From: Jacob Patterson
To: Gurewitz, Heather
Subject: Additional Comment on Inadequacy of Recirculated Draft NegDec for Update to Cannabis Regulations
Date: Thursday, May 12, 2022 12:01:46 PM

Heather,

Here is another comment for the recirculated draft Negative Declaration for the proposed updates to the cannabis regulations. The CEQA reqview remains problematic and objectionable because the proposed draft ordinance includes "wholesale and distribution" in the list of potential accessory uses for cannabis retail. Regardless of the actual direction given by the Council majority, I think the phrase "wholesale and distribution" needs to be removed at this stage and believe failing to do so would amount to an abuse of discretion. This also presents a CEQA issue because this inconsistency with the Inland General Plan amounts to a significant impact in Land Use and Planning because the proposed ordinace itself is in direct conflict with the Land Use Element of the Inland General Plan. By including wholesale and distribution, the City basically allows--potentially, subject to making the MUP findings--all commercial cannabis activities except flowering cultivation in the non-Neighborhood Commercial commercial zoning districts, including our sensitive CBD. As discussed at the meetings, making broad changes that make these industrial uses permissible in commercial zoning districts is inconsistent with the Inland General Plan and would require a companion general plan amendment, which isn't being processed as part of this applicant-initiated but City continued application for an ILUDC amendment. Just like the potential microbusiness use type, this particular change should be kept for that later companion project that includes a general plan amendment. This might not be true for some industrial(ish) accessory uses but wholesale and distribution in particular is also arguably internally inconsistent as an accessory use within the ILUDC. Wholesale and (off-site) distribution--off-site distribution is what we are talking about; the on-site distribution recommended by the City Attorney is a different matter and is listed separately--is inconsistent as an accessory use because it conflicts with the definitions and intent of the ILUDC and therefore logically cannot be an accessory use to storefront retail uses, cannabis or otherwise. To illustrate, wholesale and distribution are not "customarily incidental to, related and clearly subordinate to a primary use on the same parcel" and serve off-site uses as was evident from the first proposal for Sunshine-Holistic where they wanted to use their nursery operation to supply wholesale plants to their off-site grow locations and then bring the product back for processing/manufacturing and ultimately distribution to retail operations other than that particular dispensary even if some would be sold at the retail dispensary. We only allow wholesale and (off-site) distribution in the industrial zoning districts because those uses are not compatible with the purposes of the commercial districts as described in the Inland General Plan and ILUDC unless those definitions and general plan provisions are first amended to allow these types of uses in commercial as well as industrial districts.

The discussion points about the two somewhat analogous CBD businesses, the Fort Bragg Bakery and Roundman's Smokehouse, are easily distinguishable because neither of those uses conforms to what is currently permitted in the CBD. Roundman's is a legal non-conforming use because a butcher shop has been operating at that location with the same mix of uses since it was originally constructed (or close to that date) but it wouldn't be permitted now because meat processing and wholesale distribution is not accessory to the storefront retail butcher shop. The Fort Bragg Bakery is simply a non-conforming use and should be subject to code enforcement for not operating a retail storefront, instead operating exclusively as a wholesale

and distribution model that is only permitted in our industrial zoning districts. Referencing either of those businesses as a reason to allow that kind of flexibility for cannabis retail accessory uses is misplaced because neither example conforms to the current ILUDC use tables for CBD zoning. Overtime Brewery is also not a good precedent because it was arguably a political and not principled planning decision and doesn't really conform to the industrial zoning district but their campaign worked and it was permitted anyway. (If that approval was a court decision, it would be regarded as bad precedent and subject to being overruled by the Supreme Court.) Plus, it is a totally different zoning district. IMO, too much of our local planning appears to be politically motivated rather than examples of principled planning and we have had a series of city councils that don't appear to care about exercising their policy-making authority correctly (e.g., by amending applicable but inconsistent general plan policies and provisions prior to, and to facilitate, their desired policy-making through zoning code amendments). The current draft ordinance exhibits this issue concerning accessory uses and the recirculated draft negative declaration fails to address this issue within the Land Use and Planning Analysis.

In addition, the analysis in a few impact areas remains indefensible because they don't include a threshold of significance and instead just jump to a conclusion that the impacts are less than significant based on implied criteria. You can't determine if something is significant or not simply by stating that it is insignificant; rather, it must be measured against a threshold of significance which must be explicit in the CEQA document. Some impact areas have clear thresholds (e.g., the ACQMD standards for emissions) but other areas that are relevant and at issue don't have any explicit thresholds. The Initial Study checklist questions do not serve as thresholds of significance, which is clearly established by volumes of case law, yet this error is very common even in documents prepared by so-called qualified CEQA consultants and inexperienced planning staff. One area that includes this issue is the negative declaration's discussion of the City's municipal water supply, which it declares less than significant even though there is no threshold of significance used for the purported analysis. Instead, that section goes through some of the relevant information and baseline conditions as well as some projected numbers for future cultivation-related water use but then just jumps to the unsupported assertion that there are no significant impacts in this critical area of inquiry. That portion of the CEQA analysis requires revision because this project will likely have an actual significant impact, albeit an indirect one, through the cumulatively considerable contribution to the City's water use demand compared to the diminished available municipal water supply. What we have now is an error of omission and a lack of a meaningful threshold of significance. If we applied a reasonable threshold, it would be very low in order to be considered a cumulatively considerable contribution to the problem because our critical water supply shortages and insufficient water storage even though we have taken steps to increase raw water storage and to allow for additional use of our river sources through the desal plant. CEQA doesn't permit unsupported assertions in place of reasoned analysis and explicit calculations based on reasonable thresholds of significance but that appears to be what is presented in the current draft.

--Jacob

From: Jacob Patterson
To: Gurewitz, Heather
Subject: Fwd: Cannabis Ordinance ND
Date: Thursday, May 12, 2022 11:19:19 AM

Heather,

Please include this prior email exchange with Dave as a formal comment on the draft Negative Declaration for the cannabis ordinance. My point is that the NegDec needs to be revised to include more thorough analysis of indirect impacts that are reasonably foreseeable. We have had several large development projects that were proposed to be facilitated by this ordinance update, including the large cannabis business park proposed to be located off of Airport Road behind the Caltrans facility. In fact, this project started as an applicant-funded project to facilitate that specific development as well as other cultivation projects within the industrial district areas in town south of Pudding Creek that desired to include indoor cultivation. All of those projects are indirect but foreseeable consequences of adopting this proposed ordinance and they need to be analyzed. The prior City staff prepared a City-wide water use analysis concerning the cultivation aspect of this project but that analysis and related discussion was not included in the draft NegDec. Instead, it improperly states that water use analysis will happen in the future on a project-by-project basis so we aren't doing it now for the whole ordinance itself. That is an error and adoption of the draft NegDec would therefore be a reversible abuse of discretion unless it is first revised to address the projected water use of these foreseeable projects, particularly the large cannabis business park that would be proposed for the area north of Airport Road that the NegDec improperly dismissed as not having water infrastructure so the development isn't likely. Not only is it likely, facilitating that project and others like it was actually the reason this project to update the cannabis ordinance was initiated in the first place so it clearly meets the criteria to be considered a reasonably foreseeable consequence or potentially permitting indoor commercial cultivation that was not previously permitted.

--Jacob

---------- Forwarded message ---------
From: **Spaur, David** <Dspaur@fortbragg.com>
Date: Thu, Apr 21, 2022 at 5:50 PM
Subject: RE: Cannabis Ordinance ND
To: Jacob Patterson <jacob.patterson.esq@gmail.com>

Thank you

Let me look it to this more

Dave Spaur

Interim City Manager

City of Fort Bragg, Ca

416 North Franklin St.

Fort Bragg, CA 95437

707-961-2829

dspaur@fortbragg.com

From: Jacob Patterson <jacob.patterson.esq@gmail.com>
Sent: Thursday, April 21, 2022 4:32 PM
To: Spaur, David <Dspaur@fortbragg.com>
Subject: Cannabis Ordinance ND

Dave,

I thought I would reach out since you signed off on several of the CEQA-related documents for the cannabis ordinance project. My earlier comments were primarily procedural and about the faulty project description, which has been corrected in the new draft that is circulating now. I have a significant substantive concern that I mentioned in my prior comments but might have been dismissed because I did not (yet) provide the supporting documentation that would be necessary to constitute substantial evidence in the record supporting my particular objection. (I tend to wait until the actual public hearings to provide all the supporting documentation and then submit those documents as formal public comments but raise the substantive issues in prior written communications.)

In any case, since the City is maintaining the MUPs for all commercial cannabis uses in the current proposed ordinance, there are not direct impacts/physical changes from the ordinance itself and the future direct impacts from individual projects will be reviewed on a project-by-project basis along with their associated MUP reviews. However, the City still needs to evaluate the reasonably foreseeable indirect impacts from the zoning ordinance itself and was doing just that when this project was still an applicant-funded project intended to facilitate specific industrial development north of Pudding Creek. (In fact, there is even a CA Supreme Court case that talks about the need to perform CEQA analysis for new uses permitted or potentially-permitted under a zoning ordinance concerning cannabis regulations even when those uses will involve future conditional use permits--the case is about whether the ordinance itself is a "project" under CEQA and not about the adequacy of the CEQA document so it doesn't directly apply to the City's current project but provides clarity on the scope of the environmental reviews.) Prior staff even prepared a build-out analysis to look at the projected water use of newly-permitted cultivation in the City's industrial zoning districts but that doesn't appear to have been carried over into the current CEQA review for the cannabis ordinance. When I went in today to ask staff about that prior analysis, they were unaware of its existence so I submitted a CPRA request to ferret it out of the archives. The fact that this project (the cannabis ordinance) started as an applicant-funded project specifically

intended to facilitate an actual development project involving a significant amount of planned cultivation clearly provides a basis to find that such development is a reasonably-foreseeable consequence of adopting the facilitating ordinance that is adding these new cannabis cultivation uses. We also have at least two applications/applicant inquiries that included cultivation of at least nursery stock in existing buildings located within the CBD. In any case, that analysis needs to be added to the CEQA document because these likely development projects are not speculative but are reasonably foreseeable. I think some of this might have fallen through the cracks due to the very significant staff turnover within CDD

Regards,

--Jacob

From:	Jacob Patterson
To:	Gurewitz, Heather
Subject:	Some supporting Documents for the Comments on the Cannabis IS/ND
Date:	Thursday, May 12, 2022 2:02:31 PM
Attachments:	Fort Bragg Narrative1.2.docx Figure A.pdf RESO 4297-2020 Stage 1 Water.pdf Reso 4302-2020 Stage 2 Water.pdf 20210628 Water and Housing Needs Collide in California's Severe Drought.pdf RESO 4420-2021 Stage 2 Water Emergency.pdf RESO 4412-2021 Stage 2 Water.pdf RESO 4389-2021 Stage 1 Water.pdf 20210615 The West's Water Restriction Nightmare Is Just Beginning.pdf 20210623 California water shortages Why some places are running out CalMatters.pdf Thompson_et_al-2021-Nature_Climate_Change.pdf

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Heather,

Please also include this email and the attached files as part of the written comments on the recirculated draft IS/ND for the City's project to update the current commercial cannabis regulations. The topics covered in the attached documents are directly or indirectly referenced in other written comments. They are submitted to provide additional evidence supporting the points raised therein and are intended to help constitute substantial evidence in the record for the ordinance project supporting the preparation of an MND or EIR rather than the current ND due to the impacts of the City making indoor commercial cannabis cultivation permissible when we have no slack or capacity in our municipal water supply due to climate change, sea-level rise, and extreme drought paired with the reasonably foreseeable indirect physical development facilitated by adopting the ordinance itself. If read alone and without that context, these supporting documents would not necessarily make sense as comments on the recirculated draft IS/ND. Prior submission cover other similar documents, including the City's water model itself, as well as the agenda materials for several prior meetings that the City Clerk agreed to include in the record without having to formally download the documents from the City only to resubmit them to the City. Those were submitted at earlier stages of the public process for the development of this proposed ordinance currently scheduled to be considered for introduction at the next City Council meeting.

Thanks,

--Jacob

EXTREME WEATHER

The West's Water Restriction Nightmare Is Just Beginning

Oakley, Utah placed a moratorium on any new construction projects that would tap into the city's water system.

By Dharna Noor 6/15/21 12:56PM | Comments (4) | Alerts

Photo: Ethan Miller (Getty Images)

A small city in Utah is taking an unprecedented step to adapt to megadrought conditions in the West: halting any new construction projects that would tap into the local water. It's the first municipal ordinance of its kind.

Last month, officials from Oakley, Utah—a city of 1,500—finalized a moratorium on new development extending through November. The ordinance prohibits the "erection, construction, re-construction or alteration of any structure" that needs new water connections.

"The city is concerned that the current drought conditions will result in critical water shortages and require further drastic curtailment measures that would be detrimental to the entire city and cause significant public harm," it says.

Oakley is hardly alone, though. The West's water resources have come under increasing pressure from rising temperatures tied to the climate crisis. Heat can both melt out snowpack early and cause water stored in reservoirs to evaporate. It can also affect groundwater recharge, particularly in years with low snowfall. Explosive growth in the region has made matters worse since more homes and businesses with more lawns and more farmers with water-needy crops put extra pressure on the water system. What's happening in Oakley is a sign of what could come in other communities if the West is to stave off an even bigger water crisis.

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The measure to stop building passed amid a historic drought in Utah that has led to, among other things, the state's governor asking residents to literally pray for rain. Oakley is currently in an "extreme drought," according to the Drought Monitor, while more than 60% of the state sits in the worst category, dubbed exceptional drought.

By taking this dramatic step now, Eric Jones, a regional engineer at Utah's Division of Water Rights, said officials could help ward off the need for more "draconian measures," like restrictions on individual water usage.

"Oakley has a good understanding of their sources and is ahead of the curve," he wrote in an email.

Conserving water will be particularly important since Utah's drought is also creating conditions for catastrophic wildfires, which is shaping up to potentially be the state's worst on record. Low reservoir levels and impacts on pressure could be particularly dangerous.

“If a fire broke out in town, and the fire department came to hook into a fire hydrant to put it out, they would have no water,” Oakley Mayor Wade Woolstenhulme told a local ABC affiliate.

Even locations that are dependent on groundwater face issues. Oakley’s water sources, which include two springs and a well, are performing at lower levels than average amid the drought.

“Groundwater integrates the effects of temperature and precipitation over multiple years, so as drought conditions persist, [the] water table drops and water becomes more limited,” Paul Brooks, a hydrologist at the University of Utah, said in an email. “That makes the current exceptional heat and dry conditions a challenge for utility managers.”

The city is scheduled to bring a new well online next year as its first new source in 20 years, which could help ensure residents have more access to water. But the need for water may still outstrip the new additions. The town has seen its population grow in recent years, and it reopened an old school this year. A local city councilperson told local outlet the Park Record that the city received triple its usual number of building permits this year. The moratorium on new water connections could help ensure Oakley has enough for current residents, buying it time.

“Community leaders have a responsibility to ensure that all residents have access to safe, reliable sources of water,” Robert Adler, a law professor at University of Utah’s S.J. Quinney College of Law with expertise in environmental and water law, wrote in an email. “When growth outstrips water supply, that’s not possible, and the responsible response is to curtail growth until the balance between supply and demand can be addressed.”

Oakley’s new measure is the latest in a string of new drought adaptation policies being considered and passed by Western states and municipalities. Earlier this month, Nevada banned developers from planting new grass on street medians, traffic circles, office parks, and apartment complex entrances. In April, Oakley itself passed another ordinance to stop homeowners from installing water-intensive elements like ponds, outdoor pools, and waterfalls.

Oakley is the first town to put a moratorium in place on new building, but Adler expected more will follow suit as more growing Western cities are forced to grapple with persistent water scarcity. In fact, he said, those future policies could make Oakley’s new policy look like kid stuff, especially as they become necessary in cities with more extreme rates of growth.

“The Oakley moratorium is on the mild side of the spectrum. It is temporary, and is supposed to be lifted once a new well comes online. It also does not apply to

development permits that have already been issued, and is coupled with stricter water conservation requirements for existing users," he said.

City councilors in Oakley have said just a handful of new development proposals have been affected by the moratorium, which seems like a small price to pay to keep people safe during punishing heat and drought.

Conditions are expected to worsen this summer. This week, a heat wave has sent temperatures soaring in the West. On Tuesday, Salt Lake City—located about an hour west of Oakley—had its hottest day ever recorded when the mercury hit 107 degrees Fahrenheit (41.7 degrees Celsius). (That's also now the city's all-time high temperature for June.) Water resources will surely suffer in the blast furnace, and they'll only become more precarious as we get further into the dry season.

"Human-caused climate change has absolutely worsened drought conditions in Utah," William Anderegg, an assistant professor of biology at the University of Utah, said in an email. "A study from last year found that climate change is responsible for about half of the long-term mega-drought severity in the southwest since the early 2000s, and that is absolutely influencing the severe summer drought this year in Utah."

The West is expected to continue to dry out as the climate crisis worsens. These recent years, then, are a preview of what could come.

“No one wants to be in a situation where water supply is so limited that it needs to be rationed during times of year, especially the hottest, driest times of the year,” said Brooks.

