REPORT

DIRTY WATER:

TOXIC "FOREVER" PFAS CHEMICALS ARE PREVALENT IN THE DRINKING WATER OF ENVIRONMENTAL JUSTICE COMMUNITIES: APPENDICES A - D

Appendix A: Methodology

The goal of this analysis was to examine potential exposure to per- and polyfluoroalkyl substances (PFAS) through drinking water for communities in California at the census-tract level. To do this, PFAS test results of drinking water sources included in the first phase of the California State Water Resources Control Board's PFAS investigation were analyzed.[1] At the time of the analysis, four consecutive rounds of testing, which contain data from April 1, 2019, to June 30, 2020, were available. Our analysis focused on "total PFAS," which we calculated by summing the 18 PFAS tested for, rather than individual PFAS chemicals, since all PFAS are of concern for public health. The highest total PFAS level recorded for one of the four quarters for each public water system was then mapped to the census tracts that the public water systems serve by incorporating water system boundary information available from the Division of Drinking Water.

An additional goal of this analysis was to better understand who is potentially affected by PFAS-contaminated drinking water in California and the equity implications of those exposures. To do this, the analysis examined the relationship between the PFAS results and California's CalEnviroScreen 3.0 (CES) scores, which measure environmental burden, at the census-tract level.[2] CES identifies communities that are disproportionately burdened by and vulnerable to multiple sources of pollution. The top 25 percent of most impacted communities are identified as "disadvantaged communities" for the purpose of allocating funds from the state's cap-and-trade climate program (SB535). By examining the overlap of CES scores and PFAS results at the census level, we identify census tracts that may be the most vulnerable to PFAS-contaminated drinking water.

CALENVIROSCREEN 3.0 DATA

The shapefile for CalEnviroScreen 3.0 by census tract and the spreadsheet for CalEnviroScreen 3.0 Drinking Water Contaminants by public water systems were downloaded on July 8, 2020.[3]

CES combines 12 pollution variables and eight population characteristics to compute a score to identify the most burdened communities, or census tracts, in California. The 12 pollution variables are ozone, PM 2.5, diesel particulate matter, drinking water contaminants, pesticide use, toxic release from facilities, traffic density, cleanup sites, groundwater threats, hazardous waste generators and facilities, impaired water bodies, and solid waste sites and facilities. The eight population characteristics are asthma emergency department visits, cardiovascular disease, low birth weight infants, educational attainment, housing-burdened low-income households, linguistic isolation, poverty, and unemployment.

CES Drinking Water Contaminants data combine 13 contaminants and two types of water-quality violations in drinking water. They are 1,2,3-TCP, arsenic, cadmium, dibromochloropropane, hexavalent chromium, lead, nitrate, perchlorate, combined radium 226 and radium 228, trihalomethanes, tetrachloroethylene, trichloroethylene, and uranium. CES Drinking Water Contaminants data were analyzed in addition to the overall CES score to see whether PFAS contamination occurred in communities that already suffered from drinking water pollution.

PFAS DATA

To calculate the PFAS levels for each public water system, the data for the first four quarters were downloaded on June 30, 2020. Before calculating the PFAS levels, all PFAS data for inactive sampling sites were removed, with the assumption that the water from these sites was not served to the public. If a sampling site had at least one inactive quarter, that sampling site was removed from this analysis. Then, three types of PFAS results were analyzed. The first is total PFAS, which is the sum of the 18 PFAS chemicals tested for at each sampling site. The 18 PFAS chemicals summed are PFBS, PFHpA, PFHxS, PFNA, PFOS, PFOA, NEtFOSAA, NMeFOSAA, PFDA, PFDoA, PFHxA, PFTA, PFTrDA, PFUnA, HFPO-DA, 9Cl-PF3ONS, 11CL-PF3OUdS, and ADONA. The second and third type are PFOS and PFOA, respectively. PFOS and PFOA results were parsed out from the eighteen PFAS chemicals tested because California has set notification and response levels for these two PFAS. The maximum level of the three types of PFAS results were identified from all quarters and all sampling sites from each public water system. The maximum level for the three types of PFAS results was used because, with the data provided, information on if and how PFAS from each sampling site were blended and distributed from each water system was not known. Therefore, we chose to show the metrics for the highest PFAS level detected for each public water system to show the highest potential PFAS level that the public water system may have distributed to communities in California.

