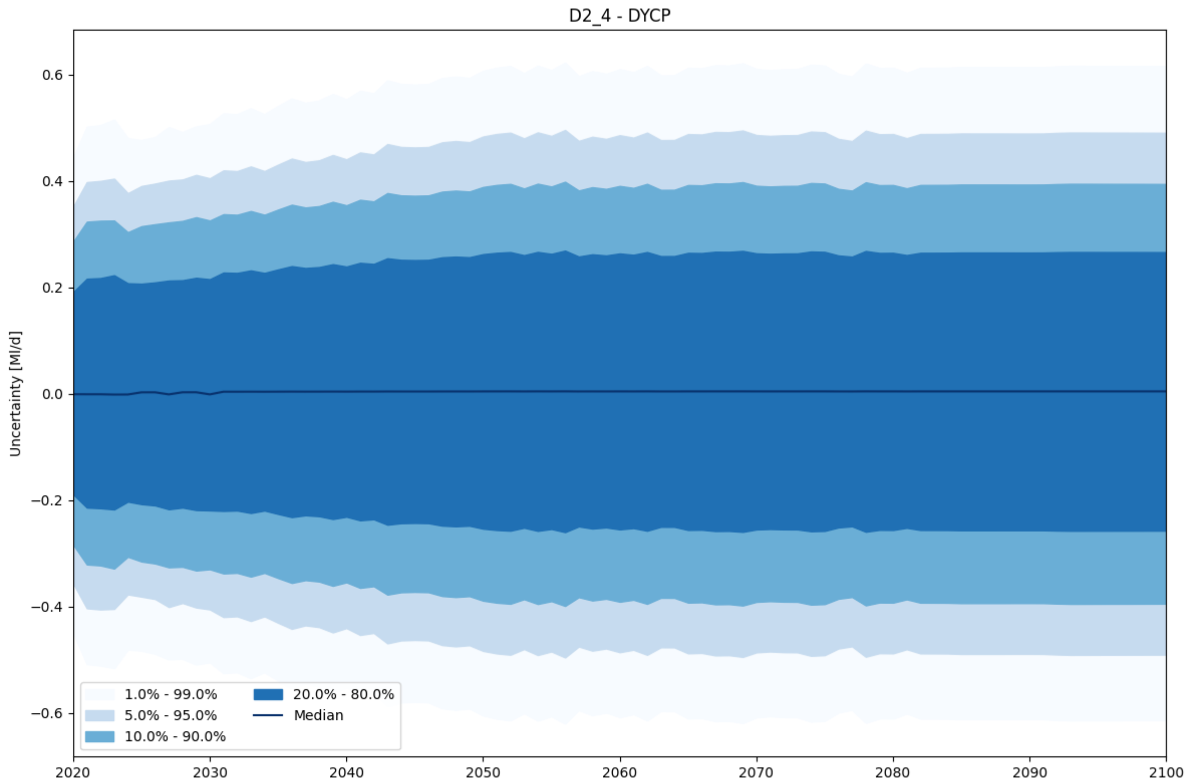

D2_2 - DYAA
Uncertainty [Ml/d]
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