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EARTHER » EXTREME WEATHER

DISCUSSION

By Dense Non Aqueous Phase Liquid

I mentioned this before on Earther and I’ll mention it again. The USGS has an awesome new interactive national water data dashboard for its water information system here:

https://waterdata.usgs.gov/nwis?

The new dashboard link is at the top of the web page. The new dashboard is experimental or in beta. There’s a whole bunch of surface (lakes and rivers) and well water (groundwater) data for the entire country a mouse click away. It use to take awhile, like a long while, to see earth science data.

What's cool is one can find the city of Oakley, UT on the map. Then realize it's not too far west of Salt Lake City. Maybe it's becoming suburbanized. Maybe it's not. There's a rodeo there. Then zoom in and see that the Weber River runs through it. Then one can click to see river flow data

See all replies

CALMATTERS

ENVIRONMENT

Water shortages: Why some Californians are running out in 2021 and others aren't

BY RACHEL BECKER , JUNE 23, 2021 UPDATED JULY 14, 2021

Stevens Creek Reservoir near Cupertino is one of the reservoirs that supplies water to Santa Clara County. It is only 17% full. This photo was shot on June 7, near the beginning of the long dry season. Photo by Nhat V. Meyer, Bay Area News Group

IN SUMMARY

Drought resilience depends on location but also extraordinary engineering — determining which California places are running out of water this year and which remain in good shape.

In Los Angeles, people have been hearing about the dangers of drought for decades. But in this land of infinity pools and backyard putting greens — better suited for rattlesnakes and scrub — water never seems to run out.

Yet little Redwood Valley in Mendocino County, which gets a bountiful **38 inches** of rain in an average year and sits **near the headwaters of the Russian River**, has been devastated by this year's drought. Each resident has been told to use no more than 55 gallons per day — enough to **fill a bathtub** and flush a toilet six times.

And in San Jose, where less than half of its usual rain has fallen this year, people have been asked to cut water use by 15% — a target that could become mandatory if locals fail to comply.

When it comes to the impact of drought, location is key. Rain and snow vary greatly across California's myriad microclimates, leaving some towns, mostly in the north, accustomed to yearly refills of their rivers, reservoirs and aquifers. Others farther south have fewer natural supplies of their own, and in parts of the Central Valley, **the drought never really left**.

But drought resilience is manufactured, too. Decades of planning and extraordinary

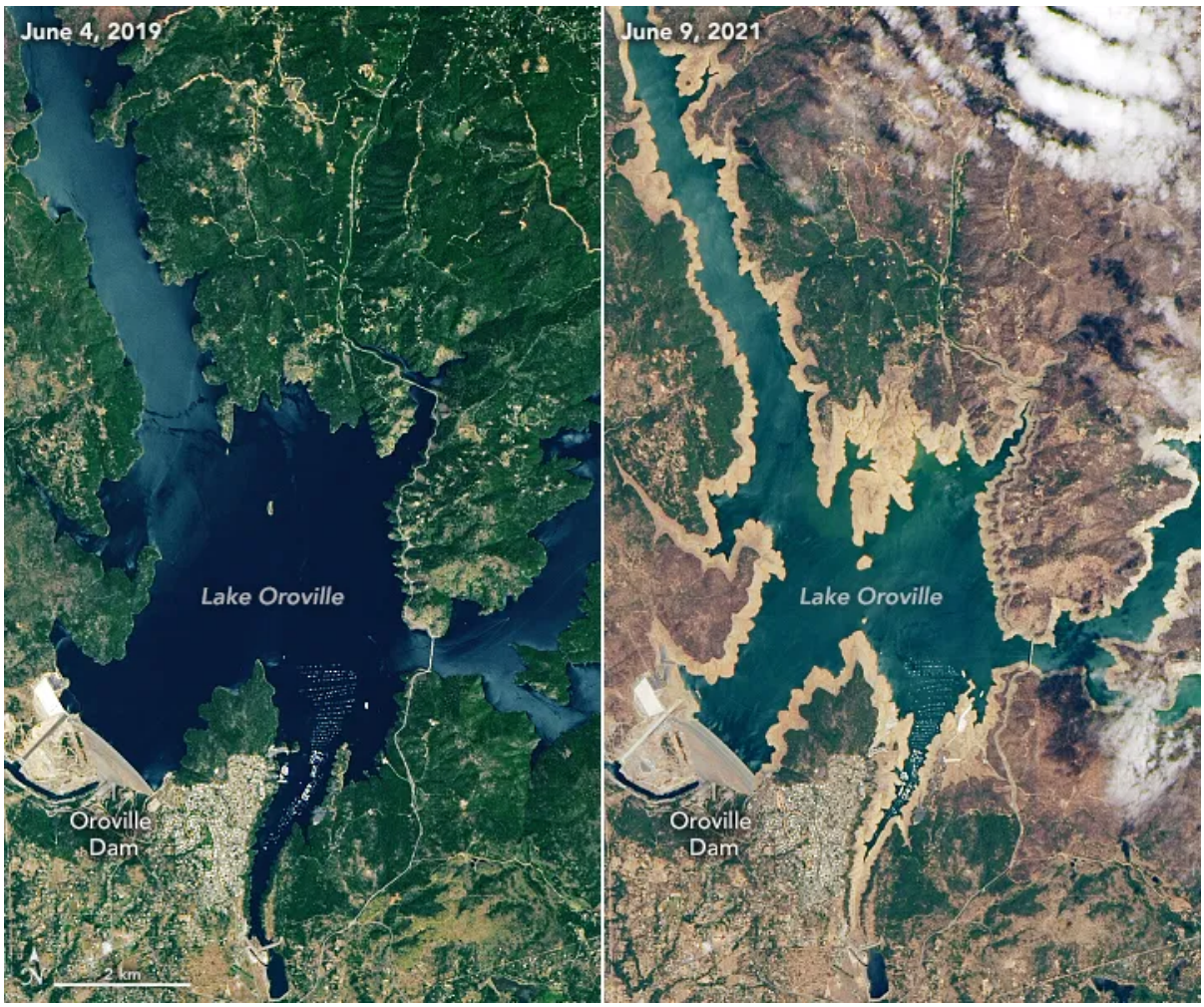
Running out of water and time: How unprepared is California for 2021's drought?

Tulare County's never-ending drought brings dried up wells and plenty of misery

engineering and technology keep the water flowing to arid places.

As drought intensifies, state warns users to stop pumping water from major rivers

"There is, of course, no single Northern California or Southern California when it comes to water," said **Peter Gleick,** founder of the Pacific Institute, a global water think tank. "Water is a very local phenomenon. And every region and every water district has a different mix of water supply options and water demands.



This satellite image shows how full Lake Oroville, which supplies much of the state's drinking water, was in June 2019 and how shallow and dry it is in June 2021. It's currently holding only 41% of its historic average for this time of year. Credit: NASA Credit: **NASA**

During the last drought, in 2015, Californians were ordered to cut their water use by an average **of 25% statewide**. This time, there is **no statewide emergency**, no universal mandate and no standardized water waste rules.

Instead, residents are facing a patchwork of restrictions. Bracing for a crisis, towns relying on the hard-hit Russian River have imposed stringent mandates on residents and coastal communities may have to truck in water to make it through the year. At the same time, most of California's urban hubs are prepared to weather the summer with only voluntary cuts and limited restrictions that in many cases are holdovers from previous droughts.

A CalMatters survey of the state's 10 largest water agencies found only one — in San Jose — has issued **new limits** on watering yards, washing cars and other outdoor uses. Eight, including **Sacramento**, already had rules curbing irrigation and water waste on the books. And four, including water agencies in the **East Bay** and **Riverside**, have asked people to voluntarily cut back between 10% and 25%.

Even though Southern California is more arid, it's better hydrated, too: That's because it has largely relied on water transported from elsewhere, dating back more than 100 years in Los Angeles and 50 years in neighboring cities and counties. About half of the water that flows from **taps in the region is imported**, while half comes from carefully nurtured groundwater reserves and recycled sewage.

As a result, Los Angeles residents are unlikely to face new water restrictions this summer. After a soggy 2019 plus declines in water use since the last drought, the Metropolitan Water District, which supplies imported water to 19 million people in six counties, **entered 2021** with record levels of water in storage.

The grip of drought even varies within single counties. For instance, one Mendocino County town is flush with recycled water and groundwater stores, but in another, residents are ordered to reduce use.

"We have a patchwork in part because (water) is managed locally," said **Felicia Marcus**, who led the state's response to the 2012-2016 drought under former Gov. Jerry Brown.

"The situation is dire in some places, and those places are making calls for higher levels of conservation," Marcus said. "In other places, they may be prepared, or they may be dreaming."

Southern California's manufactured resilience

Southern California goes to extraordinary lengths to **take water from elsewhere**. This nature-defying engineering keeps the region replete with water even when little falls from the sky. (Downtown Los Angeles averages **about 14 inches per year**, about a third as much as Mendocino.)

First came the city of **Los Angeles' aqueduct** — backed by **San Fernando Valley investors** and approved by voters in 1905 — sucking up mountain-fed streams and lakes in the Owens Valley and transporting it 137 miles.

But it wasn't enough.

Then came the Metropolitan Water District's aqueduct, drawing from California's share of the Colorado River, snaking through the desert and tunneling through mountains to deliver water to the Los Angeles basin in 1941.

But that wasn't enough, either.

Finally, the state in **the 1960s began building** a massive system to carry river water from Northern California, pumping it over the Tehachapi Mountains and through **700 miles** of pipelines and channels to deliver it to San Joaquin Valley farmland and 27 million people, **mostly in Southern California**.

And that is enough — for now.

These three extraordinary engineering feats have made much of Southern California able to pull water from a variety of places all at once, transforming its landscape and satisfying the region's thirst.

Los Angeles County also pioneered recycled water, building the nation's **first reclamation plant in 1962** to treat sewage and use it to replenish its aquifers. Neighboring Orange County has been a world leader in recycling

water, **purifying its own sewage** and capturing the Inland Empire's to feed its groundwater.

San Diego, too, has built up its resilience since the last drought. For decades it was almost **totally reliant on Metropolitan Water District's imported** water. But since the 1990s, the San Diego County Water Authority has added desalinated and recycled water, built one dam and raised another, pumped groundwater and cut a deal to get Colorado River water from Imperial County. The water authority announced the region is "drought-safe this summer" with "no shortages or mandates in the forecast."

Stephanie Pincetl, director of UCLA's California Center for Sustainable Communities, who has **studied Southern California's reliance on distant water sources**, said the decisions had far-reaching, if unintended, consequences: Los Angeles' **water grab from the Owens Valley** exploited distant ecosystems, and urban sprawl was fueled by the Metropolitan Water District's imports.

"It's really the growth machine of Southern California … by providing all this water to inland places, and allowing the sense that there's unlimited water and the sense that you can build as far as the eye can see," Pincetl said.

Construction of the 137-mile Los Angeles Aqueduct, which brought water from the Owens River to the San Fernando Valley, began in 1907 and took six years.

Still, she said, "You can point fingers a lot, but you can also be reassured that you can actually turn the tap on and have water come out of it, most of the time."

But is it enough to weather droughts aggravated by climate change?

This year, California regulators announced that they **would deliver only 5%** of the State Water Project's supplies because of extreme drought conditions.

Metropolitan, flush with funds from the cities and agencies it supplies, has spent billions to store water, nearly doubling its reservoir capacity with the completion of the **$1.9 billion** reservoir at **Diamond Valley Lake in 2000**.

Between stowing water in reservoirs, pouring it into aquifers and banking it in Lake Mead, Metropolitan Water District's storage has increased **13-fold since 1980**, shoring up supplies for residents from Ventura to San Diego to San Bernardino.

Los Angeles also doesn't anticipate issuing new water use restrictions, at least not yet.

"We don't see any need right now, because storage levels are still very good," said Delon Kwan, the Los Angeles Department of Water and Power's assistant director of water resources. "If you still have water in storage, why are you asking customers to do more?"

> **"Maybe Southern California is happy this year and jumping up and down. But if this drought continues for two more years, what will happen? Would they be as happy in two years?".**
>
> – NEWSHA AJAMI, STANFORD UNIVERSITY'S WATER IN THE WEST PROGRAM

But water experts caution about the potential for more dry days ahead, exacerbated by climate change, so a gallon of water used now is one less

saved for later.

“Maybe Southern California is happy this year and jumping up and down. But if this drought continues for two more years, what will happen? Would they be as happy in two years?” said **Newsha Ajami**, director of urban water policy at Stanford University’s Water in the West program.

Deven Upadhyay, Metropolitan’s chief operating officer, said that it could take several dry years in a row before the district imposes mandatory reductions in Southern California. “If we just continue to get dry year after dry year after dry year, there’s going to come a time where we’re going to be wrapping up messaging and asking for mandatory reductions. But that’s not where we are right now,” he said.

Imported water, recycled wastewater and collected stormwater runoff are used for irrigation and fountains at Los Angeles County’s Descanso Gardens in La Cañada Flintridge. Photo by Pablo Unzueta, CalMatters

Still, some parts of Los Angeles County are already struggling.

Palmdale, an aerospace hub in the Mojave Desert north of Los Angeles, draws water from snowmelt off the San Gabriel Mountains, taps into the State Water Project directly and pumps groundwater to supply more than 120,000 people.

The Palmdale Water District doesn't have enough storage to bank water during wet years or enough money to easily increase its supply.

"We're not as financially nimble as some of the really big players," said **Peter Thompson**, Palmdale's director of resource and analytics. "We're just getting to the point where we can start investing in those projects that have already benefited places like Metropolitan."

Residents of this desert city, where **less than an inch of rain** has fallen this year, were asked in the spring to **voluntarily cut water use** by 15%. In July, the water district's board may consider making it mandatory.

"Out in the desert, you need more water to keep things alive. So when we experience drought, then you also experience increased demand," Thompson said. "That's one of those double-edged swords that we deal with out here."

Mendocino County's isolation means no resilience

Water is much more precarious in Mendocino County, which is isolated from state and federal aqueducts. Instead, residents rely on patchy aquifers and water that's stored in **Lake Mendocino** and released into the Russian River.

Properties for sale along the oak-lined roads of Redwood Valley boast their water sources in the listings. One **$675,000 home** touts a water district hook-up and a seasonal spring. **Another $699,000** listing flaunts its "elaborately designed 22,000 gallon water storage system."

Known for its wine, weed and wild coast, Mendocino County was one of the first places where California Gov. Gavin Newsom **declared a drought emergency**.

In other parts of the state, "when there's a problem, there's a pipe and there's a canal, and you can connect one water system to the next," said Mendocino County Supervisor **Glenn McGourty** in a **June meeting** of the county's drought task force. "We don't have things like that in Mendocino County, so we're going to have to be really creative in our solutions."

This year's drought is the most dire situation they've faced in decades. At the end of May, Lake Mendocino **hit a record low of just 40% capacity**. Earlier this month, the county faced projections that the reservoir could be dry by the end of the year. In response, the state adopted **emergency regulations** that could stop 2,400 water right holders from diverting water from the Russian River as early as July 5.

Lake Mendocino in January 2020. Photo by Anne Wernikoff, CalMatters

Lake Mendocino in January 2021. Photo by Bobby Cochran Photography

Although Redwood Valley lies just north of Lake Mendocino, its water supply is never guaranteed. Residents rely on sales from a nearby water agency and any surplus left in the reservoir by nearby communities.

But at this point, there's no surplus. Agricultural connections have been shut off in Redwood Valley and residents **are limited** to 55 gallons per person per day — enough **for just a 22-minute shower** and nothing else.

"My dream was to garden," said Darrell Carpenter, a 61-year-old artist and handyman whose family has lived in Redwood Valley for three generations. Carpenter moved back full time after his partner died six years ago. When the water restrictions and rate changes were announced, he wondered, "Do I sell and move?"

Carpenter was lucky, able to restart an inactive well on his property and keep his garden alive, which he has slowly been converting to native plants and succulents. Still, he worries that his luck and the water will run out as more people stick straws into the ground.

“It might be a false sense of security,” he said.

Darrell Carpenter is converting his garden in Redwood Valley to native and drought-resistant plants. Photo courtesy of Carpenter

The water district’s cuts have left the reservation for the Redwood Valley Band of Pomo Indians with nothing to refill its tank for irrigating a community garden and filling its fire truck. Hydrants are still operating, but outdoor water use is banned and rancheria officials are investigating whether they can draw water from an old well.

“We don’t have any access to any other water,” said tribal administrator Mary Camp. “We’re really concerned.”

Farther out along the coast, in the town of Mendocino, residents depend on private wells pumping from rain-fed groundwater stores. The town declared **a stage 4 water shortage emergency** in May requiring residents to use 40% less water than allotted.

"I'm nervous. I'm definitely nervous," said Mendocino City Community Services District Superintendent Ryan Rhoades. "I'm sure that some wells will run dry this year, probably more than last year."

McGourty, the Mendocino County supervisor, blamed the county's predicament on its limited water storage.

"We've been lulled into the idea maybe that we have lots and lots of water. And we do have lots and lots of water. The problem is that we don't store lots and lots of water," McGourty told water officials across the region. "We're in a different world now, because of climate change."

