CLIMATOLOGY

Unprecedented 21st century drought risk in the American Southwest and Central Plains

2015 © The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. Distributed under a Creative Commons Attribution Non-Commercial License 4.0 (CC BY-NC).
10.1126/sciadv.1400082

Benjamin I. Cook,[1,2]* Toby R. Ault,[3] Jason E. Smerdon[2]

In the Southwest and Central Plains of Western North America, climate change is expected to increase drought severity in the coming decades. These regions nevertheless experienced extended Medieval-era droughts that were more persistent than any historical event, providing crucial targets in the paleoclimate record for benchmarking the severity of future drought risks. We use an empirical drought reconstruction and three soil moisture metrics from 17 state-of-the-art general circulation models to show that these models project significantly drier conditions in the later half of the 21st century compared to the 20th century and earlier paleoclimatic intervals. This desiccation is consistent across most of the models and moisture balance variables, indicating a coherent and robust drying response to warming despite the diversity of models and metrics analyzed. Notably, future drought risk will likely exceed even the driest centuries of the Medieval Climate Anomaly (1100–1300 CE) in both moderate (RCP 4.5) and high (RCP 8.5) future emissions scenarios, leading to unprecedented drought conditions during the last millennium.

INTRODUCTION

Millennial-length hydroclimate reconstructions over Western North America (*1*–*4*) feature notable periods of extensive and persistent Medieval-era droughts. Such "megadrought" events exceeded the duration of any drought observed during the historical record and had profound impacts on regional societies and ecosystems (*2*, *5*, *6*). These past droughts illustrate the relatively narrow view of hydroclimate variability captured by the observational record, even as recent extreme events (*7*–*9*) highlighted concerns that global warming may be contributing to contemporary droughts (*10*, *11*) and will amplify drought severity in the future (*11*–*15*). A comprehensive understanding of global warming and 21st century drought therefore requires placing projected hydroclimate trends within the context of drought variability over much longer time scales (*16*, *17*). This would also allow us to establish the potential risk (that is, likelihood of occurrence) of future conditions matching or exceeding the severest droughts of the last millennium.

Quantitatively comparing 21st century drought projections from general circulation models (GCMs) to the paleo-record is nevertheless a significant technical challenge. Most GCMs provide soil moisture diagnostics, but their land surface models often vary widely in terms of parameterizations and complexity (for example, soil layering and vegetation). There are few large-scale soil moisture measurements that can be easily compared to modeled soil moisture, and none for intervals longer than the satellite record. Instead, drought is typically monitored in the real world using offline models or indices that can be estimated from more widely measured data, such as temperature and precipitation.

One common metric is the Palmer Drought Severity Index (PDSI) (*18*), widely used for drought monitoring and as a target variable for proxy-based reconstructions (*1*, *2*). PDSI is a locally normalized index of soil moisture availability, calculated from the balance of moisture supply (precipitation) and demand (evapotranspiration). Because PDSI is normalized on the basis of local average moisture conditions, it can be used to compare variability and trends in drought across regions. Average moisture conditions (relative to a defined baseline) are denoted by PDSI = 0; negative PDSI values indicate drier than average conditions (droughts), and positive PDSI values indicate wetter than normal conditions (pluvials). PDSI is easily calculated from GCMs using variables from the atmosphere portion of the model (for example, precipitation, temperature, and humidity) and can be compared directly to observations. However, whereas recent work has demonstrated that PDSI is able to accurately reflect the surface moisture balance in GCMs (*19*), other studies have highlighted concerns that PDSI may overestimate 21st century drying because of its relatively simple soil moisture accounting and lack of direct CO2 effects that are expected to reduce evaporative losses (*12*, *20*, *21*). We circumvent these concerns by using a more physically based version of PDSI (*13*) (based on the Penman-Monteith potential evapotranspiration formulation) in conjunction with soil moisture from the GCMs to demonstrate robust drought responses to climate change in the Central Plains (105°W–92°W, 32°N–46°N) and the Southwest (125°W–105°W, 32°N–41°N) regions of Western North America.

RESULTS

We calculate summer season [June-July-August (JJA)] PDSI and integrated soil moisture from the surface to ~30-cm (SM-30cm) and ~2- to 3-m (SM-2m) depths from 17 GCMs (tables S1 and S2) in phase 5 of the Coupled Model Intercomparison Project (CMIP5) database (*22*). We focus our analyses and presentation on the RCP 8.5 "business-as-usual" high emissions scenario, designed to yield an approximate top-of-atmosphere radiative imbalance of +8.5 W m^{-2} by 2100. We also conduct the same analyses for a more moderate emissions scenario (RCP 4.5).

Over the calibration interval (1931–1990), the PDSI distributions from the models are statistically indistinguishable from the North American Drought Atlas (NADA) (two-sided Kolmogorov-Smirnov test, $p \geq 0.05$), although there are some significant deviations in some models during other historical intervals. North American drought variability during the historical period in both models and observations is driven primarily by ocean-atmosphere teleconnections,

[1]NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA. [2]Ocean and Climate Physics, Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, Palisades, NY 10964, USA. [3]Earth and Atmospheric Sciences, Cornell University, Ithaca, NY 14853, USA.
*Corresponding author. E-mail: benjamin.i.cook@nasa.gov

internal variability in the climate system that is likely to not be either consistent across models or congruent in time between the observations and models, and so such disagreements are unsurprising. In the multimodel mean, all three moisture balance metrics show markedly consistent drying during the later half of the 21st century (2050–2099) (Fig. 1; see figs. S1 to S4 for individual models). Drying in the Southwest is more severe (RCP 8.5: PDSI = −2.31, SM-30cm = −2.08, SM-2m = −2.98) than that over the Central Plains (RCP 8.5: PDSI = −1.89, SM-30cm = −1.20, SM-2m = −1.17). In both regions, the consistent cross-model drying trends are driven primarily by the forced response to increased greenhouse gas concentrations (*13*), rather than by any fundamental shift in ocean-atmosphere dynamics [indeed, there is a wide disparity across models regarding the strength and fidelity of the simulated teleconnections over North America (*23*)]. In the Southwest, this forcing manifests as both a reduction in cold season precipitation (*24*) and an increase in potential evapotranspiration (that is, evaporative demand increases in a warmer atmosphere) (*13*, *25*) acting in concert to reduce soil moisture. Even though cold season precipitation is actually expected to increase over parts of California in our Southwest region (*24*, *26*), the increase in evaporative demand is still sufficient to drive a net reduction in soil moisture. Over the Central Plains, precipitation responses during the spring and summer seasons (the main

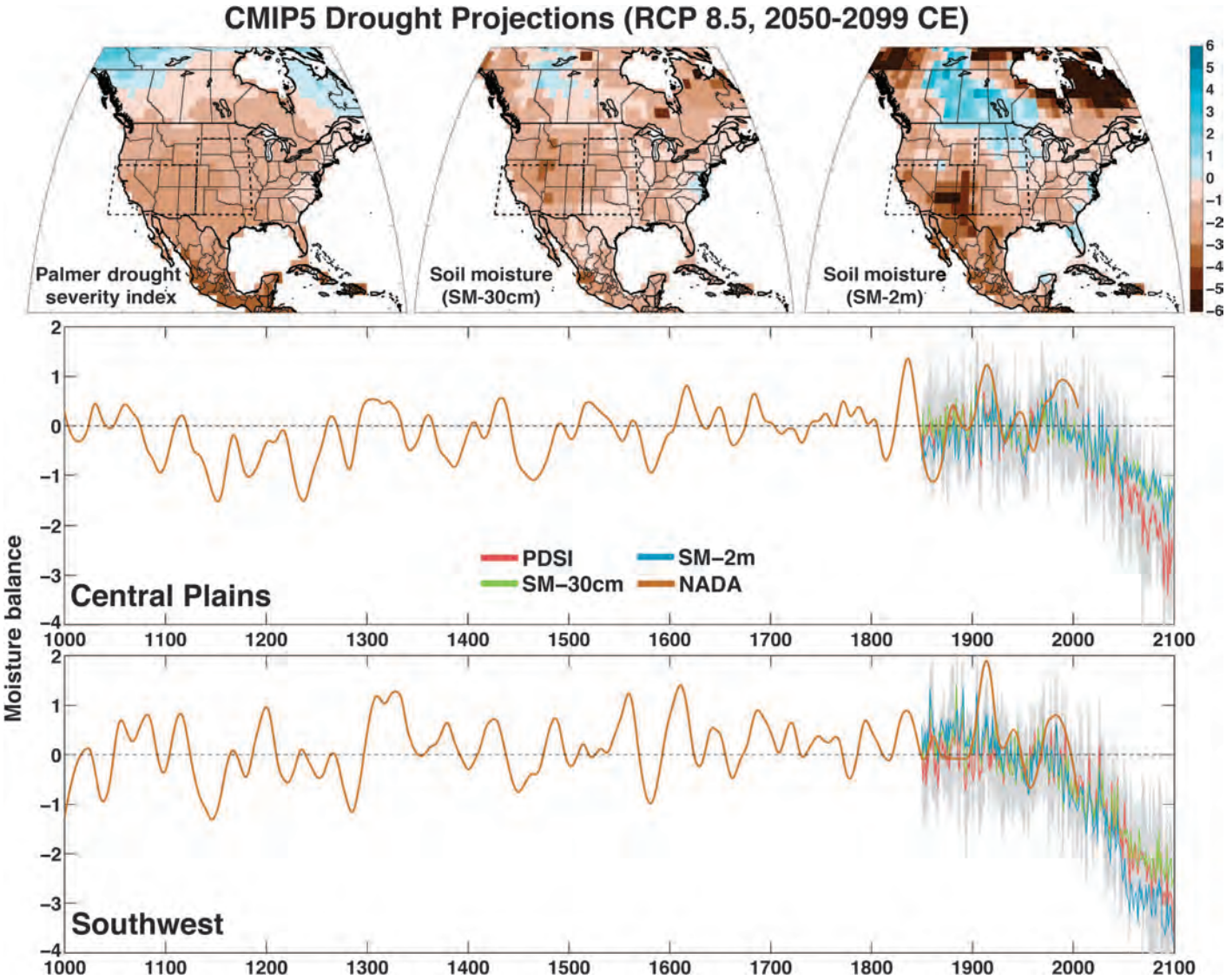


Fig. 1. Top: Multimodel mean summer (JJA) PDSI and standardized soil moisture (SM-30cm and SM-2m) over North America for 2050–2099 from 17 CMIP5 model projections using the RCP 8.5 emissions scenario. SM-30cm and SM-2m are standardized to the same mean and variance as the model PDSI over the calibration interval from the associated historical scenario (1931–1990). Dashed boxes represent the regions of interest: the Central Plains (105°W–92°W, 32°N–46°N) and the Southwest (125°W–105°W, 32°N–41°N). Bottom: Regional average time series of the summer season moisture balance metrics from the NADA and CMIP5 models. The observational NADA PDSI series (brown) is smoothed using a 50-year loess spline to emphasize the low-frequency variability in the paleo-record. Model time series (PDSI, SM-30cm, and SM-2m) are the multimodel means averaged across the 17 CMIP5 models, and the gray shaded area is the multimodel interquartile range for model PDSI.

seasons of moisture supply) are less consistent across models, and the drying is driven primarily by the increased evaporative demand. Indeed, this increase in potential evapotranspiration is one of the dominant drivers of global drought trends in the late 21st century, and previous work with the CMIP5 archive demonstrated that the increased evaporative demand is likely to be sufficient to overcome precipitation increases in many regions (*13*). In the more moderate emissions scenario (RCP 4.5), both the Southwest (RCP 4.5: PDSI = −1.49, SM-30cm = −1.63, SM-2m = −2.39) and Central Plains (RCP 4.5: PDSI = −1.21, SM-30cm = −0.89, SM-2m = −1.17) still experience significant, although more modest, drying into the future, as expected (fig. S5).

In both regions, the model-derived PDSI closely tracks the two soil moisture metrics (figs. S6 and S7), correlating significantly for most models and model intervals (figs. S8 and S9). Over the historical simulation, average model correlations (Pearson's r) between PDSI and SM-30cm are +0.86 and +0.85 for the Central Plains and Southwest, respectively. Correlations weaken very slightly for PDSI and SM-2m: +0.84 (Central Plains) and +0.83 (Southwest). The correlations remain strong into the 21st century, even as PDSI and the soil moisture variables occasionally diverge in terms of long-term trends. There is no evidence, however, for systematic differences between the PDSI and modeled soil moisture across the model ensemble. For example, whereas the PDSI trends are drier than the soil moisture condition over the Southwest in the ACCESS1-0 model, PDSI is actually less dry than the soil moisture in the MIROC-ESM and NorESM1-M simulations over the same region (fig. S7). These outlier observations, showing no consistent bias, in conjunction with the fact that the overall comparison between PDSI and modeled soil moisture is markedly consistent, provide mutually consistent support for the characterization of surface moisture balance by these metrics in the model projections.

For estimates of observed drought variability over the last millennium (1000–2005), we use data from the NADA, a tree-ring based reconstruction of JJA PDSI. Comparisons between the NADA and model moisture are shown in the bottom panels of Fig. 1. In the NADA, both the Central Plains (Fig. 2) and Southwest (Fig. 3) are drier during the Medieval megadrought interval (1100–1300 CE) than either the Little

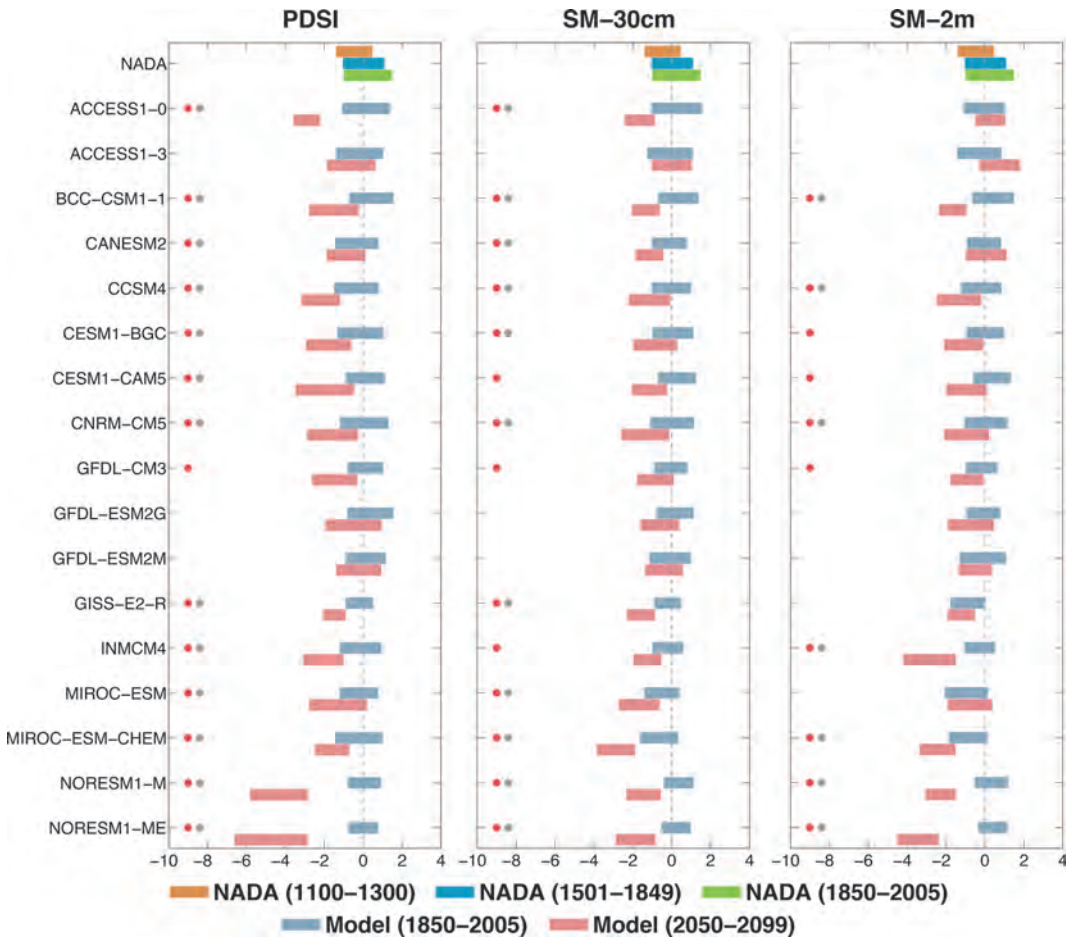


Fig. 2. Interquartile range of PDSI and soil moisture from the NADA and CMIP5 GCMs, calculated over various time intervals for the Central Plains. The groups of three stacked bars at the top of each column are from the NADA PDSI: 1100–1300 (the time of the Medieval-era megadroughts, brown), 1501–1849 (the Little Ice Age, blue), and 1850–2005 (the historical period, green). Purple and red bars are for the modeled historical period (1850–2005) and late 21st century (2050–2099) period, respectively. Red dots indicate model 21st century drought projections that are significantly drier than the model simulated historical periods. Gray dots indicate model 21st century drought projections that are significantly drier than the Medieval-era megadrought period in the NADA.

Ice Age (1501–1849) or historical periods (1850–2005). For nearly all models, the 21st century projections under the RCP 8.5 scenario reveal dramatic shifts toward drier conditions. Most models (indicated with a red dot) are significantly drier (one-sided Kolmogorov-Smirnov test, $p \leq 0.05$) in the latter part of the 21st century (2050–2099) than during their modeled historical intervals (1850–2005). Strikingly, shifts in projected drying are similarly significant in most models when measured against the driest and most extreme megadrought period of the NADA from 1100 to 1300 CE (gray dots). Results are similar for the more moderate RCP 4.5 emissions scenario (figs. S10 and S11), which still indicates widespread drying, albeit at a reduced magnitude for many models. Although there is some spread across the models and metrics, only two models project wetter conditions in RCP 8.5. In the Central Plains, SM-2m is wetter in ACCESS1-3, with little change in SM-30cm and slightly wetter conditions in PDSI. In the Southwest, CanESM2 projects markedly wetter SM-2m conditions; PDSI in the same model is slightly wetter, whereas SM-30cm is significantly drier.

When the RCP 8.5 multimodel ensemble is pooled together (Fig. 4), projected changes in the Central Plains and Southwest (2050–2099 CE) for all three moisture balance metrics are significantly drier compared to both the modern model interval (1850–2005 CE) and 1100–1300 CE in the NADA (one-sided Kolmogorov-Smirnov test, $p \leq 0.05$). In the case of SM-2m in the Southwest, the density function is somewhat flattened, with an elongated right (wet) tail. This distortion arises from the disproportionate contribution to the density function from the wetting in the five CanESM2 ensemble members. Even with this contribution, however, the SM-2m drying in the multimodel ensemble is still significant. Results are nearly identical for the pooled RCP 4.5 multimodel ensemble (fig. S12), which still indicates a significantly drier late 21st century compared to either the historical interval or Medieval megadrought period.

With this shift in the full hydroclimate distribution, the risk of decadal or multidecadal drought occurrences increases substantially. We calculated the risk (*17*) of decadal or multidecadal drought occurrences for two periods in our multimodel ensemble: 1950–2000 and 2050–2099 (Fig. 5). During the historical period, the risk of a multidecadal megadrought is quite small: <12% for both regions and all moisture metrics. Under RCP 8.5, however, there is ≥80% chance of a multidecadal drought during 2050–2099 for PDSI and SM-30cm in the Central Plains and for all three moisture metrics in the Southwest. Drought risk is reduced slightly in RCP 4.5 (fig. S13), with largest reductions in multidecadal drought risk over the Central Plains. Ultimately, the consistency of our results suggests an exceptionally high risk of a multidecadal megadrought occurring over the Central Plains and Southwest regions during the late 21st century, a level of aridity exceeding even the persistent megadroughts that characterized the Medieval era.

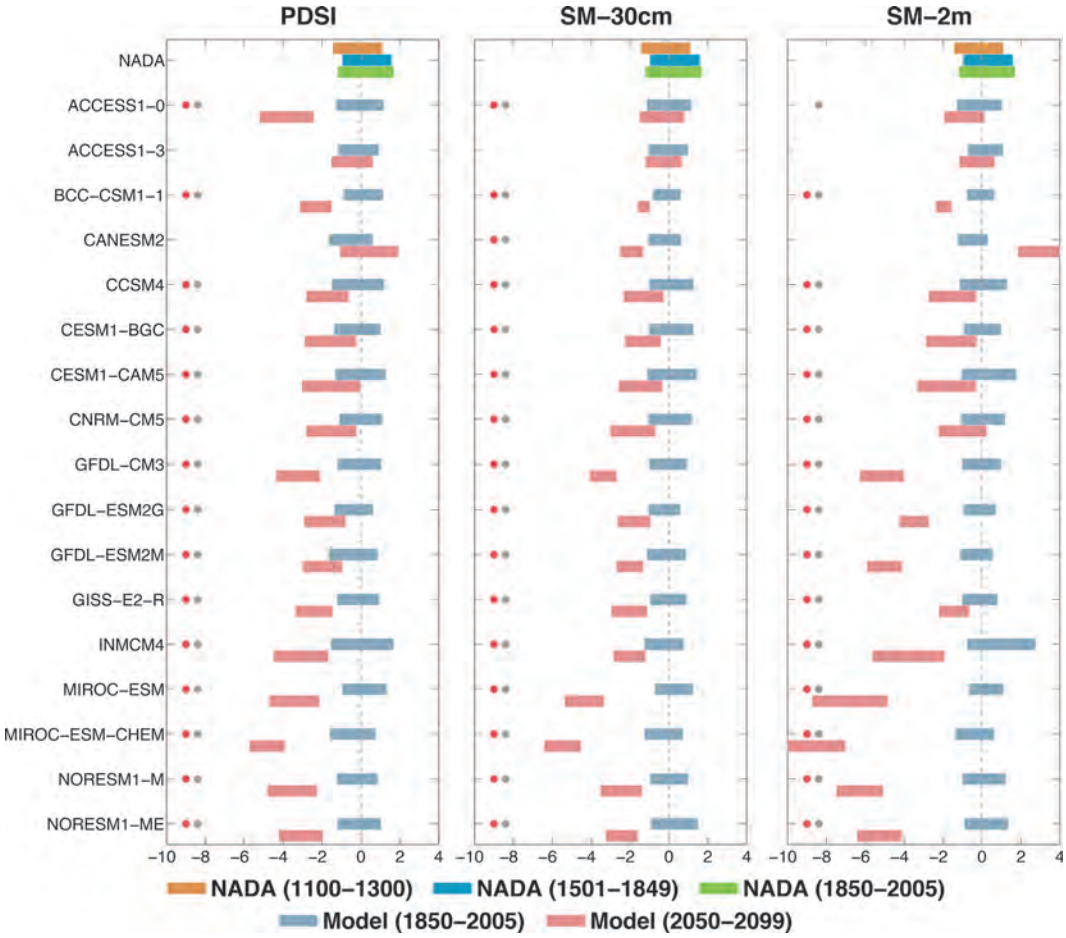


Fig. 3. Same as Fig. 2, but for the Southwest.