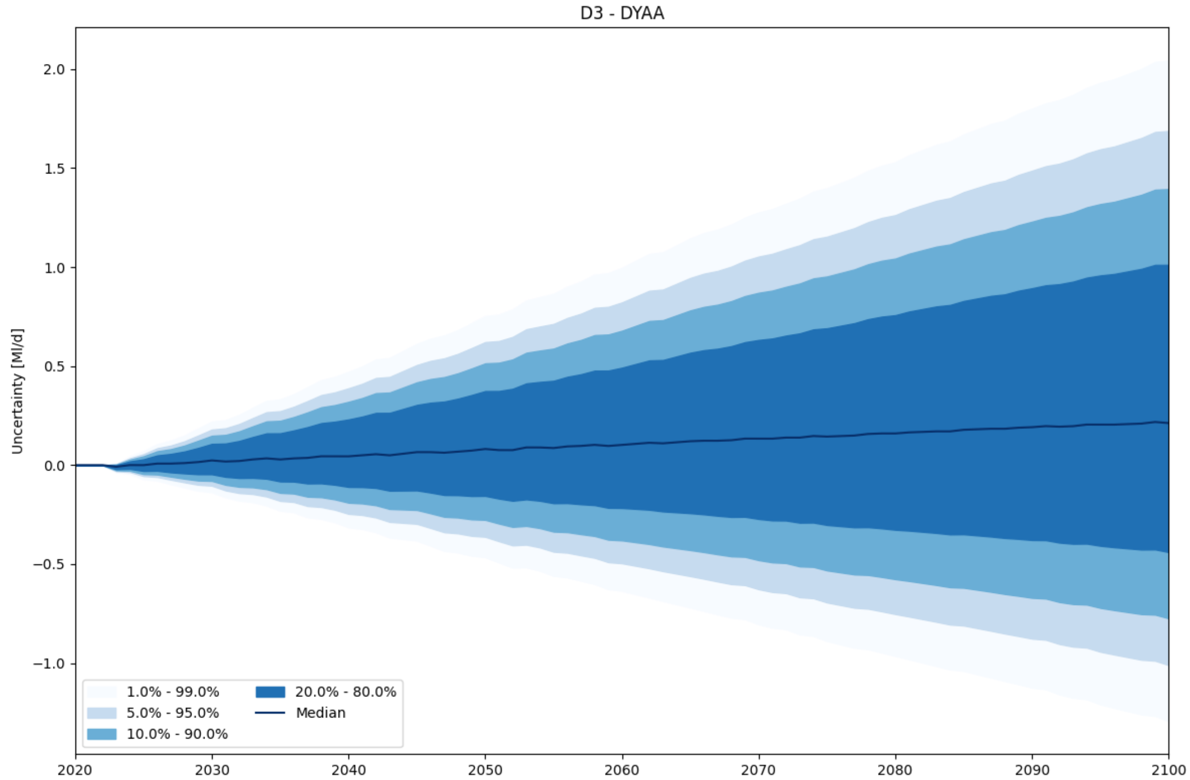

D2_2 - DYCP
Uncertainty [Ml/d]
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

