Society of Actuaries

Mortality Improvement Scale MP-2014 Report

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Section 1. Executive Summary

1.1 Background and Conceptual Framework

This Mortality Improvement Scale MP-2014[1] Report, along with its companion document, the Society of Actuaries' (SOA's) RP-2014 Mortality Tables Report [20],[2] establishes a new basis for mortality assumptions for private sector retirement programs in the United States. These two reports represent the culmination of a comprehensive study of uninsured retirement plan mortality experience begun by the Retirement Plans Experience Committee (RPEC or "the Committee") in late 2009.

For pension-related[3] purposes, the mortality projection scale presented in this report, denoted MP-2014, replaces both Scale AA[4], which was released in 1995 [27], and the interim Scale BB, which was released in 2012 [17]. As anticipated by RPEC in its Scale BB Report, the new Scale MP-2014 is two-dimensional, with gender-specific mortality improvement expressed as a function of both age and calendar year. Alternatively, the new gender-specific rates can be thought of in terms of age and year of birth, a basis that provides more insight into the underlying model.

The conceptual framework for Scale MP-2014 is similar to that used to develop the two-dimensional mortality improvement rates upon which Scale BB was based (denoted Scale BB-2D). In particular, both scales were patterned after the Mortality Projections model developed over the past decade by the Continuous Mortality Investigation[5] (CMI) [3, 4, 5, 6, 7, 8]. The key concepts underpinning that CMI model include:

(1) Short-term mortality improvement rates should be based on recent experience.
(2) Long-term mortality improvement rates should be based on expert opinion.
(3) Short-term mortality improvement rates should blend smoothly into the assumed long-term rates over an appropriate transition period.

While RPEC believes that the above conceptual framework for the construction of mortality improvement scales is sound, the Committee has come to the conclusion that certain technical aspects of the CMI methodology are more complex than is necessary for most pension-related applications in the United States. As a result, the model upon which Scale MP-2014 was based incorporates a number of computational techniques that are intended to be simpler and more transparent than those used in the CMI model without compromising any conceptual soundness. This new model, denoted RPEC_2014, has the additional benefit of being relatively easy to refresh, enhancing the prospects for more frequent updates to U.S. mortality improvement scales.

[1] The abbreviations "MP" and "RP" stand for Mortality Projection and Retirement Plans, respectively.
[2] Numbers in square brackets refer to items listed in the References section at the end of this report.
[3] The word "pension" used in the terms "pension actuary", "pension actuaries", or "pension-related" in this report should be understood to include both "pension" and "other postemployment benefits (OPEB)."
[4] The current uses of Scale AA in connection with statutory group annuity and various regulatory requirements are not affected by this report.
[5] The CMI is a U.K. private company that is supported by the Institute and Faculty of Actuaries and provides authoritative and independent mortality and sickness rate tables for U.K. life insurers and pension funds.

1.2 Data Sources and Key Assumptions Used to Develop Scale MP-2014

The development of credible mortality improvement rates requires the analysis of large quantities of consistent data over long periods of time, two requirements that are difficult to achieve when data for pension mortality studies are collected infrequently and from many different sources. As a consequence, RPEC based the starting historical array for the underlying RPEC_2014 model on the most recent Social Security mortality dataset (through calendar year 2009) supplied by the Office of the Chief Actuary (OCACT) at the Social Security Administration (SSA). The two-dimensional Scale MP-2014 rates result from inputting the Committee's best estimate set of assumptions into the RPEC_2014 model, which includes a long-term rate assumption of 1.0 percent per annum through age 85, followed first by a linear decrease to 0.85 percent at age 95, and then by a linear decrease to zero at age 115.

To mitigate any potential for increased sensitivity around the edges of the graduated historical data, RPEC used a two-year step-back from 2009, the most recent year of SSA mortality data. RPEC then selected a 20-year period for the smooth transition between 2007 and the year in which the long-term rates are first attained. Hence, the age-specific Scale MP-2014 rates are constant starting in calendar year 2027.

The RPEC_2014 model was designed to accommodate assumption sets other than that selected by the Committee. Any actuary who uses an alternate assumption set[6] within the RPEC_2014 model should be able to justify that the resulting mortality improvement rates are reasonable and appropriate for the particular application at hand.

1.3 New Interpolation Methodology

The interpolation methodology incorporated into the RPEC_2014 model (for calendar years 2008 through 2026) represents one of the major simplifications relative to the CMI model. This new methodology, described in subsection 3.3, is based on a blend of two sets of mortality improvement rates, one set reflecting anticipated mortality improvements based on cubic polynomial interpolation along fixed age lines, and the other set reflecting anticipated mortality improvements based on cubic polynomial interpolation along fixed year-of-birth cohort lines.

1.4 Financial Implications of Adopting Scale MP-2014

Most current pension-related applications in the United States involve the projection of RP-2000 (or possibly UP-94) base mortality rates using either Scale AA or Scale BB. RPEC believes that it will be considerably more meaningful for users to assess the combined effects of adopting RP-2014 and Scale MP-2014, rather than trying to isolate the impact of adopting one without the other. The financial impact of the combined change is expected to vary quite substantially based on the starting mortality assumptions, e.g., the impact of switching from a static projection using Scale AA will typically be much more significant than the impact of switching from a generational projection using Scale BB.

[6] Throughout this document, the phrase "alternate assumption set" denotes any assumption set other than the committee-selected assumption set described in Section 4.

Table 1 below presents a comparison of 2014 monthly deferred-to-age-62 annuity due values (at 6.0 percent interest) based on a number of different sets of base mortality rates and generational projection scales, along with the corresponding percentage increases of moving to RP-2014 base rates[7] projected generationally with Scale MP-2014.

		Monthly Deferred-to-62 Annuity Due Values Generational @ 2014					*Percentage Change of Moving to RP-2014 (with MP-2014) from:*			
	Base Rates	UP-94	RP-2000	RP-2000	RP-2000	RP-2014	UP-94	RP-2000	RP-2000	RP-2000
	Proj. Scale	AA	AA	BB	MP-2014	MP-2014	AA	AA	BB	MP-2014
	Age									
Males	25	1.3944	1.4029	1.4135	1.4324	**1.4379**	*3.1%*	*2.5%*	*1.7%*	*0.4%*
	35	2.4577	2.4688	2.4881	2.5259	**2.5363**	*3.2%*	*2.7%*	*1.9%*	*0.4%*
	45	4.3316	4.3569	4.3963	4.4662	**4.4770**	*3.4%*	*2.8%*	*1.8%*	*0.2%*
	55	7.6981	7.7400	7.8408	7.9735	**7.9755**	*3.6%*	*3.0%*	*1.7%*	*0.0%*
	65	11.0033	10.9891	11.2209	11.5053	**11.4735**	*4.3%*	*4.4%*	*2.3%*	*-0.3%*
	75	8.0551	7.8708	8.2088	8.5842	**8.6994**	*8.0%*	*10.5%*	*6.0%*	*1.3%*
	85	4.9888	4.6687	5.0048	5.2978	**5.4797**	*9.8%*	*17.4%*	*9.5%*	*3.4%*
Females	25	1.4336	1.4060	1.4816	1.5097	**1.5195**	*6.0%*	*8.1%*	*2.6%*	*0.6%*
	35	2.5465	2.4931	2.6145	2.6666	**2.6853**	*5.5%*	*7.7%*	*2.7%*	*0.7%*
	45	4.5337	4.4340	4.6264	4.7198	**4.7497**	*4.8%*	*7.1%*	*2.7%*	*0.6%*
	55	8.1245	7.9541	8.2532	8.4373	**8.4544**	*4.1%*	*6.3%*	*2.4%*	*0.2%*
	65	11.7294	11.4644	11.8344	12.1437	**12.0932**	*3.1%*	*5.5%*	*2.2%*	*-0.4%*
	75	8.9849	8.6971	9.0649	9.4045	**9.3996**	*4.6%*	*8.1%*	*3.7%*	*-0.1%*
	85	5.7375	5.5923	5.9525	6.2910	**6.1785**	*7.7%*	*10.5%*	*3.8%*	*-1.8%*

Table 1

1.5 Recommended Application and Adoption of Scale MP-2014

RPEC believes that Scale MP-2014 (or an appropriately parameterized RPEC_2014 model) is a reasonable basis for the projection of future pension-related mortality rates in the United States. Since Scale MP-2014 represents the Committee's current best estimate of future mortality improvement in the United States, RPEC recommends that users carefully consider the committee-selected assumption set described in Section 4. The Committee encourages the application of Scale MP-2014 (or an appropriately parameterized RPEC_2014 model) on a generational basis to all pension-related mortality tables, including those covering disabled lives.

1.6 Naming Conventions

To preempt any misunderstanding in connection to projection scales based on alternate assumption sets, the name "Scale MP-2014" should be reserved exclusively for the rates displayed in Appendix A, which are based on the committee-selected assumption set described in Section 4. Any other set of two-dimensional mortality rates based on the RPEC_2014 model should explicitly identify (1) the assumed gender-specific long-term rates for all ages between 20 and 120, (2) the assumed beginning and ending calendar years for each of the age/period and cohort convergence periods, and (3) the relative weighting percentages for the age/period (horizontal) and year-of-birth cohort (diagonal) interpolations.

[7] RP-2014 Employee mortality rates through age 61 and RP-2014 Healthy Annuitant mortality rates at ages 62 and older.

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Special Recognition of Others Not Formally on RPEC

First and foremost, the Mortality Improvement subcommittee would like to express its profound appreciation for the support and assistance it has received from Dr. Brian Ivanovic and Allen Pinkham, both employees of Swiss Re. Brian and Allen have worked very closely with the subcommittee since the inception of this project, and their insights and analyses have been extremely helpful in shaping the results contained in this report.

The Mortality Improvement subcommittee would also like to thank Michael Morris, Stephen Goss, Alice Wade, Karen Glenn and Johanna P. Maleh, all from the Office of the Chief Actuary at the SSA. In addition to providing access to the most current SSA mortality rates, the OCACT team participated in a number of very helpful conversations with RPEC regarding long-term mortality improvement trends in the United States.

RPEC would also like to thank Greg Schlappich at Pacific Pension Actuarial who helped review the cubic polynomial interpolation methodology used to develop Scale MP-2014.

Finally, the current RPEC members and SOA staff would like express their sincere gratitude to Lindsay Malkiewich and Diane Storm. Lindsay retired in May 2014 and Diane will step down from RPEC after the publication of the RP-2014 and Scale MP-2014 reports. Lindsay and Diane have each contributed 22 years of volunteer service on the Committee. RPEC thanks Lindsay for the valuable input he provided on the development of Scale BB and both of the RP-2014 and Scale MP-2014 exposure drafts and Diane for all the valuable work she did in connection with the development of Scale BB, the RP-2014 and Scale MP-2014 exposure drafts, the RP-2014 and Scale MP-2014 reports and RP-2014 and Scale MP-2014 Response to Comments documents.

Reliance and Limitations

The RPEC_2014 mortality improvement model and Scale MP-2014 are intended for use in connection with actuarial calculations related to pension and other postemployment benefit (OPEB) programs. No assessment has been made concerning the applicability of the mortality improvement model and Scale MP-2014 to other purposes.

Section 2. Background

2.1 Evolution of this Project

In late 2009, RPEC initiated a comprehensive analysis of pension plan mortality experience in the United States. At an early stage of its analysis, the Mortality Improvement subcommittee of RPEC noticed that mortality improvement experience in the United States since 2000 was clearly different from that anticipated by Scale AA. In particular, there was a noticeable degree of mismatch between the Scale AA rates and actual mortality experience for ages under 50, and the Scale AA rates were lower than the actual mortality improvement rates for most ages over 55. Given that the full Pension Mortality Study was still many months from completion at that time, the SOA decided to publish interim mortality improvement Scale BB [17], which provided pension actuaries with a more up-to-date alternative to Scale AA for the projection of base mortality rates beyond calendar year 2000.

After the publication of the interim Scale BB in September 2012, a new Mortality Improvement subcommittee was formed within RPEC to develop a new projection scale to be used in connection with the RP-2014 base pension mortality tables [20].

2.2 Review of Scale AA

In 1995, the SOA published a series of new mortality tables, along with related commentary [27, 28]. In addition to the release of the GAM-94 and UP-94 base mortality tables, these reports introduced Scale AA, which was to be used for the projection of mortality improvements beyond 1994. These new mortality assumption sets were intended to be used for both group annuity and uninsured pension plan purposes. Scale AA was based entirely on a blend of gender- and age-specific mortality experience of the SSA and the Civil Service Retirement System between 1977 and 1993, with a minimum rate of 0.5 percent for ages under 85. The Scale AA rates graded down to 0.1 percent at age 100 and were set equal to zero at ages over 100.

In July 2000, RPEC published the RP-2000 Mortality Tables Report [19]. As part of its analysis, RPEC examined trends in non-disabled mortality rates for various datasets (including Federal Civil Service and the SSA). Based on that review, the authors of the RP-2000 Report recommended the continued use of Scale AA for the projection of mortality rates beyond the year 2000.

2.3 Review of Interim Scales BB and BB-2D

The interim Scale BB was designed to be a practical, short-term alternative to the dated Scale AA that pension actuaries could use while RPEC completed its development of a more permanent mortality projection model. Specifically, RPEC had three primary objectives in releasing the Scale BB Report:

1. To present to potential users of Scale AA the results of recent analyses performed by RPEC that showed that the rates of mortality improvement in the United States over the recent past have differed quite noticeably from those predicted by Scale AA

2. To provide an alternative to Scale AA that was based on more recent data and newly developed techniques, and that could be used immediately without any changes to existing valuation software
3. To provide users and developers of actuarial software lead time prior to the release of two-dimensional pension mortality improvement scales

Scale BB was developed using SSA mortality data covering calendar years 1950 through 2007, and incorporated techniques—including analysis of U.S. mortality trends on a two-dimensional (age and calendar year) basis—that had not been used previously in the construction of mortality improvement scales published by the SOA. That resulting two-dimensional array of gender-specific mortality improvement rates, which RPEC has subsequently named Scale BB-2D, was based on the Mortality Projections model developed over the past decade by the Continuous Mortality Investigation (CMI) group within the Institute and Faculty of Actuaries in the United Kingdom. In particular, Scale BB-2D was constructed following the "Advanced Parameter Layer" version of CMI's Mortality Projections model CMI_2010 [6] along with the following assumption set:

- Pre-2005 mortality improvement rates derived from SSA mortality experience from 1950 through 2007
- Assumed long-term mortality improvement rates equal to a flat 1.0 percent for all ages through 90 (decreasing linearly to age 120 thereafter)
- Convergence periods[8] of up to 20 years for age/period effects and 10 years for cohort effects
- Fifty percent of convergence remaining at the midpoint of the convergence period

A link to the Scale BB-2D rates can be found in the answer to question A3 of the Scale BB Q&A document available on the SOA website [18].

Due to RPEC's desire for users to be able to adopt the updated mortality improvement rates immediately, the Committee took the additional step of converting the two-dimensional Scale BB-2D into a set of one-dimensional (age-only) factors that could be applied without any enhancements to existing pension valuation software. The process that produced the interim Scale BB from Scale BB-2D is described in subsection 5.3 of the Scale BB Report [17].

[8] "Convergence period" is the term adopted by CMI to describe the number of years between the start of the projection period and the time at which the long-term rates are fully phased in. RPEC has continued to use that terminology in this report.

Section 3. Development of the RPEC_2014 Mortality Projection Model

3.1 Conceptual Framework of the Mortality Projection Model

The RPEC_2014 model described in this Section 3 was patterned after the CMI Mortality Projections model, which was also the basis for Scale BB-2D. The key concepts underpinning the CMI methodology are:

- Recently observed experience is the best predictor of future near-term mortality improvement rates.
- Long-term rates of mortality improvement should be based on "expert opinion" and analysis of longer-term mortality patterns.
- Near-term rates should transition smoothly into the assumed long-term mortality improvement rates over appropriately selected convergence periods.

One additional feature embedded in the CMI model is the explicit decomposition of historical mortality improvement rates into distinct age, period, and year-of-birth cohort components that are subsequently projected and recombined to produce two-dimensional arrays of mortality improvement rates.

In an attempt to make the projection methodology more accessible, RPEC decided to simplify certain computational aspects of the CMI model. First, in lieu of penalized basis splines (P-splines), RPEC decided to use two-dimensional Whittaker-Henderson graduation to smooth historical U.S. mortality improvement rates. Second, the RPEC_2014 methodology reflects historical age/period and cohort effects using an implicit approach, in contrast to the CMI's more explicit decomposition alluded to above. In addition to making the overall model more transparent than CMI's approach, RPEC believes these new techniques greatly simplify the process of developing two-dimensional mortality improvement scales based on alternate assumption sets.[9]

Throughout this report, $f(x,y)$ will represent the gender-specific RPEC_2014 mortality improvement rate at age x in calendar year y. The RPEC_2014 model first develops $f(x,y)$ values for calendar years 1951 through 2007 based on U.S. historical mortality rates. The model then produces $f(x,y)$ values for calendar years 2008 and beyond using a family of cubic polynomials that were designed to transition smoothly between recent mortality improvement experience and the assumed long-term rates.

3.2 Development of Historical Two-Dimensional Rates

The development of credible mortality improvement rates requires the analysis of large quantities of consistent data over long periods of time, two conditions that are difficult to satisfy when data for pension mortality studies are collected infrequently from numerous diverse sources. As part of the analysis performed in connection with the Scale BB Report [17], RPEC had determined that, between calendar years 1998 and 2006, the mortality improvement patterns of two very large

[9] The development of two-dimensional mortality improvement rates based on alternate assumption sets is described in Section 5.

public/federal plans were generally consistent with those based on SSA mortality data.[10] RPEC concluded that it would be reasonable to develop historic RPEC_2014 mortality improvement rates on the most recent SSA mortality dataset,[11] which consists of gender-specific mortality rates through calendar year 2009 for ages 0 through 120 [23]. It should be noted that the SSA mortality rates for ages 100 and older are based on estimates of increasing mortality rates at those advanced ages (i.e., not based entirely on central death rates), and the SSA mortality rates between ages 95 and 99 are determined by a blending of the pre-95 and post-99 methodologies [22].

RPEC considered a number of different graduation techniques to smooth the resulting two-dimensional mortality improvement data. Those techniques included P-splines, thin plate splines, and two-dimensional Whittaker-Henderson graduation. When appropriately parameterized, all three graduation techniques produced very similar sets of historical mortality improvement rates.

Given the similarity among the three sets of graduated results, RPEC ultimately decided to proceed with the two-dimensional Whittaker-Henderson model. The Committee believes that Whittaker-Henderson graduation is considerably easier to understand and apply than the more mathematically complex P-spline and thin plate spline methodologies; e.g., sophisticated software for two-dimensional Whittaker-Henderson graduation is readily available online [9]. Testing also indicated that sensitivity of the final results to the graduation parameters was relatively low, mitigating potential concerns regarding the subjectivity of parameter selection within the Whittaker-Henderson model.

The historical U.S. population mortality improvement rates were obtained by graduating separate male and female datasets as follows:

1. Calculating the natural logarithm of each SSA mortality rate, covering all calendar years 1950 through 2009 and all ages 15 through 97.
2. Using Whittaker-Henderson weights based on U.S. population data obtained from the Human Mortality Database [10]. Normalized weights for each age and calendar year were developed by dividing the individual weights by the sum of weights.
3. Defining Whittaker-Henderson smoothness as the sum of the squares of the third finite differences.
4. Selecting two-dimensional smoothness parameters of 100 in the calendar year direction and 400 in the age direction.

The resulting graduated values, denoted *s(x, y)* for each age, *x*, from 15 through 97, and each calendar year, *y*, from 1951 through 2009, were transformed into smooth mortality improvement rates, *f(x, y)*, using the following formula:

$$f(x,y) = 1 - e^{s(x,y)-s(x,y-1)}$$

[10] Datasets for these two plans included retired lives only. Hence, this mortality improvement comparison was performed for ages 55 and above.

[11] The mortality dataset is based on Social Security's "area population," which is the population comprised of: (1) residents of the 50 states and the District of Columbia (adjusted for net census undercount); (2) civilian residents of Puerto Rico, the Virgin Islands, Guam, American Samoa and the Northern Mariana Islands; (3) federal civilian employees and persons in the U.S. Armed Forces abroad and their dependents; (4) non-citizens living abroad who are insured for Social Security benefits; and (5) all other U.S. citizens abroad [29]. This dataset was preferred over other sources, such as mortality data directly from the National Center for Health Statistics (NCHS), due to SSA's ability to supplement the NCHS dataset with Medicare mortality information.

So-called “edge effects” are instabilities that arise from the absence of data beyond the edges of the dataset being graduated. To mitigate these edge effects in the RPEC_2014 model, the Committee continued to follow the CMI technique of stepping back two years from the most recent calendar year of actual experience. Hence, even though the two-dimensional Whittaker-Henderson graduation was applied to the SSA mortality improvement rates through 2009, the most recent calendar year of historic mortality improvement rates included in RPEC_2014 is 2007. Similarly, to avoid potential edge effects with respect to ages, RPEC limited the historical mortality improvement rates to ages 20 through 95.

The resulting two-dimensional arrays of graduated mortality improvement rates, colorized to create historical U.S. mortality improvement heat maps from ages 35 through 95 (youngest to oldest upward along the y-axis) and from calendar years 1951 through 2007 (left to right along the x-axis), are displayed in Figures 1(M) and 1(F).

