Methodological Assurance Review Panel

# Geography Maintenance Methodology and Plans for the 2021 Census

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# Purpose

This paper outlines the planned programme of work and methodology for geography maintenance when the results of the 2021 Census have been fully processed. This planned geography maintenance work is in keeping with the work done following the 2011 Census, when population and households counts were used to identify where changes to statistical geographies would be required to ensure that the statistical geographies remained within established population and household thresholds.

# Ask

Members of the Methodological Assurance Review Panel (MARP) are invited to:

- Note the planned programme of work
- Provide any feedback on the rules for changing statistical geographies and the methods we are intending to use for the geography maintenance
- Provide assurance that the geography maintenance plans are fit for purpose

# Background

Output Areas (OAs) were first created for the 2001 Census data in England and Wales, specifically for the output of census estimates. The OA is the lowest geographical level for which a range of census estimates for different topics are provided.

2001 Census OAs were built from clusters of adjacent unit postcodes but as they reflected the characteristics of the actual census data, they could not be generated until after data processing. They were designed to have similar population sizes and be as socially homogenous as possible based on tenure of household and dwelling type.

OAs were required to have a specified minimum size to ensure the confidentiality of data.

In England and Wales, 2001 Census OAs were based on postcodes as at Census Day and fitted within the boundaries of 2003 statistical wards and parishes. If a postcode straddled an electoral ward/division or parish boundary, it was split between two or more OAs.

The minimum OA size was 40 resident households and 100 resident people, but the recommended size was rather larger at 125 people. These size thresholds meant that unusually small wards and parishes were incorporated into larger OAs.

For the 2011 Census, OAs were maintained as far as possible for consistency and to help ensure comparability with the 2001 OAs. Some modification of the previous OAs, LSOAs and MSOAs did take place where significant population and/or household change had occurred since 2001. The OAs, LSOAs and MSOAs form what is referred to as the statistical geography hierarchy and are collectively called statistical geographies.

For the 2011 Census, work was also done to ensure that OAs, LSOAs and MOAs were aligned to local authority district (LAD) boundaries and reflected LAD changes between 2003 and 2011.

When the 2021 Census results are fully processed, we shall have updated OA population and household counts, from which we can identify population and household change since 2011. We shall again be undertaking statistical geography maintenance work, through the identification of individual OAs, LSOAs and MSOAs which shall require modification because they are either under threshold or above threshold in their population and/or household counts.

This paper provides an overview of the planned work around this geography maintenance work. Using splits and merges of the existing OA hierarchy, rather than a total redesign by restricting the OAs which need to be changed, this allows for a continued linkage and comparison between OA statistical outputs from the 2001, 2011 and 2021 Census.

## Importance of Geography

OAs are used as the building block for producing Census outputs for the majority of other geographies for which outputs are produced. This is done through the aggregation of component statistical building blocks. The most widely used statistical building block is the OA, though LSOAs and MSOAs may also sometimes fulfil this function. The relationship of the OA to higher geographies can be established by OA look-up files, and features as part of an OA best-fit policy.

Statistical building blocks are maintained on the basis that they contain consistent numbers of residential population as recorded at the last population census. By design, they will always contain a minimum number of residents and households to safeguard the confidentiality of any census statistics released for them. In this way, statistical building blocks have been designed as a stable geography to serve the need of statistical outputs.

At each census, changes to the statistical building block boundaries are kept to a minimum to ensure their continuity and stability, and to support time series and comparison between censuses. The objective is to change building block boundaries only where necessary, and then only based on strict criteria. This is primarily where the building block population has changed significantly. Where there is now a very small population, releasing census outputs on the building block may reveal information about a person, household, or business. Where there is a very large population a building block's estimates would lose detail. Another reason for changing building block boundaries is when local authority boundaries have changed since the last census, the building blocks then need to be realigned to the changed local authority boundaries.

The use of statistical building blocks to build official statistics for other geographies features as part of the Government Statistical Service Geography Policy (see Pillar 4 – Building Blocks).

A 2018 Census consultation 'Initial View on 2021 Census Output Content Design' confirmed the importance of statistical geographies to census users. When asked to rank in order of interest the geographies most important when using 2011 Census data, LSOAs were ranked 3rd, OAs 4th and MSOAs 8th. As we generally use a best-fit approach for other geographies, the OAs are fundamental to the other geographies of interest on this list as well.