DISCUSSION

Within the body of literature investigating North American hydroclimate, analyses of drought variability in the historical and paleoclimate records are often separate from discussions of global warming–induced changes in future hydroclimate. This disconnection has traditionally made it difficult to place future drought projections within the context of observed and reconstructed natural hydroclimate variability. Here,

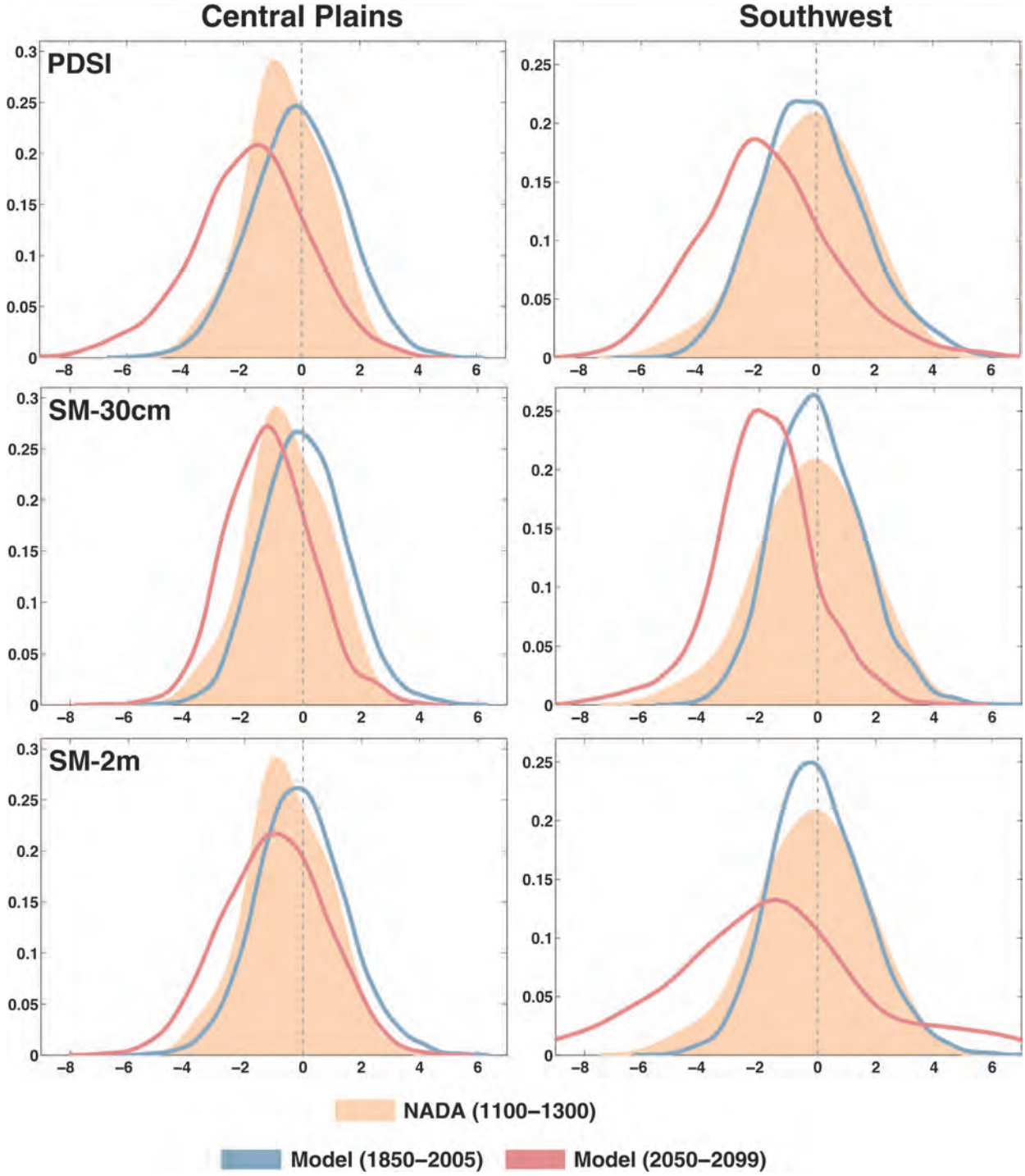


Fig. 4. Kernel density functions of PDSI, SM-30cm, and SM-2m for the Central Plains and Southwest, calculated from the NADA and the GCMs. The NADA distribution (brown shading) is from 1100–1300 CE, the timing of the medieval megadroughts. Blue lines represent model distributions calculated from all years from all models pooled over the historical scenario (1850–2005 CE). Red lines are for all model years pooled from the RCP 8.5 scenario (2050–2099 CE).

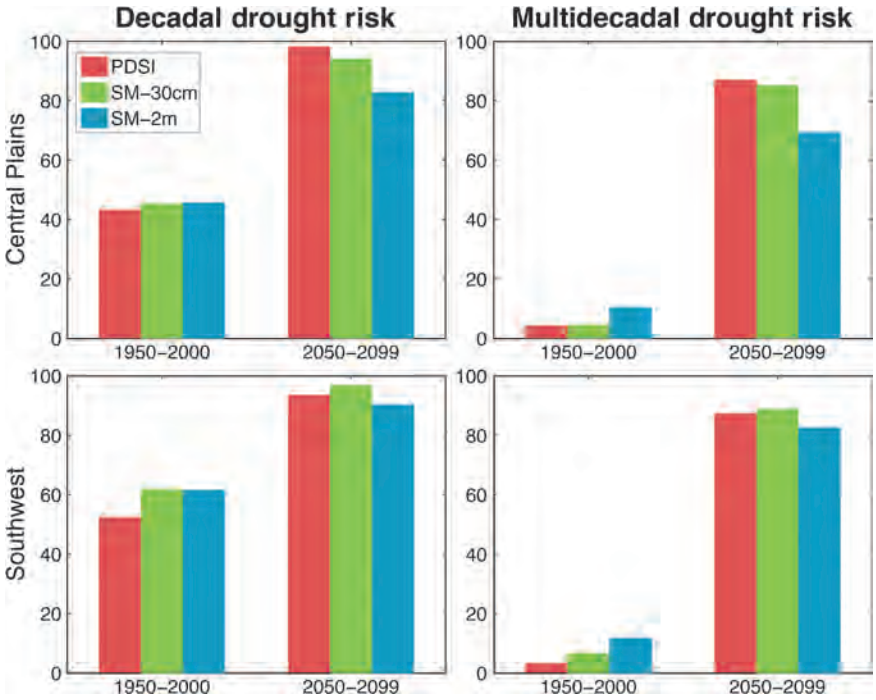


Fig. 5. Risk (percent chance of occurrence) of decadal (11-year) and multidecadal (35-year) drought, calculated from the multimodel ensemble for PDSI, SM-30cm, and SM-2m. Risk calculations are conducted for two separate model intervals: 1950–2000 (historical scenario) and 2050–2099 (RCP 8.5). Results for the Central Plains are in the top row, and those for the Southwest are in the bottom row.

we have demonstrated that the mean state of drought in the late 21st century over the Central Plains and Southwest will likely exceed even the most severe megadrought periods of the Medieval era in both high and moderate future emissions scenarios, representing an unprecedented fundamental climate shift with respect to the last millennium. Notably, the drying in our assessment is robust across models and moisture balance metrics. Our analysis thus contrasts sharply with the recent emphasis on uncertainty about drought projections for these regions (*21*, *27*), including the most recent Intergovernmental Panel on Climate Change assessment report (*28*).

Our results point to a remarkably drier future that falls far outside the contemporary experience of natural and human systems in Western North America, conditions that may present a substantial challenge to adaptation. Human populations in this region, and their associated water resources demands, have been increasing rapidly in recent decades, and these trends are expected to continue for years to come (*29*). Future droughts will occur in a significantly warmer world with higher temperatures than recent historical events, conditions that are likely to be a major added stress on both natural ecosystems (*30*) and agriculture (*31*). And, perhaps most importantly for adaptation, recent years have witnessed the widespread depletion of nonrenewable groundwater reservoirs (*32*, *33*), resources that have allowed people to mitigate the impacts of naturally occurring droughts. In some cases, these losses have even exceeded the capacity of Lake Mead and Lake Powell, the two major surface reservoirs in the region (*34*, *35*). Combined with the likelihood of a much drier future and increased demand, the loss of groundwater and higher temperatures will likely exacerbate the impacts of future droughts, presenting a major adaptation challenge for managing ecological and anthropogenic water needs in the region.

MATERIALS AND METHODS

Estimates of drought variability over the historical period and the last millennium used the latest version of the NADA (*1*), a tree ring–based reconstruction of summer season (JJA) PDSI. All statistics were based on regional PDSI averages over the Central Plains (105°W–92°W, 32°N–46°N) and the Southwest (125°W–105°W, 32°N–41°N). We restricted our analysis to 1000–2005 CE; before 1000 CE, the quality of the reconstruction in these regions declines.

The 21st century drought projections used output from GCM simulations in the CMIP5 database (*22*) (table S1). All models represent one or more continuous ensemble members from the historical (1850–2005 CE) and RCP 4.5 (15 models available) and 8.5 (17 models available) emissions scenarios (2006–2099 CE). We used the same methodology as in (*13*) to calculate model PDSI for the full interval (1850–2099 CE), using the Penman-Monteith formulation of potential evapotranspiration. The baseline period for calibrating and standardizing the model PDSI anomalies was 1931–1990 CE, the same baseline period as the NADA PDSI. Negative model PDSI values therefore indicate drier conditions than the average for 1931–1990.

To augment the model PDSI calculations and comparisons with observed drought variability in the NADA, we also calculated standardized soil moisture metrics from the GCMs for two depths: ~30 cm (SM-30cm) and ~2 to 3 m (SM-2m) (table S2). For these soil moisture metrics, the total soil moisture from the surface was integrated to these depths and averaged over JJA. At each grid cell, we then standardized SM-30cm and SM-2m to match the same mean and interannual SD for the model PDSI over 1931–1990. This allows for direct comparison of variability and trends between model PDSI and model soil moisture and between the model metrics (PDSI, SM-30cm, and SM-2m) and the NADA (PDSI) while still independently preserving any low-frequency variability or trends in the soil moisture that may be distinct from the PDSI calculation. The soil moisture standardization does not impose any artificial constraints that would force the three metrics to agree in terms of variability or future trends, allowing SM-30cm and SM-2m to be used as indicators of drought largely independent of PDSI.

Risk of decadal and multidecadal megadrought occurrence in the multimodel ensemble is estimated from 1000 Monte Carlo realizations of each moisture balance metric (PDSI, SM-30cm, and SM-2m), as in (*17*). This method entails estimating the mean and SD of a given drought index (for example, PDSI or soil moisture) over a reference period (1901–2000), then subtracting that mean and SD from the full record (1850–2100) to produce a modified z score. The differences between the reference mean and SD are then used to conduct (white noise) Monte Carlo simulations of the future (2050–2100) to emulate the statistics of that era. The fraction of Monte Carlo realizations exhibiting a decadal or multidecadal drought are then calculated from each Monte Carlo simulation of each experiment in both regions considered here. Finally, these risks from each model are averaged together to yield the overall risk estimates reported here. Additional details on the methodology can be found in (*17*).

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org

Fig. S1. For the individual models, ensemble mean soil moisture balance (PDSI, SM-30cm, and SM-2m) for 2050–2099: ACCESS1.0, ACCESS1.3, BCC-CSM1.1, and CanESM2.

Fig. S2. Same as fig. S1, but for CCSM4, CESM1-BGC, CESM-CAM5, and CNRM-CM5.

Fig. S3. Same as fig. S1, but for GFDL-CM3, GFDL-ESM2G, GFDL-ESM2M, and GISS-E2-R.

Fig. S4. Same as fig. S1, but for INMCM4.0,MIROC-ESM, MIROC-ESM-CHEM, NorESM1-M, and NorESM1-ME models.

Fig. S5. Same as Fig. 1, but for the RCP 4.5 scenario.

Fig. S6. Regional average moisture balance time series (historical + RCP 8.5) from the first ensemble member of each model over the Central Plains.

Fig. S7. Same as fig. S6, but for the Southwest.

Fig. S8. Pearson's correlation coefficients for three time intervals from the models over the Central Plains: PDSI versus SM-30cm, PDSI versus SM-2m, and SM-30cm versus SM-2m.

Fig. S9. Same as fig. S8, but for the Southwest.

Fig. S10. Same as Fig. 2, but for the RCP 4.5 scenario.

Fig. S11. Same as Fig. 3, but for the RCP 4.5 scenario.

Fig. S12. Same as Fig.4, but for the RCP 4.5 scenario.

Fig. S13. Same as Fig. 5, but for the RCP 4.5 scenario.

Table S1. Continuous model ensembles from the CMIP5 experiments (1850–2099, historical + RCP8.5 scenario) used in this analysis, including the modeling center or group that supplied the output, the number of ensemble members, and the approximate spatial resolution.

Table S2. The number of soil layers integrated for our CMIP5 soil moisture metrics (SM-30cm and SM-2m), and the approximate depth of the bottom soil layer.

REFERENCES AND NOTES

1. E. R. Cook, R. Seager, M. A. Cane, D. W. Stahle, North American drought: Reconstructions, causes, and consequences. *Earth Sci. Rev.* **81**, 93–134 (2007).
2. E. R. Cook, R. Seager, R. R. Heim Jr., R. S. Vose, C. Herweijer, C. Woodhouse, Megadroughts in North America: Placing IPCC projections of hydroclimatic change in a long-term palaeoclimate context. *J. Quat. Sci.* **25**, 48–61 (2010).
3. D. M. Meko, C. A. Woodhouse, C. A. Baisan, T. Knight, J. J. Lukas, M. K. Hughes, M. W. Salzer, Medieval drought in the upper Colorado River Basin. *Geophys. Res. Lett.* **34**, 10705 (2007).
4. C. A. Woxodhouse, D. M. Meko, G. M. MacDonald, D. W. Stahle, E. R. Cook, A 1,200-year perspective of 21st century drought in Southwester North America. *Proc. Natl. Acad. Sci. U.S.A.* **107**, 21283–21288 (2010).
5. S. Stine, Extreme and persistent drought in California and Patagonia during mediaeval time. *Nature* **369**, 546–549 (1994).
6. C. A. Woodhouse, J. T. Overpeck, 2000 years of drought variability in the Central United States. *Bull. Am. Meteorol. Soc.* **79**, 2693–2714 (1998).
7. M. Hoerling, J. Eischeid, A. Kumar, R. Leung, A. Mariotti, K. Mo, S. Schubert, R. Seager, Causes and predictability of the 2012 Great Plains drought. *Bull. Am. Meteorol. Soc.* **95**, 269–282 (2014).
8. R. Seager, L. Goddard, J. Nakamura, N. Henderson, D. E. Lee, Dynamical causes of the 2010/11 Texas–Northern Mexico drought. *J. Hydrometeor.* **15**, 39–68 (2014).
9. H. Wang, S. Schubert, R. Koster, Y.-G. Ham, M. Suarez, On the role of SST forcing in the 2011 and 2012 extreme U.S. heat and drought: A study in contrasts. *J. Hydrometeor.* **15**, 1255–1273 (2014).
10. D. Griffin, K. J. Anchukaitis, How unusual is the 2012–2014 California drought? *Geophys. Res. Lett.* **41**, 2014GL062433 (2014).
11. R. Seager, M. Hoerling, Atmosphere and ocean origins of North American droughts. *J. Clim.* **27**, 4581–4606 (2014).
12. E. J. Burke, Understanding the sensitivity of different drought metrics to the drivers of drought under increased atmospheric CO_2. *J. Hydrometeor.* **12**, 1378–1394 (2011).
13. B. I. Cook, J. E. Smerdon, R. Seager, S. Coats, Global warming and 21st century drying. *Clim. Dyn.* **43**, 2607–2627 (2014).
14. A. Dai, Drought under global warming: A review. *WIREs Clim. Change* **2**, 45–65 (2011).
15. A. Dai, Increasing drought under global warming in observations and models. *Nat. Clim. Change* **3**, 52–58 (2013).
16. T. R. Ault, J. E. Cole, J. T. Overpeck, G. T. Pederson, S. St. George, B. Otto-Bliesner, C. A. Woodhouse, C. Deser, The continuum of hydroclimate variability in Western North America during the last millennium. *J. Clim.* **26**, 5863–5878 (2013).
17. T. R. Ault, J. E. Cole, J. T. Overpeck, G. T. Pederson, D. M. Meko, Assessing the risk of persistent drought using climate model simulations and paleoclimate data. *J. Clim.* **27**, 7529–7549 (2014).
18. W. C. Palmer, Meteorological Drought (U.S. Weather Bureau, Washington, DC, 1965).
19. J. E. Smerdon, B. I. Cook, E. R. Cook, R. Seager, J. Clim., in press.
20. E. J. Burke, S. J. Brown, Evaluating uncertainties in the projection of future drought. *J. Hydrometeor.* **9**, 292–299 (2008).
21. M. P. Hoerling, J. K. Eischeid, X.-W. Quan, H. F. Diaz, R. S. Webb, R. M. Dole, D. R. Easterling, Is a transition to semipermanent drought conditions imminent in the U.S. Great Plains? *J. Clim.* **25**, 8380–8386 (2012).
22. K. E. Taylor, R. J. Stouffer, G. A. Meehl, An overview of CMIP5 and the experiment design. *Bull. Am. Meteorol. Soc.* **93**, 485–498 (2012).
23. S. Coats, J. E. Smerdon, B. I. Cook, R. Seager, Stationarity of the tropical pacific teleconnection to North America in CMIP5/PMIP3 model simulations. *Geophys. Res. Lett.* **40**, 4927–4932 (2013).
24. R. Seager, D. Neelin, I. Simpson, H. Liu, N. Henderson, T. Shaw, Y. Kushnir, M. Ting, B. Cook, Dynamical and thermodynamical causes of large-scale changes in the hydrological cycle over North America in response to global warming. *J. Clim.* **27**, 7921–7948 (2014).
25. J. Scheff, D. M. W. Frierson, Scaling potential evapotranspiration with greenhouse warming. *J. Clim.* **27**, 1539–1558 (2013).
26. J. D. Neelin, B. Langenbrunner, J. E. Meyerson, A. Hall, N. Berg, California winter precipitation change under global warming in the Coupled Model Intercomparison Project phase 5 ensemble. *J. Clim.* **26**, 6238–6256 (2013).
27. J. Sheffield, E. F. Wood, M. L. Roderick, Little change in global drought over the past 60 years. *Nature* **491**, 435–438 (2012).
28. B. Kirtman, S. B. Power, G. J. Adedoyin, R. Boer, I. Bojariu, F. J. Camilloni, A. M. Doblas-Reyes, A. M. Fiore, M. Kimoto, G. A. Meehl, M. Prather, A. Sarr, C. Schar, R. Sutton, G. J. van Oldenborgh, G. Vecchi, H. J. Wang, Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press, Cambridge, UK, and New York, NY, USA, 2013), chap. Near-term Climate Change: Projections and Predictability.
29. G. M. MacDonald, Water, climate change, and sustainability in the southwest. *Proc. Natl. Acad. Sci. U.S.A.* **107**, 21256–21262 (2010).
30. A. P. Williams, C. D. Allen, A. K. Macalady, D. Griffin, C. A. Woodhouse, D. M. Meko, T. W. Swetnam, S. A. Rauscher, R. Seager, H. D. Grissino-Mayer, J. S. Dean, Ed. R. Cook, C. Gangodagamage, M. Cai, N. G. McDowell, Temperature as a potent driver of regional forest drought stress and tree mortality. *Nat. Clim. Change* **3**, 292–297 (2013).
31. D. B. Lobell, M. J. Roberts, W. Schlenker, N. Braun, B.B. Little, R. M. Rejesus, G. L. Hammer, Greater sensitivity to drought accompanies maize yield increase in the U.S. midwest. *Science* **344**, 516–519 (2014).
32. D. Long, B. R. Scanlon, L. Longuevergne, A. Y. Sun, D. N. Fernando, H. Save, GRACE satellite monitoring of large depletion in water storage in response to the 2011 drought in Texas. *Geophys. Res. Lett.* **40**, 3395–3401 (2013).
33. B. R. Scanlon, C. C. Faunt, L. Longuevergne, R. C. Reedy, W. M. Alley, V. L. Mcguire, P. B. McMahon, Groundwater depletion and sustainability of irrigation in the US high plains and Central Valley. *Proc. Natl. Acad. Sci. U.S.A.* **109**, 9320–9325 (2012).
34. S. L. Castle, B. F. Thomas, J. T. Reager, M. Rodell, S. C. Swenson, J. S. Famiglietti, Groundwater depletion during drought threatens future water security of the Colorado River Basin. *Geophys. Res. Lett.* **41**, 5904–5911 (2014).
35. J. S. Famiglietti, M. Lo, S. L. Ho, J. Bethune, K. J. Anderson, T. H. Syed, S. C. Swenson, C. R. de Linage, M. Rodell, Satellites measure recent rates of groundwater depletion in California's Central Valley. *Geophys. Res. Lett.* **38**, L03403 (2011).

Acknowledgments: We thank H. Liu and N. Henderson for invaluable computing support at Lamont-Doherty Earth Observatory and E. Cook for providing the NADA data. All model data are freely available on the CMIP5 archive. Finally, we thank two anonymous reviewers who provided comments that greatly improved the manuscript. Lamont contribution #7865. **Funding:** Funding for B.I.C. for this work was provided by the NASA Modeling, Analysis, and Prediction Program and NASA Strategic Science. Support for J.E.S. came from NSF Awards AGS-1243204 ("Collaborative Research: EaSM2–Linking Near Term Future Changes in Weather and Hydroclimate in Western North America to Adaptation for Ecosystem and Water Management") and AGS-1401400 ("P2C2: Continental Scale Droughts in North America: Their Frequency, Character and Causes Over the Past Millenium and Near Term Future"), and NOAA Award NAOR4310137 ("Global Decadal Hydroclimate Variability, Predictability and Change: A Data-Enriched Modeling Study"). Funding for T.R.A. was provided by startup funds from Cornell University's College of Agriculture and Life Sciences (CALS). **Author contributions:** B.I.C., T.R.A., and J.E.S. conceived of the study. B.I.C. conducted all the analyses except the risk calculations and wrote the paper. T.R.A. conducted the risk calculations. T.R.A. and J.E.S. contributed feedback to the analyses and writing.

Submitted 17 November 2014
Accepted 15 January 2015
Published 12 February 2015
10.1126/sciadv.1400082

Citation: B. I. Cook, T. R. Ault, J. E. Smerdon, Unprecedented 21st century drought risk in the American Southwest and Central Plains. *Sci. Adv.* **1**, e1400082 (2015).

Anthropogenic warming has increased drought risk in California

Noah S. Diffenbaugh[a,b,1], Daniel L. Swain[a], and Danielle Touma[a]

[a]Department of Environmental Earth System Science and [b]Woods Institute for the Environment, Stanford University, Stanford, CA 94305

Edited by Jane Lubchenco, Oregon State University, Corvallis, OR, and approved January 30, 2015 (received for review November 22, 2014)

California is currently in the midst of a record-setting drought. The drought began in 2012 and now includes the lowest calendar-year and 12-mo precipitation, the highest annual temperature, and the most extreme drought indicators on record. The extremely warm and dry conditions have led to acute water shortages, groundwater overdraft, critically low streamflow, and enhanced wildfire risk. Analyzing historical climate observations from California, we find that precipitation deficits in California were more than twice as likely to yield drought years if they occurred when conditions were warm. We find that although there has not been a substantial change in the probability of either negative or moderately negative precipitation anomalies in recent decades, the occurrence of drought years has been greater in the past two decades than in the preceding century. In addition, the probability that precipitation deficits co-occur with warm conditions and the probability that precipitation deficits produce drought have both increased. Climate model experiments with and without anthropogenic forcings reveal that human activities have increased the probability that dry precipitation years are also warm. Further, a large ensemble of climate model realizations reveals that additional global warming over the next few decades is very likely to create ~100% probability that any annual-scale dry period is also extremely warm. We therefore conclude that anthropogenic warming is increasing the probability of co-occurring warm–dry conditions like those that have created the acute human and ecosystem impacts associated with the "exceptional" 2012–2014 drought in California.

drought | climate extremes | climate change detection | event attribution | CMIP5

The state of California is the largest contributor to the economic and agricultural activity of the United States, accounting for a greater share of population (12%) (1), gross domestic product (12%) (2), and cash farm receipts (11%) (3) than any other state. California also includes a diverse array of marine and terrestrial ecosystems that span a wide range of climatic tolerances and together encompass a global biodiversity "hotspot" (4). These human and natural systems face a complex web of competing demands for freshwater (5). The state's agricultural sector accounts for 77% of California water use (5), and hydroelectric power provides more than 9% of the state's electricity (6). Because the majority of California's precipitation occurs far from its urban centers and primary agricultural zones, California maintains a vast and complex water management, storage, and distribution/conveyance infrastructure that has been the focus of nearly constant legislative, legal, and political battles (5). As a result, many riverine ecosystems depend on mandated "environmental flows" released by upstream dams, which become a point of contention during critically dry periods (5).

California is currently in the midst of a multiyear drought (7). The event encompasses the lowest calendar-year and 12-mo precipitation on record (8), and almost every month between December 2011 and September 2014 exhibited multiple indicators of drought (Fig. S1). The proximal cause of the precipitation deficits was the recurring poleward deflection of the cool-season storm track by a region of persistently high atmospheric pressure, which steered Pacific storms away from California over consecutive seasons (8–11). Although the extremely persistent high pressure is at least a century-scale occurrence (8), anthropogenic global warming has very likely increased the probability of such conditions (8, 9).

