FINAL WATER RESOURCES MANAGEMENT PLAN 2024

APPENDIX 5D – METHOD STATEMENT: STOCHASTIC CLIMATE DATASETS

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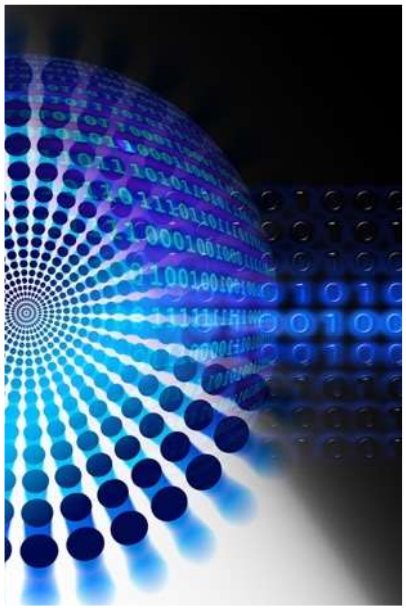

Method Statement: Stochastic Climate Datasets

Updated version

August 2021

Title	Method Statement: Stochastic Climate Datasets
Last updated	August 2021
Version	Post consultation version
History of Changes made to this version	June 2020 – First Draft Written July 2020 – Changes made after technical working group comments, Programme Management Board comments, and Quality Assurance review comments August 2021 – Changes made after consultation responses and following the publication of the updated WRPG
Summary of areas where substantive changes have been made as a result of consultation feedback	• Justification and reasoning for use of baseline period of 1950-97 (acknowledging limitations) • Acknowledgement of uncertainty in generating datasets that represent a 1:500-year drought event • Acknowledgement of inhomogeneities and need for companies to take care when applying datasets
Summary of areas where substantive changes have been made as a result of revised Water Resource Planning Guidelines	None
Summary of other substantive changes made, and reasons for these	• Removal of references to dynamic demand in simulation modelling; dynamic demand modelling not included in baseline regional simulation modelling • Revision of 'selection of drought events' section, to reflect methodology that was applied
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A consultation on the WRSE Method Statements was undertaken in Autumn 2020 – the consultation details can be viewed on the WRSE engagement hq platform at https://wrse.uk.engagementhq.com/method-statements.

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Executive Summary

Water Resources South East (WRSE) is developing a multi-sector, regional resilience plan to secure water supplies for the South East until 2100.