## Statistical Geographies

After modification to some of the OAs, LSOAs and MSOAs initially created following the 2001 Census with the results from the 2011 Census, the number of statistical geographies changed, with these counts shown in Figure 1. This reflects that 2.6% of the 2001 OAs in England and Wales were changed as a result of the 2011 Census, along with 2.5% of LSOAs and 2.1% of MSOAs.

**Figure 1 – The total of 2011 OAs, LSOAs and MSOAs for England and Wales**

| Geography | England | Wales | Total |
|---|---|---|---|
| OA | 171,372 | 10,036 | 181,408 |
| LSOA | 32,844 | 1,909 | 34,753 |
| MSOA | 6,791 | 410 | 7,201 |

**Figure 2 – Population and household minimum and maximum thresholds for OAs, LSOAs and MSOAs in England and Wales**

| Geography | Minimum population | Maximum population | Minimum number of houseolds | Maximum number of households |
|---|---|---|---|---|
| OA | 100 | 625 | 40 | 250 |
| LSOA | 1,000 | 3,000 | 400 | 1,200 |
| MSOA | 5,000 | 15,000 | 2,000 | 6,000 |

The population and household thresholds used for both the 2001 Census and 2011 Census shown in Figure 2, have now become established (and endorsed by census users as part of a geography consultation exercise). We shall continue with these same thresholds for the 2021 Census.

Using 2021 Census data, where statistical geographies are below their respective minimum population or household counts, we shall merge them with a neighbouring area; where they are above their respective maximum population or household counts, we shall split them into two or more areas. There may be exceptions to the upper threshold population count eg where an OA may contain a single communal establishment with a large resident population.

We shall ensure that aggregations of OAs nest within LSOAs and that aggregations of LSOAs nest within MSOAs.

## Output Area Best-fit policy

Output Area best-fit simply means that when OAs are aggregated and assigned to a higher geography, they may not necessarily fit exactly into the boundary of the higher geography; instead they may form an approximation to the shape of the boundary of the higher geography. OAs are assigned to higher geographies based on the location of the OA population-weighted centroid.

For each OA, a single fixed point is established that represents how the population is spatially distributed within the OA. These points are called population-weighted centroids and are calculated algorithmically based on the latest Census estimates.

## Census Geography Consultation

We invited views on our proposed Census 2021 Output Geography Policy and our plans for geography products and services through a consultation exercise in 2020[1].

Building on the success of the policy for 2011, the 2021 policy we proposed was largely consistent with the 2011 policy, reflecting an OA best-fit approach, but with the addition of targeted realignment of some OA boundaries. This is to overcome some of the degradation between OA boundaries and ward or parish boundaries over time as a result of ward and parish boundary changes, and to a far lesser extent, the OA boundary changes made after the 2011 Census. The consultation set out several options for producing outputs for wards and parishes with a view to introducing quality improvements to census statistics for them. We also detailed our recommendation from these options for a refinement to the OA best-fit approach.

Overall, 84% of users supported our recommendation set out in the consultation. We shall proceed with the maintenance plans as set out in this consultation. For statistical geographies (OAs, LSOAs, MSOAs), this will mean striking a balance between two aims. Firstly, is the need for comparability over time, by minimising changes, and secondly, the need to update statistical geography boundaries to reflect population and household changes.

For the release of 2021 Census outputs, it is again planned that the OA best-fit policy is used for producing a range of census outputs for different geographies but supplemented by targeted OA realignment.

## Geography Maintenance Work

There are a number of planned steps of work for testing the methodology and then updating the statistical geographies which were last updated following the 2011 Census:

1. Initial interim geography maintenance
2. Targeted OA realignment
3. OA alignment to LAD boundaries
4. Coastal OA boundary improvements and other OA boundary improvements
5. Review interim geography maintenance changes using early indicative Census data that will be part processed
6. Review if any further OA changes are necessary once the final census data are available
7. Make OAs available for production of Outputs and produce updated geography products

Similar changes will also be required for the LSOA and MSOA geographies.