Smoothed Historical U.S. Mortality Improvement Rates, 1951–2007

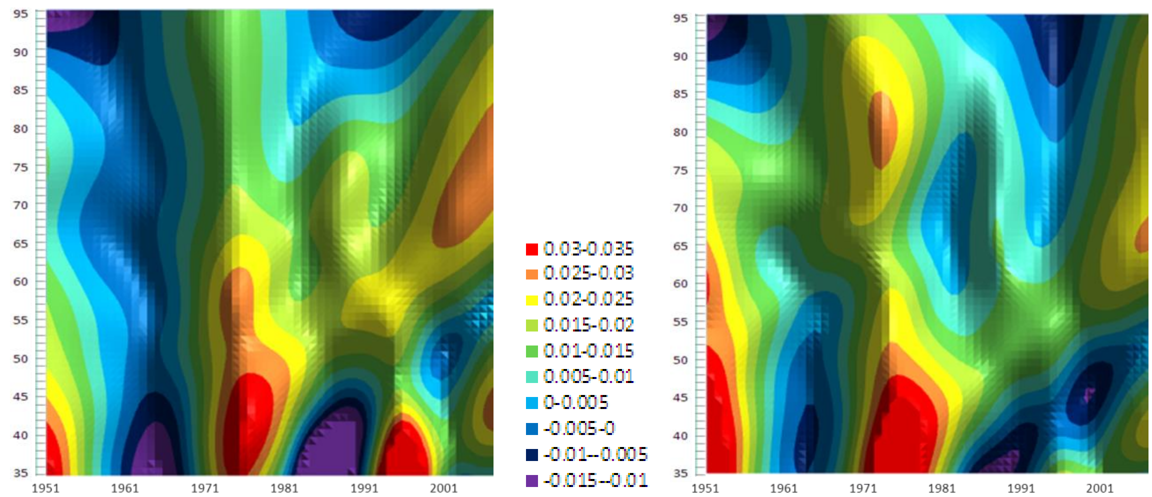

Figure 1(M) Figure 1(F)

Given that the heat maps displayed above come from the same source as Scale BB-2D (i.e., SSA-provided mortality rates, updated to include two additional years of mortality experience), it is not surprising that Figures 1(M) and 1(F) bear a strong resemblance to the corresponding Figures 3(M) and 3(F) in the Scale BB Report. This is despite the fact that the two-dimensional graduation technique used to produce the historical arrays above is not the same as the technique used in the Scale BB Report.

RPEC continues to find heat maps extremely helpful in the identification of various types of historical mortality improvement trends in the United States. For example, vertical patterns of unusually high or low mortality improvement indicate past “period” effects, while diagonal patterns of unusually high or low mortality improvement indicate year-of-birth “cohort” effects. Any “age effects” would show up as horizontal patterns, but given the lack of such patterns in the historical U.S. heat maps, age effects in the United States appear to be minimal relative to period and cohort effects. By their very structure, one-dimensional “age only” scales are unable to project period and cohort effects, which have been the predominant features of U.S. mortality improvement experience over the past 50 years.

It is important to note that the right-hand edges (calendar year 2007) of the surfaces displayed in Figures 1(M) and 1(F) above become the starting points for the smooth interpolations to the assumed long-term mortality improvement rates. The following Figure 2 displays those 2007 values for males and females.

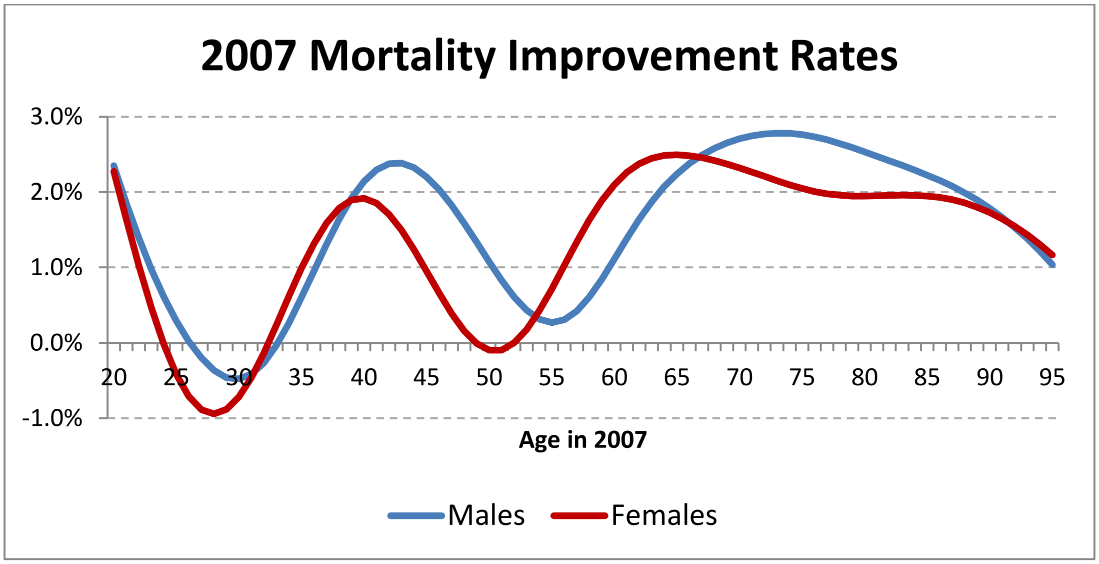

Figure 2

Figure 2 clearly exhibits relatively high levels of mortality improvement for the so-called "silent generation" born between 1925 and 1942. Conversely, Figure 2 shows low levels of mortality improvement for the "baby boom" generation (especially for males born around 1950 and females born around 1955).[12] Figures 1(M) and 1(F) show that these cohort effects have now persisted essentially uninterrupted for at least three decades.

[12] It is not yet clear whether the negative 2007 mortality improvement rates for those born around 1980 represent the start of another cohort with relatively low mortality improvement, or just a temporary aberration caused by the natural fluctuations observed in historical mortality improvement rates at young ages.

3.3 Smooth Transition between the 2007 Rates to the Assumed Long-Term Rates

RPEC sought a relatively straightforward approach that could reflect both age/period effects and cohort effects. The selected methodology utilizes a family of cubic polynomials that reproduce two selected values (one in 2007 and another at the end of the convergence period) and two selected slopes at those years. The initial slope at calendar year 2007 is determined by the change in mortality improvement values between 2006 and 2007 (not less than -0.003 or greater than 0.003),[13] and the slope at the end of the convergence period is always zero. (The Committee considered using a somewhat longer run-up period to determine the slope of the cubic polynomial in 2007, but the smoothness of the graduated historic mortality improvement rates leading up to 2007 rendered this extra step unnecessary.) The general form for this family of cubic polynomials is described in Appendix B; see formula B.1.

For each age 20 through 95, these cubic polynomials are used to interpolate mortality improvement rates over the assumed convergence period in two separate directions: one set of "horizontal" interpolations performed across fixed age paths, and a second set of "diagonal" interpolations performed along fixed year-of-birth paths. For each calendar year in the transition period, the mortality improvement rates at ages over 95 should be calculated by interpolating linearly from the value at age 95 (calculated as in the prior sentence) to a value of zero at age 115.

3.4 Blending of Age/Period and Cohort Projections

The final step of the RPEC_2014 model consists of blending the horizontal and diagonal interpolations described in the prior subsection. The two blending percentages, which must sum to 100 percent, determine the relative balance between anticipated age/period effects (horizontal interpolations) and year-of-birth cohort effects (diagonal interpolations) that will be reflected in the final set of mortality improvement rates.

[13] A very small number of gender/age combinations had initial slopes that were outside of the +/- 0.003 range. RPEC decided to limit the initial slope to a range of +/- 0.003 to minimize near-term volatility in the resulting cubic polynomials.

Section 4. Development of Scale MP-2014

4.1 Overview

Scale MP-2014 was developed using the RPEC_2014 model described in Section 3 above along with a single set of committee-selected, best estimate assumptions regarding:

- The pattern of long-term mortality improvement rates
- The length of the convergence periods
- The relative weightings of horizontal interpolation (for projected age/period effects) and diagonal interpolation (for projected year-of-birth cohort effects)

Each of these assumptions is discussed separately in the following subsections.

4.2 Selection of the Long-Term Rates of Future Mortality Improvement

Long-term averages of U.S. population mortality improvement rates have generally hovered around 1.0 percent per year. For example, between the period 1900 and 2010, the age-sex-adjusted death rate in the United States declined at an average rate of 1.07 percent per year[14], while over the more recent time period covering 1982 through 2010, the total age-sex-adjusted death rate declined at an average rate of 0.95 percent per year [24]. RPEC and OCACT participated in a number of conversations regarding the age-related shape of assumed long-term mortality improvement assumptions. OCACT reflects an "age gradient" in its projections of future mortality rates, i.e., it assumes different levels of mortality improvement based on broad age groupings as shown in Table 3 below.

Every four years, a Technical Panel of outside experts appointed by the Social Security Advisory Board publishes its independent report on the assumptions and methods used by the SSA. The 2007 Technical Panel recommended that the average long-term mortality improvement rate under the intermediate-cost set of assumptions be increased to a flat 1.0 percent, and the 2011 Technical Panel recommended that period life expectancy in 2085 should be 88.7 years, a significant increase over the 85.0 years that was included in the 2011 Trustees Report. One way to achieve such an increase in life expectancy is to assume a flat, long-term rate of improvement of 1.26 percent, though the 2011 Technical Panel made no explicit percentage-based long-term rate recommendations [24, 25, 26]. In its "2013 Long-Term Budget Outlook" report released in September 2013, the Congressional Budget Office increased its long-term mortality improvement rates from the SSA's intermediate-cost assumption set it had used previously up to an average annual rate of 1.17 percent [2].

After considering these and other opinions from experts in the field [16], RPEC concluded that its best estimate for long-term mortality improvement in the United States was a flat rate of 1.0 percent through age 85. Given the long-standing pattern of decreases in historical mortality

[14] It should be noted that, while the overall rate of age-sex-adjusted mortality improvement in the United States has remained close to 1.0 percent when averaged over long periods of time (and all ages,) various sub-periods have exhibited quite dramatic variations in mortality improvement.

improvement rates at advanced ages, RPEC decided to reflect a slight downward gradient from the 1.0 percent rate at 85 to a rate of 0.85 percent at age 95, followed by a steeper decline to 0.0 percent at age 115. The following Table 2 compares the SSA's intermediate-cost long-term rate assumptions[15] used in the 2014 Trustees' Report [30] to those selected by RPEC to construct Scale MP-2014.

Age Band	Long-Term Rate Assumption Sets	
	SSA Intermediate Cost Model; 2010–2088	Scale MP-2014; 2027 and beyond
0–14	1.55%	1.00%
15–49	0.90%	1.00%
50–64	1.10%	1.00%
65–84	0.88%	1.00%
85–94	0.55% for 85+	Linear decrease from 1.00% at age 85 to 0.85% at age 95
95+		Linear decrease from 0.85% at age 95 to 0.00% at age 115

Table 2

For purposes related to retirement programs, RPEC is most interested in the mortality improvement rates over age 50.

4.3 Selection of the Convergence Period

Similar to the underlying CMI framework used to develop Scale BB-2D, the Scale MP-2014 methodology requires selection of an appropriate time frame over which the near-term mortality improvement rates transition smoothly into the long-term rates. RPEC analyzed the impact of a number of different convergence periods. Convergence periods of less than 20 years tended to understate the anticipated continuation of current cohort effects, while convergence periods greater than 20 years produced financial results almost identical to those based on a 20-year convergence period. Therefore, RPEC selected 20-year convergence periods for both the horizontal (age/period) and diagonal (year-of-birth cohort) interpolations. As a result, the committee-selected long-term mortality improvement rates for Scale MP-2014 are fully phased in by calendar year 2027.

4.4 Relative Balance between Projected Age/Period and Projected Cohort Effects

Figures C.1 and C.2 in Appendix C display the 100 percent horizontal heat maps and the 100 percent diagonal heat maps, respectively, reflecting the committee-selected set of long-term rates and 20-year convergence period.

The 100 percent horizontal heat maps clearly do not continue any of the historical year-of-birth cohort effect diagonals beyond 2007. Given that year-of-birth effects for certain age cohorts have persisted in the U.S. population for more than 30 years, RPEC believes that it would be inappropriate not to reflect some continuation of those cohort effects into a two-dimensional array of anticipated mortality improvement factors.

[15] SSA assumed average annual reductions in the age-adjusted central death rates for the period 2010 through 2088 [24].

On the other hand, it is RPEC's opinion that the heat maps based on the 100 percent diagonal interpolations seemed to overemphasize future cohort effects. After reviewing a number of weighting combinations, RPEC concluded that a model based on the simple average of the 100 percent horizontal and the 100 percent diagonal interpolations produced an appropriate balance of anticipated age/period and cohort effects.

4.5 Scale MP-2014 Heat Maps

Heat maps of the final gender-specific Scale MP-2014 rates for calendar years 1951 through 2030 (on the horizontal axis) are displayed below. Given (1) the high degree of volatility in mortality improvement rates at ages below 35 (largely due to the extremely small value of the underlying mortality rates at those ages), and (2) the negligible impact those rates have on most pension-related calculations, RPEC selected 35 as the starting age in the following heat map displays. The dashed white line on each heat map corresponds to the smoothed mortality improvement rates in calendar year 2007 (the starting year of the interpolation period); the thin gray vertical line corresponds to calendar year 2014; and the diagonal dash-dot black line follows the rates for the cohort born in 1935.

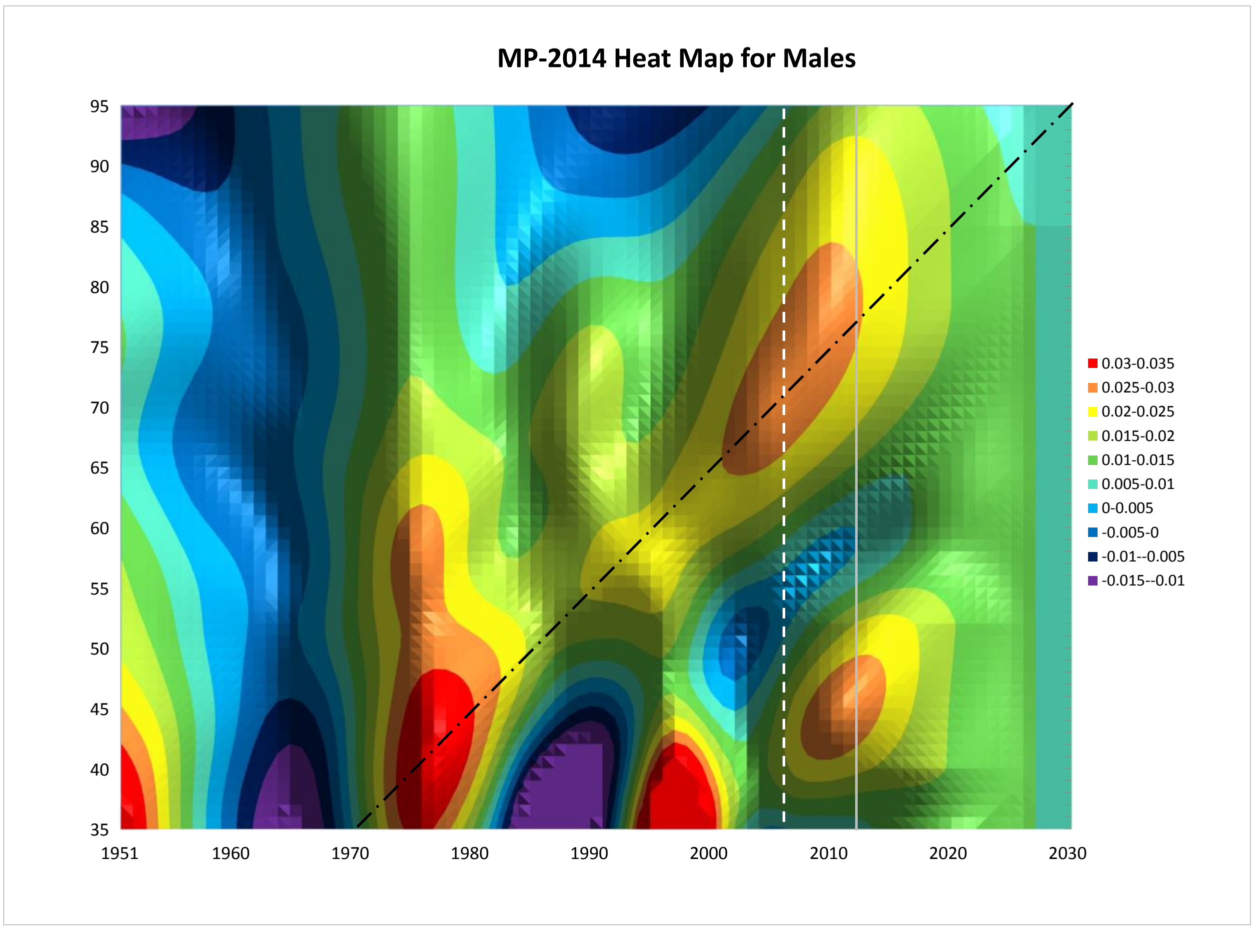

Figure 3(M)

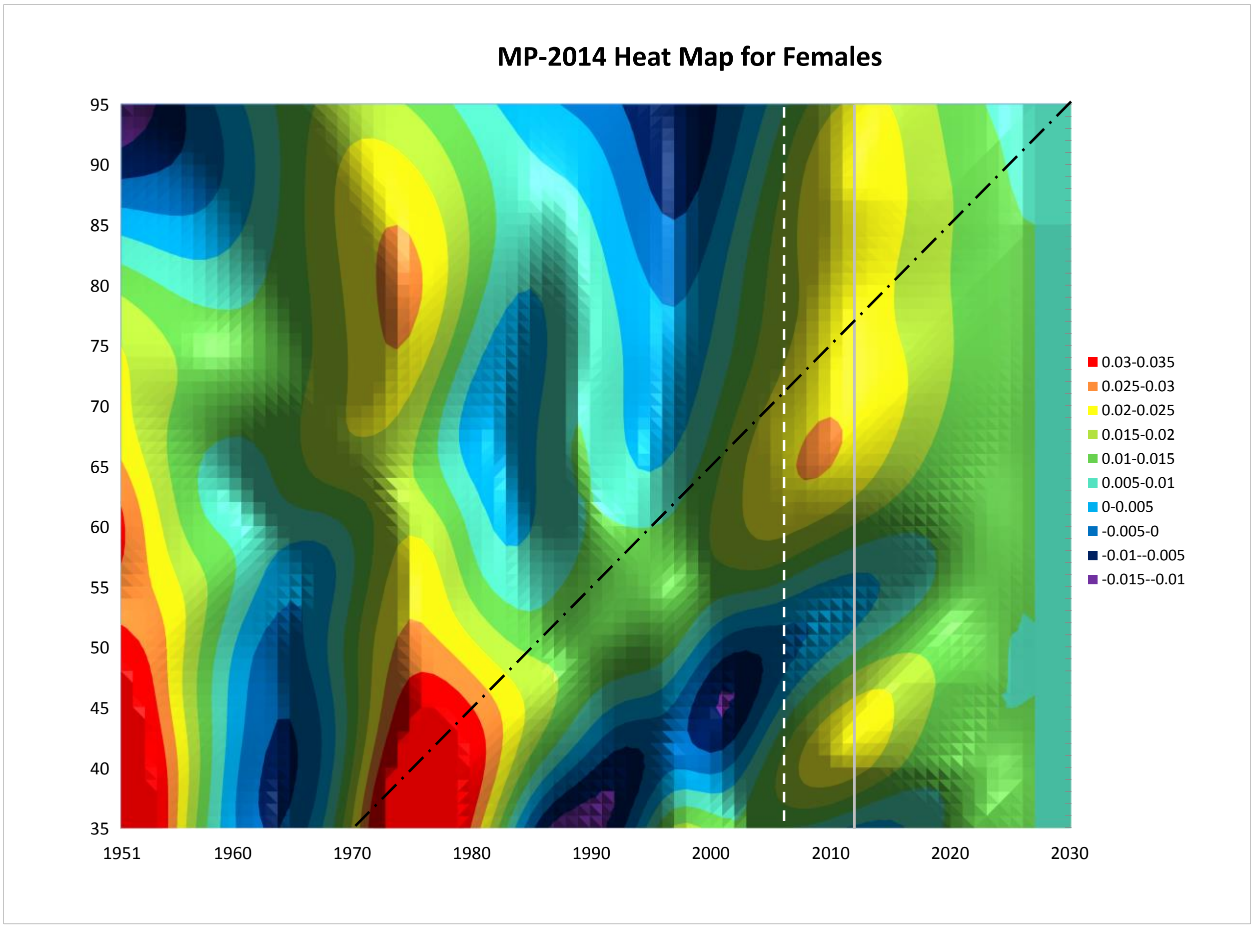

Figure 3(F)

Two-dimensional tables of the gender-specific Scale MP-2014 rates are shown in Appendix A. They are also available in electronic format in the Excel file that accompanies this report (Click [here](#) to access the file on the SOA website).

Section 5. Development of Mortality Projection Scales Based on Alternate Assumption Sets

5.1 Background

As with all forward-looking actuarial assumptions, the selection of future mortality improvement rates involves a certain degree of subjectivity. While RPEC considers the committee-selected set of assumptions underpinning Scale MP-2014 to be its best estimate, the Committee is fully aware that any number of future developments (e.g., medical breakthroughs, environmental changes and societal factors) could result in actual future rates of mortality improvement varying significantly from projected levels.

Actuaries may reasonably conclude that alternative mortality improvement scales, including those developed from assumption sets other than that selected by RPEC for Scale MP-2014, lie within an appropriate assumptions universe[16] for modeling mortality improvement. Accordingly, the RPEC_2014 model described in Section 3 was specifically designed to enable users to develop gender-specific two-dimensional mortality improvement rates based on alternate assumption sets for a variety of purposes, including model assumption sensitivity analysis.

5.2 Review of RPEC_2014 Assumptions and Interpolating Cubic Polynomials

As described in the previous sections, the RPEC_2014 model requires selection of three assumptions:

- A set of gender-/age-specific long-term rates of mortality improvement
- The convergence periods for age/period and year-of-birth cohort effects
- The relative balance between future age/period effects and year-of-birth cohort effects

The committee-selected assumptions for each of these items are described in subsections 4.2, 4.3 and 4.4, respectively.

After the gender-/age-specific long-term rates and convergence period assumptions have been selected, the family of cubic polynomials described by formula B.1 in Appendix B should be used to develop two sets of interpolated rates, one each in the horizontal and diagonal directions.[17] Once both of those two-dimensional sets of rates have been calculated, the final "relative balance" assumption blends the two resulting arrays of rates. The committee-selected assumption set includes blending percentages of 50 percent each for the horizontal and diagonal interpolations. Illustrative sets of heat maps, one based on 100 percent horizontal interpolations and another based on 100 percent on diagonal interpolations, have been included in Appendix C; see Figures C.1 (M)/(F) and C.2 (M)/(F), respectively.[18]

[16] See Section 2.2 of ASOP #35 for a definition of the term "assumption universe."