"We don't have any access to any other water...We're really concerned."

– MARY CAMP, REDWOOD VALLEY BAND OF POMO INDIANS

Ukiah, just ten miles from hard-hit Redwood Valley, is weathering the drought much better because of steps taken after the last dry spell.

Five decades ago, the Doobie Brothers **described Ukiah** as a land where "mountain streams that rush on by show the fish a jumpin.'" Today the city is facing extremely dry conditions in the Russian River, which typically makes up about half of the supply for its 16,000 residents.

Ukiah will lean more heavily on groundwater, bolstered after the last drought with a state grant that helped pay for three new wells. The city also built a $34 million recycled water plant that pumps out irrigation water, making up a third of its supply.

"The city saw the writing on the wall, and was looking to improve our drought resiliency, before it was cool," said Sean White, director of water resources for the city of Ukiah.

"It's kind of a disparate tale. If you live in the city of Ukiah, (the drought) is really not that big of a deal … If you live in some of the adjoining ones, it's either bad or terrible."

Silicon Valley's perfect storm

In Silicon Valley, aging dams and drought have collided this year, making Santa Clara County among the hardest hit in the Bay Area. Storage in reservoirs has dwindled by 74%. And supplies from state and federal aqueducts have dropped far below expected levels.

Making matters worse, the area's largest reservoir is all but empty, drained last year to retrofit it for earthquakes. Without it, the amount of water stored locally for 2 million people in **San Jose and nearby communities** has been cut by more than half.

"We're seeing the perfect storm building up and it's right in front of us," said **Rick Callender**, Valley Water's CEO, at a June board meeting. "We're indeed in a dire situation."

If dry conditions persist through next year, land could sink and wells could go dry. In the southern part of Santa Clara County, groundwater is the only drinking water source.

"The aggressiveness and the severity of this drought, the way the drought is increasing is much greater than the previous drought," **Aaron Baker**, chief operating officer at Valley Water, said at the hearing. "Conditions will be far worse in 2022 if drought conditions continue and no action is taken."

Valley Water's board this month **ordered a mandatory 33% cut** in residential water use from 2013 levels — a 15% reduction from 2019. Individual water providers will enforce it, which means rules for residents could vary depending on who sends water to their taps.

> **"Conditions will be far worse in 2022 if drought conditions continue and no action is taken."**
>
> **– AARON BAKER, VALLEY WATER**

Cupertino's director of public works, **Roger Lee**, warns that if water providers fail to coordinate, it could lead to a patchwork of restrictions in neighborhoods served by multiple retailers.

"We can have customers with one set of rules on one side of the street and different sets of rules on the other side of the street," Lee said at the hearing. "It gets very difficult with messaging."

Marin County's largest water provider, too, has been hit hard by shortages in its own reservoirs and those in Mendocino and Sonoma counties. Marin Water, which aims to cut use across the county by 40%, has banned watering plants during the day and limited sprinklers to two days a week, among other **mandatory restrictions**,

Most of the Bay Area isn't in such dire straits — at least not yet. Residents of the East Bay were asked to reduce water use by 10%, and San Francisco golf courses, parks and other irrigation customers were asked to cut back. Both water districts already prohibit wasteful use, like washing down sidewalks.

And both, like Los Angeles, pipe water from far away.

The East Bay's aqueducts snake about 90 miles from **the Pardee Reservoir in the Sierra foothills**, delivering the vast majority of the utility's supply.

"Our forefathers (thought) to create this massive infrastructure that has been our source, our lifeline to the East Bay and has positioned us well during these dry times," said Tracie Morales, an East Bay Municipal Utility

District spokesperson. Still, Morales said, "We're concerned about what another dry year will bring."

San Francisco, where residential use per person falls well below the state average, draws **about 85%** of its water from Yosemite's Hetch Hetchy, which was **dammed in 1923**, flooding the territory of **the Tuolumne Me-Wuk people**. San Francisco's reservoirs remain in decent shape **at 75% of maximum storage**, said spokesperson Will Reisman.

"The Santa Clara Valley used to be orchards here, but we didn't have the population that San Francisco had and we didn't have the impetus of the 1906 quake and the resulting fires to go grab the Hetch Hetchy water," said **Gary Kremen**, vice chair of Valley Water's board of directors. "They were there first, so they got the better deal."

Counties urgently seeking state help

Some areas, like Santa Clara, are looking for Newsom to expand drought emergencies that could unleash greater enforcement powers and reduce regulations to speed construction products and ease pricey purchases of emergency water supplies.

Compared to the counties already under drought emergencies, "we're in just as bad shape as them, if not worse," Kremen said at a press briefing.

Palmdale spokesperson Judy Shay also said her water district is looking for stronger messaging from the state as it ramps up its drought response.

"We also don't want to be the ones making all those strict rules," Shay said. "We also need direction from the state."

An oak woodland is among the lush features at Descanso Gardens in La Cañada Flintridge. The Los Angeles region was transformed with the use of imported water and recycled wastewater. Pablo Unzueta for CalMatters

The Pacific Institute's Gleick calls for urgent collective action throughout the West.

"The speed with which the western drought is accelerating and worsening makes it urgent that the governors of the western states declare water conservation mandates and targets and provide resources to help cities and farms cut water use," Gleick said.

The issue is bigger than simply responding to the current drought, said UCLA's Pincetl. Californians will need to reimagine what the future could look like and rethink their relationship to water.

"We don't actually know where we live ... we live in this kind of irrigated bubble that insulates us from the actual California," Pincetl said. "And having easily accessible water is part of that story."

Rachel Becker

rachel@calmatters.org

Rachel Becker is a reporter with a background in scientific research. After studying the links between the brain and the immune system, Rachel left the lab bench with her master's degree to become a journalist... **More by Rachel Becker**

Environment & Energy

Water and Housing Needs Collide in California's Severe Drought

By Emily C. Dooley

June 28, 2021, 3:00 AM

- 85% of California is experiencing extreme drought
- Hundreds of thousands of homes need building each year

Housing advocates and developers are warily watching California's intensifying drought and what it may mean in a state that needs millions of new homes to house its residents.

Eighty-five percent of the state is in extreme drought. And in coastal Marin County, north of San Francisco, rainfall is at its lowest levels since records began 140 years ago.

It's here where the state's twin issues of housing stock and water availability are colliding. But it could be a harbinger of things to come for the rest of the state.

Additional housing puts more stress on water supplies. The housing and water conflict "piles one major policy crisis on top of another," said Richard Frank, director of the California Environmental Law & Policy Center at University of California, Davis.

Gov. Gavin Newsom (D) signed executive orders in April and May declaring 41 counties in a drought state of emergency, giving water regulators more authority to manage water use and diversions.

At the same time, an estimated 120,000 affordable homes need to be built each year through 2030 to meeting housing needs, particularly for extremely low-income residents, according to a 2021 report from the California Housing Partnership, a nonprofit affordable housing group.

"I'm afraid I do think it's going to become a bigger issue," Partnership CEO and President Matt Schwartz said.

Stalled Project

Consideration of a moratorium on new water connections by the Marin Municipal Water District has already stalled one affordable housing project and could hurt another one 10 years in the making. The district has scheduled a July 6 meeting to discuss the moratorium.

Vivalon, a nonprofit in Marin County, is working on its final permits to build what's called an healthy aging center, with support services for older county residents on two floors and 66 affordable apartments on four higher floors. The wait list has more than 400 names.

"The last moratorium was four to five years," Vivalon Chief Executive Anne Grey said in an interview. "That's just time we don't have."

The $48 million project will have trouble getting financing without water.

"It could stop the project dead in the tracks," she said. "People are counting on this housing for the future of the community."

A 74-unit multifamily complex already approved by the county for low- and extremely low-income residents is also in limbo, said Alexis Gevorgian, a managing member for AMG & Associates, a developer.

The project in Marin City was the first development proposal submitted to the county under new state laws meant to streamline housing developments. Gevorgian was hoping to break ground in three to four months.

But he needs a letter from the water district promising service. Without that, he said, "we can't get our state and federal subsidies to build our project."

'Dire Situation'

Marin Water District held off on approving the moratorium after a lengthy meeting, where board members considered exempting affordable housing projects. A new vote hasn't been scheduled.

"It's important we not be increasing demand on a system that is already taxed," Marin Water District President Cynthia Koehler said in an interview. "We just need to send a pretty clear signal this is a dire situation."

Grey and Gevorgian are hoping affordable housing will get a pass or special consideration.

"I'm hoping the water district is sympathetic to our need," Grey said.

During the 2012 to 2106 drought, California water regulators issued 21 orders barring water districts from allowing new connections and ordering existing promises of water availability null and void if building permits weren't in place before certain deadlines.

The orders were issued in northern, central, and coastal California and targeted districts that had water rights that were junior to other users, such as agriculture and irrigation districts.

The same could happen during this drought, though it would likely affect smaller water systems and not large, urban suppliers where housing developments are typically based, said Darrin Polhemus, deputy director for drinking water programs at the State Water Resources Control Board.

“I don’t see a big impact on the state housing stock,” he said.

Legal Remedy?

During the last drought, the Hidden Valley Lake Community Services Water District west of Sacramento sued to overturn a state order prohibiting it from adding new connections beyond the more than 2,400 already in operation.

The district eventually won because they argued their supply came from groundwater and not surface water, over which the State Water Resources Control Board has regulatory power. The 2014 moratorium wasn’t lifted until July 2020.

Developers who secure water availability agreements from a local government like a county that then issues a moratorium could have some legal recourse, otherwise the cases are hard to fight, said a water rights and real estate attorney who spoke on condition of anonymity due to ongoing client representations.

Developers could, however, get special agreements in advance that they’re exempt from moratoriums, as a development in Half Moon Bay south of San Francisco was able to do several years ago, the California Housing Partnership’s Schwartz said.

For Grey, a lawsuit wouldn’t be possible for the nonprofit.

“We wouldn’t have the bandwidth to do that because it would be too expensive,” she said. “We can’t put our other services in jeopardy for an unknown outcome. It’s too risky.”

New NIMBY Threat

Housing is needed throughout the state. Where housing opponents usually cite traffic concerns, water concerns could become one more way to thwart development.

“Frankly, I think they’re looking for new bullets to tie things up,” Schwartz said. “I think the next one will be water.”

He is considering sponsoring a bill in the state legislature that would exempt affordable housing projects from moratoriums. Unlike single-family homes, affordable housing developments rarely have elaborate landscaping and come with water-efficient appliances and plumbing.

“We’ve got to get out in front of this,” Schwartz said.

Whether there’s a formal moratorium or not , developers could see pushback at the local level when it comes to building permits and NIMBY residents, said Steve Cruz, a consultant on water and resource issues for the California Building Industry Association.

Prohibiting new connections also won’t solve a problem and could force people into older homes that are less water-efficient.

“It’s not really addressing the problem,” Cruz said. “You’re not going to take us out of drought because you’re taking away new development.”

To contact the reporter on this story: Emily C. Dooley at edooley@bloombergindustry.com

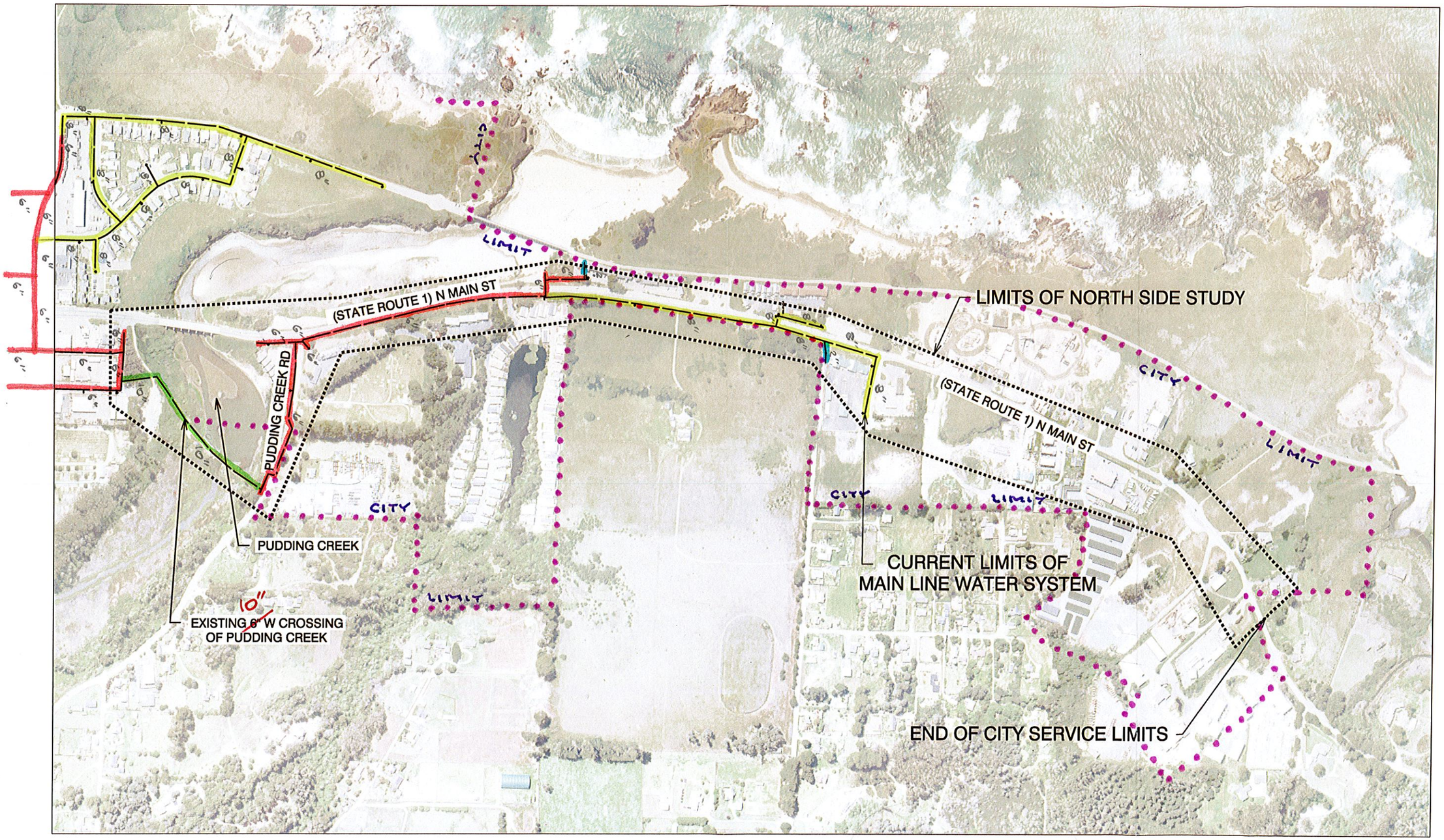
To contact the editor responsible for this story: Chuck McCutcheon at cmccutcheon@bloombergindustry.com

Documents

Document
California Housing Partnership report

Related Articles

California Drought Is So Bad Almond Farms Are Ripping Out Trees	June 23, 2021, 4:00 AM
Drought Complicates California’s Tight Housing Market	Sept. 10, 2015, 4:35 PM



6"
8"
10"

NORTH SIDE STUDY PROJECT LOCATION

CITY OF FORT BRAGG

SCALE 1"=500'

FIGURE A

FILE: S:\2719-17 North Side Water Study\Exhibits_FIG_A PROJECT LOCATION.dgn
DATE: 1/22/2019

August 24, 2018

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Dear Mr. Perkins,

This correspondence is regarding your request for an initial proposal as to our intent for the implementation for amendment to the City Ordinance as it pertains to cannabis related activities on industrial properties in the City of Fort Bragg. Our application to amend the Municipal Code will seek to permit cannabis cultivation, manufacturing, processing/packaging, analytical testing, distribution, research and development, cannabis composting management (cannabis waste) within the City's industrial zoning districts.

The recent legalization of cannabis use in the state of California has created the opportunity for entrepreneurship and investment into the revitalization of under-utilized industrial space throughout the state and the creation of thousands of working and professional class jobs. It is our belief that once implemented, the amendment of municipal code to permit those cannabis activities described will result in the development and construction of several hundred thousand square feet of industrial warehouse and greenhouse space and the creation of a multitude of full time jobs in industrial zoned properties in the City of Fort Bragg. The economic benefits of this activity will be felt throughout the city by increased retail activity, the employment of local contractors, warehouse technicians, laborers, engineers, chemists, botanists, horticulturalists, architects, attorneys, accountants, Real Estate brokers, administrators, secretarial etc. This increase in economic activity results in the overall improvement of well-being of the city populace and city government.

The cannabis industry is multifaceted, and it is our aim to construct a campus on the North side of town that is completely vertically integrated from nursery to distribution. To truly appreciate the multiple opportunities for industrial entrepreneurship we need to understand the scope of the

process from start to finish. The workflow within the industry is as follows: a nursery creates starts through seed, tissue culture and or small cuttings ("clones") from a single genetic mother which can be vegetated into mature flowering plants; these starts are transferred to a cultivation site, ideally a type of greenhouse known as a "light deprivation" house, the mature adult flower is then processed ("trimmed") to remove less desirable biomass so that the Class A flower can be distributed to retailers, the remaining biomass and Class B flower that is not suitable for retail sale in its current form is then moved to a manufacturer for further processing.