Despite insights into the causes and historical context of precipitation deficits (8–11), the influence of historical temperature changes on the probability of individual droughts has—until recently—received less attention (12–14). Although precipitation deficits are a prerequisite for the moisture deficits that constitute "drought" (by any definition) (15), elevated temperatures can greatly amplify evaporative demand, thereby increasing overall drought intensity and impact (16, 17). Temperature is especially important in California, where water storage and distribution systems are critically dependent on winter/spring snowpack, and excess demand is typically met by groundwater withdrawal (18–20). The impacts of runoff and soil moisture deficits associated with warm temperatures can be acute, including enhanced wildfire risk (21), land subsidence from excessive groundwater withdrawals (22), decreased hydropower production (23), and damage to habitat of vulnerable riparian species (24).

Recent work suggests that the aggregate combination of extremely high temperatures and very low precipitation during the 2012–2014 event is the most severe in over a millennium (12). Given the known influence of temperature on drought, the fact that the 2012–2014 record drought severity has co-occurred with record statewide warmth (7) raises the question of whether long-term warming has altered the probability that precipitation deficits yield extreme drought in California.

Significance

California ranks first in the United States in population, economic activity, and agricultural value. The state is currently experiencing a record-setting drought, which has led to acute water shortages, groundwater overdraft, critically low streamflow, and enhanced wildfire risk. Our analyses show that California has historically been more likely to experience drought if precipitation deficits co-occur with warm conditions and that such confluences have increased in recent decades, leading to increases in the fraction of low-precipitation years that yield drought. In addition, we find that human emissions have increased the probability that low-precipitation years are also warm, suggesting that anthropogenic warming is increasing the probability of the co-occurring warm–dry conditions that have created the current California drought.

Author contributions: N.S.D., D.L.S., and D.T. designed research, performed research, contributed new reagents/analytic tools, analyzed data, and wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Freely available online through the PNAS open access option.

[1]To whom correspondence should be addressed. Email: diffenbaugh@stanford.edu.

This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1422385112/-/DCSupplemental.

Results

We analyze the "Palmer" drought metrics available from the US National Climatic Data Center (NCDC) (25). The NCDC Palmer metrics are based on the Palmer Drought Severity Index (PDSI), which uses monthly precipitation and temperature to calculate moisture balance using a simple "supply-and-demand" model (26) (*Materials and Methods*). We focus on the Palmer Modified Drought Index (PMDI), which moderates transitions between wet and dry periods (compared with the PDSI) (27). However, we note that the long-term time series of the PMDI is similar to that of other Palmer drought indicators, particularly at the annual scale (Figs. S1 and S2).

Because multiple drought indicators reached historic lows in July 2014 (Figs. S1–S3), we initially focus on statewide PMDI, temperature, and precipitation averaged over the August–July 12-mo period. We find that years with a negative PMDI anomaly exceeding −1.0 SDs (hereafter "1-SD drought") have occurred approximately twice as often in the past two decades as in the preceding century (six events in 1995–2014 = 30% of years; 14 events in 1896–1994 = 14% of years) (Fig. 1*A* and Fig. S4). This increase in the occurrence of 1-SD drought years has taken place without a substantial change in the probability of negative precipitation anomalies (53% in 1896–2014 and 55% in 1995–2014) (Figs. 1*B* and 2 *A* and *B*). Rather, the observed doubling of the occurrence of 1-SD drought years has coincided with a doubling of the frequency with which a negative precipitation year produces a 1-SD drought, with 55% of negative precipitation years in 1995–2014 co-occurring with a −1.0 SD PMDI anomaly, compared with 27% in 1896–1994 (Fig. 1 *A* and *B*).

Most 1-SD drought years have occurred when conditions were both dry (precipitation anomaly < 0) and warm (temperature anomaly > 0), including 15 of 20 1-SD drought years during 1896–2014 (Fig. 2*A* and Fig. S4) and 6 of 6 during 1995–2014 (Fig. 2*B* and Fig. S4). Similarly, negative precipitation anomalies are much more likely to produce 1-SD drought if they co-occur with a positive temperature anomaly. For example, of the 63 negative precipitation years during 1896–2014, 15 of the 32 warm–dry years (47%) produced 1-SD drought, compared with only 5 of the 31 cool–dry years (16%) (Fig. 2*A*). (During 1896–1994, 41% of warm–dry years produced 1-SD droughts, compared with 17% of cool–dry years.) The probability that a negative precipitation anomaly co-occurs with a positive temperature anomaly has increased recently, with warm–dry years occurring more than twice as often in the past two decades (91%) as in the preceding century (42%) (Fig. 1*B*).

All 20 August–July 12-mo periods that exhibited a −1.0 SD PMDI anomaly also exhibited a −0.5 SD precipitation anomaly (Fig. 1*B* and 2*E*), suggesting that moderately low precipitation is prerequisite for a 1-SD drought year. However, the occurrence of −0.5 SD precipitation anomalies has not increased in recent years (40% in 1896–2014 and 40% in 1995–2014) (Fig. 2 *A* and *B*). Rather, these moderate precipitation deficits have been far more likely to produce 1-SD drought when they occur in a warm year. For example, during 1896–2014, 1-SD drought occurred in 15 of the 28 years (54%) that exhibited both a −0.5 SD precipitation anomaly and a positive temperature anomaly, but in only 5 of the 20 years (25%) that exhibited a −0.5 SD precipitation anomaly and a negative temperature anomaly (Fig. 2*A*). During 1995–2014, 6 of the 8 moderately dry years produced 1-SD drought (Fig. 1*A*), with all 6 occurring in years in which the precipitation anomaly exceeded −0.5 SD and the temperature anomaly exceeded 0.5 SD (Fig. 1*C*).

Taken together, the observed record from California suggests that (*i*) precipitation deficits are more likely to yield 1-SD PMDI droughts if they occur when conditions are warm and (*ii*) the occurrence of 1-SD PMDI droughts, the probability of precipitation deficits producing 1-SD PMDI droughts, and the probability of precipitation deficits co-occurring with warm conditions have all been greater in the past two decades than in the preceding century.

These increases in drought risk have occurred despite a lack of substantial change in the occurrence of low or moderately low precipitation years (Figs. 1*B* and 2 *A* and *B*). In contrast, statewide warming (Fig. 1*C*) has led to a substantial increase in warm conditions, with 80% of years in 1995–2014 exhibiting a positive temperature anomaly (Fig. 2*B*), compared with 45% of years in 1896–2014 (Fig. 2*A*). As a result, whereas 58% of moderately dry years were warm during 1896–2014 (Fig. 2*A*) and 50% were warm during 1896–1994, 100% of the 8 moderately dry years in 1995–2014 co-occurred with a positive temperature anomaly (Fig. 2*B*). The observed statewide warming (Fig. 1*C*) has therefore substantially increased the probability that when moderate precipitation deficits occur, they occur during warm years.

The recent statewide warming clearly occurs in climate model simulations that include both natural and human forcings ("Historical" experiment), but not in simulations that include only natural forcings ("Natural" experiment) (Fig. 3*B*). In particular, the Historical and Natural temperatures are found to be different at the 0.001 significance level during the most recent 20-, 30-, and 40-y periods of the historical simulations (using the block bootstrap resampling applied in ref. 28). In contrast, although the Historical experiment exhibits a slightly higher mean annual precipitation (0.023 significance level), there is no statistically

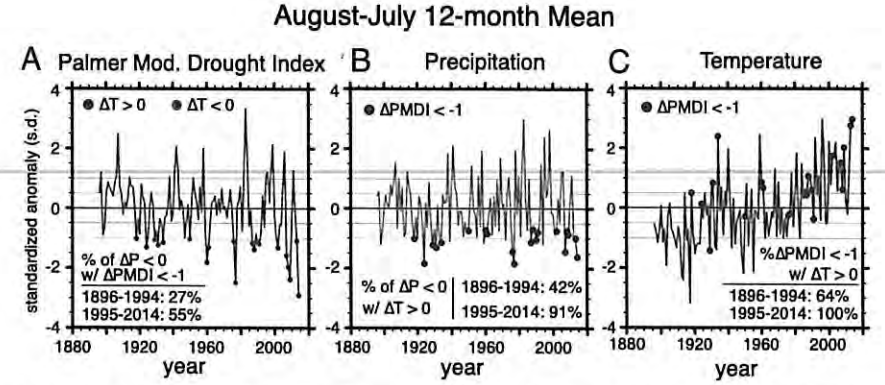


Fig. 1. Historical time series of drought (*A*), precipitation (*B*), and temperature (*C*) in California. Values are calculated for the August–July 12-mo mean in each year of the observed record, beginning in August 1895. In each year, the standardized anomaly is expressed as the magnitude of the anomaly from the long-term annual mean, divided by the SD of the detrended historical annual anomaly time series. The PMDI is used as the primary drought indicator, although the other Palmer indicators exhibit similar historical time series (Figs. S1 and S2). Circles show the years in which the PMDI exhibited a negative anomaly exceeding −1.0 SDs, which are referred to as 1-SD drought years in the text.

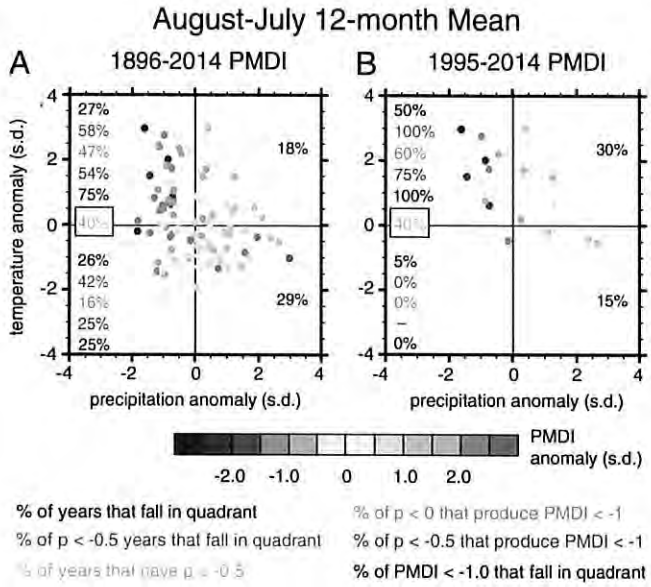


Fig. 2. Historical occurrence of drought, precipitation, and temperature in California. Standardized anomalies are shown for each August–July 12-mo period in the historical record (calculated as in Fig. 1). Anomalies are shown for the full historical record (*A*) and for the most recent two decades (*B*). Percentage values show the percentage of years meeting different precipitation and drought criteria that fall in each quadrant of the temperature–precipitation space. The respective criteria are identified by different colors of text.

significant difference in probability of a –0.5 SD precipitation anomaly (Fig. 3 *A* and *C*). However, the Historical experiment exhibits greater probability of a –0.5 SD precipitation anomaly co-occurring with a positive temperature anomaly (0.001 significance level) (Fig. 3*D*), suggesting that human forcing has caused the observed increase in probability that moderately dry precipitation years are also warm.

The fact that the occurrence of warm and moderately dry years approaches that of moderately dry years in the last decades of the Historical experiment (Fig. 3 *B* and *C*) and that 91% of negative precipitation years in 1995–2014 co-occurred with warm anomalies (Fig. 1*B*) suggests possible emergence of a regime in which nearly all dry years co-occur with warm conditions. We assess this possibility using an ensemble of 30 realizations of a single global climate model [the National Center for Atmospheric Research (NCAR) Community Earth System Model (CESM1) Large Ensemble experiment ("LENS")] (29) (*Materials and Methods*). Before ~1980, the simulated probability of a warm–dry year is approximately half that of a dry year (Fig. 4*B*), similar to observations (Figs. 1*B* and 2). However, the simulated probability of a warm–dry year becomes equal to that of a dry year by ~2030 of RCP8.5. Likewise, the probabilities of co-occurring 0.5, 1.0 and 1.5 SD warm–dry anomalies become approximately equal to those of 0.5, 1.0, and 1.5 SD dry anomalies (respectively) by ~2030 (Fig. 4*B*).

The probability of co-occurring extremely warm and extremely dry conditions (1.5 SD anomaly) remains greatly elevated throughout the 21st century (Fig. 4*B*). In addition, the number of multiyear periods in which a –0.5 SD precipitation anomaly co-occurs with a 0.5 SD temperature anomaly more than doubles between the Historical and RCP8.5 experiments (Fig. 4*A*). We find similar results using a 12-mo moving average (Fig. 4*C*). As with the August–July 12-mo mean (Fig. 4*B*), the probability of a dry year is approximately twice the probability of a warm–dry year for all 12-mo periods before ~1980 (Fig. 4*C*). However, the occurrence of warm years (including +1.5 SD temperature anomalies) increases after ~1980, reaching 1.0 by ~2030. This increase implies a transition to a permanent condition of ~100% risk that any negative—or extremely negative—12-mo precipitation anomaly is also extremely warm.

The overall occurrence of dry years declines after ~2040 (Fig. 4*C*). However, the occurrence of extreme 12-mo precipitation deficits (–1.5 SD) is greater in 2006–2080 than in 1920–2005 (<0.03 significance level). This detectable increase in extremely low-precipitation years adds to the effect of rising temperatures and contributes to the increasing occurrence of extremely warm–dry 12-mo periods during the 21st century.

All four 3-mo seasons likewise show higher probability of co-occurring 1.5 SD warm–dry anomalies after ~1980, with the probability of an extremely warm–dry season equaling that of an extremely dry season by ~2030 for spring, summer, and autumn, and by ~2060 for winter (Fig. 4*D*). In addition, the probability of a –1.5 SD precipitation anomaly increases in spring ($P < 0.001$) and autumn ($P = 0.01$) in 2006–2080 relative to 1920–2005, with spring occurrence increasing by ~75% and autumn occurrence increasing by ~44%—which represents a substantial and statistically significant increase in the risk of extremely low-precipitation events at both margins of California's wet season. In contrast, there is no statistically significant difference in the probability of a –1.5 SD precipitation anomaly for winter.

Discussion

A recent report by Seager et al. (30) found no significant long-term trend in cool-season precipitation in California during the 20th and early 21st centuries, which is consistent with our

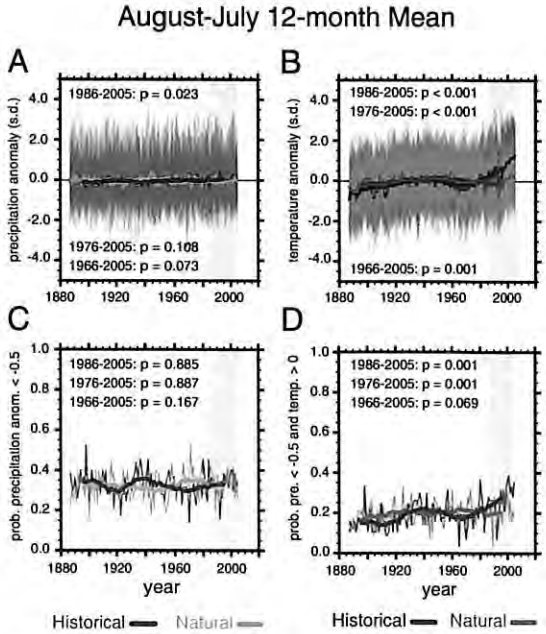


Fig. 3. Influence of anthropogenic forcing on the probability of warm–dry years in California. Temperature and precipitation values are calculated for the August–July 12-mo mean in each year of the CMIP5 Historical and Natural forcing experiments (*Materials and Methods*). The *Top* panels (*A* and *B*) show the time series of ensemble-mean standardized temperature and precipitation anomalies. The *Bottom* panels (*C* and *D*) show the unconditional probability (across the ensemble) that the annual precipitation anomaly is less than –0.5 SDs, and the conditional probability that both the annual precipitation anomaly is less than –0.5 SDs and the temperature anomaly is greater than 0. The bold curves show the 20-y running mean of each annual time series. The CMIP5 Historical and Natural forcing experiments were run until the year 2005. *P* values are shown for the difference between the Historical and Natural experiments for the most recent 20-y (1986–2005; gray band), 30-y (1976–2005), and 40-y (1966–2005) periods of the CMIP5 protocol. *P* values are calculated using the block bootstrap resampling approach of ref. 28 (*Materials and Methods*).

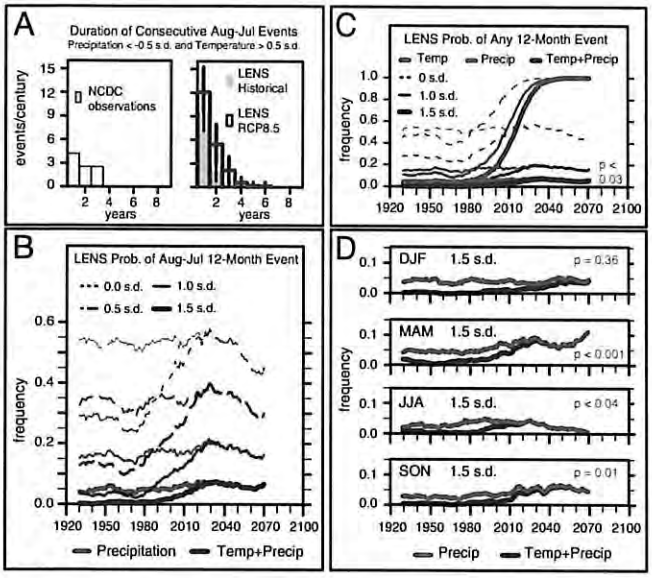


Fig. 4. Projected changes in the probability of co-occurring warm–dry conditions in the 21st century. (*A*) Histogram of the frequency of occurrence of consecutive August–July 12-mo periods in which the 12-mo precipitation anomaly is less than −0.5 SDs and the 12-mo temperature anomaly is at least 0.5 SDs, in historical observations and the LENS large ensemble experiment. (*B*) The probability that a negative 12-mo precipitation anomaly and a positive 12-mo temperature anomaly equal to or exceeding a given magnitude occur in the same August–July 12-mo period, for varying severity of anomalies. (*C*) The probability that a negative precipitation anomaly and a positive temperature anomaly equal to or exceeding a given magnitude occur in the same 12-mo period, for all possible 12-mo periods (using a 12-mo running mean; see *Materials and Methods*), for varying severity of anomalies. (*D*) The unconditional probability of a −1.5 SD seasonal precipitation anomaly (blue curve) and the conditional probability that a −1.5 SD seasonal precipitation anomaly occurs in conjunction with a 1.5 SD seasonal temperature anomaly (red curve), for each of the four 3-mo seasons. Time series show the 20-y running mean of each annual time series. *P* values are shown for the difference in occurrence of −1.5 SD precipitation anomalies between the Historical period (1920–2005) and the RCP8.5 period (2006–2080).

findings. Further, under a scenario of strongly elevated greenhouse forcing, Neelin et al. (31) found a modest increase in California mean December–January–February (DJF) precipitation associated with a local eastward extension of the mean subtropical jet stream west of California. However, considerable evidence (8–11, 31–33) simultaneously suggests that the response of northeastern Pacific atmospheric circulation to anthropogenic warming is likely to be complex and spatiotemporally inhomogeneous, and that changes in the atmospheric mean state may not be reflective of changes in the risk of extreme events (including atmospheric configurations conducive to precipitation extremes). Although there is clearly value in understanding possible changes in precipitation, our results highlight the fact that efforts to understand drought without examining the role of temperature miss a critical contributor to drought risk. Indeed, our results show that even in the absence of trends in mean precipitation—or trends in the occurrence of extremely low-precipitation events—the risk of severe drought in California has already increased due to extremely warm conditions induced by anthropogenic global warming.

We note that the interplay between the existence of a well-defined summer dry period and the historical prevalence of a substantial high-elevation snowpack may create particular susceptibility to temperature-driven increases in drought duration and/or intensity in California. In regions where precipitation exhibits a distinct seasonal cycle, recovery from preexisting drought conditions is unlikely during the characteristic yearly dry spell (34). Because California's dry season occurs during the warm summer months, soil moisture loss through evapotranspiration (ET) is typically high—meaning that soil moisture deficits that exist at the beginning of the dry season are exacerbated by the warm conditions that develop during the dry season, as occurred during the summers of 2013 and 2014 (7).

Further, California's seasonal snowpack (which resides almost entirely in the Sierra Nevada Mountains) provides a critical source of runoff during the low-precipitation spring and summer months. Trends toward earlier runoff in the Sierra Nevada have already been detected in observations (e.g., ref. 35), and continued global warming is likely to result in earlier snowmelt and increased rain-to-snow ratios (35, 36). As a result, the peaks in California's snowmelt and surface runoff are likely to be more pronounced and to occur earlier in the calendar year (35, 36), increasing the duration of the warm-season low-runoff period (36) and potentially reducing montane surface soil moisture (37). Although these hydrological changes could potentially increase soil water availability in previously snow-covered regions during the cool low-ET season (34), this effect would likely be outweighed by the influence of warming temperatures (and decreased runoff) during the warm high-ET season (36, 38), as well as by the increasing occurrence of consecutive years with low precipitation and high temperature (Fig. 4*A*).

The increasing risk of consecutive warm–dry years (Fig. 4*A*) raises the possibility of extended drought periods such as those found in the paleoclimate record (14, 39, 40). Recent work suggests that record warmth could have made the current event the most severe annual-scale drought of the past millennium (12). However, numerous paleoclimate records also suggest that the region has experienced multidecadal periods in which most years were in a drought state (14, 39, 41, 42), albeit less acute than the current California event (12, 39, 41). Although multidecadal ocean variability was a primary cause of the megadroughts of the last millenium (41), the emergence of a condition in which there is ~100% probability of an extremely warm year (Fig. 4) substantially increases the risk of prolonged drought conditions in the region (14, 39, 40).

A number of caveats should be considered. For example, ours is an implicit approach that analyzes the temperature and precipitation conditions that have historically occurred with low PMDI years, but does not explicitly explore the physical processes that produce drought. The impact of increasing temperatures on the processes governing runoff, baseflow, groundwater, soil moisture, and land-atmosphere evaporative feedbacks over both the historical period and in response to further global warming remains a critical uncertainty (43). Likewise, our analyses of anthropogenic forcing rely on global climate models that do not resolve the topographic complexity that strongly influences California's precipitation and temperature. Further investigation using high-resolution modeling approaches that better resolve the boundary conditions and fine-scale physical processes (44–46) and/or using analyses that focus on the underlying large-scale climate dynamics of individual extreme events (8) could help to overcome the limitations of simulated precipitation and temperature in the current generation of global climate models.

Conclusions

Our results suggest that anthropogenic warming has increased the probability of the co-occurring temperature and precipitation conditions that have historically led to drought in California. In addition, continued global warming is likely to cause a transition to a regime in which essentially every seasonal, annual, and multiannual precipitation deficit co-occurs with historically warm conditions. The current warm–dry event in California—as well as historical observations of previous seasonal, annual, and multiannual warm–dry events—suggests such a regime would substantially increase the risk of severe impacts on human and natural systems. For example, the projected increase in extremely

low precipitation and extremely high temperature during spring and autumn has substantial implications for snowpack water storage, wildfire risk, and terrestrial ecosystems (47). Likewise, the projected increase in annual and multiannual warm–dry periods implies increasing risk of the acute water shortages, critical groundwater overdraft, and species extinction potential that have been experienced during the 2012–2014 drought (5, 20).

California's human population (38.33 million as of 2013) has increased by nearly 72% since the much-remembered 1976–1977 drought (1). Gains in urban and agricultural water use efficiency have offset this rapid increase in the number of water users to the extent that overall water demand is nearly the same in 2013 as it was in 1977 (5). As a result, California's per capita water use has declined in recent decades, meaning that additional short-term water conservation in response to acute shortages during drought conditions has become increasingly challenging. Although a variety of opportunities exist to manage drought risk through long-term changes in water policy, management, and infrastructure (5), our results strongly suggest that global warming is already increasing the probability of conditions that have historically created high-impact drought in California.