[17] If the selected convergence periods are both 20 years, then the simpler formula B.2 in Appendix B (with the parameter p set equal to 20) can be used.

[18] Other than the interpolation blending percentages, all other assumptions used to develop Figures C.1 and C.2 are the same as in the committee-selected assumption set.

5.3 Selection of Alternate Assumption Sets

Other than stating its belief that the RPEC_2014 model with committee-selected assumption set represents RPEC's best estimate of future mortality improvement in the US, the Committee does not include any explicit ranges of assumptions that it believes could be considered as an appropriate assumption universe. RPEC directs actuaries to the relevant standards of practice, including ASOP #35 [1], for guidance on the selection of reasonable assumption sets that could be used in connection with the RPEC_2014 model.

Those comments notwithstanding, the Committee cautions users from adopting excessively short convergence periods. RPEC believes that short convergence periods could inappropriately dilute the anticipated impact of near-term mortality improvement trends. The committee-selected 20-year convergence period results in attainment of the long-term rate structure in 2027, which is only 13 years after the base year of the RP-2014 mortality tables.

5.4 Implications of Alternate Assumption Sets on RP-2014 Mortality Tables

Each of the individual gender-/age-specific raw mortality rates in the RP-2014 Report was projected from 2006 (the central year of the data set) to 2014 using the Scale MP-2014 mortality improvement rates. Those who use RPEC_2014 methodology to develop mortality improvement scales based on alternate assumption sets should be aware, therefore, that the base RP-2014 mortality tables implicitly reflect Scale MP-2014 assumptions for years 2007 through 2014. When using projection scales based on alternate assumptions sets, the individual RP-2014 base mortality rates for years after 2006 could be adjusted (if deemed appropriate) by first factoring out the Scale MP-2014 rates for years 2007 through 2014[19], and then applying the alternate projection scale to the resulting 2006 base mortality rates. See subsection 7.3 for the estimated financial impact of this "factoring out" procedure.

5.5 Naming Conventions

The name "Scale MP-2014" should be used exclusively in connection with the mortality improvement based on the RPEC_2014 model using the committee-selected set of assumptions described in Section 4; see Appendix A for the specific rates. Any other set of two-dimensional mortality rates developed in accordance with this Section 5 should be described as being based on the "RPEC_2014 model" and should explicitly identify (1) the assumed gender-specific long-term rates for all ages between 20 and 120; (2) the assumed beginning and ending calendar years for each of the age/period and cohort convergence periods; and (3) the relative weighting percentages for the age/period (horizontal) and year-of-birth cohort (diagonal) interpolations.

[19] This "factoring out" is accomplished by dividing the gender-specific RP-2014 mortality rate at age x by the product of eight terms: $(1-f(x,y))$ for y = 2007, 2008, …, 2014. A table of these adjustment factors (in electronic format) is available in the Excel spreadsheet that accompanies this report.

Section 6. Application of the RPEC_2014 Model and Scale MP-2014

6.1 Recommended Application

Based upon the research summarized in this report, RPEC believes that Scale MP-2014 (or an appropriately parameterized RPEC_2014 model) is a reasonable basis for the projection of future pension-related mortality rates in the United States. Because Scale MP-2014 represents the Committee's current best estimate of future mortality improvement in the United States, RPEC recommends that users carefully consider the committee-selected assumption set described in Section 4. The Committee encourages the application of Scale MP-2014 (or an appropriately parameterized RPEC_2014 model) on a generational basis to all pension-related mortality tables, including those covering disabled lives.

The Committee acknowledges that due to software limitations, some actuaries may require an approximation technique based on a one-dimensional mortality improvement scale. For those situations, a methodology has been developed that enables actuaries to calculate sets of one-dimensional rates[20] that closely approximate near-term annuity values determined using the full two-dimensional set of mortality improvement rates, assuming both sets of annuity values are calculated using generational projection; see subsection 8.3 for additional details.

6.2 Projection of Disabled Retiree Mortality Tables

Performing mortality research on disabled retirement plan participants has always been challenging. Not only are the datasets for disabled lives typically much smaller than those for healthy lives, researchers must contend with the wide range of disablement severity and the diversity of eligibility criteria for plan disability benefits.

The authors of the RP-2000 Report did not perform any detailed analysis of trends in disabled life mortality and, consequently, they did not offer an opinion on the use of mortality improvement for disabled retirees. Analysis performed by OCACT on SSA disabled mortality rates indicated that recent mortality improvement trends for disabled lives in the United States have generally been similar to those for non-disabled lives. The similarity in mortality improvement trends is confirmed on page 41 of the 2012 OASDI Trustees' Report: "Over the last 20 years, the rates of benefit termination [for disabled lives] due to death have declined very gradually, and generally have mirrored the improving mortality experience for the overall population" [29]. This conclusion was consistent with RPEC's comparison of the Disabled Retiree mortality rates included in the RP-2014 Mortality Tables Report[21] to the corresponding rates in the RP-2000 Report.

Being of the opinion that the forces that have driven—and will likely continue to drive—mortality improvement trends for non-disabled lives will result in similar improvements for disabled lives, RPEC believes that it is appropriate to project mortality rates for disabled lives to reflect future improvement. Given the analyses described in the previous paragraph and subject to the standard

[20] It is important to note that the resulting age-specific rates do not represent the actual level of mortality improvement at those ages. They are merely mathematical factors derived from the 2D-to-1D methodology.
[21] See subsection 10.4 of the RP-2014 Mortality Tables Report [20].

materiality criteria alluded to above, RPEC encourages that the RP-2014 Disabled Retiree rates be projected using Scale MP-2014 (or an appropriately parameterized RPEC_2014 model) for years beyond 2014.

6.3 Using the RPEC_2014 Model to Construct Two-Dimensional Mortality Tables

Let $q(x,y)$ represent a specific mortality rate at age x in calendar year y. The projected mortality rate at age x and calendar year $y+1$ under the RPEC_2014 model is calculated as:

$$q(x, y+1) = q(x,y) * (1 - f(x,y+1)),$$

where $f(x, y)$ is the RPEC_2014 mortality improvement rate at age x in calendar year y. Repeating this process recursively for each gender/age combination (starting with the first projection year) produces the two-dimensional tables of future mortality rates. Note that the above formula can also be used "in reverse" to develop mortality rates for years prior to 2014.

Although the projection formula shown above is applied purely horizontally (i.e., along fixed ages), all of the $f(x, y)$ factors for years after the start of the projection period are developed using the "double cubic" interpolation methodology described in Section 3 and, hence, reflect both anticipated age/period and year-of-birth cohort effects.

Applying the above formula to RP-2014 base mortality rates (i.e., with y = 2014) produces a projected set of rates for calendar year 2015. This process is then repeated (one year at a time) to produce a full set of two-dimensional mortality rates at each age and each calendar year beyond 2014. Additional details on the construction of two-dimensional mortality tables (and their application within the context of generational mortality projection) can be found in Q&A C3 in the document titled "Questions and Answers Regarding Mortality Improvement Scale BB," which is available on the SOA website [18].

Section 7. Financial Implications

7.1 Combined Financial Impact of Moving to RP-2014 Projected with Scale MP-2014

Most current pension-related applications in the United States involve projection of RP-2000 (or possibly UP-94) base mortality rates using either Scale AA or Scale BB. Rather than trying to isolate the financial impact of adopting the new mortality improvement scale separately from that of adopting new base mortality rates, RPEC believes that it will be considerably more meaningful for actuaries to consider the combined impact of adopting Scale MP-2014 together with a suitable RP-2014 base mortality table. Table 3 below shows the combined impact on 2014 deferred-to-age-62 annuity values (at 6.0 percent interest) of moving from RP-2000 Combined Healthy (or UP-94) base mortality rates projected generationally using Scales AA, BB and MP-2014 to RP-2014 base mortality rates[22] projected generationally using Scale MP-2014.

		Monthly Deferred-to-62 Annuity Due Values Generational @ 2014					*Percentage Change of Moving to RP-2014 (with MP-2014) from:*			
	Base Rates	UP-94	RP-2000	RP-2000	RP-2000	RP-2014	UP-94	RP-2000	RP-2000	RP-2000
	Proj. Scale	AA	AA	BB	MP-2014	MP-2014	AA	AA	BB	MP-2014
	Age									
Males	25	1.3944	1.4029	1.4135	1.4324	**1.4379**	*3.1%*	*2.5%*	*1.7%*	*0.4%*
	35	2.4577	2.4688	2.4881	2.5259	**2.5363**	*3.2%*	*2.7%*	*1.9%*	*0.4%*
	45	4.3316	4.3569	4.3963	4.4662	**4.4770**	*3.4%*	*2.8%*	*1.8%*	*0.2%*
	55	7.6981	7.7400	7.8408	7.9735	**7.9755**	*3.6%*	*3.0%*	*1.7%*	*0.0%*
	65	11.0033	10.9891	11.2209	11.5053	**11.4735**	*4.3%*	*4.4%*	*2.3%*	*-0.3%*
	75	8.0551	7.8708	8.2088	8.5842	**8.6994**	*8.0%*	*10.5%*	*6.0%*	*1.3%*
	85	4.9888	4.6687	5.0048	5.2978	**5.4797**	*9.8%*	*17.4%*	*9.5%*	*3.4%*
Females	25	1.4336	1.4060	1.4816	1.5097	**1.5195**	*6.0%*	*8.1%*	*2.6%*	*0.6%*
	35	2.5465	2.4931	2.6145	2.6666	**2.6853**	*5.5%*	*7.7%*	*2.7%*	*0.7%*
	45	4.5337	4.4340	4.6264	4.7198	**4.7497**	*4.8%*	*7.1%*	*2.7%*	*0.6%*
	55	8.1245	7.9541	8.2532	8.4373	**8.4544**	*4.1%*	*6.3%*	*2.4%*	*0.2%*
	65	11.7294	11.4644	11.8344	12.1437	**12.0932**	*3.1%*	*5.5%*	*2.2%*	*-0.4%*
	75	8.9849	8.6971	9.0649	9.4045	**9.3996**	*4.6%*	*8.1%*	*3.7%*	*-0.1%*
	85	5.7375	5.5923	5.9525	6.2910	**6.1785**	*7.7%*	*10.5%*	*3.8%*	*-1.8%*

Table 3

Similar tables of annuity value comparison calculated at other interest rates (0 percent, 4 percent and 8 percent) can be found in Appendix D of the RP-2014 Mortality Tables Report.

[22] RP-2014 Employee rates to age 61 and RP-2014 Healthy Annuitant rates for ages 62 and older.

7.2 Impact of Scale MP-2014 on Cohort Life Expectancy

Table 4 below displays the impact of projecting future mortality improvement using Scale MP-2014 relative to scales AA, BB and BB-2D on age-65 cohort life expectancies (all based on RP-2014 Healthy Annuitant mortality rates).

	Age-65 Cohort Life Expectancy in 2014				*Impact of Change From:*		
	AA	BB	BB-2D	MP-2014	*AA*	*BB*	*BB-2D*
Males	20.9	21.6	21.3	21.6	*3.4%*	*0.3%*	*1.6%*
Females	22.6	23.4	23.4	23.8	*5.2%*	*1.7%*	*1.7%*

Table 4

Table 5 below compares how age-65 cohort life expectancy is projected to change between 2015 and 2035 under two sets of current SSA mortality assumptions (intermediate cost and high cost) [30] and the new SOA pension mortality assumptions described in both the RP-2014 Report and this report.

Comparison of Projected Age-65 Cohort Life Expectancy; 2015 to 2035						
	Males			Females		
Basis	2015	2035	*Change*	2015	2035	*Change*
SSA Intermediate Cost	19.3	20.7	***1.4***	21.6	22.8	***1.2***
SSA High Cost	20.2	22.2	***2.0***	22.4	24.2	***1.8***
RP-2014/MP-2014	21.7	23.4	***1.7***	23.9	25.6	***1.7***

Table 5

The fact that the age-65 cohort life expectancies projected under the new set of SOA pension mortality assumptions are greater than both sets of corresponding SSA results is not surprising, given the well-established pattern of lower mortality rates among retirement program participants compared to those of the general U.S. population. The projected 20-year increase in age-65 cohort life expectancies based on RP-2014 Healthy Annuitant base rates projected using Scale MP-2014 ended up falling between the intermediate- and high-cost sets of SSA assumptions.

7.3 Sensitivity of RPEC_2014 Model to Alternate Long-Term Rate Assumptions

Table 6 below displays the sensitivity of 2014 immediate monthly deferred-to-age-62 annuity values (based on the same RP-2014 base mortality rates used in Table 3 and an interest rate of 6.0 percent) to two alternate sets of long-term rate assumptions. The first column of annuity values is based on Scale MP-2014, whereas the second and third columns are based on sets of long-term rates in which each rate is 0.75 or 1.25 times the committee-selected value upon which Scale MP-2014 was based. These last two columns are labeled "0.75 x LTR" and "1.25 x LTR," respectively. It is important to note that the alternate long-term rate assumptions in Table 6 are shown for illustration purposes only and, as such, should not be construed as a recommended range for such assumptions.[23] The other Scale MP-2014 assumptions (i.e., the 20-year convergence periods and

[23] In fact, an assumed long-term rate of 0.75 percent would be lower than the rate assumed by the SSA for their intermediate-cost projections for all ages under 85; see Table 2.

50/50 blend of horizontal and diagonal projections) have been left unchanged, and the underlying base mortality rates are RP-2014 Employee rates for ages up to 61, and RP-2014 Healthy Annuitant rates for ages 62 and above.

		Monthly Deferred-to-62 Annuity Due Values Generational @ 2014			***Percentage Change from RP-2014/MP-2014***	
	Basic Rates	RP-2014	RP-2014	RP-2014	RP-2014	RP-2014
	Proj. Scale	MP-2014	0.75 x LTR	1.25 x LTR	0.75 x LTR	1.25 x LTR
Males	25	1.4379	1.4078	1.4669	-2.1%	2.0%
	35	2.5363	2.4935	2.5782	-1.7%	1.7%
	45	4.4770	4.4212	4.5321	-1.2%	1.2%
	55	7.9755	7.9134	8.0375	-0.8%	0.8%
	65	11.4735	11.4183	11.5288	-0.5%	0.5%
	75	8.6994	8.6628	8.7363	-0.4%	0.4%
	85	5.4797	5.4654	5.4941	-0.3%	0.3%
Females	25	1.5195	1.4930	1.5449	-1.7%	1.7%
	35	2.6853	2.6468	2.7225	-1.4%	1.4%
	45	4.7497	4.6985	4.8000	-1.1%	1.1%
	55	8.4544	8.3947	8.5137	-0.7%	0.7%
	65	12.0932	12.0374	12.1491	-0.5%	0.5%
	75	9.3996	9.3601	9.4392	-0.4%	0.4%
	85	6.1785	6.1617	6.1956	-0.3%	0.3%

Table 6

These results are consistent with the long-term rate sensitivity analyses performed by the Continuous Mortality Investigation (CMI) group on their current model [4].

The 2014 annuity values shown in Table 7 are developed in the same way as in Table 6, except for the fact that the underlying base mortality rates have been adjusted in accordance with the "factoring out" methodology described in subsection 5.3. For example, the "adjusted RP-2014" base mortality rates used to develop the monthly annuity values in the "0.75 x LTR" column reflect the process of factoring out the Scale MP-2014 mortality improvement rates between 2006 and 2014, followed by application of the "0.75 x LTR" mortality improvement rates starting in calendar year 2006.

	Basic Rates Proj. Scale	RP-2014 MP-2014	Adjusted RP-2014 0.75 x LTR	Adjusted RP-2014 1.25 x LTR	Adjusted RP-2014 0.75 x LTR	Adjusted RP-2014 1.25 x LTR
		Monthly Deferred-to-62 Annuity Due Values Generational @ 2014			***Percentage Change from RP-2014/MP-2014***	
Males	25	1.4379	1.4072	1.4675	-2.1%	2.1%
	35	2.5363	2.4924	2.5792	-1.7%	1.7%
	45	4.4770	4.4193	4.5339	-1.3%	1.3%
	55	7.9755	7.9100	8.0408	-0.8%	0.8%
	65	11.4735	11.4134	11.5337	-0.5%	0.5%
	75	8.6994	8.6574	8.7417	-0.5%	0.5%
	85	5.4797	5.4610	5.4986	-0.3%	0.3%
Females	25	1.5195	1.4925	1.5454	-1.8%	1.7%
	35	2.6853	2.6460	2.7234	-1.5%	1.4%
	45	4.7497	4.6968	4.8016	-1.1%	1.1%
	55	8.4544	8.3919	8.5165	-0.7%	0.7%
	65	12.0932	12.0330	12.1535	-0.5%	0.5%
	75	9.3996	9.3550	9.4444	-0.5%	0.5%
	85	6.1785	6.1571	6.2001	-0.3%	0.3%

Table 7

It is worth noting that the annuity values in Table 7 differ from their corresponding values in Table 6 by less than one-tenth of 1 percent[24]. Therefore, RPEC anticipates that many users will conclude that the additional effort required to adjust RP-2014 base rates for alternate Scale MP-2014 assumption sets is not warranted.

[24] Comparing the age 65 male annuity values under the "0.75 x LTR" scenario, for example, the value of 11.4134 in Table 7 is 0.04% less than the corresponding value of 11.4183 in Table 6.

Section 8. Other Considerations

8.1 Mortality Improvement Rate Adjustments Based on Socioeconomic Factors

A number of studies have identified variations in recent U.S. mortality improvement trends linked to one or more proxies for socioeconomic status. A 2008 study, for example, found quite significant differences in mortality improvement by education levels among various subpopulations in the United States between 1993 and 2001 [11]. Although RPEC considers these studies very interesting, the Committee is of the opinion that there are two major shortcomings that have limited the current utility of this research for pension-related purposes.

The first is that the proxies for socioeconomic status (such as education level or ethnicity) are not ones that could be readily implemented in most pension-related applications. The second is that the Committee is not aware of any research that has considered the future "shape" of differences in mortality improvement by any proxy for socioeconomic status. For example, how long are the recently observed variations by education level expected to persist—and might they eventually reverse?

In contrast to socioeconomic variations in mortality improvement rates, differences in base mortality rates have been well-documented in the United States for decades. So, while the Committee continues to strongly recommend that users select the most appropriate RP-2014 tables based on their specific knowledge of the covered population, RPEC is of the opinion that the science of mortality improvement is not yet sufficiently developed for the Committee to encourage the application of different mortality improvement trend rates for different pension plan populations.

8.2 Methodology for One-Dimensional Approximations

RPEC believes that two-dimensional mortality improvement scales are considerably superior to one-dimensional versions. In particular, two-dimensional models are able to reflect the relatively high rates of improvement that have been experienced of late without being bound to continue them indefinitely. However, RPEC recognizes that not all actuaries will have immediate access to software that can handle the two-dimensional improvement methodology. Therefore, Bob Howard, a current member of RPEC, developed an Excel workbook[25] that can be used to calculate one-dimensional improvement scales that approximate Scale MP-2014. The resulting annuity values may often be considered close enough to those produced by Scale MP-2014 that the one-dimensional approximation could potentially be used in valuations. Whether the approximate scale is suitable in any particular application is a matter of actuarial judgment.

The resulting one-dimensional scale should not be considered an independently reasonable scale of age-specific mortality improvement rates; it should be treated as a table that reproduces certain annuity values (based on Scale MP-2014 projected generationally) at a specific interest rate as of a given point in time. The one-dimensional scale might not be appropriate for use with any base

[25] The required inputs to the workbook are: (1) the selection of a set of RP-2014 base rates; (2) the "as of" date of annuity value approximation; (3) the selection of an interest rate structure; and (4) the type of annuity upon which the matching process is based.

mortality table other than those contained in the RP-2014 Report and it is not appropriate for any mortality table that has a base year other than 2014.

The workbook's underlying 2D-to-1D methodology is based on the recursive application of the following basic life contingency formula, where I_x denotes the one-dimensional approximation at age x:

$$a_{x,2d}^{2015} = a_{x,1d}^{2015} = vp_{x,1d}^{2015}\ddot{a}_{x+1,1d}^{2016} = (1 - q_x^{base}(1 - I_x))v\ddot{a}_{x+1,1d}^{2016}$$

Because the Scale MP-2014 improvement rates are all zero over age 115, it is obvious that the one-dimensional scale will also be zero at those ages. The first non-zero improvement rate will be the two-dimensional rate for age 114 in 2015. Once the value of I_{x+1} is known, the value of I_x can be determined recursively since I_x is the only remaining unknown.

This methodology works perfectly for single-life annuities in the "as of" year of approximation using the assumed interest rate structure. However, the results produced by the one-dimensional scale start to become less precise for years beyond the "as of" date, for changes in interest rate structure, and for payment forms other than immediate single-life annuities.

8.3 Entry Age Cost Method

Entry Age is one of a number of cost methods that require an assumption regarding mortality rates for periods of time prior to the measurement date, and often prior to the base year of the assumed mortality table. Users should consult item B9 in the Scale BB Q&A document [18] for a suggested approach for handling two-dimensional mortality improvement in an Entry Age valuation. In particular, RPEC continues to believe that it would not be unreasonable for users to assume flat mortality improvement rates of 2.0 percent per annum for males and 3.0 percent per annum for females for all calendar years prior to 1951.

8.4 More Frequent Updates

One important feature of the new methodology used to develop Scale MP-2014 is the ease with which it can be updated. RPEC anticipates that this updating process be performed at least triennially, at which point the latest SSA mortality data would be integrated and the committee-selected assumption set reviewed for continued appropriateness. The name of successive updates would reflect the year of the update; e.g., a new scale released in 2017 would be called Scale MP-2017.

8.5 Backtesting of the Model

The Committee conducted an informal backtest of the model by developing a series of heat maps using the RPEC_2014 methodology along with the committee-selected assumption set, but limiting the historical SSA mortality data to certain calendar years earlier than the 2009 SSA dataset used to develop Scale MP-2014. For example, one heat map is based on historical SSA data only through 2000, to which the Committee applied the RPEC_2014 methodology and committee-selected assumption set. Taking the 2-year look back and twenty-year convergence periods into consideration, this produces a heat map with interpolations that begin in 1998 and end in 2018.

