Segal

Public Employees' Retirement Association of Colorado

Signal Light Reporting for the Hybrid Defined Benefit Plan

Based on the Results of the December 31, 2020 Actuarial Valuation

July 19, 2021

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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, 2020. 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.

Beginning with the 2020 Signal Light Report, as a result of discussion and analysis of the PERA Board of Trustees (Board), the Signal Light Reporting process was enhanced by employing stochastic modeling in lieu of deterministic modeling regarding the analysis of the long-term rate of return assumption. By definition, uncertain or variable factors are built into a stochastic model, whereas variable factors are external to a deterministic model. We believe that the stochastic approach better models the impact of actual market activity including the effect of the timing and order of investment returns. In addition, the stochastic methodology also considers PERA's portfolio, more precisely reflecting capital market assumptions, by investment category, within PERA's asset allocation. This methodology is detailed in *Section 1* of the report.

Beginning with this 2021 Signal Light Report*, Section 6 Short-Term Projections*, has been added to provide 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, 2021, actuarial valuation, and if triggered, the AAP adjustments would be effective as of July 1, 2023.

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 furnished by PERA and the baseline actuarial assumptions, as approved by the Board, and used in the December 31, 2020 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, 2020.

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, 2021 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 is 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.

In addition to House Bill (HB) 20-1379, suspending the July 1, 2020, $225 million Direct Distribution from the State, and HB 20-1394, modifying member and employer contribution rates for the 2020-21 and 2021-22 fiscal years for most members of the Judicial Division, the following legislation was enacted in 2020 and reflected in the Actuarial Valuation and Review as of December 31, 2020, on which this report was based:

- SB 20-057, enacted June 29, 2020, and effective as of July 1, 2020, extends the "State Trooper" benefit structure to new and existing employees of the Division of Fire Prevention and Control in the Department of Public Safety, classified as firefighter I through firefighter VII, within the State Division membership.

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. The results of the OPEB funding actuarial valuation are included in a separate report. Analysis regarding specific OPEB-related 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, 2020.

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, 2020.

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 for 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 were modified as follows:

Division Trust Fund	Prior Assumption	Current Assumption
State	1.25%	0.25%
School	1.25%	1.00%
Local Government	1.00%	1.00%
Judicial	1.00%	0.25%
Denver Public Schools	1.25%	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, 2020, 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

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July 19, 2021

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, 2020 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.

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 parameters. 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. In order 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 assumption and method set as of the most recent valuation date.

The variability of the 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	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 2041 (after 20 years)
Dark Red	Insolvent by 2041 (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. Prior to this year, the Light Yellow status, which measures whether the Plan would be 100% funded by 2058, was referred to as Light Green. However, since this represents 40 years from 2018, and is outside the range of the current target full funding year of 2048, we reclassified this status from a "green" color to a "yellow" color, so as not to imply that the funding targets are expected to be met. 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, 2020, 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 takes into consideration asset volatility and the plan's projected cash flow 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:

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)	2,611	52%	62%
Green	**100% funded by 2048 (30 years from 2018)**	**503**	**10%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	538	11%	34%
Yellow	100% funded by 2068 (50 years from 2018)	355	7%	
Orange	Solvent but longer than 50 years to reach 100% funded	778	16%	
Red	Insolvent after 2041 (after 20 years)	170	3%	4%
Dark Red	Insolvent by 2041 (within 20 years)	45	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 Projections*, addresses certain conditions and the likelihood that these conditions could trigger AAP adjustments resulting from the next (December 31, 2021) 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	52%	48th	7.31% or more
Green	**10%**	**38th**	**6.67% to 7.31%**
Light Yellow	11%	27th	5.99% to 6.67%
Yellow	7%	20th	5.40% to 5.99%
Orange	16%	4th	3.18% to 5.40%
Red	3%	1st	1.88% to 3.18%
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 62% (52% + 10%), which equates to the 38th percentile. Therefore, the Signal Light color assigned to the State Division is Green because the 7.25% investment return assumption falls within the range of 6.67% to 7.31% (or, the 38th to 48th 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 38th 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 either 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, 2020 Valuation*	December 31, 2019 Valuation
State	2041 (20 Years)	2042 (22 Years)
School	2043 (22 Years)	2044 (24 Years)
Local Government	2029 (8 Years)	2034 (14 Years)
Judicial	2028 (7 Years)	2032 (12 Years)
Denver Public Schools	2028 (7 Years)	2031 (11 Years)

