

Population Projections for Scottish Sub-Council Areas (mid-2022 based): Methodology and Limitations

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1. Methodology and assumptions

1.1 Methodology

1.1.1 The software used to produce the sub-council area population projections is a Microsoft Excel based system called POPGROUP. POPGROUP is a family of demographic models developed to generate population, household and other projections for specified geographical areas. Its platform is Excel based and projections can be developed in different ways using a variety of data inputs and assumptions. POPGROUP is one population projection software package, others are also available to use.

1.2 Trend-based projections

1.2.1 The projections are trend-based, making assumptions about future levels of fertility, mortality and migration based on levels observed over a five-year reference period preceding the projections for each local area. Therefore, they give an indication of what the future population, by age and sex structure, might be if recent local trends in fertility, mortality and migration continue, and take no account of policy or development aims within councils.

1.3 'Training' projection

1.3.1 POPGROUP uses a cohort component methodology for its population projection model broadly similar to the approach used for the National Records of Scotland (NRS) Sub-National Population Projections (SNPPs). One important difference between the methodologies is that POPGROUP uses a preparatory 'training' projection to estimate the assumptions that it uses in its projection.

1.3.2 In this project, the training projection is run from mid-2011 to mid-2022. POPGROUP uses past information to estimate net migration and other changes by looking at the difference between the annual population estimates and known information about the numbers of births and deaths. It therefore does not use NRS migration data as an input, which is estimated during the training projection process. The training projection also calculates differences between each area's fertility and mortality from past births and deaths. The outputs from the training projection, which can be thought of as a preparatory stage, are used to calculate the assumptions that are then used in the main migration-led projection. The process is set out in Figure A.

1.4 Adjusting for special populations

1.4.1 Projections may be less reliable if a major institution is present, such as a prison, student halls of residence or armed forces base, collectively known as special populations. These special populations generally maintain their age-structure through replacement of those that leave the institutions by others of a younger age. This can be somewhat accounted for by making assumptions about the future size of these populations outside of the projection of the rest of the population. In this way they are excluded from calculations for future fertility, mortality and migration assumptions.

1.4.2 However, due to issues of complexity and availability of data, in the current set of projections no special populations have been treated outside of the projection for the rest of the population. The Improvement Service determined that although accounting for special populations may influence the projections, the benefit of treating special populations separately from the general population may not outweigh the cost.

1.4.3 NRS were able to provide estimates of special populations (armed forces – people living in defence establishments, students – people living in halls of residence, and prisoners – people living in prison service establishments) using 2022 census data. However, this data

was only available for a single year, and longer-term trend data would be needed to accurately account for these special populations in the training projection so that the estimated fertility, mortality and migration are based on the rest of the population. The Improvement Service explored running sample projections accounting for these special populations by estimating the longer-term trend for the training projection. In some, the size and structure of the special population at 2022 census day was assumed to be constant in previous years, 2011 to 2021, in others the proportion of students at 2022 census day was calculated and applied to the 2011 to 2021 mid-year estimates (MYE) population data. For future years, 2023 to 2037, the special population at 2022 census day was applied as a constant. This approach was not deemed to improve the plausibility of projections. Differences between the age cut offs at 2022 census day and MYE created some implausible estimates of special populations at individual ages which created implausible projection results. The benefit of incorporating a special population adjustment is when the special population has been changing in recent years but is not expected to change in the future, so that these changes are not interpreted as part of the area's usual migration. However, because of the lack of trend data, changes in the special populations could not be accurately estimated, therefore including an adjustment assuming a stable special population may not have created more plausible migration assumptions. As a result, where there is significant fluctuation in special populations this will affect the quality of migration assumptions. Each of the projection files highlights where special populations are present.

- 1.4.4 Some councils were able to provide feedback on the projections and highlight areas where there has been significant fluctuation in the special population in recent years that could impact the quality of migration assumptions. In these instances, it was agreed that migration assumptions could be altered to exclude the years where significant fluctuation was experienced. Details of where assumptions have been adjusted are documented in the notes of each council projection file, available on the Improvement Service website. This largely affected student populations which fluctuated during years affected by Covid-19. It's worth noting that the NRS sub-national population projections treat the student population as part of the general population, therefore it was deemed reasonable to follow the same approach with the small area population projections.
- 1.4.5 Whilst it is recognised that this approach to special populations is not perfect, it enabled the production of a standardised set of population projections which fill an evidence gap and enable a starting point for which to build upon. Interpretation of these projections will benefit from local knowledge not just relating to special populations, but also other changes not accounted for here such as housing developments and other policy decisions.

