Segal

Public Employees' Retirement Association of Colorado

Signal Light Reporting for the Hybrid Defined Benefit Plan

Based on the Results of the December 31, 2021, Actuarial Valuation

July 13, 2022

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The Board of Trustees
Public Employees' Retirement Association of Colorado
1301 Pennsylvania Street
Denver, CO 80203-2386

Dear Trustees:

We are pleased to submit the results of the Signal Light Reporting for the Hybrid Defined Benefit Plan (Plan) of the Public Employees' Retirement Association of Colorado (PERA), prepared as of December 31, 2021. The purpose of this report is to provide a sensitivity analysis of the Plan's actuarial assumptions on certain funding targets and to provide a reconciliation of the changes in the expected full funding dates, which are determined assuming all actuarial assumptions are met in the future.

As a result of annual discussion and analysis of the PERA Board of Trustees (Board), the Signal Light Reporting process has been enhanced as follows:

- 2020 Report: Employed stochastic modeling in lieu of deterministic modeling regarding the analysis of the long-term rate of return assumption. A stochastic approach better models the impact of actual market activity including the effect of the timing and order of investment returns because uncertain or variable factors are built into a stochastic model, and a stochastic approach considers PERA's portfolio and more precisely reflects capital market assumptions, by investment category, within PERA's asset allocation.
- 2021 Report: Added a "short-term" view to provide a better understanding of the conditions that would need to exist as of the next automatic adjustment provision (AAP) assessment that possibly would trigger additional AAP adjustments. The next AAP assessment will be performed concurrently with the December 31, 2022, actuarial valuation, and if triggered, the AAP adjustments would be effective as of July 1, 2024.
- 2022 Report: Added an additional "short-term" view on the probability of triggering AAP adjustments within the next 10-year period under a baseline assumption scenario, as well as a few alternative scenarios.

All calculations have been made in conformity with generally accepted actuarial principles and practices, and with the Actuarial Standards of Practice issued by the Actuarial Standards Board. In our opinion, the results presented also comply with Colorado Statutes, and, where applicable, the Internal Revenue Code, ERISA, and the Statements of the Governmental Accounting Standards Board (GASB). The undersigned are independent actuaries. All are Fellows of the Society of Actuaries, Enrolled Actuaries, and Members of the American Academy of Actuaries, and are experienced in performing valuations for large

public retirement systems. All meet the Qualification Standards of the American Academy of Actuaries.

The projections included in this report are based on data provided by PERA and the baseline actuarial assumptions, as approved by the Board, and used in the December 31, 2021, actuarial valuation. As with any projection analysis, this report should not be viewed for absolute results, but should be focused on trends in the financial measurements. It is important to note that this report is based on plan assets as of December 31, 2021, and does not reflect any returns experienced by the fund after that date.

Future actuarial results may differ significantly from the current results presented in this report due to such factors as the following: plan experience differing from that anticipated by the economic or demographic assumptions; changes in economic or demographic assumptions; increases or decreases expected as part of the natural operation of the methodology used for these measurements (such as the end of an amortization period or additional cost or contribution requirements based on the plan's funded status); and changes in plan provisions or applicable law.

PENSION FINANCING OBJECTIVES

PERA maintains five pre-funded, hybrid defined benefit pension plans [i.e., State Division Trust Fund, School Division Trust Fund, Local Government Division Trust Fund, Judicial Division Trust Fund, and Denver Public Schools (DPS) Division Trust Fund]. Each defined benefit pension plan is funded through PERA-affiliated employer and member contributions including adjustments resulting from the Automatic Adjustment Provision (AAP), a $225 million direct distribution from the State of Colorado scheduled for July 1, 2022, and each year thereafter, and the investment earnings resulting from those contributions. In addition, for employees of employers of the State and Local Government Divisions, hired on or after January 1, 2019, who chose to participate in the PERAChoice Defined Contribution (DC) Plan in lieu of participating in PERA's Defined Benefit Plan, a DC Supplement is paid to the Defined Benefit Plan to help fund the unfunded actuarial accrued liability (UAAL). Determined separately for the State and Local Government Divisions and calculated as a rate of pay, the DC Supplement was first payable as of January 1, 2021, by all employers of the two divisions, updated annually with each funding actuarial valuation. The fixed contribution rate at which each division's employers and members contribute is determined by the Colorado General Assembly and defined within the statutes governing PERA.

No significant legislation was enacted in 2021 that directly impacts the actuarial valuation as of December 31, 2021; however, the following legislation, enacted in 2022, provides a repayment of the suspended 2020 direct distribution and impacts the return to work provisions for the retirees. These bills are reflected, to the extent possible, in this actuarial analysis:

- HB 22-1029, enacted and effective as of June 7, 2022, was intended to recompense PERA for the $225 million direct distribution originally scheduled for receipt

July 1, 2020, but suspended due to the enactment of HB 20-1379. Pursuant to HB 22-1029, the State treasurer is to issue a warrant to PERA in the amount of $380 million, upon enactment, with reductions to future direct distributions scheduled to occur July 1, 2023, and July 1, 2024, based upon the actual investment return reported by PERA. Based on this legislation and the known total fund investment return for 2021 of 16.1%, the July 1, 2023, direct distribution will be reduced by $190 million, resulting in a payment of $35 million, and the July 1, 2024, direct distribution will be reduced by an amount yet to be determined, but not greater than $27.55 million, resulting in a payment of not less than $197.45 million. The $35 million direct distribution scheduled to occur July 1, 2023, is considered in the 2021 AAP assessment. The reduced 2023 direct distribution does not adversely impact the resulting AAP ratio to cause a triggering of additional contribution and AI cap adjustments.

- HB 22-1057, enacted and effective as of March 17, 2022, temporarily broadens the current working after retirement provisions by removing the limitation regarding the number of days that retired teachers can work as substitute teachers without any reduction in retirement benefits, applicable to any school district or charter school subject to critical substitute teacher shortages.

- HB 22-1101, enacted and effective as of March 17, 2022, makes permanent and broadens the Rural School District Critical Shortage program that removes limitations regarding the number of days that service retirees can work without any reduction in their retirement benefits, applicable to any rural school district, Board of Cooperative Services (BOCES) or charter school subject to critical shortage of certain positions.

- HB 22-1087, enacted and effective as of March 24, 2022, excludes special district directors who begin service on or after July 1, 2022, from membership in PERA.

PERA's defined benefit pension plan funding policy, as developed and maintained by the PERA Board of Trustees (Board), is used to gauge the adequacy of the statutory contributions. The purposes of this funding policy are to state the overall funding goals and annual actuarial metrics and to guide the Board when considering whether to pursue or support proposed contribution and benefit legislation related to the Division Trust Funds. The policy also includes a brief list of governance responsibilities regarding the commissioning, collection, and review of actuarial information, as described in the Board's Governance Manual.

PERA also maintains two pre-funded defined benefit retiree health care subsidy plans (i.e., Health Care Trust Fund and DPS Health Care Trust Fund), classified as other postemployment benefit (OPEB) plans. The Board maintains a separate OPEB plan funding policy with regard to these plans. Analysis regarding specific OPEB-related plans and assumptions are not included in this report.

A summary of PERA's pension funding policy is provided in PERA's Actuarial Valuation and Review as of December 31, 2021.

BENEFIT PROVISIONS

Plan benefits are specified in Title 24, Article 51 of the Colorado Revised Statutes (C.R.S.), administrative rules set forth at 8 C.C.R. 1502-1, and applicable provisions of the federal Internal Revenue Code. The Colorado General Assembly may amend Colorado State law provisions from time to time. A summary of plan provisions is provided in PERA's Actuarial Valuation and Review as of December 31, 2021.

ASSUMPTIONS AND METHODS

The information and analysis used in selecting each assumption that has a significant effect on this actuarial valuation resulted from the 2020 Experience Analysis report, titled, *Public Employees' Retirement Association of Colorado Analysis of Actuarial Experience during the Period January 1, 2016 through December 31, 2019*. All recommended changes to the demographic and economic actuarial assumptions resulting from this study were reviewed and adopted by the Board at their November 20, 2020, meeting, to be effective beginning with the December 31, 2020, actuarial valuation.

Particularly relevant to this Signal Light report, the assumption related to annual increases in active headcount used for purposes of the open group projections are as follows:

Division Trust Fund	Current Assumption
State	0.25%
School	1.00%
Local Government	1.00%
Judicial	0.25%
Denver Public Schools	1.00%

As a result of the 2019 Asset Liability Study, concluded at the November 15, 2019, Board meeting, the Board reaffirmed the 7.25% assumed long-term rate of investment return effective as of January 1, 2020. This Board decision also was in alignment with the analysis provided in the 2020 Analysis of Actuarial Experience report.

DATA

Member data for retired, active, and inactive participants was supplied as of December 31, 2021, by PERA. We have not subjected this data to any auditing procedures but have examined the data for reasonableness and consistency with the prior year's data. Asset information was also supplied by PERA. That assistance is gratefully acknowledged.

Sincerely,
Segal

Matthew Strom, FSA, MAAA, EA

Brad Ramirez, FSA, MAAA, EA

Tatsiana Dybal, FSA, MAAA, EA

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July 13, 2022

Executive Summary

Introduction

Background & Purpose

In accordance with 24-51-204(7.5), C.R.S., each year the Public Employees Retirement Association (PERA) of Colorado, Board of Trustees (Board) requests their actuarial service provider to ***"perform a sensitivity analysis to determine when, from an actuarial perspective, model assumptions are meeting targets and achieving sustainability"***. This sensitivity analysis, known as Signal Light Reporting, has been produced for or on behalf of the Board since 2015. The current report was produced by Segal using the December 31, 2021, actuarial valuation as a basis in conjunction with a projection modeling tool.

The intent of this report is to provide a format for conveying certain actionable information to both PERA and the General Assembly for making decisions with respect to the Plan. The Signal Light process should be viewed as an enhancement to the actuarial valuation control cycle by providing additional evaluation metrics to assess the need for further, in-depth analysis of the actuarial assumptions and/or other major risks to the Plan's sustainability.

Detail regarding the background, as well as all actuarial methods and assumptions employed within this analysis, are provided in Section 1 and Section 8, respectively, of the report.

Enhancements

As a result of annual discussion and analysis of the Board, the Signal Light Reporting process has been enhanced over the last few years, as follows:

Signal Light Report	Description of Enhancement
2020	Began employing stochastic modeling in lieu of deterministic modeling regarding the analysis of the likelihood of achieving the long-term rate of return assumption. The stochastic approach enhances the analysis by considering PERA's investment portfolio and asset allocation in conjunction with the impact of actual market activity including the effect of the timing and order of investment returns.
2021	A section providing a *Short-Term View* was added to the reporting process to provide a better understanding of the conditions that would need to exist as of the next Automatic Adjustment Provision (AAP) assessment that would trigger additional AAP adjustments.
2022	Expanded the *Short-Term View* section to include 10-year projection graphs under various scenarios that show the likelihood (in any one year) of triggering the AAP adjustments in either direction, regarding the 98% and 120% thresholds. Included an Executive Summary at the front of this report.

The Board intends to continue to evolve the Signal Light Reporting process, as additional, useful modeling tools and methods present themselves or are brought to the Board's attention.

Long-Term View

Under the *Long-Term View*, the analysis within this report determines **likelihood of achieving the expected long-term rate of investment return and certain demographic assumptions**. This is done through stochastic projections, modeling 5,000 deterministic trials for each testing scenario based upon:

- The 30-year capital market assumptions, provided by the Board's investment consultants, at the time the Board last reviewed the current expected long-term rate of investment return of 7.25%,
- The resulting likelihoods of achieving certain returns based upon 50-year probability outlooks reviewed and adjusted annually, and
- The provisions of SB 18-200, reflecting the AAP.

The Signal Light reporting compares the projection of each division's funded ratio over certain time periods and assigns a color to indicate the relative strength of the result. The colors and corresponding criteria are defined in the following table.

Status Definitions – Long-Term View

Status	Definition
Dark Green	100% funded by 2041 (30 years from 2011)
Green	100% funded by 2048 (30 years from 2018)
Light Yellow	100% funded by 2058 (40 years from 2018)
Yellow	100% funded by 2068 (50 years from 2018)
Orange	Solvent but more than 50 years to reach 100% funded
Red	Insolvent after 2042 (after 20 years)
Dark Red	Insolvent by 2042 (within 20 years)

The **Dark Green** through **Yellow** status definitions maintain the benchmark year by which the Plan would be expected to be 100% funded. The **Orange** through **Dark Red** status definitions maintain the number of years that the solvency of the Plan is measured. A summary of the change in the Signal Light reporting from last year to this year is summarized in the following table.

Signal Light Status – Long-Term View			
Division	**December 31, 2021**	**December 31, 2020**	**Probability of 100% Funded by 2048**
State	**Dark Green**	**Green**	**63%**
School	**Green**	**Green**	**59%**
Local Government	**Dark Green**	**Dark Green**	**67%**
Judicial	**Dark Green**	**Dark Green**	**80%**
DPS	**Dark Green**	**Dark Green**	**84%**

Detail regarding the analysis and results related to the Long-Term View is provided in Sections 2-5 of the report.