PUBLIC WATER SYSTEMS BOUNDARIES TO CENSUS TRACT BOUNDARIES

Census tract was chosen as the unit of analysis because the CES scores are at the census-tract level. In order to convert the public water system data to the census-tract level, the California Drinking Water System Area Boundaries shapefile was downloaded on July 8, 2020.[4] The water system boundaries had two issues to resolve. First, some public water systems had multiple boundaries, and second, different public water systems had overlapping areas. In order to resolve systems with multiple boundaries, those boundaries were merged into a single system. In order to resolve the systems with overlapping areas, the area of the smaller public water system was removed from the area of the larger public water system.

For the public water systems with PFAS data that are missing in the water system boundaries shapefile, the city or county served was identified from EPA's Envirofacts Data Service API, and the boundaries for the primary city or county served were used instead, which was pulled from the CES census tract shapefile.[5] Once the remaining missing boundaries were reconciled, they were joined with the water system boundaries shapefile to create a single shapefile that contained all the public water system boundaries with PFAS data.

Before converting the public water system boundaries to census-tract boundaries, the PFAS data were joined to its respective public water system. To convert the public water system boundaries to census-tract boundaries, the public water system boundaries were split and merged at the census-tract level. If a census tract was served by multiple public water systems, then the public water system with the highest PFAS level was assigned to the census tract to show the highest potential PFAS exposure possible in the given census tract. All geographic analysis was performed on ArcGIS Desktop and R.

DATA GAPS AND LIMITATIONS

The California Drinking Water System Area Boundaries are incomplete, as some boundaries are still being reviewed and validated. The water system boundary information is not complete for all the public water systems with PFAS test results, therefore an approximate boundary had to be used for those that were not available. Moreover, although the geographic area that a public water system serves is known, current data do not include how the water from each source is blended, treated, and served. Therefore, there is no way of knowing how much PFAS is in the drinking water served to each consumer in a public water system. We therefore used the maximum total PFAS detection reported within a water system as an indicator of the maximum potential risk faced by people living in census tracts served by the water system.

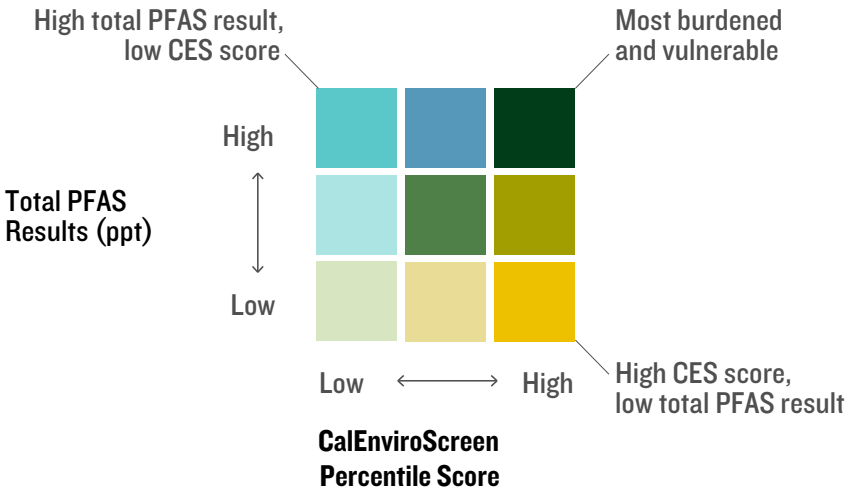
ANALYZING AND CLASSIFYING PFAS AND CES DATA

The PFAS data and CES data at census-tract level were combined into a single shapefile to analyze the relationship between PFAS potential exposure and CES scores. The percentile rank for the maximum PFAS levels was calculated to compare with the CES score percentiles.