1.5 POPGROUP model

- 1.5.1 The methodology used for these projections is set out in the following sections. Using the cohort component method, POPGROUP starts with the base year population. For each year of the projection the population is aged by one year and estimates are made for births, deaths and migration based on the fertility, mortality and migration assumptions. Whilst not accounted for in this set of projections, special populations would typically be removed at the start of each year and added back in at the end of each year, so they are not aged on and do not input to the fertility, mortality or migration assumptions. In this application of the model (refer to Figure A), assumptions about future fertility, mortality and migration trends are derived from recent historical evidence and projected forward for each future year. Each year the projection is constrained to existing council area projections, by adjusting each local area's migration for that year. POPGROUP outputs include the projections and a range of

reports, tables, charts and population pyramids. It should be noted that POPGROUP does not output whole numbers.

Figure A - Diagram of POPGROUP process used for sub-council area population projections

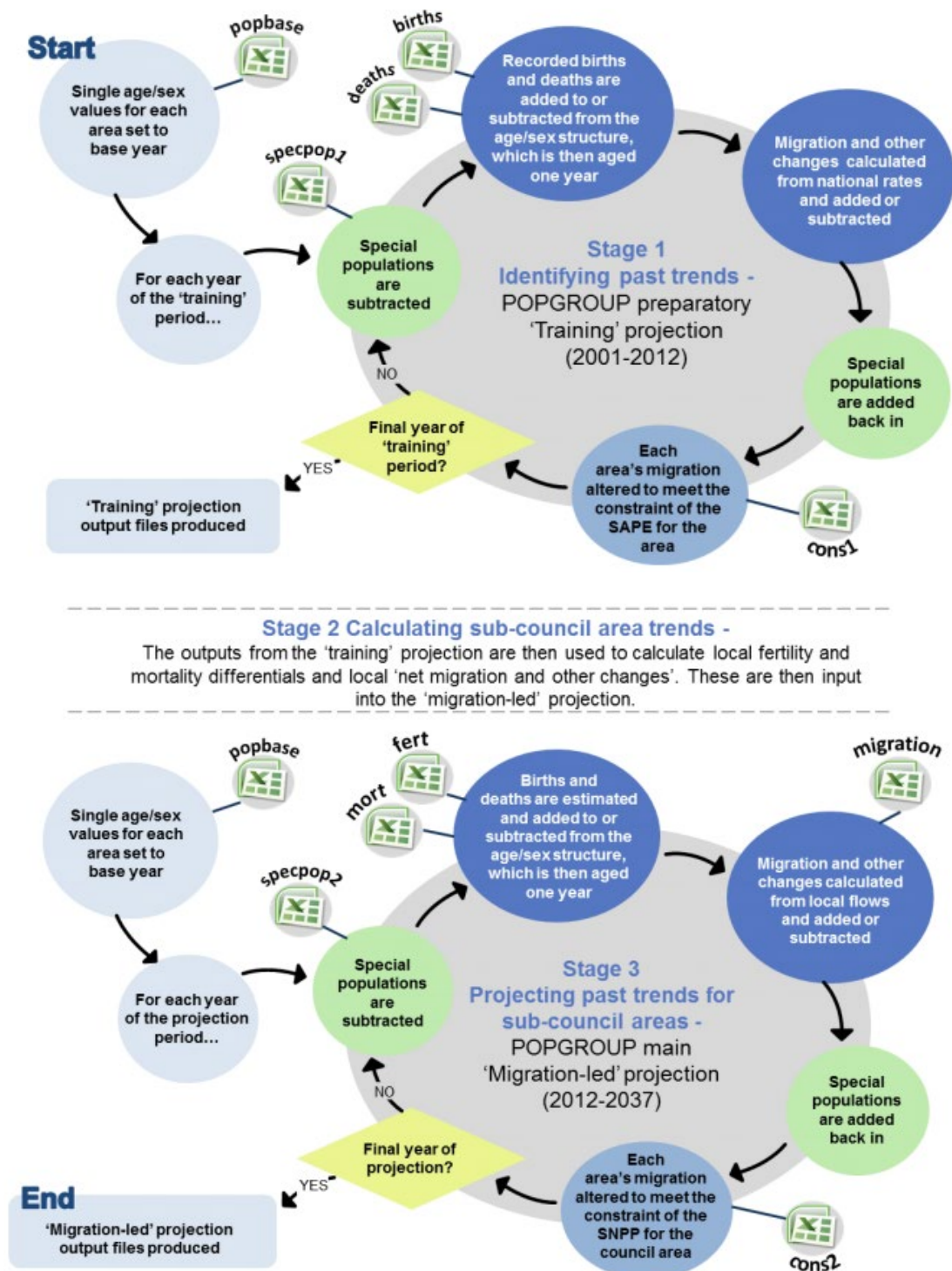


Diagram adapted from [POPGROUP Reference Manual](#)

1.6 Stages of the POPGROUP Model

- 1.6.1 POPGROUP can be used in a number of different ways. For this project we have made use of a training projection (for more detail on the training projection refer to section 1.3). The stages of the process are summarised in Table 1. A summary of the sub-council area projection assumptions are shown in Table 2.

Table 1 - POPGROUP process used for sub-council area population projections

Stages in the process	Summary of actions or outputs for each sub-council area		
Stage 1 – Identifying past trends Local inputs of past births, deaths and population estimates	Births since mid-2011	Deaths since mid-2011	Population estimates since mid-2011
Stage 2 – Calculating sub-council area trends Training projection to estimate local demographic rates up to mid-2022	Local fertility differential	Local mortality differential	Local net migration by age and sex
Stage 3 – Projecting past trends for sub-council areas Migration-led projection continuing past rates constrained to council area projection	Local fertility and mortality differences continued, with the future Scotland trend		Local net migration continued

1.7 POPGROUP Model - Stage 1 – Identifying past trends

- 1.7.1 Local inputs of past births, deaths and population estimates are used to identify fertility, mortality and migration trends in a training projection.
- 1.7.2 Base population - The base population is the 2011 NRS mid-year population estimates (MYEs) by single year of age and sex aggregated from the NRS Small Area Population Estimates (SAPE) to sub-council area projection geography (the small areas used in this project).