Processing takes the form of several types of extraction, both crude and artisan. The employment of multiple solvent types is available, and each requires its own set of regulatory parameters, engineering and capital equipment. Some of these artisan extracts are then distributed for retail sale as-is. Crude extracts require additional downstream refinement, usually in the form of distillation. These distillates are then compounded and distributed to retailers for consumer sales. At each point in the process the state requires that analytical chemical and biological testing be performed on the input material in the process and a certificate of analysis provided. It is, therefore; our aim to amend municipal code so that we can create a campus that is completely vertically integrated so that all commerce between different business segments remains within the City of Fort Bragg, maximizing local employment and business efficiency.

To accomplish this goal the following operating characteristics will be required: retractable roofs for light deprivation greenhouses; the use of well water for irrigation in cultivation activities; use of well water for incidental domestic uses; use of septic on site to treat cannabis cultivation affluent; allowance for distribution activities within city limits; use of analytical testing services; use of fractional distillation refinement activities of cannabis extracts; use of established hydrocarbon extraction with solvent recapture methods; employment of research and development activities for the further discovery of industry-leading technology in cultivation, engineering and processing of cannabinoid compounds; the use of rain capture and storage methods; uses(s) of alternative energy solutions, and the increase of Floor Area Ratio ("FAR") to 60%; maximizing the buildable space on the available industrial zoned lots within city limits.

This project presents a unique opportunity for both local business people and the City of Fort Bragg. It is our intention to build and develop industrially zoned properties in the Northern industrial district into a vertically integrated cannabis campus populated with several independently owned and operated, small cap local businesses. Overseen by a property management group that provides all the necessary resources including: standard operating procedures, compliance assistance and complimentary local resources to maximize opportunities for success of local skilled tradesmen. Accommodating cultivators, processers, manufacturers, testing services and distribution in a single hub the businesspeople that operate each facet of the campus can form strong business partnerships with upstream and downstream purveyors.

The economic impact of this project should not be understated as we estimate this campus will result in approximately 150 full-time, living wage jobs. It is our hope to create a self-sufficient industrial community, where responsible entrepreneurship and increasing local civic engagement

benefit the township for everyone. For the purposes of industrial suitability, we believe that the City of Fort Bragg, and specifically the location in the Northern industrial district, possess a natural competitive advantage to analogous projects than in other parts of the state. The marine climate conditions are optimal for environmentally sustainable fully optimized greenhouse cultivation and manufacturing activities. The businesses located in the campus will benefit from substantially reduced overhead required in both heating and cooling costs, which is a significant expense for cultivators inland and Southern California. In addition to temperature, the relatively high levels of precipitation in the local climate provide us with the opportunity to utilize rain/condensation capture and storage methods, a source of irrigation water to further reduce our environmental burden. Water capture methods also provide a solution for drainage concerns associated with the buildup of impermeable space resulting from increased FAR allowances. Furthermore, the Northern industrial zone has a well-established historical use for the storage and transport of hydrocarbons such as propane. This provides the opportunity for increased local business with established propane dealers for hydrocarbon extractors located on campus, thus reducing transport costs for both parties. Taking these factors into consideration, we believe that this project has substantially higher long-term viability and sustainability.

Looking towards the future cannabis legalization is a movement that is taking hold in many states and several nations. It is only a matter of time until the political climate of the United States embraces this on a Federal level. In the meantime, the State of California has joined the ranks of Colorado, Washington, Oregon, Maine, Massachusetts, Washington D.C., Nevada and Alaska in abolishing prohibition and extending the opportunity for legitimacy of the cannabis industry. It is our belief that by embracing this moment the City of Fort Bragg will experience an economic revitalization that will benefit the people of our town for many years to come. We thank you for your consideration and look forward to the opportunity to engage in a dialogue with City Officials so that we may address concerns and outline specific details of our proposal.

Best Regards,

Jon McColley
Charles Ellis

RESOLUTION NO. 4297-*2020*

RESOLUTION OF THE FORT BRAGG CITY COUNCIL RECOMMENDING AND ENCOURAGING VOLUNTARY IMPLEMENTATION OF STAGE 1 WATER CONSERVATION MEASURES

WHEREAS, the City of Fort Bragg has experienced significantly less rainfall in the last twelve months than would be considered normal; and

WHEREAS, the water flows in the Noyo River have declined more quickly this summer than prior years and is currently at 2.0 cubic feet per second (csf) and are nearing 1.0 csf; and

WHEREAS, historically, it is in the months of August, September and October that the Noyo River experiences King Tides, where the gravitational pull between the sun and the moon increase tide levels to a foot or two higher than high tide levels. High tides such as the King Tides during periods of low flow levels on the Noyo River increases salinity content impairing the City's ability to replenish water supply from the Noyo River; and

WHEREAS, the weather forecasts continue to show no significant rainfall in the area in the coming weeks; and

WHEREAS, the City's water supply and ability to replenish its supply have not dropped to the levels established in the Fort Bragg Municipal Code section 14.06.020 which would require that the City declare a water emergency. However, implementing conservation measures now will reduce future impacts on the City's water supply and water storage levels and potentially avoid a greater level of water emergency; and

WHEREAS, based on all the evidence presented, the City Council finds as follows:

1. It is in the best interest of the City of Fort Bragg to encourage voluntary compliance with Stage 1 water conservation measures.
2. Waiting to implement water conservation measures until the established triggers set forth in Fort Bragg Municipal Code section 14.06.020 may be too late avoid or reduce future water shortages.

NOW, THEREFORE, BE IT RESOLVED that the City Council of Fort Bragg does hereby recommend and encourage voluntary implementation of water conservation measures consistent with a Stage 1 Water Emergency with a goal of reducing City-wide water usage by 10%, as set forth in Fort Bragg Municipal Code section 14.06.050 A. and below:

1. All users of potable water shall reduce their potable water consumption by 10% as compared to the same month of the base year.

2. Consistent with state requirements to prevent the waste and unreasonable use of potable water and to promote water conservation, each of the following actions is prohibited:

a. The use of potable water on outdoor landscapes in a manner that causes runoff such that water flows onto adjacent property, nonirrigated areas, private and public walkways, roadways, parking lots, or structures.

b. The use of a hose that dispenses potable water to wash a motor vehicle, or to irrigate landscaped areas, including trees and shrubs located on residential and commercial properties that are not irrigated by a landscape irrigation system, except where the hose is fitted with a shut-off nozzle or device attached to it that causes it to cease dispensing water immediately when not in use.

c. The use of potable water to wash driveways, sidewalks, and similar hardscapes.

d. The use of potable water in a fountain or other decorative water feature, except where the water is part of a recirculating system.

e. The irrigation of outdoor landscapes during and within 48 hours after measurable rainfall.

f. The irrigation of residential and commercial landscapes, at any time other than before 10:00 a.m. and after 6:00 p.m.

g. The serving of drinking water other than upon request in eating or drinking establishments, including but not limited to restaurants, hotels, cafes, cafeterias, bars, or other public places where food or drink are served and/or purchased.

h. The irrigation with potable water of ornamental turf on public street medians.

i. The irrigation with potable water of landscapes outside of newly constructed homes and buildings in a manner inconsistent with regulations or other requirements established by the California Building Standards Commission and the Department of Housing and Community Development.

3. In addition, each of the following uses of potable water is prohibited:

a. The use of any hose or similar device, irrespective of whether a nozzle, valve, or other shut-off mechanism is attached thereto, for washing or cleaning the exterior surface of any dwelling, garage, commercial or industrial building. Persons painting building exteriors shall be exempted from this provision when potable water is used to clean or prepare a surface for painting.

b. The use of potable water for filling or refilling any existing or new swimming pool. Replenishing existing pools which have lost water due to evaporation shall be permitted.

c. The use of potable water in construction projects for backfill consolidation or compaction, or for dust control purposes; provided, however, that the City Manager may permit the use of potable water upon a determination by the City Manager that no other source of water for the purpose is available, or that no other method of compaction, consolidation, or dust control is reasonably available. The reuse of water system flush water is permitted.

d. The use of water through, with or by any plumbing, sprinkler, watering or irrigation system, or other device, equipment, or appliance which is broken or defective, or which, for any reason, fails to use water in the ordinary and customary manner or quantity for which it was designed, constructed, or manufactured.

4. To promote water conservation, operators of hotels and motels shall provide guests with the option of choosing not to have towels and linens laundered daily. Each hotel or motel shall prominently display notice of this option in each guestroom using clear and easily understood language.

5. To prevent waste and unreasonable use of potable water and to promote water conservation, lawn watering and landscape irrigation with potable water shall be limited to no more than 2 days per week for all water users.

6. Tampering with any part of the water system to circumvent the provisions contained within this section, include tampering with hydrants or water meters, is prohibited.

7. Residents and business owners shall repair all water leaks as soon as feasibly possible, but no later than 5 days after notification by the City, unless other arrangements are made with the Public Works Director.

The above and foregoing Resolution was introduced by Councilmember Peters, seconded by Councilmember Norvell, and passed and adopted at a regular meeting of the City Council of the City of Fort Bragg held on the 10th day of August, 2020, by the following vote:

AYES:	**Councilmembers Albin-Smith, Morsell-Haye, Norvell, Peters and Mayor Lee.**
NOES:	**None.**
ABSENT:	**None.**
ABSTAIN:	**None.**
RECUSED:	**None.**

WILLIAM V. LEE
Mayor

ATTEST:

June Lemos, CMC City Clerk

RESOLUTION NO. 4302-*2020*

RESOLUTION OF THE FORT BRAGG CITY COUNCIL DECLARING A STAGE 2 WATER EMERGENCY AND IMPLEMENTING STAGE 2 WATER CONSERVATION MEASURES

WHEREAS, the City of Fort Bragg has experienced significantly less rainfall in the last twelve months than would be considered normal; and

WHEREAS, the water flow in the Noyo River has declined more quickly this summer than in prior years and is currently at 0.90 cubic feet per second (cfs); and

WHEREAS, historically, in the months of August, September and October, the Noyo River experiences King Tides, where the gravitational pull between the sun and the moon increase tide levels to a foot or two higher than high tide levels. High tides such as the King Tides during periods of low flow levels on the Noyo River increase salinity content and shorten pump run times, impairing the City's ability to replenish water supply from the Noyo River; and

WHEREAS, the weather forecasts continue to show no significant rainfall in the area in the coming weeks; and

WHEREAS, the City's water supply and ability to replenish its supply have dropped to the levels established in Fort Bragg Municipal Code section 14.06.020 which requires that the City declare a water emergency; and

WHEREAS, based on all the evidence presented, the City Council finds as follows:

1. Fort Bragg Municipal Code section 14.06.020 mandates that the City declare a water emergency when one or more of four conditions are met.
2. The first of those conditions is that the City is unable to maintain a ten percent (10%) buffer between its ability to replenish water in its storage tanks and the total daily demand for water.
3. As set forth in Exhibit A, attached hereto and incorporated herein, on August 12, 2020, total daily demand for water exceeded the City's three raw water sources (Noyo River, Newman Gulch and Waterfall Gulch) by eleven percent (11%) and the seven-day average dropped to an eight percent (8%) buffer between the City's ability to replenish water in its storage tanks and the total daily demand for water.
4. Since August 12, 2020, water available from the Noyo River (set forth in Exhibit A) has continued to drop and the City has been unable to maintain a ten percent (10%) buffer between its ability to replenish water in its storage tanks and the total daily demand for water.
5. As of August 26, 2020, the seven-day average of total city water demand versus the City's available sources was a deficit of twenty-one percent (21%).
6. Implementation of the Stage 2 water conservation measures set forth in Fort Bragg Municipal Code section 14.06.020 are essential at this time.

NOW, THEREFORE, BE IT RESOLVED that the City Council of Fort Bragg does hereby declare a Stage 2 Water Emergency pursuant to Chapter 14.06 of the Fort Bragg Municipal Code and requires implementation of Stage 2 Water Conservation Measures, as set forth in Fort Bragg Municipal Code section 14.06.050 B.

The above and foregoing Resolution was introduced by Councilmember Norvell, seconded by Councilmember Morsell-Haye, and passed and adopted at a special meeting of the City Council of the City of Fort Bragg held on the 31st day of August, 2020, by the following vote:

AYES:	**Councilmembers Albin-Smith, Morsell-Haye, Norvell, Peters and Mayor Lee.**
NOES:	**None.**
ABSENT:	**None.**
ABSTAIN:	**None.**
RECUSED:	**None.**

WILLIAM V. LEE
Mayor

ATTEST:

June Lemos, CMC City Clerk

RESOLUTION NO. 4389-*2021*

RESOLUTION OF THE FORT BRAGG CITY COUNCIL RECOMMENDING AND ENCOURAGING VOLUNTARY IMPLEMENTATION OF STAGE 1 WATER CONSERVATION MEASURES

WHEREAS, the City of Fort Bragg has experienced significantly less rainfall over the past two years placing the City in an extreme drought condition**;** and

WHEREAS, the water flows from the City's three raw water sources continue on a downward trend; and

WHEREAS, the Noyo River flow is nearing 10.0 cubic feet per second (csf) and continues to decline at a rate of 0.5 cfs per day; and

WHEREAS, the high tides during periods of low flow levels on the Noyo River increases salinity content impairing the City's ability to replenish water supply from the Noyo River; and

WHEREAS, the weather forecasts continue to show no significant rainfall in the area in the coming weeks; and

WHEREAS, on April 21, 2021, Governor Newsom declared a state of emergency in Mendocino County due to drought conditions; and

WHEREAS, on March 5, 2021, the USDA declared that 50 counties in California, including Mendocino County were designated as a primary natural disasters area due to recent drought; and

WHEREAS, the City's water supply and ability to replenish its supply have not dropped to the levels established in the Fort Bragg Municipal Code section 14.06.020 which would require that the City declare a water emergency. However, implementing conservation measures now will reduce future impacts on the City's water supply and water storage levels and potentially avoid a greater level of water emergency; and

WHEREAS, based on all the evidence presented, the City Council finds as follows:

1. It is in the best interests of the City of Fort Bragg to encourage voluntary compliance with Stage 1 water conservation measures.
2. Waiting to implement water conservation measures until the established triggers set forth in Fort Bragg Municipal Code section 14.06.020 may be too late to avoid or reduce future water shortages.

NOW, THEREFORE, BE IT RESOLVED that the City Council of the City of Fort Bragg does hereby recommend and encourage voluntary implementation of water conservation measures consistent with a Stage 1 Water Emergency (Fort Bragg Municipal Code section 14.06.050 A) with a goal of reducing citywide water usage by 10%, as outlined below:

1. All users of potable water are strongly encouraged to reduce their potable water consumption by 10% as compared to the same month of the base year.

2. Consistent with state requirements to prevent the waste and unreasonable use of potable water and to promote water conservation, each of the following actions is strongly discouraged:

a. The use of potable water on outdoor landscapes in a manner that causes runoff such that water flows onto adjacent property, nonirrigated areas, private and public walkways, roadways, parking lots, or structures.

b. The use of a hose that dispenses potable water to wash a motor vehicle, or to irrigate landscaped areas, including trees and shrubs located on residential and commercial properties that are not irrigated by a landscape irrigation system, except where the hose is fitted with a shut-off nozzle or device attached to it that causes it to cease dispensing water immediately when not in use.

c. The use of potable water to wash driveways, sidewalks, and similar hardscapes.

d. The use of potable water in a fountain or other decorative water feature, except where the water is part of a recirculating system.

e. The irrigation of outdoor landscapes during and within 48 hours after measurable rainfall.

f. The irrigation of residential and commercial landscapes, at any time other than before 10:00 a.m. and after 6:00 p.m.

g. The serving of drinking water other than upon request in eating or drinking establishments, including but not limited to restaurants, hotels, cafes, cafeterias, bars, or other public places where food or drink are served and/or purchased.

h. The irrigation with potable water of ornamental turf on public street medians.

i. The irrigation with potable water of landscapes outside of newly constructed homes and buildings in a manner inconsistent with regulations or other requirements established by the California Building Standards Commission and the Department of Housing and Community Development.

3. In addition, each of the following uses of potable water is strongly discouraged:

a. The use of any hose or similar device, irrespective of whether a nozzle, valve, or other shut-off mechanism is attached thereto, for washing or cleaning the exterior surface of any dwelling, garage, commercial or industrial building. Persons painting building exteriors shall be exempted from this provision when potable water is used to clean or prepare a surface for painting.

b. The use of potable water for filling or refilling any existing or new swimming pool. Replenishing existing pools which have lost water due to evaporation shall be permitted.

c. The use of potable water in construction projects for backfill consolidation or compaction, or for dust control purposes; provided, however, that the City Manager may permit the use of potable water upon a determination by the City Manager that no other source of water for the purpose is available, or that no other method of

compaction, consolidation, or dust control is reasonably available. The reuse of water system flush water is permitted.

d. The use of water through, with or by any plumbing, sprinkler, watering or irrigation system, or other device, equipment, or appliance which is broken or defective, or which, for any reason, fails to use water in the ordinary and customary manner or quantity for which it was designed, constructed, or manufactured.