Short-Term View

One-Year Analysis

In order for the projected AAP ratio as of December 31, 2022, to be lower than 98% or greater than 120% (and therefore trigger a series of AAP adjustments), experience for 2022 of any single variable above (assuming the other two variables meet their respective assumptions for the year) would need to be:

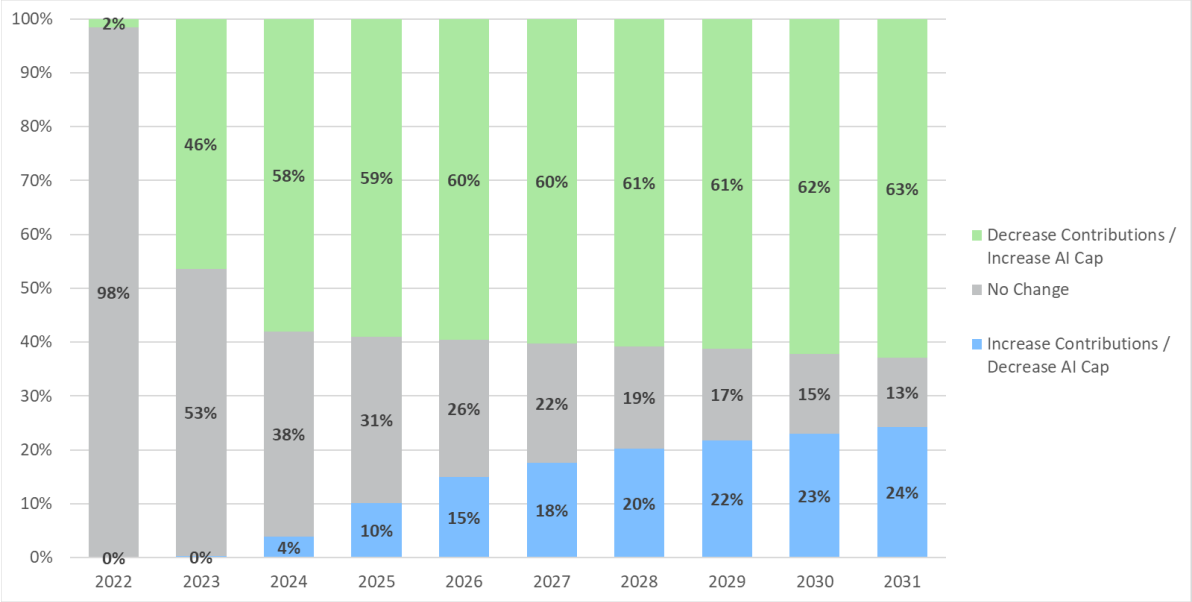
Variable	AAP Ratio of 98% or Less	AAP Ratio of 120% or More
Market value investment return	Worse than -44.6%	Better than 31.9%
Year-over-year change in total payroll	Lower than 21.6% decrease	Higher than 19.3% increase
Demographic experience	More than 9.2% loss	More than 4.2% gain

Note that the three static parameters shown above are NOT “equally likely” to achieve their expected or assumed value, but under the scenarios provided within the report (pages 30-32) they represent anecdotal metrics for “worse-than-expected” and “better-than-expected” experience in a given year. To provide context for the pages referenced, as well as the modeled results shown above: over the last 30 years, a market value return of 0% or lower has occurred five times, a 1% or more demographic loss has occurred ten times, and a 0% or lower decrease in total payroll has occurred four times. A market value return of 20% or greater has occurred four times, a 1% or more demographic gain has not occurred, and a 6% or higher increase in total payroll has occurred eight times.

Ten-Year Analysis

Using the 5,000 stochastically modeled investment return simulations and the baseline open group liability projection results, Segal has estimated the PERA AAP ratio in each scenario for the following ten valuation years. Based on these results, the probability in each year of the AAP test triggering contribution increases and a reduction in the AI cap (from an AAP ratio below 98%) or triggering contribution decreases and an increase in the AI cap (from an AAP ratio exceeding 120%) are determined and illustrated in the following graphic:

Likelihood of Triggering the AAP in the Next[1] Year
Baseline Liability Forecast[2]



[1] Each year's results are determined independently. The probabilities shown in any one year do not consider the impact of any potential AAP changes in any prior or subsequent years.
[2] Due to rounding, values shown here may not sum as expected.

Additional scenarios are provided on pages 33-38.

Detail regarding the analysis and results related to the Short-Term View is provided in Section 6 of the report.

Take-Aways – Reflecting the December 31, 2021, Actuarial Valuation Results

Long-Term View

- The likelihood of PERA achieving full funding status by or before 2048, has a 59%, or better, probability of success.
- The State, Local Government, Judicial and DPS Division Trust Funds are categorized as **Dark Green** and the School Division Trust Fund as **Green**, regarding the likelihood of achieving full funding status by or before 2048.
- The favorable 2021 investment performance strengthened PERA's overall position regarding the likelihood of being 100% funded by or before 2048. See the table, *Increase/(Decrease) in Projected Full Funding Year* provided at the bottom of page 11.
- Although annual demographic plan experience is important to gauge, investment performance has the single most impactful influence on the success or failure of achieving the Board's funding targets within the stated 30-year timeframe.

Short-Term View

- To trigger the 98% (lower) boundary of the AAP assessment for 2022, would take a -44.6% investment return for 2022, assuming all other assumptions were exactly met.
- To trigger the 120% (upper) boundary of the AAP assessment for 2022, would take a 31.9% investment return for 2022, assuming all other assumptions were exactly met.
- At some point in time during the next ten years, under a baseline forecast, it is more likely that the AAP ratio will exceed the 120% (upper) boundary, than the AAP assessment triggering the 98% (lower) boundary.
- At some point in time during the next ten years, under a baseline forecast, but assuming a -5.75%[1] investment return for 2022, it is less likely that the AAP ratio will exceed the 120% (upper) boundary, than the AAP assessment triggering the 98% (lower) boundary.
- Section 6 – Ten-Year Analysis, contains additional scenarios of possible economic observations to which to compare the ten-year baseline forecast.

A complete summary of all significant Signal Light results as of December 31, 2021, is provided in Section 7 of the report.

Note: Because actual experience will not unfold exactly as expected, actual results can be expected to differ from the results presented herein. The Signal Light process, like other actuarial modeling, is not intended to provide absolute results, but rather to identify anticipated trends and to compare various outcomes, under a given methodology. The results produced by the Signal Light Reporting process do not:

- predict the financial condition of PERA, or
- indicate the PERA's ability to pay benefits in the future, or
- provide any guarantee of PERA's future financial soundness.

[1] A -5.75% investment return, represents one standard deviation to the left, as discussed on page 7 of this report.

Section 1: Background

In accordance with 24-51-204(7.5), C.R.S., each year the PERA Board of Trustees (Board) requests their actuarial service provider to "perform a sensitivity analysis to determine when, from an actuarial perspective, model assumptions are meeting targets and achieving sustainability". This Sensitivity Analysis, currently known as Signal Light Reporting, has been produced by Segal using the December 31, 2021, actuarial valuation as a basis in conjunction with a projection modeling tool. This report provides a format for communicating the Plan's funding progress and providing certain actionable information to both PERA and the General Assembly for making decisions with respect to the Plan's funding.

PERA's long-term goals generally focus on the level of funding leading up to the year 2048. However, emerging experience in the next five to ten years can materially affect the pathway to achieving those goals. This report focuses primarily on the factors that lead to PERA meeting its long-term funding goals (*Sections 3–5*), but also examines a short-term view and the emerging experience that impacts the long-term pathway (*Section 6*).

The intended purpose of the Signal Light process is to help assess the Plan's funding progress and to provide information to decision makers to help ensure that the applicable pension liabilities and funding mechanisms are managed in a manner that promotes sustainability. The Signal Light process should be viewed as an enhancement to the actuarial valuation control cycle by providing additional evaluation metrics to assess the need for further, in-depth analysis of the risks to the Plan's sustainability. The actuarial valuation control cycle is a key component of managing a long-term liability whose ultimate value is based upon uncertain future events. As the ultimate value of future cash flows cannot be predicted with certainty, pension liabilities are managed in the short-term through the continuous monitoring of economic and demographic assumptions, with a keen eye on the identification, measurement, and management of risks.

The Signal Light process, like other actuarial modeling, is not intended to provide absolute results. The intended purpose of the Signal Light process is to identify anticipated trends and to compare various outcomes, under a given methodology, rather than to predict some future state of events. The results produced by the Signal Light process do not predict the financial condition of the Plan or the Plan's ability to pay benefits in the future and do not provide any guarantee of future financial soundness of the Plan. Because actual experience will not unfold exactly as expected, actual results can be expected to differ from the results presented herein. To the extent actual experience deviates significantly from the assumptions, results could be significantly better or significantly worse than the expected outcomes indicated in this report.

Actuarial assumptions are a key component of both the snapshot measurements in the actuarial valuation process and the projection of future valuation results. Actual experience can be expected to vary from year to year, even if the actuarial assumptions are met over the long term. The variability of certain key measures can have a significant impact on the date the Plan will reach full funding (actuarial assets equal to or greater than the actuarial accrued liability). The key variables include investment return, active membership growth,

individual pay increases for active members, and demographic experience (e.g., post-retirement mortality).

Of these variables, investment return is the most significant variable and the most volatile. The active membership growth and pay increase variables are also very important, but not nearly as significant as the investment return variable. Mortality and other demographic assumptions may change over the long term in unanticipated ways, but, in this study, we are primarily modeling the variation of total experience and not possible changes in the valuation assumptions. However, *Section 4* does include an analysis of the impact of an alternate set of certain demographic assumptions (i.e., retirement, turnover, and disability incidence rates, as well as rates of individual salary increase).

The standard deviation is a statistical measure of variability, providing a basis for determining how widely the result of any single year, or multiple years, is expected to vary from the expected result. It can also be used to assess the probability of results occurring within a certain range. For example, if the expected rate of investment return is 7.25% annually, the standard deviation is 13.0%, and returns follow the normal distribution, there is a 68% probability that the actual investment return in any one year will be between one standard deviation higher or lower than the expected return. The resulting range is -5.75% to +20.25%. The standard deviation and resulting ranges of annualized return become smaller over longer periods of time. However, the ranges of total return become larger as the time period increases.

While the underlying assumption is that the non-investment variables outlined in this study follow the normal distribution, the interaction between investment volatility and the Plan's projected cash flow can yield non-normally distributed results. To best demonstrate this interaction, we have modeled investment return variation using a technique called stochastic modeling. Under this approach, annual portfolio returns were simulated using expected returns, standard deviations, and covariances of the asset classes held in the fund.

As noted previously, one aspect of the actuarial control cycle is the continuous monitoring of the assumptions and methods used in the valuation process. Over time, PERA's actuaries will periodically re-evaluate the assumptions and methods, with the PERA Board's review and/or approval, to reflect updated experience and changes in future expectations. As such, each year's update to the Signal Light results will incorporate the PERA Board's assumptions and methods set as of the most recent valuation date.

The variability of investment returns and other experience will affect the projected full funding date (the point at which the actuarial value of assets equals the actuarial accrued liabilities) of each of the Plan's five divisions (State, School, Local Government, Judicial, and DPS). This methodology and Signal Light reporting tool are used to communicate the significance of the variability in achieving funding goals, with the intent that policymakers would have a more understandable picture of both the current funded status of the Plan and the probability of conditions that will improve or weaken that status in the future. The process reflects the possibility of actual future experience varying from that assumed in the long-term. The assumed investment return is a key variable in that it has the greatest potential for variability and has the most significant effect on the Plan's projected funded

status. A similar methodology can be used to evaluate the potential impact of the variability in actual experience versus that assumed for other variables (discussed later).

The Signal Light reporting compares the projection of each division's funded ratio over certain time periods and assigns a color to indicate the relative strength of the result. The colors and corresponding criteria are as follows:

Status Definitions – Long-Term View

Status	Definition
Dark Green	100% funded by 2041 (30 years from 2011)
Green	100% funded by 2048 (30 years from 2018)
Light Yellow	100% funded by 2058 (40 years from 2018)
Yellow	100% funded by 2068 (50 years from 2018)
Orange	Solvent but more than 50 years to reach 100% funded
Red	Insolvent after 2042 (after 20 years)
Dark Red	Insolvent by 2042 (within 20 years)

The Dark Green through Yellow status definitions maintain the benchmark year by which the Plan would be expected to be 100% funded. For example, the Dark Green status measures whether the Plan would be 100% funded by 2041, which is the Plan's target for full funding as initiated through the passage of Senate Bill 2010-001. The Orange through Dark Red status definitions maintain the number of years that the solvency of the Plan is measured. For example, the Dark Red status measures whether the Plan would be insolvent within 20 years of the December 31, 2021, valuation date. Each year, as more experience is gathered and users become more familiar with the tool, these criteria and thresholds will be reviewed to determine if adjustments are appropriate.

