Segal

Public Employees' Retirement Association of Colorado

Signal Light Reporting for the Hybrid Defined Benefit Plan

Based on the Results of the December 31, 2019 Actuarial Valuation

July 17, 2020

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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, 2019. 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 discussion and analysis at the September 11, 2019, and January 17, 2020, PERA meetings, the PERA Board of Trustees (Board) further enhanced the Signal Light Reporting process 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. The stochastic approach will better reflect 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. The revised methodology is detailed in *Section 1* of the report.

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, used in the December 31, 2019 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, 2019. Due to the COVID-19 pandemic, market conditions have changed significantly since this date and we anticipate continued volatility through the next valuation date as financial markets react to news regarding the pandemic. The projections in this report are based on views of capital markets and expected returns under more normal market conditions than what has transpired in the short-term as impacted by COVID-19.

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.

In the last five actuarial valuations, PERA has seen liability increases due to demographic experience losses (i.e., actual experience that is less favorable than the assumptions) that total over $3 billion. The results from this report do not reflect this level of demographic losses persisting in the future. Prior to the next actuarial valuation, an experience study will be conducted and revised actuarial assumptions will be recommended. A revised package of demographic assumptions that address persistent experience losses would have a material impact on the information provided in this report.

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. 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.

Pursuant to recent legislation enacted in June 2020, passed in response to budgetary needs due to the COVID-19 pandemic, contribution rates of employers and members, as well as the Direct Distribution from the State are impacted as follows:

- HB 20-1379 suspends the July 1, 2020, $225 million Direct Distribution allocated to the State, School, Judicial, and DPS Divisions, as required under Senate Bill 18-200.

- HB 20-1394 requires five percent of the Judicial Division base employer contribution rate to be paid by the members of the Judicial Division effective for the State's 2020-21 and 2021-22 fiscal years. This contribution rate modification does not apply to employees of the Denver County Court within the Judicial Division.

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, 2019.

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, 2019.

ASSUMPTIONS AND METHODS

The information and analysis used in selecting each assumption that has a significant effect on this actuarial valuation resulted from the 2016 Actuarial Experience Study covering plan experience over the four-year period January 1, 2012, through December 31, 2015, and Board discussion at the November 18, 2016, Board meeting. 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. Based on professional judgment, no assumption changes are warranted at this time. A summary of the assumptions and methods applied in this analysis is provided in PERA's Actuarial Valuation and Review as of December 31, 2019.

DATA

Member data for retired, active, and inactive participants was supplied as of December 31, 2019, 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

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July 17, 2020

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, 2019 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 outcome 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 modeling the variation of total experience and not possible changes in the parameters.

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 based on 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 average 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 Green	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 2040 (after 20 years)
Dark Red	Insolvent by 2040 (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, 2019, valuation date. Each year, as more experience is gathered and users become more familiar with the tool, these criteria and thresholds will be reviewed and evaluated to determine if adjustments are appropriate.

The methodology for determining the results of the Signal Light reporting with respect to investment returns has been changed from deterministic modeling to stochastic modeling to account for asset volatility and negative cash flow. Under the prior deterministic method, a static investment return that would be required every year to achieve each Signal Light condition was determined. The probability of achieving that investment return was determined using the portfolio's expected return and standard deviation. The Signal Light color was then assigned based upon where the 7.25% investment return assumption falls relative to the ranges of static returns. As a result, the probability was based solely on compound average returns and without respect to the plan's projected cash flows.

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 1.25% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	2,461	49%	75%
Green	**100% funded by 2048 (30 years from 2018)**	**607**	**12%**	
Light Green	100% funded by 2058 (40 years from 2018)	706	14%	
Yellow	100% funded by 2068 (50 years from 2018)	520	11%	24%
Orange	Solvent but longer than 50 years to reach 100% funded	644	13%	
Red	Insolvent after 2040 (after 20 years)	14	0%	1%
Dark Red	Insolvent by 2040 (within 20 years)	48	1%	

* Based on 5,000 simulations

The Signal Light chart quantifies the probability of achieving the benchmark for a particular 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 was in the Red or Dark Red status for a number of years (e.g., 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).