To visualize the intersection between potentially high exposure to PFAS and a high CES score, a bivariate choropleth map was utilized. A bivariate choropleth map has nine classes as seen in Figure A-1. The x-axis is the CES percentile score divided into terciles, from low to high pollution burden: 0 to 32 percent, 33 to 66 percent, and 67 to 100 percent. The y-axis is the total maximum PFAS result divided into terciles, where each tercile contains an equal number of census tracts, from low to high PFAS results. The census tracts in the highest PFAS tercile rank and the CES percentile score in the highest

tercile rank are identified as the communities that are both the most disproportionately burdened and have potentially the highest exposure to PFAS, which is represented by the darkest color of the nine classes. This bivariate choropleth map method was repeated to visualize the intersection between potentially high exposure to PFAS and a high CES drinking water contaminants score (Appendix D).

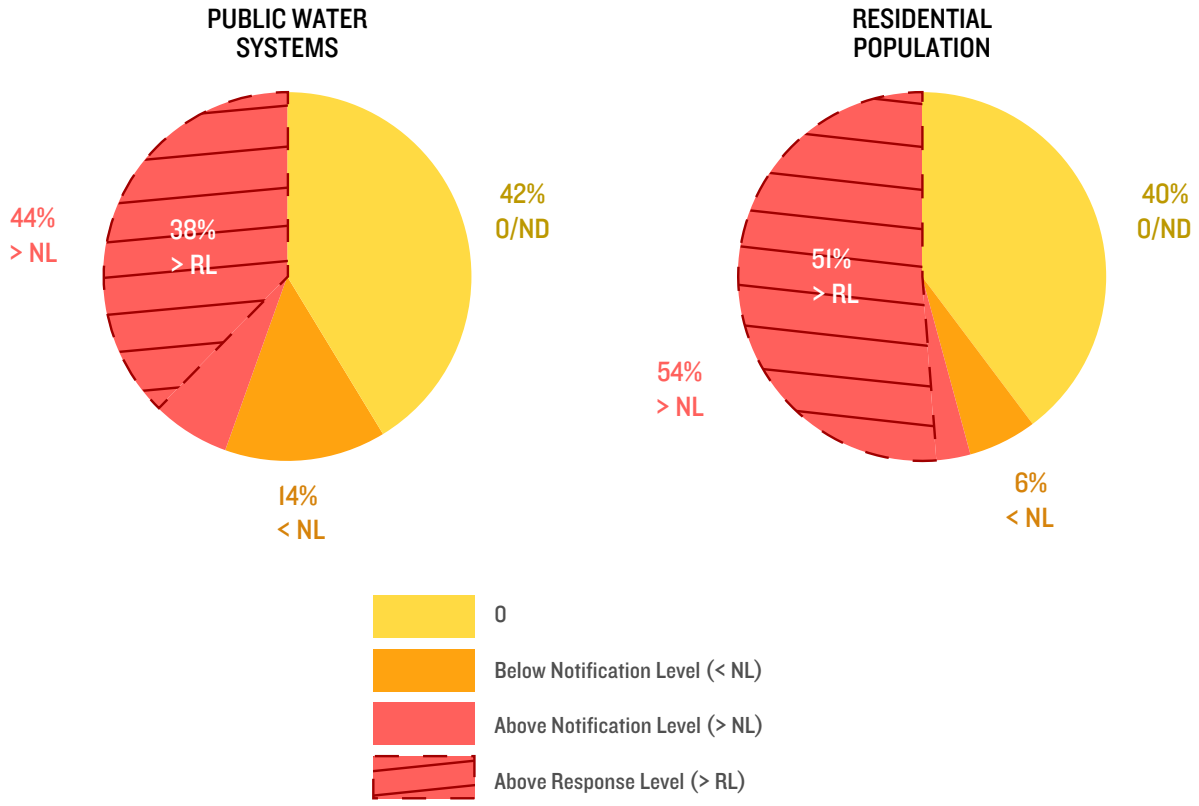
FIGURE A-1: BIVARIATE CHOROPLETH MAP LEGEND