- 1.7.3 Constraints - The training projection runs to mid-2022 and is constrained to the 2011-2022 MYEs by single year of age and sex aggregated from the SAPE to sub-council area projection geography.
- 1.7.4 Births and Deaths - Total births by sex and deaths by five-year age bands and sex mid-2012 to mid-2022 are taken from the SAPE at sub-council area projection geography.
- 1.7.5 Fertility and Mortality - Scotland's schedule of age-sex specific rates (the 2023/24 values from the Office of National Statistics (ONS) 2022-based National Population Projections (NPPs)) are changed during the training projection to match the number of births and deaths each year in each local area.
- 1.7.6 Migration – Plausible initial flows of migrants are set in the training projection as a starting point. This initial number is set to avoid the risk of tiny migration flows that could lead to implausible population projections. The initial flow of in-migrants is set to be equal to 4% of the base year population for the local authority. The standard distribution of out-migration

comes from the ONS 2022-based NPPs UK standard migration rates. Its results are changed during the training projection at every single year of age and sex, by the constraint to the MYEs.

- 1.7.7 POPGROUP produces several output files which are used to calculate assumptions in Stage 2 of the process.

1.8 POPGROUP model - Stage 2 - Calculating sub-council area trends

- 1.8.1 The outputs from the training projection are then used to calculate local fertility and mortality differentials from the rates for Scotland (refer to section 1.7.5) and local net migration.
- 1.8.2 Fertility - For fertility the difference between each area's Total Fertility Rate (TFR) and the Scottish TFR is calculated to provide a differential (scaling factor) based on the five-year period mid-2018 to mid-2022. This is applied for each year of the projection.
- 1.8.3 Mortality - Similarly for mortality the difference between each area's Standardised Mortality Ratio (SMR) and the Scottish SMR is calculated to provide a differential (scaling factor) based on the five-year period mid-2018 to mid-2022. This is applied for each year of the projection.
- 1.8.4 Migration - POPGROUP calculates estimates of local migrants and age-specific migration rates using the difference between the annual small area population estimates (SAPE). In and out migrants are estimated separately but only the net impact for each age-sex group is known from the past. Therefore, the in and out flows estimated by POPGROUP are indicative rather than a true estimate of in and out flows experienced over the period. Migrant age-sex groups and age-sex-specific migration rates are calculated over a five-year period from mid-2018 to mid-2022. The balance of short-distance, long-distance and international migration is unknown. However, net migration also includes migration within Scotland, migration from the rest of the UK and overseas migration.