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	49%	51st	7.51% or more
Green	12%	39th	6.74% to 7.51%
Light Green	14%	25th	5.84% to 6.74%
Yellow	11%	14th	4.99% to 5.84%
Orange	13%	1st	1.88% to 4.99%
Red	0%	1st	n/a
Dark Red	1%	n/a	Less than 1.88%

For example, in the table above, the probability of meeting Green status is 61% (49% + 12%), which equates to the 39th percentile. Therefore, the Signal Light assigned to the State Division is Green because the 7.25% investment return assumption falls within the range of 6.74% to 7.51% (or, the 39th to 51st 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 39th 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 changes during the annual actuarial valuation and projection processes, we are 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, 2019 Valuation	December 31, 2018 Valuation
State	2042 (22 Years)	2047 (28 Years)
School	2044 (24 Years)	2053 (34 Years)
Local Government	2034 (14 Years)	2048 (29 Years)
Judicial	2032 (12 Years)	2040 (21 Years)
Denver Public Schools	2031 (11 Years)	2036 (17 Years)

The following table shows the factors that contributed to the decreases, not including the one year decrease due to the passage of time:

	Increase/(Decrease) in Projected Full Funding Date (in Years)				
	State	School	Local Government	Judicial	DPS
Based on expected values	1	0	(2)	(2)	1
Investment return	(7)	(9)	(13)	(6)	(6)
Payroll growth	0	(2)	0	(1)	0
Demographic gain/loss	1	2	1	1	0
HB 20-1379 and HB 20-1394	0	0	0	0	0
Total	**(5)**	**(9)**	**(14)**	**(8)**	**(5)**

Note the results in the table above could 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 market value return of 20.3% and an actuarial value return of 9.9% for the 2019 plan year were the primary drivers behind the change in full funding dates.
- The combined effect of House Bill 20-1379 and House Bill 20-1394 had a negligible increase in the projected full funding dates.
- The higher than expected payroll growth for School and Judicial divisions resulted in a decrease in the projected full funding dates.
- Demographic losses (except for DPS division, which experienced a small demographic gain) for the 2019 plan year occurred due to actual experience differing from expected, based on the actuarial assumptions, including service retirements and termination of employment, all of which contributed to increases in the full funding dates of varying degrees.

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 2.40% 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. Below is a breakdown of the investment policy adopted by the PERA Board and the capital market analysis most recently reviewed by the PERA Board upon which this section is based.

Current Asset Classes	Long-Term Asset Allocation	Expected Nominal Return	Expected Risk
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	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%	

*Provided by PERA's investment consultant, Aon Hewitt as included in the "Asset-Liability Study Follow-Up" presentation dated September 13, 2019.

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 1.25% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	2,461	49%	75%
Green	**100% funded by 2048 (30 years from 2018)**	**607**	**12%**	
Light Green	100% funded by 2058 (40 years from 2018)	706	14%	
Yellow	100% funded by 2068 (50 years from 2018)	520	11%	24%
Orange	Solvent but longer than 50 years to reach 100% funded	644	13%	
Red	Insolvent after 2040 (after 20 years)	14	0%	1%
Dark Red	Insolvent by 2040 (within 20 years)	48	1%	

* Based on 5,000 simulations

The State Division table above provides the following information:

- Of the 5,000 simulations ran, 2,461, or 49%, resulted in the State Division Trust Fund being fully funded by 2041, meeting the criteria for Dark Green status. An additional 607 scenarios resulted in being fully funded no later than 2048, meeting the criteria for Green status. Including the 706 simulations that met the criteria for Light Green status, 75% of the 5,000 simulations resulted in the State Division meeting a criteria for one of the green status definitions.

- For the worst-case scenarios, 62 simulations resulted in the State Division Trust Fund becoming depleted. However, as mentioned in *Section 1* of this report, the Signal Light reporting reflects only the variations of the assumptions we are testing. 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 2,461 that result in Dark Green status where 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 1.25% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	2,249	45%	66%
Green	**100% funded by 2048 (30 years from 2018)**	**499**	**10%**	
Light Green	100% funded by 2058 (40 years from 2018)	548	11%	
Yellow	100% funded by 2068 (50 years from 2018)	449	9%	30%
Orange	Solvent but longer than 50 years to reach 100% funded	1,069	21%	
Red	Insolvent after 2040 (after 20 years)	123	3%	4%
Dark Red	Insolvent by 2040 (within 20 years)	63	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)**	**2,709**	**54%**	65%
Green	100% funded by 2048 (30 years from 2018)	267	5%	
Light Green	100% funded by 2058 (40 years from 2018)	309	6%	
Yellow	100% funded by 2068 (50 years from 2018)	255	5%	23%
Orange	Solvent but longer than 50 years to reach 100% funded	866	18%	
Red	Insolvent after 2040 (after 20 years)	461	9%	12%
Dark Red	Insolvent by 2040 (within 20 years)	133	3%	

* 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 1.00% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	3,145	63%	80%
Green	100% funded by 2048 (30 years from 2018)	395	8%	
Light Green	100% funded by 2058 (40 years from 2018)	428	9%	
Yellow	100% funded by 2068 (50 years from 2018)	311	6%	19%
Orange	Solvent but longer than 50 years to reach 100% funded	690	13%	
Red	Insolvent after 2040 (after 20 years)	27	1%	1%
Dark Red	Insolvent by 2040 (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 1.25% per Year