Appendix B: PFOA- and PFOS-Specific Results

Out of the 18 PFAS chemicals tested, the Water Board has designated notification and response levels for three: PFOA, PFOS, and PFBS. A notification level triggers a requirement for a utility to inform its consumers about the presence of the chemical and about health concerns associated with exposure to it. A response level triggers a recommendation that the drinking water system take the source out of service or treat it. PFOS has a notification level of 6.5 parts per trillion (ppt) and response level of 40 ppt, PFOA has a notification level of 5.1 ppt and response level of 10 ppt, and PFBS has a notification level of 500 ppt and a response level of 5,000 ppt. The following graph and table show the proportion of public water systems and residential population that exceed notification and response levels. We have found that 38 percent of the public water systems tested for PFAS have exceeded the response level for PFOA or PFOS (Figure B-1). This 38 percent of public water systems serve almost 10 million people in California. No public water systems tested for PFAS have exceeded the response level for PFBS.

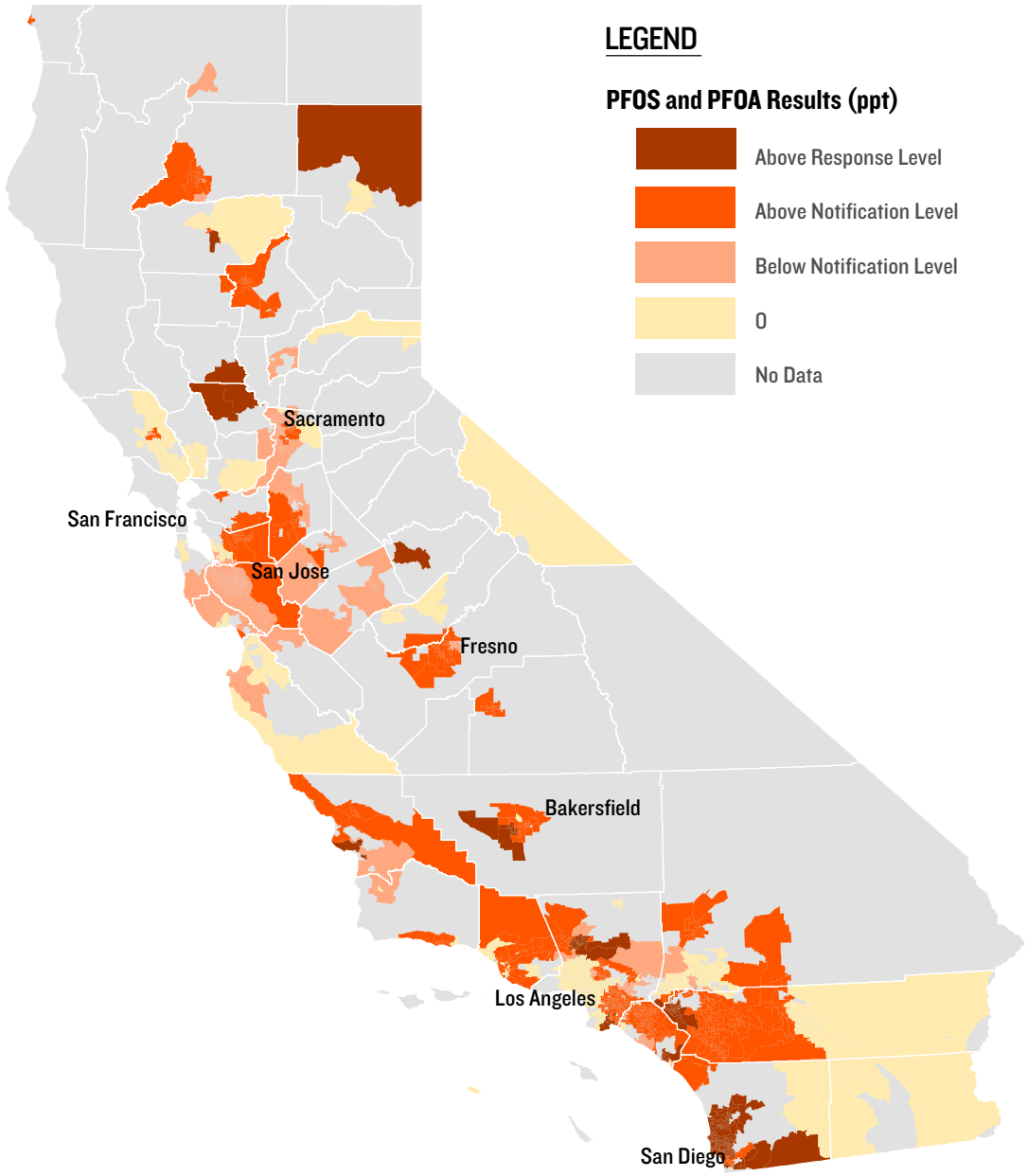
FIGURE B-1: PFOA AND PFOS RESULTS RELATIVE TO NOTIFICATION AND RESPONSE LEVELS IN PUBLIC WATER SYSTEMS