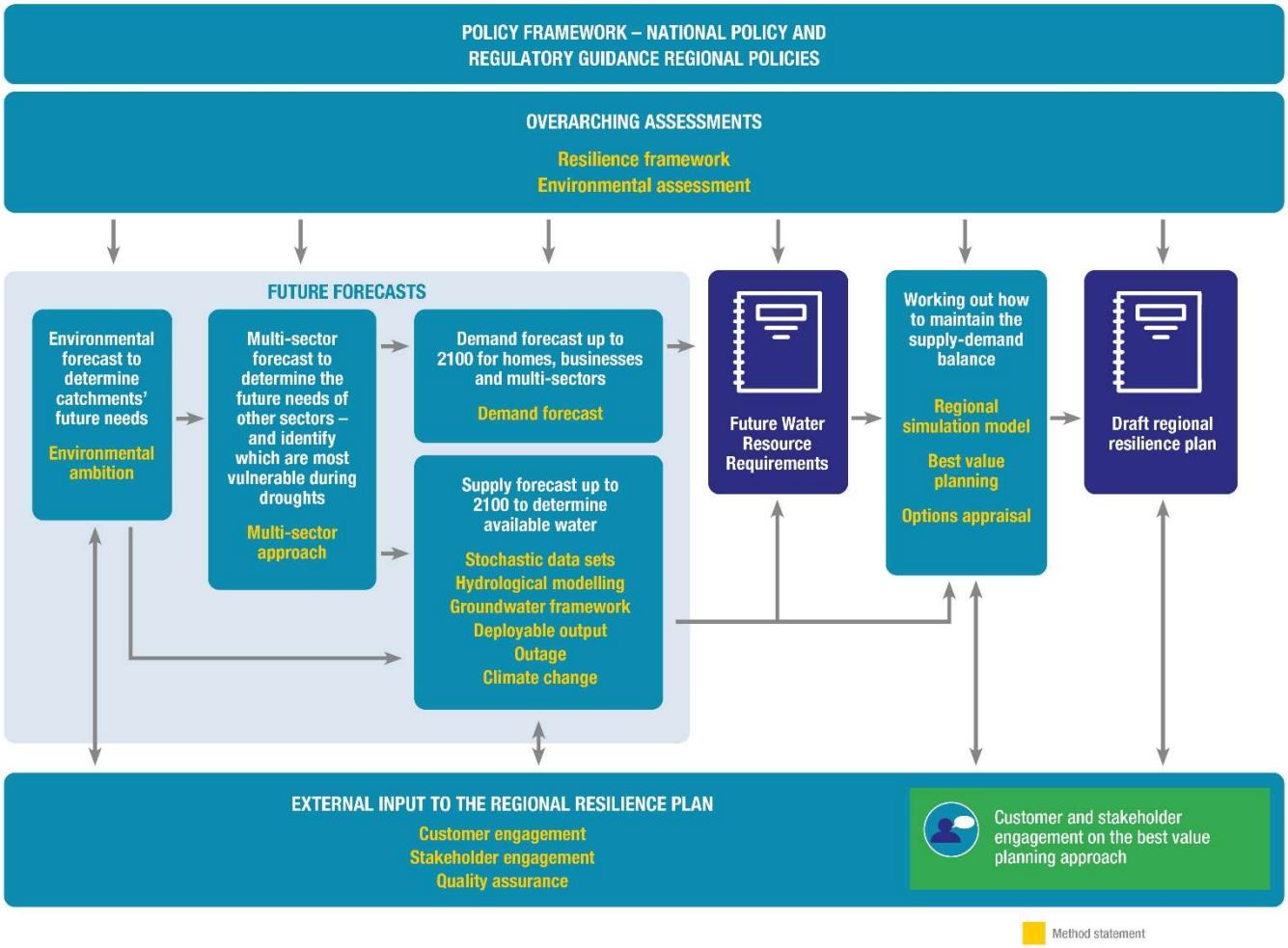
We have prepared method statements setting out the processes and procedures we will follow when preparing all the technical elements for our regional resilience plan. We consulted on these early in the plan preparation process to ensure that our methods are transparent and, as far as possible, reflect the views and requirements of customers and stakeholders.

Figure ES1 illustrates how this stochastic datasets method statement will contribute to the preparation process for the regional resilience plan.

Water companies are required to consider droughts beyond those in the historical record, in order that companies can demonstrate that their plans will bring resilience to more severe and/or different droughts to those which have occurred previously. The method that has been applied in the water industry in the UK is the generation of 'stochastic datasets', time series of rainfall and potential evapotranspiration which are wholly/partially statistically generated and which allow companies to explore droughts beyond the historical record.

This method statement gives an overview of the stochastic datasets that have been generated for WRSE and how they will be applied in WRSE's regional plan.

Figure ES1: Figure 1 Overview of the method statements and their role in the development of the WRSE regional resilience plan



1 Introduction

1.1 The use of 'stochastic' climate datasets is growing within water resources planning, driven by a need to consider the impact of droughts that have not happened in the past. Historically, water resources planning has been carried out based on assessing supply capability considering droughts that have happened in the past. This use of the historical record gives climate datasets that water companies, regulators, and stakeholders can be confident in (being based on weather that has happened) but does not allow for thorough exploration of impacts of droughts which could happen in the future.

1.2 The need for water companies to consider droughts beyond those in the historical record has increased in recent years due to the introduction of requirements from the Environment Agency that water companies show how companies would make their water supply systems resilient to '1 in 200-year' drought as part of WRMP19, and a new requirement for regional planning and WRMP24 that companies' water supply systems are resilient to '1 in 500-year' drought by 2039 at the latest. Reliable historical records for rainfall and potential evapotranspiration (PET), which are two of the most important inputs to hydrological models, are generally no more than around 100 years long, and so for companies to confidently assess their supply capability under '1 in 500 year' drought requires a significant amount of statistical analysis of climatic drivers and historical records.

1.3 The variables most needed to feed hydrological and water resources models are rainfall, PET, and temperature, and so these are the variables contained in the stochastic datasets that have been produced.