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	3,520	70%	90%
Green	100% funded by 2048 (30 years from 2018)	543	11%	
Light Green	100% funded by 2058 (40 years from 2018)	457	9%	
Yellow	100% funded by 2068 (50 years from 2018)	257	5%	10%
Orange	Solvent but longer than 50 years to reach 100% funded	223	5%	
Red	Insolvent after 2040 (after 20 years)	0	0%	0%
Dark Red	Insolvent by 2040 (within 20 years)	0	0%	

* Based on 5,000 simulations

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 (1.25% for State, School and DPS Divisions and 1.00% for Local Government 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%	0.79%	0.11%
Population Growth	1.25% or 1.00%	1.39%	0.20%
Demographic Changes	0.00%	0.52%	0.07%

* Based on the actual experience over 19 years (2001-2019).

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 0.01% loss or better**	**54%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average 0.51% loss to 0.01% loss	46%	
Light Green	100% funded by 2058 (40 years from 2018)	Average 0.90% loss to 0.51% loss	0%	
Yellow	100% funded by 2068 (50 years from 2018)	Average 1.12% loss to 0.90% loss	0%	0%
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.40% loss to 1.12% loss	0%	
Red	Insolvent after 2040 (after 20 years)	Average 3.09% loss to 1.40% loss	0%	0%
Dark Red	Insolvent by 2040 (within 20 years)	Average worse than 3.09% 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 1.21% or more**	**58%**	100%
Green	100% funded by 2048 (30 years from 2018)	Average (0.43%) to 1.21%	42%	
Light Green	100% funded by 2058 (40 years from 2018)	Average (1.34%) to (0.43%)	0%	
Yellow	100% funded by 2068 (50 years from 2018)	Average (1.68%) to (1.34%)	0%	0%
Orange	Solvent but longer than 50 years to reach 100% funded	Average (3.40%) to (1.68%)	0%	
Red	Insolvent after 2040 (after 20 years)	Average (10.00%) to (3.40%)	0%	0%
Dark Red	Insolvent by 2040 (within 20 years)	Average less than (10.00%)	0%	

Please see *Section 7* 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 0.01% loss or better**	55%	100%
Green	100% funded by 2048 (30 years from 2018)	Average 0.51% loss to 0.01% loss	45%	
Light Green	100% funded by 2058 (40 years from 2018)	Average 0.90% loss to 0.51% loss	0%	
Yellow	100% funded by 2068 (50 years from 2018)	Average 1.12% loss to 0.90% loss	0%	0%
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.40% loss to 1.12% loss	0%	
Red	Insolvent after 2040 (after 20 years)	Average 3.09% loss to 1.40% loss	0%	0%
Dark Red	Insolvent by 2040 (within 20 years)	Average worse than 3.09% 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 0.13% gain or better	12%	100%
Green	**100% funded by 2048 (30 years from 2018)**	**Average 0.29% loss to 0.13% gain**	**87%**	
Light Green	100% funded by 2058 (40 years from 2018)	Average 0.62% loss to 0.29% loss	1%	
Yellow	100% funded by 2068 (50 years from 2018)	Average 0.80% loss to 0.62% loss	0%	0%
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.36% loss to 0.80% loss	0%	
Red	Insolvent after 2040 (after 20 years)	Average 3.25% loss to 1.36% loss	0%	0%
Dark Red	Insolvent by 2040 (within 20 years)	Average worse than 3.25% loss	0%	

Please see *Section 7* 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 1.87% or more	0%	100%
Green	**100% funded by 2048 (30 years from 2018)**	**Average 0.05% to 1.87%**	**100%**	
Light Green	100% funded by 2058 (40 years from 2018)	Average (0.95%) to 0.05%	0%	
Yellow	100% funded by 2068 (50 years from 2018)	Average (1.33%) to (0.95%)	0%	0%
Orange	Solvent but longer than 50 years to reach 100% funded	Average (3.31%) to (1.33%)	0%	
Red	Insolvent after 2040 (after 20 years)	Average (10.00%) to (3.31%)	0%	0%
Dark Red	Insolvent by 2040 (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 0.13% gain or better	4%	100%
Green	**100% funded by 2048 (30 years from 2018)**	**Average 0.29% loss to 0.13% gain**	**96%**	
Light Green	100% funded by 2058 (40 years from 2018)	Average 0.62% loss to 0.29% loss	0%	
Yellow	100% funded by 2068 (50 years from 2018)	Average 0.80% loss to 0.62% loss	0%	0%
Orange	Solvent but longer than 50 years to reach 100% funded	Average 1.36% loss to 0.80% loss	0%	
Red	Insolvent after 2040 (after 20 years)	Average 3.25% loss to 1.36% loss	0%	0%
Dark Red	Insolvent by 2040 (within 20 years)	Average worse than 3.25% loss	0%	

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

Please see *Section 7* 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 will 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.

