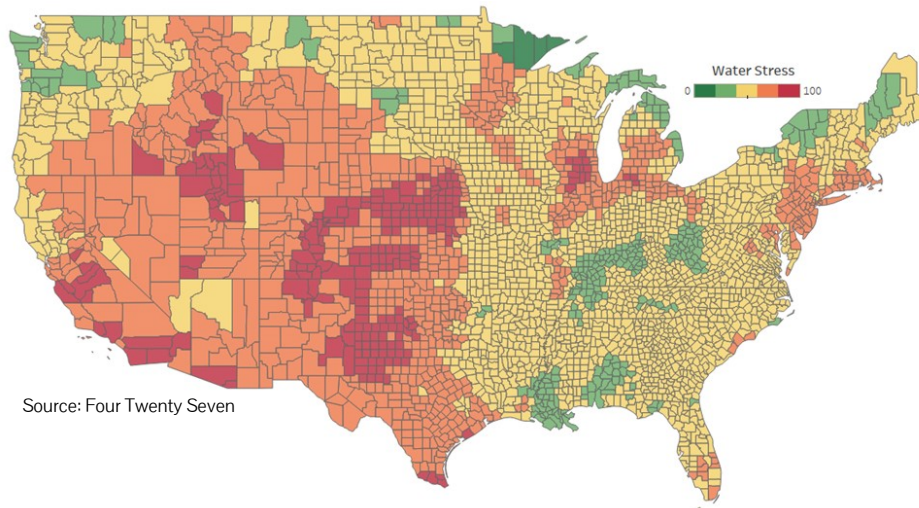


Assessing Exposure to Climate Change in U.S. Munis



Source: Four Twenty Seven

Four Twenty Seven, May 2018

KEY TAKEAWAYS

- Rating agencies are increasingly considering climate change and previous extreme weather events as part of their evaluation of U.S. cities and counties. These evaluations could be better informed by incorporating forward-looking, comparable data on the climate risks that impact these municipalities.
- New climate risk scores from Four Twenty Seven provide comparable, consistent estimates of U.S. cities' and counties' exposure to major climate hazards. These risk scores lay the foundations for more accurate modeling of the economic impacts of climate change on municipal bond issuers.
- Major hazards from climate change include cyclones, sea level rise, extreme precipitation, heat stress and water stress.
- Findings show climate change will pose challenges to several economically important U.S. municipalities, especially those that are both highly exposed and financially vulnerable. These cases most often occur along the Atlantic and Gulf coasts and inland areas that rely upon a concentrated set of sectors for revenue and employment.

INTRODUCTION

Credit rating agencies are increasingly incorporating physical climate risk into their municipal rating criteria. Following Hurricane Harvey, Moody's downgraded Port Arthur, from A1 to A2 due to its "weak liquidity position that is exposed to additional financial obligations from the recent hurricane damage, that are above and beyond the city's regular scope of operations."¹ Likewise, after Hurricane Katrina, S&P Global Ratings (S&P) downgraded New Orleans from BBB+ to B after considerable emigration and decline in taxable assessed value by 22%.²

With sixteen billion-dollar disasters in the United States in 2017 and cost estimates at approximately \$300 billion, hundreds of cities and counties are bearing the costs of extreme weather events.³ While these cost estimates capture the insured and uninsured losses reported by storm victims they do not account for the long-term costs associated with credit downgrades that can occur when property values plummet and city expenditures rise following these events.

Revenues come from property taxes, and municipalities often offer property tax relief following natural disasters, which then leads to a decline in revenue and a concomitant increase in credit risk. With impoverished residents who have lost their property, temporary or permanently out of a job or relocated, local governments can experience a more permanent reduction in their tax base. Just one month after Maria faded from the shores of Puerto Rico, The US Postal Service received 10,600 requests for address changes from Puerto Rico and the US Virgin Islands to one of the 50 states and District of Columbia.⁴ Airline data from the US Department of Transportation shows that 179,000 Puerto Ricans booked airline tickets bound for the states following Maria.⁵ The long-term exodus of people is likely much higher, and one study from Lyman Stone, an economist working with the Puerto Rican Financial Oversight and Management Board, estimates that Puerto Rico's population could decline between 9.1% and 38.2% by 2060 (or 16.1% by 2032) if Puerto Rico is ravaged by another hurricane of equal or greater intensity as Maria. A dwindling tax base can have long-term implications, affecting the quality and costs of public services such as education or local water utilities.

ACCOUNTING FOR CLIMATE RISK IN CREDIT RATINGS

Moody's and S&P both released reports in 2017 explaining their methodologies for incorporating climate change into their municipal credit ratings. However, they face the persistent challenge of obtaining comparable, granular, forward-looking data. Current methodologies focus mostly on historical instances of extreme weather events, local governments' adaptive capacity and financial resilience, but

lack concrete metrics that measure how municipalities are exposed to specific hazards.

Moody's methodology for local governments, public utilities, and states does not explicitly integrate climate change exposure as a credit risk, but rather, incorporates historical occurrences of extreme weather events that affect "economic strength and diversity, capital asset management, fiscal strength

¹"Storm-damaged Port Arthur, TX receives a Moody's downgrade." The Bond Buyer. October 25, 2017. <https://www.bondbuyer.com/news/moodys-downgrades-hurricane-harvey-damaged-port-arthur-texas>

²Forsgren, Kurt E. and Theodore A. Chapman, "Understanding Climate Change Risk and U.S. Municipal Ratings." S&P Global Ratings. 17 October 2017, p. 2.

³NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2018). <https://www.ncdc.noaa.gov/billions/>

⁴CNN Analysis. US Postal Service.

⁵Bureau of Transportation Statistics T-100 Market data

and governance, among other credit factors.”⁶ When evaluating the broader economy, fiscal position, and capital infrastructure of a municipality or state, Moody’s factors in the potential risks to infrastructure, the economy, and revenue base.

Like Moody’s, S&P evaluations consider financial management, planning, and the economic diversity of municipalities. If a local economy relies heavily on one industry, like tourism, it would affect a local government’s ability to recover quickly after a natural disaster. S&P also tracks coastal infrastructure and

storm hardening efforts to assess the adequacy of adaptation efforts and long-term creditworthiness.⁷ Both rating agencies acknowledge that climate change can influence credit risks, but in the absence of forward-looking climate projections, such estimates may grossly underestimate the magnitude of future risks, or at least fail to characterize the type of climate risks that may eventually make it more difficult for a municipality to meet its financial obligations.