The methodology for determining the results of the Signal Light reporting with respect to investment returns is based on stochastic modeling to account for asset volatility and negative cash flow. Stochastic modeling projects future cash flows by simulating investment portfolio return scenarios and projecting valuation results into the future. The 30-year capital market assumptions, provided by the Board's investment consultants in the Asset-Liability Study Follow-Up presentation (September 2019) are used with PERA's target asset allocation in order to simulate 5,000 investment portfolio return scenarios. The simulated investment returns, along with open group liability forecasts, are used to model the projected funded ratio, which reflect the timing of investment returns. The probabilities of achieving the Signal Light funded ratio levels are determined based upon the simulated trials and include the effect of "path dependency".

While it is useful to understand the long-term funded status if future experience exactly follows the assumptions, the Signal Light methodology provides sensitivity analysis of the long-term funding progress relative to some key variables. An example of the resulting output for the long-term investment return assumption of the State Division is shown in the following table:

Long-Term View Signal Lights for State Division
Stochastic Modeling of Investment Return – Open Group Projection Basis
Assumes Active Membership Grows by 0.25% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**2,813**	**56%**	65%
Green	100% funded by 2048 (30 years from 2018)	445	9%	
Light Yellow	100% funded by 2058 (40 years from 2018)	469	9%	29%
Yellow	100% funded by 2068 (50 years from 2018)	293	6%	
Orange	Solvent but longer than 50 years to reach 100% funded	684	14%	
Red	Insolvent after 2042 (after 20 years)	248	5%	6%
Dark Red	Insolvent by 2042 (within 20 years)	48	1%	

* Based on 5,000 simulations

The Signal Light chart quantifies the probability of achieving the benchmark for each Signal Light status. PERA has requested that these signals be monitored annually for all divisions. The results for each division are shown in *Section 3*. If a dramatic shift in status occurs, additional analysis might need to be performed. **Given the volatility associated with investment returns and the standard deviation of the expected return from year to year, dramatic changes in the Signal Light color from year to year are to be expected and the results should be viewed with this knowledge.** Furthermore, the Signal Light reporting reflects only variations in the variables considered (investment return, population growth, salary increases, etc.) while assuming no change is made to the benefit structure, contributions, or other assumptions or methods over the entire projection period. This is unlikely to occur if a PERA division were to be in the Red or Dark Red status for a number of years. One purpose of the Signal Light reporting process is to provide information in advance to allow for adjustments to be made in a timely manner.

As implied above, future AAP assessments and possible AAP adjustments have not been considered in the determination of the Signal Light results provided within this report. However, *Section 6 Short-Term View*, addresses certain conditions and the likelihood that these conditions could trigger AAP adjustments resulting from the next (December 31, 2022) AAP assessment.

The Signal Light color is assigned by equating the probability of meeting various status definitions to the return percentiles from the stochastically modeled portfolio returns. Percentiles based on 30-year geometric returns using Aon's capital market assumptions are:

- 95th percentile: 11.3% return
- 75th percentile: 9.0% return
- 50th percentile: 7.5% return
- 25th percentile: 5.8% return
- 5th percentile: 3.4% return

For the State Division, the probabilities of meeting each status criteria line up with the geometric return percentiles as follows:

Status	Probability of Meeting	Equivalent Return Percentile	30-Year Return Band at Percentile
Dark Green	**56%**	**44th**	**7.06% or more**
Green	9%	35th	6.52% to 7.06%
Light Yellow	9%	26th	5.92% to 6.52%
Yellow	6%	20th	5.40% to 5.92%
Orange	14%	6th	3.68% to 5.40%
Red	5%	1st	1.88% to 3.68%
Dark Red	1%	n/a	Less than 1.88%

For example, in the table above, the probability of meeting Green status (including Dark Green) is 65% (56% + 9%), which equates to the 35th percentile. Therefore, the Signal Light color assigned to the State Division is Dark Green because the 7.25% investment return assumption falls within the range of 7.06% or more (or, the 44th percentile).

It is also worth noting that when allowing all of the modeled variables to vary, the method assumes that all variables are independent. For example, it is assumed that asset returns are independent from payroll growth. This assumption is likely not the case, but the statistical methodology to determine the interrelationships would be extremely complex and beyond the scope of this study. For the "all variables" portion of the study, the probability shown is based on the assumption that each of the variables is observed at the same percentile ranking – that is, the investment return, the population growth, etc., are all at, for example, the 44th percentile for each year. This would happen only if they were all perfectly correlated. Nonetheless, the results provide a general sense of the relative volatility of the ultimate funding status of the Plan in the presence of natural variability.

Section 2: Changes in Expected Full Funding Dates

Based on our analysis of experience gains and/or losses and plan provision and/or assumption changes during the annual actuarial valuation and projection processes, Segal is able to report on the factors that contributed to increases or decreases in the projected full funding dates for each division from the previous year's results. Here are the results of the full funding dates for the past two valuations:

	Estimated Projected Year the Funding Ratio Reaches 100%	
Division Trust Fund	December 31, 2021 Valuation*	December 31, 2020 Valuation*
State	2038 (16 Years)	2041 (20 Years)
School	2038 (16 Years)	2043 (22 Years)
Local Government	2024 (2 Years)	2029 (8 Years)
Judicial	2025 (3 Years)	2028 (7 Years)
Denver Public Schools	2024 (2 Years)	2028 (7 Years)

* Reflects AAP adjustments effective July 1, 2022, based upon Actuarial Value of Assets

The following table shows the factors that contributed to the net change in "Projected Full Funding Year", not including the one year decrease due to the passage of time:

	Increase/(Decrease) in Projected Full Funding Year				
	State	School	Local Government	Judicial	DPS
Investment return	(4)	(5)	(5)	(3)	(3)
Demographics	1	0	0	0	0
Assumption changes	N/A	N/A	N/A	N/A	N/A
HB 22-1029	0	0	0	0	(1)
Total	**(3)**	**(5)**	**(5)**	**(3)**	**(4)**

Note the results in the table above could be observed to be slightly different based upon the order that the factors are observed. For this purpose, we have performed this reconciliation in the order as shown above.

The following are a few observations from the reconciliation of the projected full funding dates for each division:

- The asset returns (market value return of 16.1% and an actuarial value return of 13.2%) for the 2021 plan year were the primary driver behind the change in full funding dates. The higher-than-expected investment returns reduced the number of years until full funding.

- Small demographic losses for the 2021 plan year occurred due to actual experience differing from expected, based on the actuarial assumptions, including service retirements and termination of employment, along with the higher-than-expected pay increases for individual active members (except for the State, Local Government and Judicial Divisions) and higher-than-expected payroll growth for all active members (except for the State and Judicial Divisions), contributed to negligible changes in the full funding dates, except for the State Division.

Section 3: Sensitivity on Investment Return Assumption

For this analysis, we have used the 30-year capital market assumptions provided by the Board's investment consultants in the Asset-Liability Study Follow-Up presentation in September 2019. In that analysis, the midpoint of expected investment returns over a 50-year time horizon, using a 2.30% price inflation assumption, was 7.47% (with a standard deviation over this time horizon of 1.84%). This implies that there is a 50% probability of returns averaging less than 7.47% and a 50% probability of returns averaging more than 7.47% over a 50-year time period. The current long-term rate of return assumption of 7.25%, adopted effective with the December 31, 2016, actuarial valuation and reaffirmed at the November 15, 2019, Board meeting, is at approximately the 47th percentile. This implies that there is a 53% probability that the 50-year average rate of return will be 7.25% or more. Below is a breakdown of 30-year capital market assumptions and analysis most recently reviewed by the PERA Board upon which their investment policy and this section is based.

Asset Classes[1]	Long-Term Asset Allocation[1]	Expected Nominal Return[1]	Expected Risk[1,2]
Global Equity	53.0%	8.00%	19.00%
Fixed Income	23.0	3.60	5.00
Real Estate	8.5	6.65	20.00
Private Equity	8.5	9.60	24.50
Opportunity Fund[3]	6.0	7.12	9.46
Cash	1.0	2.70	2.00
Inflation		2.30	
Total Fund:			
Expected Return		7.47%	
Expected Risk		13.00%	

[1] Based on the existing long-term asset allocation and the 30-year capital market assumptions as of the first quarter 2019, as provided by PERA's investment consultant, Aon Hewitt. This assumption set was used in the 2019 asset liability study and displayed in the "Asset-Liability Study Follow-Up" presentation, dated September 13, 2019.

[2] Expected risk is represented by the standard deviation of results.

[3] Effective January 1, 2020, the asset class titled "Opportunity Fund" was changed to "Alternatives" within PERA's asset allocation.

The next five tables show the Signal Light results of the investment return assumption.

Long-Term View Signal Lights for State Division
Stochastic Modeling of Investment Return – Open Group Projection Basis
Assumes Active Membership Grows by 0.25% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**2,813**	**56%**	65%
Green	100% funded by 2048 (30 years from 2018)	445	9%	
Light Yellow	100% funded by 2058 (40 years from 2018)	469	9%	29%
Yellow	100% funded by 2068 (50 years from 2018)	293	6%	
Orange	Solvent but longer than 50 years to reach 100% funded	684	14%	
Red	Insolvent after 2042 (after 20 years)	248	5%	6%
Dark Red	Insolvent by 2042 (within 20 years)	48	1%	

* Based on 5,000 simulations

The State Division table above provides the following information:

- **Best-case scenarios:** Of the 5,000 simulations ran, 2,813, or 56%, resulted in the State Division Trust Fund being fully funded by 2041, meeting the criteria for Dark Green status. An additional 445 scenarios resulted in being fully funded no later than 2048, meeting the criteria for Green status. Therefore, 65% of the 5,000 simulations resulted in the State Division meeting a criteria for one of the green status definitions.

- **Worst-case scenarios:** Of the 5,000 simulations, 296, or 6%, resulted in the depletion of the State Division Trust Fund.

As mentioned in *Section 1* of this report, the Signal Light reporting reflects only the variations of the assumptions being tested. In actuality, if the Signal Light testing was showing the State Division in the Red or Dark Red status for a number of years, it is highly likely that changes to the benefit structure and/or contributions would be considered. Similarly, there are some scenarios of the 2,813 that resulted in Dark Green status where future applications of the AAP test would increase the AI cap and decrease future contributions; however, this dynamic has not been contemplated in the model.

Long-Term View Signal Light Results for School Division
Stochastic Modeling of Investment Return – Open Group Projection Basis
Assumes Active Membership Grows by 1.00% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**2,675**	**54%**	62%
Green	100% funded by 2048 (30 years from 2018)	411	8%	
Light Yellow	100% funded by 2058 (40 years from 2018)	454	9%	31%
Yellow	100% funded by 2068 (50 years from 2018)	306	6%	
Orange	Solvent but longer than 50 years to reach 100% funded	814	16%	
Red	Insolvent after 2042 (after 20 years)	316	6%	7%
Dark Red	Insolvent by 2042 (within 20 years)	24	1%	

* Based on 5,000 simulations

Long-Term View Signal Light Results for Local Government Division
Stochastic Modeling of Investment Return – Open Group Projection Basis
Assumes Active Membership Grows by 1.00% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,269**	**65%**	69%
Green	100% funded by 2048 (30 years from 2018)	219	4%	
Light Yellow	100% funded by 2058 (40 years from 2018)	251	5%	21%
Yellow	100% funded by 2068 (50 years from 2018)	172	3%	
Orange	Solvent but longer than 50 years to reach 100% funded	616	13%	
Red	Insolvent after 2042 (after 20 years)	432	9%	10%
Dark Red	Insolvent by 2042 (within 20 years)	41	1%	

* Based on 5,000 simulations

Long-Term View Signal Light Results for Judicial Division
Stochastic Modeling of Investment Return – Open Group Projection Basis
Assumes Active Membership Grows by 0.25% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,866**	**77%**	82%
Green	100% funded by 2048 (30 years from 2018)	258	5%	
Light Yellow	100% funded by 2058 (40 years from 2018)	259	5%	16%
Yellow	100% funded by 2068 (50 years from 2018)	147	3%	
Orange	Solvent but longer than 50 years to reach 100% funded	373	8%	
Red	Insolvent after 2042 (after 20 years)	96	2%	2%
Dark Red	Insolvent by 2042 (within 20 years)	1	0%	