1.4 Climate datasets were produced for many companies/regions for WRMP19 assessments. The methods and data underlying the generation of stochastic datasets have been improved in recent years, and so new datasets have been generated in a project commissioned by the Regional Coordination Group and delivered by Atkins (WRSE Regional Climate Data Tools)

1.5 The use of the term 'stochastic' regarding climate datasets references the nature of rainfall and the way that these datasets are derived. Rainfall cannot be predicted based solely on climatological indicators and rainfall volumes are instead climate-driven, but partially random (i.e. it would not have been possible at the beginning of 1976 to determine how much rain would have fallen that year, or when). The climate datasets are derived using relationships between output variables needed (temperature, rainfall) and climate indicators (e.g. North Atlantic Oscillation (NAO), Sea Surface Temperature (SST)), along with 'random chance' to generate datasets which are statistically consistent with the historical baseline, but which represent different versions of what 'could' have happened.

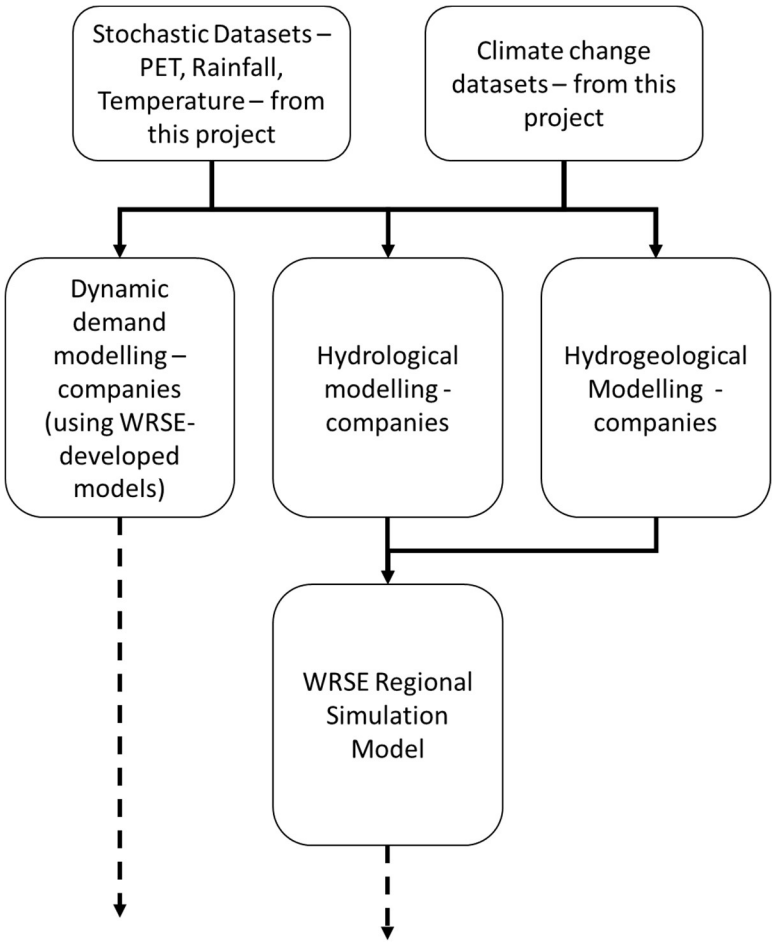
1.6 Figure 1 is a flow chart summarising the use of stochastic and climate datasets in WRSE. This figure shows how the climatic datasets drive the hydrological, hydrogeological and dynamic demand modelling to ensure there are spatially coherent responses to the input climatic data. A notable change to supply-side WRSE methods since the consultation is that 'dynamic demand' (demand factors coherent with rainfall and temperature inputs) has not been included in regional simulation modelling to determine deployable

output. Outputs from the 'dynamic demand' workstream have been used to determine demand forecasts, and there is an ambition that 'dynamic demand' is included in simulation modelling when testing option portfolios.

1.7 This method statement contains the following sub-sections:

a) Generation of stochastic climate datasets
b) Application of datasets
c) Selection of subsets.