TRANSPARENCY: A DOUBLE EDGED SWORD FOR MUNIS?

Municipalities and investors both stand to benefit from more climate-informed credit ratings. Generally speaking, more informed credit ratings result in better pricing of instruments by markets and allow for more efficient capital flows. Further, investing in resilience is an essential way for cities to maintain their credit in the face of increasingly severe and frequent climate hazards, and should be rewarded as prudent investment. A better understanding of which climate hazards stand to pose the greatest future threat will help municipalities allocate adaptation efforts more efficiently and effectively. Likewise, when coupled with indicators about fiscal health, detailed, standardized, and comparable climate exposure data can help rating agencies and investors more completely understand municipal credit risk.

However, not all cities stand to benefit from better data. In fact, adjusting credit ratings based on climate change exposure could hurt some municipalities. The future financial obligations of climate exposed municipalities could dissuade investors from allocating capital to investment vehicles that are

designed to mitigate those very exposures. Even those investors with a healthy appetite for risk may balk at investing in a city like Virginia Beach, given its need to incur more frequent costs to recover from large storms and the upfront costs of installing and hardening coastal flood infrastructure. There is a real possibility that a climate-informed rating may unfairly penalize the exposed and poor municipalities that are most in need of funding for adaptation.

Take Puerto Rico, for example. When Hurricane Maria hit last year, the island had recently filed for bankruptcy and was still reeling from its own recession. Though its credit was already rated ‘D’ by S&P, the economic impacts to manufacturing and tourism, and the destruction of taxable property, will make it difficult for Puerto Rico to improve its credit rating in the foreseeable future.⁸ It is unclear exactly how Puerto Rico can simultaneously meet its financial obligations, recover from Hurricane Maria, and adequately prepare for the next hurricane.

⁶Environmental risks: Evaluating the impact of climate change on US state and local issuers. Moody’s Investors Service. November 28, 2017, p. 9.

⁷Forsgren, Kurt E. and Theodore A. Chapman, “Understanding Climate Change Risk And U.S. Municipal Ratings.” S&P Global Ratings. 17 October 2017

⁸Kearney, Laila. “Hurricane Maria may spell more trouble for Puerto Rico bondholders.” 22 September 2017. <https://www.reuters.com/article/us-puertorico-bonds/hurricane-maria-may-spell-more-trouble-for-puerto-rico-bondholders-idUSKCNIBX2L1>.

ASSESSING CLIMATE EXPOSURE FOR U.S. CITIES AND MUNIS

Four Twenty Seven has taken the first important step to address the need for quantitative, forward looking climate risk assessments by scoring every county and medium and large city in the U.S. for their exposure to several climate change hazards. Each city and county is assigned a score based on how it ranks nationwide, which provides investors with comparable detail to complement the assessments of credit rating agencies.

The analysis takes stock of a wide breadth of climate risks, and exposure levels are determined by the degree to which extreme conditions will change over time, in both absolute and relative terms. Early findings show which risks are likely to affect which municipalities, even when these risks might not be

apparent today or through the historical data.

This initial assessment includes cyclones, sea level rise, extreme rainfall, heat stress, and water stress. Scores are available for all 3,142 U.S. counties and cities over 50,000 in population (761 cities as of 2015).

Four Twenty Seven uses an index scoring method, evaluating several precipitation- and temperature-based indices together for each county and city and “scoring” them relative to other areas. This allows for the inclusion of several important dimensions of future climate risk: relative and absolute change in frequency and severity of extreme conditions between historical conditions and a forecast period of 2030-2040.

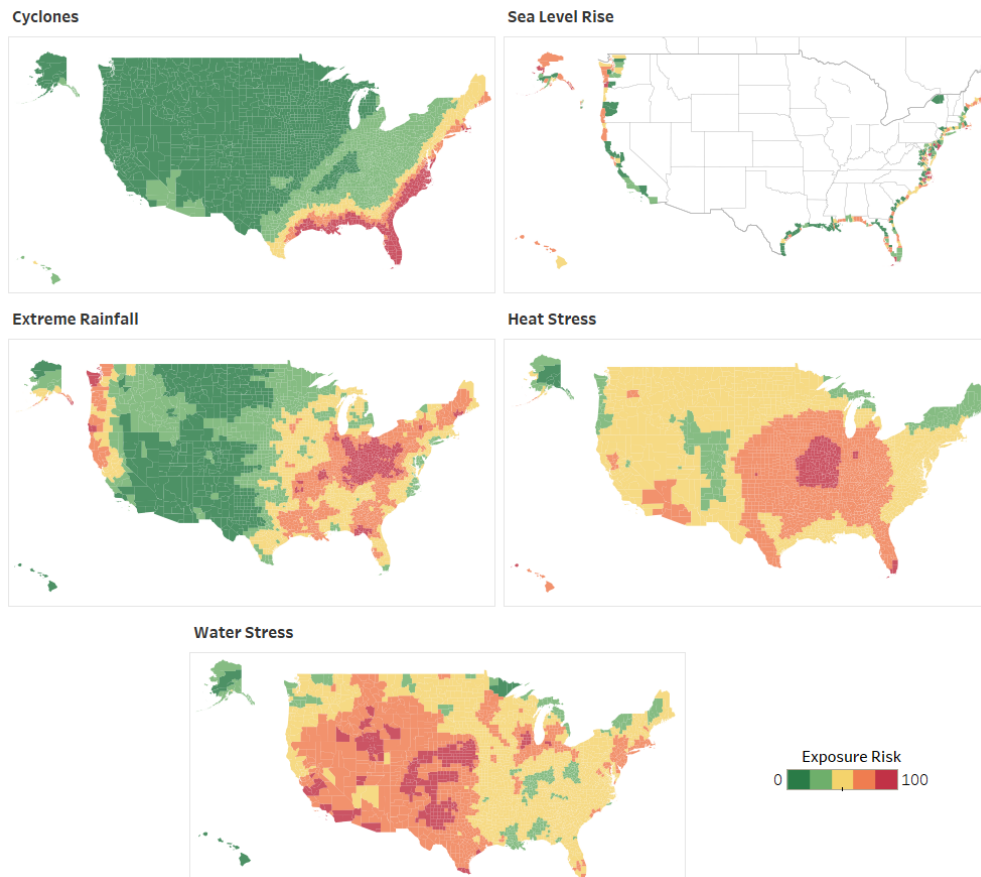


Figure 1. U.S. counties exposure to climate change, by type of hazard. Red areas represent counties that are most exposed to climate hazards, while dark green areas represent counties that are less exposed.