* Based on 5,000 simulations

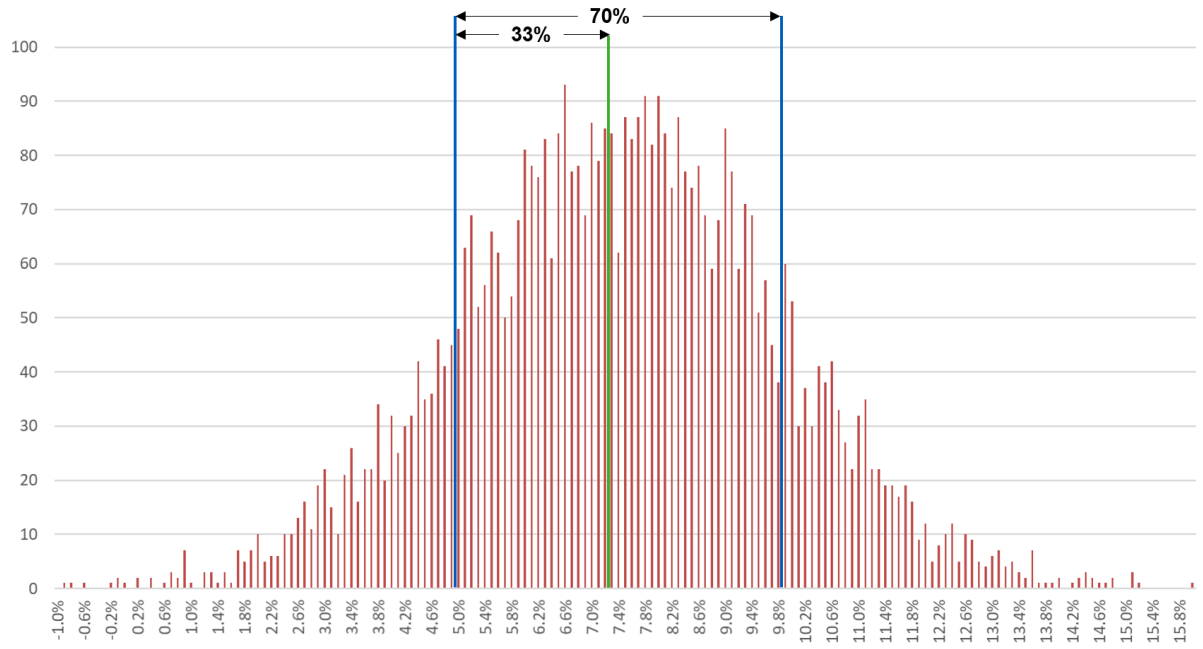
Long-Term View Signal Light Results for Denver Public Schools Division
Stochastic Modeling of Investment Return – Open Group Projection Basis
Assumes Active Membership Grows by 1.00% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,984**	**80%**	87%
Green	100% funded by 2048 (30 years from 2018)	347	7%	
Light Yellow	100% funded by 2058 (40 years from 2018)	297	6%	13%
Yellow	100% funded by 2068 (50 years from 2018)	164	3%	
Orange	Solvent but longer than 50 years to reach 100% funded	208	4%	
Red	Insolvent after 2042 (after 20 years)	0	0%	0%
Dark Red	Insolvent by 2042 (within 20 years)	0	0%	

* Based on 5,000 simulations

The 50th percentile based on 30-year average geometric returns using Aon's capital market assumptions is 7.5% (with a mean of 7.4%). However, the 5,000 simulated portfolio returns include a wide array of outcomes, which are reflected in the stochastic analysis and depicted in the histogram below (30-year geometric average returns, rounded to the nearest 0.1%).

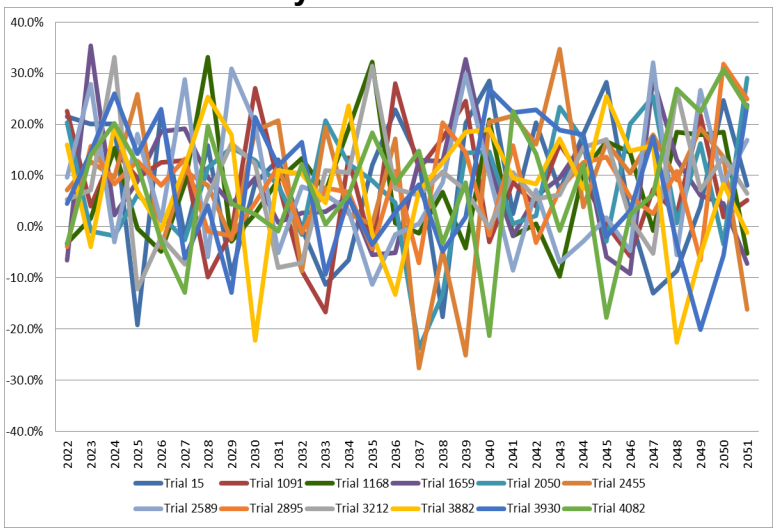
30-year Geometric Averages from 5,000 Simulated Portfolio Returns



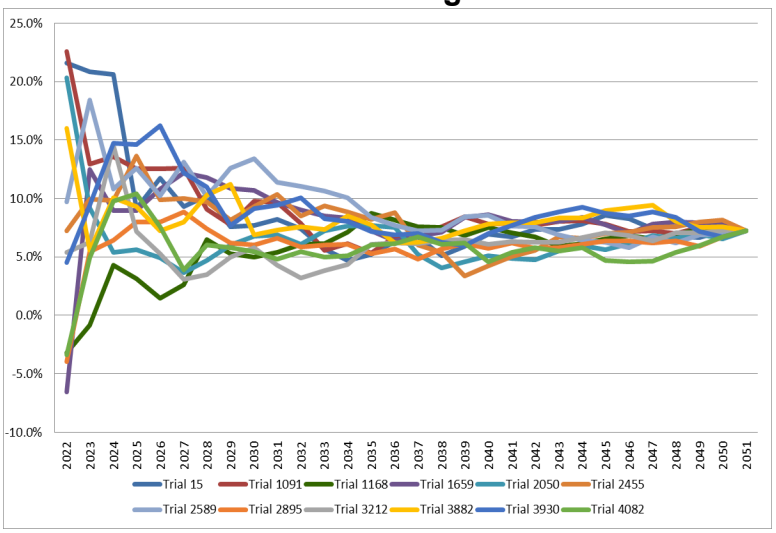
With the capital market assumptions for each asset class assumed to be normally distributed, the results of the 5,000 simulated portfolio returns approximate a normal distribution. In the chart above, the largest cluster of outcomes were near the mean return of 7.4% and the majority are within one standard deviation from the mean (between 5.0% and 9.8%), which represents about 70% of all outcomes. However, that leaves about 30% of outcomes that fall outside of that range. In addition, about one-third of the 30-year average geometric returns fall between 5.0% and PERA's assumed rate of investment return of 7.25%.

Annual year-to-year volatility within an individual trial can have a material impact on projected funded percentages, even for scenarios that have similar average returns, because of projected cash flows (member and employer contributions into the Plan relative to benefit payments, refunds, and administrative expenses paid out of the Plan). To demonstrate this, consider the following 12 portfolio simulations (out of the 5,000 used in the stochastic analysis), which all have 30-year average returns of 7.25% – PERA's assumed rate of investment return.

Year-by-Year Annual Returns



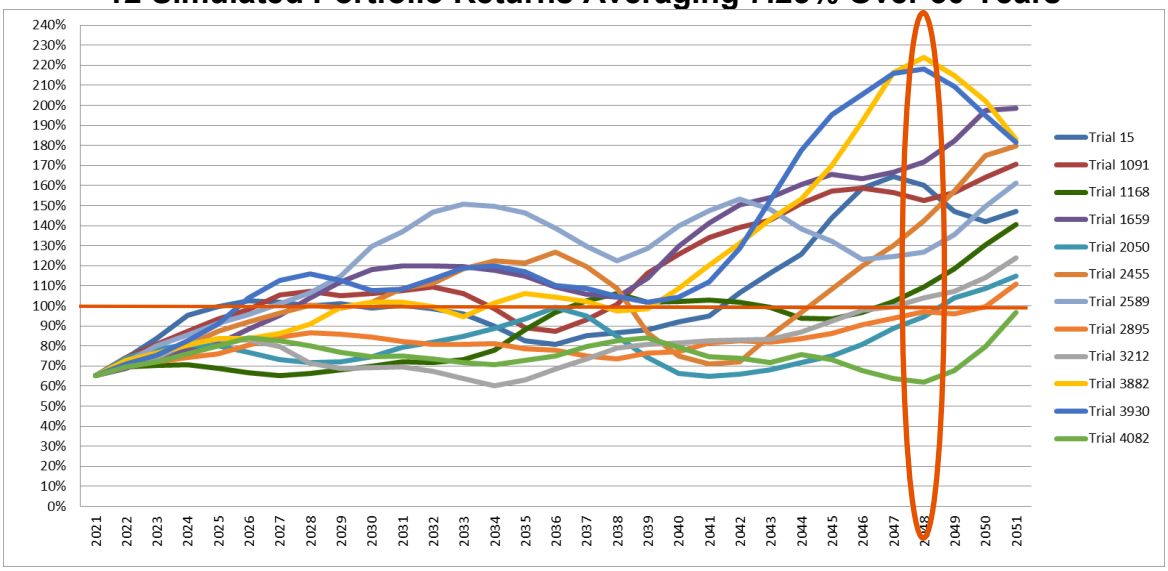
Geometric Average Returns



The graph above on the left shows year-by-year portfolio returns and is meant to illustrate the degree of volatility that can be found within the simulated portfolio return scenarios. The graph on the right shows the compound geometric average returns through each year and illustrates how the volatility within each scenario is offsetting, resulting in geometric average returns that converge to 7.25% for each of the 12 simulations.

A single $1,000 initial investment accumulates to $8,164 in 30 years in each of the return simulations above. However, the PERA Division Trust Funds have more complex cash flows, which can lead to vastly different outcomes over long periods of time. The graph below shows the projected School Division funded percentage over the same 30-year projection period, illustrating a wide array of outcomes based on the timing and volatility of annual portfolio returns. Note that in some scenarios, the School Division Trust Fund does not meet its funding policy goal of full funding by 2048, despite the average rate of return meeting the assumption over the period.

Projection of Funded Percentage for School Division
12 Simulated Portfolio Returns Averaging 7.25% Over 30 Years



Segal

Section 4: Sensitivity on Other Assumptions

While actual investment return is the most critical driver of future full funding dates, many other assumptions are used in the actuarial valuation and projections. Variances in these assumptions over the long-term could also have an impact on the date of full funding. Important non-investment assumptions include salary increases, population growth, and demographic assumptions (including mortality, retirement and withdrawal).

In addition, adverse experience could occur in most/all of the assumptions (low population growth, high salary increases, and other actuarial losses), which combined, would extend the date the Plan is projected to reach full funding. However, variations in these assumptions do not have as significant an impact as those resulting from variations in the investment return. These demographic assumptions add to the uncertainty associated with investment return, making outcomes at the extreme ranges somewhat more likely.

A normal distribution was used for all three of these assumptions. For the population growth assumption, the expected mean used for this study is the current assumption for population growth in the annual baseline projections prepared for the Plan (1.00% for School, Local Government, and DPS Divisions and 0.25% for State and Judicial Divisions). For the salary increases and other demographic assumptions, we assume that actual experience is expected to match the current assumptions so the mean is zero, meaning 0.0% gain and 0.0% loss. Because the demographic assumptions are modeled using a normal distribution, stochastic modeling is not required to adequately model these scenarios. The following is a chart of each assumption's expected mean value and standard deviation, over a 1-year period and over a 50-year period.

		Standard Deviation*	
Assumption	**Expected Mean**	**Over 1-Year Period**	**Over 50-Year Period**
Salary Gain/Loss	0.00%	0.78%	0.11%
Population Growth	1.00% or 0.25%	1.85%	0.26%
Demographic Changes	0.00%	0.60%	0.09%

* Based on the actual experience over 30 years (1992-2021).

Due to the limited impact these other variables have on the outcomes, they are evaluated individually only for the State and School Divisions.

Long-Term View Signal Light Results for State Division (Based on Salary Increases)

Status	Definition	Possible Outcomes to Attain This	Probability of Meeting Outcome	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**Average 0.45% loss or better**	**100%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average 0.80% loss to 0.45% loss	0%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average 1.07% loss to 0.80% loss	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average 1.22% loss to 1.07% loss	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.39% loss to 1.22% loss	0%	
Red	Insolvent after 2042 (after 20 years)	Average 3.55% loss to 1.39% loss	0%	0%
Dark Red	Insolvent by 2042 (within 20 years)	Average worse than 3.55% loss	0%	

Long-Term View Signal Light Results for State Division (Based on Population Growth)

Status	Definition	Possible Outcomes to Attain This	Probability of Meeting Outcome	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**Average (2.47%) or more**	**100%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average (3.99%) to (2.47%)	0%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average (4.64%) to (3.99%)	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average (4.82%) to (4.64%)	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average (6.12%) to (4.82%)	0%	
Red	Insolvent after 2042 (after 20 years)	Average (10.00%) to (6.12%)	0%	0%
Dark Red	Insolvent by 2042 (within 20 years)	Average less than (10.00%)	0%	

Please see *Section 8* for the methodology used to determine the percentages in the tables above.