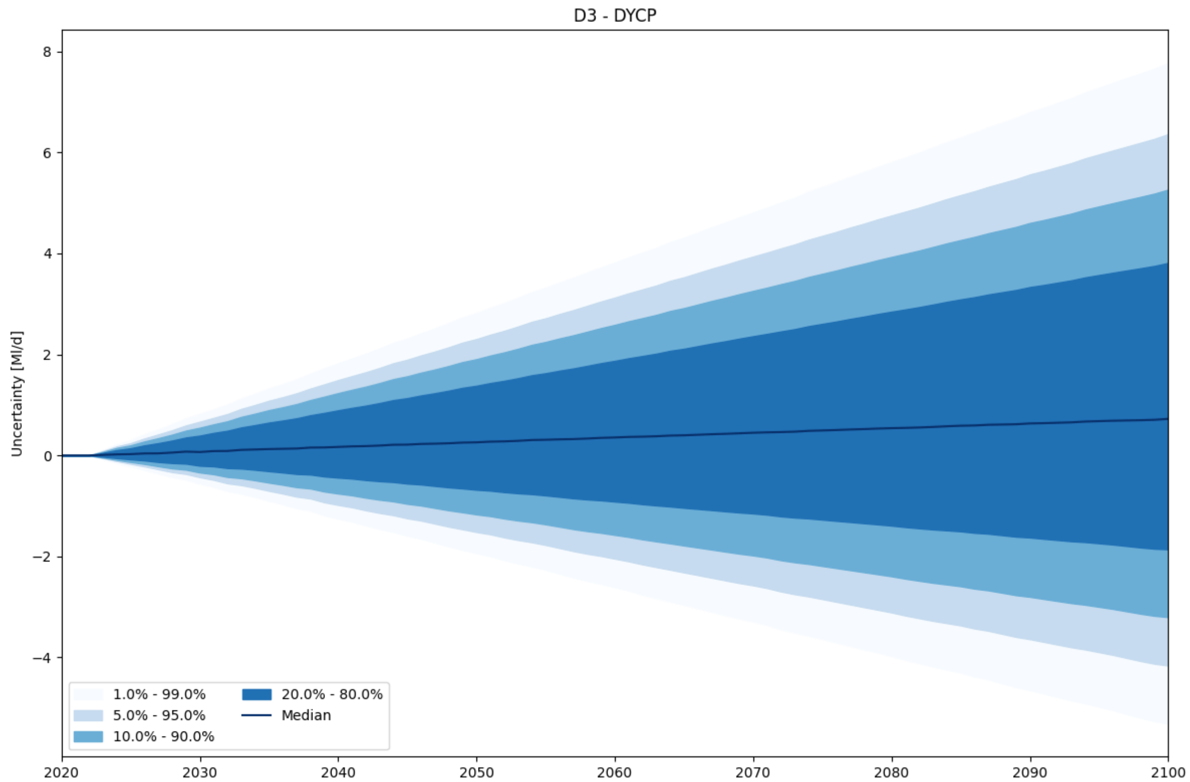

D2_3 - DYAA
Uncertainty [Ml/d]
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
−12.5
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

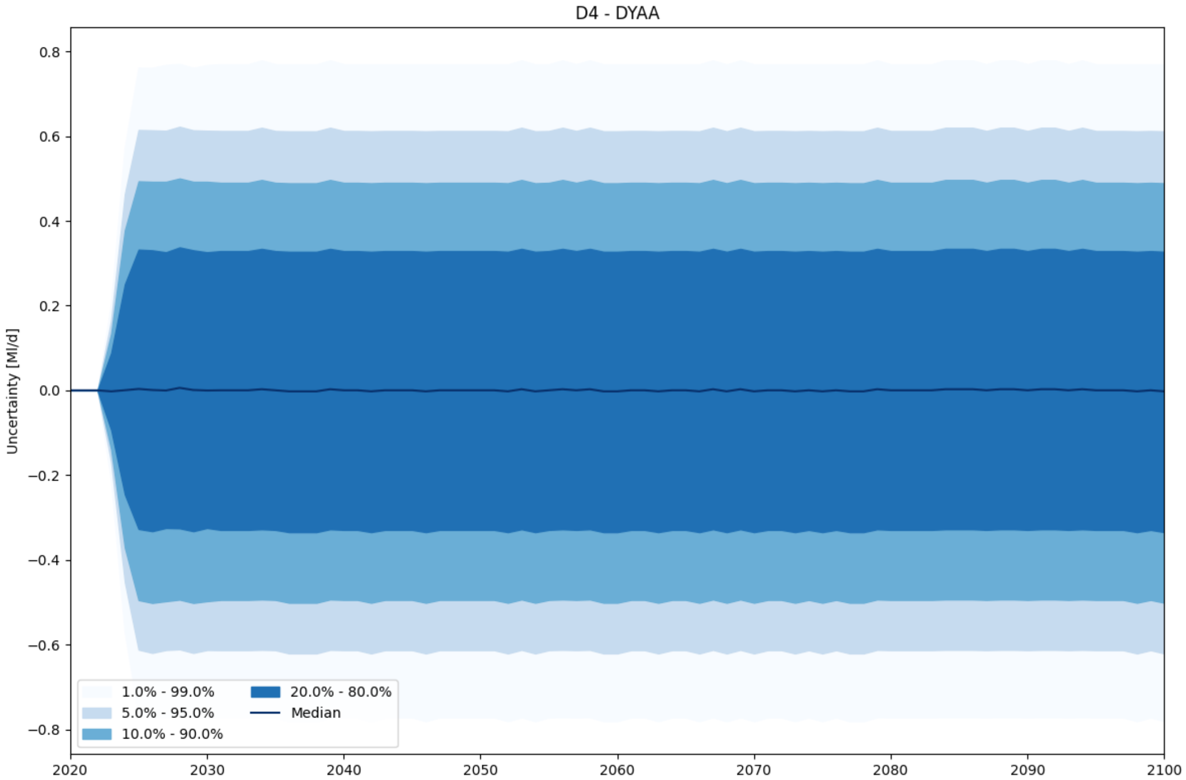

D2_3 - DYCP
Uncertainty [Ml/d]
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
−12.5
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