Source: Four Twenty Seven

KEY FINDINGS: SEA LEVEL RISE

Sea level rise, particularly when combined with storm surge, can result in significant and widespread coastal flooding. The Four Twenty Seven indicator for sea level rise uses projections to measure the relative change from historical extreme water levels (sea level rise plus storm surge) and combines them with digital elevation models (DEM) and population data to evaluate exposure to coastal flooding.

The mid-Atlantic, particularly New Jersey, Virginia, North Carolina, and Florida, are the regions most exposed to coastal flooding, while several cities and counties in the California Bay Area and Pacific Northwest are also highly exposed.

Technical note: sea level rise

Sea level rise estimates capture the absolute and relative increase in the annual frequency of coastal floods. Estimates of sea level rise exposure are intended to capture: (1) the frequency of inundation due to a combination of sea level rise, storm surge, and high tides, and (2) change in the frequency of inundation between historical and projected periods. Estimates leverage global high resolution digital elevation model data, as well as local storm surge and sea level rise estimates between 2017 and 2040. This analysis incorporates local flood risk statistics, as well as local median sea level rise projections under carbon emissions scenario RCP 8.5. Each county is screened to only include its most densely populated regions, and both cities and counties are scored based on a population-weighted average of sea level rise exposure within its boundaries.

Like so many other climate impacts, disruptions may not culminate in single, well-defined events. Rather, local stakeholders will be forced to deal with intruding waters throughout the century. Businesses may ultimately be forced to relocate, potentially out of the region entirely. Costs for cities and counties for repairing and maintaining roads, bridges, ports, and other coastal infrastructure will certainly rise, resulting in significant negative economic impact and reallocation of resources and financial assets from other projects and programs.

Monroe County, FL (Florida Keys) is one of the most exposed counties to sea level rise and in the highest risk class for cyclones. This high exposure to several hazards is particularly important to understand, as the impacts of individual hazards can compound one another, and resilience priorities must account for

These are regions where extreme water levels exceed coastline elevation, leading to inundation, and also where population centers are concentrated in coastal-adjacent, low-lying regions. In each of these places, major storm events result in widespread inundation of valuable assets, and even less severe and more frequent storm events can result in damaging floods. Major storms driving significant storm surge, such as Hurricane Sandy in New York and New Jersey in 2012, can result in widespread power outages, compromised or destroyed infrastructure, and major business and essential service disruptions as communities are forced to evacuate, rebuild, and recover.

both chronic and acute risks. For example, sea level rise will exacerbate the storm surge and flooding that already occurs during cyclones. However, even in the absence of major storms, sea level rise may cause "nuisance" or "sunny day" flooding to occur more frequently and reach further inland.

Property values are likely to decline in these exposed areas of Florida and costs of home ownership will rise as insurance premiums and property taxes begin to account for more severe cyclones and more coastal flooding. Businesses, government buildings, homes, and critical infrastructure may need to be permanently relocated to higher ground, a costly and resource intensive endeavor that could change the shape and feel of many iconic coastal cities, while also decreasing their revenues.

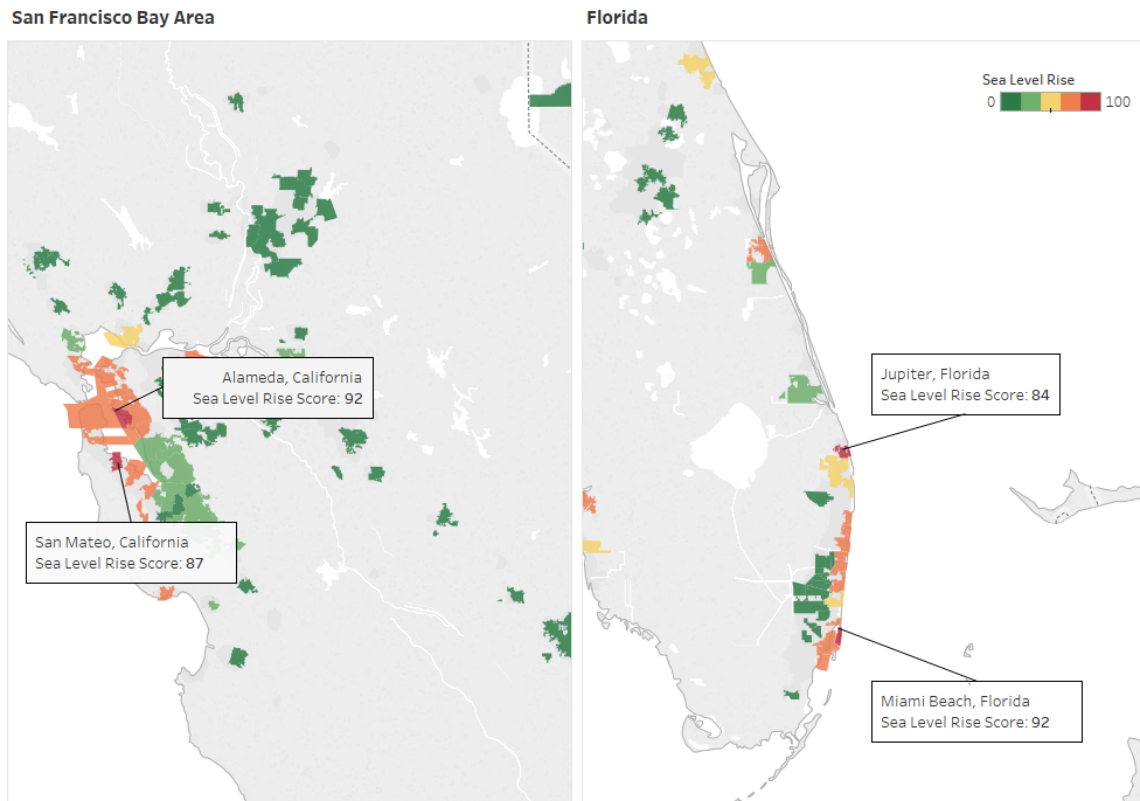


Figure 2. Cities in the San Francisco Bay Area and Southeast Florida are among the most exposed to sea level rise. Red areas represent cities that are most exposed to sea level rise, while dark green areas represent cities that are least exposed. Scores range from 0 (no risk) to 100 (high risk). Source: Four Twenty Seven

KEY FINDINGS: CYCLONES

Four Twenty Seven's hurricane risk scores identify where more severe, energy-charged hurricanes are likely to occur in the future. The Four Twenty Seven cyclone risk indicator reflects the cumula-

tive wind velocity from recorded cyclones and includes both the severity of storms with the highest maximum winds and the frequency with which an area is subjected to severe storms.