Materials and Methods

We use historical time series of observed California statewide temperature, precipitation, and drought data from the National Oceanic and Atmospheric Administration's NCDC (7). The data are from the NCDC "nClimDiv" divisional temperature–precipitation–drought database, available at monthly time resolution from January 1895 to the present (7, 25). The NCDC nClimDiv database includes temperature, precipitation, and multiple Palmer drought indicators, aggregated at statewide and substate climate division levels for the United States. The available Palmer drought indicators include PDSI, the Palmer Hydrological Drought Index (PHDI), and PMDI.

PMDI and PHDI are variants of PDSI (25–27, 48, 49). PDSI is an index that measures the severity of wet and dry anomalies (26). The NCDC nClimDiv PDSI calculation is reported at the monthly scale, based on monthly temperature and precipitation (49). Together, the monthly temperature and precipitation values are used to compute the net moisture balance, based on a simple supply-and-demand model that uses potential evapotranspiration (PET) calculated using the Thornthwaite method. Calculated PET values can be very different when using other methods (e.g., Penman–Monteith), with the Thornthwaite method's dependence on surface temperature creating the potential for overestimation of PET (e.g., ref. 43). However, it has been found that the choice of methods in the calculation of PET does not critically influence the outcome of historical PDSI estimates in the vicinity of California (15, 43, 50). In contrast, the sensitivity of the PET calculation to large increases in temperature could make the PDSI inappropriate for calculating the response of drought to high levels of greenhouse forcing (15). As a result, we analyze the NCDC Palmer indicators in conjunction with observed temperature and precipitation data for the historical period, but we do not calculate the Palmer indicators for the future (for future projections of the PDSI, refer to refs. 15 and 40).

Because the PDSI is based on recent temperature and precipitation conditions (and does not include human demand for water), it is considered an indicator of "meterological" drought (25). The PDSI calculates "wet," "dry," and "transition" indices, using the wet or dry index when the probability is 100% and the transition index when the probability is less than 100% (26). Because the PMDI always calculates a probability-weighted average of the wet and dry indices (27), the PDSI and PMDI will give equal values in periods that are clearly wet or dry, but the PMDI will yield smoother transitions between wet and dry periods (25). In this work, we use the PMDI as our primary drought indicator, although we note that the long-term time series of the PMDI is similar to that of the PDSI and PHDI, particularly at the annual scale considered here (Figs. S1 and S2).

We analyze global climate model simulations from phase 5 of the Coupled Model Intercomparison Project (CMIP5) (51). We compare two of the CMIP5 multimodel historical experiments (which were run through 2005): (*i*) the Historical experiment, in which the climate models are prescribed both anthropogenic and nonanthropogenic historical climate forcings, and (*ii*) the Natural experiment, in which the climate models are prescribed only the nonanthropogenic historical climate forcings. We analyze those realizations for which both temperature and precipitation were available from both experiments at the time of data acquisition. We calculate the temperature and precipitation values over the state of California at each model's native resolution using all grid points that overlap with the geographical borders of California, as defined by a high-resolution shapefile (vector digital data obtained from the US Geological Survey via the National Weather Service at www.nws.noaa.gov/geodata/catalog/national/html/us_state.htm).

We also analyze NCAR's large ensemble ("LENS") climate model experiment (29). The LENS experiment includes 30 realizations of the NCAR CESM1. This large single-model experiment enables quantification of the uncertainty arising from internal climate system variability. Although the calculation of this "irreducible" uncertainty likely varies between climate models, it exists independent of uncertainty arising from model structure, model parameter values, and climate forcing pathway. At the time of acquisition, LENS results were available for 1920–2005 in the Historical experiment and 2006–2080 in the RCP8.5 (Representative Concentration Pathway) experiment. The four RCPs are mostly indistinguishable over the first half of the 21st century (52). RCP8.5 has the highest forcing in the second half of the 21st century and reaches ~4 °C of global warming by the year 2100 (52).

Given that the ongoing California drought encompasses the most extreme 12-mo precipitation deficit on record (8) and that both temperature and many drought indicators reached their most extreme historical values for California in July 2014 (7) (Fig. 1 and Figs. S1 and S2), we use the 12-mo August–July period as one period of analysis. However, because severe conditions can manifest at both multiannual and subannual timescales, we also analyze the probability of occurrence of co-occurring warm and dry conditions for multiannual periods, for all possible 12-mo periods, and for the winter (DJF), spring (March–April–May), summer (June–July–August), and autumn (September–October–November) seasons.

We use the monthly-mean time series from NCDC to calculate observed time series of statewide 12-mo values of temperature, precipitation, and PMDI. Likewise, we use the monthly-mean time series from CMIP5 and LENS to calculate simulated time series of statewide 12-mo and seasonal values of temperature and precipitation. From the time series of annual-mean values for each observed or simulated realization, we calculate (*i*) the baseline mean value over the length of the record, (*ii*) the annual anomaly from the baseline mean value, (*iii*) the SD of the detrended baseline annual anomaly time series, and (*iv*) the ratio of each individual annual anomaly value to the SD of the detrended baseline annual anomaly time series. (For the 21st-century simulations, we use the Historical simulation as the baseline.) Our time series of standardized values are thereby derived from the time series of 12-mo annual (or 3-mo seasonal) mean anomaly values that occur in each year.

For the multiannual analysis, we calculate consecutive occurrences of August–July 12-mo values. For the analysis of all possible 12-mo periods, we generate the annual time series of each 12-mo period (January–December, February–January, etc.) using a 12-mo running mean. For the seasonal analysis, we generate the time series by calculating the mean of the respective 3-mo season in each year.

We quantify the statistical significance of differences in the populations of different time periods using the block bootstrap resampling approach of ref. 28. For the CMIP5 Historical and Natural ensembles, we compare the populations of the August–July values in the two experiments for the 1986–2005, 1976–2005, and 1966–2005 periods. For the LENS seasonal analysis, we compare the respective populations of DJF, March–April–May, June–July–August, and September–October–November values in the 1920–2005 and 2006–2080 periods. For the LENS 12-mo analysis, we compare the populations of 12-mo values in the 1920–2005 and 2006–2080 periods, testing block lengths up to 16 to account for temporal autocorrelation out to 16 mo for the 12-mo running mean data. (Autocorrelations beyond 16 mo are found to be negligible.)

Throughout the text, we consider drought to be those years in which negative 12-mo PMDI anomalies exceed −1.0 SDs of the historical interannual PMDI variability. We stress that this value is indicative of the variability of the annual (12-mo) PMDI, rather than of the monthly values (compare Fig. 1 and Figs. S1 and S2). We consider "moderate" temperature and precipitation anomalies to be those that exceed 0.5 SDs ("0.5 SD") and "extreme" temperature and precipitation anomalies to be those that exceed 1.5 SDs ("1.5 SD").

ACKNOWLEDGMENTS. We thank the editor and two anonymous reviewers for insightful comments; Deepti Singh for assistance with the block bootstrap resampling; the National Oceanic and Atmospheric Administration's NCDC for access to the historical temperature, precipitation, and drought data; the World Climate Research Program and Department of Energy's Program for Climate Model Diagnosis and Intercomparison for access to the CMIP5 simulations; and NCAR for access to the LENS simulations. Our work was supported by National Science Foundation Award 0955283 and National Institutes of Health Award 1R01AI090159-01.

1. US Census Bureau (2014) *State and County QuickFacts*. Available at quickfacts.census.gov/qfd/states/06000.html.
2. US Bureau of Economic Analysis (2014) *Bureau of Economic Analysis Interactive Data*. Available at www.bea.gov/.
3. US Department of Agriculture (2013) *CALIFORNIA Agricultural Statistics 2012 Crop Year*. Available at www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/2012cas-all.pdf.
4. Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* 403(6772):853–858.
5. Hanak E, et al. (2011) *Managing California's Water: From Conflict to Reconciliation* (Public Policy Institute of California, San Francisco).
6. California Energy Commission (2014) *California Energy Almanac*. Available at www.energyalmanac.ca.gov/.
7. US National Climate Data Center (2014) *National Climate Data Center NNDC Climate Data Online*. Available at www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp.
8. Swain DL, et al. (2014) The extraordinary California drought of 2013-2014: Character, context, and the role of climate change. *Bull Am Meteorol Soc* 95(7):S3–S7.
9. Wang S, Hipps L, Gillies RR, Yoon J (2014) Probable causes of the abnormal ridge accompanying the 2013–2014 California drought: ENSO precursor and anthropogenic warming footprint. *Geophys Res Lett* 41(9):3220–3226.
10. Wang H, Schubert S (2014) Causes of the extreme dry conditions over California during early 2013. *Bull Am Meteorol Soc* 95(7):S7–S11.
11. Funk C, Hoell A, Stone D (2014) Examining the contribution of the observed global warming trend to the California droughts of 2012/13 and 2013/2014. *Bull Am Meteorol Soc* 95(7):S11–S15.
12. Griffin D, Anchukaitis KJ (2014) How unusual is the 2012-2014 California drought? *Geophys Res Lett* 41(24):9017–9023.
13. AghaKouchak A, Cheng L, Mazdiyasni O, Farahmand A (2014) Global warming and changes in risk of concurrent climate extremes: Insights from the 2014 California drought. *Geophys Res Lett* 41(24):8847–8852.
14. Overpeck JT (2013) Climate science: The challenge of hot drought. *Nature* 503(7476): 350–351.
15. Dai A (2010) Drought under global warming: A review. *Wiley Interdiscip Rev Clim Chang* 2(1):45–65.
16. Dai A (2013) Increasing drought under global warming in observations and models. *Nat Clim Chang* 3(1):52–58.
17. Dai A, Trenberth KE, Qian T (2004) A global dataset of Palmer Drought Severity Index for 1870-2002: Relationship with soil moisture and effects of surface warming. *J Hydrometeorol* 5(6):1117–1130.
18. Famiglietti JS, et al. (2011) Satellites measure recent rates of groundwater depletion in California's Central Valley. *Geophys Res Lett* 38(3):L03403.
19. Borsa AA, Agnew DC, Cayan DR (2014) Remote hydrology. Ongoing drought-induced uplift in the western United States. *Science* 345(6204):1587–1590.
20. Christian-Smith J, Levy M, Gleick P (2014) Maladaptation to drought: A case report from California. *Sustain Sci*, 10.1007/s11625-014-0269-1.
21. Westerling AL, Hidalgo HG, Cayan DR, Swetnam TW (2006) Warming and earlier spring increase western U.S. forest wildfire activity. *Science* 313(5789):940–943.
22. King NE, et al. (2007) Space geodetic observation of expansion of the San Gabriel Valley, California, aquifer system, during heavy rainfall in winter 2004–2005. *J Geophys Res Solid Earth* 112(3):B03409.
23. US Energy Information Administration (2014) California drought leads to less hydropower, increased natural gas generation. *Today in Energy*. Available at www.eia.gov/todayinenergy/detail.cfm?id=182.
24. Palmer MA, et al. (2009) Climate change and river ecosystems: Protection and adaptation options. *Environ Manage* 44(6):1053–1068.
25. US National Climate Data Center (2014) *nClimDiv STATEWIDE-REGIONAL-NATIONAL DROUGHT*. Available at ftp://ftp.ncdc.noaa.gov/pub/data/cirs/climdiv/drought-readme.txt.
26. Palmer WC (1965) *Meteorological Drought* (US Department of Commerce, Weather Bureau, Washington, DC).
27. Heddinghaus TR, Sabol P (1991) in *Proceedings of the Seventh Conference on Applied Climatology* (American Meteorological Society, Boston).
28. Singh D, Tsiang M, Rajaratnam B, Diffenbaugh NS (2014) Observed changes in extreme wet and dry spells during the South Asian summer monsoon season. *Nat Clim Chang* 4(6):456–461.
29. Kay JE, et al. (2015) The Community Earth System Model (CESM) large ensemble project: A community resource for studying climate change in the presence of internal climate variability. *Bull Am Meteorol Soc*, 10.1175/BAMS-D-13-00255.1.
30. Seager R, et al. (2014) *Causes and Predictability of the 2011-14 California Drought*. Available at cpo.noaa.gov/sites/cpo/MAPP/Task%20Forces/DTF/californiadrought/california_drought_report.pdf.
31. Neelin JD, Langenbrunner B, Meyerson JE, Hall A, Berg N (2013) California winter precipitation change under global warming in the Coupled Model Intercomparison Project Phase 5 Ensemble. *J Clim* 26(17):6238–6256.
32. Seager R, et al. (2014) Dynamical and thermodynamical causes of large-scale changes in the hydrological cycle over North America in response to global warming. *J Clim* 27(17):7921–7948.
33. Simpson IR, Shaw TA, Seager R (2014) A diagnosis of the seasonally and longitudinally varying midlatitude circulation response to global warming. *J Atmos Sci* 71(7): 2489–2515.
34. Van Loon AF, et al. (2014) How climate seasonality modifies drought duration and deficit. *J Geophys Res Atmos* 119(8):4640–4656.
35. Rauscher SA, Pal JS, Diffenbaugh NS, Benedetti MM (2008) Future changes in snowmelt-driven runoff timing over the western US. *Geophys Res Lett* 35(16):L16703.
36. Ashfaq M, et al. (2013) Near-term acceleration of hydroclimatic change in the western U.S. *J Geophys Res* 118(10):10,676–10,693.
37. Blankinship JC, Meadows MW, Lucas RG, Hart SC (2014) Snowmelt timing alters shallow but not deep soil moisture in the Sierra Nevada. *Water Resour Res* 50(2):1448–1456.
38. Diffenbaugh NS, Ashfaq M (2010) Intensification of hot extremes in the United States. *Geophys Res Lett* 37(15):L15701.
39. Ault TR, Cole JE, Overpeck JT, Pederson GT, Meko DM (2014) Assessing the risk of persistent drought using climate model simulations and paleoclimate data. *J Clim* 27(20):7529–7549.
40. Cook BI, Ault TR, Smerdon JE (2015) Unprecedented 21st century drought risk in the American Southwest and Central Plains. *Science Advances* 1(1):e1400082.
41. Cook BI, Smerdon JE, Seager R, Cook ER (2013) Pan-continental droughts in North America over the last millennium. *J Clim* 27(1):383–397.
42. Cook BI, Seager R, Smerdon JE (2014) The worst North American drought year of the last millennium: 1934. *Geophys Res Lett* 41(20):7298–7305.
43. Sheffield J, Wood EF, Roderick ML (2012) Little change in global drought over the past 60 years. *Nature* 491(7424):435–438.
44. Diffenbaugh NS, Pal JS, Trapp RJ, Giorgi F (2005) Fine-scale processes regulate the response of extreme events to global climate change. *Proc Natl Acad Sci USA* 102(44): 15774–15778.
45. Diffenbaugh NS, Ashfaq M, Scherer M (2011) Transient regional climate change: Analysis of the summer climate response in a high-resolution, century-scale, ensemble experiment over the continental United States. *J Geophys Res* 116(D24):D24111.
46. Lebassi-Habtezion B, Diffenbaugh NS (2013) Nonhydrostatic nested climate modeling: A case study of the 2010 summer season over the western United States. *J Geophys Res Atmos* 118(19):10944–10962.
47. Romero-Lankao P, et al. (2014) Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of working group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change. *Climate Change*, eds Barros VR, et al. (Cambridge Univ Press, Cambridge, UK), pp 1439–1498.
48. Heim RR, Jr (2002) A review of twentieth-century drought indices used in the United States. *Bull Am Meteorol Soc* 83(8):1149–1165.
49. Karl TR (1986) The sensitivity of the Palmer drought severity index and Palmer's Z-index to their calibration coefficients including potential evapotranspiration. *J Clim Appl Meteorol* 25(1):77–86.
50. Van der Schrier G, Jones PD, Briffa KR (2011) The sensitivity of the PDSI to the Thornthwaite and Penman-Monteith parameterizations for potential evapotranspiration. *J Geophys Res Atmos* 116(D3):D03106.
51. Taylor KE, Stouffer RJ, Meehl GA (2012) An overview of CMIP5 and the experiment design. *Bull Am Meteorol Soc* 93(4):485–498.
52. Rogelj J, Meinshausen M, Knutti R (2012) Global warming under old and new scenarios using IPCC climate sensitivity range estimates. *Nat Clim Chang* 2(4):248–253.

GOVERNOR BROWN DECLARES DROUGHT STATE OF EMERGENCY

1-17-2014

SAN FRANCISCO – With California facing water shortfalls in the driest year in recorded state history, Governor Edmund G. Brown Jr. today proclaimed a State of Emergency and directed state officials to take all necessary actions to prepare for these drought conditions.

"We can't make it rain, but we can be much better prepared for the terrible consequences that California's drought now threatens, including dramatically less water for our farms and communities and increased fires in both urban and rural areas," said Governor Brown. "I've declared this emergency and I'm calling all Californians to conserve water in every way possible."

In the State of Emergency declaration, Governor Brown directed state officials to assist farmers and communities that are economically impacted by dry conditions and to ensure the state can respond if Californians face drinking water shortages. The Governor also directed state agencies to use less water and hire more firefighters and initiated a greatly expanded water conservation public awareness campaign (details at saveourh2o.org).

In addition, the proclamation gives state water officials more flexibility to manage supply throughout California under drought conditions.

State water officials say that California's river and reservoirs are below their record lows. Manual and electronic readings record the snowpack's statewide water content at about 20 percent of normal average for this time of year.

The Governor's drought State of Emergency follows a series of actions the administration has taken to ensure that California is prepared for record dry conditions. In May 2013, Governor Brown issued an Executive Order to direct state water officials to expedite the review and processing of voluntary transfers of water and water rights. In December, the Governor formed a Drought Task Force to review expected water allocations, California's preparedness for water scarcity and whether conditions merit a drought declaration. Earlier this week, the Governor toured the Central Valley and spoke with growers and others impacted by California's record dry conditions.

Photo captions and the full text of the emergency proclamation are below:

1.) Governor Brown announces Drought State of Emergency with Natural Resources Agency Secretary John Laird, Department of Water Resources Director Mark Cowin, Water Resources Control Board Chair Felicia Marcus and Governor's Office of Emergency Services Director Mark Ghilarducci (left to right). Photo Credit: Justin Short, Office of the Governor.

2.) Governor Brown signs proclamation declaring Drought State of Emergency. From left to right: CAL FIRE Director Chief Ken Pimlott, Department of Food and Agriculture Secretary Karen Ross, Secretary Laird, Director Cowin, Chair Marcus and Director Ghilarducci. Photo Credit: Justin Short, Office of the Governor.

For high resolution copies of these photos, please contact Danella Debel, Office of the Governor at Danella.Debel@gov.ca.gov.

A PROCLAMATION OF A STATE OF EMERGENCY

WHEREAS the State of California is experiencing record dry conditions, with 2014 projected to become the driest year on record; and

WHEREAS the state's water supplies have dipped to alarming levels, indicated by: snowpack in California's mountains is approximately 20 percent of the normal average for this date; California's largest water reservoirs have very low water levels for this time of year; California's major river systems, including the Sacramento and San Joaquin rivers, have significantly reduced surface water flows; and groundwater levels throughout the state have dropped significantly; and

WHEREAS dry conditions and lack of precipitation present urgent problems: drinking water supplies are at risk in many California communities; fewer crops can be cultivated and farmers' long-term investments are put at risk; low-income communities heavily dependent on agricultural employment will suffer heightened unemployment and economic hardship; animals and plants that rely on California's rivers, including many species in danger of extinction, will be threatened; and the risk of wildfires across the state is greatly increased; and

WHEREAS extremely dry conditions have persisted since 2012 and may continue beyond this year and more regularly into the future, based on scientific projections regarding the impact of climate change on California's snowpack; and

WHEREAS the magnitude of the severe drought conditions presents threats beyond the control of the

Latest News

Governor Brown Announces Appointments 07-01-2015

Governor Brown Announces Appointments 06-30-2015

Governor Brown Signs Legislation 06-30-2015

Governor Brown Announces Appointments 06-26-2015

Governor Brown Issues Statement on Death of Bakersfield Police Officer 06-26-2015

Governor Brown Appoints Luis A. Lavin to the Second District Court of Appeal 06-26-2015

Governor Brown Issues Statement on U.S. Supreme Court Ruling on Same-Sex Marriage 06-26-2015

Governor Brown Announces Appointments 06-25-2015

Governor Brown Announces Appointments 06-24-2015

Governor's Military Council Releases Report on California's National Security Mission 06-24-2015

services, personnel, equipment and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist in California due to water shortage and drought conditions with which local authority is unable to cope.

NOW, THEREFORE, I, EDMUND G. BROWN JR., Governor of the State of California, in accordance with the authority vested in me by the state Constitution and statutes, including the California Emergency Services Act, and in particular, section 8625 of the California Government Code **HEREBY PROCLAIM A STATE OF EMERGENCY** to exist in the State of California due to current drought conditions.

IT IS HEREBY ORDERED THAT:

1.State agencies, led by the Department of Water Resources, will execute a statewide water conservation campaign to make all Californians aware of the drought and encourage personal actions to reduce water usage. This campaign will be built on the existing Save Our Water campaign (www.saveourh20.org) and will coordinate with local water agencies. This campaign will call on Californians to reduce their water usage by 20 percent.

2.Local urban water suppliers and municipalities are called upon to implement their local water shortage contingency plans immediately in order to avoid or forestall outright restrictions that could become necessary later in the drought season. Local water agencies should also update their legally required urban and agricultural water management plans, which help plan for extended drought conditions. The Department of Water Resources will make the status of these updates publicly available.

3.State agencies, led by the Department of General Services, will immediately implement water use reduction plans for all state facilities. These plans will include immediate water conservation actions, and a moratorium will be placed on new, non-essential landscaping projects at state facilities and on state highways and roads.

4.The Department of Water Resources and the State Water Resources Control Board (Water Board) will expedite the processing of water transfers, as called for in Executive Order B-21-13. Voluntary water transfers from one water right holder to another enables water to flow where it is needed most.

5.The Water Board will immediately consider petitions requesting consolidation of the places of use of the State Water Project and Federal Central Valley Project, which would streamline water transfers and exchanges between water users within the areas of these two major water projects.

6.The Department of Water Resources and the Water Board will accelerate funding for water supply enhancement projects that can break ground this year and will explore if any existing unspent funds can be repurposed to enable near-term water conservation projects.

7.The Water Board will put water right holders throughout the state on notice that they may be directed to cease or reduce water diversions based on water shortages.

8.The Water Board will consider modifying requirements for reservoir releases or diversion limitations, where existing requirements were established to implement a water quality control plan. These changes would enable water to be conserved upstream later in the year to protect cold water pools for salmon and steelhead, maintain water supply, and improve water quality.

9.The Department of Water Resources and the Water Board will take actions necessary to make water immediately available, and, for purposes of carrying out directives 5 and 8, Water Code section 13247 and Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are suspended on the basis that strict compliance with them will prevent, hinder, or delay the mitigation of the effects of the emergency. Department of Water Resources and the Water Board shall maintain on their websites a list of the activities or approvals for which these provisions are suspended.

10. The state's Drinking Water Program will work with local agencies to identify communities that may run out of drinking water, and will provide technical and financial assistance to help these communities address drinking water shortages. It will also identify emergency interconnections that exist among the state's public water systems that can help these threatened communities.

11.The Department of Water Resources will evaluate changing groundwater levels, land subsidence, and agricultural land fallowing as the drought persists and will provide a public update by April 30 that identifies groundwater basins with water shortages and details gaps in groundwater monitoring.

12.The Department of Water Resources will work with counties to help ensure that well drillers submit required groundwater well logs for newly constructed and deepened wells in a timely manner and the Office of Emergency Services will work with local authorities to enable early notice of areas experiencing problems with residential groundwater sources.

13.The California Department of Food and Agriculture will launch a one-stop website (www.cdfa.ca.gov/drought) that provides timely updates on the drought and connects farmers to state and federal programs that they can access during the drought.

14.The Department of Fish and Wildlife will evaluate and manage the changing impacts of drought on threatened and endangered species and species of special concern, and develop contingency plans for state Wildlife Areas and Ecological Reserves to manage reduced water resources in the public interest.

15. The Department of Fish and Wildlife will work with the Fish and Game Commission, using the best available science, to determine whether restricting fishing in certain areas will become necessary and prudent as drought conditions persist.

16.The Department of Water Resources will take necessary actions to protect water quality and water

supply in the Delta, including installation of temporary barriers or temporary water supply connections as needed, and will coordinate with the Department of Fish and Wildlife to minimize impacts to affected aquatic species.