Long-Term View Signal Light Results for State Division (Based on Demographic Changes*)

Status	Definition	Possible Outcomes to Attain This	Probability of Meeting Outcome	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**Average 0.45% loss or better**	**100%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average 0.80% loss to 0.45% loss	0%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average 1.07% loss to 0.80% loss	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average 1.22% loss to 1.07% loss	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.39% loss to 1.22% loss	0%	
Red	Insolvent after 2042 (after 20 years)	Average 3.55% loss to 1.39% loss	0%	0%
Dark Red	Insolvent by 2042 (within 20 years)	Average worse than 3.55% loss	0%	

* Could include mortality, retirement, and withdrawal gains and losses

Long-Term View Signal Light Results for School Division (Based on Salary Increases)

Status	Definition	Possible Outcomes to Attain This	Probability of Meeting Outcome	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**Average 0.35% loss or better**	**100%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average 0.68% loss to 0.35% loss	0%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average 0.92% loss to 0.68% loss	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average 1.07% loss to 0.92% loss	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.32% loss to 1.07% loss	0%	
Red	Insolvent after 2042 (after 20 years)	Average 3.87% loss to 1.32% loss	0%	0%
Dark Red	Insolvent by 2042 (within 20 years)	Average worse than 3.87% loss	0%	

Please see *Section 8* for the methodology used to determine the percentages in the tables above.

Long-Term View Signal Light Results for School Division (Based on Population Growth)

Status	Definition	Possible Outcomes to Attain This	Probability of Meeting Outcome	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**Average (1.65%) or more**	**100%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average (3.39%) to (1.65%)	0%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average (4.14%) to (3.39%)	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average (4.33%) to (4.14%)	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average (5.86%) to (4.33%)	0%	
Red	Insolvent after 2042 (after 20 years)	Average (10.00%) to (5.86%)	0%	0%
Dark Red	Insolvent by 2042 (within 20 years)	Average less than (10.00%)	0%	

Long-Term View Signal Light Results for School Division (Based on Demographic Changes*)

Status	Definition	Possible Outcomes to Attain This	Probability of Meeting Outcome	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**Average 0.35% loss or better**	**100%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average 0.68% loss to 0.35% loss	0%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average 0.92% loss to 0.68% loss	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average 1.07% loss to 0.92% loss	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.32% loss to 1.07% loss	0%	
Red	Insolvent after 2042 (after 20 years)	Average 3.87% loss to 1.32% loss	0%	0%
Dark Red	Insolvent by 2042 (within 20 years)	Average worse than 3.87% loss	0%	

* Could include mortality, retirement, and withdrawal gains and losses

Please see *Section 8* for the methodology used to determine the percentages in the tables above.

Over a long projection period, gains and losses due to salary increases, population growth and other demographic experience are expected to be relatively concentrated around the expected mean value. Furthermore, experience studies throughout the projection period will result in changes to assumptions, reducing variance from the assumptions. Because of the relatively limited impact that these variables have on the overall funding results, this translates to low probabilities of changing the Signal Light color. Thus, all of the last six tables have a high probability of meeting their current status definition, or better.

When active population growth for the School Division is reviewed, we find that there is a 100% probability of the population growth averaging between -3.39% and -1.65% (shrinking by 1.65% per year) over a 50-year period. Of course, this is assuming that the current expected value for population growth of 1.00% is maintained over the timeframe. Without recognizing volatility from any other actual experience compared to that expected, the School Division would indicate a Dark Green status path.

All of the above analysis is based on the premise that the current demographic assumptions represent the mean expected outcome. Actuarial assumptions are designed to target an average future outcome, understanding that there will be deviations from year-to-year that generate annual gains and losses over time. However, systemic shifts may occur over time that cause emerging experience to differ from expectations one direction more than the other. For example, a tendency for members to stay employed longer than historically observed or life expectancies exceeding predictions. In these cases, changes to actuarial assumptions are required, which accelerates what would otherwise emerge as consistent gains or losses and causes an immediate increase or decrease in actuarial liabilities. The impact of these types of changes typically exceed the impact from “normal” volatility in emerging experience as illustrated earlier.

The 2020 Experience Analysis reflected a situation where recent historical experience – particularly related to turnover and retirement decrements – did not line up well with the actuarial assumptions and revisions were required. In accordance with common practice, the recommended assumptions were set in between the prevailing assumption and the recent experience. In this way, the actuarial valuation and funding process do not “overreact” to short-term, recent experience.

Presume, for illustrative purposes, that recent historical experience was, in fact, fully indicative of future trends. In this case, further changes in actuarial assumptions to mitigate future actuarial losses would be required. To quantify the potential impact this could have, we have created projections that use alternative turnover, retirement, disability incidence, and salary increase assumptions based entirely on recent historical experience.

The following charts illustrate the Signal Light modeling results for the State and School Divisions using these hypothetical assumptions.

Long-Term View Signal Lights for State Division
Using Hypothetical Actuarial Assumptions Fully Reflecting Recent Experience

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**2,674**	**53%**	62%
Green	100% funded by 2048 (30 years from 2018)	444	9%	
Light Yellow	100% funded by 2058 (40 years from 2018)	464	9%	32%
Yellow	100% funded by 2068 (50 years from 2018)	309	6%	
Orange	Solvent but longer than 50 years to reach 100% funded	822	17%	
Red	Insolvent after 2042 (after 20 years)	262	5%	6%
Dark Red	Insolvent by 2042 (within 20 years)	25	1%	

* Based on 5,000 simulations

Long-Term View Signal Lights for School Division
Using Hypothetical Actuarial Assumptions Fully Reflecting Recent Experience

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	2,310	46%	54%
Green	**100% funded by 2048 (30 years from 2018)**	**424**	**8%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	460	9%	38%
Yellow	100% funded by 2068 (50 years from 2018)	332	7%	
Orange	Solvent but longer than 50 years to reach 100% funded	1,095	22%	
Red	Insolvent after 2042 (after 20 years)	372	7%	8%
Dark Red	Insolvent by 2042 (within 20 years)	7	1%	

* Based on 5,000 simulations

Compared to the baseline Signal Light results, application of the hypothetical demographic assumptions result in the State Division maintaining its Dark Green status and the School Division dropping from Dark Green to Green. For the State Division, the probability of falling into one of the Green statuses declines from 65% to 62%. For the School Division, the probability of falling into one of the Green statuses declines from 62% to 54%.

Compared to the baseline projection of the projected number of years until 100% funded, application of the hypothetical demographic assumptions based upon a replication of recent (past) experience would cause the State Division to increase from 16 years to 17 years and the School Division to increase from 16 years to 20 years.

Section 5: Sensitivity on All Assumptions

To complete the Signal Light analysis, we have aggregated the sensitivity of these other actuarial assumptions with the investment rate of return for all five divisions. As an interim step, aggregate results were first run assuming that investment returns approximate a normal distribution and are perfectly correlated with active membership growth, salary increases, and other demographic gain/loss experience and without respect to the interaction with other cash flows. The number of scenarios meeting the status definitions were adjusted based on the relationship of the investment return-only results under this normal distribution condition compared to the stochastically modeled results.

Long-Term View Signal Light Results for State Division
Assumes Active Membership Grows by 0.25% per Year
Based on All Assumptions[4]

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**2,739**	**55%**	63%
Green	100% funded by 2048 (30 years from 2018)	387	8%	
Light Yellow	100% funded by 2058 (40 years from 2018)	412	8%	26%
Yellow	100% funded by 2068 (50 years from 2018)	267	6%	
Orange	Solvent but longer than 50 years to reach 100% funded	631	12%	
Red	Insolvent after 2042 (after 20 years)	509	10%	11%
Dark Red	Insolvent by 2042 (within 20 years)	55	1%	

* Adjusted, based on 5,000 simulations

Please see *Section 8* for the methodology used to determine the percentages in the tables above.

[4] Assumes each of the variables are observed at the same percentile ranking.

Long-Term View Signal Light Results for School Division
Assumes Active Membership Grows by 1.00% per Year
Based on All Assumptions[5]

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	2,620	52%	59%
Green	**100% funded by 2048 (30 years from 2018)**	**357**	**7%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	404	8%	28%
Yellow	100% funded by 2068 (50 years from 2018)	269	6%	
Orange	Solvent but longer than 50 years to reach 100% funded	716	14%	
Red	Insolvent after 2042 (after 20 years)	607	12%	13%
Dark Red	Insolvent by 2042 (within 20 years)	27	1%	

* Adjusted, based on 5,000 simulations

Long-Term View Signal Light Results for Local Government Division
Assumes Active Membership Grows by 1.00% per Year
Based on All Assumptions[5]

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,165**	**63%**	67%
Green	100% funded by 2048 (30 years from 2018)	205	4%	
Light Yellow	100% funded by 2058 (40 years from 2018)	236	5%	19%
Yellow	100% funded by 2068 (50 years from 2018)	164	4%	
Orange	Solvent but longer than 50 years to reach 100% funded	544	10%	
Red	Insolvent after 2042 (after 20 years)	643	13%	14%
Dark Red	Insolvent by 2042 (within 20 years)	43	1%	

* Adjusted, based on 5,000 simulations

Please see *Section 8* for the methodology used to determine the percentages in the tables above.

[5] Assumes each of the variables are observed at the same percentile ranking.

Long-Term View Signal Light Results for Judicial Division
Assumes Active Membership Grows by 0.25% per Year
Based on All Assumptions[6]

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,749**	**75%**	80%
Green	100% funded by 2048 (30 years from 2018)	245	5%	
Light Yellow	100% funded by 2058 (40 years from 2018)	249	5%	16%
Yellow	100% funded by 2068 (50 years from 2018)	145	4%	
Orange	Solvent but longer than 50 years to reach 100% funded	394	7%	
Red	Insolvent after 2042 (after 20 years)	217	4%	4%
Dark Red	Insolvent by 2042 (within 20 years)	1	0%	

* Adjusted, based on 5,000 simulations

Long-Term View Signal Light Results for Denver Public Schools Division
Assumes Active Membership Grows by 1.00% per Year
Based on All Assumptions[6]

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,861**	**77%**	84%
Green	100% funded by 2048 (30 years from 2018)	334	7%	
Light Yellow	100% funded by 2058 (40 years from 2018)	288	6%	15%
Yellow	100% funded by 2068 (50 years from 2018)	159	3%	
Orange	Solvent but longer than 50 years to reach 100% funded	335	6%	
Red	Insolvent after 2042 (after 20 years)	23	1%	1%
Dark Red	Insolvent by 2042 (within 20 years)	0	0%	

* Adjusted, based on 5,000 simulations

Please see *Section 8* for the methodology used to determine the percentages in the tables above.

[6] Assumes each of the variables are observed at the same percentile ranking.

A metric established in Senate Bill (SB) 18-200 to gauge whether PERA is on track to achieve full funding by 2048 is having at least a 67% likelihood of such occurrence when measured periodically. Based on the analysis in this section, the probabilities of each PERA division being 100% funded by 2048 are:

Division Trust Fund	Signal Light Probability of 100% Funded by 2048
State	63%
School	59%
Local Government	67%
Judicial	80%
Denver Public Schools	84%

In the above Signal Light reporting analysis, a scenario is counted as meeting a certain status definition if: 1) the funded percentage in the specified year is greater than or equal to 100%; 2) the funded percentage beyond the specified year remains greater than 100%; and 3) the funded percentage prior to the specified year is always greater than 0%. For purposes of evaluating the SB 18-200 goal of full funding by 2048, this method of counting scenarios and determining probabilities is conservative. By counting ANY scenarios that achieve full funding by 2048 (including those that eventually drop back below 100% subsequent to 2048), the probabilities of each PERA division being 100% funded by 2048 would be slightly greater as shown below:

Division Trust Fund	Alternative Probability of 100% Funded by 2048
State	67%
School	66%
Local Government	75%
Judicial	85%
Denver Public Schools	89%

Section 6: Short-Term View

The Signal Light analysis and this report primarily focus on long-term projections over a period of 30 or more years. However, a look at the near-term can also provide valuable information about the impact of certain risks to PERA. On a one-year basis, this section examines the expected AAP ratio projected to December 31, 2022, and stress tests how actual demographic and investment experience during 2022 would affect the projected ratio. Looking out over the next ten years, this section models the likelihood of triggering future AAP adjustments based on stochastically modeled investment experience under different demographic scenarios.

ONE-YEAR ANALYSIS

The one-year projection of the AAP ratio can be modeled with three key variables for experience during the year:

- Market value investment return for the year – baseline assumption is 7.25%
- Increase in total payroll for the year – baseline assumption is 3.00%
- Level of demographic gain/loss for the year[7] – baseline assumption is 0.00%

By rolling forward the December 31, 2021, actuarial valuation results and relying on the baseline assumptions outlined above for experience during 2022, the expected AAP ratio as of December 31, 2022, is 112.2%. This reflects changes in liabilities and contribution rates due to the AAP adjustments effective July 1, 2022, based on the results of the December 31, 2020, actuarial valuation, as well as an approximate 15.2% return on the actuarial value of assets due to an assumed 7.25% market value return on assets and recognizing a portion of deferred investment gains. An AAP ratio of 112.2% as of December 31, 2022, would not result in any additional AAP adjustments effective July 1, 2024.