Given RPEC's expectation that these mortality improvement rates will be updated on a triennial basis, the Committee produced backtesting heat maps reflecting SSA datasets through calendar years 2000, 2003, and 2006. These heat maps, along with the Scale MP-2014 heat maps, are shown as the following figures in Appendix C.

- Figure C.3: Males; SSA data through 2000; 20-year interpolations starting in 1998
- Figure C.4: Males; SSA data through 2003; 20-year interpolations starting in 2001
- Figure C.5: Males; SSA data through 2006; 20-year interpolations starting in 2004
- Figure C.6: Males; Scale MP-2014[26]
- Figure C.7: Females; SSA data through 2000; 20-year interpolations starting in 1998
- Figure C.8: Females; SSA data through 2003; 20-year interpolations starting in 2001
- Figure C.9: Females; SSA data through 2006; 20-year interpolations starting in 2004
- Figure C.10: Females; Scale MP-2014

This backtesting exercise shows that the same general patterns appear over all four tests, for both males and females. In particular, the distinctive diagonal patterns of year-of-birth cohort effects seem reasonably well established in the earliest set of backtesting heat maps (based on SSA data through 2000,) with those diagonal patterns becoming more well-defined in successive updates. In comparing successive tests, most of the mortality improvement rates change little, but there can be material differences in rates in the few years after that last year of history common to both.[27] The biggest changes are between tests for 2003 and 2006 (a period during which many U.S. mortality improvement rates began to trend upward quite significantly) and most prominently at ages below 40 (ages for which historical mortality improvement rates have tended to be more volatile.)

[26] SSA data through 2009; 20-year interpolations from 2007

[27] Comparing figures C.3 and C.4, for example, the most significant changes tend to appear in the calendars years immediately following 2000.

Appendix A: Scale MP-2014 Rates

The gender-specific Scale MP-2014 rates for calendar years 2000 and beyond are displayed in this Appendix A. These rates, as well as those for calendar years starting in 1951 (e.g., for use in conjunction with Entry Age cost methods), are available in electronic format in the Excel file that accompanies this report.

Male	Calendar Year														
Age	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
≤ 20	0.0105	0.0025	-0.0033	-0.0058	-0.0044	0.0012	0.0107	0.0235	0.0261	0.0280	0.0292	0.0298	0.0298	0.0294	0.0286
21	0.0069	-0.0015	-0.0075	-0.0101	-0.0089	-0.0035	0.0059	0.0185	0.0236	0.0256	0.0268	0.0275	0.0277	0.0274	0.0268
22	0.0043	-0.0046	-0.0111	-0.0140	-0.0129	-0.0077	0.0015	0.0139	0.0189	0.0233	0.0247	0.0255	0.0258	0.0257	0.0251
23	0.0030	-0.0068	-0.0138	-0.0172	-0.0164	-0.0114	-0.0024	0.0098	0.0146	0.0189	0.0227	0.0236	0.0240	0.0240	0.0236
24	0.0029	-0.0078	-0.0156	-0.0195	-0.0191	-0.0144	-0.0057	0.0061	0.0107	0.0149	0.0187	0.0220	0.0225	0.0226	0.0223
25	0.0042	-0.0076	-0.0163	-0.0209	-0.0211	-0.0167	-0.0084	0.0029	0.0073	0.0113	0.0150	0.0183	0.0212	0.0213	0.0212
26	0.0069	-0.0061	-0.0158	-0.0212	-0.0220	-0.0182	-0.0104	0.0002	0.0044	0.0082	0.0118	0.0151	0.0179	0.0203	0.0202
27	0.0106	-0.0034	-0.0141	-0.0204	-0.0219	-0.0189	-0.0118	-0.0020	0.0019	0.0056	0.0091	0.0122	0.0150	0.0175	0.0194
28	0.0153	0.0004	-0.0112	-0.0184	-0.0208	-0.0186	-0.0125	-0.0036	0.0000	0.0035	0.0068	0.0098	0.0126	0.0150	0.0170
29	0.0203	0.0048	-0.0075	-0.0154	-0.0186	-0.0173	-0.0123	-0.0046	-0.0013	0.0019	0.0051	0.0080	0.0107	0.0130	0.0150
30	0.0253	0.0095	-0.0033	-0.0116	-0.0155	-0.0151	-0.0112	-0.0048	-0.0019	0.0010	0.0039	0.0067	0.0092	0.0115	0.0135
31	0.0297	0.0140	0.0012	-0.0074	-0.0117	-0.0121	-0.0093	-0.0042	-0.0017	0.0009	0.0035	0.0060	0.0083	0.0105	0.0124
32	0.0332	0.0179	0.0055	-0.0030	-0.0074	-0.0085	-0.0066	-0.0026	-0.0006	0.0015	0.0037	0.0059	0.0080	0.0100	0.0118
33	0.0354	0.0210	0.0093	0.0013	-0.0030	-0.0044	-0.0032	-0.0003	0.0013	0.0029	0.0046	0.0064	0.0082	0.0099	0.0115
34	0.0365	0.0230	0.0123	0.0052	0.0013	-0.0001	0.0005	0.0026	0.0035	0.0044	0.0054	0.0066	0.0079	0.0092	0.0105
35	0.0364	0.0241	0.0146	0.0084	0.0051	0.0040	0.0044	0.0060	0.0064	0.0067	0.0071	0.0077	0.0085	0.0094	0.0104
36	0.0353	0.0242	0.0159	0.0108	0.0083	0.0076	0.0082	0.0096	0.0098	0.0097	0.0097	0.0097	0.0100	0.0105	0.0111
37	0.0335	0.0235	0.0164	0.0123	0.0107	0.0107	0.0116	0.0131	0.0134	0.0132	0.0129	0.0125	0.0123	0.0123	0.0125
38	0.0311	0.0222	0.0161	0.0131	0.0123	0.0130	0.0145	0.0164	0.0169	0.0169	0.0164	0.0158	0.0152	0.0147	0.0145
39	0.0282	0.0204	0.0153	0.0131	0.0131	0.0146	0.0167	0.0192	0.0202	0.0204	0.0200	0.0193	0.0184	0.0176	0.0168
40	0.0251	0.0182	0.0139	0.0125	0.0133	0.0154	0.0183	0.0214	0.0229	0.0235	0.0233	0.0226	0.0216	0.0204	0.0193
41	0.0218	0.0158	0.0123	0.0116	0.0130	0.0157	0.0192	0.0230	0.0248	0.0256	0.0256	0.0249	0.0237	0.0223	0.0209
42	0.0183	0.0132	0.0105	0.0103	0.0123	0.0155	0.0195	0.0238	0.0260	0.0271	0.0273	0.0267	0.0256	0.0240	0.0224
43	0.0147	0.0106	0.0085	0.0089	0.0113	0.0149	0.0193	0.0238	0.0264	0.0279	0.0284	0.0280	0.0270	0.0255	0.0237
44	0.0113	0.0079	0.0065	0.0073	0.0100	0.0139	0.0184	0.0232	0.0261	0.0280	0.0288	0.0287	0.0279	0.0265	0.0247
45	0.0083	0.0053	0.0044	0.0055	0.0084	0.0124	0.0171	0.0220	0.0252	0.0274	0.0286	0.0289	0.0283	0.0271	0.0255
46	0.0057	0.0030	0.0023	0.0036	0.0066	0.0106	0.0154	0.0203	0.0238	0.0263	0.0279	0.0285	0.0283	0.0273	0.0259
47	0.0037	0.0011	0.0003	0.0015	0.0045	0.0085	0.0133	0.0182	0.0219	0.0247	0.0266	0.0276	0.0277	0.0271	0.0259
48	0.0025	-0.0004	-0.0014	-0.0005	0.0023	0.0063	0.0109	0.0159	0.0197	0.0227	0.0249	0.0262	0.0267	0.0265	0.0256
49	0.0021	-0.0012	-0.0027	-0.0021	0.0003	0.0041	0.0086	0.0133	0.0171	0.0204	0.0229	0.0246	0.0254	0.0256	0.0250
50	0.0024	-0.0012	-0.0032	-0.0032	-0.0012	0.0021	0.0063	0.0108	0.0145	0.0178	0.0206	0.0227	0.0238	0.0243	0.0241
51	0.0035	-0.0005	-0.0029	-0.0034	-0.0020	0.0008	0.0044	0.0083	0.0119	0.0152	0.0180	0.0205	0.0221	0.0229	0.0230
52	0.0051	0.0010	-0.0017	-0.0027	-0.0019	0.0001	0.0030	0.0061	0.0095	0.0127	0.0156	0.0181	0.0201	0.0213	0.0218
53	0.0071	0.0032	0.0004	-0.0010	-0.0009	0.0003	0.0022	0.0043	0.0070	0.0098	0.0124	0.0148	0.0168	0.0184	0.0193
54	0.0094	0.0059	0.0032	0.0015	0.0010	0.0012	0.0021	0.0032	0.0049	0.0070	0.0093	0.0115	0.0134	0.0150	0.0164
55	0.0117	0.0088	0.0063	0.0046	0.0035	0.0029	0.0027	0.0027	0.0034	0.0048	0.0066	0.0085	0.0104	0.0120	0.0134
56	0.0141	0.0117	0.0096	0.0078	0.0063	0.0051	0.0040	0.0031	0.0028	0.0033	0.0045	0.0061	0.0078	0.0094	0.0109
57	0.0163	0.0144	0.0127	0.0110	0.0093	0.0076	0.0059	0.0042	0.0031	0.0028	0.0033	0.0045	0.0060	0.0075	0.0090
58	0.0183	0.0169	0.0154	0.0139	0.0122	0.0103	0.0082	0.0061	0.0043	0.0033	0.0031	0.0037	0.0049	0.0063	0.0078
59	0.0200	0.0190	0.0178	0.0165	0.0149	0.0129	0.0108	0.0084	0.0063	0.0047	0.0039	0.0039	0.0046	0.0057	0.0071
60	0.0215	0.0207	0.0198	0.0187	0.0173	0.0155	0.0134	0.0111	0.0088	0.0069	0.0055	0.0049	0.0050	0.0058	0.0069
61	0.0226	0.0221	0.0215	0.0206	0.0194	0.0179	0.0160	0.0138	0.0116	0.0095	0.0078	0.0066	0.0061	0.0064	0.0071
62	0.0234	0.0232	0.0228	0.0222	0.0213	0.0200	0.0184	0.0164	0.0144	0.0123	0.0104	0.0088	0.0078	0.0074	0.0077
63	0.0240	0.0241	0.0239	0.0235	0.0229	0.0219	0.0205	0.0187	0.0169	0.0150	0.0131	0.0113	0.0099	0.0089	0.0086
64	0.0242	0.0246	0.0248	0.0247	0.0243	0.0235	0.0223	0.0207	0.0191	0.0174	0.0156	0.0138	0.0121	0.0107	0.0099

Male	Calendar Year												
Age	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027+**
≤ 20	0.0274	0.0259	0.0242	0.0224	0.0205	0.0186	0.0167	0.0149	0.0133	0.0120	0.0109	0.0102	0.0100
21	0.0258	0.0245	0.0230	0.0214	0.0196	0.0179	0.0162	0.0145	0.0131	0.0118	0.0109	0.0102	0.0100
22	0.0243	0.0232	0.0219	0.0204	0.0188	0.0172	0.0157	0.0142	0.0128	0.0117	0.0108	0.0102	0.0100
23	0.0229	0.0220	0.0208	0.0195	0.0181	0.0167	0.0152	0.0139	0.0126	0.0116	0.0107	0.0102	0.0100
24	0.0218	0.0209	0.0199	0.0187	0.0175	0.0161	0.0148	0.0136	0.0124	0.0114	0.0107	0.0102	0.0100
25	0.0207	0.0200	0.0191	0.0181	0.0169	0.0157	0.0145	0.0133	0.0123	0.0113	0.0106	0.0102	0.0100
26	0.0198	0.0192	0.0184	0.0175	0.0164	0.0153	0.0142	0.0131	0.0121	0.0113	0.0106	0.0102	0.0100
27	0.0191	0.0186	0.0179	0.0170	0.0160	0.0150	0.0139	0.0129	0.0120	0.0112	0.0106	0.0102	0.0100
28	0.0186	0.0181	0.0175	0.0167	0.0157	0.0148	0.0138	0.0128	0.0119	0.0111	0.0105	0.0101	0.0100
29	0.0167	0.0179	0.0172	0.0164	0.0156	0.0146	0.0137	0.0127	0.0119	0.0111	0.0105	0.0101	0.0100
30	0.0151	0.0164	0.0172	0.0164	0.0155	0.0146	0.0136	0.0127	0.0119	0.0111	0.0105	0.0101	0.0100
31	0.0140	0.0152	0.0161	0.0165	0.0156	0.0147	0.0137	0.0128	0.0119	0.0111	0.0105	0.0101	0.0100
32	0.0133	0.0145	0.0153	0.0158	0.0159	0.0149	0.0139	0.0129	0.0120	0.0112	0.0106	0.0101	0.0100
33	0.0128	0.0139	0.0147	0.0152	0.0153	0.0151	0.0140	0.0130	0.0120	0.0112	0.0106	0.0102	0.0100
34	0.0117	0.0128	0.0135	0.0140	0.0143	0.0142	0.0139	0.0129	0.0119	0.0112	0.0105	0.0101	0.0100
35	0.0114	0.0123	0.0129	0.0134	0.0136	0.0136	0.0134	0.0129	0.0120	0.0112	0.0105	0.0101	0.0100
36	0.0117	0.0124	0.0129	0.0133	0.0134	0.0134	0.0131	0.0127	0.0121	0.0112	0.0106	0.0102	0.0100
37	0.0128	0.0131	0.0134	0.0136	0.0136	0.0135	0.0132	0.0127	0.0121	0.0114	0.0106	0.0102	0.0100
38	0.0143	0.0143	0.0143	0.0143	0.0141	0.0138	0.0134	0.0128	0.0121	0.0114	0.0107	0.0102	0.0100
39	0.0163	0.0158	0.0155	0.0151	0.0148	0.0143	0.0137	0.0130	0.0122	0.0114	0.0107	0.0102	0.0100
40	0.0182	0.0174	0.0167	0.0160	0.0154	0.0147	0.0140	0.0132	0.0123	0.0115	0.0108	0.0102	0.0100
41	0.0195	0.0183	0.0172	0.0163	0.0155	0.0147	0.0139	0.0131	0.0122	0.0114	0.0107	0.0102	0.0100
42	0.0207	0.0191	0.0178	0.0166	0.0156	0.0147	0.0138	0.0130	0.0121	0.0114	0.0107	0.0102	0.0100
43	0.0218	0.0200	0.0184	0.0169	0.0157	0.0146	0.0137	0.0128	0.0120	0.0113	0.0106	0.0102	0.0100
44	0.0228	0.0208	0.0190	0.0173	0.0159	0.0146	0.0136	0.0127	0.0119	0.0112	0.0106	0.0102	0.0100
45	0.0236	0.0215	0.0195	0.0177	0.0161	0.0147	0.0136	0.0126	0.0118	0.0111	0.0105	0.0102	0.0100
46	0.0241	0.0220	0.0200	0.0180	0.0163	0.0148	0.0135	0.0125	0.0117	0.0110	0.0105	0.0101	0.0100
47	0.0243	0.0224	0.0203	0.0183	0.0165	0.0149	0.0136	0.0125	0.0116	0.0110	0.0105	0.0101	0.0100
48	0.0242	0.0225	0.0206	0.0186	0.0167	0.0150	0.0136	0.0125	0.0116	0.0109	0.0104	0.0101	0.0100
49	0.0239	0.0224	0.0206	0.0188	0.0169	0.0152	0.0137	0.0125	0.0116	0.0109	0.0104	0.0101	0.0100
50	0.0233	0.0221	0.0205	0.0188	0.0170	0.0153	0.0138	0.0126	0.0116	0.0109	0.0104	0.0101	0.0100
51	0.0226	0.0216	0.0203	0.0188	0.0171	0.0154	0.0139	0.0127	0.0116	0.0109	0.0104	0.0101	0.0100
52	0.0217	0.0210	0.0200	0.0186	0.0171	0.0155	0.0141	0.0128	0.0117	0.0109	0.0104	0.0101	0.0100
53	0.0195	0.0192	0.0185	0.0175	0.0162	0.0149	0.0136	0.0125	0.0115	0.0108	0.0103	0.0101	0.0100
54	0.0170	0.0171	0.0167	0.0160	0.0151	0.0141	0.0131	0.0121	0.0113	0.0107	0.0103	0.0101	0.0100
55	0.0145	0.0150	0.0150	0.0146	0.0140	0.0133	0.0125	0.0117	0.0111	0.0106	0.0102	0.0100	0.0100
56	0.0121	0.0130	0.0134	0.0134	0.0131	0.0126	0.0120	0.0114	0.0109	0.0105	0.0102	0.0100	0.0100
57	0.0103	0.0113	0.0121	0.0125	0.0124	0.0121	0.0117	0.0113	0.0108	0.0104	0.0102	0.0100	0.0100
58	0.0091	0.0102	0.0111	0.0117	0.0120	0.0118	0.0116	0.0112	0.0108	0.0104	0.0102	0.0100	0.0100
59	0.0084	0.0096	0.0105	0.0112	0.0117	0.0118	0.0116	0.0112	0.0109	0.0105	0.0102	0.0101	0.0100
60	0.0082	0.0094	0.0103	0.0110	0.0115	0.0117	0.0117	0.0113	0.0110	0.0106	0.0103	0.0101	0.0100
61	0.0082	0.0093	0.0103	0.0110	0.0115	0.0117	0.0117	0.0115	0.0111	0.0107	0.0103	0.0101	0.0100
62	0.0084	0.0094	0.0103	0.0110	0.0115	0.0117	0.0117	0.0116	0.0112	0.0108	0.0104	0.0101	0.0100
63	0.0089	0.0095	0.0103	0.0110	0.0115	0.0117	0.0117	0.0116	0.0113	0.0108	0.0104	0.0101	0.0100
64	0.0096	0.0098	0.0103	0.0109	0.0114	0.0116	0.0117	0.0115	0.0112	0.0108	0.0104	0.0101	0.0100