* Reflects AAP adjustments effective July 1, 2022

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)	(8)	(4)	(5)
Demographic gain/loss	0	(1)	0	0	0
Assumption changes	6	9	6	1	3
December 31, 2020 with AAP adjustments effective July 1, 2022	(3)	(4)	(3)	(1)	(1)
Total	**(1)**	**(1)**	**(5)**	**(4)**	**(3)**

Note the results in the table above could be observed to be 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 17.4% and an actuarial value return of 13.1%) for the 2020 plan year, as well as the impact of revised actuarial assumptions, were the primary drivers behind the change in full funding dates. These two factors had offsetting effects, with higher than expected investment returns reducing the number of years until full funding and assumption changes pushing out the number of years until full funding.

- Small demographic losses for the 2020 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 and lower than expected payroll growth (except for the DPS Division), contributed to negligible changes in the full funding dates, except for the School Division.

- The scheduled July 1, 2022 AAP adjustments have the effect of reducing the number of years until full funding.

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%). Meaning, 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 represents 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.

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)	2,611	52%	62%
Green	**100% funded by 2048 (30 years from 2018)**	**503**	**10%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	538	11%	34%
Yellow	100% funded by 2068 (50 years from 2018)	355	7%	
Orange	Solvent but longer than 50 years to reach 100% funded	778	16%	
Red	Insolvent after 2041 (after 20 years)	170	3%	4%
Dark Red	Insolvent by 2041 (within 20 years)	45	1%	

* Based on 5,000 simulations

The State Division table above provides the following information:

- **Best-case scenarios:** Of the 5,000 simulations ran, 2,611, or 52%, resulted in the State Division Trust Fund being fully funded by 2041, meeting the criteria for Dark Green status. An additional 503 scenarios resulted in being fully funded no later than 2048, meeting the criteria for Green status. Therefore, 62% 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, 215, or 4%, 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 2,611 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.

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)	2,341	47%	56%
Green	**100% funded by 2048 (30 years from 2018)**	**453**	**9%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	493	10%	37%
Yellow	100% funded by 2068 (50 years from 2018)	374	7%	
Orange	Solvent but longer than 50 years to reach 100% funded	975	20%	
Red	Insolvent after 2041 (after 20 years)	319	6%	7%
Dark Red	Insolvent by 2041 (within 20 years)	45	1%	

* Based on 5,000 simulations

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)**	**2,938**	**59%**	64%
Green	100% funded by 2048 (30 years from 2018)	244	5%	
Light Yellow	100% funded by 2058 (40 years from 2018)	262	5%	23%
Yellow	100% funded by 2068 (50 years from 2018)	225	4%	
Orange	Solvent but longer than 50 years to reach 100% funded	684	14%	
Red	Insolvent after 2041 (after 20 years)	575	12%	13%
Dark Red	Insolvent by 2041 (within 20 years)	72	1%	

* Based on 5,000 simulations

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)**	**3,516**	**70%**	76%
Green	100% funded by 2048 (30 years from 2018)	311	6%	
Light Yellow	100% funded by 2058 (40 years from 2018)	308	6%	20%
Yellow	100% funded by 2068 (50 years from 2018)	204	4%	
Orange	Solvent but longer than 50 years to reach 100% funded	483	10%	
Red	Insolvent after 2041 (after 20 years)	174	4%	4%
Dark Red	Insolvent by 2041 (within 20 years)	4	0%	