Figure 1: Flow chart centred on use of stochastic datasets for WRSE



2 Methods and approach

Generation of stochastic climate datasets

2.1 The generation of stochastic climate datasets involves a significant amount of complex analysis involving climate science and statistics. This method statement does not give an in-depth description of the methods used to generate these datasets but does outline key differences between those datasets generated for WRMP19 and those generated for this round of planning, as well as highlighting key characteristics of these datasets. For a detailed description of the methods used, please see the technical report on the production of these datasets (Atkins, 2020). In essence the work that Atkins have undertaken allows the key climatic indicator time sequences between 1950 to 1997 to be resampled to produce varying temporal and spatial climatic patterns across the South East region.

2.2 Four hundred replicates of a 48-year baseline have been produced, meaning that the climate datasets represent a total of 19,200 years. The dataset should not, however, be seen as a continuous sequence of 19,200 years and represents 400 different versions of what a baseline period (1950-1997) could have resulted in, given underlying climate drivers.

2.3 Time series of rainfall, PET and temperature have been generated for locations across the WRSE region. These can be used as required as inputs for various models, by reformatting inputs to be gridded or amalgamated to catchments.

2.4 A key change from data generated for WRMP19 is that these stochastic datasets are based on a greater range of climate drivers and little bias correction. Data generated for WRMP19 only included NAO and SST as climate drivers, but several more climate drivers have been used in this recent project, as have interaction terms between climate drivers. The inclusion of a greater range of climate drivers has resulted in a better model fit and a smaller need to bias correct outputs. Where bias correction has been used, improved methods have been applied to reduce the production of implausible droughts.

2.5 The use of a greater range of climate drivers has also driven a change to the baseline period used on which to fit the models. For WRMP19, 1920-1997 was used as a baseline, but this has been changed to 1950-1997 due to better quality data for more climate drivers being available only from 1950.

2.6 HadUK data (Met Office; Hollis, D.; McCarthy, M.; Kendon, M.; Legg, T.; Simpson, I. (2018): HadUK-Grid gridded and regional average climate observations for the UK. Centre for Environmental Data Analysis) has been used to derive these datasets, as opposed to the catchment average time series used for WRMP19. This HadUK data is a more flexible and consistent product, suitable for this application.

2.7 As with any dataset generated based on existing datasets using statistical methods, the stochastic weather sequences are only as good as the datasets on which they are trained. As stated above, the stochastic dataset is formed of 400, 48-year sequences and is trained on the 1950-1997 baseline period. There is a risk that extreme, extended droughts may not necessarily be well reflected in the dataset, although quantifying this risk is extremely difficult. Companies may complement the stochastic dataset with drought artificial weather series to represent prolonged drought events (which the stochastic generator will not have been trained on).

2.8 The new EA-PET dataset has not been used in the generation of these climate datasets, due to the dataset not being available at the time needed for generation of the stochastic data.

2.9 The datasets that have been generated exclude leap years (i.e. all 48 years within each replicate are 365 days long). Where models require representation of the 29th Feb, a 'zero rainfall' day should be inserted, and PET should be copied from the day before. The biasing effect that this introduces will be negligible.

2.10 Stochastic sequences have been generated consistent with a baseline of 1950-1997. Water company historical baselines may have previously included data up to 2019, although their previous (WRMP19) stochastic data is unlikely to have been generated on a baseline ending more recently than 2000. Climate change impact on DO will be assessed using a baseline of 1981-2000 and so the baseline period of 1950-1997 is consistent with the climate change assessment.

2.11 EA Guidance states that the EA believes that weather datasets are non-stationary until around 2010. As such, the use of a stochastic timeseries with a baseline up until 1997 is considered appropriate. To extend the training set until the present day would result in double counting of the impacts of climate change.

2.12 It is recognised that the use of a baseline period of 1950-97, rather than 1920-97, means that this stochastic weather data generator has not been trained on a period including several of the most severe droughts to have affected the South East of England (1920/21, 1933/34, early 1940s). However, this new stochastic dataset does show an improved fit when compared to the historical record and has been validated against a 1920-97 dataset. The use of the 1950-97 period allows for the inclusion of a wider range of climate drivers.