Male	Calendar Year														
Age	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
65	0.0243	0.0250	0.0254	0.0256	0.0254	0.0248	0.0238	0.0224	0.0210	0.0195	0.0178	0.0161	0.0143	0.0126	0.0114
66	0.0241	0.0251	0.0259	0.0263	0.0263	0.0259	0.0250	0.0238	0.0226	0.0212	0.0197	0.0181	0.0163	0.0146	0.0130
67	0.0236	0.0250	0.0261	0.0268	0.0270	0.0267	0.0260	0.0249	0.0238	0.0226	0.0212	0.0197	0.0181	0.0164	0.0147
68	0.0231	0.0248	0.0261	0.0270	0.0274	0.0273	0.0267	0.0258	0.0248	0.0237	0.0225	0.0211	0.0196	0.0180	0.0163
69	0.0224	0.0243	0.0259	0.0271	0.0276	0.0277	0.0272	0.0265	0.0257	0.0247	0.0235	0.0223	0.0209	0.0194	0.0178
70	0.0216	0.0237	0.0255	0.0269	0.0276	0.0278	0.0276	0.0271	0.0264	0.0255	0.0244	0.0232	0.0220	0.0206	0.0190
71	0.0207	0.0230	0.0249	0.0265	0.0274	0.0278	0.0278	0.0275	0.0269	0.0261	0.0251	0.0240	0.0228	0.0215	0.0201
72	0.0199	0.0222	0.0242	0.0259	0.0270	0.0276	0.0278	0.0277	0.0274	0.0267	0.0258	0.0247	0.0235	0.0223	0.0209
73	0.0191	0.0213	0.0234	0.0252	0.0265	0.0273	0.0277	0.0278	0.0277	0.0271	0.0263	0.0253	0.0242	0.0229	0.0216
74	0.0183	0.0205	0.0226	0.0244	0.0259	0.0268	0.0274	0.0278	0.0278	0.0275	0.0268	0.0258	0.0247	0.0234	0.0221
75	0.0176	0.0197	0.0218	0.0236	0.0252	0.0263	0.0271	0.0276	0.0278	0.0276	0.0271	0.0262	0.0251	0.0239	0.0225
76	0.0170	0.0190	0.0210	0.0229	0.0245	0.0257	0.0266	0.0273	0.0277	0.0277	0.0272	0.0264	0.0254	0.0242	0.0229
77	0.0164	0.0183	0.0202	0.0221	0.0237	0.0251	0.0261	0.0269	0.0275	0.0276	0.0273	0.0266	0.0256	0.0244	0.0231
78	0.0159	0.0177	0.0196	0.0214	0.0230	0.0244	0.0255	0.0265	0.0271	0.0273	0.0272	0.0266	0.0257	0.0246	0.0233
79	0.0153	0.0171	0.0189	0.0207	0.0223	0.0237	0.0249	0.0259	0.0267	0.0270	0.0269	0.0265	0.0257	0.0246	0.0234
80	0.0147	0.0164	0.0183	0.0200	0.0216	0.0230	0.0242	0.0253	0.0262	0.0266	0.0266	0.0263	0.0256	0.0246	0.0234
81	0.0140	0.0158	0.0176	0.0193	0.0209	0.0223	0.0236	0.0248	0.0257	0.0261	0.0262	0.0259	0.0253	0.0245	0.0233
82	0.0132	0.0150	0.0168	0.0186	0.0202	0.0216	0.0229	0.0241	0.0251	0.0256	0.0258	0.0256	0.0250	0.0243	0.0232
83	0.0123	0.0142	0.0160	0.0178	0.0194	0.0209	0.0223	0.0235	0.0245	0.0251	0.0253	0.0252	0.0247	0.0240	0.0230
84	0.0113	0.0132	0.0151	0.0169	0.0186	0.0202	0.0216	0.0229	0.0240	0.0246	0.0249	0.0248	0.0244	0.0237	0.0228
85	0.0102	0.0121	0.0140	0.0159	0.0177	0.0193	0.0208	0.0223	0.0234	0.0241	0.0244	0.0243	0.0240	0.0234	0.0225
86	0.0090	0.0109	0.0129	0.0149	0.0167	0.0184	0.0200	0.0215	0.0228	0.0236	0.0239	0.0239	0.0236	0.0230	0.0222
87	0.0076	0.0096	0.0116	0.0137	0.0156	0.0174	0.0191	0.0208	0.0221	0.0230	0.0234	0.0235	0.0232	0.0227	0.0219
88	0.0062	0.0082	0.0103	0.0124	0.0144	0.0163	0.0181	0.0199	0.0214	0.0223	0.0229	0.0230	0.0228	0.0223	0.0216
89	0.0048	0.0068	0.0088	0.0110	0.0131	0.0151	0.0170	0.0190	0.0205	0.0216	0.0223	0.0225	0.0223	0.0219	0.0212
90	0.0033	0.0052	0.0073	0.0095	0.0116	0.0138	0.0158	0.0179	0.0196	0.0208	0.0216	0.0219	0.0218	0.0214	0.0208
91	0.0017	0.0036	0.0057	0.0079	0.0101	0.0123	0.0145	0.0167	0.0185	0.0199	0.0207	0.0211	0.0212	0.0209	0.0203
92	0.0001	0.0020	0.0041	0.0063	0.0085	0.0108	0.0130	0.0153	0.0173	0.0188	0.0198	0.0203	0.0204	0.0202	0.0197
93	-0.0016	0.0003	0.0024	0.0045	0.0068	0.0091	0.0115	0.0138	0.0159	0.0175	0.0187	0.0193	0.0196	0.0194	0.0190
94	-0.0032	-0.0014	0.0006	0.0028	0.0050	0.0074	0.0098	0.0122	0.0144	0.0161	0.0174	0.0182	0.0185	0.0185	0.0182
95	-0.0049	-0.0032	-0.0012	0.0009	0.0032	0.0055	0.0079	0.0104	0.0126	0.0145	0.0159	0.0168	0.0174	0.0175	0.0173
96	-0.0047	-0.0030	-0.0012	0.0009	0.0030	0.0052	0.0075	0.0099	0.0120	0.0138	0.0151	0.0160	0.0165	0.0166	0.0164
97	-0.0044	-0.0029	-0.0011	0.0008	0.0028	0.0050	0.0071	0.0093	0.0114	0.0130	0.0143	0.0152	0.0156	0.0157	0.0155
98	-0.0042	-0.0027	-0.0010	0.0008	0.0027	0.0047	0.0067	0.0088	0.0108	0.0123	0.0135	0.0143	0.0147	0.0149	0.0147
99	-0.0039	-0.0025	-0.0010	0.0007	0.0025	0.0044	0.0063	0.0083	0.0101	0.0116	0.0127	0.0135	0.0139	0.0140	0.0138
100	-0.0037	-0.0024	-0.0009	0.0007	0.0024	0.0041	0.0060	0.0078	0.0095	0.0109	0.0119	0.0126	0.0130	0.0131	0.0130
101	-0.0034	-0.0022	-0.0009	0.0006	0.0022	0.0039	0.0056	0.0073	0.0089	0.0101	0.0111	0.0118	0.0121	0.0122	0.0121
102	-0.0032	-0.0021	-0.0008	0.0006	0.0021	0.0036	0.0052	0.0067	0.0082	0.0094	0.0103	0.0109	0.0113	0.0114	0.0112
103	-0.0030	-0.0019	-0.0007	0.0005	0.0019	0.0033	0.0048	0.0062	0.0076	0.0087	0.0095	0.0101	0.0104	0.0105	0.0104
104	-0.0027	-0.0018	-0.0007	0.0005	0.0017	0.0030	0.0044	0.0057	0.0070	0.0080	0.0087	0.0093	0.0095	0.0096	0.0095
105	-0.0025	-0.0016	-0.0006	0.0005	0.0016	0.0028	0.0040	0.0052	0.0063	0.0072	0.0079	0.0084	0.0087	0.0087	0.0086
106	-0.0022	-0.0014	-0.0006	0.0004	0.0014	0.0025	0.0036	0.0047	0.0057	0.0065	0.0072	0.0076	0.0078	0.0079	0.0078
107	-0.0020	-0.0013	-0.0005	0.0004	0.0013	0.0022	0.0032	0.0042	0.0051	0.0058	0.0064	0.0067	0.0069	0.0070	0.0069
108	-0.0017	-0.0011	-0.0004	0.0003	0.0011	0.0019	0.0028	0.0036	0.0044	0.0051	0.0056	0.0059	0.0061	0.0061	0.0060
109	-0.0015	-0.0010	-0.0004	0.0003	0.0010	0.0017	0.0024	0.0031	0.0038	0.0044	0.0048	0.0051	0.0052	0.0052	0.0052
110	-0.0012	-0.0008	-0.0003	0.0002	0.0008	0.0014	0.0020	0.0026	0.0032	0.0036	0.0040	0.0042	0.0043	0.0044	0.0043
111	-0.0010	-0.0006	-0.0003	0.0002	0.0006	0.0011	0.0016	0.0021	0.0025	0.0029	0.0032	0.0034	0.0035	0.0035	0.0035
112	-0.0007	-0.0005	-0.0002	0.0001	0.0005	0.0008	0.0012	0.0016	0.0019	0.0022	0.0024	0.0025	0.0026	0.0026	0.0026
113	-0.0005	-0.0003	-0.0001	0.0001	0.0003	0.0006	0.0008	0.0010	0.0013	0.0015	0.0016	0.0017	0.0017	0.0018	0.0017
114	-0.0003	-0.0002	-0.0001	0.0000	0.0002	0.0003	0.0004	0.0005	0.0006	0.0007	0.0008	0.0008	0.0009	0.0009	0.0009
115+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Male	Calendar Year												
Age	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027+**
65	0.0105	0.0103	0.0104	0.0108	0.0112	0.0115	0.0116	0.0114	0.0112	0.0108	0.0104	0.0101	0.0100
66	0.0118	0.0110	0.0107	0.0108	0.0110	0.0113	0.0114	0.0113	0.0111	0.0108	0.0104	0.0101	0.0100
67	0.0132	0.0120	0.0113	0.0110	0.0110	0.0111	0.0112	0.0112	0.0110	0.0107	0.0104	0.0101	0.0100
68	0.0147	0.0132	0.0121	0.0114	0.0111	0.0110	0.0110	0.0110	0.0109	0.0106	0.0104	0.0101	0.0100
69	0.0161	0.0145	0.0132	0.0121	0.0114	0.0111	0.0110	0.0109	0.0108	0.0106	0.0103	0.0101	0.0100
70	0.0174	0.0158	0.0143	0.0130	0.0120	0.0114	0.0110	0.0108	0.0107	0.0105	0.0103	0.0101	0.0100
71	0.0186	0.0170	0.0154	0.0140	0.0127	0.0118	0.0112	0.0109	0.0106	0.0105	0.0103	0.0101	0.0100
72	0.0195	0.0180	0.0164	0.0149	0.0135	0.0124	0.0116	0.0110	0.0106	0.0104	0.0102	0.0101	0.0100
73	0.0202	0.0188	0.0172	0.0157	0.0143	0.0130	0.0120	0.0112	0.0107	0.0104	0.0102	0.0101	0.0100
74	0.0208	0.0194	0.0179	0.0164	0.0150	0.0136	0.0125	0.0115	0.0109	0.0105	0.0102	0.0101	0.0100
75	0.0212	0.0198	0.0184	0.0169	0.0155	0.0141	0.0129	0.0119	0.0111	0.0106	0.0102	0.0101	0.0100
76	0.0215	0.0201	0.0187	0.0173	0.0159	0.0145	0.0133	0.0122	0.0113	0.0107	0.0103	0.0101	0.0100
77	0.0217	0.0203	0.0189	0.0175	0.0161	0.0148	0.0135	0.0124	0.0115	0.0108	0.0103	0.0101	0.0100
78	0.0219	0.0204	0.0190	0.0176	0.0162	0.0150	0.0137	0.0126	0.0116	0.0109	0.0104	0.0101	0.0100
79	0.0220	0.0205	0.0191	0.0176	0.0163	0.0150	0.0138	0.0127	0.0117	0.0110	0.0104	0.0101	0.0100
80	0.0220	0.0206	0.0191	0.0177	0.0163	0.0150	0.0138	0.0128	0.0118	0.0110	0.0104	0.0101	0.0100
81	0.0220	0.0206	0.0191	0.0177	0.0163	0.0150	0.0138	0.0127	0.0118	0.0111	0.0105	0.0101	0.0100
82	0.0220	0.0206	0.0191	0.0177	0.0163	0.0149	0.0137	0.0127	0.0118	0.0111	0.0105	0.0101	0.0100
83	0.0219	0.0206	0.0191	0.0177	0.0163	0.0149	0.0137	0.0126	0.0117	0.0110	0.0105	0.0101	0.0100
84	0.0217	0.0205	0.0191	0.0177	0.0163	0.0149	0.0137	0.0126	0.0117	0.0109	0.0104	0.0101	0.0100
85	0.0215	0.0203	0.0191	0.0177	0.0163	0.0149	0.0137	0.0126	0.0116	0.0109	0.0104	0.0101	0.0100
86	0.0213	0.0201	0.0189	0.0176	0.0162	0.0149	0.0136	0.0125	0.0115	0.0108	0.0102	0.0099	0.0099
87	0.0210	0.0199	0.0187	0.0174	0.0161	0.0148	0.0135	0.0124	0.0114	0.0106	0.0101	0.0098	0.0097
88	0.0207	0.0196	0.0184	0.0172	0.0160	0.0147	0.0135	0.0123	0.0113	0.0105	0.0099	0.0096	0.0096
89	0.0203	0.0193	0.0182	0.0170	0.0157	0.0145	0.0134	0.0122	0.0112	0.0104	0.0098	0.0095	0.0094
90	0.0200	0.0190	0.0178	0.0167	0.0154	0.0142	0.0131	0.0121	0.0111	0.0103	0.0097	0.0093	0.0093
91	0.0195	0.0185	0.0175	0.0163	0.0151	0.0139	0.0128	0.0118	0.0109	0.0101	0.0095	0.0092	0.0091
92	0.0190	0.0181	0.0170	0.0159	0.0147	0.0136	0.0125	0.0115	0.0106	0.0100	0.0094	0.0090	0.0090
93	0.0183	0.0175	0.0165	0.0154	0.0143	0.0132	0.0121	0.0112	0.0103	0.0097	0.0092	0.0089	0.0088
94	0.0176	0.0168	0.0159	0.0149	0.0138	0.0128	0.0118	0.0108	0.0100	0.0094	0.0089	0.0087	0.0087
95	0.0168	0.0161	0.0152	0.0143	0.0133	0.0123	0.0113	0.0104	0.0097	0.0090	0.0086	0.0084	0.0085
96	0.0159	0.0153	0.0145	0.0136	0.0126	0.0117	0.0108	0.0099	0.0092	0.0086	0.0082	0.0080	0.0081
97	0.0151	0.0145	0.0137	0.0129	0.0120	0.0111	0.0102	0.0094	0.0087	0.0081	0.0078	0.0076	0.0077
98	0.0143	0.0137	0.0130	0.0122	0.0113	0.0104	0.0096	0.0089	0.0082	0.0077	0.0073	0.0072	0.0072
99	0.0134	0.0129	0.0122	0.0114	0.0106	0.0098	0.0091	0.0083	0.0077	0.0072	0.0069	0.0067	0.0068
100	0.0126	0.0121	0.0114	0.0107	0.0100	0.0092	0.0085	0.0078	0.0072	0.0068	0.0065	0.0063	0.0064
101	0.0118	0.0113	0.0107	0.0100	0.0093	0.0086	0.0079	0.0073	0.0068	0.0063	0.0060	0.0059	0.0060
102	0.0109	0.0105	0.0099	0.0093	0.0086	0.0080	0.0074	0.0068	0.0063	0.0059	0.0056	0.0055	0.0055
103	0.0101	0.0097	0.0092	0.0086	0.0080	0.0074	0.0068	0.0063	0.0058	0.0054	0.0052	0.0051	0.0051
104	0.0092	0.0089	0.0084	0.0079	0.0073	0.0068	0.0062	0.0057	0.0053	0.0050	0.0047	0.0046	0.0047
105	0.0084	0.0080	0.0076	0.0072	0.0067	0.0061	0.0057	0.0052	0.0048	0.0045	0.0043	0.0042	0.0043
106	0.0076	0.0072	0.0069	0.0064	0.0060	0.0055	0.0051	0.0047	0.0043	0.0041	0.0039	0.0038	0.0038
107	0.0067	0.0064	0.0061	0.0057	0.0053	0.0049	0.0045	0.0042	0.0039	0.0036	0.0035	0.0034	0.0034
108	0.0059	0.0056	0.0053	0.0050	0.0047	0.0043	0.0040	0.0037	0.0034	0.0032	0.0030	0.0030	0.0030
109	0.0050	0.0048	0.0046	0.0043	0.0040	0.0037	0.0034	0.0031	0.0029	0.0027	0.0026	0.0025	0.0026
110	0.0042	0.0040	0.0038	0.0036	0.0033	0.0031	0.0028	0.0026	0.0024	0.0023	0.0022	0.0021	0.0021
111	0.0034	0.0032	0.0031	0.0029	0.0027	0.0025	0.0023	0.0021	0.0019	0.0018	0.0017	0.0017	0.0017
112	0.0025	0.0024	0.0023	0.0021	0.0020	0.0018	0.0017	0.0016	0.0015	0.0014	0.0013	0.0013	0.0013
113	0.0017	0.0016	0.0015	0.0014	0.0013	0.0012	0.0011	0.0010	0.0010	0.0009	0.0009	0.0008	0.0009
114	0.0008	0.0008	0.0008	0.0007	0.0007	0.0006	0.0006	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004
115+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Female	Calendar Year														
Age	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
≤ 20	0.0024	-0.0005	-0.0018	-0.0010	0.0023	0.0077	0.0147	0.0227	0.0253	0.0272	0.0285	0.0291	0.0292	0.0288	0.0280
21	0.0009	-0.0025	-0.0044	-0.0042	-0.0015	0.0030	0.0092	0.0164	0.0222	0.0242	0.0255	0.0263	0.0265	0.0263	0.0257
22	0.0003	-0.0037	-0.0063	-0.0066	-0.0048	-0.0011	0.0041	0.0103	0.0155	0.0212	0.0226	0.0235	0.0239	0.0239	0.0236
23	0.0007	-0.0041	-0.0072	-0.0083	-0.0072	-0.0045	-0.0004	0.0047	0.0094	0.0144	0.0200	0.0210	0.0216	0.0217	0.0216
24	0.0018	-0.0036	-0.0074	-0.0092	-0.0089	-0.0072	-0.0041	-0.0002	0.0040	0.0086	0.0133	0.0188	0.0195	0.0198	0.0198
25	0.0037	-0.0023	-0.0067	-0.0092	-0.0098	-0.0089	-0.0070	-0.0042	-0.0007	0.0034	0.0078	0.0123	0.0176	0.0180	0.0181
26	0.0061	-0.0004	-0.0053	-0.0084	-0.0098	-0.0098	-0.0088	-0.0071	-0.0047	-0.0017	0.0021	0.0062	0.0103	0.0152	0.0154
27	0.0088	0.0020	-0.0034	-0.0070	-0.0090	-0.0098	-0.0096	-0.0088	-0.0075	-0.0054	-0.0025	0.0010	0.0049	0.0088	0.0134
28	0.0115	0.0046	-0.0010	-0.0050	-0.0075	-0.0089	-0.0094	-0.0094	-0.0090	-0.0078	-0.0058	-0.0030	0.0005	0.0042	0.0078
29	0.0139	0.0072	0.0016	-0.0026	-0.0055	-0.0072	-0.0082	-0.0088	-0.0092	-0.0088	-0.0077	-0.0056	-0.0027	0.0006	0.0042
30	0.0158	0.0096	0.0042	0.0000	-0.0030	-0.0049	-0.0062	-0.0072	-0.0081	-0.0084	-0.0080	-0.0068	-0.0046	-0.0018	0.0014
31	0.0170	0.0115	0.0066	0.0027	-0.0002	-0.0021	-0.0034	-0.0046	-0.0058	-0.0067	-0.0070	-0.0066	-0.0052	-0.0030	-0.0003
32	0.0174	0.0126	0.0085	0.0052	0.0027	0.0010	-0.0002	-0.0013	-0.0027	-0.0039	-0.0048	-0.0050	-0.0044	-0.0030	-0.0009
33	0.0169	0.0130	0.0098	0.0073	0.0055	0.0043	0.0033	0.0023	0.0011	-0.0003	-0.0016	-0.0024	-0.0025	-0.0019	-0.0005
34	0.0155	0.0127	0.0105	0.0090	0.0080	0.0073	0.0068	0.0062	0.0051	0.0038	0.0024	0.0011	0.0004	0.0002	0.0009
35	0.0134	0.0115	0.0104	0.0100	0.0100	0.0100	0.0100	0.0099	0.0092	0.0081	0.0067	0.0052	0.0040	0.0032	0.0030
36	0.0108	0.0097	0.0097	0.0103	0.0113	0.0121	0.0128	0.0132	0.0131	0.0123	0.0111	0.0095	0.0080	0.0067	0.0059
37	0.0077	0.0074	0.0082	0.0099	0.0118	0.0135	0.0148	0.0159	0.0163	0.0161	0.0152	0.0138	0.0121	0.0105	0.0091
38	0.0045	0.0047	0.0062	0.0087	0.0115	0.0140	0.0161	0.0179	0.0190	0.0192	0.0187	0.0177	0.0160	0.0142	0.0125
39	0.0012	0.0018	0.0038	0.0070	0.0105	0.0137	0.0166	0.0190	0.0208	0.0216	0.0215	0.0208	0.0195	0.0177	0.0157
40	-0.0019	-0.0012	0.0011	0.0047	0.0088	0.0127	0.0162	0.0192	0.0216	0.0231	0.0236	0.0232	0.0222	0.0207	0.0187
41	-0.0046	-0.0040	-0.0017	0.0021	0.0066	0.0110	0.0150	0.0185	0.0213	0.0232	0.0242	0.0241	0.0234	0.0221	0.0203
42	-0.0069	-0.0065	-0.0043	-0.0005	0.0041	0.0088	0.0132	0.0171	0.0201	0.0224	0.0238	0.0244	0.0239	0.0228	0.0214
43	-0.0085	-0.0086	-0.0067	-0.0031	0.0015	0.0063	0.0109	0.0150	0.0182	0.0209	0.0227	0.0237	0.0238	0.0231	0.0218
44	-0.0094	-0.0100	-0.0085	-0.0053	-0.0009	0.0037	0.0083	0.0124	0.0158	0.0187	0.0209	0.0223	0.0230	0.0228	0.0218
45	-0.0095	-0.0106	-0.0097	-0.0070	-0.0031	0.0013	0.0056	0.0095	0.0130	0.0160	0.0185	0.0204	0.0215	0.0219	0.0215
46	-0.0087	-0.0104	-0.0101	-0.0081	-0.0048	-0.0009	0.0030	0.0066	0.0100	0.0131	0.0159	0.0181	0.0196	0.0205	0.0206
47	-0.0071	-0.0093	-0.0097	-0.0084	-0.0058	-0.0026	0.0007	0.0039	0.0071	0.0102	0.0131	0.0156	0.0175	0.0188	0.0194
48	-0.0049	-0.0074	-0.0084	-0.0078	-0.0061	-0.0037	-0.0010	0.0016	0.0044	0.0072	0.0099	0.0125	0.0146	0.0162	0.0173
49	-0.0021	-0.0049	-0.0064	-0.0065	-0.0055	-0.0039	-0.0020	-0.0001	0.0021	0.0044	0.0068	0.0093	0.0115	0.0133	0.0147
50	0.0008	-0.0020	-0.0038	-0.0044	-0.0041	-0.0033	-0.0021	-0.0010	0.0005	0.0022	0.0042	0.0064	0.0085	0.0105	0.0121
51	0.0038	0.0012	-0.0007	-0.0017	-0.0019	-0.0018	-0.0013	-0.0009	-0.0002	0.0008	0.0023	0.0040	0.0060	0.0079	0.0097
52	0.0065	0.0043	0.0026	0.0015	0.0009	0.0005	0.0003	0.0000	0.0000	0.0004	0.0012	0.0025	0.0041	0.0058	0.0076
53	0.0090	0.0072	0.0059	0.0049	0.0041	0.0034	0.0027	0.0018	0.0012	0.0009	0.0011	0.0018	0.0029	0.0044	0.0060
54	0.0109	0.0098	0.0090	0.0083	0.0076	0.0067	0.0056	0.0042	0.0031	0.0023	0.0020	0.0021	0.0027	0.0037	0.0051
55	0.0125	0.0120	0.0117	0.0114	0.0109	0.0101	0.0088	0.0072	0.0057	0.0045	0.0036	0.0032	0.0033	0.0038	0.0048
56	0.0136	0.0138	0.0140	0.0142	0.0140	0.0133	0.0120	0.0103	0.0087	0.0072	0.0060	0.0052	0.0047	0.0048	0.0053
57	0.0144	0.0151	0.0159	0.0164	0.0166	0.0161	0.0150	0.0134	0.0118	0.0102	0.0088	0.0077	0.0068	0.0064	0.0064
58	0.0149	0.0160	0.0172	0.0181	0.0187	0.0185	0.0177	0.0163	0.0148	0.0133	0.0118	0.0105	0.0094	0.0085	0.0080
59	0.0151	0.0166	0.0180	0.0193	0.0202	0.0204	0.0199	0.0189	0.0177	0.0163	0.0148	0.0134	0.0121	0.0109	0.0101
60	0.0151	0.0168	0.0185	0.0201	0.0212	0.0217	0.0216	0.0210	0.0201	0.0189	0.0176	0.0161	0.0147	0.0134	0.0122
61	0.0149	0.0168	0.0187	0.0205	0.0218	0.0226	0.0229	0.0226	0.0221	0.0212	0.0200	0.0186	0.0172	0.0157	0.0144
62	0.0145	0.0166	0.0187	0.0206	0.0222	0.0232	0.0237	0.0238	0.0235	0.0229	0.0220	0.0207	0.0193	0.0178	0.0163
63	0.0139	0.0162	0.0185	0.0206	0.0223	0.0235	0.0242	0.0245	0.0245	0.0242	0.0234	0.0223	0.0210	0.0195	0.0179
64	0.0133	0.0158	0.0182	0.0204	0.0223	0.0236	0.0244	0.0249	0.0251	0.0250	0.0245	0.0235	0.0223	0.0209	0.0193