* Based on 5,000 simulations

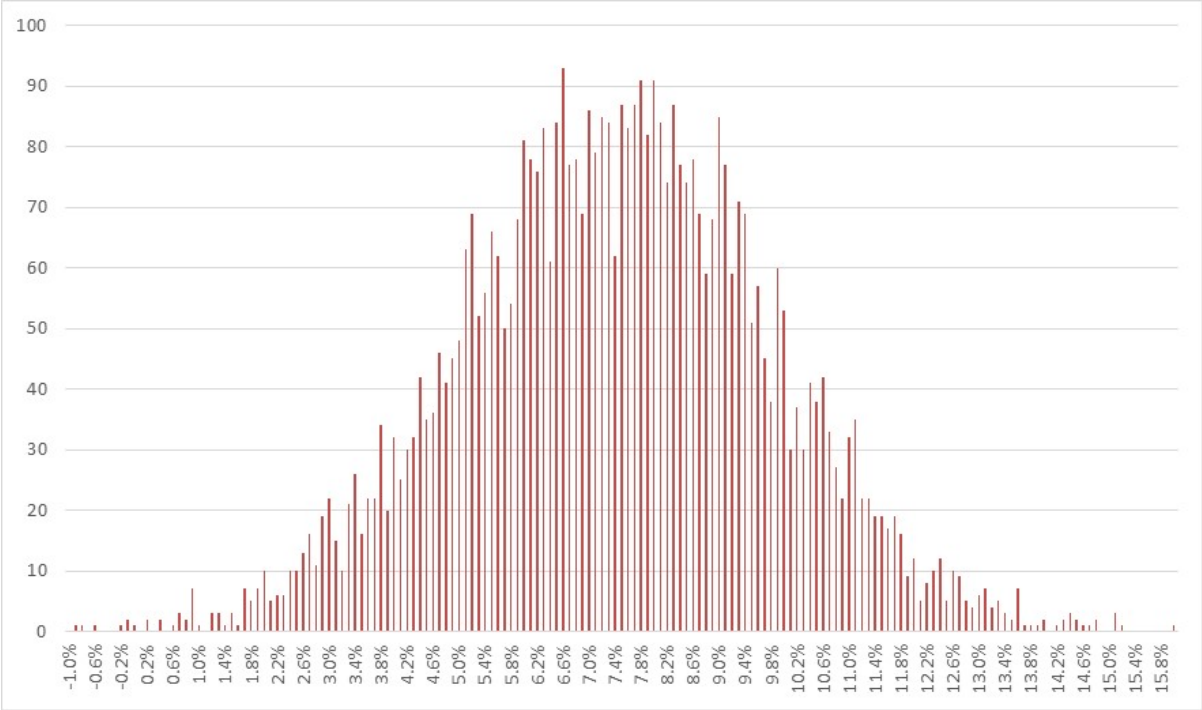
Signal Light Results for Denver Public Schools Division
Stochastic Modeling of Investment Return – Open Group Projection Basis
Assumes Active Membership Grows by 1.00% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,781**	**76%**	85%
Green	100% funded by 2048 (30 years from 2018)	452	9%	
Light Yellow	100% funded by 2058 (40 years from 2018)	364	7%	15%
Yellow	100% funded by 2068 (50 years from 2018)	195	4%	
Orange	Solvent but longer than 50 years to reach 100% funded	208	4%	
Red	Insolvent after 2041 (after 20 years)	0	0%	0%
Dark Red	Insolvent by 2041 (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%).