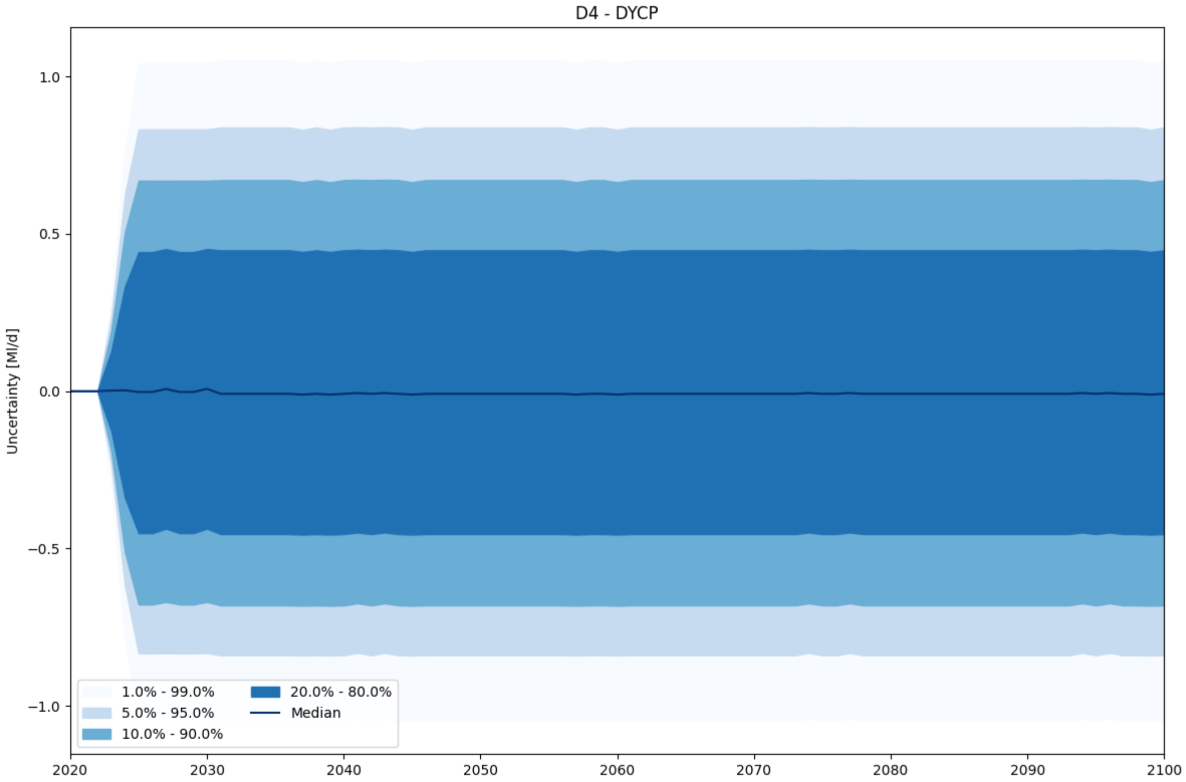

D2_4 - DYAA
Uncertainty [Ml/d]
4
2
0
−2
−4
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median


D2_4 - DYCP
Uncertainty [Ml/d]
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median


D3 - DYAA
Uncertainty [Ml/d]
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median
2020
2030
2040
2050
2060
2070
2080
2090
2100