	# of Tested PWS	% of Tested PWS	Residential Population Served	% of Total Residential Population Served
PWS Tested for PFAS	248	--	19,363,240	--
PFOA/PFOS = 0	103	42%	7,694,639	40%
PFOA/PFOS < NL	35	14%	1,166,553	6%
├ PFOA/PFOS > NL	├ 110	├ 44%	├ 10,502,048	├ 54%
└ PFOA/PFOS > RL	└ 93	└ 38%	└ 9,922,259	└ 51%

Figure B-2 shows where notification and response levels have been exceeded for PFOA and/or PFOS. The PFOS and PFOA exceedances were identified at the water system level then allocated to each census tract by the water system's service area.

FIGURE B-2: POTENTIAL EXPOSURE TO PFOA AND PFOS IN CALIFORNIA DRINKING WATER BY CENSUS TRACT



Appendix C: Highest PFAS Pollution Burden in California

Our analysis suggests that PFAS pollution is more prevalent and intense in communities already overburdened by pollution and socioeconomic factors. The following map and analysis compare the demographics of overburdened communities with high PFAS levels to the state average. Disadvantaged communities that have high total PFAS were identified as census tracts that have both top 25 percent CES scores and top 25 percent maximum total PFAS. Demographic analysis of these communities shows that in addition to environmental pollution and high PFAS levels in drinking water, these communities, on average, have a more diverse population, lower education level, higher rates of unemployment, and higher housing burden than California's state average (Figure C-1).

FIGURE C-1: DEMOGRAPHICS OF COMMUNITIES WITH A CALENVIROSCREEN 3.0 SCORE AND MAXIMUM TOTAL PFAS RESULT IN THE TOP 25 PERCENT IN CALIFORNIA

The following table (Figure C-2) lists all the counties in California with the highest total PFAS result found and the average CES percentile score. Counties with values that are in the top 25 percent of CES scores and top 25 percent maximum total PFAS (over 64 ppt) are highlighted in the table. Fresno, San Joaquin, and Tulare Counties have some of the highest total PFAS results as well as high CES scores. It is important to note that a county having zero for their maximum total PFAS result does not necessarily mean that its residents are safe from PFAS pollution, since the county may also include public water systems that have not tested for PFAS.

FIGURE C-2: HIGHEST TOTAL PFAS RESULT AND AVERAGE CALENVIROSCREEN 3.0 PERCENTILE SCORE BY COUNTY

COUNTY	MAXIMUM TOTAL PFAS RESULT	AVERAGE CES PERCENTILE SCORE
Alameda	374.5	41.9%
Alpine	0	16.0%
Amador	0	43.3%
Butte	524.7	40.9%
Calaveras	0	23.8%
Colusa	91.95	54.2%
Contra Costa	810.35	35.2%
Del Norte	62.2	25.3%
El Dorado	0	14.5%
Fresno	1380.1	72.5%
Glenn	191.5	45.7%
Humboldt	0	27.5%
Imperial	5.2	71.8%
Inyo	0	32.7%
Kern	65.5	62.5%
Kings	0	66.4%
Lake	0	34.5%
Lassen	172	24.1%
Los Angeles	276.5	63.8%
Madera	1380.1	64.0%
Marin	0	11.7%
Mariposa	497.3	21.2%
Mendocino	0	32.1%
Merced	18	81.1%
Modoc	0	28.8%
Mono	0	20.0%
Monterey	30.4	36.0%
Napa	0	28.6%
Nevada	0	23.7%