2.13 It is recognised that the methods and datasets used in the generation of these datasets do have limitations, particularly considering the cascade of uncertainty through the generation of stochastic datasets into hydrological modelling, and on into system simulation modelling. These stochastic datasets should not be seen as 'the truth' and will not be the final iteration in water companies attempting to identify extreme hydrological events. WRSE does, however, believe that these stochastic datasets provide a reasonable basis on which we can conduct water resources planning, as long as we keep limitations in mind when interpreting results.

2.14 WRSE encourages (but does not require) water companies to consider the use of other datasets to build a range of evidence on which to assess the impact of 1 in 500-year drought, including the WRMP19-derived stochastics, historical datasets, and other datasets.

2.15 WRSE recognises that the generation of datasets designed to investigate '1 in 500-year' events using a baseline period of only 50 or 100 years is a task which will inherently involve a large amount of uncertainty. However, the quantification of this uncertainty and inclusion within a water resources investment plan is a very difficult task. WRSE has not yet attempted to incorporate an allowance for the uncertainty associated with the assessment of '1 in 500-year' events. In a traditional 'target headroom' approach, attempting something such as this would result in a larger target headroom value. WRSE does not consider it appropriate to make potentially large allowances for extreme drought events, and then further allowance for the large uncertainty that exists in the determination of these events, as this may result in an overly conservative plan.

Application of stochastic climate datasets

2.16 The datasets that have been produced will see wider use than has previously been the case. The data will be applied in deployable output assessment, assessment of the impact of climate change, assessment of the benefit that different supply-side options will have, and examining the outcomes that portfolios of options result in. The data will also be used in considering the impact of weather and climate change on demand, and how this interacts with the supply system.

2.17 Many of the applications that these stochastic datasets will be used for involves the use of rainfall and PET data in hydrological and/or hydrogeological models. Companies may be required to conduct translation and/or bias correction to align data that has been produced with existing rainfall-runoff and groundwater models. This is to deal with spatial issues (some models may require gridded data, others require point/catchment average time series) as well as bias impacts (models may have been calibrated using different datasets and application without bias correction may result in bias of model outputs).

2.18 WRSE recognises that the use of stochastic datasets, which include potentially very severe drought events, in hydrological and hydrogeological models brings another element of uncertainty, given that such datasets are likely to include events which are well beyond the bounds within which models have been calibrated/validated. WRSE has not yet attempted to quantify this uncertainty or include it in investment planning, but recognises that this uncertainty exists.

2.19 Since these datasets have been produced, the EA has advised WRSE that there are some inhomogeneities in the historical rainfall datasets (HadUK single grid square datasets) that were used in training. Where such inhomogeneities are known to exist, or where inconsistencies have been found, companies have applied appropriate measures (for example excluding data associated with some grid squares). WRSE has not, however, conducted a full review of all datasets used in training the stochastic weather generator.

Deployable output (DO) assessment

2.20 Stochastic datasets will be used in the assessment of baseline deployable output. Please see the **Method Statement 1320 WRSE Deployable Output** for full details of how deployable output will be calculated using the regional system simulator. Stochastic climate data will be used in hydrological and hydrogeological models to generate flows (**Method Statement 1330 WRSE Hydrological Modelling**) and groundwater yields, which are key inputs to the regional system simulator.

2.21 As per the groundwater framework (**Method Statement 1322 WRSE Groundwater Framework**), many groundwater sources will have outputs which are either modelled dynamically within the regional simulator, or are modelled outside the simulator but which have yields which are coherent with climate sequences determining yields which are different during different drought events. In these cases, this will be the first time that WRSE companies will have considered groundwater yields in this way, and this will give a better assessment of system-level conjunctive use. It will highlight the types of drought to which company systems are most vulnerable. Baseline deployable output will, where possible, be calculated using the whole stochastic record and will be assessed as the supply capability of systems under '1 in 500-year' drought conditions, as determined by system response.

Assessment of impact of climate change

2.22 Stochastic datasets will be used extensively in the assessment of climate change impacts on deployable output. Please see **Method Statement 1335 WRSE climate change - supply side methods** for full details of the supply-side assessment of the impacts of climate change. Environment Agency guidance recognises that the impact of climate change can change the relative severity of different droughts. As such, water companies cannot simply apply climate change factors to 'DO-defining' droughts (those identified as having a severity of 1 in 500-years) to assess the impact of climate change on DO. It would, however, be infeasible to use the whole stochastic sequence to assess the supply-side impacts of climate change, given that this would involve running 19,200 years-worth of data through groundwater models, hydrological models and the regional simulator for each climate change scenario and that there will be many tens of climate change scenarios investigated. As such, a range of droughts that exist within the stochastic sequences will be used to assess the impact of climate change on deployable output.