1.9 POPGROUP model - Stage 3 - Projecting past trends for sub-council areas

- 1.9.1 The fertility and mortality differentials calculated from the training projection are used in the migration-led projection which assumes the continuation of recent experience in each small area. These are constrained to the 2022-based SNPPs. It also incorporates the future changes in fertility and mortality that are expected for Scotland as a whole.
- 1.9.2 Constraints - The projections are constrained to the 2022-based SNPPs mid-2022 to mid-2037 by single year of age and sex at council area. Due to the way POPGROUP carries out the constraining process there may be slight differences between the single year of age and sex data published for a council area in the SNPPs and the council area POPGROUP outputs.
- 1.9.3 Fertility differential - The total fertility differential calculated over the most recent five years for sub-council areas is applied to Scotland's trend in the 2022-based NPPs to mid-2037.
- 1.9.4 Mortality differential - The total mortality differential calculated over the most recent five years for sub-council areas is applied to Scotland's trend in the 2022-based NPPs to mid-2037.
- 1.9.5 Sex ratio of future births - The standard male/female sex ratio of 1.05 is used in the projection. The sex ratio is the proportion of males per number of females.
- 1.9.6 Migration - Migrant inflow and outflow for each age-sex average over the most recent five years is applied to each year of the projection at sub-council area geography level.
- 1.9.7 POPGROUP produces several output files containing the results of the projections. The relevant outputs have been summarised and are available to download from the Improvement Service website.

Table 2 - Summary of sub-council area projection assumptions

Data	Source	Geography
Stage 1 – Identifying past trends – preparatory Training projection		
Population Base	NRS Mid-Year Population Estimates (MYE) population (Census year) 2011 Single Year of Age (SYOA)/Sex (Small Area Population Estimates (SAPE))	Sub-Council Area Projection (SCAP) area
Constraints	NRS MYE population 2012-2022 SYOA/SEX	SCAP area
Births	NRS SAPE input – total births 2011-2022 by sex	SCAP area
Age specific fertility and mortality rates	Standard Scottish Age Specific Fertility Rates (ASFR) and Age Specific Mortality Rates (ASMR) from Office of National Statistics (ONS) 2022-based national population projections (NPPs) SYOA are used as a starting point and are scaled to agree with births and deaths.	Scotland
Deaths	NRS SAPE input – deaths 2011-2022 5-year age bands/sex.	SCAP area
In-Migration	The initial flow of in-migrants is set to be equal to 4% of the base year population for the local authority and is used as a starting point. Local migration is estimated from changes in the SAPE – see ‘Calculations’ below.	Council area
Out-Migration	The standard distribution of out-migration is from the ONS 2022-based (NPPs) UK standard migration rates and are used as a starting point. Local migration is estimated from changes in the SAPE – see ‘Calculations’ below.	UK
Stage 2 – Calculating sub-council area trends – from Training projection data		
Local fertility differentials	Calculate the difference between each area’s Total Fertility Rate (TFR) and the Scottish TFR to calculate a differential (weighting factor) based on the 5-year period mid-2018 to mid-2022	SCAP area