17.The Department of Water Resources will refine its seasonal climate forecasting and drought prediction by advancing new methodologies piloted in 2013.

18.The California Department of Forestry and Fire Protection will hire additional seasonal firefighters to suppress wildfires and take other needed actions to protect public safety during this time of elevated fire risk.

19.The state's Drought Task Force will immediately develop a plan that can be executed as needed to provide emergency food supplies, financial assistance, and unemployment services in communities that suffer high levels of unemployment from the drought.

20.The Drought Task Force will monitor drought impacts on a daily basis and will advise me of subsequent actions that should be taken if drought conditions worsen.

I FURTHER DIRECT that as soon as hereafter possible, this Proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this Proclamation.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 17th day of January, 2014.

_____
EDMUND G. BROWN JR.,
Governor of California

ATTEST:

_____
DEBRA BOWEN,
Secretary of State

###

Back to Top | Contact Us | Privacy Policy | Conditions of Use | F.A.Q.
Copyright © 2010 State of California

http://ca.gov/drought/#
California Drought
File Edit View Favorites Tools Help
CA.GOV
California
DROUGHT
Search
(Left) NASA satellite image of Sierra Nevada on January 18, 2013
(Right) NASA satellite image Sierra Nevada on January 18, 2014
1 2 3 4 5
1.3K
With California facing one of the most severe droughts on record, Governor Brown declared a drought State of Emergency in January and directed state officials to take all necessary actions to prepare for water shortages. The state has continued to lead the way to make sure California is able to cope with an unprecedented drought.
Top Story: Fire Officials Urge Extreme Caution As Fireworks Go On Sale
June 30, 2015 - With the Independence Day holiday rapidly approaching, CAL FIRE is reminding all Californians and visitors to do their part to prevent fires caused by illegal fireworks or the misuse of "Safe and Sane" fireworks. On Sunday, June 28 "Safe and Sane" Fireworks went on sale in approximately 300 communities throughout California. Although fireworks are a symbolic display of patriotism during this time of celebration, they can be dangerous when
Office of Governor
Edmund G. Brown Jr.
Click here to visit his website
Save Our
WATER

(#) (#) (#)
(#) (#) (#) 1.3K
(#)

With California facing one of the most severe droughts on record, Governor Brown declared a drought State of Emergency in January and directed state officials to take all necessary actions to prepare for water shortages. The state has continued to lead the way to make sure California is able to cope with an unprecedented drought.

Top Story: Fire Officials Urge Extreme Caution As Fireworks Go On Sale

June 30, 2015 - With the Independence Day holiday rapidly approaching, CAL FIRE is reminding all Californians and visitors to do their part to prevent fires caused by illegal fireworks or the misuse of “Safe and Sane” fireworks. On Sunday, June 28 “Safe and Sane” Fireworks went on sale in approximately 300 communities throughout California. Although fireworks are a symbolic display of patriotism during this time of celebration, they can be dangerous when handled incorrectly or used in the wrong environment.
Read More (topstory/top-story-40.html)

1 2 3 4 5

Save Our Water Launches Summer Public Education Campaign

June 30, 2015 - With California in the grip of the worst drought in a generation, Save Our Water – California’s official statewide conservation education program – is launching a new public education campaign urging Californians to step up and make even more cuts in their water use. The campaign comes at the start of a hot, dry summer and potentially dangerous fire season. Save Our Water’s campaign urges Californians to “Let It Go” by limiting outdoor water use and letting lawns fade to gold for the summer, while preserving precious water resources for trees and other important landscapes.
Read More (news/story-107.html)

State Water Board Extended Curtailments on the Merced River

June 26, 2015 - With drought conditions continuing into the summer months, the State Water Resources Control Board (State Water Board) extended curtailments on the Merced River for senior water rights dating back to 1858; and all pre-1914 and post-1914 appropriative rights on the Upper San Joaquin River.
Read More (topstory/top-story-39.html)

Drought Prompts Fish Evacuation at American River and Nimbus Hatcheries

June 25, 2015 - With a fourth year of extreme drought conditions reducing the cold water supply available, the California Department of Fish and Wildlife (CDFW) is moving fish out of the American River and the Nimbus hatcheries for the second year in a row.
Read More (news/story-106.html)

Emergency Regulation to Protect Coho Salmon and Steelhead Approved on Russian River Tributaries

June 17, 2015 - The State Water Resources Control Board today approved an emergency regulation to provide a small amount of additional water in four tributaries of the Russian River to protect threatened fish. The regulation affects about 13,000 properties in the watersheds of Dutch Bill Creek, Green Valley Creek, Mark West Creek and Mill Creek. Water users in those watersheds will be subject to enhanced conservation measures and water use reporting.
Read More (news/story-105.html)

Drought Conditions Force Difficult Management Decisions For Sacramento River Temperatures

June 16, 2015 - State and federal officials today announced the outlines of a revised plan for managing water flows in the Sacramento River for cities and farms while keeping enough cold water in Shasta Reservoir to avoid high temperatures in the river that could be catastrophic for endangered winter-run Chinook salmon. The Sacramento River Temperature Management Plan, which is required annually, guides the release of water from Shasta Reservoir to maintain healthy fisheries during the summer and fall, when water temperatures rise. In this fourth year of extended drought, with low reservoir storage levels and higher-than-normal predicted summer temperatures, the plan seeks to prevent another catastrophic loss of this year's class of juvenile salmon. Federal and state fish agencies believe such a loss would have devastating impacts to the long-term viability of this important species of native salmon.
Read More (topstory/top-story-38.html)

Senior Water Rights Curtailed in Delta, San Joaquin & Sacramento Watersheds

June 12, 2015 - With drought conditions continuing into the summer months, the State Water Resources Control Board (State Water Board) announced today that there is insufficient water available for senior water right holders with a priority date of 1903 or later in the San Joaquin and Sacramento watersheds and the Delta. The need for further curtailment of more senior rights and curtailments in other watersheds is being assessed weekly.
Read More (topstory/top-story-37.html)

Revised Ordinance Would Cut Water Use by at Least 30 Percent on New Landscapes for Homes and Businesses

June 12, 2015 - New California yards and commercial landscaping would use far less water under the rules of a model landscape ordinance updated by the California Department of Water Resources (DWR) at the direction of Governor Edmund G. Brown Jr.
Read More (news/story-104.html)

Governor Brown Issues Statement on Federal Drought Aid

June 12, 2015 - Governor Edmund G. Brown Jr. issued a following statement today after President Barack Obama announced new actions and investments to support workers, farmers and rural communities suffering from drought and to combat wildfires, including $18 million for the State of California to provide jobs for workers dislocated by the drought.
Read More (news/story-103.html)

Urban Water Conservation Improves in April Ahead of June 25 Percent Conservation Mandate

June 2, 2015 - With a mandatory average conservation rate of 25 percent beginning this month for all state residents, the State Water Resources Control Board (State Water Board) announced that Californians in cities and towns increased their water conservation to 13.5 percent in April. In addition, nearly 400 water suppliers responded to a first-ever enforcement report, indicating a high level of local activity to respond to reports of leaks and suspected water wasting.
Read More (topstory/top-story-36.html)

The California Department of Housing and Community Development Announces Emergency Adoption of Building Codes to Conserve Water

June 1, 2015 - In view of the urgency to conserve California's water resources, as deemed essential by Governor Brown's Executive Order, the Department of Housing and Community Development (HCD) is establishing new building standards through an emergency adoption process. These regulations are set forth in the California Green Building Standards (CALGreen) Code and will ensure that newly constructed residential buildings, permitted on or after June 1, 2015, include water-efficient landscaping.
Read More (news/story-102.html)

Show More

Governor's Drought Task Force

Governor Brown has convened an interagency Drought Task Force to provide a coordinated assessment of the State's dry conditions and provide recommendations on current and future state actions. The response to this statewide disaster requires the combined efforts of all state agencies and the state's model mutual aid system to address.

In support of this unified effort, all state agencies with a role in supporting drought mitigation and relief efforts are organized under the Incident Command System and will continue provide emergency planning, response, and mitigation support as long as needs exist. Similar task forces have been assembled in the droughts of the 2000's, 1990's, 1980's and 1970's.

Office of Governor

Edmund G. Brown Jr.

Click here to visit his website (http://gov.ca.gov)

Save Our WATER (http://www.saveourh2o.org/)

What You Can Do

Water your lawn only when it needs it.

Adjust your watering schedule to the season.

Save Water in Your Home! (http://www.h2ouse.org/tour/index.cfm)

Media

We Are Californians, And We Don't Waste Water! (http://youtu.be/Ow3P7KpJ-e8)

Don't Waste Water: Laundry (http://youtu.be/XVtazcwHxLg)

Don't Waste Water: Carwash (http://youtu.be/ZPCbp_zmdjU)

Don't Waste Water: Bathtub (http://youtu.be/Vgn6IfUzeeI)

Drought Resources

Weekly Drought Brief - June 23 (/drought/pdf/Weekly-Drought-Update.pdf)

California Drought Assistance Programs (/drought/pdf/DROPS-State-Fed-Funding-Program-Matrix-04-08-15.pdf)

Drought Assistance Brochure (/drought/pdf/Drought-Assistance-Brochure-2015.pdf)

Federal Funding Programs for Drought - May 2015 (/drought/pdf/Fed-Funding-Program-Matrix-04-08-15.pdf)

State Funding Programs for Drought - May 2015 (/drought/pdf/State-Funding-Program-Matrix-04-08-15.pdf)

Summary of Water Management Actions (managementactions.html)

Dept. of Water Resources (http://water.ca.gov/waterconditions/)

Dept. of Water Resources Publications (http://www.water.ca.gov/waterconditions/publications.cfm)

Dept. of Food & Ag Drought Portal (http://www.cdfa.ca.gov/drought/)

Dept. of Fish and Wildlife (https://www.wildlife.ca.gov/drought)

Dept. of General Services (http://www.dgs.ca.gov/dgs/Home/water.aspx)

Dept. of Public Health (http://www.cdph.ca.gov/certlic/drinkingwater/Pages/DroughtPreparedness.aspx)

Office of Emergency Services (http://www.caloes.ca.gov/ICESite/Pages/Drought.aspx)

State Water Resources Control Board (http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/index.shtml)

Office of Planning and Research (http://www.opr.ca.gov/s_droughtinfo.php)

CPUC Drought Information (http://www.cpuc.ca.gov/PUC/Water/Drought_Information.htm)

Drought News Archive

June 2015 (/Drought/archive-june-2015.html)

May 2015 (/Drought/archive-may-2015.html)

April 2015 (/Drought/archive-april-2015.html)

March 2015 (/Drought/archive-march-2015.html)

February 2015 (/Drought/archive-february-2015.html)

January 2015 (/Drought/archive-january-2015.html)

2014 Releases (/Drought/archive-2014.html)

2013 Releases (/Drought/archive-2013.html)

Weekly Drought Brief Archive

June 2015 (/Drought/WeeklyDroughtUpdate/archive-june-2015.html)

May 2015 (/Drought/WeeklyDroughtUpdate/archive-may-2015.html)

April 2015 (/Drought/WeeklyDroughtUpdate/archive-april-2015.html)

March 2015 (/Drought/WeeklyDroughtUpdate/archive-march-2015.html)

Februray 2015 (/Drought/WeeklyDroughtUpdate/archive-february-2015.html)

January 2015 (/Drought/WeeklyDroughtUpdate/archive-january-2015.html)

2014 Briefs (/Drought/WeeklyDroughtUpdate/archive-2014.html)

Drought Partner Links

Find Your Local Water Agency (http://saveourwater.com/find-your-water-agency)

California Weather Data (http://cdec.water.ca.gov/weather.html)

California Reservoir Conditions (http://cdec.water.ca.gov/cgi-progs/products/rescond.pdf)

Daily Reservoir Storage Summary (http://cdec.water.ca.gov/cgi-progs/reservoirs/RES)

Central Valley Project Water Supply Information (http://www.usbr.gov/mp/cvo/Day_Rpts_Current.html)

U.S. Drought Portal (http://www.drought.gov/drought/)

USGS Drought Information (http://ca.water.usgs.gov/data/drought/index.html)

U.S. Navy Region Southwest Conservation Actions (http://www.navyregionsouthwest.com/external/content/document/4275/2136198/1/NRSW_Water_Conservation_Actions.pdf)

California Urban Water Conservation Council (http://www.cuwcc.org/)

Copyright © 2014 State of California

Squaw Valley Public Service District
305 Squaw Valley Road
Post Office Box 2026
Olympic Valley, CA 96146

Why are Second Homeowners Charged the Same as Full-Time Residents?

District staff are often asked why second homeowners are charged the same as full-time residents when they're only here a fraction of the time. To help answer this question, below is a brief outline of the components that determine rates.

District rates are dictated by the actual costs required to provide water and sewer services, with a requirement to assure that each customer class pays their fair share. The District currently uses two structures: a base rate to cover fixed costs and a consumption rate to cover variable costs.

Fixed costs are incurred to assure that water is constantly running and ready to use any time of the day, regardless if it is used daily or once a year. These costs include the operating and maintenance of key infrastructure that include wells, storage tanks, and water mains, in addition to administrative services, and include such expenses as payroll, facilities, fleet, and capital reserves to replace aging infrastructure and other assets. These costs are considered "fixed" and do not fluctuate based on the volume of services used. These cumulative fixed costs are equitably allocated as a "base rate" to District customers.

Variable costs are expenses that change based on the volume of water produced, and can include expenses such as water treatment and electricity to pump the water. Since these costs are directly tied to the volume of water produced, they are allocated as a "consumption rate" to District customers.

Due to the size of our service district and its corresponding economies of scale, fixed costs are greater than variable consumption costs and often are the larger portion of your utility bill. As these rates need to be allocated equally between customer classes, there is no difference between customers who use water and sewer services year-round and those who use them less frequently.

Board of Directors Meetings

Regularly scheduled meetings are held the last Tuesday of each month at 8:30 a.m. at 305 Squaw Valley Road, Olympic Valley, California.

Board of Directors

Dale Cox
President

Eric Poulsen
Vice President

John Wilcox
Director

Brian Sheehan
Director

Carl Gustafson
Director

Mike Geary
General Manager/Treasurer

Kathy Obayashi-Bartsch
Board Secretary

Water Supply Assessment — Village at Squaw

As required by state law for large development projects, a Water Supply Assessment (WSA) for the proposed Village at Squaw Valley Specific Plan (VSVSP) was prepared by the PSD on behalf of Placer County with funds provided by the developer, Squaw Valley Real Estate (SVRE). The WSA was completed last July, in 2014.

The WSA concluded there is adequate water supply in the Squaw Valley aquifer to support the proposed VSVSP as well as all other anticipated development in the valley for the next 25 years. There is not now, and there never has been, a shortage of water in Squaw Valley. There is a shortage of wells because the previous owners of the ski area would not allow any additional wells to be drilled on their land, which overlies the most productive part of the aquifer. However, SVRE will allow and cooperate on new wells in support of their VSVSP.

The WSA satisfies requirements of state law (Senate Bill 610) and is intended to support long-term water resource planning and to ensure adequate water supplies are available to meet demand for the project, as well as existing and future water demands. The WSA will be considered for approval by the Placer County Board of Supervisors along with the project's Environmental Impact Report (EIR).

In response to one of California's worst droughts, the WSA is being amended to reassess the sufficiency of the proposed supply of water. Data used in the District's numerical groundwater model are being updated to include the last three years of drought conditions. The updated data includes precipitation, pumping, streamflow, and groundwater levels in the aquifer. Although this update is not required by law, SVRE, Placer County, and the PSD all agree that it is prudent given the historic nature of the state's current drought. The WSA Amendment is scheduled to be completed and presented to the District's Board of Directors in July 2015.

If the project is approved, state law requires the District *verify* the new wells can supply the quality and quantity of water needed for the project. The verification process includes pump testing and thorough water quality analyses. The PSD is currently negotiating the terms of a Development Agreement with SVRE to define specific criteria for the proposed new wells.

SVPSD WINS BLUE RIBBON FOR BEST TASTING WATER IN CALIFORNIA!

Now there's another reason to stop buying bottled water – the Best Tasting Water in the state of California flows right from the tap. The Squaw Valley Public Service District is proud to announce that it serves California's **Best Tasting Water**. In April of this year, the PSD was awarded with this distinction by the California Rural Water Association. The blind taste test was held at the group's 2015 Annual Expo held in South Lake Tahoe. The blue ribbon win qualifies the District to compete in the national competition in Washington DC for the Best Tasting Water in America.

The water served to your tap is relatively young – often less than one-year old. This helps explain why it's so delicious. With only a short period between the time our water falls as snow and rain and the time it flows through your tap, there is little opportunity for the water to pick up the physical and chemical characteristics associated with bad tasting water.

Of course, protection of our watershed is a critical component to ensuring we continue providing top quality water. Ongoing environmental stewardship and low impact land use contribute to this success. So stop buying bottled water and fill up your own personal bottle with our refreshing tap water. Keep yourself hydrated with the Golden State's Best Tasting Water!

SQUAW VALLEY PUBLIC SERVICE DISTRICT
Post Office Box 2026
Olympic Valley, California 96146-2026
530/583-4692 - voice 530/583-6228 - fax
http://www.svpsd.org

SQUAW VALLEY FIRE DEPARTMENT

Fire and Safety Notes

Summer, 2015

Travel Safety Tips From the Chief

I just returned from a short trip out of town and thought I would share some of my personal safety tips while travelling.

Are you Joe Cool who dons the earbuds and studiously ignores the safety briefing when flying? **Don't.** Statistics show that folks who pay attention to the safety talk are much more likely to survive in a plane crash than those who don't. I prefer to sit near the exit row (or IN it when I can manage that) rather than towards the front of the plane. People tend to leave a space the same way they entered, so knowing alternative exit/escape pathways is always a good idea.

When staying in a hotel, I always locate the closest stairwell and count the doors between my room and the exit. In a fire, elevators are off limits: knowing where the stairwell is and being able to find it in dark, smoky conditions may save your life. I'll also find time to walk down the stairs so that I know that the exit at the bottom is unimpeded.

I never go anywhere without a good flashlight and when staying in a hotel, it's on the bedside table every night. You can buy an amazingly bright, durable LED flashlight for less than $40 at REI or from Amazon and keep it in your briefcase, purse or suitcase. The Fenix E12 has three levels of brightness, is tough, great looking and is only slightly larger than the single AA battery that powers it.

The main requirement in coping with an emergency - whether at home or away - is the right attitude. The ability to remain calm, think clearly and take prompt, decisive action are the keys to personal safety.

Apparatus Replacement Tops 2015 Agenda

Squaw Valley Fire Department plans to replace several pieces of apparatus during the coming year - providing improved reliability, lower maintenance costs and expanding operational capabilities. The two pieces of equipment will be our 'first-out' engine: a four wheel drive Type 1 pumper and our water tender. When replaced, the rigs will have been in service for 15 years and 22 years respectively, which is slightly longer than industry standard.

The Fire Department staff formed an apparatus committee which determined the needs and characteristics that would be desirable in the new pieces of equipment and has been working with several vendors to determine whether a new specification or a "tag-on" to an apparatus order placed by another department would be more appropriate. North Tahoe Fire District has several engines on order currently and their vendor offered the opportunity to order additional rigs at a somewhat reduced cost over a stand-alone order. The committee evaluated demo engines from as far away as Anchorage and has spent countless hours poring over detailed specifications and drawings. The cost for the all-wheel drive Type 1 engine is estimated at about $500,000 and the water tender at about $200,000. That's about double what the rigs being replaced cost when they were new, although the water tender was constructed in 1994 on a used chassis, which reduced the overall cost for that unit significantly.

It takes 6 to 12 months from the time an order is placed to take delivery, so look for the new engine and water tender to be in service sometime in 2016.

"We're Class 2" (and why that's good…)

We were delighted last summer when the Insurance Services Office revised the Public Protection Class for our service area from a 5/8 to a 2/2Y. The Public Protection Class rating is the metric that evaluates the capability of a fire department to address the risks specific to its service area - and, perhaps most importantly for homeowners - the primary tool for establishing insurance premiums for properties with that service area. The scale is a simple 1 to 10, with 1 being the absolute best and 10 representing basically no fire protection capability. There are close to 50,000 fire departments in the United States. Only 60 have a Public Protection Class of 1 (0.12%) and 810 fire departments have a PPC of 2 or better, placing us in the top 1.6% of fire departments in the U.S.

The good news for Squaw Valley (and this is truly *great* news from the perspective of a fire chief) is that in addition to being an wonderful achievement for a small operation such as ours, the new PPC rating may result in reduced fire insurance premiums for Squaw Valley property owners. The challenge now is to maintain - or improve - that rating and we're undertaking several initiatives to do so. Third-party testing of apparatus and equipment, improved recordkeeping and statistical analysis, documentation of virtually every aspect of the operations of our Department - these will be the key factors going forward that will allow us to demonstrate that we deserve the excellent rating that we've been assessed.

Nixle Will Keep You Informed

We continue to be excited about ***Nixle*** as a way of better communicating emergency information to our residents. The texted information and link allow us to provide rapid and effective notification to our community - it's easy to subscribe and equally easy to unsubscribe if you choose, simply text our zip code - 96146 - to 888777 on your phone - you'll receive a confirmation text immediately.

For more information, see: http://www.nixle.com/

Redundant Water Supply Planning

The Squaw Valley Public Service District continues to plan a project to provide its customers with a redundant water supply source from Martis Valley as an emergency back-up source. This plan is in pursuit to fulfill the District's mission to provide a safe, reliable water supply to our existing customers. Residents and businesses in Squaw Valley currently have only one source of water and without a backup supply, they are unacceptably vulnerable. If our sole source is compromised by extended drought or contamination, there is currently no alternative or back-up supply. Every water provider in this region has a back-up, emergency or redundant, water supply except for the Squaw Valley PSD and two other small water districts, similarly isolated from infrastructure necessary to connect our water systems.

A redundant water supply source from Martis Valley is NOT to enable new development.

It's important to the District that the facts about our plans are clearly communicated and that the public has accurate information to form opinions.

The PSD's plan to construct a redundant water supply source from Martis Valley is NOT to enable new development.

All new large development in Squaw must provide its own primary source of water; no future development is relying on a supplemental water supply from Martis Valley for its primary source of water. Careful and conservative assessments and modeling show that the proposed Village expansion has sufficient water supply from the aquifer under the land owned by the developer. To verify this, the District had its supply and demand analyses peer-reviewed by a qualified independent third party.

The District does not make land use decisions in Squaw Valley. Placer County has jurisdiction over what is approved for construction in Squaw Valley. Although supplemental water supply can induce growth, it is NOT why the District is pursuing this project; decisions to approve additional growth are made by Placer County – not the PSD.

The District is compelled to provide a safe, reliable water supply in support of public health and safety.

The PSD will NOT construct a water supply project from Martis Valley if it jeopardizes the supply needed by our companion water purveyors in Truckee or if it negatively impacts the natural environment.

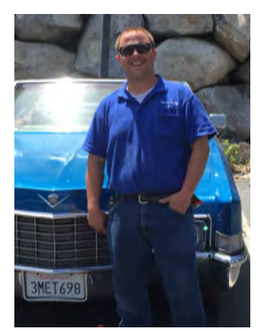
We will collaborate with partners to coordinate the project with installation of underground high speed fiber-optic cable and natural gas to homes and businesses in Squaw Valley, along with a Class 1 bike trail connection between Squaw and Truckee.

A water pipeline will allow installation of fire hydrants along the Truckee River corridor, providing significantly improved fire suppression capability for residences along the Truckee River as well as the wildland flanking the highway. Natural gas in Squaw Valley will improve public safety by eradicating propane tanks and by reducing the risk of transporting propane in / out of the valley.

The District's plan faces many challenges including funding, public outreach / education, assessment of environmental impacts, and the timing of our planning relative to the proposed Village at Squaw Valley Specific Plan. The timing of this project spurs the District to ramp-up its public outreach as groups opposed to development link the need for a redundant water supply source to the proposed Village expansion. The project pre-dates not only the proposal to expand the Village, but also the purchase of the ski area by KSL.

Phase three of the Redundant Water Supply - Preferred Alternative Evaluation is due in December, 2015. If you have any questions, comments or concerns, or need any additional information, please see our website's Current Topics page at www.svpsd.org or call us at (530) 583-4692.