Female	Calendar Year												
Age	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027+**
≤ 20	0.0269	0.0255	0.0239	0.0221	0.0202	0.0184	0.0165	0.0148	0.0132	0.0119	0.0109	0.0102	0.0100
21	0.0248	0.0237	0.0223	0.0208	0.0191	0.0175	0.0158	0.0143	0.0129	0.0117	0.0108	0.0102	0.0100
22	0.0229	0.0219	0.0208	0.0195	0.0181	0.0166	0.0152	0.0138	0.0126	0.0115	0.0107	0.0102	0.0100
23	0.0211	0.0203	0.0194	0.0183	0.0171	0.0158	0.0146	0.0134	0.0123	0.0114	0.0106	0.0102	0.0100
24	0.0195	0.0189	0.0181	0.0172	0.0162	0.0151	0.0141	0.0130	0.0121	0.0112	0.0106	0.0102	0.0100
25	0.0179	0.0175	0.0169	0.0162	0.0153	0.0144	0.0135	0.0126	0.0118	0.0111	0.0105	0.0101	0.0100
26	0.0154	0.0152	0.0148	0.0143	0.0138	0.0131	0.0125	0.0119	0.0113	0.0108	0.0104	0.0101	0.0100
27	0.0134	0.0134	0.0132	0.0129	0.0125	0.0121	0.0117	0.0113	0.0109	0.0105	0.0103	0.0101	0.0100
28	0.0121	0.0121	0.0121	0.0119	0.0117	0.0114	0.0112	0.0109	0.0106	0.0104	0.0102	0.0100	0.0100
29	0.0076	0.0115	0.0115	0.0114	0.0112	0.0110	0.0109	0.0106	0.0104	0.0103	0.0101	0.0100	0.0100
30	0.0048	0.0079	0.0114	0.0113	0.0111	0.0110	0.0108	0.0106	0.0104	0.0103	0.0101	0.0100	0.0100
31	0.0028	0.0059	0.0086	0.0116	0.0114	0.0112	0.0109	0.0107	0.0105	0.0103	0.0101	0.0100	0.0100
32	0.0017	0.0045	0.0072	0.0096	0.0120	0.0117	0.0113	0.0110	0.0107	0.0104	0.0102	0.0100	0.0100
33	0.0015	0.0039	0.0064	0.0086	0.0105	0.0123	0.0118	0.0113	0.0109	0.0105	0.0103	0.0101	0.0100
34	0.0021	0.0039	0.0060	0.0081	0.0099	0.0112	0.0125	0.0118	0.0112	0.0107	0.0103	0.0101	0.0100
35	0.0036	0.0047	0.0062	0.0079	0.0095	0.0108	0.0117	0.0123	0.0116	0.0109	0.0104	0.0101	0.0100
36	0.0056	0.0060	0.0069	0.0081	0.0094	0.0106	0.0114	0.0118	0.0119	0.0111	0.0105	0.0101	0.0100
37	0.0082	0.0078	0.0080	0.0087	0.0095	0.0104	0.0111	0.0115	0.0115	0.0113	0.0106	0.0102	0.0100
38	0.0110	0.0100	0.0095	0.0095	0.0099	0.0105	0.0110	0.0113	0.0113	0.0111	0.0107	0.0102	0.0100
39	0.0139	0.0123	0.0112	0.0106	0.0105	0.0107	0.0109	0.0111	0.0112	0.0110	0.0106	0.0102	0.0100
40	0.0166	0.0146	0.0130	0.0119	0.0112	0.0110	0.0109	0.0110	0.0110	0.0108	0.0105	0.0102	0.0100
41	0.0182	0.0161	0.0142	0.0127	0.0116	0.0110	0.0107	0.0107	0.0107	0.0106	0.0104	0.0101	0.0100
42	0.0195	0.0173	0.0153	0.0135	0.0121	0.0112	0.0107	0.0105	0.0104	0.0104	0.0103	0.0101	0.0100
43	0.0202	0.0183	0.0162	0.0143	0.0127	0.0115	0.0108	0.0104	0.0102	0.0102	0.0101	0.0101	0.0100
44	0.0204	0.0188	0.0170	0.0150	0.0133	0.0119	0.0110	0.0104	0.0101	0.0101	0.0101	0.0100	0.0100
45	0.0204	0.0189	0.0173	0.0156	0.0139	0.0124	0.0113	0.0105	0.0101	0.0100	0.0100	0.0100	0.0100
46	0.0201	0.0189	0.0174	0.0159	0.0143	0.0128	0.0116	0.0107	0.0102	0.0100	0.0100	0.0100	0.0100
47	0.0193	0.0187	0.0174	0.0161	0.0147	0.0133	0.0120	0.0110	0.0104	0.0101	0.0100	0.0100	0.0100
48	0.0177	0.0175	0.0168	0.0157	0.0144	0.0132	0.0121	0.0111	0.0105	0.0101	0.0100	0.0100	0.0100
49	0.0155	0.0158	0.0156	0.0150	0.0140	0.0129	0.0120	0.0111	0.0105	0.0101	0.0100	0.0100	0.0100
50	0.0133	0.0140	0.0142	0.0140	0.0134	0.0126	0.0118	0.0111	0.0105	0.0101	0.0100	0.0100	0.0100
51	0.0111	0.0122	0.0128	0.0130	0.0128	0.0123	0.0116	0.0110	0.0105	0.0102	0.0100	0.0100	0.0100
52	0.0092	0.0105	0.0114	0.0119	0.0121	0.0119	0.0115	0.0109	0.0105	0.0102	0.0100	0.0100	0.0100
53	0.0077	0.0091	0.0102	0.0110	0.0114	0.0115	0.0113	0.0110	0.0106	0.0103	0.0101	0.0100	0.0100
54	0.0066	0.0080	0.0093	0.0103	0.0109	0.0112	0.0111	0.0109	0.0106	0.0103	0.0101	0.0100	0.0100
55	0.0061	0.0074	0.0087	0.0097	0.0105	0.0109	0.0110	0.0109	0.0107	0.0104	0.0102	0.0100	0.0100
56	0.0061	0.0072	0.0084	0.0094	0.0102	0.0108	0.0110	0.0110	0.0108	0.0105	0.0102	0.0101	0.0100
57	0.0068	0.0075	0.0084	0.0094	0.0101	0.0107	0.0110	0.0110	0.0108	0.0106	0.0103	0.0101	0.0100
58	0.0080	0.0083	0.0088	0.0095	0.0102	0.0107	0.0110	0.0111	0.0109	0.0106	0.0103	0.0101	0.0100
59	0.0095	0.0094	0.0095	0.0099	0.0104	0.0108	0.0110	0.0111	0.0110	0.0107	0.0104	0.0101	0.0100
60	0.0113	0.0107	0.0105	0.0105	0.0107	0.0109	0.0111	0.0111	0.0110	0.0107	0.0104	0.0101	0.0100
61	0.0132	0.0122	0.0115	0.0112	0.0110	0.0111	0.0111	0.0111	0.0109	0.0107	0.0104	0.0101	0.0100
62	0.0149	0.0137	0.0127	0.0119	0.0115	0.0113	0.0111	0.0110	0.0109	0.0106	0.0104	0.0101	0.0100
63	0.0164	0.0150	0.0138	0.0128	0.0120	0.0115	0.0112	0.0110	0.0108	0.0106	0.0103	0.0101	0.0100
64	0.0177	0.0162	0.0148	0.0136	0.0126	0.0118	0.0113	0.0110	0.0108	0.0105	0.0103	0.0101	0.0100

Female	Calendar Year														
Age	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
65	0.0125	0.0152	0.0178	0.0201	0.0221	0.0235	0.0244	0.0249	0.0253	0.0254	0.0251	0.0243	0.0233	0.0219	0.0204
66	0.0117	0.0145	0.0172	0.0197	0.0217	0.0232	0.0242	0.0248	0.0253	0.0255	0.0253	0.0248	0.0239	0.0227	0.0213
67	0.0108	0.0137	0.0165	0.0191	0.0212	0.0227	0.0238	0.0246	0.0251	0.0254	0.0254	0.0250	0.0243	0.0232	0.0219
68	0.0100	0.0129	0.0158	0.0184	0.0205	0.0221	0.0233	0.0242	0.0249	0.0252	0.0252	0.0250	0.0244	0.0236	0.0224
69	0.0091	0.0120	0.0149	0.0175	0.0197	0.0214	0.0227	0.0237	0.0245	0.0249	0.0250	0.0249	0.0244	0.0237	0.0227
70	0.0084	0.0112	0.0140	0.0166	0.0188	0.0206	0.0221	0.0232	0.0241	0.0246	0.0247	0.0246	0.0243	0.0237	0.0228
71	0.0076	0.0103	0.0131	0.0157	0.0180	0.0198	0.0214	0.0227	0.0237	0.0242	0.0244	0.0244	0.0240	0.0235	0.0228
72	0.0069	0.0095	0.0123	0.0148	0.0171	0.0191	0.0207	0.0221	0.0232	0.0238	0.0241	0.0240	0.0237	0.0232	0.0226
73	0.0063	0.0088	0.0115	0.0141	0.0164	0.0184	0.0201	0.0215	0.0227	0.0234	0.0237	0.0237	0.0234	0.0229	0.0223
74	0.0057	0.0082	0.0108	0.0134	0.0157	0.0177	0.0195	0.0210	0.0222	0.0230	0.0234	0.0234	0.0231	0.0226	0.0219
75	0.0052	0.0076	0.0102	0.0128	0.0152	0.0172	0.0190	0.0205	0.0217	0.0226	0.0230	0.0231	0.0228	0.0223	0.0216
76	0.0047	0.0071	0.0097	0.0124	0.0148	0.0168	0.0185	0.0201	0.0213	0.0222	0.0226	0.0227	0.0225	0.0221	0.0214
77	0.0042	0.0066	0.0093	0.0120	0.0144	0.0165	0.0182	0.0198	0.0210	0.0219	0.0224	0.0225	0.0223	0.0219	0.0212
78	0.0038	0.0062	0.0089	0.0116	0.0141	0.0162	0.0180	0.0196	0.0209	0.0217	0.0222	0.0223	0.0222	0.0218	0.0211
79	0.0033	0.0058	0.0085	0.0113	0.0138	0.0160	0.0178	0.0195	0.0208	0.0217	0.0221	0.0223	0.0221	0.0217	0.0211
80	0.0027	0.0053	0.0081	0.0109	0.0135	0.0158	0.0177	0.0195	0.0208	0.0217	0.0222	0.0223	0.0222	0.0217	0.0211
81	0.0021	0.0047	0.0076	0.0105	0.0132	0.0156	0.0176	0.0195	0.0210	0.0219	0.0224	0.0225	0.0223	0.0219	0.0212
82	0.0014	0.0041	0.0071	0.0101	0.0129	0.0153	0.0175	0.0195	0.0211	0.0221	0.0226	0.0227	0.0225	0.0221	0.0214
83	0.0007	0.0034	0.0064	0.0095	0.0124	0.0150	0.0174	0.0196	0.0213	0.0224	0.0229	0.0231	0.0228	0.0223	0.0216
84	-0.0001	0.0027	0.0057	0.0089	0.0119	0.0147	0.0172	0.0196	0.0215	0.0227	0.0233	0.0234	0.0232	0.0227	0.0219
85	-0.0009	0.0019	0.0050	0.0082	0.0113	0.0142	0.0169	0.0195	0.0216	0.0229	0.0236	0.0238	0.0236	0.0230	0.0222
86	-0.0016	0.0011	0.0041	0.0074	0.0106	0.0137	0.0165	0.0193	0.0216	0.0231	0.0239	0.0241	0.0239	0.0234	0.0225
87	-0.0024	0.0002	0.0033	0.0066	0.0099	0.0130	0.0161	0.0190	0.0214	0.0231	0.0241	0.0244	0.0242	0.0237	0.0228
88	-0.0031	-0.0006	0.0025	0.0057	0.0090	0.0123	0.0155	0.0186	0.0212	0.0229	0.0240	0.0244	0.0243	0.0238	0.0229
89	-0.0038	-0.0013	0.0016	0.0049	0.0082	0.0115	0.0148	0.0180	0.0207	0.0226	0.0237	0.0242	0.0242	0.0237	0.0228
90	-0.0044	-0.0020	0.0008	0.0040	0.0073	0.0107	0.0140	0.0173	0.0201	0.0221	0.0233	0.0239	0.0240	0.0235	0.0227
91	-0.0049	-0.0027	0.0001	0.0032	0.0064	0.0097	0.0131	0.0165	0.0193	0.0214	0.0228	0.0235	0.0236	0.0233	0.0225
92	-0.0054	-0.0032	-0.0006	0.0024	0.0055	0.0088	0.0121	0.0155	0.0184	0.0206	0.0221	0.0229	0.0232	0.0229	0.0222
93	-0.0057	-0.0037	-0.0012	0.0016	0.0046	0.0078	0.0111	0.0144	0.0173	0.0196	0.0212	0.0222	0.0225	0.0224	0.0218
94	-0.0060	-0.0041	-0.0018	0.0009	0.0037	0.0068	0.0099	0.0131	0.0160	0.0184	0.0201	0.0212	0.0218	0.0217	0.0213
95	-0.0061	-0.0044	-0.0023	0.0002	0.0029	0.0057	0.0086	0.0117	0.0146	0.0170	0.0189	0.0201	0.0208	0.0210	0.0206
96	-0.0058	-0.0042	-0.0022	0.0002	0.0027	0.0054	0.0082	0.0111	0.0139	0.0162	0.0179	0.0191	0.0198	0.0199	0.0196
97	-0.0055	-0.0039	-0.0020	0.0002	0.0026	0.0051	0.0078	0.0105	0.0131	0.0153	0.0170	0.0181	0.0187	0.0189	0.0185
98	-0.0052	-0.0037	-0.0019	0.0002	0.0024	0.0048	0.0074	0.0099	0.0124	0.0145	0.0160	0.0171	0.0177	0.0178	0.0175
99	-0.0049	-0.0035	-0.0018	0.0001	0.0023	0.0046	0.0069	0.0093	0.0117	0.0136	0.0151	0.0161	0.0166	0.0168	0.0165
100	-0.0046	-0.0033	-0.0017	0.0001	0.0021	0.0043	0.0065	0.0088	0.0109	0.0128	0.0142	0.0151	0.0156	0.0157	0.0155
101	-0.0043	-0.0031	-0.0016	0.0001	0.0020	0.0040	0.0061	0.0082	0.0102	0.0119	0.0132	0.0141	0.0146	0.0147	0.0144
102	-0.0040	-0.0029	-0.0015	0.0001	0.0019	0.0037	0.0056	0.0076	0.0095	0.0111	0.0123	0.0131	0.0135	0.0136	0.0134
103	-0.0037	-0.0026	-0.0014	0.0001	0.0017	0.0034	0.0052	0.0070	0.0088	0.0102	0.0113	0.0121	0.0125	0.0126	0.0124
104	-0.0034	-0.0024	-0.0013	0.0001	0.0016	0.0031	0.0048	0.0064	0.0080	0.0094	0.0104	0.0111	0.0114	0.0115	0.0113
105	-0.0030	-0.0022	-0.0011	0.0001	0.0014	0.0029	0.0043	0.0058	0.0073	0.0085	0.0094	0.0101	0.0104	0.0105	0.0103
106	-0.0027	-0.0020	-0.0010	0.0001	0.0013	0.0026	0.0039	0.0053	0.0066	0.0077	0.0085	0.0091	0.0094	0.0094	0.0093
107	-0.0024	-0.0018	-0.0009	0.0001	0.0011	0.0023	0.0035	0.0047	0.0058	0.0068	0.0075	0.0081	0.0083	0.0084	0.0082
108	-0.0021	-0.0015	-0.0008	0.0001	0.0010	0.0020	0.0030	0.0041	0.0051	0.0060	0.0066	0.0070	0.0073	0.0073	0.0072
109	-0.0018	-0.0013	-0.0007	0.0001	0.0009	0.0017	0.0026	0.0035	0.0044	0.0051	0.0057	0.0060	0.0062	0.0063	0.0062
110	-0.0015	-0.0011	-0.0006	0.0000	0.0007	0.0014	0.0022	0.0029	0.0036	0.0043	0.0047	0.0050	0.0052	0.0052	0.0052
111	-0.0012	-0.0009	-0.0005	0.0000	0.0006	0.0011	0.0017	0.0023	0.0029	0.0034	0.0038	0.0040	0.0042	0.0042	0.0041
112	-0.0009	-0.0007	-0.0003	0.0000	0.0004	0.0009	0.0013	0.0018	0.0022	0.0026	0.0028	0.0030	0.0031	0.0031	0.0031
113	-0.0006	-0.0004	-0.0002	0.0000	0.0003	0.0006	0.0009	0.0012	0.0015	0.0017	0.0019	0.0020	0.0021	0.0021	0.0021
114	-0.0003	-0.0002	-0.0001	0.0000	0.0001	0.0003	0.0004	0.0006	0.0007	0.0009	0.0009	0.0010	0.0010	0.0010	0.0010
115+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Female	Calendar Year												
Age	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027+
65	0.0188	0.0172	0.0157	0.0143	0.0132	0.0122	0.0115	0.0111	0.0107	0.0105	0.0103	0.0101	0.0100
66	0.0197	0.0181	0.0165	0.0150	0.0137	0.0126	0.0118	0.0112	0.0107	0.0104	0.0102	0.0101	0.0100
67	0.0204	0.0188	0.0172	0.0157	0.0143	0.0131	0.0121	0.0114	0.0108	0.0105	0.0102	0.0101	0.0100
68	0.0210	0.0195	0.0179	0.0163	0.0149	0.0136	0.0125	0.0116	0.0109	0.0105	0.0102	0.0101	0.0100
69	0.0214	0.0200	0.0184	0.0169	0.0154	0.0140	0.0128	0.0118	0.0111	0.0106	0.0102	0.0101	0.0100
70	0.0217	0.0204	0.0189	0.0173	0.0158	0.0144	0.0131	0.0121	0.0113	0.0107	0.0103	0.0101	0.0100
71	0.0218	0.0206	0.0192	0.0177	0.0162	0.0147	0.0134	0.0123	0.0114	0.0108	0.0103	0.0101	0.0100
72	0.0217	0.0206	0.0193	0.0179	0.0164	0.0150	0.0137	0.0125	0.0116	0.0108	0.0104	0.0101	0.0100
73	0.0215	0.0205	0.0193	0.0180	0.0166	0.0152	0.0139	0.0127	0.0117	0.0109	0.0104	0.0101	0.0100
74	0.0211	0.0202	0.0191	0.0179	0.0166	0.0153	0.0140	0.0128	0.0118	0.0110	0.0104	0.0101	0.0100
75	0.0208	0.0199	0.0189	0.0178	0.0166	0.0153	0.0141	0.0129	0.0119	0.0111	0.0105	0.0101	0.0100
76	0.0206	0.0197	0.0187	0.0176	0.0165	0.0153	0.0141	0.0130	0.0119	0.0111	0.0105	0.0101	0.0100
77	0.0204	0.0195	0.0185	0.0174	0.0164	0.0152	0.0141	0.0130	0.0120	0.0111	0.0105	0.0101	0.0100
78	0.0203	0.0193	0.0183	0.0173	0.0162	0.0151	0.0140	0.0130	0.0120	0.0112	0.0105	0.0101	0.0100
79	0.0203	0.0193	0.0183	0.0172	0.0161	0.0150	0.0140	0.0130	0.0120	0.0112	0.0105	0.0101	0.0100
80	0.0203	0.0194	0.0183	0.0172	0.0161	0.0150	0.0139	0.0130	0.0120	0.0112	0.0106	0.0101	0.0100
81	0.0204	0.0195	0.0184	0.0173	0.0161	0.0150	0.0139	0.0129	0.0120	0.0112	0.0106	0.0102	0.0100
82	0.0206	0.0196	0.0185	0.0174	0.0162	0.0150	0.0139	0.0129	0.0120	0.0112	0.0106	0.0102	0.0100
83	0.0208	0.0198	0.0187	0.0175	0.0163	0.0151	0.0139	0.0129	0.0119	0.0112	0.0106	0.0102	0.0100
84	0.0210	0.0200	0.0189	0.0177	0.0164	0.0152	0.0140	0.0129	0.0119	0.0111	0.0105	0.0102	0.0100
85	0.0213	0.0202	0.0191	0.0178	0.0165	0.0153	0.0140	0.0129	0.0119	0.0111	0.0105	0.0101	0.0100
86	0.0215	0.0204	0.0192	0.0179	0.0166	0.0153	0.0140	0.0128	0.0118	0.0110	0.0103	0.0099	0.0099
87	0.0217	0.0205	0.0192	0.0179	0.0166	0.0153	0.0140	0.0128	0.0117	0.0108	0.0102	0.0098	0.0097
88	0.0218	0.0205	0.0192	0.0178	0.0165	0.0152	0.0139	0.0127	0.0116	0.0107	0.0100	0.0096	0.0096
89	0.0217	0.0204	0.0190	0.0176	0.0162	0.0149	0.0137	0.0125	0.0114	0.0105	0.0099	0.0095	0.0094
90	0.0216	0.0203	0.0189	0.0174	0.0160	0.0147	0.0134	0.0123	0.0113	0.0104	0.0097	0.0093	0.0093
91	0.0214	0.0201	0.0187	0.0172	0.0158	0.0144	0.0131	0.0120	0.0111	0.0102	0.0096	0.0092	0.0091
92	0.0212	0.0199	0.0185	0.0170	0.0156	0.0142	0.0129	0.0117	0.0108	0.0101	0.0094	0.0090	0.0090
93	0.0208	0.0196	0.0182	0.0168	0.0153	0.0139	0.0126	0.0115	0.0105	0.0098	0.0093	0.0089	0.0088
94	0.0204	0.0193	0.0179	0.0165	0.0150	0.0136	0.0123	0.0112	0.0102	0.0095	0.0090	0.0087	0.0087
95	0.0199	0.0188	0.0176	0.0162	0.0147	0.0133	0.0120	0.0109	0.0099	0.0092	0.0087	0.0084	0.0085
96	0.0189	0.0179	0.0167	0.0154	0.0140	0.0127	0.0114	0.0103	0.0094	0.0087	0.0082	0.0080	0.0081
97	0.0179	0.0169	0.0158	0.0146	0.0133	0.0120	0.0108	0.0098	0.0089	0.0083	0.0078	0.0076	0.0077
98	0.0169	0.0160	0.0149	0.0137	0.0125	0.0113	0.0102	0.0092	0.0084	0.0078	0.0074	0.0072	0.0072
99	0.0159	0.0151	0.0140	0.0129	0.0118	0.0107	0.0096	0.0087	0.0079	0.0073	0.0069	0.0068	0.0068
100	0.0149	0.0141	0.0132	0.0121	0.0111	0.0100	0.0090	0.0082	0.0074	0.0069	0.0065	0.0063	0.0064
101	0.0139	0.0132	0.0123	0.0113	0.0103	0.0093	0.0084	0.0076	0.0069	0.0064	0.0061	0.0059	0.0060
102	0.0129	0.0122	0.0114	0.0105	0.0096	0.0087	0.0078	0.0071	0.0064	0.0060	0.0056	0.0055	0.0055
103	0.0119	0.0113	0.0105	0.0097	0.0088	0.0080	0.0072	0.0065	0.0059	0.0055	0.0052	0.0051	0.0051
104	0.0109	0.0104	0.0097	0.0089	0.0081	0.0073	0.0066	0.0060	0.0055	0.0050	0.0048	0.0046	0.0047
105	0.0099	0.0094	0.0088	0.0081	0.0074	0.0067	0.0060	0.0054	0.0050	0.0046	0.0043	0.0042	0.0043
106	0.0089	0.0085	0.0079	0.0073	0.0066	0.0060	0.0054	0.0049	0.0045	0.0041	0.0039	0.0038	0.0038
107	0.0080	0.0075	0.0070	0.0065	0.0059	0.0053	0.0048	0.0044	0.0040	0.0037	0.0035	0.0034	0.0034
108	0.0070	0.0066	0.0061	0.0057	0.0052	0.0047	0.0042	0.0038	0.0035	0.0032	0.0030	0.0030	0.0030
109	0.0060	0.0057	0.0053	0.0049	0.0044	0.0040	0.0036	0.0033	0.0030	0.0028	0.0026	0.0025	0.0026
110	0.0050	0.0047	0.0044	0.0040	0.0037	0.0033	0.0030	0.0027	0.0025	0.0023	0.0022	0.0021	0.0021
111	0.0040	0.0038	0.0035	0.0032	0.0029	0.0027	0.0024	0.0022	0.0020	0.0018	0.0017	0.0017	0.0017
112	0.0030	0.0028	0.0026	0.0024	0.0022	0.0020	0.0018	0.0016	0.0015	0.0014	0.0013	0.0013	0.0013
113	0.0020	0.0019	0.0018	0.0016	0.0015	0.0013	0.0012	0.0011	0.0010	0.0009	0.0009	0.0008	0.0009
114	0.0010	0.0009	0.0009	0.0008	0.0007	0.0007	0.0006	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004
115+	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix B: Mathematical Formulae