[1] Census 2021 Output Geography Policy, products and services

## 1. Initial interim geography maintenance (interim geography maintenance stage 1)

Using indicative sources for population and household counts we shall undertake an exercise to create interim OA geographies based on the population and household criteria as set out previously. This will also act as our rehearsal – to make sure that we can undertake the necessary data processing in an efficient way, and to test our software programs and systems.

These interim geographies will be not be published or disseminated outside the Geography Team, as they do not reflect any official statistical geography changes, but instead allow us to do some pre-Census processing work to identify the statistical geography changes which we may expect will need to be done when the final census counts are available.

To undertake the initial geography maintenance work, two key input sources are required – population and household counts.

Whilst there are administrative data sources which could potentially be used such as admin-based population estimates (ABPEs) or the Personal Demographics Service (PDS patient register data) we decided against using administrative datasets for our interim geography maintenance work because of a concern over total population and household counts and variability geographically. Instead for our input sources we used the mid-2019 OA population estimates for OA population counts and the Ordnance Survey product AddressBase for household counts. Residential addresses from AddressBase were used as a proxy for household counts and could be aggregated to OA level.

We are currently in the process of finalising the interim geography maintenance work – and creating updated OAs, LSOAs and MSOAs where OAs are either under threshold or over threshold for both the population and household counts. The interim geography maintained geographies however will not be used when we undertake the actual Census maintenance work early next year but will be used to identify the OAs to be considered as part of targeted OA realignment work.

## 2. OA alignment to LAD boundaries (interim geography maintenance stage 2)

Apart from mergers of local authorities, typically to form larger unitary authorities, as has occurred in parts of England since 2011 as part of local government reorganisation, there were also some minor boundary changes between local authorities in 2012 and 2013 (affecting six LADs). A small number of OAs will need to be changed so that they align to the LAD boundaries.

## 3. Targeted OA realignment (interim geography maintenance stage 3)

In the census geography consultation, we set out a recommendation that we should continue with the OA best-fit policy for producing census outputs for wards and parishes (as done previously following both the 2001 Census and 2011 Census).

Some wards and/or parishes will contain split OAs resulting from ward/parish boundary changes since 2003 - when OAs were aligned to both wards and parishes where possible. Where this occurs, census counts for split OAs will either be wholly attributed to the ward or parish, or instead attributed to a neighbouring ward or parish. This will be done by

considering which ward or parish the OA population-weighted centroid falls within, using the OA best-fit approach. The quality of census outputs for some wards and parishes containing split OAs could be improved by realigning some OA boundaries.

There is an opportunity therefore, endorsed by Census users through their responses to the Census geography consultation, to make additional OA changes to reflect the planned targeted OA realignment.

## 4. Coastal OA boundary improvements and other OA boundary improvements (interim geography maintenance stage 4)

When OAs were first created following the 2001 Census, digital boundaries were made available for mapping of OA data. The majority of these OAs will have remained unchanged following the 2011 Census, and unless otherwise reviewed may remained unchanged following the 2021 Census if they fall within population and household thresholds.

There is an opportunity with coastal OAs to make sure that the clipped to the coastline version of the digital boundaries accurately reflect the coastline, which may since 2001 have been subject to erosion, deposition, or developments such as marinas.

In a similar way, in inland areas, improvements may have been made to ward and parish boundaries which are reflected in the Ordnance Survey product Boundary-Line - which contains all levels of electoral and administrative boundaries**.** There is an opportunity to tidy up some OA boundaries which aren't currently shown to be in total alignment with ward or parish boundaries, where neither the ward nor parish boundaries have been subject to official boundary changes.

## 5. Review interim geography maintenance changes using an early Census data extract

We have requested an early cut of the 2021 Census data from stage 4 processing (post edit and imputation and pre adjustment) so that we can review our previous OA changes. We shall be using the data as an opportunity to get an early indication of the Census counts to be expected when Census data further down the processing chain are supplied (as indicated in step 6).

## 6. Undertake final geography maintenance work using a near final Census data extract

We shall be using a near final cut of the census data from stage 6 processing (post adjustment, and prior to statistical disclosure control) to undertake our data processing tasks to identify what changes are needed to the 2011 OAs, as adjusted, if applicable, following any changes under the interim geography maintenance stages 2 to 4. This will reflect any changes made to OA, LSOAs or MSOAs which based on Census population and household counts appear either under or above threshold.