SVPSD'S NEWEST TEAM MEMBER!



The District welcomes Devin Walsh to the Operations Maintenance Department's team.

Devin worked with the Northstar Community Service District as a seasonal worker for five summers and has been with the District full-time since November 2014. He moved to the Truckee area from Pittsburgh, PA in 2008 to snowboard and loves the area so much, he has decided to make this his permanent home.

We are very pleased to have Devin working with us.

2014 CONSUMER CONFIDENCE REPORT NOW AVAILABLE ONLINE

The Squaw Valley Public Service District is proud to supply safe, reliable and healthy water that meets or exceeds State and Federal public health standards for drinking water. Annually, the PSD publishes a water quality report titled "Consumer Confidence Report" as required by the State Department of Public Health to inform customers about the quality of their drinking water. This report is based on a culmination of water sample data collected throughout the year from selected sample sites. It can be accessed on our website at the following link:

http://www.svpsd.org/sites/default/files/documents/Annual_water_quality_report_2014.pdf

California State Regulators Adopt *NEW* Emergency Drought Regulations

Squaw Valley PSD Takes Steps to Comply

The District is taking action to implement restrictions on outdoor water use as required by law. Compliance is mandatory and there are provisions for penalties and fines. *With this notice, you are required to comply immediately with the mandatory regulations*.

On April 1, 2015 Governor Brown issued a Drought Executive Order which directs the State Water Resources Control Board (SWRCB) to implement mandatory water reductions across the state to reduce water usage by 25% in potable urban usage through February 2016.

On May 5, 2015 the California Department of Water Resources approved an emergency regulation to ensure water conservation. Smaller water suppliers, such as the District (serving fewer than 3,000 connections) must either reduce water use by 25 percent or restrict outdoor irrigation to no more than two days per week.

The key impacts today to District customers from the SWRCB's 2015 emergency drought regulations include:

Prohibitions for all Californians, punishable by a fine of up to $500 for each day in which each violations occurs, are:

- *Runoff when irrigating with potable water;*
- *Using hoses with no shutoff nozzles to wash cars;*
- *Using potable water to wash sidewalks and driveways;*
- *Using potable water in decorative water features that do not recirculate the water;*
- *Using outdoor irrigation during and /or 48 hours following measurable precipitation (**NEW**);*
- *Limiting outdoor irrigation to 2 days a week (**NEW**);*
- *Restaurants and other food service establishments can only serve water to customers upon request and*
- *Hotels and motels must provide guests with the option of not having towels and linens*

Please visit www.svpsd.org and keep an eye out for other outreach regarding the additional regulations.

It is important to note that, although Squaw Valley is in a drought, we are not experiencing a water supply shortage. However, we must all comply with the mandatory state emergency drought regulations and it is required that we conserve water.

The District is available to help you save water through our leak detection and conservation information. For information on the emergency drought regulations, visit ***www.svpsd.org***. For additional information, call 530.583.4692 or visit the District's office at 305 Squaw Valley Road, Olympic Valley, CA 96146.

WHAT DOES A 20% REDUCTION *in water use look like?*

OUTDOOR WATER

The average Californian uses 196 gallons of water per day and 30-60% of their water outdoors. Here are some easy outdoor tips to reduce water use. Find the right combination for you to reduce by 20% or 39 gallons a day.

USE A BROOM TO CLEAN OUTDOOR AREAS

saves

8-18 GALLONS

per minute

ADJUST SPRINKLER TO WATER PLANTS, NOT DRIVEWAY

saves

12-15 GALLONS

each time you water

USE MULCH ON SOIL SURFACE

saves

20-30 GALLONS

per 1,000 sq. ft. each time

WATER PLANTS EARLY IN THE AM

saves

25 GALLONS

each time you water

SET MOWER BLADE TO 3" (ENCOURAGES DEEPER ROOTS)

saves

16-50 GALLONS

per day

PLANT DROUGHT-RESISTANT TREES AND PLANTS

saves

30-60 GALLONS

per 1,000 sq. ft. each time

INSTALL DRIP-IRRIGATION

saves

15 GALLONS

each time you water

INSTALL A "SMART" CONTROLLER

saves

24+ GALLONS

per day

For more tips on reducing water use, visit saveourH_2O.org!

Save Our WATER

APPENDIX A

CONSTRUCTION HEALTH RISK ASSESSMENT

Prepared By:

ILLINGWORTH & RODKIN, INC.

December 2013

505 LINCOLN AVENUE RESIDENTIAL PROJECT – CONSTRUCTION HEALTH RISK ASSESSMENT SAN JOSE, CALIFORNIA

December 3, 2013

Prepared for:

Kristy Weis
David J. Powers & Associates, Inc.
1871 The Alameda, Suite 200
San Jose, California 95126

Prepared by:

James A. Reyff
and William Popenuck

ILLINGWORTH & RODKIN, INC.
Acoustics • Air Quality
1 Willowbrook Court, Suite 120
Petaluma, CA 94954
(707) 794-0400

Project 13-208

INTRODUCTION

This report provides the results of an assessment of potential health risk impacts from construction of a 190-unit residential project at 505 Lincoln Avenue in San Jose, California. The project proposes to rezone an approximately three-acre site from *IP – Industrial Park* to *PD – Planned Development* to allow for the development of up to 190 residential units. The proposed zoning would allow for buildings of up to six stories with a maximum building height of 85 feet. The conceptual site plan shows the development of a five-story (85 feet tall), 190-unit residential building. The building could be a podium structure with one level of below ground parking, parking and residential units on the first floor (the parking facilities would be located on the interior of the first floor with residential units wrapped around the exterior), and residential units on the upper four floors. A recreational courtyard with amenities, such as a pool and barbeque area, could be constructed on top of the podium (i.e., on the second floor).

Discussion of TACs

Toxic Air Contaminants (TACs) are a broad class of compounds known to cause morbidity or mortality (usually because they cause cancer or serious illness) and include, but are not limited to, criteria air pollutants. TACs are found in ambient air, especially in urban areas, and are caused by industry, agriculture, fuel combustion, and commercial operations (e.g., dry cleaners). TACs are typically found in low concentrations, even near their source (e.g., diesel particulate matter near a highway). Because chronic exposure can result in adverse health effects, TACs are regulated at the regional, state, and federal level. The identification, regulation, and monitoring of TACs is relatively new compared to that for criteria air pollutants that have established ambient air quality standards. TACs are regulated or evaluated on the basis of risk to human health rather than comparison to an ambient air quality standard or emission-based threshold.

Diesel Particulate Matter

Diesel exhaust, in the form of diesel particulate matter (DPM), is the predominant TAC in urban air with the potential to cause cancer. It is estimated to represent about two-thirds of the cancer risk from TACs (based on the statewide average). According to the California Air Resource Board (CARB), diesel exhaust is a complex mixture of gases, vapors, and fine particles. This complexity makes the evaluation of health effects of diesel exhaust a complex scientific issue. Some of the chemicals in diesel exhaust, such as benzene and formaldehyde, have been previously identified as TACs by the CARB, and are listed as carcinogens either under the State's Proposition 65 or under the federal Hazardous Air Pollutants programs. California has adopted a comprehensive diesel risk reduction program. The U.S. Environmental Protection Agency (EPA) and the CARB have adopted low-sulfur diesel fuel standards in 2006 that reduces diesel particulate matter substantially. The CARB recently adopted new regulations requiring the retrofit and/or replacement of construction equipment, on-highway diesel trucks, and diesel buses in order to lower fine particulate matter ($PM_{2.5}$) emissions and reduce statewide cancer risk from diesel exhaust.

Fine Particulate Matter ($PM_{2.5}$)

Particulate matter in excess of state and federal standards represents another challenge for the Bay Area. Elevated concentrations of $PM_{2.5}$ are the result of both region-wide (or cumulative) emissions and localized emissions. High particulate matter levels aggravate respiratory and cardiovascular diseases,

reduce lung function, increase mortality (e.g., lung cancer), and result in reduced lung function growth in children.

Sensitive Receptors

There are groups of people more affected by air pollution than others. CARB has identified the following persons who are most likely to be affected by air pollution: children under 14, the elderly over 65, athletes, and people with cardiovascular and chronic respiratory diseases. These groups are classified as sensitive receptors. Locations that may contain a high concentration of these sensitive population groups include residential areas, hospitals, daycare facilities, elder care facilities, elementary schools, and parks. For cancer risk assessments, children are the most sensitive receptors, since they are more susceptible to cancer causing TACs. Residential locations are assumed to include infants and small children. The closest sensitive receptors to the project site are existing apartments immediately west of the site. Additionally, there are residences to the south-southwest between Race and Lincoln Avenues.

TAC Thresholds of Significance

The Bay Area Air Quality Management District (BAAQMD) identified significance thresholds for exposure to TACs and $PM_{2.5}$ as part of its May 2011 *CEQA Air Quality Guidelines*[1]. This report uses the thresholds and methodologies from BAAQMD's May 2011 *CEQA Air Quality Guidelines* to determine whether there would be any project health risk impacts. This report addresses single-source (construction) impacts to nearby off-site receptors. This impact would be considered significant and mitigation would be required if:

1. An excess cancer risk level of more than 10 in 1 million, or a non-cancer (chronic or acute) hazard index greater than 1.0.
2. An incremental increase of more than 0.3 micrograms per cubic meter ($\mu g/m^3$) annual average $PM_{2.5}$.

Construction TAC Impacts

Construction activity is anticipated to include demolition of existing structures and paved areas, excavation, grading, building construction, paving and application of architectural coatings. During demolition, excavation, grading, and some building construction activities, substantial amounts of dust could be generated. Most of the dust would result during grading activities. The amount of dust generated would be highly variable and would be dependent on the size of the area disturbed at any given time, amount of activity, soil conditions, and meteorological conditions. To address fugitive dust emissions that lead to elevated PM_{10} and $PM_{2.5}$ levels near construction sites, the BAAQMD *CEQA Air Quality Guidelines* identify best control measures. If included in construction projects, these impacts will be considered less than significant.

Construction equipment and associated heavy-duty truck traffic generates diesel exhaust, which is a TAC. BAAQMD has developed screening tables for evaluating potential impacts from toxic air contaminants emitted at construction projects.[2] The screening tables are described by BAAQMD as "environmentally conservative interim guidance" and are meant to be used to identify potentially significant impacts that should be modeled using refined techniques. These screening tables indicate that construction activities similar to this project could have significant impacts at distances beyond 100 meters or 330 feet, with the primary impact being excess cancer risk. However, these screening tables are based on older construction

[1] BAAQMD, 2011. *BAAQMD CEQA Air Quality Guidelines*. May.
[2] BAAQMD. 2010. *Screening Tables for Air Toxics Evaluation During Construction*. May.

equipment that has higher emission rates and the load factors assumed were considerably higher than those recently recommended by the CARB. Since project construction activities would include demolition, excavation, grading, and building construction that would last longer than 6 months and would be located within 330 feet of residences, a more refined- level study of community risk assessment was conducted. Because the gross analysis indicated that impacts were possible, a refined analysis was conducted to evaluate whether impact would be significant, and if so, identify the project features or mitigation measures that would be necessary to avoid significant impacts in terms of community risk impacts to nearby sensitive receptors (e.g., adjacent residences).

On-Site Construction TAC Emissions

The refined health risk assessment focused on modeling on-site construction activity using construction fleet information included in the project design features. For these reasons, construction period emissions were modeled using the California Emissions Estimator Model, Version 2013.2.2 (CalEEMod) along with projected construction activity. The number and types of construction equipment and diesel vehicles, along with the anticipated length of their use for different phases of construction were based on site-specific construction activity schedules. Construction of the project is expected to occur for about 470 working days over about a twenty month period beginning in October 2014. The CalEEMod model provided total annual $PM_{2.5}$ exhaust emissions (assumed to be diesel particulate matter) for the off-road construction equipment and for exhaust emissions from on-road vehicles (haul trucks, vendor trucks, and worker vehicles), with total emissions of 0.0808 tons (161.6 pounds). The on-road emissions are a result of haul truck travel during demolition and grading activities, worker travel, and vendor deliveries during building construction. A trip length of 0.3 miles was used to represent vehicle travel while at or near the construction site. It was assumed that these emissions from on-road vehicles traveling at or near the site would occur at the construction site. Fugitive $PM_{2.5}$ dust emissions were calculated by CalEEMod as 0.0054 tons (10.8 pounds) for the overall construction period. The CalEEMod model output with emission calculations are provided in *Attachment 1*.

Dispersion Modeling

The U.S. EPA ISCST3 dispersion model was used to predict concentrations of DPM at existing sensitive receptors in the vicinity of the project site. The ISCST3 modeling utilized two area sources to represent the on-site construction emissions, one for DPM exhaust emissions and one for fugitive $PM_{2.5}$ dust emissions. To represent the construction equipment exhaust emissions, an emission release height of 6 meters was used for the area source. The elevated source height reflects the height of the equipment exhaust pipes and buoyancy of the exhaust plume. For modeling fugitive $PM_{2.5}$ emissions, a near ground level release height of 2 meters was used for the area source. Emissions from truck travel at the project site were also included in the area source for exhaust emissions. Emissions were modeled as occurring daily between 7 am - 4 pm. The model used a 5-year data set (1991 - 1995) of hourly meteorological data from the San Jose Airport available from the BAAQMD. Annual DPM concentrations from construction activities were predicted for 2014 through 2016, with the annual average concentrations based on the 5-year average concentrations from modeling 5 years of meteorological data. DPM concentrations were calculated at nearby sensitive receptors at heights of 1.5 meters (4.9 feet), 4.5 meters (14.8 feet), and 7.6 meters (24.9 feet) representative of the first three levels of the nearby residential buildings.

Cancer Risk and Hazards

The maximum-modeled DPM concentration occurred at the residence adjacent to the western boundary of the construction area at a receptor height of 4.5 meters. The location of this receptor is identified on Figure 1. Increased cancer risks were calculated using the modeled annual concentrations and BAAQMD

recommended risk assessment methods for both a child exposure (3rd trimester through 2 years of age) and for an adult exposure. Since the modeling was conducted under the conservative assumption that emissions occurred 365 days per year, the default BAAQMD exposure period of 350 days per year was used.

Results of this assessment indicate that, with project construction, the incremental child cancer risk at the maximally exposed individual (MEI) would be 8.8 in one million and the adult incremental cancer risk would be 0.6 in one million. These predicted excess cancer risks are below the BAAQMD significance threshold of 10 in one million and be considered a less than significant impact.

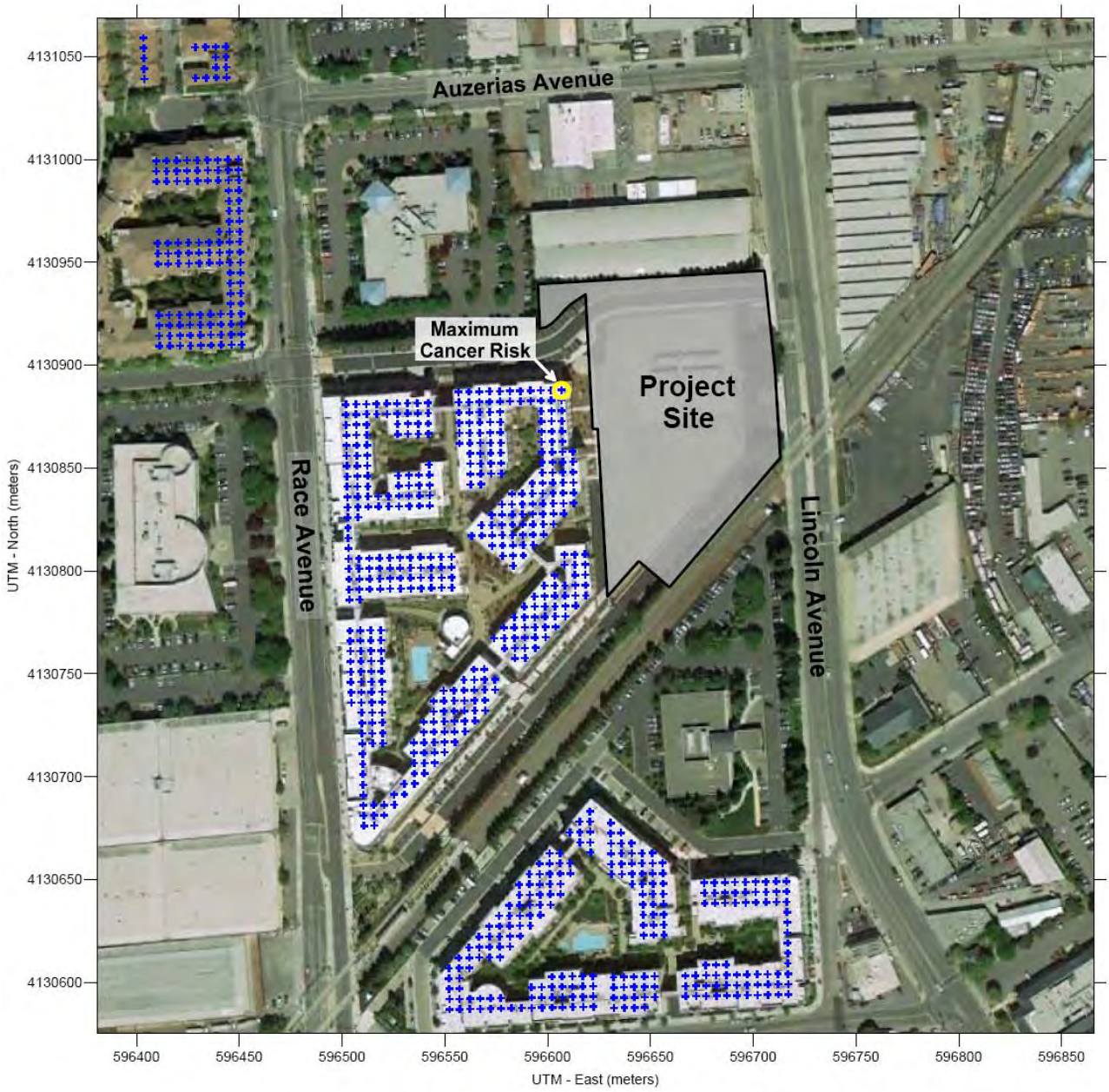
The modeled maximum annual $PM_{2.5}$ concentration was 0.07 micrograms per cubic meter ($\mu g/m^3$) occurring at the residence adjacent to the western boundary of the construction area at a height of 1.5 meters. This $PM_{2.5}$ concentration is well below the BAAQMD threshold of 0.3 $\mu g/m^3$ used to judge the significance of impacts for $PM_{2.5}$.

Potential non-cancer health effects due to chronic exposure to DPM were also evaluated. The chronic inhalation reference exposure level (REL) for DPM is 5 $\mu g/m^3$. The maximum predicted annual DPM concentration was 0.065 $\mu g/m^3$, which is much lower than the REL. The Hazard Index (HI), which is the ratio of the annual DPM concentration to the REL, is 0.013. This HI is much lower than the BAAQMD significance criterion of a HI greater than 1.0.

The project would have *a less-than-significant* impact with respect to community risk caused by construction activities.

Attachment 1 includes the emission calculations used for the area source modeling, dispersion modeling inputs, and the cancer risk calculations.

Figure 1 – Project Construction Site and Residential Receptor Locations



ATTACHMENT 1

505 Lincoln Ave, San Jose, CA - Without Mitigation
DPM Construction Emissions and Modeling Emission Rates

Construction Year	Activity	DPM (ton/year)	Area Source	DPM Emissions (lb/yr)	(lb/hr)	(g/s)	Modeled Area (m^2)	DPM Emission Rate ($g/s/m^2$)
2014	Construction	0.0095	CON_DPM	19.0	0.00577	7.27E-04	10,703	6.79E-08
2015	Construction	0.0422	CON_DPM	84.4	0.02569	3.24E-03	10,703	3.02E-07
2016	Construction	0.0292	CON_DPM	58.4	0.01778	2.24E-03	10,703	2.09E-07

Notes:
Emissions assumed to be evenly distributed over each construction areas

hr/day =	9	(7am - 4pm)
days/yr =	365	
hours/year =	3285	

505 Lincoln Ave, San Jose, CA - Without Mitigation
PM2.5 Fugitive Dust Construction Emissions for Modeling

Construction Year	Activity	Area Source	PM2.5 Emissions (ton/year)	(lb/yr)	(lb/hr)	(g/s)	Modeled Area (m^2)	DPM Emission Rate $g/s/m^2$
2014	Construction	CON_FUG	0.0025	4.9	0.00150	1.89E-04	10,703	1.76E-08
2015	Construction	CON_FUG	0.0019	3.7	0.00114	1.43E-04	10,703	1.34E-08
2016	Construction	CON_FUG	0.0011	2.2	0.00067	8.44E-05	10,703	7.88E-09

Notes:
Emissions assumed to be evenly distributed over each construction areas

hr/day =	9	(7am - 4pm)
days/yr =	365	
hours/year =	3285	

505 Lincoln Ave, San Jose, CA - Construction Impacts - Unmitigated Emissions
Maximum DPM Cancer Risk Calculations From Construction
Off-Site Residential Receptor Locations - 4.5 meters

Cancer Risk (per million) = CPF x Inhalation Dose x 1.0E6

Where: CPF = Cancer potency factor $(mg/kg\text{-}day)^{-1}$

Inhalation Dose = C_{air} x DBR x A x EF x ED x 10^{-6} / AT

Where: C_{air} = concentration in air ($\mu g/m^3$)
DBR = daily breathing rate (L/kg body weight-day)
A = Inhalation absorption factor
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
AT = Averaging time period over which exposure is averaged.
10^{-6} = Conversion factor

Values

Parameter	Child	Adult
CPF =	1.10E+00	1.10E+00
DBR =	581	302
A =	1	1
EF =	350	350
AT =	25,550	25,550

Construction Cancer Risk by Year - Maximum Impact Receptor Location

Year	Exposure Exposure Duration (years)	Child - Exposure Information DPM Conc (ug/m3) Year	Annual	Exposure Adjust Factor	Child Cancer Risk (per million)	Adult - Exposure Information Modeled DPM Conc (ug/m3) Year	Annual	Exposure Adjust Factor	Adult Cancer Risk (per million)	Fugitive PM2.5	Total PM2.5
1	1	2014	0.0145	10	1.27	2014	0.0145	1	0.07	0.0041	0.019
2	1	2015	0.0645	10	5.65	2015	0.0645	1	0.29	0.0032	0.068
3	1	2016	0.0447	4.75	1.86	2016	0.0447	1	0.20	0.0019	0.047
4	1		0.0000	3	0.00		0.0000	1	0.00		
5	1		0.0000	3	0.00		0.0000	1	0.00		
6	1		0.0000	3	0.00		0.0000	1	0.00		
7	1		0.0000	3	0.00		0.0000	1	0.00		
8	1		0.0000	3	0.00		0.0000	1	0.00		
9	1		0.0000	3	0.00		0.0000	1	0.00		
10	1		0.0000	3	0.00		0.0000	1	0.00		
11	1		0.0000	3	0.00		0.0000	1	0.00		
12	1		0.0000	3	0.00		0.0000	1	0.00		
13	1		0.0000	3	0.00		0.0000	1	0.00		
14	1		0.0000	3	0.00		0.0000	1	0.00		
15	1		0.0000	3	0.00		0.0000	1	0.00		
16	1		0.0000	3	0.00		0.0000	1	0.00		
17	1		0.0000	1.5	0.00		0.0000	1	0.00		
18	1		0.0000	1	0.00		0.0000	1	0.00		
.•	.•	.•	.•	.•	.•	.•	.•	.•	.•		
.•	.•	.•	.•	.•	.•	.•	.•	.•	.•		
.•	.•	.•	.•	.•	.•	.•	.•	.•	.•		
65	1		0.0000	1	0.00		0.0000	1	0.00		
66	1		0.0000	1	0.00		0.0000	1	0.00		
67	1		0.0000	1	0.00		0.0000	1	0.00		
68	1		0.0000	1	0.00		0.0000	1	0.00		
69	1		0.0000	1	0.00		0.0000	1	0.00		
70	1		0.0000	1	0.00		0.0000	1	0.00		
Total Increased Cancer Risk					**8.78**				**0.56**		

EDMUND G. BROWN JR.
Attorney General

State of California
DEPARTMENT OF JUSTICE

1515 CLAY STREET, 20TH FLOOR
P.O. BOX 70550
OAKLAND, CA 94612-0550

Public: (510) 622-2100
Telephone: (510) 622-2260
Facsimile: (510) 622-2121
E-Mail: Cliff.Rechtschaffen@doj.ca.gov

December 21, 2009

Dave Warner
Director of Permit Services
San Joaquin Valley Air Pollution Control District
1990 East Gettysburg Ave.
Fresno, CA 93726-0244

Re: District Policy And Guidance Document For Addressing GHG Emission Impacts under CEQA; Governing Board Meeting on Dec 17, 2009

Dear Mr. Warner:

I am writing concerning the Governing Board's meeting on December 17, 2009 at which the Board approved the District's Policy and Guidance documents for addressing Greenhouse Gas Impacts under the California Environmental Quality Act. We observed during the webcast of the Governing Board's meeting that certain representations were made by the District about our office's position on the policy, including our position in light of additions made to the policy by the District subsequent to the Board's November 5, 2009 meeting. I am writing to make clear that the Attorney General's position on the District's policy and guidance document is reflected in our November 4, 2009 letter (copy attached), and that our position has not changed since then.