In order for the projected AAP ratio as of December 31, 2022, to be lower than 98% or greater than 120% (and therefore trigger a series of AAP adjustments), experience for 2022 of any **single** variable above (assuming the other two variables meet their respective assumptions for the year) would need to be:

Variable	AAP Ratio of 98% or Less	AAP Ratio of 120% or More
Market value investment return	Worse than −44.6%	Better than 31.9%
Year-over-year change in total payroll	Lower than 21.6% decrease	Higher than 19.3% increase
Demographic experience	More than 9.2% loss	More than 4.2% gain

[7] Note, to prevent double-counting, the level of demographic gain/loss would not include any gain or loss from salary experience that contributed to the total increase in payroll.

For context, none of the experience for any variable outlined above has occurred in a single year in the last 30 years.

In order for the projected AAP ratio to be lower than 98%, experience for 2022 of any **two** variables above (assuming the third variable meets expectations) would be:

- 0% market value investment return and 18.3% or lower decrease in payroll
- 0% market value investment return and 7.9% or more demographic loss

- 0% increase in total payroll and −38.5% or lower market value investment return
- 0% increase in total payroll and 8.1% or more demographic loss

- 1% demographic loss and −39.0% or lower market value investment return
- 1% demographic loss and 19.0% or lower decrease in payroll

Similarly, in order for the projected AAP ratio to be greater than 120%, experience for 2022 of any **two** variables above (assuming the third variable meets expectations) would be:

- 20% market value investment return and 10.7% or higher increase in payroll
- 20% market value investment return and 2.0% or more demographic gain

- 6% increase in total payroll and 27.2% or higher market value investment return
- 6% increase in total payroll and 3.4% or more demographic gain

- 1% demographic gain and 26.1% or higher market value investment return
- 1% demographic gain and 15.4% or more increase in payroll

Note that not all of the three static parameters above (0% investment return, flat year-over-year payroll, and a 1% loss from demographic experience or 20% investment return, 6% increase in payroll, and a 1% gain from demographic experience) are “equally likely”, but they do represent anecdotal metrics for “worse-than-expected” and “better-than-expected” experience in a given year. For context, over the last 30 years, a market value return of 0% or lower has occurred five times, a 1% or more demographic loss has occurred ten times, and a 0% or lower decrease in total payroll has occurred four times. A market value return of 20% or greater has occurred four times, a 1% or more demographic gain has not occurred, and a 6% or higher increase in total payroll has occurred eight times.

The normal distribution methodology previously described and applied within *Section 5* assumes that each variable is linked and modeled on a unified basis. In other words, if the investment return is assumed to occur at the mean value of 7.25%, then experience for total payroll increase and demographic gain/loss also occur at their mean values of 3% and 0%, respectively. Similarly, when the investment return is modeled at plus one-half standard deviation from the mean (equivalent to an annual return of 14.63%), the total increase in payroll and demographic experience are also modeled at plus one-half standard deviations

from those variables' respective means, or an increase in payroll of 4.40%[8] and demographic gain of 0.30%, respectively.

We have determined that based on one-year values for mean and standard deviation, experience for 2022 at or worse than 2.44 standard deviations to the left of the mean would result in a projected AAP ratio lower than 98%. This equates to:

- −22.5% or lower market value investment return;
- 3.8% or lower decrease in total payroll; and
- 1.4% or more demographic loss.

Putting this in estimated probabilistic terms, 2.44 standard deviations or more to the left of the mean is expected to occur less than 1% of the time under the normal distribution.

Similarly, we have determined that based on one-year values for mean and standard deviation, experience for 2022 at or better than 1.16 standard deviations to the right of the mean would result in a projected AAP ratio greater than 120%. This equates to:

- 23.0% or higher market value investment return;
- 6.2% or more increase in total payroll; and
- 0.7% or more demographic gain.

Again, putting this scenario in terms of estimated probability, 1.16 standard deviations or more to the right of the mean is expected to occur 12% of the time under the normal distribution.

The reality is that more than three variables are involved in the actual asset and liability experience for the current year and these variables are unlikely to be perfectly correlated with one another. However, for purely illustrative purposes, this exercise does give some sense as to what types of circumstances, as measured within the December 31, 2022, actuarial valuation, that would trigger additional AAP adjustments, in either direction, to be effective July 1, 2024.

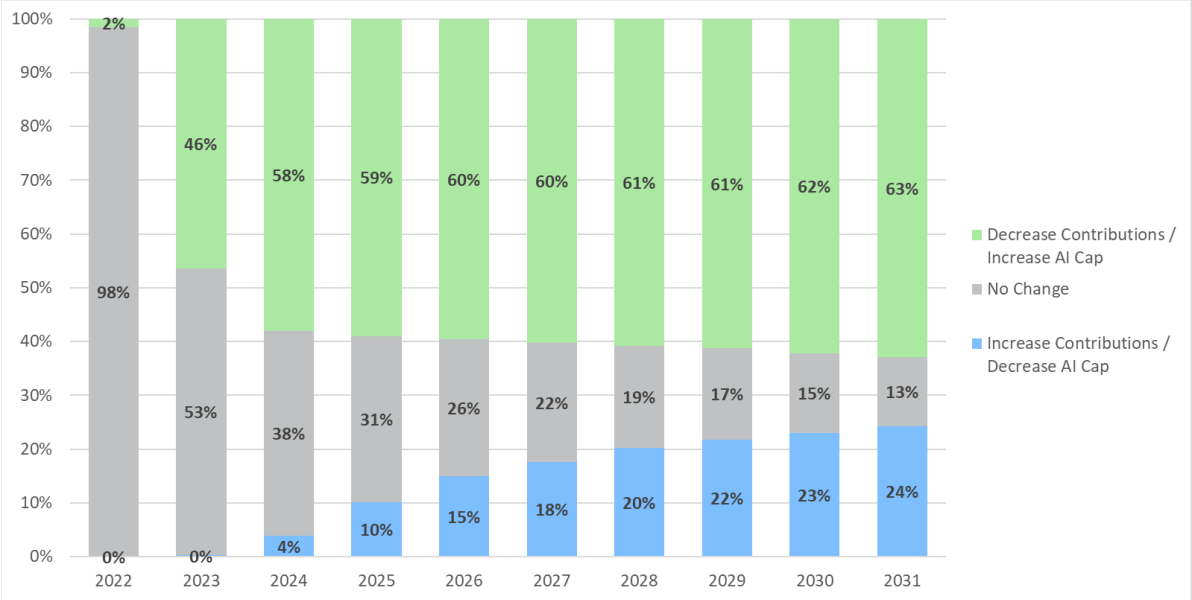
TEN-YEAR ANALYSIS

Scenario: Baseline Liability Forecast

Using the 5,000 stochastically modeled investment return simulations and the baseline open group liability projection results, we have estimated the PERA AAP ratio in each scenario for the following ten valuation years. Based on these results, the probability in each year of the AAP test triggering contribution increases and a reduction in the AI cap (from an AAP ratio below 98%) or triggering contribution decreases and an increase in the AI cap (from an AAP ratio exceeding 120%) are determined and illustrated in the following graphic:

[8] A standard deviation of 2.75% for total payroll growth relative to expected was calculated based on 30 years of historical covered payroll increases for 1992-2021 compared to the existing assumption for payroll growth in effect for each year.

Likelihood of Triggering Automatic Adjustment Provision
Baseline Liability Forecast



* Due to rounding, values shown here may not sum as expected

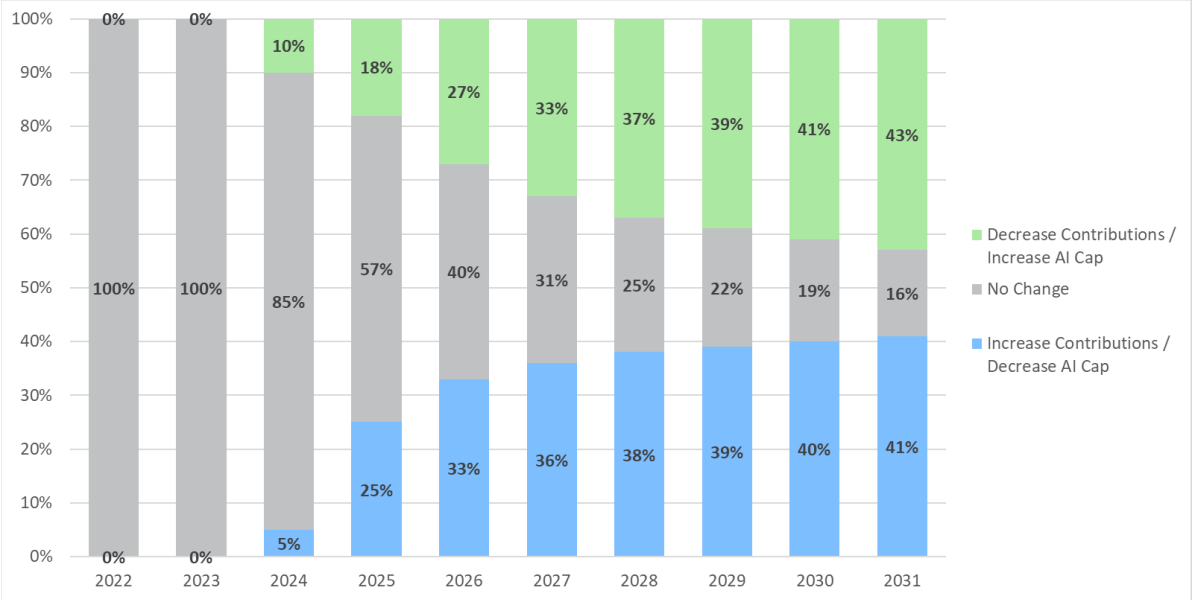
Note that the model used for this scenario and those that follow relies on a static liability forecast and member/employer contribution schedule and does not contemplate the impact of any AAP changes in subsequent years. For example, the 15% of scenarios in 2026 that trigger contribution increases and a reduction in the AI cap effective 18 months later do not impact the results in years 2027 through 2031.

Without any non-investment gains or losses from sources such as demographic experience, increases in total payroll, and active membership growth, the most likely outcome over the next ten years is that the AAP ratios that trigger contribution decreases and AI cap increases.

Scenario: Baseline Liability Forecast Reflecting a -5.75% Investment Return for 2022

To better illuminate possible outcomes given a "less-than-assumed" return for 2022, using the baseline static liability forecast, we reflected a -5.75% investment return (represents one standard deviation to the left of the current assumption) for 2022 and applied the same 5,000 investment return simulations to all subsequent years to generate a new series of AAP ratios. Based on these results, the probability in each year of the AAP test triggering contribution increases and a reduction in the AI cap (from an AAP ratio below 98%) or triggering contribution decreases and an increase in the AI cap (from an AAP ratio exceeding 120%) are determined and illustrated in the following graphic:

Likelihood of Triggering Automatic Adjustment Provision
Baseline Liability Forecast Reflecting a -5.75% Investment Return for 2022



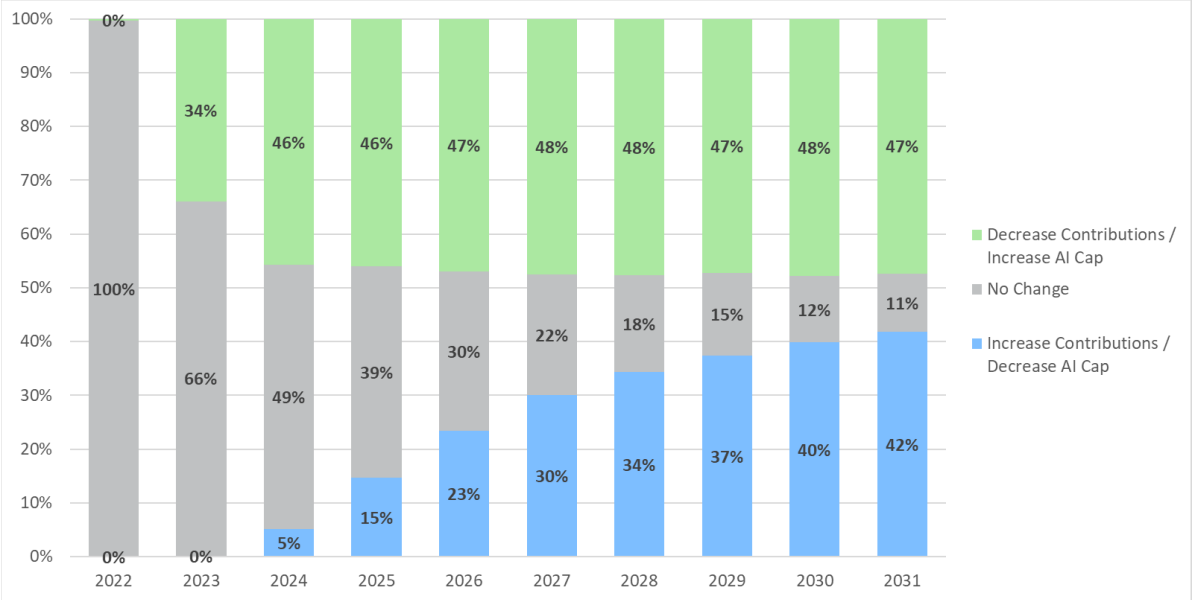
* Due to rounding, values shown here may not sum as expected

A less-than-assumed investment return for 2022 produces a relatively greater unfunded actuarial accrued liability, which increases the actuarially determined employer contribution (ADC) value in the AAP test. The ADC value is used in the denominator in the AAP ratio, so larger values initially cause relatively lower ratios. When compared to the baseline projections, this scenario produces more outcomes that result in AAP ratios below 98%, triggering contribution increases and AI cap decreases.