Local mortality differentials	Calculate the difference between each area's Standardised Mortality Ratio (SMR) and the Scottish SMR to calculate a differential (weighting factor) based on the 5-year period mid-2018 to mid-2022	SCAP area
Migration and other changes	POPGROUP calculates the estimates of local migrations and age-specific migration rates using the difference between the annual population estimates (SAPE). In and out migrants are estimated separately but only the net impact at each age-sex is known from the past. Migrant age-sex groups and age-sex-specific-migration rates calculated over a 5-year period mid-2018 to mid-2022	SCAP area
Stage 3 – Projecting past trends for sub-council areas – Migration-led projection		
Constraints	NRS 2022-based sub-national population projections mid-2023 to mid-2037 SYOA/Sex (Migration for each SCAP area is adjusted to meet this constraint)	Council area
Fertility Differentials	Total fertility differential mid-2018 to mid-2022 calculated and applied to Scotland's trend in the 2022 based NPPs to 2037 (m/f ratio 1.05) (Calculated from training projection outputs)	SCAP area differential, Scotland trend
Mortality differentials	Total mortality differential mid-2018 to mid-2022 calculated and applied to Scotland's trend in the 2022 based NPPs to 2037 (Calculated from training projection outputs)	SCAP area differential, Scotland trend
Migration	Migrant inflow and outflow for each age-sex average mid-2018 to mid-2022 calculated above and applied to each year of the projection (Calculated from training projection outputs)	SCAP area

	Single year of age distribution with age-sex groups based on the 5-year average rates from mid-2018 to mid-2022	SCAP area
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1.10 Implications of methodological decisions

1.10.1 Several methodological decisions have impacted the results. They are discussed below.

1.11 Constraining the population projections

1.11.1 The population projections have been constrained to the 2022-based SNPPs at council area level. By constraining the projections POPGROUP needs to make an adjustment to its assumptions to meet the constraint. POPGROUP does this by using the estimated gross migration flows to share out each discrepancy between the sum of an initial projection and the SNPP council area projection. While consistency with council area projections has been considered an advantage, the constraining can occasionally cause unusual results, for example:-

a) Any difference may be due to under/over estimation of migration in just one sub-council area. Alternatively, it could be due to very small differences in all areas. As this is unknown, the method spreads the adjustment between all sub-council areas based on their past migration flows. This could mean that in some sub-council areas an unnecessary adjustment has been made while in others a larger adjustment should have been applied.

b) Patterns of migration may be emphasised (particularly for young adults) in some areas, more than the input data would suggest. It is therefore possible that recent trends observed in some areas have been altered to meet the constraint.

1.12 Special populations

1.12.1 Users should treat the projections with caution where there are known to be recent large fluctuations in special populations.

1.13 Future migration

1.13.1 In this project, future migration was specified as numbers of people, and the numbers of people moving at each five-year age group and sex were kept fixed each year. Within the five-year age grouping, the numbers of migrants are then distributed to each single year of age. There are other options such as using proportions rather than constant numbers of migrants. In this project the local migration was estimated from the change in annual population, in effect a net number of people moving into or out of the area each year at each age and sex. It was appropriate to use this number in the assumptions about future years. However, in some cases where the population of an age group was projected to change significantly, the fixed impact of migration has either accelerated or dampened the change depending on its direction.

1.14 Local differences in methodology

1.14.1 Although the project methodology has attempted to be sensitive to local area conditions, for example changing assumptions where there is known to be large fluctuations in special populations or where covid-19 has impacted the quality of net migration assumptions, there are many other decisions that could be influenced by local knowledge. The training projection, Stage 1 of the projection, provides information about the annual levels of

fertility, mortality and migration by age and sex composition in each local area since mid-2011. These could be used to choose assumptions for the future using local area knowledge. To produce projections for all sub-council areas of Scotland within a year, the preference was for decisions that could be applied to all areas.