Sincerely,

/s/

CLIFFORD L. RECHTSCHAFFEN
Special Assistant Attorney General

For EDMUND G. BROWN JR.
Attorney General

Attachment

Cc: Seyed Sadredin, Executive Director (w/o attachment)

EDMUND G. BROWN JR.
Attorney General

State of California
DEPARTMENT OF JUSTICE

1515 CLAY STREET, 20TH FLOOR
P.O. BOX 70550
OAKLAND, CA 94612-0550

Public: (510) 622-2100
Telephone: (510) 622-4038
Facsimile: (510) 622-2270
E-Mail: Timothy.Sullivan@doj.ca.gov

November 4, 2009

VIA E-MAIL & U.S. MAIL

Dave Warner
Director of Permit Services
San Joaquin Valley Air Pollution Control District
1990 East Gettysburg Ave.
Fresno, CA 93726-0244

RE: Final Draft Staff Report on Greenhouse Gas Emissions Under CEQA

Dear Mr. Warner:

We have reviewed the San Joaquin Valley Air Pollution Control District's September 17, 2009, Final Draft Staff Report on "Addressing Greenhouse Gas Emissions Under the California Environmental Quality Act."[1] We appreciate the Air District's extensive efforts and leadership in this area.[2] We are concerned, however, that the approaches suggested in the Staff Report will not withstand legal scrutiny and may result in significant lost opportunities for the Air District and local governments to require mitigation of greenhouse gas (GHG) emissions.

The Staff Report sets out a proposed threshold of significance for GHG emissions for stationary source projects under the Air District's permitting authority. A threshold of significance is, in effect, a working definition of significance to be applied on a project-by-project basis that can help a lead agency determine which projects normally will be determined to be less than significant, and which normally will be determined to be significant.[3] In the context of GHG emissions, the relevant question is whether the project's emissions, when considered in conjunction with the emissions of past, current, and probable future projects, are

[1] The Attorney General submits these comments pursuant to his independent power and duty to protect the natural resources of the State. (See Cal. Const., art. V., § 13; Cal. Gov. Code, §§ 12511, 12600-12612; *D'Amico v. Board of Medical Examiners* (1974) 11 Cal.3d 1, 14-15.)
[2] The Staff Report states that "[n]o state agency has provided substantial and helpful guidance on how to adequately address GHG emissions under CEQA, nor has there been guidance on how to determine if such impacts are significant." (Report at p. 2.) In fact, there are numerous sources of guidance, including information on the Attorney General's website (http://ag.ca.gov/globalwarming/ceqa.php), a Technical Advisory issued by the Governor's Office of Planning and Research (http://opr.ca.gov/ceqa/pdfs/june08-ceqa.pdf); and the Resources Agency's proposed CEQA Guidelines amendments (http://ceres.ca.gov/ceqa/guidelines/), which is accompanied by a detailed, 78-page Initial Statement of Reasons (http://ceres.ca.gov/ceqa/docs/Initial_Statement_of_Reasons.pdf).
[3] Cal. Code Regs., tit. 14, § 15064.7, subd. (a).

cumulatively considerable.[4] Thresholds can be a useful interim tool until cities and counties have in place programmatic approaches, e.g., Climate Action Plans, which allow local government to consider a wide variety of mitigation opportunities and can substantially streamline the CEQA process for individual projects.[5] Staff's proposed stationary source GHG threshold relies on implementation of GHG emission control technologies. Under this proposal, projects that implement currently unspecified GHG Best Performance Standards ("BPS") would be deemed to not have significant impacts, regardless of the total amount of GHGs emitted.

The Staff Report also recommends a threshold of significance for cities and counties to use in determining whether a development or transportation project's GHG emissions are significant under CEQA. Like the stationary source threshold, this threshold would also rely on performance measures that are not currently identified. BPS for these projects would be any combination of identified GHG reduction measures that reduce project-specific GHG emission by at least 29 percent as compared to "business as usual," as calculated based on a point system to be developed in the future by the Air District.

The Staff Report contains a useful analysis of possible GHG mitigation measures for a variety of stationary sources and for development and transportation projects. This discussion will certainly assist lead agencies and project proponents in considering what mitigation measures currently are available and should be considered. It is not clear to us, however, how much additional analysis the Air District plans to do to support the proposed CEQA thresholds of significance recommended in the Staff Report. A public agency proposing to adopt a CEQA threshold of significance should be able to answer at least the following questions about its proposed approach:

What defined, relevant environmental objective is the threshold designed to meet, and what evidence supports selection of that objective?

The Staff Report does not discuss a particular environmental objective that would be achieved by implementing the proposed thresholds, such as meeting a GHG emissions reduction trajectory consistent with that set forth in AB 32 and Executive Order S-03-05 within the Air District's jurisdiction.[6] It appears that the Air District has not yet determined what amount of

---

[4] Cal. Code Regs., tit. 14, § 15064, subd. (h)(1); see also Initial Statement of Reasons at p. 17 ("Due to the global nature of GHG emissions and their potential effects, GHG emissions will typically be addressed in a cumulative impacts analysis.")

[5] See Proposed Cal. Code Regs., tit. 14, § 15183.5, subd. (b) (describing tiering and streamlining available under "Plans for the Reduction of Greenhouse Gas Emissions"), available at http://ceres.ca.gov/ceqa/docs/FINAL_Text_of_Proposed_Amendemts.pdf; Draft Initial Statement of Reasons (discussing proposed § 15183.5) , available at http://ceres.ca.gov/ceqa/docs/Initial_Statement_of_Reasons.pdf#page=56; see also See Attorney General's General Plan/CEQA Frequently Asked Questions, available at http://ag.ca.gov/globalwarming/pdf/CEQA_GP_FAQs.pdf.

[6] Pursuant to these mandates, California is committed to reducing GHG emissions to 1990 levels by 2020, and to 80 percent below 1990 levels by 2050. These objectives are consistent with the underlying environmental objective of stabilizing atmospheric concentrations of greenhouse gases at a level that will substantially reduce the risk of dangerous climate change. (See AB 32 Scoping Plan at p. 4 ["The 2020 goal was established to be an aggressive,

GHG reduction it is aiming to achieve. Setting a relevant environmental objective is an essential step in establishing any legally defensible threshold of significance; without it, there is nothing against which to gauge the success of the threshold in operation.

What is the evidence that adopting the threshold will meet this objective?

Because the BPS discussed in the Staff Report are described as "illustrative" only, it is not possible at this time to determine whether the BPS ultimately adopted will reduce GHG emissions in the San Joaquin Valley and, if so, by how much. There is no stated commitment to tie BPS proposed in the future to regional GHG reduction objectives.

How does the threshold take into account the presumptive need for new development to be more GHG-efficient than existing development?

The Staff Report seems to assume that if new development projects reduce emissions by 29 percent compared to "business as usual," the 2020 statewide target of 29 percent below "business as usual" will also be achieved, but it does not supply evidence of this. Indeed, it seems that new development must be more GHG-efficient than this average, given that past and current sources of emissions, which are substantially less efficient than this average, will continue to exist and emit.[7]

Will the threshold routinely require new projects to consider mitigation beyond what is already required by law?

Because "business as usual" for a development project is defined by the Staff Report as what was typically done in similar projects in the 2002-2004 timeframe, and requirements affecting GHG emissions have advanced substantially since that date, it appears that the Air District's proposal would award emission reduction "points" for undertaking mitigation measures that are already required by local or state law.[8]

Similarly, we are concerned that project proponents could "game" the system. Under the current proposal, each project will be considered against a hypothetical project that could have been built on the site in the 2002-2004 time period. It is not clear why the project should be compared against a hypothetical project if that hypothetical project could not legally be built

---

but achievable, mid-term target, and the 2050 greenhouse gas emissions reduction goal represents the level scientists believe is necessary to reach levels that will stabilize climate."])

[7] We note that CAPCOA expressly found that an approach that would rely on 28 to 33 percent reductions from BAU would have a "low" GHG emissions reduction effectiveness. CAPCOA, CEQA and Climate Change (Jan. 2008) at p. 56, available at http://www.capcoa.org/CEQA/CAPCOA%20White%20Paper.pdf.

[8] To take one important example, Title 24 has undergone two updates since 2002-2004 – in 2005 and 2008. The 2008 Title 24 standards are approximately 15 percent more stringent that the 2005 version. In addition, a significant number of local governments have adopted green building ordinances that go beyond Title 24 in just the past few years, and many more are considering adopting such ordinances as part of their Climate Action Plans. See http://ag.ca.gov/globalwarming/pdf/green_building.pdf.

today,[9] and the approach would appear to offer an incentive to project proponents to artificially inflate the hypothetical project to show that the proposed project is, by comparison, GHG-efficient.[10]

Will operation of the threshold allow projects with large total GHG emissions to avoid environmental review? What evidence supports such a result?

It appears that any project employing certain, as of yet unidentified, mitigation measures would be considered to not be significant, regardless of the project's total GHG emissions, which could be very large. For instance, under the Air District's proposal, it would appear that even a new development on the scale of a small city would be considered to not have a significant GHG impact and would not have to undertake further mitigation, provided it employs the specified energy efficiency and transportation measures. This would be true even if the new development emitted hundreds of thousands of tons of GHG each year, and even though other feasible measures might exist to reduce those impacts.[11] The Staff Report has not supplied scientific or quantitative support for the conclusion that such a large-emitting project, even if it earned 29 "points," would not have a significant effect on the environment.

Will the threshold benefit lead agencies in their determinations of significance?

For the reasons set forth above, we fear that the recommended approach in its current form may unnecessarily subject lead agencies that follow them to CEQA litigation. This would be detrimental not only to the lead agencies, but to the many project proponents who may face unnecessary delay and legal uncertainty.[12]

---

[9] The appropriate baseline under CEQA is not a hypothetical future project, but rather existing physical conditions. (Cal. Code Regs., tit. 14, § 15126.2, subd. (a).)

[10] A detailed analysis of the proposed amendments to Rule 2301 (emissions reduction credit banking) is beyond the scope of this letter. It is important, however, that any such plan comply with CEQA's requirements for additionality. As the most recent draft of the proposed CEQA Guidelines notes, only "[r]eductions in emissions that are not otherwise required may constitute mitigation pursuant to this subdivision." Proposed Cal. Code Regs., tit. 14, § 15126.4, subd. (c), available at http://ceres.ca.gov/ceqa/docs/Text_of_Proposed_Changes.pdf.

[11] In the advance of a programmatic approach to addressing GHG emissions, lead agencies must examine even GHG-efficient projects with some scrutiny where total emissions are large. Once a programmatic approach is in place, the lead agency will be able to determine whether even a larger-emitting project is, or is not, consistent with the lead agency's overall strategy for reducing GHG emissions. If it is, the lead agency may be able to determine that its incremental contribution to climate change is not cumulatively considerable.

[12] The Staff Report states that "[l]ocal land-use agencies are facing increasing difficulties in addressing GHG emissions in their efforts to comply with CEQA." (Report at p. 2.) We strongly believe that this experience is not universal. In fact, many cities and counties are actively taking up their role as "essential partners" in addressing climate change (see AB 32 Scoping Plan at p. 26) by making commitments to develop local Climate Action Plans.

We support staff's continued work in this area. However, before formally endorsing or adopting any particular threshold, we recommend that the Air District consider the issues that we have raised in this letter; if warranted, evaluate the approaches currently under consideration by other districts; and, if possible, work with those districts to devise approaches that are complementary and serve CEQA's objectives.

Sincerely,

/ s /

TIMOTHY E. SULLIVAN
Deputy Attorney General

For EDMUND G. BROWN JR.
Attorney General

CALIFORNIA NATURAL RESOURCES AGENCY

FINAL STATEMENT OF REASONS FOR REGULATORY ACTION

Amendments to the State CEQA Guidelines Addressing Analysis and Mitigation of Greenhouse Gas Emissions Pursuant to SB97

December 2009

find it difficult to demonstrate a good faith effort through a purely qualitative analysis. (See, e.g., *Berkeley Keep Jets Over the Bay Com. v. Board of Port Comm.* (2001) 91 Cal.App.4th 1344, 1370.)

In the context of Project 1, however, a qualitative analysis would likely be appropriate. Project 1's emissions are not easily modeled, and the Project is small in scale. While it may be technically possible, quantification of the emissions may not reveal any additional information that indicates the significance of those emissions or how they may be reduced that could not be provided in a qualitative assessment of emissions sources. (See, e.g., Public Resources Code, § 21003(f) ("public agencies involved in the environmental review process be responsible for carrying out the process in the most efficient, expeditious manner in order to conserve the available financial, governmental, physical, and social resources with the objective that those resources may be better applied toward the mitigation of actual significant effects on the environment").)

Factors Potentially Indicating Significance

The qualitative factors listed in the proposed section 15064.4(b) are intended to assist lead agencies in collecting and considering information relevant to a project's incremental contribution of GHG emissions and the overall context of such emissions. Notably, while subdivision (b) provides a list of factors that should be considered by public agencies in determining the significance of a project's GHG emissions, other factors can and should be considered as appropriate.

Determine Whether Emissions Will Increase or Decrease

The first factor in subdivision (b), for example, asks lead agencies to consider whether the project will result in an increase or decrease in different types of GHG emissions relative to the existing environmental setting. All project components, including construction and operation, equipment and energy use, and development phases must be considered in this analysis. (State CEQA Guidelines, § 15378 (project includes "the whole of the action").) For example, a mass transit project may involve GHG emissions during its construction phase, but substantial evidence may also indicate that it will cause existing commuters to switch from single-occupant vehicles to mass transit use. Operation of such a project may ultimately result in a decrease in GHG emissions. Such analysis, provided that it is supported with substantial evidence and fully accounts for all project emissions, may support a lead agency's determination that GHG emissions associated with a project are not cumulatively considerable.

This section's reference to the "existing environmental setting" reflects existing law requiring that impacts be compared to the environment as it currently exists. (State CEQA Guidelines, § 15125.) This clarification is necessary to avoid a comparison of the project against a "business as usual" scenario as defined by ARB in the Scoping Plan. Such an approach would confuse "business as usual" projections used in ARB's Scoping Plan with CEQA's separate requirement of analyzing project effects in

comparison to the environmental baseline. (*Compare* Scoping Plan, at p. 9 ("The foundation of the Proposed Scoping Plan's strategy is a set of measures that will cut greenhouse gas emissions by nearly 30 percent by the year 2020 as compared to business as usual") *with Fat v. County of Sacramento* (2002) 97 Cal.App.4th 1270, 1278 (existing environmental conditions normally constitute the baseline for environmental analysis); see also *Center for Bio. Diversity v. City of Desert Hot Springs*, Riverside Sup. Ct. Case No. RIC464585 (August 6, 2008) (rejecting argument that a large subdivision project would have a "beneficial impact on CO2 emissions" because the homes would be more energy efficient and located near relatively uncongested freeways).) Business as usual may be relevant, however, in the discussion of the "no project alternative" in an EIR. (State CEQA Guidelines, § 15126.6(e)(2) (no project alternative should describe what would reasonably be expected to occur in the future in the absence of the project).)

Notably, section 15064.4(b)(1) is not intended to imply a zero net emissions threshold of significance. As case law makes clear, there is no "one molecule rule" in CEQA. (CBE, *supra*, 103 Cal.App.4th at 120.)

Thresholds of Significance

The second factor in subdivision (b) asks whether a project exceeds a threshold of significance for GHG emissions. Section 21000(d) of the Public Resources Code expressly directs public agencies to identify whether there are any critical thresholds for health and safety to identify those areas where the capacity of the environment is limited. A threshold is an "identifiable quantitative, qualitative or performance level" at which impacts are normally less than significant. (State CEQA Guidelines, § 15064.7(a); *see also Protect the Historic Amador Waterways*, *supra*, 116 Cal.App.4th at 1107.) Lead agencies may rely on thresholds developed by other agencies that have particular expertise in the subject matter under consideration. (*See*, *e.g.*, State CEQA Guidelines, Appendix G, Sample Question III ("[w]here available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make" a significance determination).) For example, a lead agency may look to standards included in a Basin Plan to assist in the determination of whether water quality impacts are significant. (*Protect the Historic Amador Waterways*, *supra*, 116 Cal.App.4th at 1107 ("[s]uch thresholds can be drawn from existing environmental standards, such as other statutes or regulations").)

Several agencies have developed, or are in the process of developing, thresholds of significance for GHG emissions.[3] For example, thresholds are currently being developed, or have already been adopted by the Bay Area Air Quality Management District for operations and construction,[4] the City of Davis for residential

[3] Reference to these thresholds and proposed thresholds does not reflect an endorsement of those thresholds; rather, they are cited solely for the purpose of demonstrating that agencies are developing such thresholds.
[4] BAAQMD CEQA Guidelines Update: work in progress - http://www.baaqmd.gov/pln/ ceqa/index.htm.

6 GREENHOUSE GAS EMISSIONS

6.1 INTRODUCTION

The California Environmental Quality Act (CEQA) requires that lead agencies consider the reasonably foreseeable adverse environmental effects of projects they are considering for approval. Greenhouse gas (GHG) emissions adversely affect the environment through contributing, on a cumulative basis, to global climate change. In turn, global climate change will increase sea levels, which can inundate low-lying areas; affect rain and snow fall, leading to changes in water supply; and increase temperatures, leading to adverse effects on habitats and biological and other resources. Thus, GHG emissions require consideration in CEQA documents.

Climate change is a global problem. GHGs are global pollutants, unlike CAPs and TACs, which are pollutants of regional and local concern. Whereas pollutants with localized air quality effects have relatively short atmospheric lifetimes (about 1 day), GHGs have long atmospheric lifetimes (1 year to several thousand years). GHGs persist in the atmosphere for long enough time periods to be dispersed around the globe. Similarly, the effects of GHGs are also borne globally. The atmospheric concentration of GHGs determines the intensity of climate change, with current levels already leading to increases in global temperatures, sea level rise, severe weather, and other environmental impacts. The continued increase in atmospheric GHG concentrations will only worsen the severity and intensity of climate change, locking in perhaps irrevocable environmental changes. Therefore, from the standpoint of CEQA, GHG impacts to global climate change are inherently cumulative.

Prominent GHGs of primary concern from land use development projects include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Other GHGs such as hydrofluorocarbons, chlorofluorocarbons, and sulfur hexafluoride are of less concern because construction and operational activities associated with land use development projects are not likely to generate substantial quantities of these GHGs.

Land use development projects typically include the following sources of GHG emissions:

- Construction activities resulting in exhaust emissions of GHGs from fuel combustion for mobile heavy-duty diesel- and gasoline-powered equipment, portable auxiliary equipment, material delivery trucks, and worker commuter trips;
- Motor vehicle trips generated by the particular land use (i.e. vehicles arriving and leaving the project site), including those by residents, shoppers, workers, and vendors;

- Onsite fuel combustion for space and water heating, landscape maintenance equipment, and fireplaces/stoves; and
- Offsite emissions at utility providers associated with the project's demand for electricity, water conveyance, and wastewater processing.

Generally, the District believes that GHG emissions are best analyzed and mitigated at the program-level; however, until more program-level GHG analyses have been performed in Sacramento County, the District offers the guidance contained in this chapter for addressing the GHG emissions associated with individual development projects. Please refer to Chapter 9, Program Level Analysis of Plans, for recommendations for assessing and mitigating GHG emissions-related impacts at the program-level.

The guidance presented in this chapter takes into consideration the following bodies of work produced by other agencies and organizations in the state:

- California Air Pollution Control Officers Association's (CAPCOA) white paper titled *CEQA & Climate Change: Evaluating and Addressing Greenhouse Gas Emissions from Projects Subject to the California Environmental Quality Act* (January 2008);
- California Air Resources Board's (ARB) *Climate Change Scoping Plan* (December 2008, re-approved August 24, 2011);
- ARB's *First Update to the Climate Change Scoping Plan* (May 2014);
- Governor's Office of Planning and Research's (OPR) technical advisory, *CEQA and Climate Change: Addressing Climate Change through California Environmental Quality Act Review* (June 2008);
- The California Natural Resources Agency's CEQA Guidelines;
- California Air Pollution Control Officers Association's (CAPCOA) white paper titled Model Policies for Greenhouse Gases in General Plans (June 2009); and
- California Air Pollution Control Officers Association's (CAPCOA) *Quantifying Greenhouse Gas Mitigation Measures* (August 2010).

In November 2008, Governor Arnold Schwarzenegger issued Executive Order S-13-08 to enhance the state's management of climate impacts from sea level rise, increased temperatures, shifting precipitation, and extreme weather events. The Executive Order directs the state agencies to request that the National Academy of Sciences convene an independent panel to complete the first California Sea Level Rise Assessment Report. The agencies involved in the project include the California Resources Agency; the Department of Water Resources; the California Coastal Commission; the California Ocean Protection Council; California State Parks; and the California Energy Commission (CEC). The Executive Order directs OPR to provide state land-use planning guidance related to sea level rise and other

climate change impacts. Therefore, the District recommends that lead agencies address the impacts of climate change on a proposed project and its ability to adapt to these changes in CEQA documents. It is anticipated that guidance on addressing this issue will be provided by the state agencies identified above and not the District. OPR's website contains resources and links related to adaptation. Additional resources include the California Climate Change Portal, Safeguarding California, and Cal-Adapt. The District acknowledges that the warming trends associated with climate change in the Sacramento region are expected to result in more episodes of unhealthy levels of ground-level ozone that will adversely affect residents and workers of proposed projects. Nevertheless, the primary focus of this chapter is to provide guidance about evaluating whether the GHG emissions associated with a proposed project will be responsible for making a cumulatively considerable contribution to global climate change.

Evolving Regulatory Setting

In September 2006, Governor Arnold Schwarzenegger signed Assembly Bill (AB) 32, the California Global Warming Solutions Act of 2006. AB 32 establishes regulatory, reporting, and market mechanisms to achieve quantifiable reductions in GHG emissions and a cap on statewide GHG emissions. AB 32 requires that statewide GHG emissions be reduced to 1990 levels by 2020. AB 32 also includes guidance to institute emission reductions in an economically efficient manner and conditions to ensure that businesses and consumers are not unfairly affected by the reductions. AB 32 demonstrates California's commitment to reducing the rate of GHG emissions and the state's associated contribution to climate change, without intent to limit population or economic growth.

CEQA requires lead agencies to identify the potentially significant effects on the environment of projects they intend to carry out or approve, and to mitigate significant effects whenever it is feasible to do so. Although AB 32 did not amend CEQA, it identifies the myriad environmental problems in California caused by global warming (Health and Safety Code, Section 38501(a)).

Senate Bill (SB) 97, enacted in 2007, amended the CEQA statute to establish that GHG emissions and their effects are a prominent environmental issue that requires analysis and identification of feasible mitigation under CEQA. GHG was included in the CEQA Guidelines on March 18, 2010.