4. To promote water conservation, operators of hotels and motels should provide guests with the option of choosing not to have towels and linens laundered daily. Each hotel or motel shall prominently display notice of this option in each guestroom using clear and easily understood language.

5. To prevent waste and unreasonable use of potable water and to promote water conservation, lawn watering and landscape irrigation with potable water should be limited to no more than 2 days per week for all water users.

6. Residents and business owners should repair all water leaks as soon as feasibly possible, but no later than 5 days after notification by the City, unless other arrangements are made with the Public Works Director.

The above and foregoing Resolution was introduced by Councilmember Morsell-Haye, seconded by Councilmember Peters, and passed and adopted at a regular meeting of the City Council of the City of Fort Bragg held on the 10th day of May, 2021, by the following vote:

AYES:	**Councilmembers Morsell-Haye, Rafanan, Peters and Mayor Norvell**
NOES:	**None.**
ABSENT:	**Councilmember Albin-Smith.**
ABSTAIN:	**None.**
RECUSED:	**None.**

BERNIE NORVELL
Mayor

ATTEST:

June Lemos, CMC City Clerk

RESOLUTION NO. 4412-*2021*

RESOLUTION OF THE FORT BRAGG CITY COUNCIL RECOMMENDING AND ENCOURAGING VOLUNTARY IMPLEMENTATION OF STAGE 2 WATER CONSERVATION MEASURES

WHEREAS, the City of Fort Bragg has experienced significantly less rainfall over the past two years, placing the City in an extreme drought condition; and

WHEREAS, the water flows from the City's three raw water sources continue on a downward trend; and

WHEREAS, as of June 18, 2021, the Noyo River flow was 3.85 cubic feet per second (csf) and had declined 83% since April 12, 2021 as compared to 1977 for the same time period when flows declined 78%; and

WHEREAS, as of June 24, 2021, the Noyo River flow was nearing 2.57 cubic feet per second; and

WHEREAS, as of June 18, 2021, total stream flow in Waterfall Gulch had declined by 12.5% since April 12, 2021; and

WHEREAS, as of June 18, 2021, total stream flow in Newman Gulch had declined by 8% since April 12, 2021; and

WHEREAS, the high tides during periods of low flow levels on the Noyo River increases salinity content impairing the City's ability to replenish water supply from the Noyo River; and

WHEREAS, the weather forecasts continue to show no significant rainfall in the area in the coming weeks; and

WHEREAS, on April 21, 2021, Governor Newsom declared a state of emergency in Mendocino County due to drought conditions; and

WHEREAS, the City's water supply and ability to replenish its supply have not dropped to the levels established in the Fort Bragg Municipal Code section 14.06.020 which would require that the City declare a water emergency. However, implementing further conservation measures now will reduce future impacts on the City's water supply and water storage levels and potentially avoid a greater level of water emergency; and

WHEREAS, based on all the evidence presented, the City Council finds as follows:

1. It is in the best interests of the City of Fort Bragg to encourage voluntary compliance with Stage 2 water conservation measures.
2. Waiting to implement water conservation measures until the established triggers set forth in Fort Bragg Municipal Code section 14.06.020 may be too late to avoid or reduce future water shortages.

NOW, THEREFORE, BE IT RESOLVED that the City Council of the City of Fort Bragg does hereby recommend and encourage voluntary implementation of water conservation

measures consistent with a Stage 2 Water Warning (Fort Bragg Proposed Ordinance 969-2021) with a goal of reducing citywide water usage by 10-20%, as outlined below:

1. Water will only be used for "beneficial uses" as that term is defined in Subarticle 2 of Article 2 of Chapter 2 of Division 3 of Title 23 of the California Code of Regulations, [14 CCR § 659 et seq]. Beneficial uses include, but are not limited to, domestic use and irrigation use. All wasteful use of water that constitutes water misuse as defined in 23 CCR § 4000(c) is prohibited. Wasteful uses include, but are not limited to, any unreasonable water use or unreasonable method of water use.

2. During water use, water shall be confined to the customer's property and shall not be allowed to run off to adjoining property private or public walkways and sidewalks, roadways, parking lots or other structures. Care shall be taken not to water past the point of saturation.

3. Landscape irrigation, including public and private streetscape landscaping (medians and frontage), shall be limited to a maximum of three days per week, with the exception of drip irrigation, which may be conducted on any day.

    a. Customers may only irrigate on Tuesdays, Thursdays and Saturdays from 12am to 9am and 6pm to 11:59pm.

    b. No irrigation is permitted on Mondays, Wednesdays, Fridays, or Sundays.

4. Free flowing hoses are prohibited for all uses including landscape watering, vehicle and equipment washing, ponds, and evaporative coolers. Automatic shut-off devices shall be installed on any hose or filling apparatus while in use.

5. All pools, spas and ornamental fountains/ponds shall be equipped with a recirculation pump and shall be constructed to be leak proof. Pool draining and refilling shall be allowed only to the extent required for health, maintenance, or structural considerations, and must otherwise comply with all applicable federal, state and local stormwater management requirements, including but not limited to Chapter 12.14, Drainage Facility Improvements and Drainage Fees.

6. Residents and business owners shall repair all water leaks as soon as feasibly possible, but no later than 5 days after notification by the City or discovery by the owner.

B. During a Stage 2 (Water Warning) conservation stage, the following restrictions shall apply:

1. All Stage 1 (basic stage) restrictions shall continue to apply, except to the extent they are replaced by more restrictive requirements imposed by this subsection.

2. Landscape irrigation, including public and private streetscape landscaping (medians and frontage), shall be limited to a maximum of two days per week, with the exception of drip irrigation, which may be conducted on any day.

a. Customers may irrigate only on Tuesdays and Saturdays from 12am to 9am and 6pm to 11:59pm.

b. No irrigation is permitted on Mondays, Wednesdays, Thursdays, Fridays and Sundays.

3. Water use for the washing of streets, parking lots, driveways, sidewalks, buildings or other hardscape surfaces is prohibited, except as necessary for health, sanitation or fire protection purposes.

4. Restaurants shall serve water only upon specific request.

5. Hotels, motels and other commercial lodging establishments shall offer patrons the option to forego the daily laundering of towels, sheets and linens. Each lodging establishment shall prominently display notice of this option in each guestroom using clear and easily understood language.

6. Residents and business owners shall repair all water leaks as soon as feasibly possible, but no later than 3 days after notification by the City or discovery by the owner.

The above and foregoing Resolution was introduced by Councilmember Morsell-Haye, seconded by Councilmember Peters, and passed and adopted at a regular meeting of the City Council of the City of Fort Bragg held on the 28th day of June, 2021, by the following vote:

AYES:	**Councilmembers Albin-Smith, Morsell-Haye, Rafanan, Peters and Mayor Norvell.**
NOES:	**None.**
ABSENT:	**None.**
ABSTAIN:	**None.**
RECUSED:	**None.**

BERNIE NORVELL
Mayor

ATTEST:

June Lemos, CMC
City Clerk

RESOLUTION NO. 4420-*2021*

RESOLUTION OF THE FORT BRAGG CITY COUNCIL CONFIRMING CITY MANAGER'S DECLARATION OF A STAGE 2 WATER WARNING AND IMPLEMENTING MANDATORY STAGE 2 WATER CONSERVATION MEASURES

WHEREAS, the City of Fort Bragg has experienced significantly less rainfall over the past two years, placing the City in an extreme drought condition**;** and

WHEREAS, the water flows from the City's three raw water sources continue on a downward trend; and

WHEREAS, as of June 18, 2021, the Noyo River flow was 3.85 cubic feet per second (csf) and had declined 83% since April 12, 2021 as compared to 1977 for the same time period when flows declined 78%; and

WHEREAS, as of June 24, 2021, the Noyo River flow was nearing 2.57 cubic feet per second; and

WHEREAS, as of July 2, 2021, the Noyo River flow fell from 2.27 cubic feet per second to 1.47 cubic feet per second; and

WHEREAS, as of July 4, 2021, the Noyo River flow fluctuated between 1.23 cubic feet per second and 1.01 cubic feet per second; and

WHEREAS, as of July 5, 2021, the Noyo River flow fluctuated between 1.01 cubic feet per second and .80 cubic feet per second; and

WHEREAS, as of July 6, 2021, the Noyo River flow fluctuated between .80 cubic feet per second and .59 cubic feet per second; and

WHEREAS, as of June 18, 2021, total stream flow in Waterfall Gulch had declined by 12.5% since April 12, 2021; and

WHEREAS, as of June 18, 2021, total stream flow in Newman Gulch had declined by 8% since April 12, 2021; and

WHEREAS, the high tides during periods of low flow levels on the Noyo River increase salinity content impairing the City's ability to replenish water supply from the Noyo River; and

WHEREAS, the weather forecasts continue to show no significant rainfall in the area in the coming weeks; and

WHEREAS, on April 21, 2021, Governor Newsom declared a state of emergency in Mendocino County due to drought conditions; and

WHEREAS, based on all the evidence presented, the City Council finds as follows:

1. Fort Bragg Municipal Code Section 14.06.020 sets forth the five water conservation stages for the City of Fort Bragg and provides the City Manager with the authority to determine the appropriate water conservation stage and mandatory water restrictions.

2. The City Manager has considered the record low current water flows in the City's three surface water sources; the short-term and long-term weather forecasts with no measurable rainfall; the lack of other available potable and nonpotable water sources; drought conditions in the surrounding counties and states; and the need to ensure continued reduction of seasonal water demand by 10-20%.

NOW, THEREFORE, BE IT RESOLVED that the City Council of the City of Fort Bragg does hereby declare a Stage 2 Water Warning pursuant to Chapter 14.06 of the Fort Bragg Municipal Code and requires implementation of Stage 2 Water Conservation Measures, as set forth in Fort Bragg Municipal Code section 14.06.050 B.

The above and foregoing Resolution was introduced by Councilmember Morsell-Haye, seconded by Councilmember Peters, and passed and adopted at a regular meeting of the City Council of the City of Fort Bragg held on the 12th day of July, 2021, by the following vote:

AYES:	**Councilmembers Albin-Smith, Morsell-Haye, Rafanan, Peters and Mayor Norvell.**
NOES:	**None.**
ABSENT:	**None.**
ABSTAIN:	**None.**
RECUSED:	**None.**

BERNIE NORVELL
Mayor

ATTEST:

June Lemos, CMC
City Clerk

ARTICLES
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nature climate change

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Rapid increases and extreme months in projections of United States high-tide flooding

Philip R. Thompson[1,2]✉, Matthew J. Widlansky[2], Benjamin D. Hamlington[3], Mark A. Merrifield[4], John J. Marra[5], Gary T. Mitchum[6] and William Sweet[7]

Coastal locations around the United States, particularly along the Atlantic coast, are experiencing recurrent flooding at high tide. Continued sea-level rise (SLR) will exacerbate the issue where present, and many more locations will begin to experience recurrent high-tide flooding (HTF) in the coming decades. Here we use established SLR scenarios and flooding thresholds to demonstrate how the combined effects of SLR and nodal cycle modulations of tidal amplitude lead to acute inflections in projections of future HTF. The mid-2030s, in particular, may see the onset of rapid increases in the frequency of HTF in multiple US coastal regions. We also show how annual cycles and sea-level anomalies lead to extreme seasons or months during which many days of HTF cluster together. Clustering can lead to critical frequencies of HTF occurring during monthly or seasonal periods one to two decades prior to being expected on an annual basis.

The impact of high-tide flooding (HTF) accumulates over numerous seemingly minor occurrences, which can exceed the impact of rare extremes over time[1–3]. These impacts are subtle—for example, the loss of revenue due to recurrent road and business closures[4]—compared with the physical damage of property and infrastructure associated with extreme storm-driven events. As sea-level rise (SLR) increases the frequency of HTF in the United States[5–11], coastal communities will need to adapt. However, developing adaptation pathways for recurrent coastal flooding is challenging and requires knowledge of environmental and social tipping points at which current actions and policies become ineffective[12–14].

Here we characterize projected increases in US HTF (including the impact of the 18.6-year nodal cycle in tidal amplitude[15–17]) in a way that can be used to establish planning horizons and develop adaptation pathways. First, we focus on the rate of flooding-frequency increase, which is not well understood despite being critical to establishing SLR impact timelines[18]. More specifically, we examine acute inflections, or tipping points, in the rate of increase that mark transitions from periods of gradual (and potentially imperceptible) change to rapid increase in HTF frequency. Second, we focus on the tendency of HTF episodes to cluster in time[19]. Scientists, engineers and decision-makers are accustomed to the statistics and impacts of isolated extreme events[20–23], but given the cumulative nature of HTF impacts[1–3], we describe extreme months or seasons during which the number of flooding episodes, rather than the magnitude, is exceptional.

Projections of HTF frequency

Ensemble projections of twenty-first-century HTF frequency (Methods) are generated for 89 tide-gauge locations across the contiguous United States and US-affiliated Pacific and Caribbean islands (Supplementary Data). HTF frequencies are represented as counts of days in monthly and annual windows for which at least one hourly sea-level value exceeds the flooding threshold of interest. US National Oceanic and Atmospheric Administration (NOAA) SLR scenarios[24] and derived HTF thresholds[10], which are ubiquitous in US coastal planning, are used to produce the projections. NOAA minor and moderate flooding thresholds correspond to levels 50–60 cm and 80–90 cm, respectively, above the local mean higher high water tidal datum[10] (Supplementary Data). Here we focus on the NOAA Intermediate Low and Intermediate SLR scenarios corresponding to 0.5 m and 1.0 m, respectively, of global mean SLR by 2100. At present, it is not possible to assess which of the NOAA SLR scenarios the observations are tracking due to decadal variability in global and local sea level[25–27] and the lack of divergence in the scenarios (<2 cm) during 2000–2020. However, these two scenarios bracket the bulk of global and local SLR possibilities during the twenty-first century, being roughly equivalent to the 4th and 83rd percentiles[24] of probabilistic local sea-level projections[28] based on IPCC Fifth Assessment Report Representative Concentration Pathway 8.5 (ref. [29]).

Under the Intermediate scenario, annual projections of HTF days from different regions of the US coastline show dramatic increases in HTF frequency over the next 30–40 years (Fig. 1). The 10th–90th percentile range of each ensemble projection represents the degree to which the count in any given year can vary due to local sea-level variability across a variety of processes and timescales from high-frequency surge to decadal climate variability. Including the effect of local sea-level variability is essential for producing useful HTF projections, as SLR and astronomical tides alone will underestimate HTF frequency (Extended Data Fig. 1)[10]. Note that the range of projections over the ensemble at each location should not be interpreted as a true uncertainty, because uncertainty in anthropogenic SLR is excluded in this case by using a discrete NOAA SLR scenario. Incorporating uncertainty in SLR (as in the probabilistic projection[28] from which the NOAA scenarios are extracted[24]) would produce a much wider range of possibilities.

Rapid transitions in the frequency of HTF

The projections in Fig. 1 exhibit an important commonality: pronounced inflections in HTF frequency before mid-century. Such

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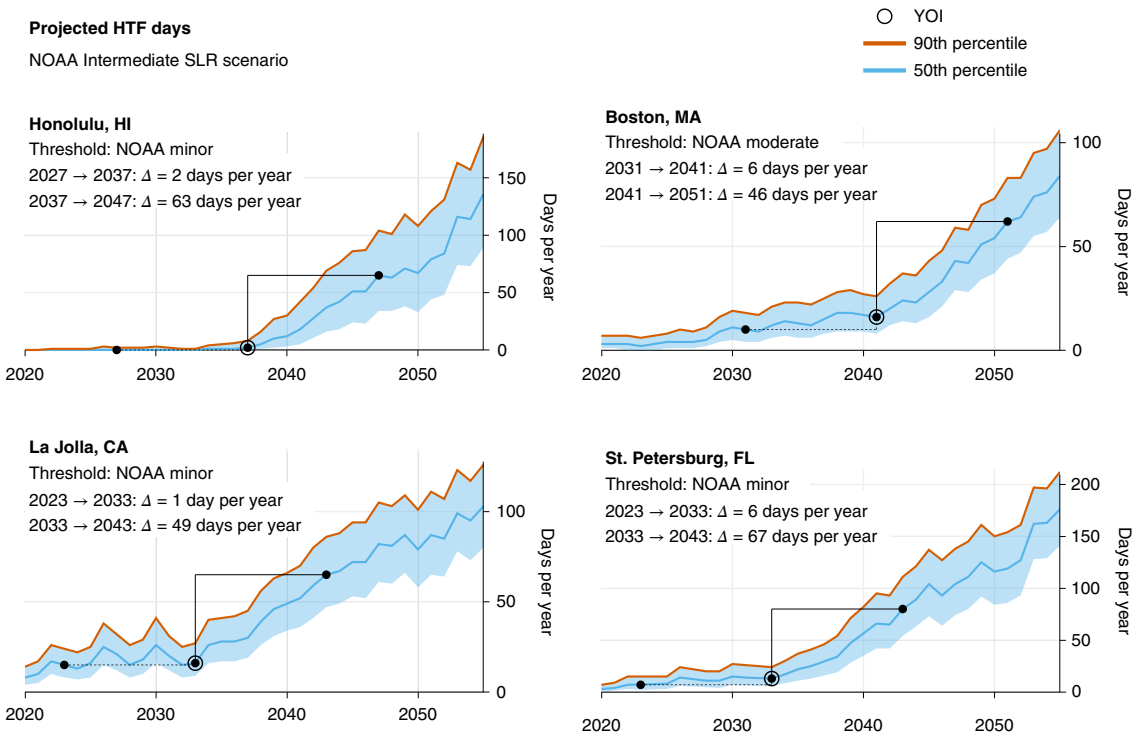

Fig. 1 | Projections of annual counts of HTF days for the NOAA Intermediate SLR scenario. The NOAA minor flooding threshold is used for Honolulu, San Diego and St. Petersburg. The NOAA moderate flooding threshold is used for Boston to highlight a threshold that is not yet routinely exceeded, which is not the case for the Boston minor threshold[11]. The 50th percentile from the ensemble of projections (blue line) and the 10th–90th percentile range (blue shading, with the 90th percentile highlighted in orange) show increasing numbers of HTF days per year. The YOI (open black circle) for each projection corresponds to abrupt increases in the frequency of HTF days, which are highlighted by comparing the projected increases (Δ) over two adjacent ten-year periods (dashed and solid black lines).

inflections, or tipping points, are essential for planning, because they represent transitions from regimes of gradual—and in some cases almost imperceptible—change to regimes of rapid increase in HTF frequency. These transitions can produce acute impacts in unsuspecting and underprepared communities if not identified in advance and communicated to stakeholders and decision-makers. The timing and severity of inflections are related to multiple factors. First, present-day HTF in most locations occurs during only the highest astronomical tides of the year. With SLR, increasing moderate (and more common) high tides will reach flood thresholds, resulting in a rapid increase in the number of HTF days. Second, high-tide amplitudes vary predictably in space and time due to astronomical forcing over timescales from monthly (that is, spring–neap cycles) to decadal (that is, the 18.6-year nodal cycle; see below). The interplay between SLR elevating increasing numbers of high tides towards the threshold and modulations of the tidal amplitude by astronomical forces dictates the timing and nature of inflections in HTF frequency.