Technical note: cyclones and hurricanes

Cyclone exposure scores measure geographic exposure to tropical cyclones, also known as hurricanes and typhoons. These measures are derived exclusively from historical data (1980-2016), though the spatial extent of the frequency and severity of past cyclones provides an accurate estimation of where more severe, energy-charged cyclones are likely to occur in the future. Projections of increased vertical wind shear, which dampens cyclone formation, compete with increases in the sea surface temperatures that fuel their development. Nevertheless, given the projected increases in oceanic heat content, cyclones in the coming decades will have more energy to fuel their transition to major hurricanes, as well as more water vapor to enhance their precipitation potential. Changes in cyclone tracks are highly uncertain; however, given the proximity of the Gulf and Southeast Coast of the U.S. to extremely warm seas, high risk areas today are likely to remain exposed to cyclones.

The majority of cyclone risk in the United States is concentrated in the Southeast because of its geographic proximity to the Gulf of Mexico and the tropical Atlantic Ocean. The coastal Mid-Atlantic and Northeast are also exposed to cyclones, but they tend to be less frequent than in the Southeast and somewhat weaker on average after interacting with land or cooler ocean waters. Both regions are prone to the genesis of strong cyclones because of their abundance of warm water as a fuel source for these storms. Low lying coastal areas in the Southeast US, like south Florida, southeast Texas, and coastal

Louisiana can experience extreme impacts from cyclones as storm surge inundates land areas and extreme winds and rainfall damage or destroy economically critical infrastructure and properties.

Strong cyclones already stress and damage vital infrastructure as experienced with critical failures during Hurricane Katrina in Louisiana in 2005. Increased water vapor content due to warmer temperatures also super-charges cyclones with extreme amounts of precipitation and flooding, leading to stronger events like Hurricane Harvey in Texas.

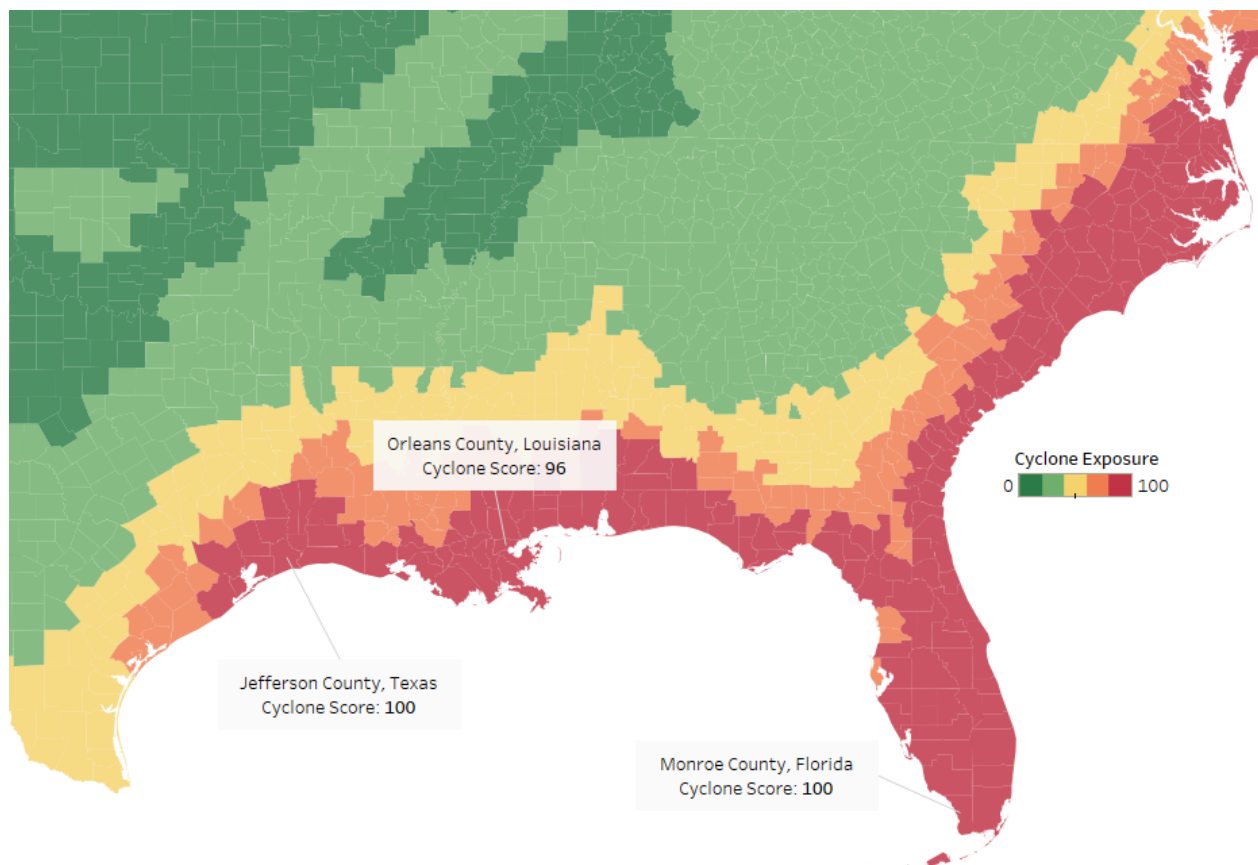


Figure 4. Counties that have experienced damaging cyclones have among the highest cyclone risk in the nation, which shows that they are likely to continue to experience extreme storms. Red areas indicate counties with the highest cyclone exposure, while dark green areas represent those with the least cyclone exposure. Scores range from 0 (no risk) to 100 (high risk). Source: Four Twenty Seven

Southeast Texas and coastal Louisiana are also vulnerable to extreme impacts from cyclones. Exposed municipalities in these areas, such as Port Arthur in Jefferson County, TX and Orleans, LA, may also face increasing insurance-related costs while damages to residential property deteriorate home values and subsequently erode the tax base. Highly valuable coastal properties in states like Florida are likely to see property values decline and costs of home ownership rise as insurance premiums and property taxes begin to account for more severe cyclones and more coastal flooding. Entire real estate markets may vanish as Gulf Coast hurricanes intensify.^{9,10} In the lower Florida Keys, Hurricane Irma wiped out working-class, affordable housing and the Federal Emergency Management Administration (FEMA) will no longer allow the County to build new dwellings in the hardest hit areas.