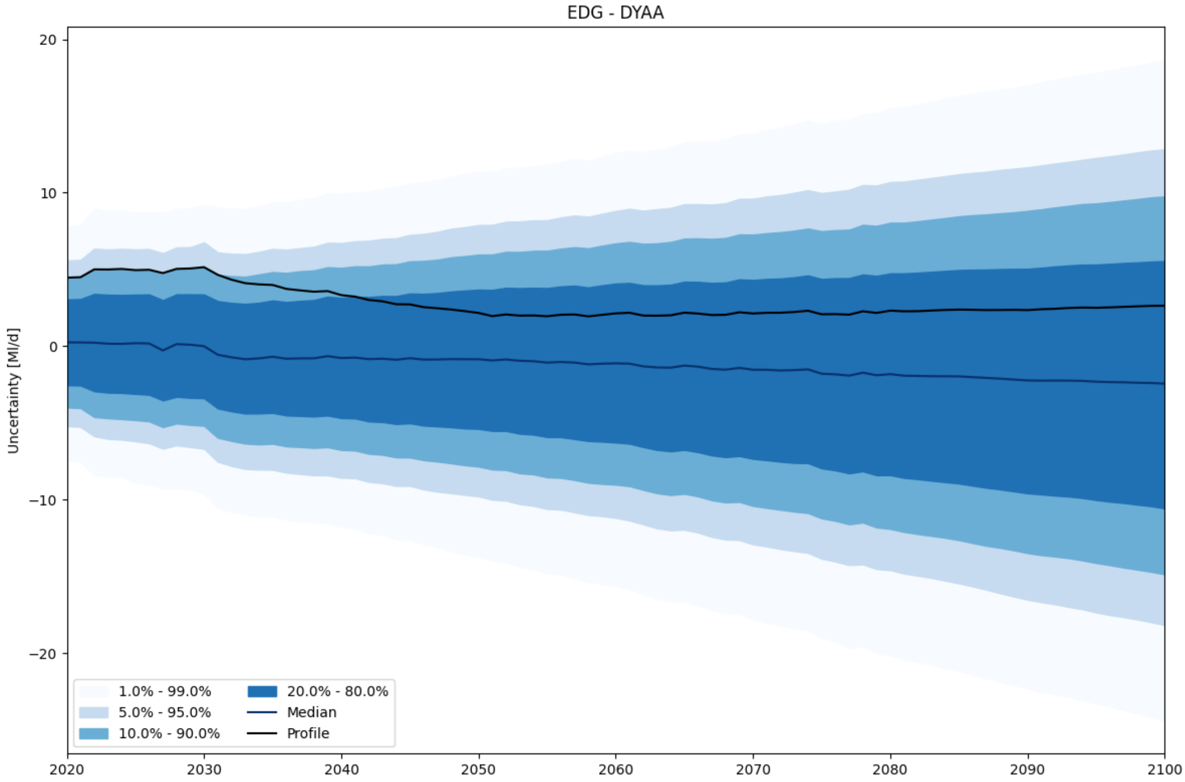

D3 - DYCP
Uncertainty [Ml/d]
8
6
4
2
0
−2
−4
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median
2020
2030
2040
2050
2060
2070
2080
2090
2100