If active population growth for the School Division is reviewed, we find that there is a 100% probability of having the population growth average between 0.05 and 1.87% over a 50-year period. Of course, this is assuming that the current expected value for population growth of 1.25% 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 0.05% for the School Division over this projection period (which has a 0.00% probability), then the status path would trend downward.

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 were normally distributed and 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 1.25% per Year

Based on All Assumptions

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	2,459	49%	71%
Green	**100% funded by 2048 (30 years from 2018)**	**488**	**10%**	
Light Green	100% funded by 2058 (40 years from 2018)	609	12%	
Yellow	100% funded by 2068 (50 years from 2018)	477	10%	27%
Orange	Solvent but longer than 50 years to reach 100% funded	861	17%	
Red	Insolvent after 2040 (after 20 years)	52	1%	2%
Dark Red	Insolvent by 2040 (within 20 years)	54	1%	

* Adjusted, based on 5,000 simulations

Please see *Section 7* for the methodology used to determine the percentages in the tables above.

Signal Light Results for School Division
Assumes Active Membership Grows by 1.25% per Year

Based on All Assumptions

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	100% Funded by 2041 (30 years from 2011)	2,275	46%	63%
Green	**100% funded by 2048 (30 years from 2018)**	**411**	**8%**	
Light Green	100% funded by 2058 (40 years from 2018)	466	9%	
Yellow	100% funded by 2068 (50 years from 2018)	390	8%	29%
Orange	Solvent but longer than 50 years to reach 100% funded	1,066	21%	
Red	Insolvent after 2040 (after 20 years)	322	7%	8%
Dark Red	Insolvent by 2040 (within 20 years)	70	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

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**2,652**	**53%**	64%
Green	100% funded by 2048 (30 years from 2018)	238	5%	
Light Green	100% funded by 2058 (40 years from 2018)	288	6%	
Yellow	100% funded by 2068 (50 years from 2018)	224	4%	18%
Orange	Solvent but longer than 50 years to reach 100% funded	711	14%	
Red	Insolvent after 2040 (after 20 years)	744	15%	18%
Dark Red	Insolvent by 2040 (within 20 years)	143	3%	

* Adjusted, based on 5,000 simulations

Please see *Section 7* for the methodology used to determine the percentages in the tables above.

Signal Light Results for Judicial Division
Assumes Active Membership Grows by 1.00% per Year

Based on All Assumptions

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,033**	**61%**	76%
Green	100% funded by 2048 (30 years from 2018)	368	7%	
Light Green	100% funded by 2058 (40 years from 2018)	398	8%	
Yellow	100% funded by 2068 (50 years from 2018)	294	6%	20%
Orange	Solvent but longer than 50 years to reach 100% funded	678	14%	
Red	Insolvent after 2040 (after 20 years)	224	4%	4%
Dark Red	Insolvent by 2040 (within 20 years)	5	0%	

* Adjusted, based on 5,000 simulations

Signal Light Results for Denver Public Schools Division
Assumes Active Membership Grows by 1.25% per Year

Based on All Assumptions

Status	Definition	Number of Scenarios Meeting *	Probability of Meeting	
Dark Green	**100% Funded by 2041 (30 years from 2011)**	**3,387**	**68%**	87%
Green	100% funded by 2048 (30 years from 2018)	511	10%	
Light Green	100% funded by 2058 (40 years from 2018)	443	9%	
Yellow	100% funded by 2068 (50 years from 2018)	256	5%	12%
Orange	Solvent but longer than 50 years to reach 100% funded	370	7%	
Red	Insolvent after 2040 (after 20 years)	33	1%	1%
Dark Red	Insolvent by 2040 (within 20 years)	0	0%	

* Adjusted, based on 5,000 simulations

Please see *Section 7* for the methodology used to determine the percentages in the tables above.

Section 6: 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, 2019 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 with the first adjustment on July 1, 2020.

Notwithstanding the initiation of the AAP adjustments and subsequent law changes, Segal has kept the Signal Light status definitions basically the same 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 and should not elicit extreme concern without further analysis. 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, 2019	December 31, 2018
State	Green	Green
School	Green	Light Green
Local Government	Dark Green	Green
Judicial	Dark Green	Dark Green
DPS	Dark Green	Dark Green

As mentioned earlier, this process will need continuous monitoring of the assumptions and methods and 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 7: 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, 2019.

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 12 of this report, the one-year standard deviation for the State Division population growth is 1.39%. 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 0.14% and positive 2.64%. While one-year returns have a fairly high variance, extending the time horizon to a 50-year period, the standard deviation becomes less volatile and more condensed. The variance over a 50-year period for population growth is approximately 0.20%. Therefore, over a 50-year period, there is a 68% probability that average annual population growth will be between 1.05% and 1.45%.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.

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