Additionally, the concentration of oil and gas infrastructure and business in southern and eastern Texas will likely lead to an outsized impact due to shut-

downs and damage to extraction and distribution infrastructure.

While cyclones are less frequent and often weaker in the Mid-Atlantic and Northeast, coastal infrastructure like the New York City Subway system could experience prolonged disruptions and require significant repair and investment costs, as seen in the wake of Hurricane Sandy.



Figure 5. Housing debris following Hurricane Irma in Big Pine Key.

Credit: Emily Craig

KEY FINDINGS: EXTREME RAINFALL

During the last century, extreme rainfall events and subsequent flooding have increased in frequency and severity, and these trends are expected to continue. As was historically the case, the Midwest, Northeast, and parts of the Gulf Coast are expected to experience the greatest increase in rainfall intensity.

The Midwest is particularly exposed to heightened flood risk due to changing rainfall patterns. Recent advancements in attribution science show extreme rainfall to be the main driver of recent floods rather

than 20th century agricultural practices, as was largely believed to be the case until recently.¹¹

One of the cities most exposed to extreme rainfall is Carmel, Indiana, a suburb just north of Indianapolis. Throughout April and early May 2018¹² persistent flooding led to recurring travel restrictions, barricades for flooding roadways, evacuations and school closures after 3.9 inches of rain fell in a single day.¹³ While cities are increasingly upgrading their storm water and sewage management to eliminate combined sewage overflows,¹⁴ cities in Indiana and else-

⁹Emanuel, K. (2005). Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, 436(7051), 686.

¹⁰Knutson, T. R., & Tuleya, R. E. (2004). Impact of CO₂-induced warming on simulated hurricane intensity and precipitation: Sensitivity to the choice of climate model and convective parameterization. *Journal of climate*, 17(18), 3477-3495.

¹¹Attribution science is the investigation of determining if, and to what extent, human influence on climate variables can be distinguished from natural variability. Detection and attribution studies can help evaluate whether model simulations are consistent with observed trends or other changes in the climate system.

¹²Mack, Justin. "Central Indiana flood warnings extended as barrage of rain continues." *IndyStar*. 4 May 2018. <https://www.indystar.com/story/news/2017/05/04/central-indiana-flood-warnings-extend-barrage-rain-continues/101283706/>

¹³"USA - Flood Rescues and Evacuations in Indiana and Illinois." *Floodlist*. 5 April 2018. <http://floodlist.com/america/usa/flood-storm-indiana-illinois-april-2018>

¹⁴Janzen, Nick. "More Than 100 Indiana Communities Working To Reduce Combined Sewer Overflow." *WFYI Indianapolis*. 20 April 2016. <https://www.wfyi.org/news/articles/more-than-100-indiana-communities-working-to-reduce-combined-sewer-overflow>

Technical note: extreme rainfall and flood risk

Extreme rainfall variables include changes in five-day rainfall volumes, additional wet days, and additional number of days with heavy rainfall.

- The percent change in five-day rainfall volumes measures percent change in the total maximum volume (mm) of rainfall in a five-day period in an average year at 2030.
- Additional wet days measures the additional number of days when daily precipitation exceeds 10 mm.
- Additional very wet days measures the additional number of days when daily precipitation exceeds the local 95th percentile rainfall history.

Rainfall-induced flooding is generally delivered via rivers and creeks or urban flooding not always associated with proximity to riverways.

where, risk outbreaks of water-borne illnesses during storms as raw sewage can overflow into storm water drainage.¹⁵

Extreme rainfall can also have costly impacts on supply chains. Logistical hubs such as railway and trucking terminals and arterial roadways represent

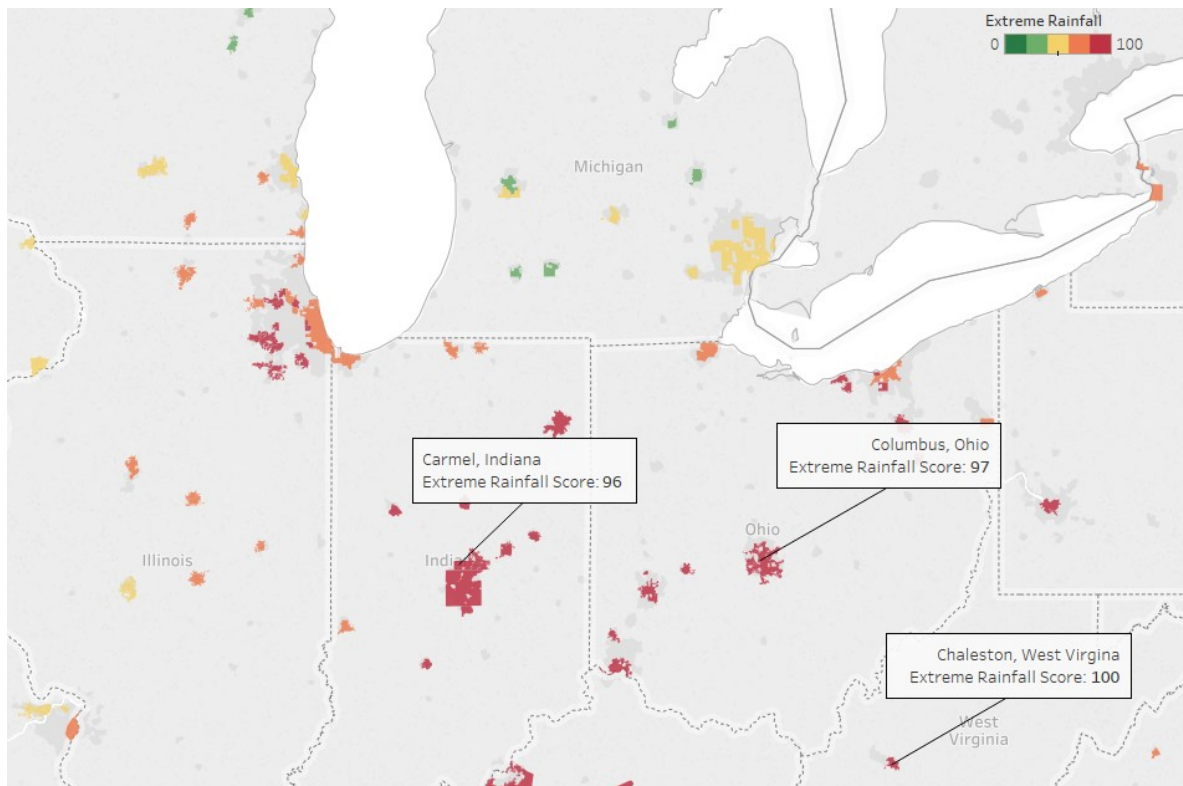


Figure 6 Cities in the Midwest are among the most exposed to extreme rainfall. Red areas indicate counties with the highest exposure to extreme rainfall, while dark green areas represent those with the least exposure to extreme rainfall. Scores range from 0 (no risk) to 100 (high risk). Source: Four Twenty Seven