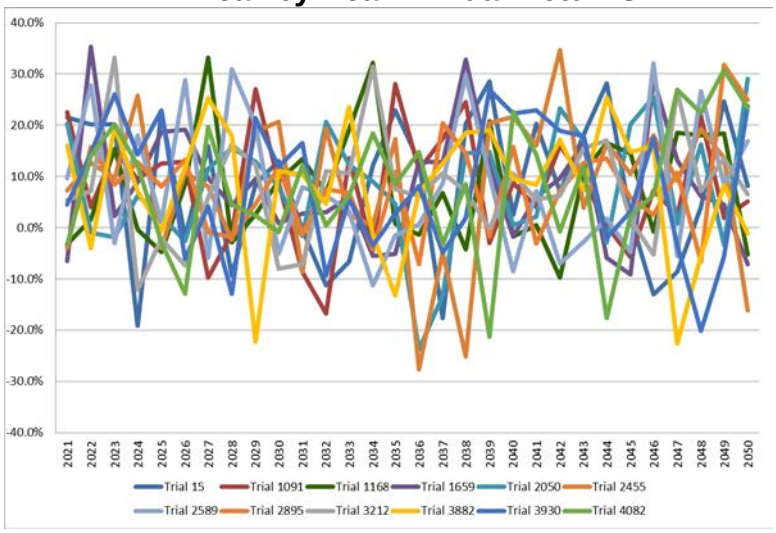
30-year Geometric Averages from 5,000 Simulated Portfolio Returns



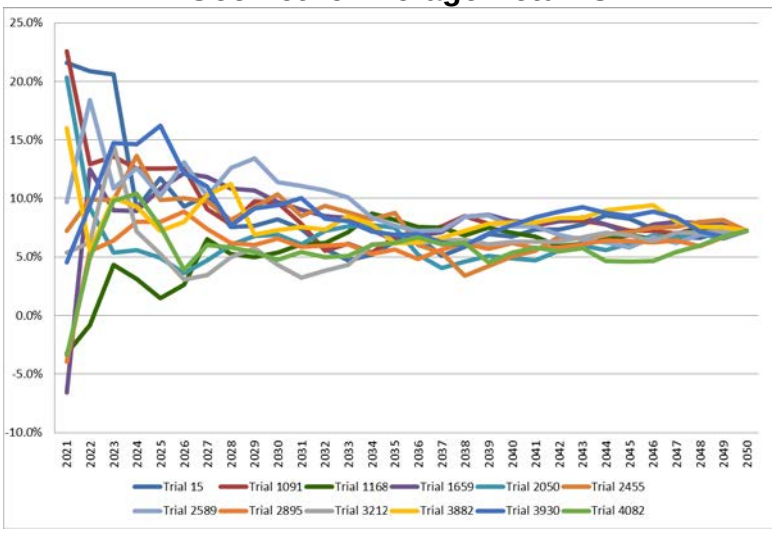
With the capital market assumptions for each asset class assumed to be normally distributed, the results of the 5,000 simulated portfolio returns approximate a normal distribution. In the chart above, the largest cluster of outcomes were near the mean return of 7.4% and the majority are within one standard deviation from the mean (between 5.0% and 9.8%), which represent about 68% of all outcomes. However, that leaves over 30% of outcomes that fall outside of that range.