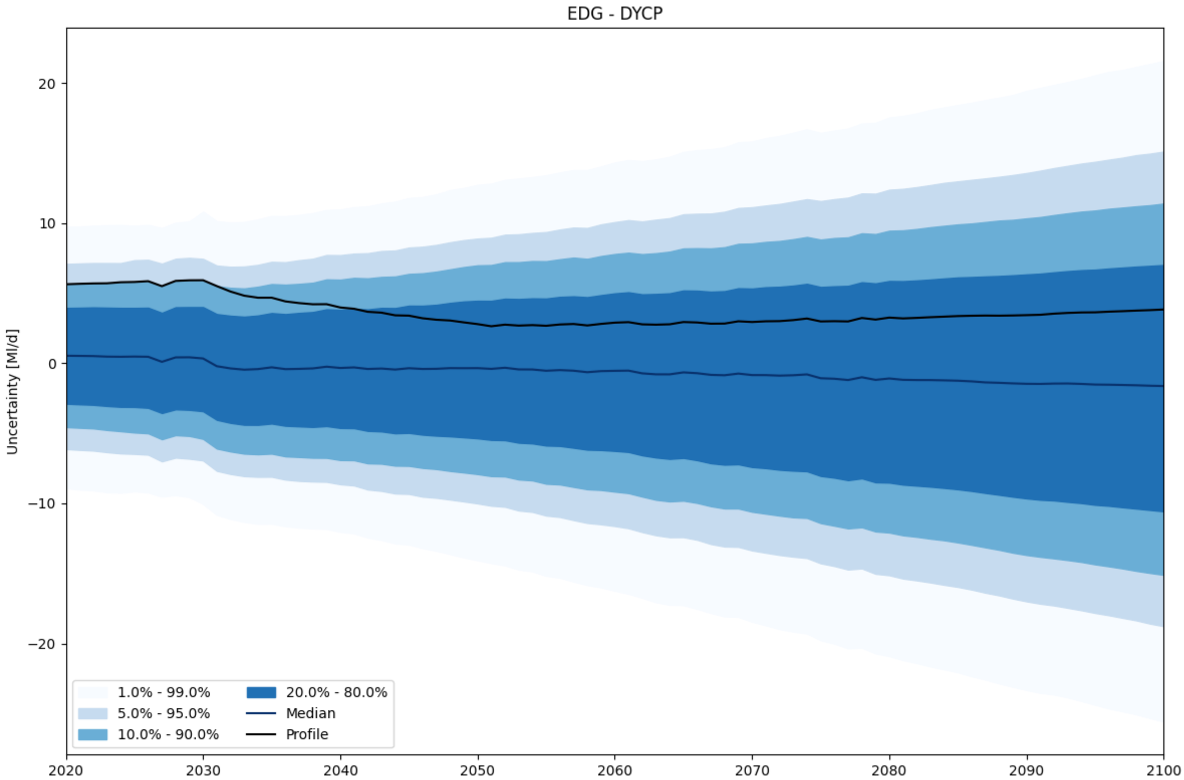

D4 - DYAA
Uncertainty [Ml/d]
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

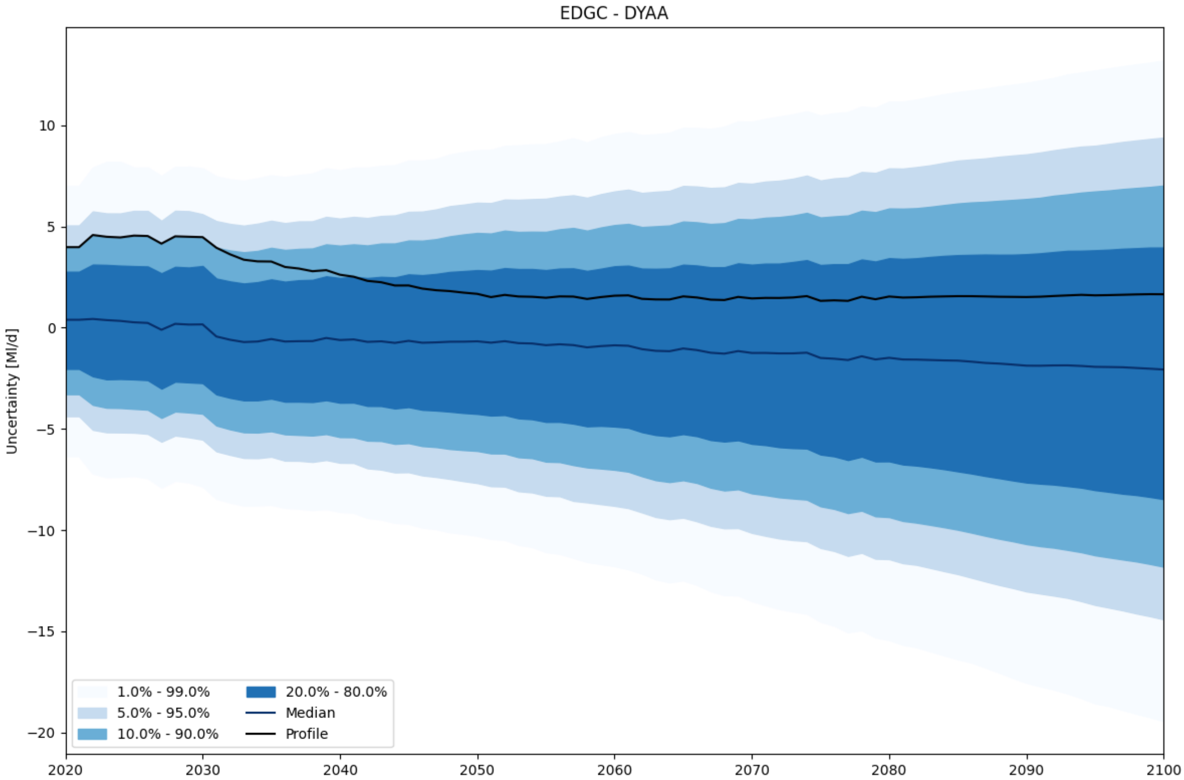

D4 - DYCP
Uncertainty [Ml/d]
1.0
0.5
0.0
−0.5
−1.0
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median