In June of 2008, OPR published a technical advisory, entitled "CEQA and Climate Change: Addressing Climate Change through California Environmental Quality Act Review." OPR recommends that the lead agencies under CEQA make a good-faith effort, based on available information, to estimate the quantity of GHG emissions that will be generated by a proposed project, including the emissions associated with vehicular traffic, energy consumption, water usage, and construction activities, to determine whether the impacts have the potential to result in a project or cumulative impact and to mitigate the impacts where feasible. In that document, OPR acknowledged that "perhaps the most difficult part of the climate change analysis will be the determination of significance," and noted that "OPR

has asked the California Air Resources Board (ARB) technical staff to recommend a method for setting thresholds which will encourage consistency and uniformity in the CEQA analysis of GHG emissions throughout the state." To date, ARB has not adopted thresholds.

In December 2008, ARB adopted its Climate Change Scoping Plan (*Scoping Plan*), which is the State's plan to achieve GHG reductions in California required by AB 32. The *Scoping Plan* includes ARB-recommended GHG reductions for each emission sector of the state's GHG inventory. The largest proposed GHG reductions are recommended from improving emission standards for light-duty vehicles , implementation of the Low-Carbon Fuel Standard, energy efficiency measures in buildings and appliances and the widespread development of combined heat and power systems, and a renewable portfolio standard for electricity production. ARB has not determined what statewide reduction in GHG emissions shall be achieved from changes in local government (municipal) operations; however, the *Scoping Plan* does state that land use planning and urban growth decisions will play an important role in the state's GHG reductions because local governments have primary authority to plan, zone, approve, and permit how land is developed to accommodate population growth and the changing needs of their jurisdictions. ARB further acknowledges that decisions on how land is used will have large impacts on the GHG emissions that will result from the transportation, housing, industry, forestry, water, agriculture, electricity, and natural gas emission sectors. The *Scoping Plan* was re-approved by the ARB on August 24, 2011, after ARB updated its Functional Equivalent Document. ARB adopted the First Update to the Climate Change Scoping Plan on May 22, 2014. The update reports on the progress made towards meeting the 2020 GHG reduction goals; lays groundwork for longer term reduction goals; and discusses opportunities to leverage funds to drive additional GHG reductions.

In addition, SB 375, signed in September 2008, aligns regional transportation planning efforts, regional GHG reduction targets, and land use and housing allocations. SB 375 requires Metropolitan Planning Organizations (MPOs) to adopt a Sustainable Communities Strategy (SCS) or Alternative Planning Strategy (APS), which will prescribe land use allocations in that MPO's Regional Transportation Plan (RTP). On April 19, 2012, SACOG adopted its 2035 Metropolitan Transportation Plan and associated SCS to meet the requirements of SB 375. Please refer to Chapter 9 for further detail on SB 375.

6.2 ANALYSIS EXPECTATIONS

The District recommends that CEQA analyses addressing the potential impacts of project-generated GHG emissions include the following:

- A summary of the current state of the science with respect to GHGs and climate change (The Intergovernmental Panel on Climate Change and the U.S. Global Change Research Program provide good resources.);

- A description of the existing environmental conditions or setting, without the project, which constitutes the baseline physical conditions for determining the project's impact;
- A discussion of the existing regulatory environment pertaining to GHGs;
- Identification of the thresholds of significance applicable to the proposed project. The District provides recommended thresholds for agencies without adopted GHG reduction plans (climate action plans) or their own adopted thresholds;
- A discussion of the GHG emission sources associated with the project's construction and operational activities;
- Identification of the earliest year in which operational emissions of GHGs are anticipated to commence;
- A quantification of the annual and finite mass emissions of GHGs that will be generated by project construction, and the input parameters and assumptions used to estimate these values;
- A quantification of the annual mass emissions of GHGs that will be generated by project operations, and the input parameters and assumptions used to estimate these values:
    - If comparing to the District's recommended operational threshold, the quantification should show emissions from the first fully operational year,
    - If demonstrating a 21.7% reduction consistent with the ARB Scoping Plan, the quantification should show emissions in 2020 as a No Action Taken scenario and emissions in 2020 including all state measures and project-specific mitigation measures;
- A discussion of whether project construction- and operations-related GHG emissions will exceed the established significance threshold and the resulting determination of whether the construction and operational GHG emissions, without mitigation, will represent a cumulatively considerable contribution to the significant cumulative impact; and
- A discussion of feasible construction and operational mitigation necessary to reduce impacts and make a determination whether the mitigation will be sufficient to reduce the project's GHG contribution to the significant cumulative impact to a less-than-considerable level.

6.3 METHODOLOGIES

The evaluation of GHG emissions pertains to the following questions regarding "Greenhouse Gas Emissions" from the Environmental Checklist Form (Appendix G) of the State CEQA Guidelines:

VII.a. Will the project generate GHG emissions, either directly or indirectly, that may have a significant impact on the environment?

VII.b. Will the project conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of GHGs?

The State CEQA Guidelines indicate that a lead agency shall make a good faith effort, based on available information, to describe, calculate, or estimate the amount of GHG emissions resulting from a project. The guidelines give the lead agency the discretion to select the most appropriate tools based on substantial evidence. The District's recommendations on appropriate methodology and tools for analyzing GHG emissions are provided below.

6.3.1 ASSESSING MASS EMISSIONS

LAND USE DEVELOPMENT PROJECTS

Screening

The District assumes that projects described in CEQA's categorical and statutory exemption provisions (Articles 18 and 19 of the California Code of Regulations, Title 14) will not interfere with achieving emission reductions from new projects subject to CEQA. The District also assumes that GHG emissions from residential and commercial projects that are described in the categorical exemption language appear to be relatively small from a GHG perspective and may be considered less-than-cumulatively considerable.

CEQA Guidelines Section 15183.5 (search Title 14, CA Code of Regulations) includes the provision for tiering and streamlining the analysis of GHG emissions in CEQA documents. Under this provision, lead agencies may analyze and mitigate the effects of GHG emissions at a programmatic level, such as in a general plan, a long range development plan, or a separate plan to reduce GHG emissions such as a Climate Action Plan developed by a local jurisdiction or a sustainable communities strategy developed by the metropolitan planning organization. Later project-specific CEQA documents may tier and/or incorporate by reference that existing programmatic review if the proposed project is consistent with the applicable regional or local plan that adequately addresses GHG emissions, and that that plan has been evaluated pursuant to CEQA and has a certified or approved environmental document. More guidance on program-level GHG emissions analysis is included in Chapter 9.

Pursuant to CEQA Guidelines Sections 15064(h)(3) and 15130(d) (search Title 14, CA Code of Regulations), a lead agency may determine that a project's incremental contribution to a cumulative effect is not cumulatively considerable if the project complies with the requirements in a previously adopted plan or mitigation program under specified circumstances. CEQA Guidelines Section 15183.5(b)(2) provides additional detail regarding use of an adopted GHG emissions reduction plan with later projects.

The District has developed screening levels to help lead agencies analyze operational GHG emissions from projects in Sacramento County. The GHG Operational Screening Levels table represents the size of development by land use type at which the District's operational GHG emissions thresholds of significance would not be exceeded. Therefore, emissions from the operation of projects that are below the screening levels presented in the table may be considered less-than-cumulatively considerable.

Quantification of GHG Emissions

CEQA is a public disclosure law that requires lead agencies to make a good faith, reasoned effort, based upon available information, to identify the potentially significant direct and indirect environmental impacts - including cumulative impacts - of a proposed project. For proposed projects that do not meet the requirements of a categorical or statutory exemption; cannot show consistency with the jurisdiction's adopted GHG reduction plan (if applicable); or exceed the screening levels in the GHG Operational Screening Levels table, the District recommends that lead agencies quantify the GHG emissions anticipated to be generated by the project. Direct and indirect emissions of GHGs from the project, which include construction emissions, area- and mobile-source emissions, and indirect emissions from in-state energy production and water consumption (energy for conveyance, treatment, distribution, and wastewater treatment), shall be quantified and disclosed in the CEQA document. The annual and total amount of a project's construction-related GHG emissions and the operational GHG emissions generated per year over the lifetime of the project shall be disclosed separately. The *California Emissions Estimator Model* (CalEEMod) is the recommended analysis tool to quantify project GHG emissions.

Construction Emissions

District-recommended methodologies for quantifying construction GHG emissions include using CalEEMod for proposed land use development projects and the Roadway Construction Emissions Model for proposed projects that are linear in nature.

Please note that sources of construction-related GHG emissions only include exhaust, for which the lead agency can follow the same detailed guidance as described in Chapter 3, Construction-Generated Criteria Air Pollutant and Precursor Emissions for criteria air pollutants and precursors. CalEEMod output for

construction-related GHG emissions shall be disclosed in the CEQA document and treated as a net increase in emissions.

For linear construction projects such construction of a new roadway, road widening, roadway overpass, levees, or pipelines, the District recommends the use of the most recent version of the Roadway Construction Emissions Model. The Roadway Construction Emissions Model is a spreadsheet-based model able to use basic project information (e.g., total construction months, project type, total project area) to estimate a construction schedule and quantify GHG emissions from heavy-duty construction equipment, haul trucks, and worker commute trips associated with linear construction projects. Lead agencies shall refer to Chapter 3 for guidance on using the Roadway Construction Emissions Model. The Roadway Construction Emissions Model reports the emissions output in tons per construction project. To enable comparison to the SMAQMD's threshold, the emissions need to be estimated in tons per year. Additionally, lead agencies shall convert the Roadway Construction Emissions Model outputs from English tons to metric tons by multiplying by 0.91.

Operational Emissions

Operational GHG emissions for a project should be calculated for the first full year of operations to compare to the GHG operational threshold of 1,100 metric tons per year. Direct and indirect emissions from the project shall be estimated using the most recent version of CalEEMod in accordance with the CalEEMod User's Guide and the District's User Tips. The District generally recommends using the default values in CalEEMod if detailed information about the project is not known at the time of analysis, but encourages the use of project-specific information whenever possible. Lead agencies shall report the project's annual GHG emissions in units of metric tons of carbon dioxide equivalent (CO_2e) in the CEQA document.

Please note that sources of operational-related GHGs do not include all the operational categories discussed in Chapter 4, Operational Criteria Air Pollutant and Precursor Emissions; however, the lead agency can follow the same detailed guidance as described in Chapter 4 for CAPs and precursors for quantifying GHGs.

If project emissions exceed the GHG operational threshold, the project would calculate emissions for the fully mitigated project scenario in 2020, and the no action taken project scenario in 2020 (absent project mitigation and state reduction measures). The District provides technical guidance to conduct this analysis: Quantification of GHG Emissions for Transportation Activities and Quantification of GHG Emissions for Non-Transportation Activities. The results of the analysis will measure emission reductions from the project and demonstrate consistency with AB 32 and ARB Scoping Plan reduction goals. Adequate mitigation levels and measures are fully described in Section 6.4, Mitigation.

STATIONARY-SOURCE FACILITIES

An emissions unit consists of a single emission source with an identified emission point, such as a stack, at a facility. Facilities can have multiple emission units

located on-site and sometimes the facility as a whole is referred to as a "stationary source." Stationary sources are typically associated with industrial processes. Examples include boilers, heaters, flares, cement plants, and other types of combustion equipment.

AB 32 requires ARB to adopt regulations that require the monitoring and annual reporting of GHG emissions from the sources that "contribute the most to statewide emissions", and account for the GHG emissions from all electricity consumed in California, including transmission and distribution line losses from electricity generated within the state or "imported from outside the state." Pursuant to AB 32, ARB adopted the Greenhouse Gas Mandatory Reporting Regulation in December 2007. The regulations require certain stationary sources, including, but not limited to, cement plants, petroleum refineries, and operators, retail providers and marketers involved in electric generation within California or the import or export of electricity across California borders, to comply with monitoring and reporting guidelines associated with their GHG emissions. The rule also applies to operators of other facilities in California that emit greater than or equal to 25,000 metric tons CO_2/year from stationary combustion sources.

GHG Emissions Reporting Tool

The California Electronic Greenhouse Gas Reporting Tool, or Cal e-GGRT, is a web-based annual reporting tool managed by ARB. The tool facilitates tracking and reporting of annual data required under the ARB Mandatory Reporting Regulation. It provides for the assignment of reporting personnel, set-up of source inventory information, and annual reporting of emissions and other data in a manner that directly addresses the requirements of the regulation. Additional elements of the same tool provide for tracking and certification of emission reports and data verification by third-party verifiers. Reporters subject to California's Greenhouse Gas Mandatory Reporting Regulation must submit their data to ARB using Cal e-GGRT. The Reporting Tool can be used to disclose a stationary source's GHG emissions in a CEQA document.

Manual Estimation

Stationary source GHG emissions may be estimated manually. District staff should be consulted to ensure the emission factors and calculation methods are appropriate for CEQA and permitting purposes.

6.3.2 Determining Level of Significance

Land Use Development Projects

AB 32 demonstrates California's commitment to reducing GHG emissions and the state's associated contribution to climate change, without intent to limit population or economic growth within the state. To meet AB 32 goals, California will need to reduce GHG emissions to 1990 levels by 2020. The District recognizes, however, that although there is no known level of emissions that determines if a single project will substantially impact overall GHG emission levels in the

atmosphere, a threshold must be set to trigger a review and assessment of the need to mitigate project GHG emissions. Recommended thresholds were developed to ensure at least 90 percent of new GHG emissions would be reviewed and assessed for mitigation, thereby contributing to GHG emissions reduction goals of AB 32 and the Scoping Plan.

Lead agencies shall compare the project's estimated GHG emissions to the District's recommended thresholds of significance for construction, operational, and stationary source emissions:

- Construction phase of projects - 1,100 metric tons of CO2e per year.
- Operational phase of a land development project - 1,100 metric tons of CO2e per year.
- Stationary source projects - 10,000 metric tons of CO2e per year.

If a project's emissions exceed the thresholds of significance, then the project emissions may have a cumulatively considerable contribution to a significant cumulative environmental impact, answering Appendix G's first GHG-related question on whether the project would generate GHG emissions, either directly or indirectly, that may have a significant impact on the environment.

For projects that exceed the District's threshold of significance, lead agencies shall implement all feasible mitigation to reduce GHG emissions.

The second GHG-related question in Appendix G asks if the project will conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of GHGs. In order to answer this question, project emissions should be evaluated with respect to consistency with the following plans that have been adopted to reduce GHG emissions:

- AB 32 and the Scoping Plan, and
- The Metropolitan Transportation Plan/Sustainable Communities Strategy (MTP/SCS).

The District's recommended thresholds and mitigation measures were developed to show consistency with AB 32 and the Scoping Plan. The Sacramento Area Council of Governments provides a consistency worksheet for comparison to the MTP/SCS.

Construction Emissions

Lead agencies shall estimate and present a project's construction GHG emissions on an annual basis. Lead agencies shall compare the project's annual construction GHG emissions to the District's 1,100 metric ton per year threshold of significance. If the threshold is exceeded, then the project may have a cumulatively considerable contribution to a significant cumulative environmental impact, and all feasible mitigation is required.

Operational Emissions

Lead agencies shall estimate and present a project's operational GHG emissions on an annual basis. Lead agencies shall compare the project's annual operational GHG emissions to the District's 1,100 metric ton per year threshold of significance. If the threshold is exceeded, then the project may have a cumulatively considerable contribution to a significant cumulative environmental impact, and all feasible mitigation is required.

STATIONARY SOURCE FACILITIES

Lead agencies shall compare the stationary source project's annual direct operational GHG emissions to the District's 10,000 metric ton per year threshold of significance for stationary sources. If the project's annual direct GHG emissions will exceed the District's threshold of significance, then the project may have a cumulatively considerable contribution to a significant cumulative environmental impact. Additionally, the GHG emissions from the construction of a stationary source shall be compared to the 1,100 metric ton per year construction threshold of significance.

Stationary source GHG emissions shall also be evaluated in the context of the applicable regulatory environment that is in place under the mandate of AB 32, and ARB's Scoping Plan. Over time, implementation of AB 32 will reduce or mitigate GHG emissions from industrial sources.

6.4 MITIGATION

The State CEQA Guidelines Section 15126.4(c) (search Title 14, CA Code of Regulations) requires lead agencies to consider feasible means of mitigating GHG emissions that may include, but not be limited to:

1. Measures in an existing plan or mitigation program for the reduction of emissions that are required as part of the lead agency's decision in which the plan or program provides specific requirements that will avoid or substantially lessen the potential impacts of the project;

2. Reductions in emissions resulting from a project through implementation of project features, project design, or other measures, such as those described in CEQA Guidelines Appendix F - Energy Conservation (search Title 14, CA Code of Regulations);

3. Off-site measures, including offsets, to mitigate a project's emissions;

4. Measures that sequester greenhouse gases; and

5. In the case of the adoption of a plan, such as a general plan, long range development plan, or GHG reduction plan, mitigation may include the identification of specific measures that may be implemented on a project-by-project basis. Mitigation may also include the incorporation of specific

measures or policies found in an adopted ordinance or regulation that reduces the cumulative effect of emissions.

GHG mitigation measures could also be included in a Climate Action Plan or similar plan-level document adopted by a lead agency.

The lead agency must impose all mitigation measures that are necessary to reduce GHG emissions to a less-than-cumulatively considerable level. CEQA does not require mitigation measures that are infeasible for specific legal, economic, technological, or other reasons. A lead agency is not responsible for wholly eliminating all GHG emissions from a project; the CEQA standard is to mitigate to a level that is "less than significant" or, in the case of cumulative impacts, less than cumulatively considerable.

Along with the recommended thresholds of significance, the District provides that a 21.7 percent reduction of GHG emissions is adequate mitigation and shows consistency with AB 32 and ARB Scoping Plan GHG reduction goals.

For every GHG emission reduction measure included in a CEQA document, the District recommends that the text shall be as detailed as possible and shall clearly identify who is responsible for implementation, funding, monitoring, enforcement, and any required maintenance activities. The lead agency shall also explain why the measure will be effective in reducing emissions and why each measure is considered to be feasible. In the case that GHG emission reduction measures relate directly or indirectly to policies in the local jurisdiction's General Plan, the District encourages the explanation of these relationships also be included.

If, after the identification of all feasible mitigation measures, a project is still deemed to have a cumulatively considerable contribution to a significant cumulative environmental impact, the lead agency can approve a project, but must adopt a Statement of Overriding Consideration to explain why further mitigation measures are not feasible, and why approval of a project with significant unavoidable impacts is warranted.

6.4.1 Reducing Mass Emissions from Land Use Development Projects

When a lead agency does not have a previously approved community-wide GHG Reduction Plan or Climate Action Plan from which it could tier subsequent CEQA analyses for land use development projects and project GHG emissions exceed the thresholds of significance, the District recommends the project proponent develop a project-specific GHG Reduction Plan describing how the project will reduce GHG emissions to a minimum 21.7 percent from a no action taken scenario for the operational phase of the project. Mitigating construction emissions by 21.7 percent from a project that exceeds the threshold of significance is also described.

Construction Emissions

The District provides Recommended Measures for Reducing GHG emissions from construction activities. These measures are best management practices, and some do not produce easily quantifiable GHG emission reductions. Other options for reducing GHG emissions from construction activities include obtaining emission reduction offsets or amortizing the construction emissions along with the operational emissions prior to applying mitigation.

Lead agencies may decide to amortize the level of short-term construction emissions over the expected (long-term) operational life of a project. Operational life of a building can be estimated to be 40 years for new residential and 25 years for conventional commercial. These estimates are derived from the State of California Executive Order D-16-00 and US Green Building Council's October 2003 report on The Costs and Financial Benefits of Green Buildings. The US Green Building Council's report provides longer operational life estimates for LEED certified buildings.

Operational Emissions

The District's Guide to Land Use Emissions Reductions (District Guidance) provides a description of the most current feasible mitigation measures to reduce a project's operational criteria pollutant and GHG emissions. The District Guidance provides detailed information on how to utilize CalEEMod to select the most appropriate mitigation measures for the project and quantify GHG emission and criteria pollutant reductions from the mitigation measures selected. Additionally, the District provides technical documents (Quantification of GHG Emissions for Transportation Activities and Quantification of GHG Emissions for Non-Transportation Activities) describing how to conduct the GHG analyses to demonstrate the 21.7 percent reduction of project operational emissions compared to the project no action taken scenario. All of the measures in the District Guidance include information about the reductions that might be achieved by each measure. The measures and reductions have been substantiated through research identified by a comprehensive literature review including the California Air Pollution Control Officers Association's *Quantifying Greenhouse Gas Mitigation Measures* document. Lead agencies and project proponents can also research and develop additional measures, in consultation with the District, which have reductions that are both quantifiable and substantiated. To assist in documenting, quantifying, and monitoring the mitigation measures selected by the project proponent, the District has prescribed that the selected GHG mitigation measures be explained in the context of a project-specific GHG Reduction Plan. The GHG Reduction Plan can be a standalone document or incorporated into the environmental document. During the environmental review process, and before certification of the CEQA environmental document by the lead agency, the District independently verifies the benefits of the selected measures in the GHG Reduction Plan with a letter. The GHG Reduction Plan shall then be referenced in the CEQA document as a GHG mitigation measure, appended to the document, and referenced as a condition of approval by the lead agency.

6.4.2 Reducing Emissions from Stationary Sources

Mitigation measures developed for reducing GHG emissions from stationary-source facilities shall be developed on a case-by-case basis in consultation with the District's permitting staff. To be consistent with AB 32, a 21.7 percent reduction is the target for stationary source mitigation. Area- and mobile-source emissions shall be mitigated in the same ways as land use development projects, as discussed in Section 6.4.1. Additional offsets could be implemented, including, but not limited to, the purchase of verified emission reduction credits, to ensure that a facility's GHG emissions are reduced to a less-than-cumulatively considerable level.

SMAQMD Thresholds of Significance Table

All Projects Subject to CEQA		
	Construction Phase	Operational Phase
Mass Emission Thresholds for Ozone Precursors		
NO_X	85 pounds/day	65 pounds/day
ROG (VOC)	NONE	65 pounds/day
Concentration Thresholds (based on the California Ambient Air Quality Standard, identical threshold for both phases of development)		
PM_{10}	50 µg/m^3 24-hour standard; 20 µg/m^3 Annual Arithmetic Mean	
$PM_{2.5}$	12 µg/m^3 Annual Arithmetic Mean	
CO	20 ppm 1-hour standard (23 mg/m^3); 9 ppm 8-hour standard (10 mg/m^3)	
NO_2	0.18 ppm 1-hour standard (339 µg/m^3); 0.03 ppm Annual Arithmetic Mean (57 µg/m^3)	
SO_2	0.25 ppm 1-hour standard (665 µg/m^3); 0.04 ppm 24-hour standard (105 µg/m^3)	
Lead	1.5 µg/m^3 30-day average	
Visibility Reducing Particles	Extinction coefficient of 0.23 per kilometer - visibility of ten miles or more due to particles when relative humidity is less than 70 percent	
Sulfates	25 µg/m^3 24-hour standard	
H_2S	0.03 ppm (42 µg/m^3) 1-hour standard	
Vinyl Chloride	0.01 ppm (26 µg/m^3) 24-hour standard	

Land Development and Construction Projects		
	Construction Phase	Operational Phase
Greenhouse Gas Emissions (GHG) Thresholds		
GHG as CO2e	1,100 metric tons/year	1,100 metric tons/year

Stationary Source Only	
Toxic Air Contaminant (TAC) Thresholds	
Cancer Risk	An incremental increase in cancer risk greater than 10 in one million at any off-site receptor.
Non-cancer (Hazard Index)	Ground-level concentration of project-generated TACs that would result in a Hazard Index greater than 1 at any off-site receptor.

	Construction Phase	Operational Phase
Greenhouse Gas Emissions (GHG) Thresholds		
GHG as CO2e	1,100 metric tons/year	10,000 metric tons/year

Notes:
The SMAQMD Board of Directors adopted the air quality thresholds of significance for criteria pollutants on March 28, 2002, via resolution AQMD2002018.
A project is considered significant if emissions exceed a CAAQS or contribute substantially to an existing or projected violation of a CAAQS.
A substantial contribution is considered an emission that is equal to or greater than 5% of a CAAQS.
Revisions to the CAAQS are automatically adopted as revisions to these thresholds.
Official citation for the CAAQS: California Code of Regulations, Title 17, Section 70200, Table of Standards.
The TAC thresholds were developed as part of the SMAQMD's AB2588 program.
The SMAQMD Board of Directors has not established a threshold for mobile source or non-permitted sources of TAC, see Chapter 5.
The SMAQMD Board of Directors adopted GHG thresholds on October 23, 2014, via resolution AQMD2014-028