COUNTY	MAXIMUM TOTAL PFAS RESULT	AVERAGE CES PERCENTILE SCORE
Orange	225.7	41.0%
Placer	53.3	15.8%
Plumas	0	24.4%
Riverside	1276.1	53.0%
Sacramento	306.2	47.3%
San Benito	18	56.1%
San Bernardino	1276.1	64.8%
San Diego	698.9	33.0%
San Francisco	0	30.1%
San Joaquin	340.3	73.1%
San Luis Obispo	1152.2	17.7%
San Mateo	18	27.5%
Santa Barbara	24.333333	25.7%
Santa Clara	340.3	32.8%
Santa Cruz	52.6	23.1%
Shasta	93.5	25.5%
Sierra	0	38.0%
Siskiyou	4.85	28.2%
Solano	0	42.4%
Sonoma	20.7	27.8%
Stanislaus	28.6	80.5%
Sutter	0	52.6%
Tehama	483.6	53.5%
Trinity	0	12.0%
Tulare	409.6	71.6%
Tuolumne	0	36.1%
Ventura	6.9	35.7%
Yolo	91.95	36.2%
Yuba	5.3	57.3%

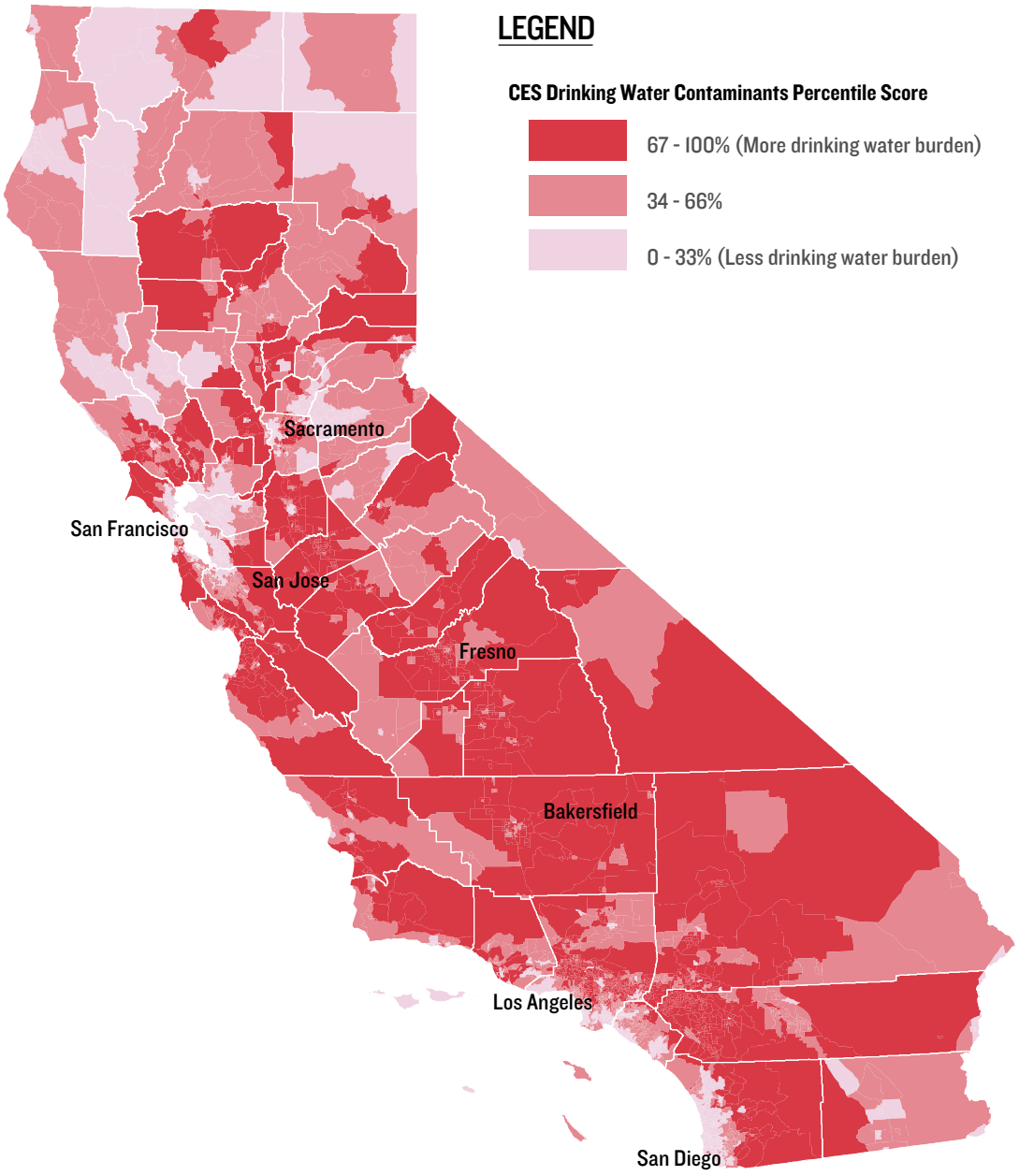
Appendix D: Drinking Water Specific Results