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



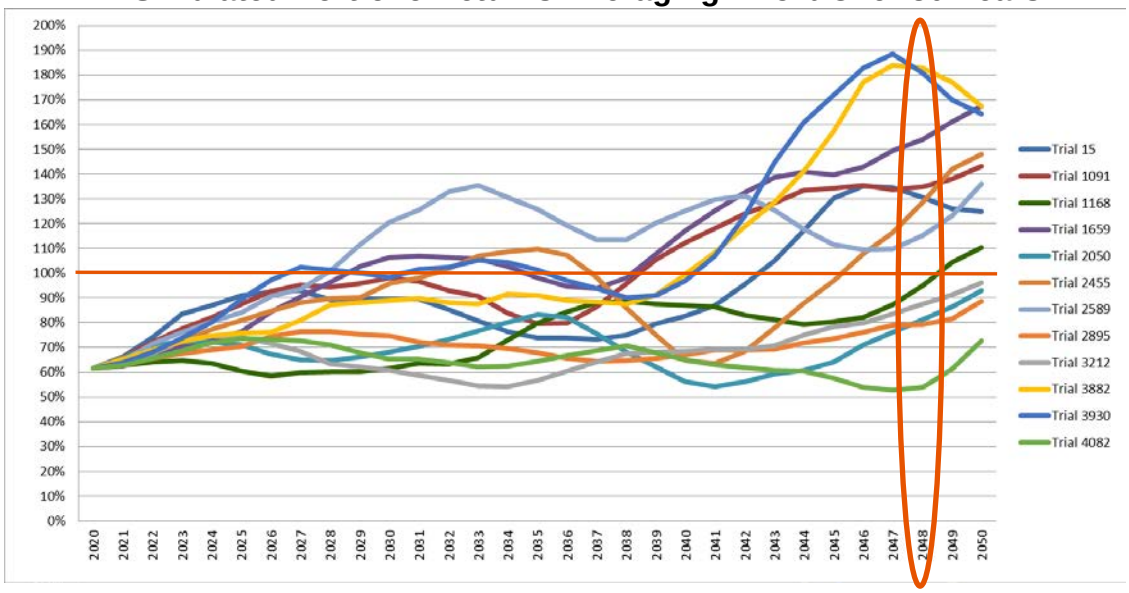
Geometric Average Returns



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.

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 will 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%	0.77%	0.11%
Population Growth	1.00% or 0.25%	1.85%	0.26%
Demographic Changes	0.00%	0.59%	0.08%

* Based on the actual experience over 30 years (1991-2020).

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

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 0.15% loss or better**	**92%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average 0.58% loss to 0.15% loss	8%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average 0.90% loss to 0.58% loss	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average 1.08% loss to 0.90% loss	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.30% loss to 1.08% loss	0%	
Red	Insolvent after 2041 (after 20 years)	Average 3.26% loss to 1.30% loss	0%	0%
Dark Red	Insolvent by 2041 (within 20 years)	Average worse than 3.26% loss	0%	

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 (0.43%) or more**	**100%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average (2.00%) to (0.43%)	0%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average (2.81%) to (2.00%)	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average (3.08%) to (2.81%)	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average (4.34%) to (3.08%)	0%	
Red	Insolvent after 2041 (after 20 years)	Average (10.00%) to (4.34%)	0%	0%
Dark Red	Insolvent by 2041 (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.

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 0.15% loss or better**	**96%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average 0.58% loss to 0.15% loss	4%	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average 0.90% loss to 0.58% loss	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average 1.08% loss to 0.90% loss	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.30% loss to 1.08% loss	0%	
Red	Insolvent after 2041 (after 20 years)	Average 3.26% loss to 1.30% loss	0%	0%
Dark Red	Insolvent by 2041 (within 20 years)	Average worse than 3.26% loss	0%	

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

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 0.05% gain or better	32%	100%
Green	**100% funded by 2048 (30 years from 2018)**	**Average 0.34% loss to 0.05% gain**	**68%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average 0.65% loss to 0.34% loss	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average 0.82% loss to 0.65% loss	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.17% loss to 0.82% loss	0%	
Red	Insolvent after 2041 (after 20 years)	Average 3.39% loss to 1.17% loss	0%	0%
Dark Red	Insolvent by 2041 (within 20 years)	Average worse than 3.39% loss	0%	

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

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 1.29% or more	13%	100%
Green	**100% funded by 2048 (30 years from 2018)**	**Average (0.63%) to 1.29%**	**87%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average (1.64%) to (0.63%)	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average (2.00%) to (1.64%)	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average (3.54%) to (2.00%)	0%	
Red	Insolvent after 2041 (after 20 years)	Average (10.00%) to (3.54%)	0%	0%
Dark Red	Insolvent by 2041 (within 20 years)	Average less than (10.00%)	0%	