To investigate contributions to projected rapid HTF increases, we identify a year of inflection (YOI) for each combination of tide-gauge location, scenario and threshold (Methods). In practice, a continuum of YOIs exists at each location corresponding to the range of possibilities for threshold height and evolution of twenty-first-century SLR. While the YOIs here are specific to the scenarios and thresholds used, they indicate the approximate timing at which rapid transitions will occur for similar scenarios and thresholds. For the four highlighted cases (Fig. 1), the YOI marks the end of a decade experiencing little increase in the expected number of HTF days per year, while decades following the YOIs experience a quadrupling or more.

YOI timing at the four locations is linked to modulations of tidal amplitude associated with the 18.6-year nodal cycle[15,16]. For example, in St. Petersburg, the nodal cycle range is 4.7 cm, representing the peak-to-trough difference in the height of the highest (annual 99th percentile) astronomical tides over a nodal cycle (Fig. 2, left). While not large compared with nodal cycle ranges exceeding 20 cm in other parts of the world[30], the range in St. Petersburg is sufficient to impact the evolution of increasing HTF. During 2024–2033, the Intermediate scenario projects 8.9 cm of SLR in St. Petersburg (Fig. 2, left). The height of the highest tides, however, is projected to increase by just 4.3 cm due to decreasing tidal amplitude associated with the nodal cycle. The opposite occurs during the following decade, and the increase in the height of the highest tides (14.1 cm) is enhanced relative to SLR (9.4 cm). Importantly, the decadal difference in high-tide height increase in St. Petersburg (14.1 − 4.3 = 9.8 cm) is larger than a decade of projected SLR (~9 cm per decade for the Intermediate scenario).

In St. Petersburg, the ratio of the nodal cycle range to a decade of projected SLR is roughly 0.5. Calculating this ratio across the United States highlights locations and regions where the nodal cycle is of sufficient magnitude to contribute to rapid inflections in HTF frequency (Fig. 2, right). Ratios in many locations, including 73% along the Pacific and Gulf of Mexico coastlines, exceed 0.4. In the near term, such locations are most susceptible to rapid inflections in HTF frequency due to the confluence of SLR and nodal cycle modulations of tidal amplitude.

The projection algorithm employed here (Methods) explicitly incorporates twenty-first-century predictions of astronomical tides and captures the effects of long-period tidal modulation on HTF frequency. The nonlinear relationship between the height of the

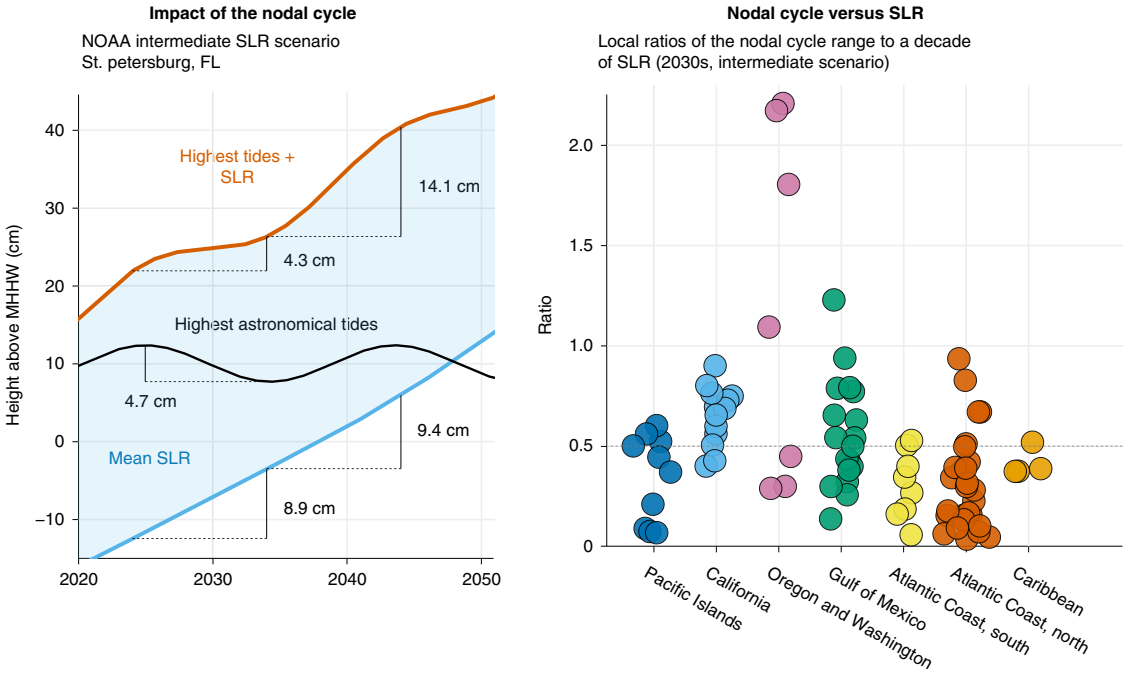

Fig. 2 | Impact of the nodal cycle. Left, projected heights of the highest tides in St. Petersburg, Florida (red), due to the combination of projected mean SLR (blue, NOAA Intermediate SLR scenario) and the 18.6-year nodal cycle expressed in the annual 99th percentile of astronomical tidal height (black). All time series are relative to the current mean higher high water (MHHW) tidal datum. Right, ratios at each US tide-gauge location of nodal cycle peak-to-trough range to ten years of projected SLR (2030s, NOAA Intermediate SLR scenario). The dot colours correspond to US coastal regions.

highest tides and HTF frequency (Methods) further amplifies the inflection in the HTF projection, which manifests in a rapid increase from 13 to 80 HTF days per year on average in St. Petersburg over the decade following the YOI in 2033 (Fig. 1, lower right). Not coincidentally, the YOI for St. Petersburg also corresponds to the nodal cycle minimum in tidal amplitude, marking the transition between suppression and enhancement of increasing high-tide height by the nodal cycle.

YOI timing around the United States tends to be similar (though not uniform) within regions (Fig. 3 and Supplementary Data). Timing generally depends on (1) threshold height, (2) local rates of relative SLR and (3) the timing of nodal cycle minima in tidal amplitude. Higher rates of relative SLR and/or lower thresholds lead to earlier YOIs. Glacial isostatic adjustment[31] can offset absolute SLR, leading to YOIs later in the century (for example, in Oregon and Washington). The relative importance of the nodal cycle varies with the ratios in Fig. 2. For locations and regions where the nodal cycle is a leading order contribution to changes in HTF, YOIs tend to occur near minima in tidal amplitude. We note, however, that the timing of minima in tidal amplitude varies regionally depending on the tidal constituent for which nodal cycle modulations are most prominent. For Hawai'i, the Pacific Coast and the Gulf of Mexico, the nodal cycle is most prominent in modulations of the lunar diurnal (K1) tidal constituent, which has amplitude minima in the mid-2030s, mid-2050s and early 2070s. For northern portions of the Atlantic coast, the nodal cycle is most prominent in modulations of the lunar semidiurnal (M2) tidal constituent, which has amplitude minima in the mid-2020s, mid-2040s and early 2060s. Hence, the YOI for Boston in Fig. 1 occurs in the mid-2040s, while YOIs for the other three cases occur in the mid-2030s.

The purpose of the YOI calculation is to provide a marker for the potential onset of rapid HTF increases. The severity of the increase following YOIs is indicated in two ways in Fig. 3. The values along the vertical axis correspond to absolute increases in the expected number of HTF days per year during the decade following each YOI. The sizes of the markers correspond to relative increases (that is, ten-year multipliers) in HTF days per year over the decade following the YOI. The most acute inflections occur where the ten-year period following the YOI experiences both large absolute (that is, the upper portion of the vertical-axis domain) and large relative (that is, large marker) changes.

Under the Intermediate scenario, many Atlantic locations will experience modest inflections in the frequency of minor HTF in the mid-2020s (Fig. 3, top), which in some cases correspond to minima in nodal cycle modulations of the M2 tidal constituent. The relative ten-year increases for Atlantic locations are generally modest compared with those for other regions, because the minor threshold is already routinely exceeded for many of these sites[11]. Around the mid-2030s, locations along the Pacific and Gulf of Mexico coastlines will experience rapid increases in HTF frequency (Fig. 3, top). The timing and severity of inflections in these regions are influenced by nodal cycle modulations of the K1 tidal constituent and are generally associated with large ten-year multipliers, indicating transitions from few to many HTF days per year. Under the Intermediate SLR scenario, 71% of Pacific Island, California and Gulf of Mexico locations will experience at least a tripling, and 59% at least a quadrupling, of minor HTF days per year over a ten-year period beginning in the 2030s.

NOAA moderate flooding thresholds are rarely exceeded at present[11]. For the Intermediate SLR scenario, rapid transitions in moderate HTF tend to begin in the mid-2040s along the Atlantic coast and during the 2050s for the Pacific and Gulf coasts (Fig. 3, bottom). Exceptions include Gulf of Mexico locations (for example, Grand Isle, Louisiana, and Galveston, Texas) where YOIs occur during the mid-2030s due to high subsidence rates and substantially larger relative SLR. In general, YOIs for moderate thresholds occur later in the century than those for minor thresholds. Since the projected rate of SLR accelerates during the twenty-first century, YOIs

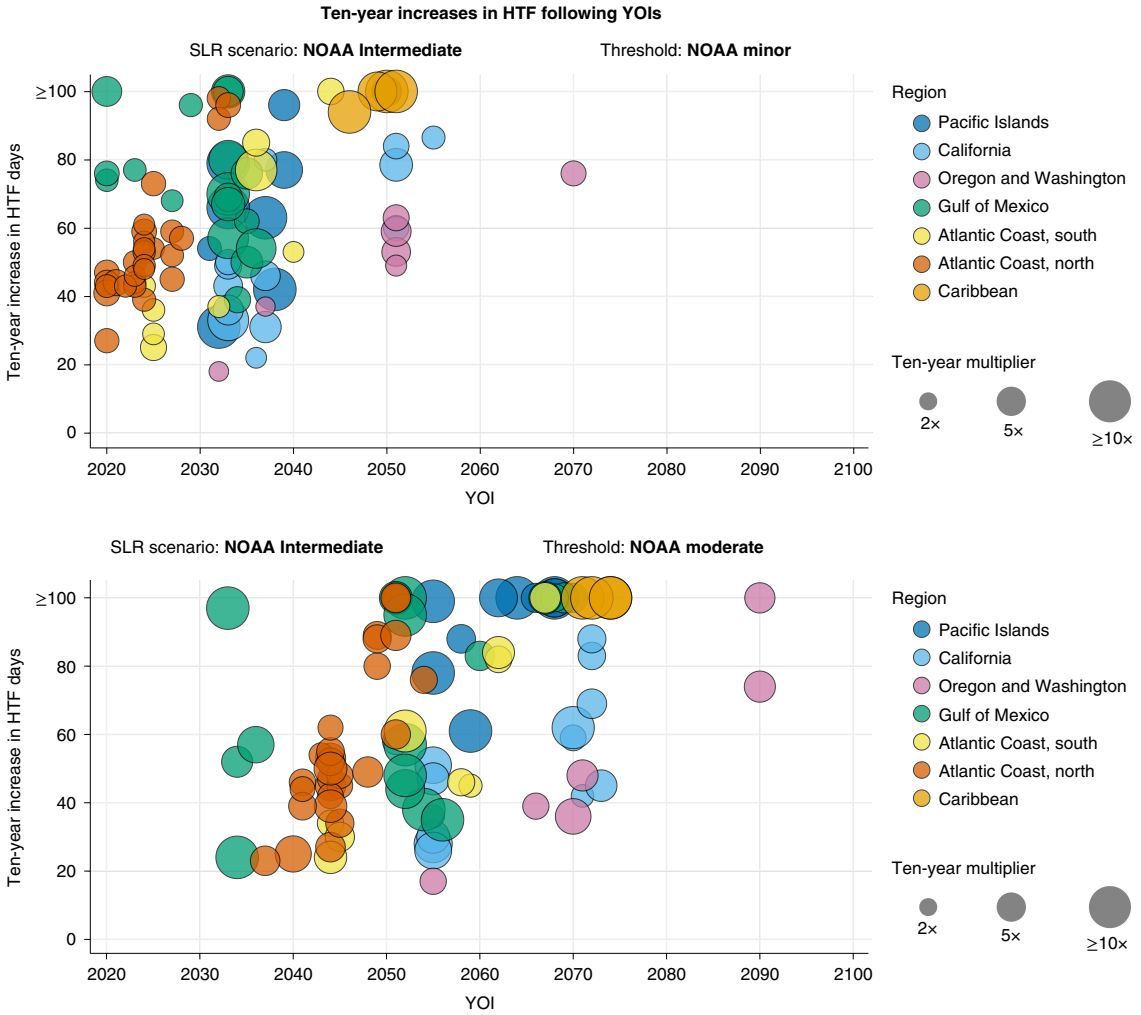

Fig. 3 | YOIs for the NOAA Intermediate SLR scenario. The upper and lower panels correspond to the NOAA minor and moderate flooding thresholds, respectively. The position along the horizontal axis corresponds to the timing of the YOI. The vertical axis indicates projected ten-year increases in annual counts of HTF days following YOIs. The dot sizes correspond to ten-year multipliers following the YOIs. The colours denote geographic regions. See Extended Data Fig. 2 for an analogous figure assuming the NOAA Intermediate Low SLR scenario.

for moderate thresholds tend to occur during periods when SLR rates are higher. As a result, the ten-year multipliers for decades following YOIs are larger for the moderate flooding thresholds than for the minor thresholds. For the Intermediate SLR scenario, 79% of locations would experience at least a fourfold increase in the HTF frequency above the moderate threshold during a single decade (compared with 39% for the minor threshold), and 35% would experience a sixfold increase during a single decade (compared with 20% for the minor threshold).

Clustering of HTF days

The 90th percentile of the ensemble spread for annual projections (Fig. 1) is expected to be exceeded about once per decade on average. Thus, year-to-year sea-level variability unrelated to secular SLR will lead to occasional but inevitable extreme years when many HTF days cluster together[19]. The 4.4-year modulation of tidal amplitude[32] can also contribute to extreme years, apparent in the HTF projection for La Jolla (Fig. 1) and other locations, especially the Pacific Coast and Southeast-Atlantic Bight (not shown). Clustering occurs at subannual timescales as well, and there are typically one or two seasons at any location for which the number of HTF days increases more rapidly due to annual and semiannual cycles in mean sea level and tidal amplitude (Extended Data Fig. 3). In Honolulu, for example, the most likely (50th percentile) annual count of HTF days in 2047 is 63 (Fig. 1). However, splitting the analysis into monthly counts reveals that 30 of those events are expected to occur over a span of three months (October–December, Extended Data Fig. 3). The expected temporal density of HTF days during this season (ten days per month) is thus approximately double that expected from considering the annual count alone (about five days per month). Similar differences in the seasonal density of HTF days are expected for the other three locations. Note that the seasonal timing of peaks in semiannual modulations of tidal amplitude (and hence HTF frequency) vary year to year and are linked to the 4.4-year modulations mentioned above[32].