CALENVIROSCREEN 3.0 DRINKING WATER SPECIFIC SCORE

Communities Disproportionately Burdened by, and Vulnerable to, Drinking Water Contaminants

The CES drinking water contaminant score is an index for a select number of contaminants found in drinking water. Average concentrations of contaminants and average violations are ranked by census tract and assigned percentiles. The following map (Figure D-1) shows the CES drinking water contaminant percentile scores by census tract, divided into terciles from low to high drinking water pollution burden: 0 to 33 percent, 34 to 66 percent, and 67 to 100 percent.

FIGURE D-1: CALENVIROSCREEN 3.0 DRINKING WATER SPECIFIC SCORE

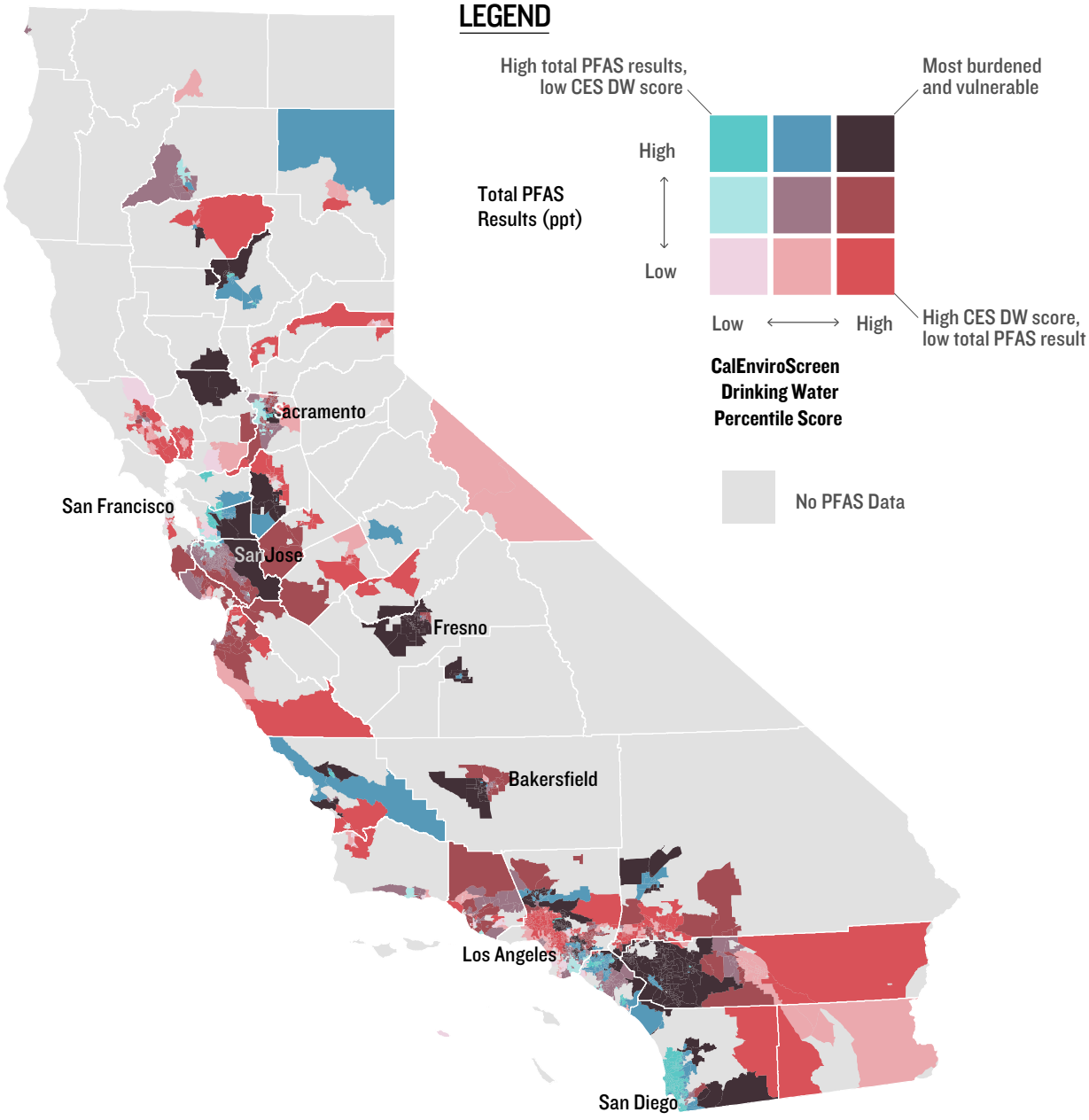


POTENTIAL EXPOSURE TO PFAS AND CALENVIROSCREEN 3.0 DRINKING WATER SPECIFIC SCORE

Communities With Highest Drinking Water Pollution and Highest Potential PFAS Exposure From Drinking Water

The following bivariate map combines the summed PFAS results and CES drinking water contaminant percentile scores to identify census tracts with the greatest drinking water pollution burden and potential PFAS drinking water exposure. The summed PFAS results are divided into terciles, where each tercile contains an equal number of census tracts. The CES drinking water contaminant percentile score