### 7. Produce and deliver updated geography products

Following the geography maintenance work, we shall provide a number of geography products reflecting any updated OAs, LSOAs and MSOAs. The key product to be delivered to be used in further census processing is an updated UPRN to OA to statistical geography lookup file, to be provided and processed within 4 to 10 working days from receipt of the Census data when provided in batches by delivery group.

Other geography products such as postcode and OA lookup files, and digital boundaries will follow.

For all the above geography maintenance steps there will be documented quality assurance procedures in place to ensure that all the planned statistical geography changes are of suitable accuracy and quality. Two teams within Data Architecture Division will be working together in undertaking the geography maintenance work and geography product production. Each team shall also be quality assuring work of the other team.

## Data Processing

Key census geography information is required for data processing purposes. This includes for residential and communal establishment Unique Property Reference Numbers (UPRNs) and the following fields:

accommodation type, ownership type, postcode, grid reference, OA, local authority, delivery group, household number, and number of usual residents.

Some of the OA information will need to be updated, to reflect any OAs which have changed, through splits (if under threshold) or mergers (if over threshold). New OA codes will be supplied through the provision of a UPRN to OA to statistical geography look-up file. Census will then use this lookup file to update their census records with updated OA codes for just those records where the OA has been updated. It is anticipated that around 5% of OAs may need updating.

## Methodology for Geography Maintenance Processing

For undertaking the geography maintenance work and maintaining the breached areas (where under or over population or household thresholds) we shall use a combination of software packages and code. This includes Feature Manipulation Engine (FME) software, the programming language R, ArcMap (GIS software), and toolboxes created in Python, which plug into ArcMap and an Automated Zoning Tool (AZTool[2]).

The AZTool has previously been used by ONS when maintaining OAs after the 2011 Census and is therefore tried and tested and has proved to be a valuable tool for geography maintenance.

[2] The AZTool was developed by Prof David Martin, Dr Samantha Cockings, Andrew Harfoot and various colleagues in the School of Geography and Environmental Science at the University of Southampton.

Whilst it is possible to maintain the statistical geographies manually, it is preferable to create an automated process for these to allow for more regular and faster processing, and for producing consistent results.

For the OA geography maintenance, we shall initially use the existing 2011 OA and take the 2021 Census UPRN address data for enumerated addresses and turn this into spatially referenced points using R code. These points are then joined to the existing 2011 OA boundaries. Following this, FME is used to identify the under, within, and over threshold address points, creating several input files needed to run the AZ Tool, including files which constrains the splits and mergers to the appropriate geography. FME is used to create Thiessen polygons around those points found in over threshold OAs in preparation for creating building blocks based on address point postcodes. Using a toolbox in ArcMap based on Python code, the Thiessen polygons are clipped to the OA boundaries and aligned to the road network, to produce building blocks with neater geometries that nest within the existing OA boundaries.

To maintain the minimum breaches, using the FME files created in previous steps, the AZTool identifies all the neighbouring OAs to those that breach which are within the same LSOA. A similar list also forms one of the input files for over threshold OAs, identifying which postcode building blocks are within the same OA.

The AZ Tool additionally requires several parameter files, which specify the constraints on population and household size, including the household accommodation and tenure type for merging under threshold OAs and splitting over threshold OAs, so that the newly created OAs are as far as possible socially homogenous.

A FME model is then used to merge the OAs which are under threshold and split those OAs which are over threshold to create the final within threshold OAs. Lastly an R script is used to generate new codes for newly created OAs.

There will however be some permissible exceptions for over threshold population/household counts for all the statistical geographies. Most typically this will occur at OA level, as it should be possible to prevent such occurrences for LSOAs and MSOAs through the splitting of these geographies, which cannot be so easily achieved at OA level.

Hypothetical examples of where over threshold OAs may remain after geography processing of 2021 Census data:

1. A high-rise multi-level block of flats in excess of 250 households (addresses), with three stacked postcodes (meaning that the different postcodes have the same grid reference but cover different flat levels). It would be impossible to create OAs based on properties assigned to each postcode without the OAs covering the same geographical area. In this example we would most likely create an OA around the whole tower block and accepting that it is an over threshold OA which cannot be satisfactorily split into two or more OAs.