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 0.05% gain or better	27%	100%
Green	**100% funded by 2048 (30 years from 2018)**	**Average 0.34% loss to 0.05% gain**	**73%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	Average 0.65% loss to 0.34% loss	0%	0%
Yellow	100% funded by 2068 (50 years from 2018)	Average 0.82% loss to 0.65% loss	0%	
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.17% loss to 0.82% loss	0%	
Red	Insolvent after 2041 (after 20 years)	Average 3.39% loss to 1.17% loss	0%	0%
Dark Red	Insolvent by 2041 (within 20 years)	Average worse than 3.39% 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. 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 an 87% probability of having the population growth average between -0.63% (shrinking by 0.63% per year) and 1.29% 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 remains on the Green status path. If the population growth were to average lower than -0.63% (shrinking by 0.63% per year) for the School Division over this projection period (which happens to have a less than 0.5% probability based on the model used), then the status path would trend downward.

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 way more than the other. For example, a tendency for members to stay employed longer than historically 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.

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)	2,394	48%	58%
Green	**100% funded by 2048 (30 years from 2018)**	**523**	**10%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	545	11%	38%
Yellow	100% funded by 2068 (50 years from 2018)	382	8%	
Orange	Solvent but longer than 50 years to reach 100% funded	949	19%	
Red	Insolvent after 2041 (after 20 years)	185	4%	4%
Dark Red	Insolvent by 2041 (within 20 years)	22	0%	

* Based on 5,000 simulations

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)	1,999	40%	49%
Green	100% funded by 2048 (30 years from 2018)	439	9%	
Light Yellow	**100% funded by 2058 (40 years from 2018)**	**459**	**9%**	43%
Yellow	100% funded by 2068 (50 years from 2018)	402	8%	
Orange	Solvent but longer than 50 years to reach 100% funded	1,297	26%	
Red	Insolvent after 2041 (after 20 years)	387	8%	8%
Dark Red	Insolvent by 2041 (within 20 years)	17	0%	

* Based on 5,000 simulations

Compared to the baseline Signal Light results, application of the hypothetical demographic assumptions result in the State Division its Green color and the School Division dropping from Green to Light Yellow. For the State Division, the probability of falling into one of the Green statuses declines from 62% to 58%. For the School Division, the probability of falling into one of the Green statuses declines from 56% to 49%.

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 20 years to 21 years and the School Division to increase from 22 years to 27 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.

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)	2,580	52%	60%
Green	**100% funded by 2048 (30 years from 2018)**	**405**	**8%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	464	9%	30%
Yellow	100% funded by 2068 (50 years from 2018)	312	6%	
Orange	Solvent but longer than 50 years to reach 100% funded	745	15%	
Red	Insolvent after 2041 (after 20 years)	440	9%	10%
Dark Red	Insolvent by 2041 (within 20 years)	54	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.

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)	2,353	47%	55%
Green	**100% funded by 2048 (30 years from 2018)**	**371**	**8%**	
Light Yellow	100% funded by 2058 (40 years from 2018)	418	8%	31%
Yellow	100% funded by 2068 (50 years from 2018)	321	6%	
Orange	Solvent but longer than 50 years to reach 100% funded	824	17%	
Red	Insolvent after 2041 (after 20 years)	659	13%	14%
Dark Red	Insolvent by 2041 (within 20 years)	54	1%	

* Adjusted, based on 5,000 simulations

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)**	**2,856**	**57%**	62%
Green	100% funded by 2048 (30 years from 2018)	224	5%	
Light Yellow	100% funded by 2058 (40 years from 2018)	235	5%	20%
Yellow	100% funded by 2068 (50 years from 2018)	210	4%	
Orange	Solvent but longer than 50 years to reach 100% funded	572	11%	
Red	Insolvent after 2041 (after 20 years)	824	16%	18%
Dark Red	Insolvent by 2041 (within 20 years)	79	2%	

* 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.