The seasonal clustering of events can be further compounded by monthly to seasonal sea-level anomalies associated with modes of internal climate variability (for example, El Niño) or other atmosphere–ocean processes. If, for example, a large monthly mean sea-level anomaly occurs during peak HTF season, the two factors produce elevated numbers of HTF days during a brief period that far exceeds the expected annual density of events[33]. To demonstrate the impact of clustering, we calculate the average number of HTF days per month in five-year periods for the four locations

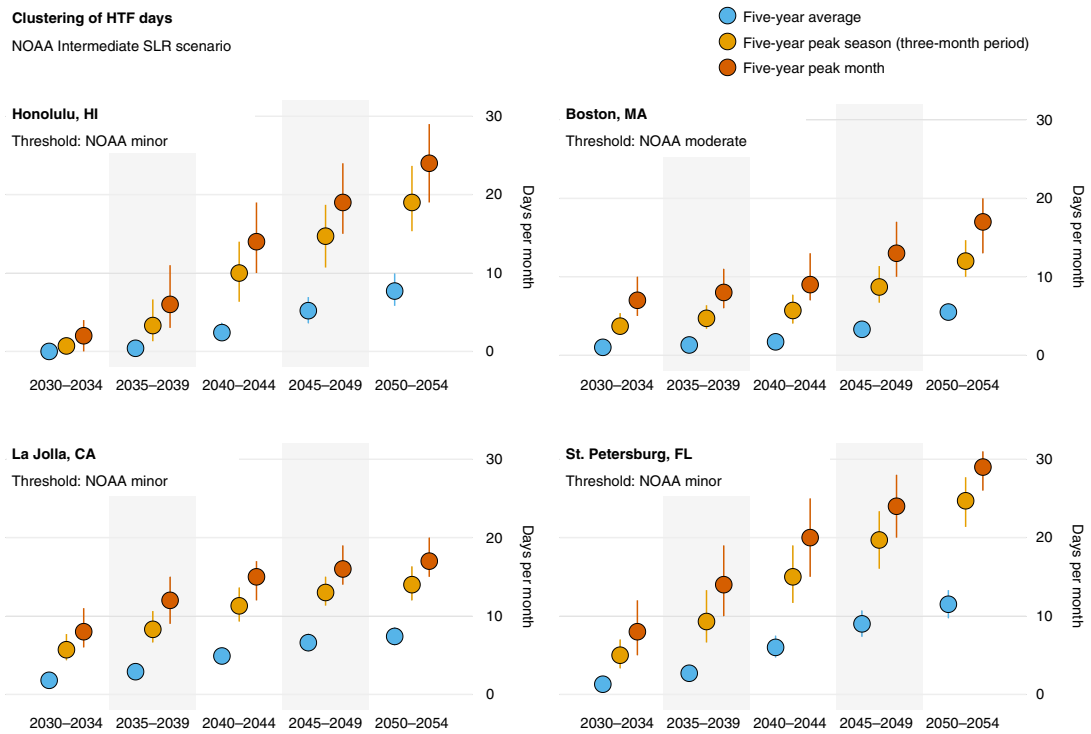

Fig. 4 | Extreme months and seasons. Projections of HTF days in five-year periods for the four US stations in Fig. 1 under the NOAA Intermediate SLR scenario, including the average number of HTF days per month in each five-year period (blue), the average number of HTF days per month during the five-year peak season (light orange) and the number of HTF days in the five-year peak month (dark orange). The circles represent the 50th percentile from the ensemble. The vertical lines show the 10th–90th percentiles of the ensemble range.

(Fig. 4). Using the ensemble projections, we also estimate the counts of HTF days during the most extreme season (that is, consecutive three-month period) and most extreme individual month over each five-year span (Fig. 4). For example, the 2040–2044 pentad in Honolulu is projected to experience ~2.5 minor HTF days per month on average (or about 150 minor HTF days over the entire five-year span). However, projected counts of minor HTF days during the most extreme season and month during this five-year span are 6–14 and 10–19 HTF days per month, respectively. Similar clustering is expected for St. Petersburg, while the effect is smaller for Boston and La Jolla. In general, using the expected number of HTF days per year (or pentad or decade) for decision-making will greatly underestimate the cumulative impact during brief periods experiencing extreme numbers of HTF days.

Another consequence of clustering is that any given HTF frequency will occur during brief periods long before it becomes expected on an annual basis. For example, consider the case for which minor flooding occurs on a majority of days during a given period. For most locations under the Intermediate scenario, this frequency of minor HTF will not occur on an annual basis until the second half of the twenty-first century[10]. Projections of minor HTF confirm this timeline for annual periods (Fig. 5, top row). However, if the focus shifts to monthly periods and includes the impact of clustering, we find that the timeline for experiencing flooding on a majority of days during a given period shifts towards the present (Fig. 5, bottom three rows). To estimate the importance of this effect, we calculated the probability that each location will experience minor flooding on a majority of days during a single month at least two decades before the year when minor flooding becomes expected on a majority of days annually. The probabilities were calculated by determining the fraction of projection ensemble members for each location that met this criterion. For the Intermediate scenario, this probability exceeds 50% (that is, it is more likely than not) at 42% of the locations analysed. The percentage increases to 81% of stations for lead times of 15 or more years. By incorporating the combined effects of month-to-month variations in mean sea level and tidal amplitude, our results suggest that planning horizons based on the emergence time[34] of a particular HTF frequency may need to be adjusted by decades towards the present to account for the clustering of HTF days during extreme months.

Discussion

Multiple strategies have been developed to identify key impact thresholds in terms of either HTF frequency[5] or the cumulative economic impact of frequent HTF events[3]. The YOI calculation here complements existing metrics by focusing on the pace of change and identifying the onset (rather than the endpoint) of rapid increases from few to many expected HTF events per year. The application of adaptation pathways requires updating policy and management strategies when predetermined environmental triggers or decision points occur[12–14]. Site-specific YOIs are candidates for such decision points, and the methodology underpinning the calculation provides important environmental context for stakeholders and decision-makers. In particular, nodal cycle modulations of tidal amplitude will suppress SLR-induced increases in HTF during certain periods and may delay the onset of environmental adaptation triggers. Such delays could produce complacency and inaction through false confidence in benign pathways. The effect of the nodal cycle is implicit in the YOI calculation, which will allow decision-makers and stakeholders to communicate that periods of little perceptible change are expected in many locations—only to be followed by periods of exponential HTF increase.

In general, if SLR approaches or exceeds the NOAA Intermediate scenario in the coming decades, the United States should expect the

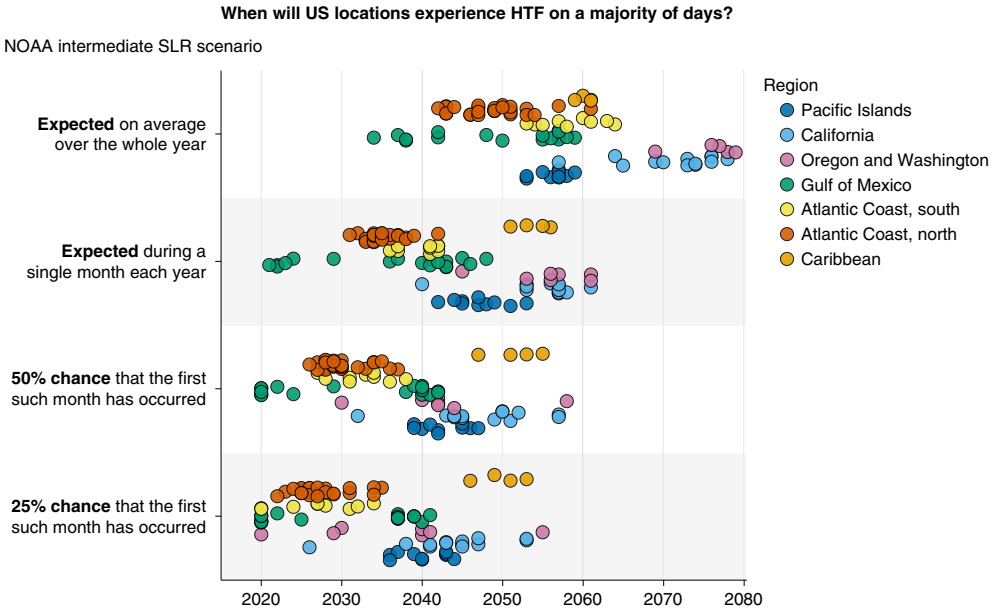

Fig. 5 | Years for which US coastal locations will experience HTF on a majority of days during annual and monthly windows. The calculations assume the NOAA Intermediate SLR scenario. Years for which HTF is expected to occur on a majority of days on average during annual and monthly periods (top two rows) are compared with years for which flooding will first occur on a majority of days during a single month (bottom two rows). The dot colours denote station regions. The vertical position of each dot within the rows is an arbitrary vertical offset to allow visual distinction between regions and individual locations. See Extended Data Fig. 4 for an analogous figure assuming the NOAA Intermediate Low SLR scenario.

onset of a rapid increase in HTF frequency during the mid-2030s corresponding to the combined effects of ongoing SLR and increasing tidal amplitude associated with nodal cycle modulations. The increase would be concentrated along the continental Pacific, Pacific Island and Gulf of Mexico coastlines, which are more vulnerable to SLR due to relatively narrow sea-level distributions[35], infrequent historical exposure to high storm surge[14] or both. Thus, under the NOAA Intermediate SLR scenario, the mid-2030s marks the onset of an expected transition in HTF from a regional issue to a national issue with a majority of US coastlines being affected. An important caveat to this result is that the YOIs represent the most likely inflection point, and decadal fluctuations in local mean sea levels may affect its timing.

The cumulative nature of impacts associated with minor HTF[1–3] suggests the need to account for severe seasons or months during which many HTF days cluster together in time. Just as engineers and coastal planners are accustomed to planning for rare, large-amplitude extreme events, adaptation and mitigation strategies focused on HTF should account for brief periods experiencing an extreme number of HTF days. The logic for basing decision-making on severe periods of HTF is the same as for basing design decisions on long (10-year or 100-year) return intervals rather than annual maxima, where the former has a planning horizon far in advance of the latter. Knowledge of the tendency for HTF days to cluster in time can aid the interpretation of HTF projections with coarse (annual and longer) temporal resolutions. On the basis of an aggregate analysis of clustering calculations across all US locations (not shown), we suggest the following rules of thumb for interpreting such projections. For a five-year period expected to experience a total of 100 HTF days, the six most severe months will experience 7–10 HTF days per month on average, while the remaining months will experience fewer than 1 HTF day per month on average. For 200 total HTF days over a five-year period, the six most severe months will experience 10–17 HTF days per month on average, while the remaining months will experience fewer than 2.5 HTF days per month on average. Importantly, this tendency for HTF days to cluster in time underscores the need for monthly-to-seasonal forecasting of sea-level anomalies to provide advance warning of periods likely to experience extreme numbers of events[36,37]. It is also possible that event clustering will be influenced by non-stationarity in the statistics of extreme non-tidal sea-level anomalies[38], which have not been considered here.

Finally, we reiterate that our analysis focused on existing and widely used NOAA SLR scenarios and derived HTF thresholds. The results are therefore unique to the specific combinations of location, SLR scenario and flooding threshold. As SLR continues and communities adapt, locally relevant flooding thresholds will evolve, and periodic reassessments will be required. Nevertheless, the concepts presented here are broadly applicable in identifying planning horizons and developing adaptation pathways for managing ongoing and future impacts of HTF. There is a need for nuanced understanding of projected increases in HTF frequency beyond quantifying, for example, bulk changes from one decade to the next. It is important to communicate to decision-makers that changes in HTF frequency will not be incremental in the coming decades but will include acute inflections in the rate of increase punctuated by extreme months and seasons during which many events will cluster together in time. These results form the basis of ongoing work to communicate projected increases in HTF to US decision-makers[39].

Online content

Any methods, additional references, Nature Research reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41558-021-01077-8.

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Methods

Projections of HTF days. The projection framework is based on the idea that the number of observed hourly flooding threshold exceedances in a month—including the combined effect of tides, surge and other high-frequency contributions—is statistically related to monthly mean sea level and the amplitude of the highest tides during the month. For higher monthly mean sea level or tidal amplitude, there is a tendency to experience a greater number of flooding threshold exceedances, because the baseline sea level is higher. A higher baseline means that smaller-amplitude, more common surges can raise the total water level above the threshold.

An overview of the projection methodology is as follows:

1. Find a statistical relationship that maps monthly mean sea level, tidal amplitude and threshold height onto observed monthly counts of threshold exceedances in hourly tide-gauge data. The hourly tide-gauge data includes high-frequency surge and so on.
2. Generate ensemble projections of monthly mean sea level and tidal amplitude for the twenty-first century.
3. Map the ensemble projections of mean sea level and tidal amplitude from step 2 onto future counts of threshold exceedances using step 1. The resultant ensemble projections of threshold exceedances (that is, HTF) represent a range of possibilities for the number of exceedances a tide gauge would be expected to observe during a given future month.

The details of these steps are provided in the subsequent sections.

Relating tidal range, mean sea level and counts of HTF days. The methodology employed here builds on an approach previously developed for projecting the frequency of HTF in Honolulu, Hawai'i[19]. The fundamental assertion of this approach is that the probability distribution governing the number of HTF days at a given location during a single month is closely related to a single parameter, Δ_{99}:

$$\Delta_{99} \equiv (\zeta_{99} + \overline{\eta}) - H, \tag{1}$$

where ζ_{99} is the 99th percentile of predicted astronomical hourly tidal heights relative to current tidal datums, $\overline{\eta}$ is the monthly mean of the non-tidal sea level variability and H is the height of the flooding threshold of interest. Previous work focused on annual periods; here we calculate monthly values of ζ_{99} and $\overline{\eta}$ to produce monthly values of Δ_{99}. The term in parentheses, $\zeta_{99} + \overline{\eta}$, provides a general measure of the height of high tides during a given month. The specific role of ζ_{99} is to capture variability in high-tide levels due to seasonal-to-decadal modulations of tidal range. Note that the results herein are not sensitive to the particular percentile used. The specific role of $\overline{\eta}$ is to capture variability in high-tide levels due to changes in the mean level about which the tides oscillate. By subtracting the threshold height, H, from this sum, we can interpret variability in Δ_{99} as a measure of whether high tides are generally higher (more positive Δ_{99}) or lower (more negative Δ_{99}) than the threshold for a given month. The presence of stochastic, submonthly water level variability prevents relating Δ_{99} to a specific monthly count of threshold exceedances. Instead, we state that the Δ_{99} parameter is related to the probability mass distribution (PMD) governing the number of days during a month for which the maximum hourly water level exceeds the threshold. In other words, we cannot precisely predict the observed number of threshold exceedances on the basis of monthly quantities, because we do not know the exact number and magnitude of high-frequency anomalies that will occur in the future. We can, however, predict the likelihood of any given number of threshold exceedances on the basis of the observed historical relationships between mean sea level, tidal amplitude and threshold exceedances.

To demonstrate the relationship between Δ_{99} and monthly counts of HTF days, we first calculate observed values of ζ_{99} and $\overline{\eta}$ using hourly tide-gauge observations. We then tally the number of daily maximum water levels that exceed a range of thresholds in each month (that is, monthly counts of HTF days) and record the Δ_{99} value corresponding to each monthly count. Scatter plots of January HTF day counts versus January values of Δ_{99} for Honolulu and Boston, respectively, give insight into the functional form relating the two quantities (Extended Data Fig. 5). As expected, increasing Δ_{99} (that is, high tides rising relative to the threshold) corresponds to greater numbers of HTF days in each month. Note that the domain of Δ_{99} values is much narrower for Honolulu than for Boston, reflecting a much narrower distribution of daily maximum water levels for the former than for the latter. It is also important to note that the relationship between Δ_{99} and HTF days is nonlinear, and a unit change in Δ_{99} leads to varying increases in HTF days depending on the value of Δ_{99}.

To capture the probabilistic relationship between Δ_{99} and the monthly counts of HTF days, we model the PMD for monthly counts of HTF days as a beta-binomial distribution[40]. The beta-binomial distribution describes the probability of a discrete number of successes over N binary trials, where the probability that any single trial is a success is itself a continuous beta-distributed random variable, $p \in [0, 1]$. In this case, each of the N days in a month is a 'trial', and each time the daily maximum water level exceeds the threshold of interest is a 'success'. The beta distribution governing p can be described by its mean, μ, and variance, σ^2. Because p is beta-distributed, the beta-binomial distribution offers a general representation of binomially distributed counts that can take a variety of shapes. The flexibility of the beta-binomial distribution is useful, because the shape of the PMD for the monthly counts changes drastically depending on the value of Δ_{99}. For example, when Δ_{99} takes a large negative value (that is, when the highest tides of the month are well below the threshold), we expect a highly asymmetric, one-sided PMD with a high probability of zero exceedances and a low probability of many exceedances. As Δ_{99} increases to an expected (or mean) count of 10–20 days per month, the distribution of counts about the mean becomes approximately symmetric. As Δ_{99} increases further, the distribution becomes asymmetric and one-sided again as the counts begin to saturate at the maximum number of days per month.