2. A large communal establishment (eg a large prison) containing 500 people. By design OAs do not contain only a single large CE alone, as otherwise Census counts for this OA would be wholly attributable to the CE residents. To safeguard the confidentiality of CE residents, an OA containing a single CE will also have to include at least 40 other surrounding households. In this example, whilst the CE is within the population threshold, due to the need to include households within the OA, it could then become over threshold for population ie exceed 625 people.

A similar, simpler process exists for updating the LSOAs and MSOAs which breach threshold limits.

## Census Recording of Students

The date of the 2021 Census – 21 March 2021 coincided with COVID-19 lockdown restrictions. Some students, who ordinarily would have been expected to be in student halls of accommodation or privately renting (such as student lodgings) close to their place of study, were residing instead at an alternative address on Census day – typically their parental address.

Guidance on completing the census form for students indicated that they needed to be counted at both their term-time address and their home address. This meant that students should have been included on a census form at both addresses.

Because of the COVID-19 pandemic some students may have been living away from their usual term-time address on Census day, and therefore may not have completed a Census form at their term-time address. This term-time address however should have been captured and recorded for them when the census form was completed at the address where they were residing on on Census day.

If both usual term-time address and non-term time address have been successfully recorded for students, then as part of Census processing it is possible to copy all students to their term-time address, and it is this address which shall be used for Census reporting purposes. Census population estimates for example will therefore consider students to be resident at their term-time address.

Many international students to the UK who ordinarily may have been expected to commence their academic studies for 2020/21 as undergraduate students in their first year due to the pandemic may have decided to either, defer, cancel their studies, or enrol and study remotely whilst living abroad. In these cases, these students will not have entered the UK for their studies and therefore not been captured on Census day as resident in England and Wales. This may have resulted in some halls of residences which usually cater for first year international students being under occupied and therefore will have experienced a lower occupancy rate than would otherwise be expected.

The impact on the pandemic for international students who had commenced their academic studies prior to the 2020/21 academic year is less clear, but it is likely that a sizeable proportion would have been living at their term-time address on Census day.

Consequently, it is very likely that numbers for international undergraduate students starting their studies in the 2020/21 academic year will have been noticeably down compared to usual numbers, whilst other international students, in their 2nd year onwards and post graduate students may have remained in the UK – though not necessarily at a term-time address.

This will have an impact on the usually resident population of England and Wales as some international students who otherwise would have been expected and included on our population estimates, due to the pandemic will not be included as they were not resident in the country.

## Implications of Students being away from their term-time address

The Census, due to the pandemic, will not necessarily be representative of the usually resident population during non-pandemic times, and we simply do not know the extent to which post pandemic patterns will be consistent with those pre pandemic. This may noticeably be the case in student areas, whereas previously mentioned, students may not have been present on Census day. The Census responses should therefore reflect this.

As the intention for Census reporting purposes is to include students at their usual term-time address, where students were not present at their time-term address but were recorded at an alternative address where usual term-time address was stated, then this information will be used to copy students to their usual term-time address.

There are implications for the geography maintenance work if following the planned allocation of students to their usual term-address if not recorded there on Census day, the student numbers, whether present there or not on Census day, are not reflective of the student numbers, after allowing for international students not present in the country, which ordinarily would be expected.

The main implication for geography maintenance work is that some student areas may have lower than expected population numbers, this may cause statistical geographies (OAs, LSOAs and MSOAs) to be under threshold (see Figure 2) and result in statistical geographies becoming merged.

This does however raise a fundamental question about whether we should keep some student area geographies unchanged, which would otherwise need to be merged due to below threshold population numbers, in anticipation that when students do return that the statistical geographies within these areas remain within threshold.

The counter argument to this is that we would be going against our geography maintenance change criteria, and this could result in disclosure control breaches. For this reason, we are not considering such an approach.

However, it does need to be recognised that for student areas, after the copying of students to their term-time address, any smaller than expected below threshold population (or household) Census estimates will result in OA mergers. This will also lead to a larger number of OA changes than would otherwise be required. In subsequent years this may mean that some OAs are too big in terms of their population and household thresholds, and result in a greater variance of OA population and household numbers.