A key component of the RPEC_2014 model is a family of polynomial curves, *C(t)*, that pass through two known points with known slopes at those points. Because there are four elements specified, the resulting polynomial is a cubic. The first point is at 2007, and its value and slope there are denoted y_0 and m[28], respectively. Let p denote the length (in years) of the desired convergence period and let y_1 denote the desired value of the point in year 2007 + p. Note that the desired slope of the curve at year 2007 + p is zero. Given the convergence period (p), the two values (y_0 and y_1) and two slopes (m and 0), the general form of the resulting cubic for interpolations starting in 2007 can be expressed as follows:

$$C(t) = y_0 + m\,(t - 2007) + \left(\frac{-2\,p\,m + 3\,(y_1 - y_0)}{p^2}\right)(t - 2007)^2 + \left(\frac{p\,m - 2\,(y_1 - y_0)}{p^3}\right)(t - 2007)^3 \qquad Formula\ B.1$$

Straightforward calculations show that this cubic polynomial satisfies the four desired conditions, namely:

- $C(2007) = y_0$
- $C(2007 + p) = y_1$
- $C'(2007) = m$
- $C'(2007 + p) = 0$

By plugging the committee-selected 20-year convergence period into the above formula, the function RPEC used to develop Scale MP-2014 reduces to:

$$C(t) = y_0 + m\,(t - 2007) + \left(\frac{-40\,m + 3\,(y_1 - y_0)}{400}\right)(t - 2007)^2 + \left(\frac{20\,m - 2\,(y_1 - y_0)}{8000}\right)(t - 2007)^3 \qquad Formula\ B.2$$

The cubic polynomial, $C(t)$, is used to interpolate annual mortality improvement rates in two directions—horizontally and diagonally—for values of t starting at 2008 and ending at 2026. These interpolated values were rounded to five decimal places. Throughout the remainder of this Appendix B, *f(x, y)* shall denote the mortality improvement rate at age x in calendar year y, first introduced in subsection 3.1.

[28] Tables of gender-/age-specific initial values (y_0) and initial slopes (m) in calendar year 2007 have been included in the MP-2014 Excel file that accompanies this report. In accordance with the RPEC_2014 model, all initial slopes have been restricted to the closed interval [-0.003, 0.003].

Horizontal Interpolation

For each fixed age, x, the following values are known:

- The starting mortality improvement rate, $y_0 = f(x, 2007)$
- The starting slope, $m = f(x, 2007) – f(x, 2006)$, restricted to the closed interval [-.003, +.003]
- The ending mortality improvement rate, y_1 = the assumed long-term rate at age x

Given these three values and the 20-year committee-selected convergence period assumed by RPEC, the horizontal interpolations can be performed using the function C(t) above. For example, the corresponding values (accurate to five places) for a male age 65 in 2007 are:

- $y_0 = 0.02242$
- $m = 0.02242 – 0.02375 = – 0.00133$
- $y_1 = 0.01$

If we call this fixed-age-65 interpolating polynomial, $C_{age=65}(t)$, then

$$C_{age=65}(t) = 0.02242 – 0.00133\ (t-2007) + 0.00003985\ (t – 2007)^2 – 0.00000022\ (t – 2007)^3,$$

and the fixed-age-65 interpolated value in calendar year 2012 equals $C_{age=65}(2012) = 0.01674$.

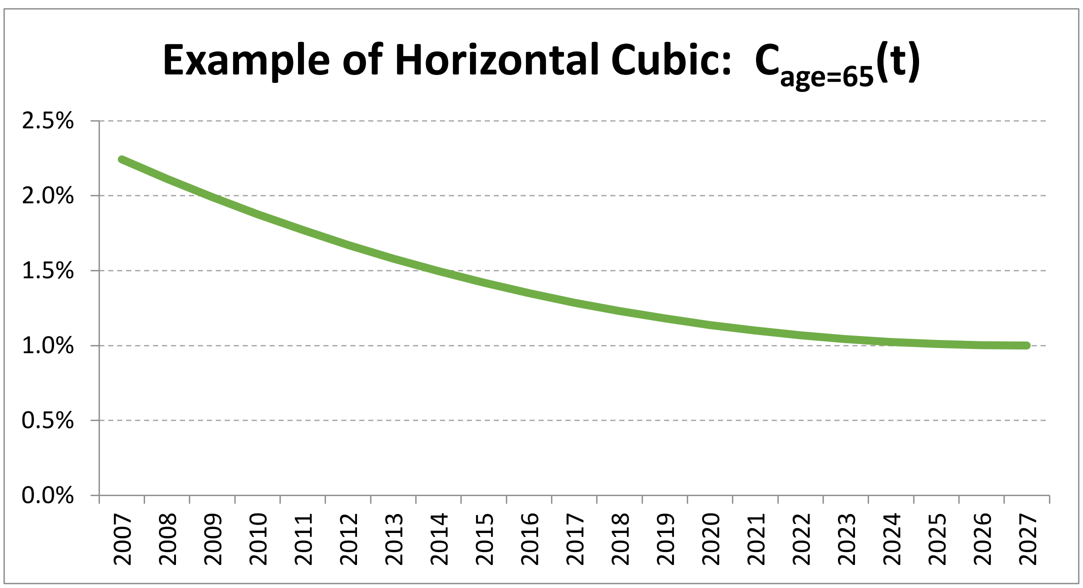

Figure B.1

The reader can confirm that the graph of $C_{age=65}(t)$ above reproduces the desired mortality improvement values and slopes at the beginning and the end of the interpolation period.

Diagonal Interpolation

For each fixed cohort year-of-birth, b, the following values are determined:

- The starting mortality improvement rate, $y_0 = f(2007 - b, 2007)$; (if $b > 1987$, then the value for $b = 1987$ is used instead)
- The starting slope, $m = f(2007 - b, 2007) - f(2006 - b, 2006)$, restricted to the closed interval [-.003, +.003]; (if $b > 1987$, then the value for $b = 1987$ is used instead)
- The ending mortality improvement rate, y_1 = the assumed long-term rate at age $2027\text{-}b$. If the quantity $2027 - b$ is less than 20 (or greater than 120), the value of y_1 is set equal to the assumed long-term rate at age 20 (respectively, age 120)

As with the horizontal interpolation, these three values (and the 20-year committee-selected convergence period) determine the cubic polynomials used for the diagonal interpolations along fixed year-of-birth paths. For example, the values (accurate to five places) for a female born in 1930 are:

- $y_0 = 0.01977$
- $m = 0.01977 - 0.01853 = 0.00124$
- $y_1 = 0.00765$, the assumed long-term rate for a female age 97 in 2027

If we call this fixed-1930-cohort interpolating polynomial, $C_{coh=1930}(t)$, then

$$C_{coh=1930}(t) = 0.01977 + 0.00124\,(t\text{-}2007) - 0.00021490\,(t\text{-}2007)^2 + 0.00000613\,(t\text{-}2007)^3,$$

and the fixed-1930-cohort interpolated value in calendar year 2022 equals $C_{coh=1930}(2022) = 0.01071$.

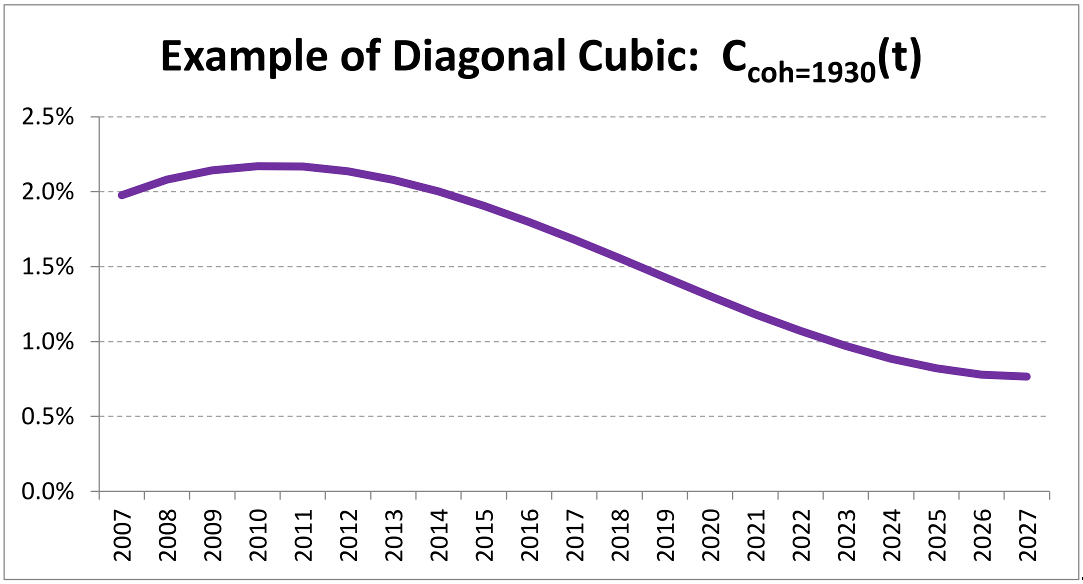

Figure B.2

Beyond calendar year 2027, the fixed-cohort values are equal to the assumed long-term rates at the projected ages. For example, the fixed-cohort mortality improvement rate in 2028 for a female born in 1930 would be 0.00723, the assumed long-term rate at age 98, and so on.

Completing the Smooth Transition

While each of the two sets of interpolations transitions smoothly from 2007 to 2027 on its own, the fixed-age interpolations exhibited a tendency to overemphasize purely horizontal patterns, and the fixed-cohort interpolations exhibited a tendency to overemphasize purely diagonal patterns. RPEC concluded that an equal blend of the two interpolation sets for all ages up through 95 would be a reasonable way to balance anticipated age and cohort effects. So, for a given age, x $(20 \le x \le 95)$, and calendar year, y $(2007 \le y \le 2027)$, the Scale MP-2014 mortality improvement rate, $f(x,y)$, can be expressed as:

$$f(x,y) = 50\%\, C_{age=x}(y) + 50\%\, C_{coh=(y-x)}(y)$$

The final (blended) Scale MP-2014 rates were rounded to four decimal places.

Given the special methodology used by the SSA to develop mortality improvement rates above age 95 (see first paragraph of subsection 3.2), RPEC decided to interpolate linearly from the age 95 mortality improvement rates described above to 0.0 percent at age 115 for each calendar year starting in 1951. In calendar year 2015, for example, the Scale MP-2014 rate for a female age 95 is 0.0199. The Scale MP-2014 rate for a female age 96 in 2015 is calculated as (19/20) x 0.0199 = 0.0189.

Appendix C: Supplementary Heat Maps

Heat Maps Based on 100 Percent Horizontal Projections

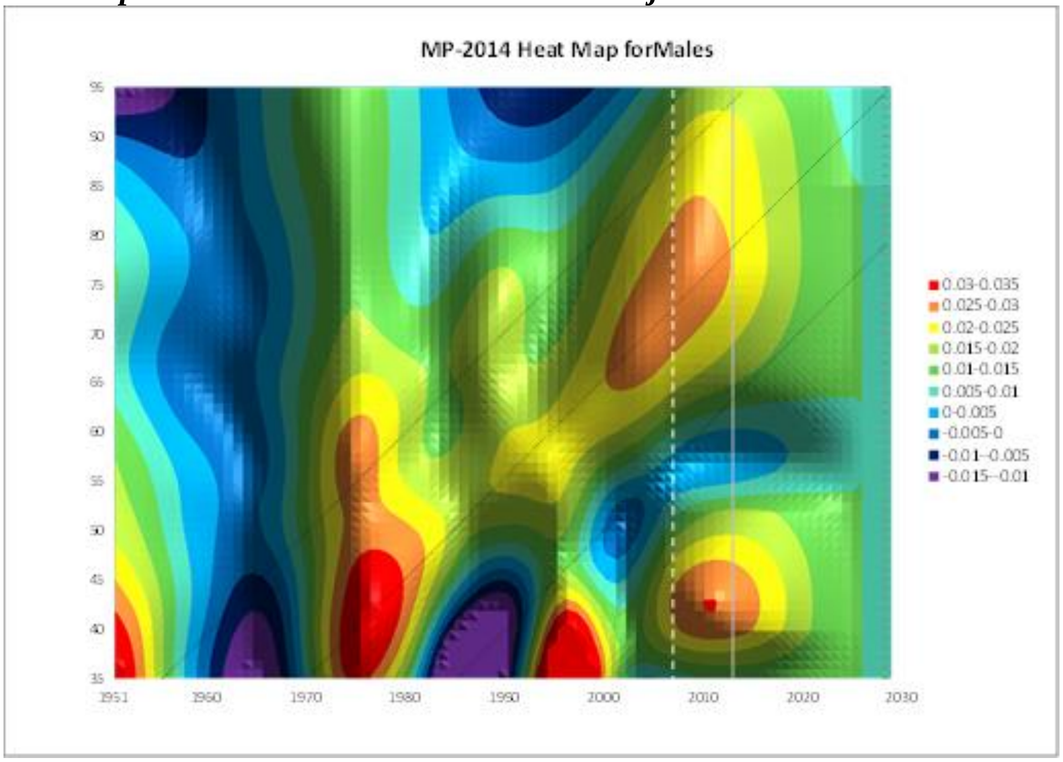

Figure C.1(M)

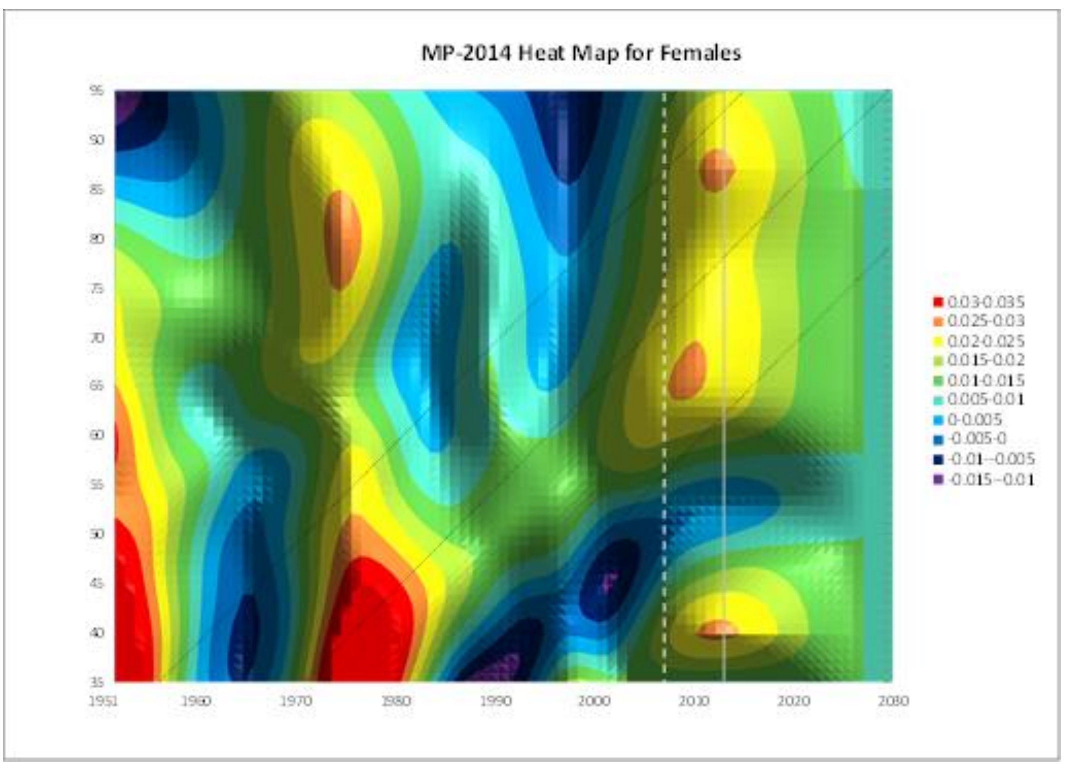

Figure C.1(F)

Heat Maps Based on 100 Percent Diagonal Projections

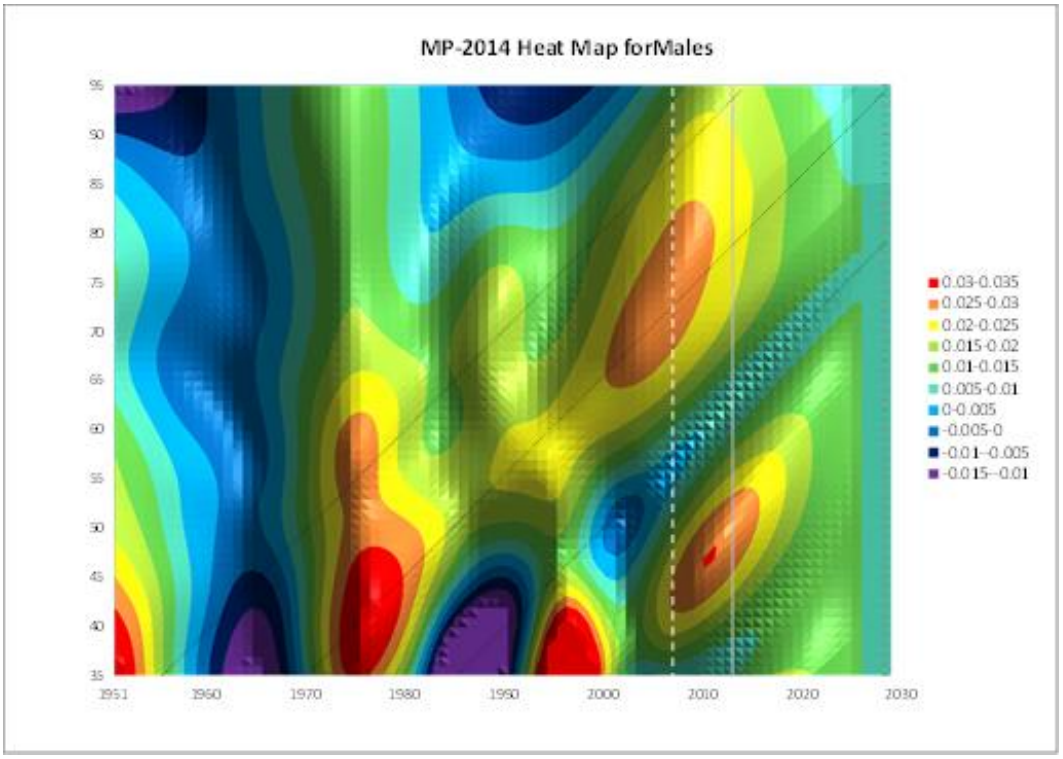

Figure C.2(M)