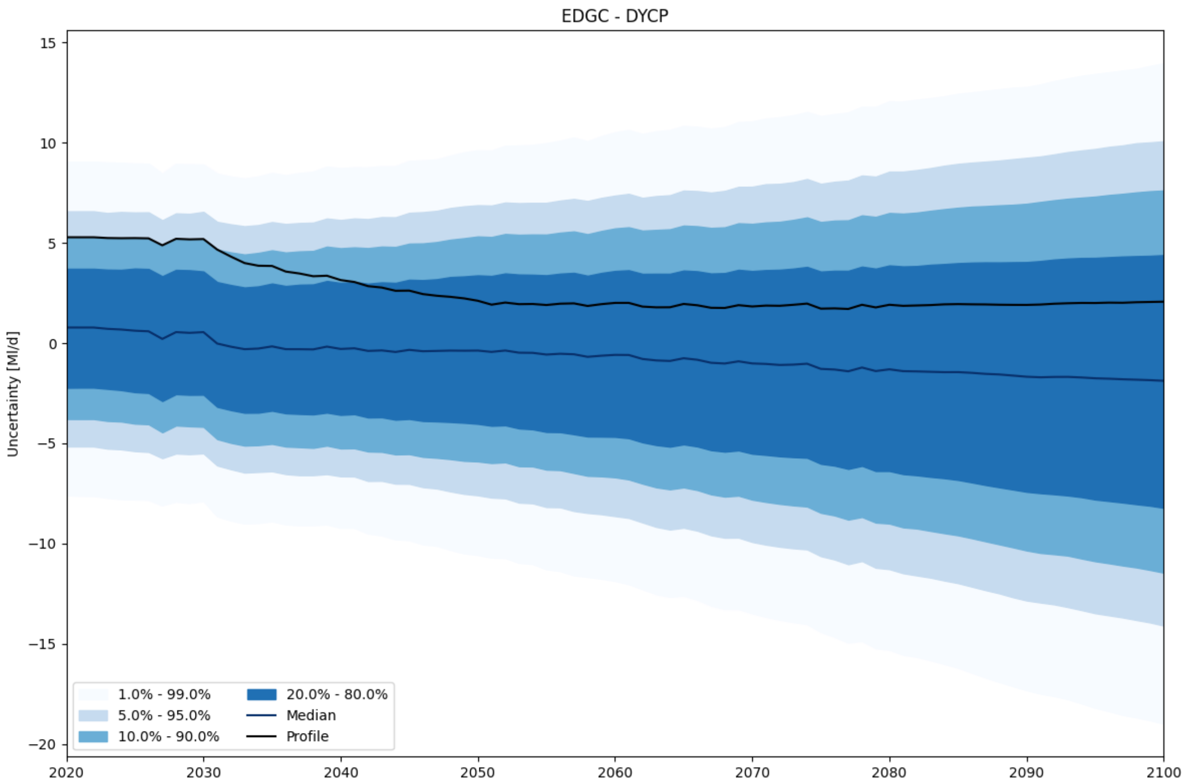
APPENDIX 2 – COMBINED HEADROOM DISTRIBUTIONS

(Note: FTHR distributions are identical to EDG distributions)






EDGC - DYAA
Uncertainty [Ml/d]
10
5
0
−5
−10
−15
−20
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median
Profile


EDGC - DYCP
Uncertainty [Ml/d]
15
10
5
0
−5
−10
−15
−20
2020
2030
2040
2050
2060
2070
2080
2090
2100
1.0% - 99.0%
5.0% - 95.0%
10.0% - 90.0%
20.0% - 80.0%
Median
Profile