Scenario: Alternate Liability Forecast Reflecting Flat 0% Payroll Growth

Stress testing results for "worse-than-expected" payroll growth experience, we created an alternate static liability forecast reflecting flat year-over-year payroll and applied the same 5,000 investment return simulations to generate a new series of AAP ratios. Based on these results, the probability in each year of the AAP test triggering contribution increases and a reduction in the AI cap (from an AAP ratio below 98%) or triggering contribution decreases and an increase in the AI cap (from an AAP ratio exceeding 120%) are determined and illustrated in the following graphic:

Likelihood of Triggering Automatic Adjustment Provision
Alternate Liability Forecast Reflecting Flat 0% Payroll Growth



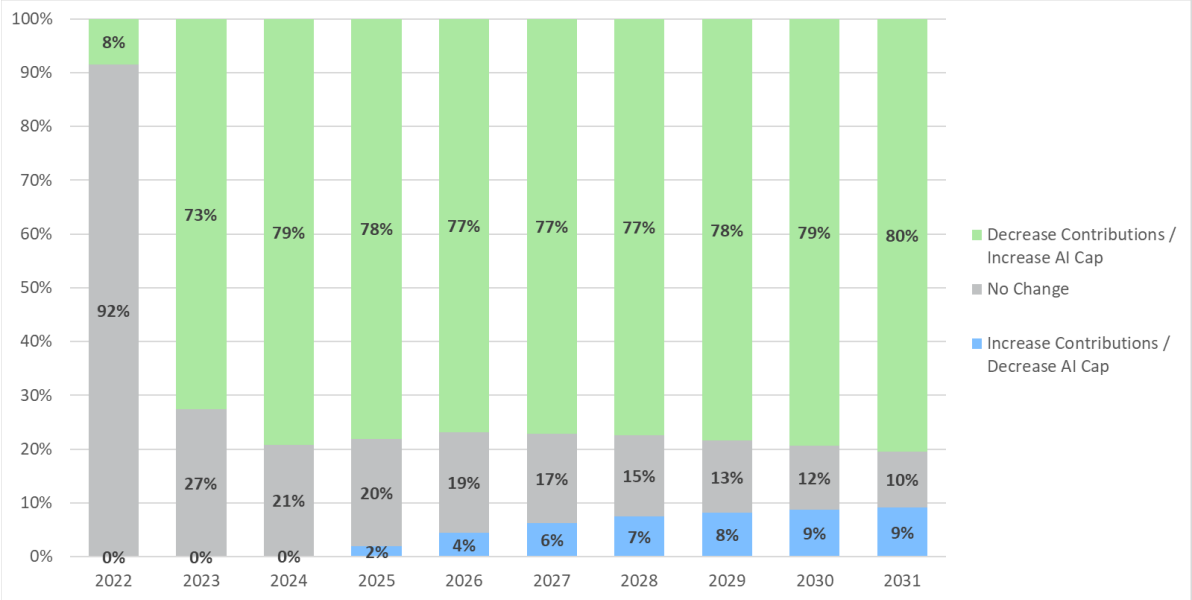
* Due to rounding, values shown here may not sum as expected

As contributions are collected as a percentage of payroll, lower levels of future total payroll translate to fewer contributions into PERA, which delays funding progress. When compared to the baseline projections, this scenario produces fewer outcomes resulting in AAP ratios in excess of 120%, triggering contribution decreases and AI cap increases. Sustained periods of no growth in covered payroll may be unlikely, but are not impossible.

Scenario: Alternate Liability Forecast Reflecting 4% Payroll Growth (1% More Than Assumed)

On the other hand, increases in total payroll greater than expected could emerge under the right circumstances. In this case, relatively higher levels of payroll would translate into more contributions flowing into PERA. This could lead to more scenarios where the AAP test results in ratios that exceed 120% and trigger contribution decreases and AI cap increases. For purposes of testing the sensitivity of higher than assumed payroll growth experience, we created an alternate static liability forecast reflecting annual increases in payroll of 4%, an additional 1% per year above the current 3% assumption. We then applied the same 5,000 investment return simulations to generate a new series of AAP ratios. Based on these results, the probability in each year of the AAP test triggering contribution increases and a reduction in the AI cap (from an AAP ratio below 98%) or triggering contribution decreases and an increase in the AI cap (from an AAP ratio exceeding 120%) are determined and illustrated in the following graphic:

Likelihood of Triggering Automatic Adjustment Provision
Alternate Liability Forecast Reflecting 4% Payroll Growth (1% More Than Assumed)



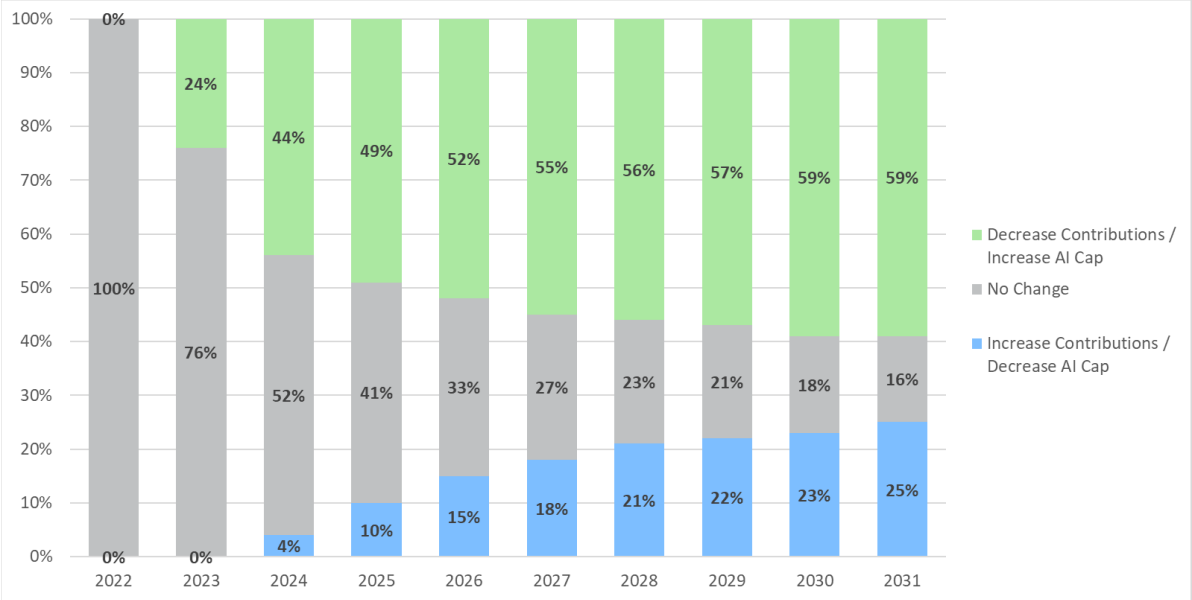
* Due to rounding, values shown here may not sum as expected

When compared to the baseline projections, this scenario produces more outcomes that result in AAP ratios in excess of 120%, triggering contribution decreases and AI cap increases.

Scenario: Alternate Liability Forecast Reflecting a 7.00% Investment Return Assumption

Liability measures in the scenarios above are all based on PERA's investment return assumption of 7.25%. In the next scenario, rather than stress-testing actual experience against the current assumption, we demonstrate the impact that a lower investment return would have on projected AAP tests in the short-term. For this, we created an alternate static liability forecast reflecting a 7.00% investment return assumption, which is 25 basis points below the current assumption, and applied the same 5,000 investment return simulations to generate a new series of AAP ratios. Based on these results, the probability in each year of the AAP test triggering contribution increases and a reduction in the AI cap (from an AAP ratio below 98%) or triggering contribution decreases and an increase in the AI cap (from an AAP ratio exceeding 120%) are determined and illustrated in the following graphic:

Likelihood of Triggering Automatic Adjustment Provision
Alternate Liability Forecast Reflecting a 7.00% Investment Return Assumption



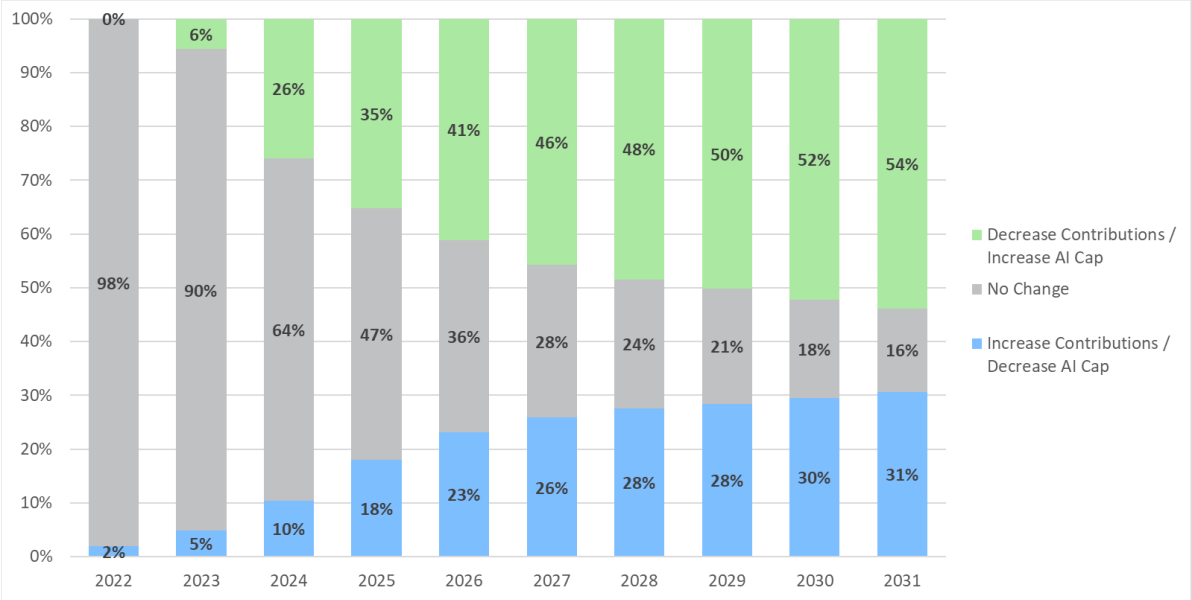
* Due to rounding, values shown here may not sum as expected

A lower investment return assumption initially creates relatively higher accrued liability and normal cost, which increases the ADC value in the AAP test. The ADC value is used in the denominator in the AAP ratio, so larger values initially cause relatively lower ratios. When compared to the baseline projections, this scenario produces more outcomes that result in AAP ratios below 98%, triggering contribution increases and AI cap decreases.

Scenario: Alternate Liability Forecast Reflecting a 6.75% Investment Return Assumption

In the next scenario, we demonstrate the impact that an even lower investment return assumption would have on projected AAP tests in the short-term. For this, we created an alternate static liability forecast reflecting a 6.75% investment return assumption, which is 50 basis points below the current assumption, and applied the same 5,000 investment return simulations to generate a new series of AAP ratios. Based on these results, the probability in each year of the AAP test triggering contribution increases and a reduction in the AI cap (from an AAP ratio below 98%) or triggering contribution decreases and an increase in the AI cap (from an AAP ratio exceeding 120%) are determined and illustrated in the following graphic:

Likelihood of Triggering Automatic Adjustment Provision
Alternate Liability Forecast Reflecting a 6.75% Investment Return Assumption



* Due to rounding, values shown here may not sum as expected

A lower investment return assumption initially creates relatively higher accrued liability and normal cost, which increases the ADC value in the AAP test. The ADC value is used in the denominator in the AAP ratio, so larger values initially cause relatively lower ratios. When compared to the baseline projections, this scenario produces more outcomes that result in AAP ratios below 98%, triggering contribution increases and AI cap decreases.

Section 7: Conclusions

The Signal Light Reporting provides a sensitivity analysis of each division's actuarial assumptions on certain full funding targets. This analysis reflects the results and plan experience from the December 31, 2021, actuarial valuation.