## Plausibility checks on student numbers at their term-time address

As part of standard Census processing work, some adjustments to the actual Census responses will be made as part of edit and imputation, estimation, and adjustment processes. This will include some work to review student numbers at student locations based on Census intelligence gathering around occupancy of individual halls of residences, including a student halls survey which will tell us about the number of people who were there.

What this work may not provide answers to is how many students weren't recorded in halls of residences who were expected to be recorded. However, there is an opportunity for the Geography Team to get involved with quality assurance work on student numbers prior to the actual geography maintenance work using an early cut of the Census data as described on page 6.

To try and answer the question on how many students weren't recorded in halls of residences who were expected to be recorded, here are some examples of plausibility checks which we could undertake to help answer this:

1. Compare identified student numbers at OA level from the 2011 Census with numbers from the 2021 Census – are there many OAs with a noticeable fall in student numbers in 2021 compared with 2011? If so, do we have any intelligence as to whether this is a genuine drop (eg halls of residence closures, closure of campuses)?

2. Look at students with address one year ago outside the UK from the 2011 Census – compare with 2021 Census results, does this help to explain any drop in student numbers from 1 above

3. Look to see if there is any information collected on the capacity of halls of residences by postcode which Census may hold and compare with actual Census estimates for these same postcodes. Are there any halls of residences with particularly low occupancy which cannot be accounted for?

4. Investigate if there is intelligence on halls of residences where first year international students would ordinarily expect to live during term-time, and where we could expect recorded student numbers from the Census to be much lower than otherwise expected.

## Deliverables for Census

Following the geography maintenance work, there are a planned set of deliverables for Census, which will be prioritised in the following order:

1. UPRN to Output Area to statistical geography lookup. CSV format. Attributes to contain OA code, LSOA code, LSOA name, MSOA code and MSOA name

2. UPRN to National Park geography lookup. CSV format. Attributes to contain National Park code and National Park name

3. Postcode to Output Area to statistical geography lookup. CSV format. Attributes to include postcode, OA code, LSOA code, LSOA name, MSOA code and MSOA name

4. Updated OA to LSOA to MSOA to Local Authority District lookup. CSV format. Attributes to contain OA code, LSOA code, LSOA name, MSOA code, MSOA name, local authority code and local authority name (to reflect local authorities in existence in England and Wales as at 1 April 2021).

5. Updated Output Area (OA) boundaries, maintained using 2021 Census data, and reflecting previous interim OA geographies created. Boundaries supplied will be full (not generalised) and extent of the realm (mean low water mark). Attributes to contain the OA Code.

6. Updated Lower Super Output Area (LSOA) boundaries, built from OA. Boundaries supplied will be full (not generalised) and extent of the realm (mean low water mark). Attributes to contain the LSOA Code and LSOA Name.
7. Updated Middle Super Output Area (MSOA) boundaries, built from LSOA. Boundaries supplied will be full (not generalised) and extent of the realm (mean low water mark). Attributes to contain the MSOA Code and MSOA Name.

It is the first listed deliverable which is needed most urgently by Census, as this lookup file will be used to update Census records, and the updated geography information will be used for generating Census outputs.

## Summary

This paper sets out a programme of work which will result in changes made to the statistical geographies in England and Wales – to OAs, LSOAs and MSOAs. There are some challenges associated with this work, most noticeably to ensure that despite the national pandemic that the geography maintenance changes are consistently applied and fit for purpose, even though, particularly for some student areas, population numbers may differ to the numbers which would otherwise be expected. There is an opportunity here to be involved in quality assurance work around student numbers.

In essence, the methodology to be used for the geography maintenance is relatively unchanged from the methodology used for 2011 Census, and again reflects usage of the AZTool. We are however taking an opportunity to further refine OA boundaries through targeted OA realignment which will result in improvements to the quality of Census outputs for other geographies, namely wards and parishes, and improvements to OA coastal boundaries.

# References

Changes to Output Areas and Super Output Areas in England and Wales, 2001 to 2011 (294.2 kB pdf)

University of Southampton - Methods for creating the 2011 Census output geographies for England and Wales (1.3 MB pdf)

University of Southampton - Evaluation of automated maintenance procedures (605.7 kB pdf)