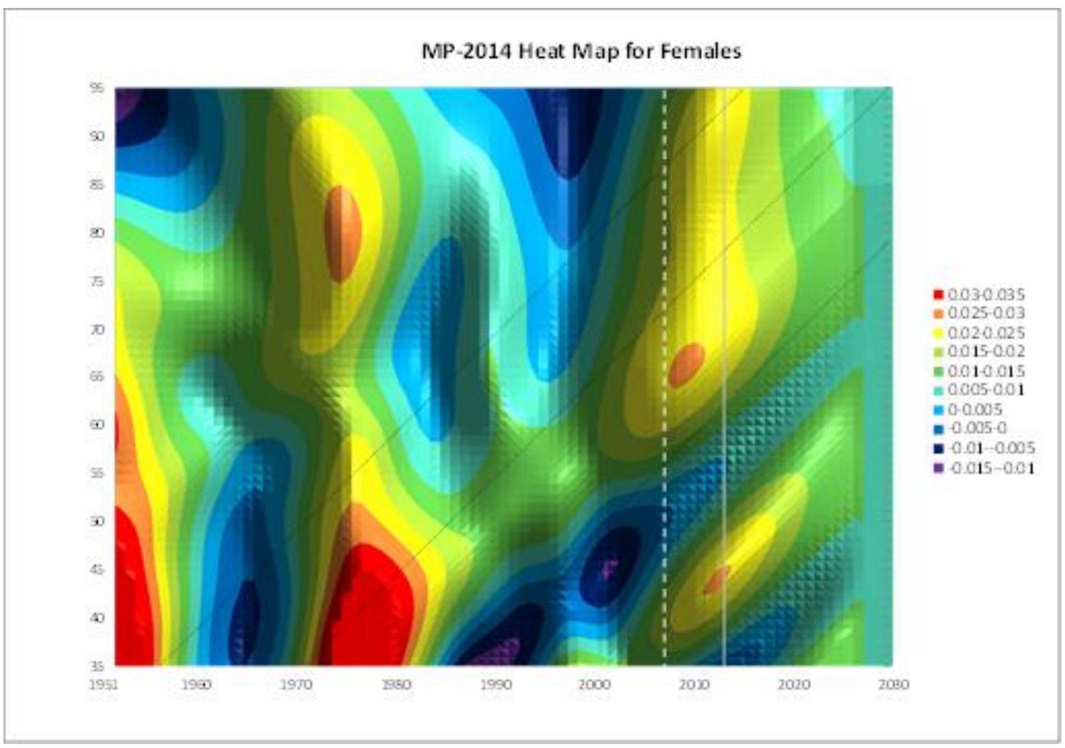

Figure C.2(F)

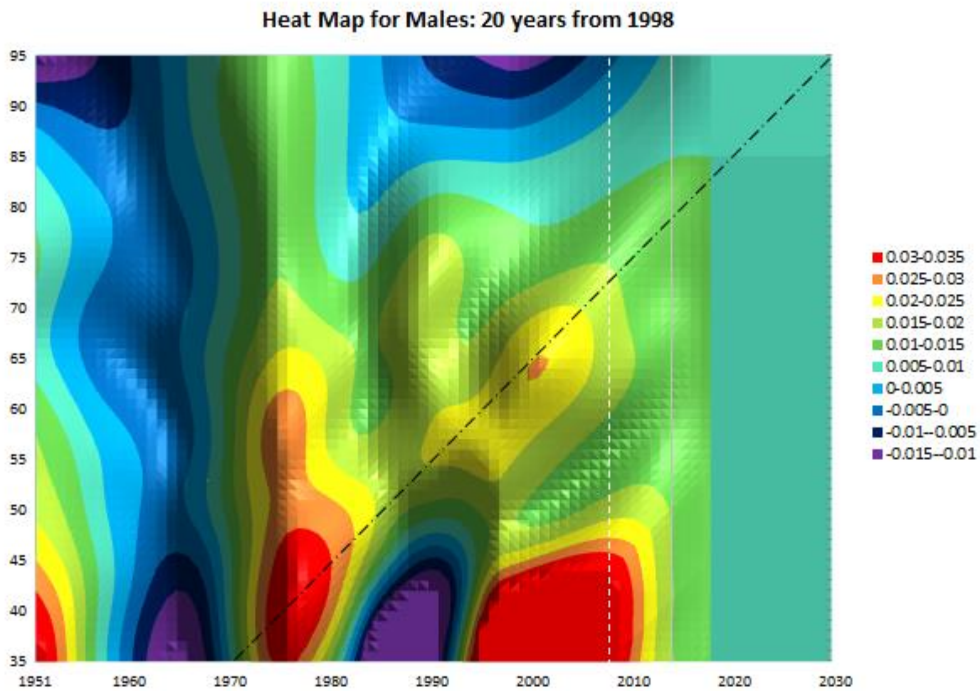

Figure C.3

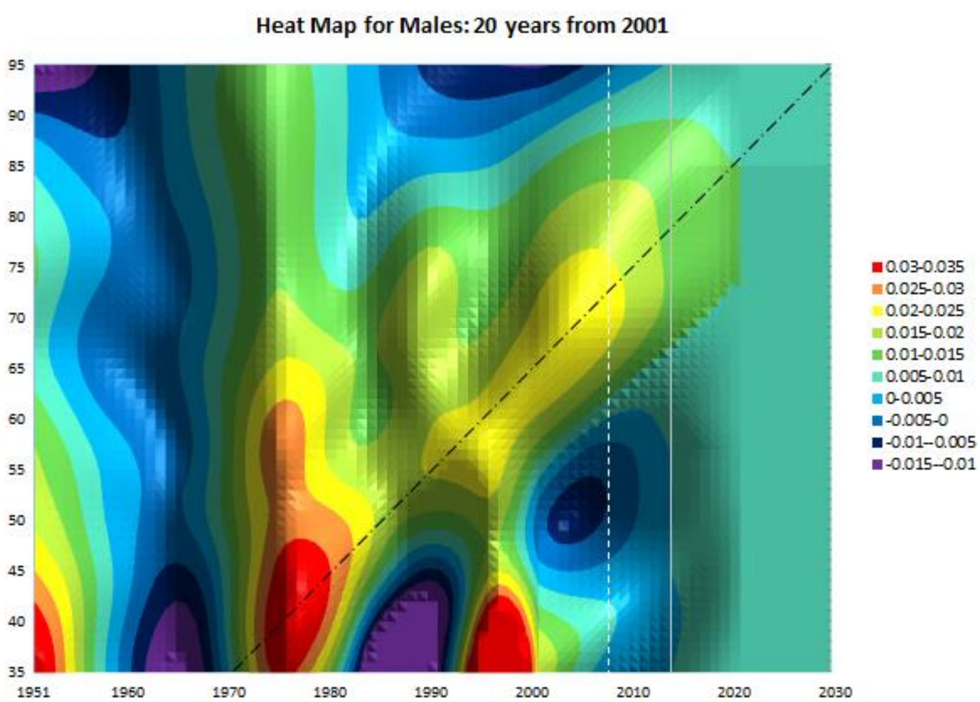

Figure C.4

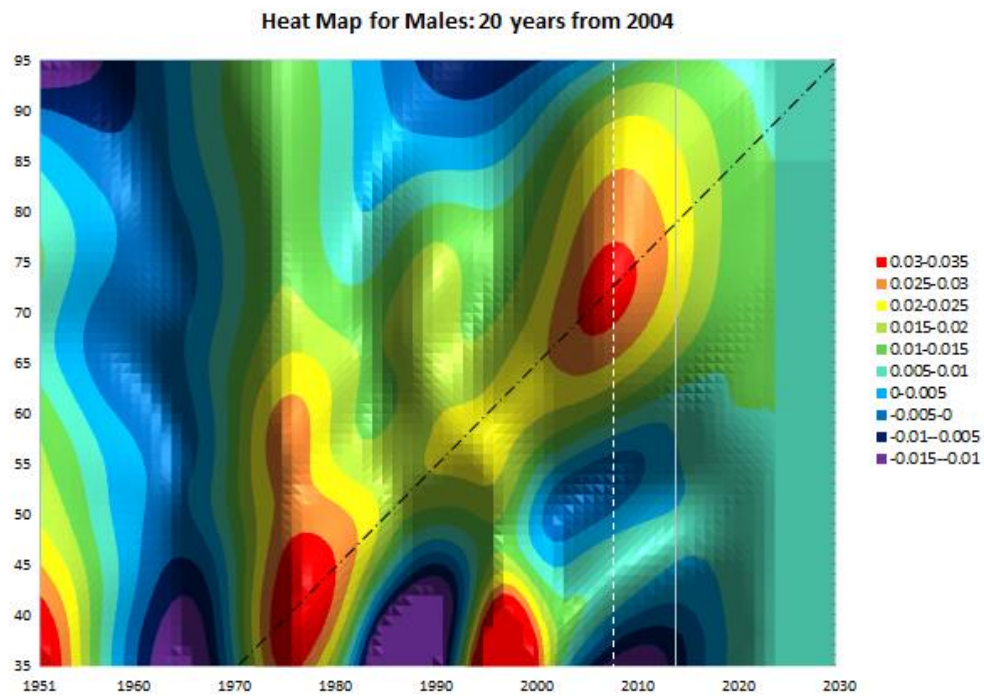

Figure C.5

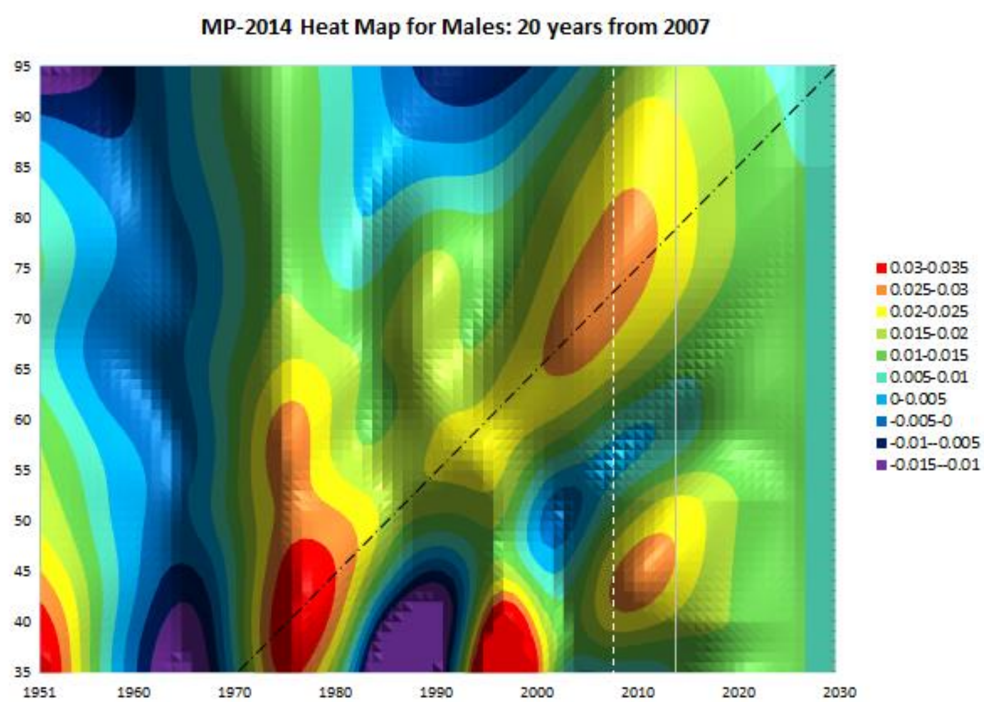

Figure C.6

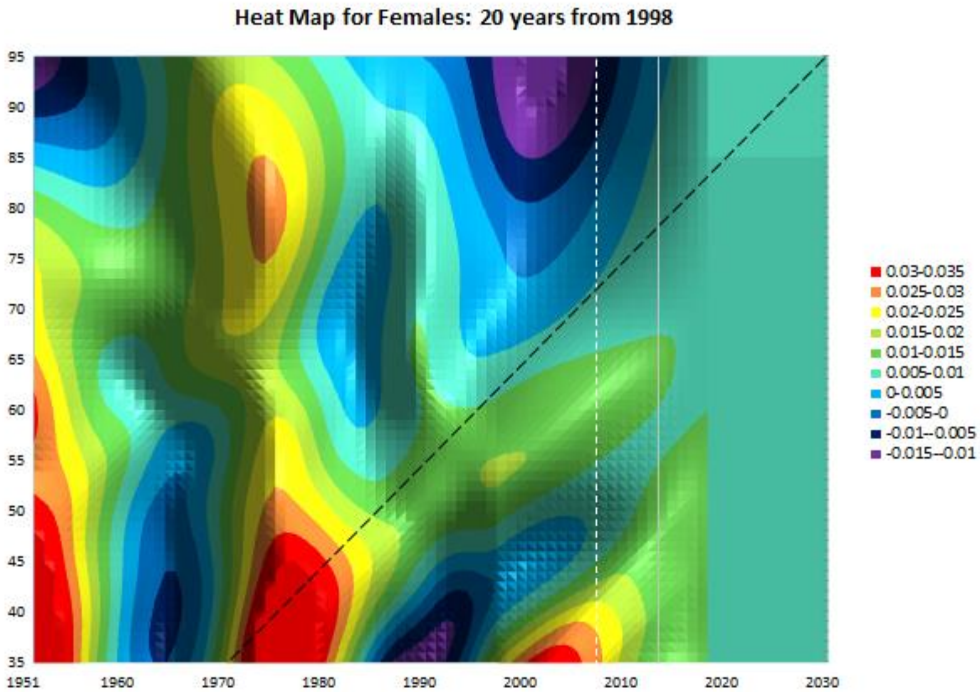

Figure C.7

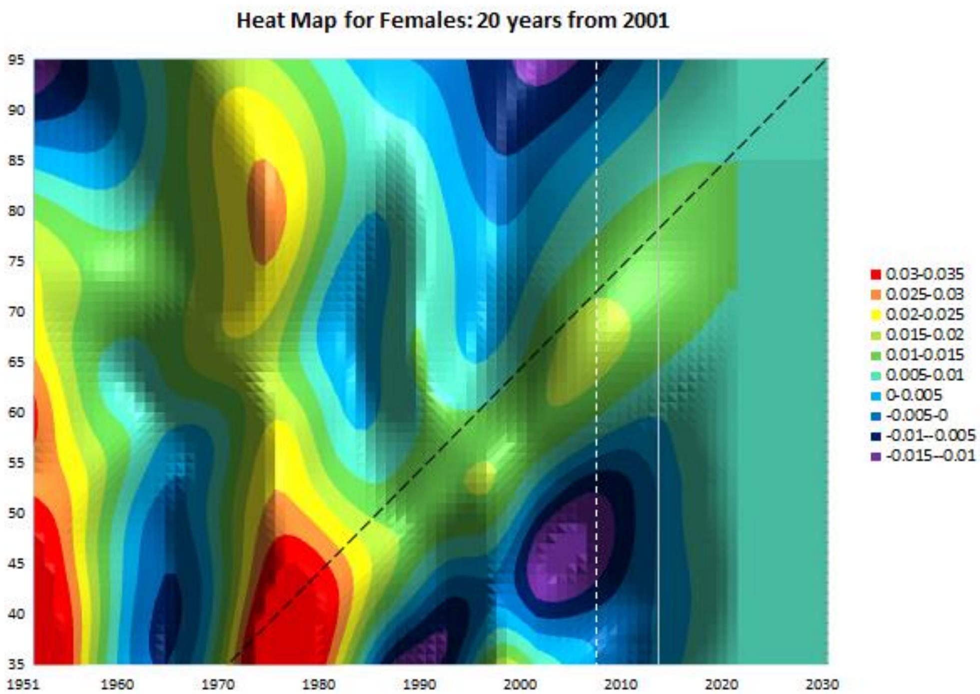

Figure C.8

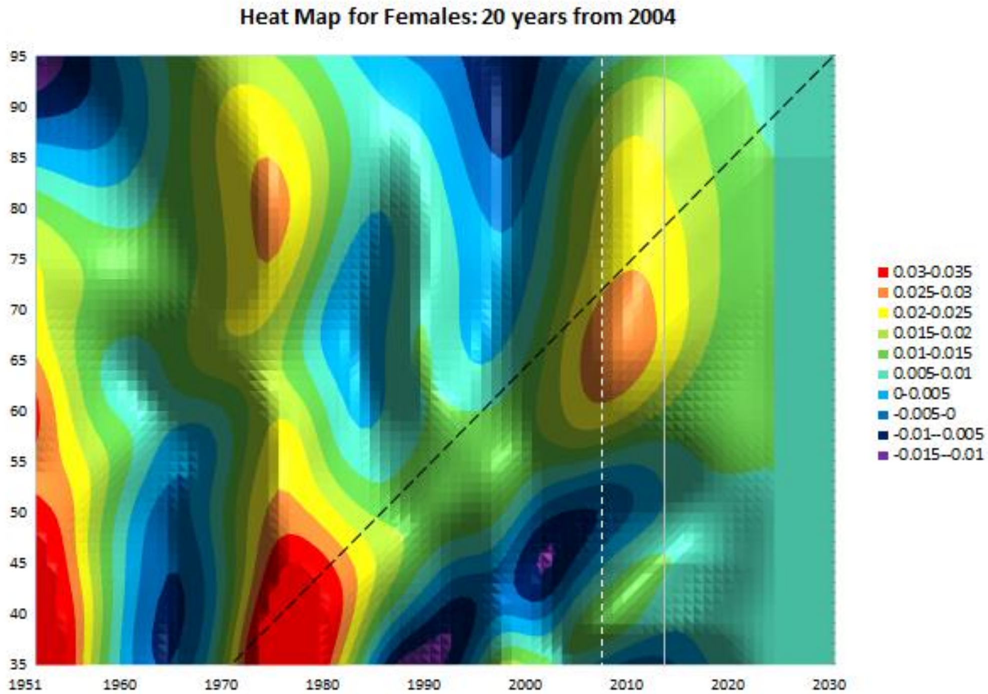

Figure C.9

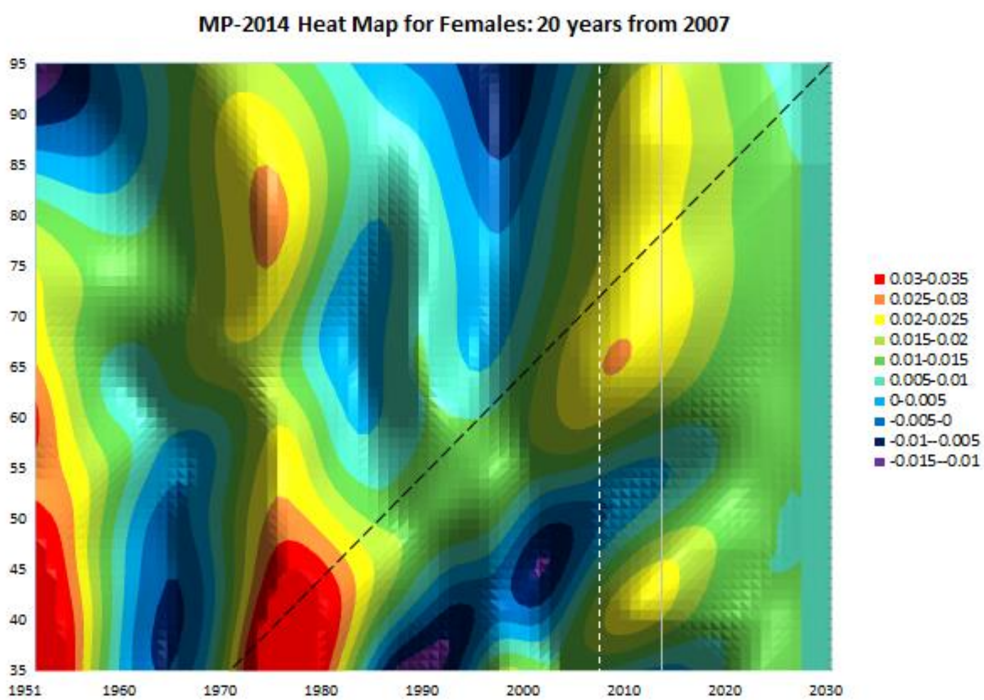

Figure C.10

Appendix D: Factors Affecting Future Mortality Trends

The scope of scholarly research on human longevity has been extensive, especially over the past two decades. In addition to reviewing this research, RPEC commissioned its own literature review of relevant mortality topics and an assessment of U.S. mortality improvement rates [16].

RPEC believes that "The Long-Range Demographic Assumptions for the 2014 Trustees Report" [24] provides a good summary of the key factors that could affect future U.S. mortality patterns. The following has been extracted directly from Section 2.2 (Considerations in Selecting Mortality Assumptions) of that OCACT report:

> *A number of extremely important developments have contributed to the generally rapid overall rate of mortality improvement during the past century. These developments include:*
>
> - *Access to primary medical care for the general population (in particular, the access due to Medicare and Medicaid health coverage for the elderly, disabled, and poor),*
> - *Discovery of and general availability of antibiotics and immunizations,*
> - *Clean water supply and waste removal, and*
> - *The rapid rate of growth in the general standard of living.*
>
> *Each of these developments is expected to make a substantially smaller contribution to annual rates of mortality improvement in the future.*
>
> *Future reductions in mortality will depend upon such factors as:*
>
> - *The development and application of new diagnostic, surgical, and life-sustaining techniques,*
> - *The rate of future increase in health spending and the efficiency of that spending relative to mortality improvement,*
> - *The presence of environmental pollutants,*
> - *Changes in amount and type of physical activity,*
> - *Improvements in nutrition,*
> - *The incidence of violence and suicide,*
> - *The isolation and treatment of causes of disease,*
> - *The emergence of new forms of disease,*
> - *The evolution of existing forms of disease,*
> - *Improvements in prenatal care,*
> - *The prevalence of obesity,*
> - *The prevalence of cigarette smoking,*
> - *The misuse of drugs (including alcohol),*
> - *The extent to which people assume responsibility for their own health,*
> - *Education regarding health, and*
> - *Changes in our perception of the value of life.*

In reviewing the above list, future progress for some factors seems questionable when recent statistics are considered. Recent National Center for Health Statistics (NCHS) releases have reported a substantial increase in the prevalence of obesity and diabetes, decreased environmental air quality, and an increase in negative side effects from invasive surgical procedures. On the other hand, there is good basis for speculation that there will be substantial breakthroughs in advancing medical technology and treatment in the future. The extent to which such new technologies will have purely positive effects (like improved sanitation) versus mixed effects (as in the case of chemotherapy) will determine their potential for improving mortality. A fundamental consideration, however, is the ability and willingness of our society to pay for the development of new treatments and technologies, and to provide these to the population as a whole.

Those who are interested in additional perspectives on future mortality improvement in the United States can consult the following sources (many of which can be found at *http://www.soa.org/professional-interests/pension/resources/pen-mortality-resources.aspx*):

- Longevity in the 21st Century [31]
- Confronting the Boundaries of Human Longevity [12]
- The Great Debate on the Outlook for Human Longevity: Exposition and Evaluation of Two Divergent Views [21]
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