LONG-TERM VIEW

Segal has determined the likelihood of achieving the investment return and certain demographic assumptions based upon:

- The 30-year capital market assumptions, provided by the Board's investment consultants, at the time the Board last reviewed the investment return of 7.25% (Asset Liability Study concluded in November of 2019)
- The resulting likelihoods of achieving certain returns based upon 50-year probability outlooks prepared at the time
- The provisions of SB 18-200, reflecting the Automatic Adjustment Provisions (AAP), initiating adjustments for
    - employer contributions,
    - member contributions, and
    - annual increases to benefits,

  with the intent to keep PERA on the path to full funding, reflecting the first set of adjustments on July 1, 2020, and the second set of adjustments on July 1, 2022.

Notwithstanding the initiation of the AAP adjustments and subsequent law changes, Segal has kept the Signal Light status definitions basically the same to compare year-over-year results.

Going forward, short-term variations, both positive and negative, are to be expected given the volatility inherent in the actual investment return from year to year. The following tables pertain to the Signal Light analysis based on "all assumptions". A summary of the change in the Signal Light reporting from last year to this year is summarized in the following table:

	Signal Light Status – Long-Term View	
Division	December 31, 2021	December 31, 2020
State	Dark Green	Green
School	Green	Green
Local Government	Dark Green	Dark Green
Judicial	Dark Green	Dark Green
DPS	Dark Green	Dark Green

In terms of the SB 18-200 goal of achieving 100% funded by 2048 and monitoring whether PERA is on track vis-à-vis a 67% probability, the following table summarizes the probabilities evaluated in this analysis on the conservative basis of counting scenarios:

	Probability of 100% Funded by 2048*
Division	Signal Light Basis
State	63%
School	59%
Local Government	67%
Judicial	80%
DPS	84%

As mentioned earlier, this process will require continuous monitoring of the assumptions and methods used in the valuation and projections. Segal will evaluate and update these Signal Light results each year incorporating the PERA Board's assumption and method set as of the most recent valuation date.

SHORT-TERM VIEW

While PERA's goals are largely focused on the long-term, experience in the short-term can have a significant impact on how those long-term goals are achieved. PERA's AAP ratio test is performed annually as part of the actuarial valuation process and the outcome of this test influences the level of future employer and member contributions as well as increases in annuities in payment status. As part of the Signal Light reporting, Segal evaluates the type of short-term plan experience that could cause changes in contributions and the AI cap.

In order for the projected AAP ratio as of December 31, 2022, to be lower than 98% or greater than 120% (and therefore trigger a series of AAP adjustments), actual investment experience for 2022 (assuming other variables meet their respective assumptions for the year) would need to be worse than −44.6% or better than 31.9%, respectively. This has not occurred in a single year in the last 30 years.

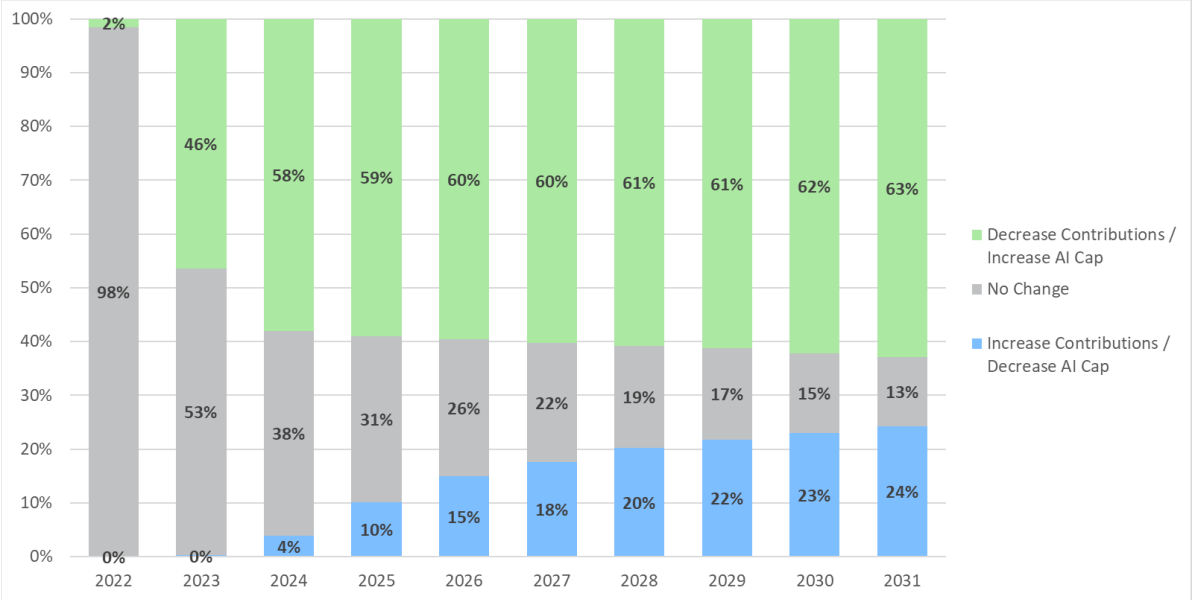
Experience for 2022 related to market value investment return, decrease in total payroll, and level of demographic loss as a percentage of accrued liability would need to be −22.5%, 3.8%, and 1.4% (at or worse than 2.44 standard deviations to the left of the mean) to result in a projected AAP ratio lower than 98%. In estimated probabilistic terms, 2.44 standard deviations or more to the left of the mean is expected to occur less than 1% of the time under the normal distribution.

Similarly, experience for 2022 related to market value investment return, increase in total payroll, and level of demographic gain as a percentage of accrued liability would need to be 23.0%, 6.2%, and 0.7% (at or better than 1.16 standard deviations to the right of the mean) to result in a projected AAP ratio greater than 120%. In estimated probabilistic terms, 1.16

standard deviations or more to the right of the mean is expected to occur 12% of the time under the normal distribution.

It is unlikely that the next actuarial valuation as of December 31, 2022, will result in an AAP ratio that triggers increases to contribution rates and a decrease in the AI cap. Using the investment return simulations from the long-term stochastic analysis, we observe that under the baseline liability forecast there is a 15% likelihood that the AAP ratio will fall below 98% and trigger contribution rate increases and a decrease in the AI cap in the next five years. Scenarios reflecting favorable investment return experience and using the baseline liability forecast yield a 60% likelihood that the AAP ratio will exceed 120% and trigger contribution rate decreases and an increase in the AI cap in the next five years.

Likelihood of Triggering Automatic Adjustment Provision
Baseline Liability Forecast



* Due to rounding, values shown here may not sum as expected

Section 8: Actuarial Assumptions and Methods and Statistical Approach

For a complete description of the assumptions and methods used, see the Actuarial Valuation and Review as of December 31, 2021.

Additional assumptions used for the projections are as follows:

The statistical methodology was produced in the original sensitivity analysis report completed by Pension Trustee Advisors in 2015, which was initially mandated by Senate Bill (SB) 14-214 and conducted under the direction of the Office of the State Auditor. We have continued this statistical approach as required by 24-51-204(7.5), C.R.S., with updates as appropriate and at PERA's request.

Variables Studied and Nature of Modeling

The future funding position of PERA depends on many uncertain future events. Because of the uncertainty, it is appropriate to use historical data and expert inputs to estimate the potential variability of these future events and examine the potential impact. Throughout the report, many future events are uncertain and can be analyzed statistically. These include:

- Investment return
- Salary experience
- Growth in the active population
- Mortality experience and other actuarial gains and losses

The modeling in this report is intended to estimate the impact of observed variability in ordinary experience under these sources of risk. We have modeled annual investment return using stochastic modeling. Stochastic projections aggregate thousands of deterministic projections to provide a range of results that can be used to determine likelihood or probability outcomes within a specified range. This approach is used to model complicated distributions such as fund returns with multiple asset classes. In our analysis, the distribution of each asset class was used to model the total fund. The stochastic projections were modeled using 5,000 deterministic trials for each scenario.

The non-investment variables are based on the normal distribution. This model is generally reasonable for modeling variables where for each observation, the outcome is determined by the aggregate result of a large number of individual events with no single dominant driver among the group. This type of model is a better fit for certain components of plan experience than for other components of plan experience. The following table gives some illustrative examples of items that have an impact on plan funding categorized by how well this type of model fits.

Events with impact on plan funding that can be modeled as independent events with aggregate experience following a normal distribution	Events with impact on plan funding that are difficult to statistically model
Investment returns of individual asset classes over most periods of time	Investment returns that have been affected by a large non-recurring or infrequent event (e.g. a credit crisis or a change in government policy)
Year-to-year variation in deaths, retirements, voluntary turnover, and termination for cause	Layoffs, changes in HR policy with an impact on hiring, turnover or retirement patterns, and long-term mortality improvements
Variation in inflation component of salary increases and variation in hiring and retention	Structural changes in compensation and staffing policy
	Political, economic and environmental changes over time

The items in the left column have some common elements. These events happen frequently due to a wide variety of specific causes that have a body of data documenting their historical variability. The items on the right can have significant impacts on plan experience and do not occur often enough to make it possible to meaningfully fit a statistical model. It is appropriate to study these types of events as a source of potential impact on a plan, but since it is not possible to empirically quantify these types of events with a statistical model based on historical data and expert inputs, the analysis in this report does not constitute an estimate of the likelihoods of these types of events.

Standard Deviation

Standard deviation is the statistical measure used to quantify the amount of variation on a set of assumptions. While the analysis shows that the average occurrence of an assumption over many years will be near the mean, we need to analyze what possible other outcomes may occur and what is the likelihood of those occurrences.

For example, as shown on page 19 of this report, the one-year standard deviation for the State Division population growth is 1.85%. Assuming a normal distribution of this assumption, there is a 68% likelihood that population growth in any year will fall within one standard deviation of the mean, between negative 1.60% and positive 2.10%. While one-year time frames have a fairly high range, extending the time horizon to a 50-year period, the standard deviation becomes less volatile and more condensed. The standard deviation over a 50-year period for population growth is approximately 0.26%. Therefore, over a 50-year period, there is a 68% probability that average annual population growth will be between negative 0.01% and positive 0.51%. This statistical methodology is used for each of the non-investment independent variables.

Model Simplifications

This report uses a deterministic methodology for calculating the funding impact of variability in the non-investment sources previously outlined. We determined ranges for each variable that resulted in each signal light status and then calculated the likelihood of actual experience falling within that range over a 50-year period based on our normal distribution assumption and the stated expected values and standard deviations. This approximates, but does not equal, the probability of each signal light status being met in a stochastic simulation of the assumed distributions.

This simplification makes the calculations required substantially simpler and the distinction between this deterministic method and the stochastic simulation approach is not necessarily relevant to decision making based on this analysis. Both the stochastic simulation approach and this deterministic simplification provide metrics that relate sources of variability to likelihoods of different funding outcomes and both approaches should respond to new data similarly. Generally, if new plan experience has the effect of making a particular signal light status more likely under one approach, it should have the same effect under the other approach.

In order to model the effect of these variables on funding outcomes, we had to relate each one to specific adjustments to a deterministic funding projection model. The variables were incorporated into the projection as follows:

- Demographic gains and losses were assumed to cause a compounding, proportional increase to all benefit payments subsequent to the year in which the gain or loss was recognized. This approach interprets a 1% demographic loss scenario as a scenario where the actuary's projection of all future benefit payments is increasing by 1%, year after year.
- For the purposes of the numerical results in this report, salary gains and losses were treated as gains and losses as a percentage of total actuarial accrued liability and were treated as having identical impact on funding results as the same value demographic gain or loss. No linkage between salary gains and losses and contributions was assumed. This model can be interpreted as treating the salary gains and losses as primarily driven by pay "spiking" prior to termination. This interpretation is conservative, but not necessarily realistic.
    - We evaluated but did not include results from a model that treated salary gains and losses as resulting in an adjustment to benefit payments based on assuming that these items changed linearly proportional to the changes produced by a benefit payment projection that incorporated a 0.50% loss on salary in each future year and included additional contributions in proportion to the cumulative loss (or reduced contributions in proportion to the cumulative gain).

      This alternative model indicated significantly less potential for funding impact from salary increases, but the salary model presented in this report was chosen due to consistency with the prior actuary, conservatism, and the fact that the alternative model does not contradict the selected salary model's conclusion that variability in salary increases has a very limited probability of influencing signal light status.

- Population changes were modeled by adjusting the projection of liabilities to scale the number of future entrants by an amount that results in the effective population equaling the target population based on the population growth assumption.

The analysis based on all variables was performed by adjusting all variables in tandem, proportional to their individual standard deviations. For the purpose of calculating the probability of each signal light status, the investment return was treated as an index for the other assumptions.

Segal results are based on proprietary actuarial modeling software. The actuarial valuation models generate a comprehensive set of liability and cost calculations that are presented to meet regulatory, legislative and client requirements. Deterministic cost projections are based on a proprietary forecasting model. Our Actuarial Technology and Systems unit, comprised of both actuaries and programmers, is responsible for the initial development and maintenance of these models. The models have a modular structure that allows for a high degree of accuracy, flexibility and user control. The client team programs the assumptions and the plan provisions, validates the models, and reviews test lives and results, under the supervision of the responsible actuary.

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