2. Limitations of projections

- 2.1 It is increasingly important to have high quality statistics on migration and the population, for policy development and for planning and providing public services. Population projections can be used to help with the planning of services in different geographical areas.
- 2.2 In this project the Improvement Service has produced a set of experimental statistics on sub-council area projections using a consistent methodology. As with the sub-national projections at council and NHS Board level they have limitations and particular caution should be exercised when using these projections as smaller areas show more short-term change than larger areas. The local levels of fertility, mortality and migration and other changes in age-sex composition estimated from mid-2018 to mid-2022 are continued for the length of the projection. As the process of change is cumulative, the reliability of projections decreases over time and this is particularly true for small areas. Caution should be exercised when considering these projections in the longer-term. It should also be noted that as these projections are trend based, they are less reliable in periods of rapid change.
- 2.3 Projections can be produced for small areas of any population but are not as robust for small populations as for larger populations. Although projections use recent trends to inform the assumptions, small populations can be more susceptible to change over time. The Improvement Service did not set a minimum population threshold for the sub-council area projection geography. Previous research into small area projections recommends a minimum population of three thousand. In NRS's experience it is difficult to produce sensible and robust projections at this small level and councils have also indicated that they have experienced this. Rather than a threshold of population size, it is the instability of fertility, mortality and migration that complicates small area projections that use components of change. As a rule of thumb, generally projections for populations of fewer than ten thousand could be considered more prone to errors. However, for some areas, projections for populations between eight and ten thousand appear to be reasonable. Where changes in fertility, mortality and the age and sex composition of migration are not typical for the area in the observed period (mid-2018 to mid-2022), unexpected outcomes in the population projections may occur.
- 2.4 The projection may be less reliable if a major institution is present, such as a prison, student halls of residence or armed forces base, collectively known as special populations. The difficulty arises because when such populations have changed their size in the recent past, this change is included in estimates of migration which the projections continue into the future. Special populations maintain their age-structure through replacement of those that leave the institution by others of a younger age. The migration data available for small areas are not robust enough to model this replacement precisely. The projections must be examined and used with caution for areas with large institutional populations/special populations.
- 2.5 The sub-council area projections are constrained to the council totals in the [NRS 2022-based sub-national population projections for council areas](#) and as such the same limitations apply. A projection is a calculation showing what happens if particular assumptions are made. As

with the NRS sub-national population projections (SNPPs), the sub-council area projections are trend-based. They are, therefore, not policy-based forecasts of what the government expects to happen. Many social and economic factors influence population and household change including policies adopted by both central and local government, and levels of house building.

- 2.6 Population projections are calculations showing what happens under certain assumptions about future fertility, mortality and migration. The assumptions in these projections continue these past trends in local fertility, mortality and migration. They do not take account of any future changes that may occur as a result of policy initiatives, social or economic change. They will reflect changes in population which occurred as the result of past policy changes and trends in house building, but they do not incorporate information on planned future policy changes or house building. For example, an area may have had a high level of house building over the last few years, which is now coming to an end, meaning the projections would show a continuation of any demographic changes which occurred in the five years preceding the projections as a result of these houses being built. These projections are not, therefore, forecasts of what the Improvement Service, NRS, government or council, expects to happen.
- 2.7 The benefit of these projections is that they estimate each sub-council area's characteristics. The current size and age composition of the population is the starting point of the projections and a major influence on the future. Areas differ in their level of fertility and mortality in ways that can be expected to continue. The direction and age composition of migration is different in areas of family housing, in rural areas, inner city areas and areas that attract older and retiring adults. The estimates of these sub-council area differences are the strength of the projections and they provide the evidence for projecting each area separately.
- 2.8 Population projections, like some other types of projections, may indicate that existing trends and policies are likely to lead to outcomes which are judged undesirable. Some areas exhibit significant change for a limited period of time after which growth is not sustainable and needs to occur elsewhere. Population growth in some small urban areas cannot continue indefinitely as there is not the space to allow trends to continue. Availability of land can heavily influence where growth will be, and this is much more evident in projections for sub-council areas than for projections across council areas. New local planning policies are often intended to modify past trends. Development plans may be based on reasoned and agreed departures from the projections that seem better able to fit particular local circumstances. If new policies are introduced, they may result in the original projections not being realised. However, this means the projections will have fulfilled one of their prime functions, to show the consequences of present demographic trends with sufficient notice for any necessary action to be taken.

2.9 COVID-19

- 2.9.1 This set of projections is based on the 2022 mid-year estimates and uses recent trends. They therefore take account of recent changes occurring as a result of the COVID-19 crisis. In some areas this has resulted in large fluctuations in migration. This is most notable in areas where a large student population is present as well as some rural areas. In most areas, a large fluctuation in migration between mid-2020 and mid-2021 is followed by a similar scale fluctuation in the opposite direction between mid-2021 and mid-2022. Within the model,

migrant inflow and outflow for each age-sex uses an average over the most recent five years, mid-2018 to mid-2022, therefore although the years affected by COVID-19 are included in this estimate, the average period smooths out much of these fluctuations. Some councils were able to provide feedback on the projections and highlight areas where significant fluctuations were likely to have impacted the quality of migration assumptions. In these instances, it was agreed that migration assumptions would be altered to exclude the years where significant fluctuation was experienced. Details of where assumptions have been adjusted are documented in the notes of each council projection file, available on the Improvement Service website.