Assessment of supply-side option benefits

2.23 As well as the baseline deployable output, stochastic datasets will be used in the assessment of the DO benefit that different options and interventions bring. The benefit that some options bring is more dependent on climate variables than others, for example the benefits associated with reservoirs are more impacted by climate and hydrology than desalination plants. As such, a tiered approach to the detail associated with DO benefit assessment will be used. Those options where climate significantly impacts option benefit will have their benefits assessed using the whole stochastic climate record. Those options where climate slightly impacts option benefit will have their benefits assessed using selected droughts from the stochastic record. Those options which are not impacted by climate will not be modelled in the regional simulator.

Examining outcomes associated with option portfolios

2.24 After the investment model has been run and potential future portfolios of options and interventions have been developed, these portfolios of options will be run in the regional simulator to analyse whether the system outcomes associated with portfolios align with the benefits that are anticipated. This will involve use of the stochastic climate datasets.

Dynamic demand

In water resources planning, demand variation within years has been considered based on static profiles (i.e. profiles which are the same for all modelled years). For this round of planning WRSE have developed models which are able to give profiles of demand in each WRZ dependent on climate inputs including temperature and rainfall (**Method Statement 1319 WRSE demand forecast**).

Selection of drought events

2.25 Some of the applications above imply the selection of subsets of the whole climate dataset for specific applications. Environment Agency guidance requires that 'system response' is considered where possible, recognising that rainfall deficit alone cannot reliably be used to determine system-level outcomes. Due to time restrictions, where subsets were required, replicates were largely selected based on the analysis of rainfall deficits. This selection was, however, consistent across the WRSE region, and was validated using initial results of hydrological and hydrogeological modelling. Where subsets have been selected, they have generally been selected such that they contain severe drought events, and as such are not representative of the whole stochastic dataset. Methods used for analysis are, therefore, different and do not treat subsets as though they are representative of the whole.

Decision points and documentation

2.26 While there have been many decisions made in producing stochastic datasets for WRSE, there are relatively few decisions which WRSE and/or water companies must make specifically regarding these datasets. The datasets represent an improvement on those which are available and so it is expected that companies will apply them throughout their assessments. The technical report (Atkins, 2020) which describes in detail the production of the datasets contains significant detail on the methods used and how these methods were chosen. No feedback loops exist in the generation and application of stochastic datasets.

2.27 There are decisions that companies should make regarding how stochastic datasets are applied in hydrological/hydrogeological modelling, but these decisions are detailed in **Method Statement 1330 WRSE Hydrological Modelling**.

2.28 Should companies wish to consider drought events/time series not contained within the stochastic record, they should document their decision to do so. Justification and explanation should be captured by companies regarding the drought events that they are exploring and the rationale behind doing so.

Confidence grades

2.29 It is recognised that a methodology will be required for assigning confidence grades. However, this has not yet been determined.

3 Summary

3.1 This method statement has briefly outlined the stochastic datasets that have been produced for WRSE, which will be applied in WRSE's regional planning.

3.2 The methods underlying these datasets are complex, and so those seeking to explore the technical detail of these methods should read the technical report detailing their production (WRSE Regional Climate Data Tools).

3.3 The applications which stochastic datasets will be used for have been outlined. These include assessment of deployable output, assessment of climate change impacts, assessment of supply-side option benefits, exploring outcomes associated with different option portfolios, and assessing the variation of demand with weather and climate.

4 Next steps

4.1 An initial version of this document was consulted upon between 1st August 2020 to 30th October 2020 and comments received during this time have been incorporated in this version.

4.2 We have also reviewed this document against the final WRPG and supplementary guidance notes issued by the regulators.

4.3 If any other further relevant guidance notes or policies are issued then we will review this Method Statement to see if it needs to be updated.

4.4 When we have finalised our Method Statement, we will ensure that we explain any changes we have made and publish an updated Method Statement on our website.