¹⁵ Indianapolis, IN, USA" Union of Concerned Scientists. 2011 <http://www.climatehotmap.org/global-warming-locations/indianapolis-in-usa.html>

major concentrations of goods and commercial activity. Rainfall-induced flooding at any point in these commercial transportation networks could lead to system-wide shutdowns. Not only does this affect commerce and markets downstream, but municipalities may incur additional costs assisting with repairs and paying a premium for critical goods and services.

In the West, atmospheric river storms are a main and frequent driver of heavy precipitation patterns. Atmospheric rivers (also known as “Pineapple Express” in the region) can result in severe local flooding, although the frequency of their occurrence varies sub-

stantially year-to-year. As is often the case in other areas, local rainfall risk may not be as easy to discern as the frequency of precipitation-based events is not highly detectable in climate models, and urban infrastructure is often an adequate substitute for judging impact size in flood-prone cities. For example, highly impervious cities like Houston, Texas and San Jose, California, can become quickly overrun by rainfall as concrete-lined creeks snake through the metro area, and rains can quickly overflow engineered waterways, which then spill into downtown streets and neighborhoods.

KEY FINDINGS: HEAT STRESS

Rising temperatures are one of the most observable outcomes of climate change and pose serious risks to the nation’s energy infrastructure and labor force. The highest heat stress scores tend to be centered in the Southeast and Midwest, concentrated in Missouri and western Illinois and then fanning out to the

Great Plains, Mississippi River Basin, and Florida (Figure 1). High scores are largely disjointed, and high heat stress scores also occur in the West, such as the desert Southwest and agriculturally-dominated counties in the Sacramento Valley and southeastern Washington State.

Technical note: heat stress

Heat stress is measured by the relative change over time in the frequency and severity of hot days as well as in average temperature. High forecasted changes relative to recent history signal locations that are more likely to be affected due to temperatures that will be unlike previously experienced conditions, even if these locations are not projected to experience the warmest temperatures.

Cities stand to bear much of the costs of rising temperatures. Four-fifths of Americans now live in urban areas, many of which are built in a way that amplifies heat. On average, the U.S. is losing 36 million urban trees per year, representing a cost of \$96 million a year, including the loss of carbon storage, pollution reduction, and the need for more air conditioning.¹⁶

Several of the busiest airports could also experience more disruptions. Last July, flights were grounded in Phoenix due to extreme heat and airlines noted that

operational manuals didn’t include information for temperatures above 118 degrees Fahrenheit.

Manufacturing, which has slowly migrated further south following changes in the US auto industry, is highly sensitive to heat stress due to energy demands and labor productivity. Several manufacturing hubs in Missouri are highly exposed to heat stress. Both Ford and GM have signed long-term leases across Missouri, and growth is expected to continue. Though accustomed to extreme heat, workers, and the managers paying the electricity

¹⁶Nowak et al., (2018). Declining urban and community tree cover in the United States. *Urban Forestry & Urban Greening*. V.32. 32-35

bills, may find new extremes unbearable for both working conditions, and the assembly plant's bottom-line.

In parts of the South and Midwest, the rate of warming and severity of more frequent and prolonged

temperatures, combined with high humidity, will, in many instances, challenge known capacities to adapt and habituate to new extremes.¹⁷

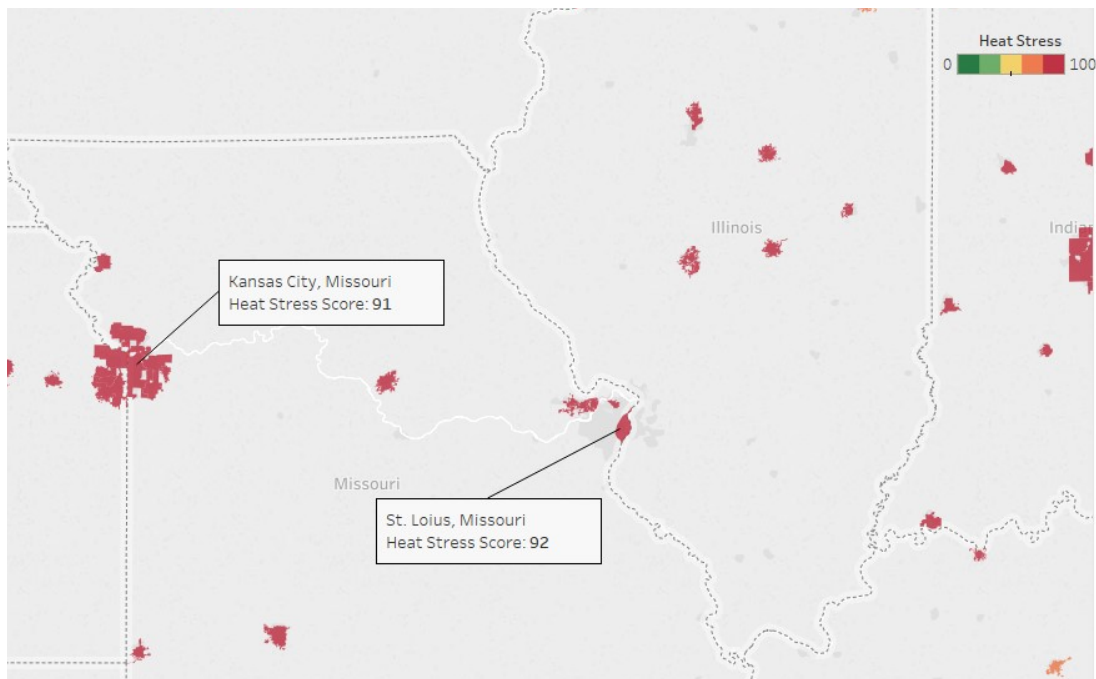


Figure 7. Manufacturing hubs in Missouri are both highly vulnerable and highly exposed to extreme heat. Red areas indicate cities with the highest exposure to extreme heat. Scores range from 0 (no risk) to 100 (high risk). Source: Four Twenty Seven

KEY FINDINGS: WATER STRESS

Water stress measures the projected changes in drought-like patterns. Water intensive activities, such as agriculture or energy production, are often dependent upon local water availability and stand to suffer the most severe consequences of water supply shortages. Across many parts of the United States, water stress is expected to worsen due to a combination of less consistent and abundant rainfall, as well as growing and competing consumption trends.