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)**	**3,387**	**68%**	74%
Green	100% funded by 2048 (30 years from 2018)	293	6%	
Light Yellow	100% funded by 2058 (40 years from 2018)	295	6%	19%
Yellow	100% funded by 2068 (50 years from 2018)	197	4%	
Orange	Solvent but longer than 50 years to reach 100% funded	470	9%	
Red	Insolvent after 2041 (after 20 years)	354	7%	7%
Dark Red	Insolvent by 2041 (within 20 years)	4	0%	

* Adjusted, based on 5,000 simulations

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)**	**3,638**	**73%**	82%
Green	100% funded by 2048 (30 years from 2018)	432	9%	
Light Yellow	100% funded by 2058 (40 years from 2018)	357	7%	18%
Yellow	100% funded by 2068 (50 years from 2018)	189	4%	
Orange	Solvent but longer than 50 years to reach 100% funded	360	7%	
Red	Insolvent after 2041 (after 20 years)	24	0%	0%
Dark Red	Insolvent by 2041 (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.

Section 6: Short-Term Projections

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. This section examines the expected AAP ratio projected one year to December 31, 2021 and stress tests how actual experience during 2021 would affect the projected ratio.

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, 2020 actuarial valuation results and relying on the baseline assumptions outlined above for experience during 2021, the expected AAP ratio as of December 31, 2021 is 101.9%. 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 10.7% 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 101.9% as of December 31, 2021 would not result in any additional AAP adjustments effective July 1, 2023.

In order for the projected AAP ratio as of December 31, 2021 to be lower than 98% (and therefore trigger another series of AAP adjustments), experience for 2021 of any **single** variable above (assuming the other two variables meet their respective assumptions for the year) would need to be:

- -9.66% or lower market value investment return; or
- -4.60% or lower decrease in total payroll; or
- 2.75% or more demographic loss

For context, a market value return of -9.66% or lower has occurred twice in the last 30 years, a -4.60% or lower decrease in total payroll has never occurred in the last 30 years, and a 2.75% or more demographic loss has occurred once in the last 30 years.

In order for the projected AAP ratio to be lower than 98%, experience for 2021 of any **two** variables above (assuming the third variable meets expectations) would be:

- 0% market value investment return and -1.36% or lower increase in payroll
- 0% market value investment return and 1.57% or more demographic loss

[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.

- 0% increase in total payroll and -3.02% or lower market value investment return
- 0% increase in total payroll and 1.67% or more demographic loss

- 1% demographic loss and -3.52% or lower market value investment return
- 1% demographic loss and -1.84% or lower 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) are "equally likely", but they do represent anecdotal metrics for "worse-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 increase in total payroll has occurred five 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 fall at the mean value of 7.25%, then experience for total payroll increase and demographic gain/loss also fall at their mean values of 3% and 0%, respectively. However, 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 2021 at or worse than 0.80 standard deviations to the left of the mean would result in a projected AAP ratio lower than 98%. This equates to:

- -1.78% or lower market value investment return;
- 0.77% or lower increase in total payroll; and
- 0.47% or more demographic loss.

Putting this in estimated probabilistic terms, 0.80 standard deviations or more to the left of the mean is expected to occur 21.1% 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, 2021, actuarial valuation, that would trigger additional AAP adjustments to be effective July 1, 2023.

[8] A standard deviation of 2.79% for total payroll growth relative to expected was calculated based on 30 years of historical covered payroll increases for 1991-2020 compared to the existing assumption for payroll growth in effect for each year.

Section 7: Conclusion

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, 2020 actuarial valuation.

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, effective July 1, 2019 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 (with slight modifications) to compare this year's results with last year's 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. 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	
Division	**December 31, 2020**	**December 31, 2019**
State	**Green**	**Green**
School	**Green**	**Green**
Local Government	**Dark Green**	**Dark Green**
Judicial	**Dark Green**	**Dark Green**
DPS	**Dark Green**	**Dark Green**

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.

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, 2020.

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 14 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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