is divided into terciles from low to high pollution burden: 0 to 33 percent, 34 to 66 percent, and 67 to 100 percent. The census tracts that have summed PFAS results higher than 57.2 ppt and CES drinking water contaminant scores higher than 66 percent are identified as the communities that are facing the greatest exposure to drinking water pollutants (Figure D-2).

FIGURE D-2: POTENTIAL EXPOSURE TO TOTAL PFAS AND CALENVIROSCREEN 3.0 DRINKING WATER SPECIFIC SCORE



ENDNOTES

1 State Water Resources Control Board, "Public Water System Testing Results," accessed June 30, 2020, https://www.waterboards.ca.gov/pfas/drinking_water.html.

2 California Office of Environmental Health Hazard Assessment (OEHHA), "CalEnviroScreen 3.0," June 25, 2018, https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30.

3 OEHHA, "Drinking Water Contaminants," accessed July 15, 2020, https://oehha.ca.gov/calenviroscreen/indicator/drinking-water-contaminants.

4 California Water Boards, "California Drinking Water System Area Boundaries," California State Geoportal, accessed July 8, 2020, https://gis.data.ca.gov/datasets/fbba842bf134497c9d611ad506ec48cc_0.

5 U.S. Environmental Protection Agency, "Envirofacts Data Service API," accessed July 20, 2020, https://www.epa.gov/enviro/envirofacts-data-service-api.