In the West (Southwest, Pacific Northwest, and western Pacific), snowpack and streamflow amounts are projected to decline, affecting the freshwater (groundwater and surface water) reliability for agriculture, ecosystems, and residential consumption in cities. Increased warming is a pervasive and almost certain effect of climate change that accelerates and partially enables drought-like conditions, which can also lead to increased probability of wildfires and significant ecosystem degradation.

¹⁷Hanna et al. (2015). Limitations to thermoregulation and acclimatization challenge human adaptation to global warming." *International journal of environmental research and public health* 12.7. 8034-8074

Technical note: water stress

Water stress variables include absolute and relative percent changes in water supply and demand between the current period and 2030, as well as inter-annual variability.

- Water supply change measures the absolute percent change in the availability of blue water for withdrawal between the current period and 2030.
- Water demand change measures the absolute and percent change in demand for annual water withdrawals (municipal, industrial, and agricultural) between the current period and 2030.
- Interannual variability measures the variation in water supply between years.

Agriculture will experience the direct effects of water stress. Key watersheds for agricultural production such as the Ogallala Aquifer in the Great Plains and the Central Valley aquifer system in California show the highest water stress. The agriculturally-dominated areas of Bakersfield, Delano, and Visalia,

California along the Central Valley Aquifer are among the ten cities in the nation most exposed to water stress. These agricultural dependent economies are particularly vulnerable to drought.

Municipalities within the Ogallala Aquifer in the

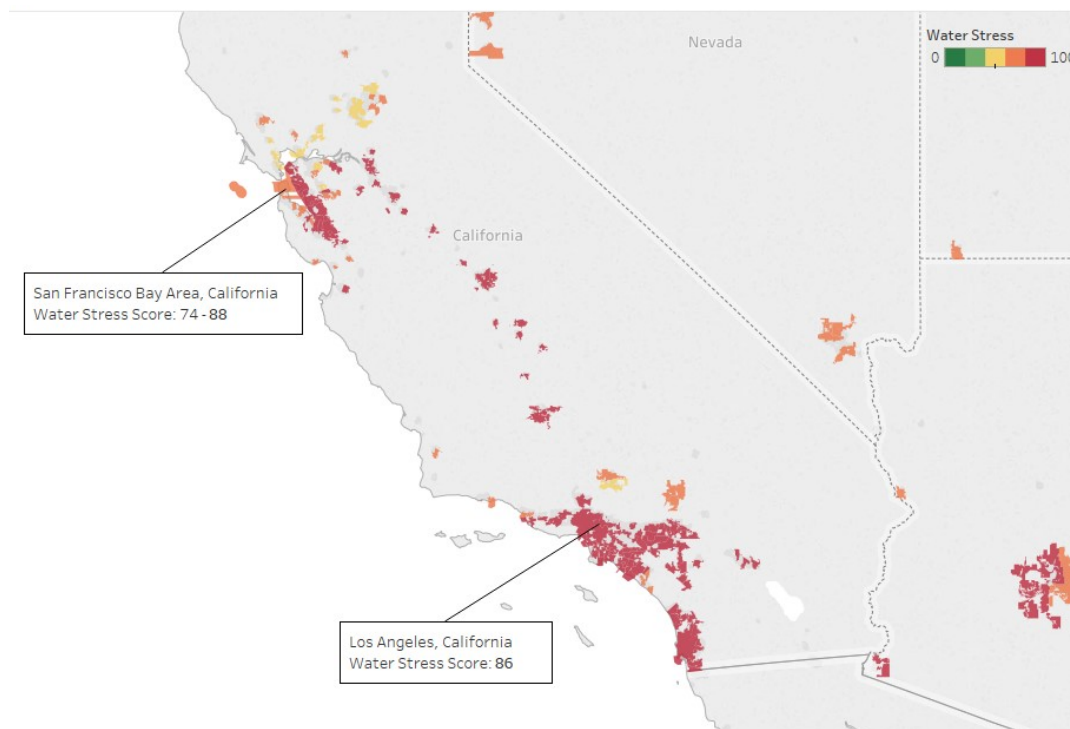


Figure 8 Major cities in California's could face credit downgrades in the absence of water supply alternatives and sustained cutbacks in water use. Red areas indicate cities with the highest water stress exposure, while dark green areas represent those with the less exposure. Scores range from 0 (no risk) to 100 (high risk). Source: Four Twenty Seven

Great Plains also rely heavily on agriculture and are among the most exposed to water stress. In the heart of the Ogallala Aquifer, Sheridan County, Kansas took drastic measures amidst growing water stress in 2013 and imposed water restrictions on its farmers. Farmers under this restriction enjoyed cash-flow that was 4.3 percent higher and yields just 1.2 percent smaller than those nearby farmers who used standard irrigation practices.¹⁸ The success of these restrictions for both water conservation and farmers, have led nearby counties along the aquifer to implement similar practices. This demonstrates the positive outcomes of increasing awareness of water concerns and the actions some water districts are taking to abate serious economic impacts.

Cities will also bear much of the costs of growing water stress. The costs of adapting to water stress, either through capital expenditures or new pricing structures, will affect water utility providers and users equally. Growing consumption needs due to ur-

banization trends will also influence water stress levels in large metropolitan areas such the Greater Los Angeles area, Chicagoland, and New York-New Jersey, which are all deemed medium to high risk in Figure 1. In the absence of sustainable water supply alternatives or ambitious wastewater recycling efforts, many large US cities are facing significant investment costs to deal with water challenges.

In 2003, Moody's downgraded Atlanta's city and sewer bonds partially due to its reliance on a single, water-stressed sourced. Credit rating agencies have warned downgrades could be assigned to Los Angeles and San Francisco for those very same reasons. Utilities that are planning for a water scarce future have actually seen a boost in their ratings. Orange County Water District, for example, is benefiting from a simple groundwater replenishment system that recycles wastewater and effectively relieves the area's dependency on the state's dwindling and fragile water supply.

REMAINING CHALLENGES

Exposure to physical climate hazards is just one element of municipalities' vulnerability to climate impacts. A municipality's exposure to climate change risks and the vulnerability of its economy to long-term negative impacts depends on its capacity to adapt to changing conditions, otherwise known as adaptive capacity. A wide variety of indicators, ranging from the existence of hazard-specific adaptation plans and budget allocations for resilience building to local sentiment for climate programs and financial incentives for renewable energy, can provide some insight into a municipality's ability to implement adaptation efforts. Evaluations of municipalities have used a spectrum for adaptive capacity that ranges

from early awareness, to active planning, and finally, to concrete action,^{19,20} that might involve a mix of policy, infrastructure, and financing. Gathering and analyzing this data at a comparably consistent, granular scale is challenging. As cities vary greatly in their size, resources and adaptation needs, credit rating agencies must decide what level of adaptation is considered sufficient to meet long-term financial obligations. There must be an enduring conversation around determining, for example, how many flood barriers may be considered suitable for a city given its long-term exposure to flooding.

Conflicting views on what the future might hold, as well as uncertainties inherent to climate models,

¹⁸Walden, Brett. "Kansas Farmers Cut Ogallala Water Use - And Still Make Money" Circle of Blue. 6 March 2018. <http://www.circleofblue.org/2018/world/kansas-farmers-cut-ogallala-water-use-and-still-make-money/>

¹⁹Ekstrom, J. A., Bedworth, L., & Fencl, A. (2017). Gauging climate preparedness to inform adaptation needs: local level adaptation in drinking water quality in CA, USA. *Climatic change*, 140(3-4), 467-481.

²⁰Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the national academy of sciences*, 107(51), 22026-22031.

present challenges in assessing what level of risk municipalities must prepare for. This uncertainty is further compounded by uncertainties over what measures will prove most effective and adequate in reducing risk. Lastly, different cities and their population may have different tolerance levels and be willing to make different trade-offs on how to spend public money and what to prioritize when planning for climate adaptation. Assessing preparedness for a city must be a combination of science-driven analysis of risk exposure and the quality of engineering and policy responses considering the complexity of voter preferences and budget decisions.

For some municipalities, more severe impacts may only emerge decades into the future and will require credit ratings agencies to adopt new and comparable criteria for muni credit risk. As made clear by both

Moody's and S&P's analyses of climate risks impacts on credit ratings, the economic consequences of a single extreme weather event can have a long-term impact on a municipality's ability to repay debt, including its ability to finance and implement the necessary resilience efforts. Consistent and forward-looking metrics play an important role in this process. Credit rating agencies and muni bond investors need a unified and comparable baseline from which to judge the influence of climate change on local resilience. Having a baseline understanding of cities' exposure to climate risk will also continue to help rating agencies engage with specific cities and ensure ratings reflect both foreseeable risks and local adaptation efforts, and in doing so avoid penalizing the most exposed and in need municipalities.

CONCLUSION

The impacts of climate change are already affecting the U.S. economy, but the widespread, long-term consequences for local economies, economic growth and equity are just starting to emerge. Four Twenty Seven's local climate risk exposure risk scores brings science-driven analytics to support efforts to understand local financial vulnerability to climate change and can be leveraged to engage

more effectively with munis about how they are addressing their most threatening climate risks. Likewise, investors can use this information as a starting point for wiser investing. By coupling an understanding of a municipality's climate risk with a knowledge of its resilience-building efforts, investors can play a key role in the development of more resilient and thriving economies.



Four Twenty Seven

AUTHORS

Lead author: Nik Steinberg, Director of Analytics • nsteinberg@427mt.com

Contributors: Natalie Ambrosio, Colin Gannon, Lindsay Ross

Editors: Frank Freitas • ffreitas@427mt.com, Emilie Mazzacurati • emazzacurati@427mt.com

ABOUT FOUR TWENTY SEVEN

Four Twenty Seven (427mt.com) is the leading provider of market intelligence on the impacts of climate change for financial markets. We tackle physical risk head on by identifying the locations of corporate production and retail sites around the world and their vulnerability to climate change hazards such as sea level rise, droughts, floods and tropical storms, which pose an immediate threat to investment portfolios.

Four Twenty Seven's ever-growing database now includes close to one million corporate sites and covers over 2000 publicly-traded companies. We offer [subscription products and advisory](#)

[services](#) to access this unique dataset. Options include data licenses, an interactive analytics platform, and company scorecards, as well as reporting services, scenario analysis, and real asset portfolio risk assessments.

Four Twenty Seven has won multiple awards for its innovative work on climate risk and resilience and our work has been featured by Bloomberg, the Financial Times and the UNFCCC. Four Twenty Seven was founded in 2012 and is headquartered in Berkeley, California with offices in Washington, DC and Paris, France.

DISCLAIMER

The information provided in this report was collated by Four Twenty Seven. Publications of Four Twenty Seven are for information purposes only. Other than disclosures relating to Four Twenty Seven, the information contained in this publication has been obtained from sources that Four Twenty Seven believes to be reliable, but no representation or warranty, express or implied, is made as to the accuracy, completeness, reliability or timeliness of any of the content or information contained herein. As such, the information is provided 'as-is,' 'with all faults' and 'as available.' The opinions and views expressed in this publication are those of Four Twenty Seven and are subject to change without notice, and Four Twenty Seven has no obligation to update the information contained in this publication. Further, neither Four Twenty Seven nor its directors, officers, employees or agents shall be held liable for any improper or incorrect use of the infor-

mation described and/or contained herein, nor does Four Twenty Seven assume responsibility for anyone's use of the information. Under no circumstances shall Four Twenty Seven or any of its directors, officers, employees or agents be liable for any direct, indirect, incidental special, exemplary or consequential damages (including, but not limited to: procurement of substitute goods or services; loss of use, data or profits; or business interruption) related to the content and/or to the user's subsequent use of the information contained herein, however caused and on any theory of liability. User agrees to defend, indemnify, and hold harmless Four Twenty Seven and its directors, officers, employees and agents from and against all claims and expenses, including attorneys' fees, arising out of the use of information herein provided.

CONTACT INFORMATION

San Francisco Bay Area, CA

2000 Hearst Ave, Ste 304

Berkeley, CA 94709

Tel: +1.415.930.9090

Washington, D.C.

718 7th St. NW

Washington, D.C. 20001

Tel: +1.202.897.4020

Paris, France

2, rue du Helder

75009 Paris, France

Tel: +33. 01.53.34.11.87