We use the beta-binomial distribution to formulate a hierarchical model describing the probabilistic relationships between the vector of observed monthly counts of HTF days ($\mathbf{Y}$) and the vector of observed Δ_{99} values ($\mathbf{x}$). The model is summarized

$$\begin{aligned} \mathbf{Y} \,|\mathbf{x},\ \boldsymbol{\Theta},\ \nu\ &\sim\ \text{BetaBinomial}(N, \boldsymbol{\mu}, \boldsymbol{\sigma}^2), \\ \boldsymbol{\mu}\ &=\ S(\mathbf{x}; \boldsymbol{\Theta}), \\ \boldsymbol{\sigma}^2\ &=\ \nu\boldsymbol{\mu}(1-\boldsymbol{\mu}), \end{aligned} \tag{2}$$

where $\boldsymbol{\mu}$ and $\boldsymbol{\sigma}^2$ are vectors of μ and σ^2 that determine the shape of the beta-binomial distribution at each value in $\mathbf{x}$. The elements in $\boldsymbol{\sigma}^2$ are related to the elements in $\boldsymbol{\mu}$ by a scalar parameter, $\nu \in (0, 1)$, and the third relation in equation (2), which can be derived from the analytical function describing the distribution. This leaves only μ to be defined explicitly as a function of x (that is, Δ_{99}), which is represented by a function S requiring parameters $\boldsymbol{\Theta}$.

Since μ describes the expectation value of the probability, p, that a single day experiences a maximum hourly water level above the threshold, and since daily maximum water levels at any given station tend to be approximately normally distributed, we base the function S on the normal cumulative distribution function:

$$\Phi(x) = \frac{1}{2}\left[1 + \text{erf}\left(\frac{x-\xi}{\omega\sqrt{2}}\right)\right], \tag{3}$$

where erf(·) is the Gauss error function, and ξ and ω are parameters representing the location and scale of the function, respectively. In practice, we found that using this function alone as in prior work[19] (that is, $S(x) = \Phi(x)$) did not perform optimally in many cases due to minor deviations from a purely normal distribution—namely, slight asymmetries in the distribution of daily maximum water levels. We improved the ability of the model to describe the observed counts by defining S as the sum of two normal cumulative distribution functions blended across a change point via a logistic function:

$$S(x; r, x_0, \xi_1, \omega_1, \xi_2, \omega_2) = L(x; -r, x_0)\Phi(x; \xi_1, \omega_1) + L(x; r, x_0)\Phi(x; \xi_2, \omega_2), \tag{4}$$

where $L(x)$ is a logistic function:

$$L(x) = \frac{1}{1 + e^{-r(x-x_0)}}, \tag{5}$$

with r determining the slope of the transition—note the sign change of r from the first to the second term in equation (4)—and x_0 determining the location of the change point. This blended version of S allows the shape of the function to be determined by ω_1 and ξ_1 for $x < x_0$ and ω_2 and ξ_2 for $x > x_0$ with a narrow, smooth transition band of length scale $1/r$ to avoid discontinuity. In practice, we fix the length scale to 10% of the Δ_{99} domain and treat the change point x_0 as a free parameter. The vector of parameters required for the S in the hierarchical model is then $\boldsymbol{\Theta} = \{x_0, \xi_1, \omega_1, \xi_2, \omega_2\}$.

We estimate distributions of the free parameters in equation (2)—that is, $\boldsymbol{\Theta}$ and ν—for each station individually using Bayesian inference implemented via a Markov chain Monte Carlo (MCMC) method. Bayesian inference via MCMC was implemented by building and evaluating the hierarchical model in PyMC3 (ref. [41]), an open-source probabilistic programming framework for Python. Uninformative uniform prior distributions were assumed for all model parameters. Posterior distributions for the parameters were conditioned on vectors of observed monthly counts ($\mathbf{Y}$) and Δ_{99} values ($\mathbf{x}$) such as those represented by the scatter plots in Extended Data Fig. 5. Given the posterior distributions for the free parameters, we can then input a monthly value for Δ_{99} as $\mathbf{x}$ into equation (2) and output a probability distribution for the monthly count of HTF days above a threshold. The posterior models for Honolulu and Boston demonstrate the ability of the method to capture the probabilistic relationships underlying the scatter plots (Extended Data Fig. 5). Thus, given a projection (or ensemble of projections) of Δ_{99} during the twenty-first century, we can produce probabilistic projections for monthly counts of HTF days above a threshold.

Twenty-first-century projections of Δ_{99}. Projecting future Δ_{99} values for each station and threshold during the twenty-first century requires projections of ζ_{99} and $\overline{\eta}$ in equation (1). The latter is composed of two components: (1) secular local mean sea level (LMSL) rise related to forced climate variability and vertical land motion, and

(2) stochastic monthly LMSL variability related to atmosphere–ocean dynamics and internal climate variability. This gives three components of Δ_{99} (ζ_{99} plus two components of $\overline{\eta}$), which we project independently as discussed below.

Secular LMSL rise projections. We use the NOAA local SLR scenarios[24] obtained from the NOAA Center for Operational Oceanographic Products and Services (CO-OPS, https://tidesandcurrents.noaa.gov/publications/techrpt083.csv). These are discrete projections with predetermined amounts of LMSL rise by 2100, which are designed to provide planning scenarios corresponding to various risk tolerances. The scenarios for each site include local factors such as glacial isostatic adjustment and regional patterns of sea level change due to the gravitational and rotational effects of melting glaciers and ice sheets. We focus on the Intermediate Low and Intermediate scenarios, which correspond to twenty-first-century global mean SLR of 0.5 m and 1.0 m, respectively. The NOAA scenarios are provided with decadal resolution, which we interpolate to monthly resolution via cubic spline.

Projecting monthly LMSL variability. Gaussian processes have been used previously to model parameters relating mean sea level variability and HTF[42]. We modelled non-secular monthly LMSL variability, $m(t)$, as the weighted sum of a zero-mean Gaussian process with unit variance G and normally distributed white noise with zero mean and unit variance Σ:

$$m(t) = aG + b\Sigma\,. \tag{6}$$

Serial correlation in G is determined by an exponentiated quadratic covariance function, K:

$$K(t,t') = \exp\left[\frac{(t-t')^2}{2l^2}\right], \tag{7}$$

where l is a timescale. The distributions of the free parameters, $\{a, b, l\}$, were determined from observed monthly mean tide-gauge observations for each station via Bayesian inference and MCMC using PyMC3 (ref. [41]). Given the variance in the observed non-secular monthly mean sea level time series, σ_m^2, the parameters a and b were chosen from a multivariate beta (or Dirichlet) prior to ensure that $a^2 + b^2 = \sigma_m^2$ and for any given draw from the posterior. The parameter l was given an uninformative gamma-distributed prior. We generated an ensemble of 10^4 posterior samples of $m(t)$ spanning the twenty-first century for each US tide-gauge station.

99th percentile of astronomical tides. Tides are often treated as if they are unchanging in HTF assessments, and tide predictions are often performed and interpreted as if they are free from uncertainty. These are not good assumptions in many locations[17] due to correlations of tidal amplitude with mean sea level variability[43] and changes in the geometry of harbours and estuaries[44]. Here, we generate an ensemble of tide predictions for each location that accounts for portions of the non-stationarity in future tidal amplitudes. In particular, we include the observed relationship between mean sea level variability and constituent amplitudes and phases, and we include an extrapolation of secular trends in tidal amplitude and phase that are unrelated to mean SLR. Our method does not represent a complete accounting of the uncertainty and sources of non-stationarity—and some assumptions have been made—but the result is preferable to not considering non-stationarity and uncertainty in the tides.

Ensemble projections of ζ_{99} were determined for each location individually in a multistep process:

1. Generate an initial estimate of tidal constituents from harmonic analysis of hourly tide-gauge data. For this initial step, tidal constituents were estimated from the complete record using an implementation of UTide[45] for Python. Note that the development of UTide for Python is ongoing, but comparisons of UTide predictions to NOAA tide predictions suggest that results from the former are robust.
2. Distinguish between minor and major constituents with signal-to-noise ratios less than two and greater than two, respectively.
3. Subtract predictions of minor constituents over the observed period and perform harmonic fits on the remaining hourly variability using UTide[45] for the major constituents in each year of the record individually. Year-to-year variations in major-constituent amplitudes and phases reflect both astronomical (for example, nodal cycle) and non-astronomical (for example, correlation with mean sea level[43]) processes.
4. Model the variability in the phases and amplitudes of each constituent as a sum of Gaussian processes with periodic and linear kernels, plus a term proportional to detrended annual mean sea level variability and an additional white-noise term. The periodic kernels represent major tidal modulation periodicities (18.61, 9.305, 8.85 and 4.425 years)[16]. Linear trends in the constituent amplitudes and phases were modelled as two linear processes linked at a variable change point, which allows for an inflection in the secular trend of each constituent and ensures that extrapolated linear trends in the amplitude and phase of each constituent are representative of the most recent trend. The change point was required to be consistent for both amplitude and phase. The model parameters and the relative weight of each component were determined via Bayesian inference and MCMC using PyMC3 (ref. [41]).
5. Generate an ensemble projection of each constituent individually from the components of amplitude and phase variability in the previous step. When projecting tidal variability for the twenty-first century, we confine the relationship with mean sea level to be a relationship with steric (or density-related) changes in mean sea level. In general, the relationship between mean sea level and constituent amplitude can be related to water depth or stratification, but it is difficult to disentangle these effects in the absence of dedicated, local modelling studies[46]. The decision to confine the relationship to steric changes in mean sea level is thus a conservative choice to limit overestimating this effect. Only the steric component of the NOAA SLR scenario used in each case is added to the ensemble of monthly LMSL variability (described earlier in the Methods) to produce estimates of steric sea level variability in the twenty-first century.
6. Construct an ensemble of 10^4 hourly twenty-first-century tidal height predictions from the ensemble of annual projections for each major constituent and add a deterministic prediction of the minor constituents. The Gaussian process representations underlying each major constituent allow us to construct tidal predictions with hourly resolution that modulate smoothly from one annual window to the next. Note that in every case, our methodology for tide prediction produces a reduction in non-tidal residual variability over the observed period compared with the standard NOAA harmonic analysis.
7. From the ensemble of hourly tidal height predictions, generate an ensemble of 10^4 projections of ζ_{99}.

Ensemble projections of HTF days. To produce ensemble twenty-first-century projections of HTF days above a given threshold, we performed the following procedure for each combination of station, SLR scenario and threshold:

1. Generate 10^4 projections of Δ_{99} by adding the ensemble of $\overline{\eta}$ projections (SLR scenario plus monthly variability) to the ensemble of ζ_{99} and subtracting the threshold height, H.
2. For each value in the ensemble of Δ_{99} projections, make a draw from the posterior of the model in equation (2).
3. Generate a random positive integer representing a monthly count of HTF days from the beta-binomial distribution described by each combination of Δ_{99} value and posterior draw.

The result is an ensemble of 10^4 twenty-first-century projections of HTF days per month for each combination of station, SLR scenario and threshold. We can then leverage these ensembles of monthly counts to generate likely ranges and assess the relationship of extreme months and seasons to counts over longer periods of years to decades. Note that the spread in each ensemble grows with SLR due to the nature of counting exceedances above a threshold (for example, the 10th–90th percentile ranges in Fig. 1). For example, when a threshold is rarely exceeded, most years will experience zero HTF days, and the range of possible annual counts is narrow (for example, zero to five HTF days per year). With SLR, exceedances become more common, and the range of possible annual counts grows.

Determination of YOIs. YOIs were identified using the 50th-percentile curve from the ensemble of annual HTF projections (see below) for each combination of location, scenario and threshold. Two characteristics of the 50th-percentile curve were used. The first is the difference in the change in HTF frequency between two adjacent ten-year periods, which is analogous to the second derivative of the 50th-percentile curve and is largest when the slope of the projection changes rapidly. There can be multiple acute inflections over a single projection, however, which motivated the use of a second quantity: the ten-year multiplier (or x-fold increase) over the second of the two adjacent ten-year periods. The ten-year multiplier is largest for inflections that represent a transition from few to many expected days of HTF per year. For example, a change from 10 to 50 HTF days per year over the second ten-year period has a multiplier of 5; a change from 50 to 100 has a multiplier of 2. In practice, we computed both quantities in sliding 21-year windows centred on each year in the HTF projection curves. We identified the YOI for each combination of location, scenario and threshold as the year with the highest average rank over both quantities.

Data availability

The tide-gauge sea-level data used in this analysis are publicly accessible and were obtained from the NOAA CO-OPS Data Retrieval API (https://api.tidesandcurrents.noaa.gov/api/prod/). The NOAA SLR scenarios are publicly available and were obtained from the NOAA CO-COPS website (https://tidesandcurrents.noaa.gov/publications/techrpt083.csv).

Code availability

All code generated for the data analysis and figure creation is archived in a public repository[47] under the GNU Affero General Public License v.3.0. The repository includes the Python environment, which provides the versions of all third-party libraries and packages used in this work.

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Author contributions

P.R.T. designed the approach, performed the analyses and drafted the paper. M.J.W., B.D.H. and M.A.M. made substantive revisions. All authors made substantive contributions to the interpretation and communication of the results.

Competing interests

The authors declare no competing interests.

Additional information

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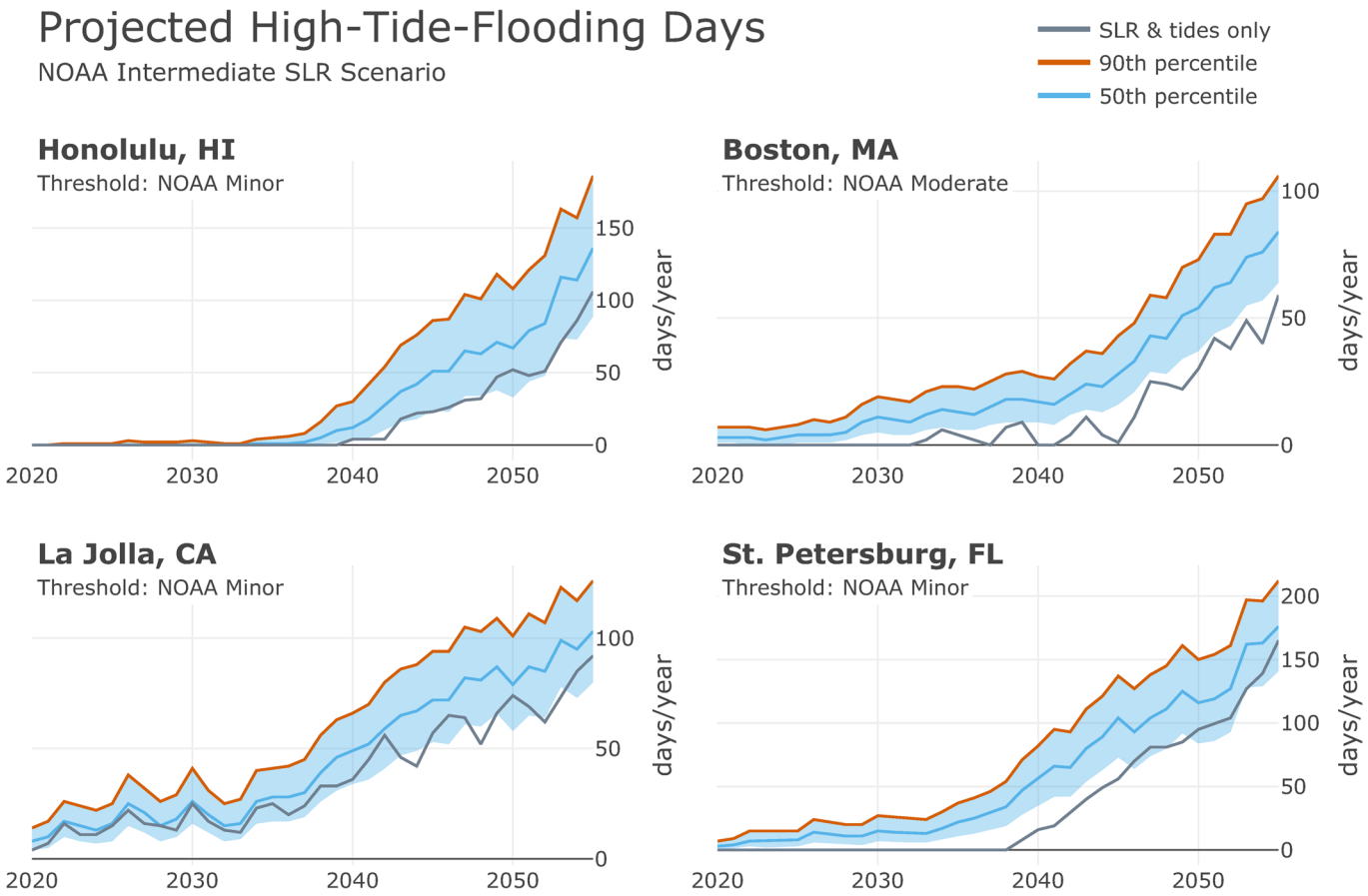
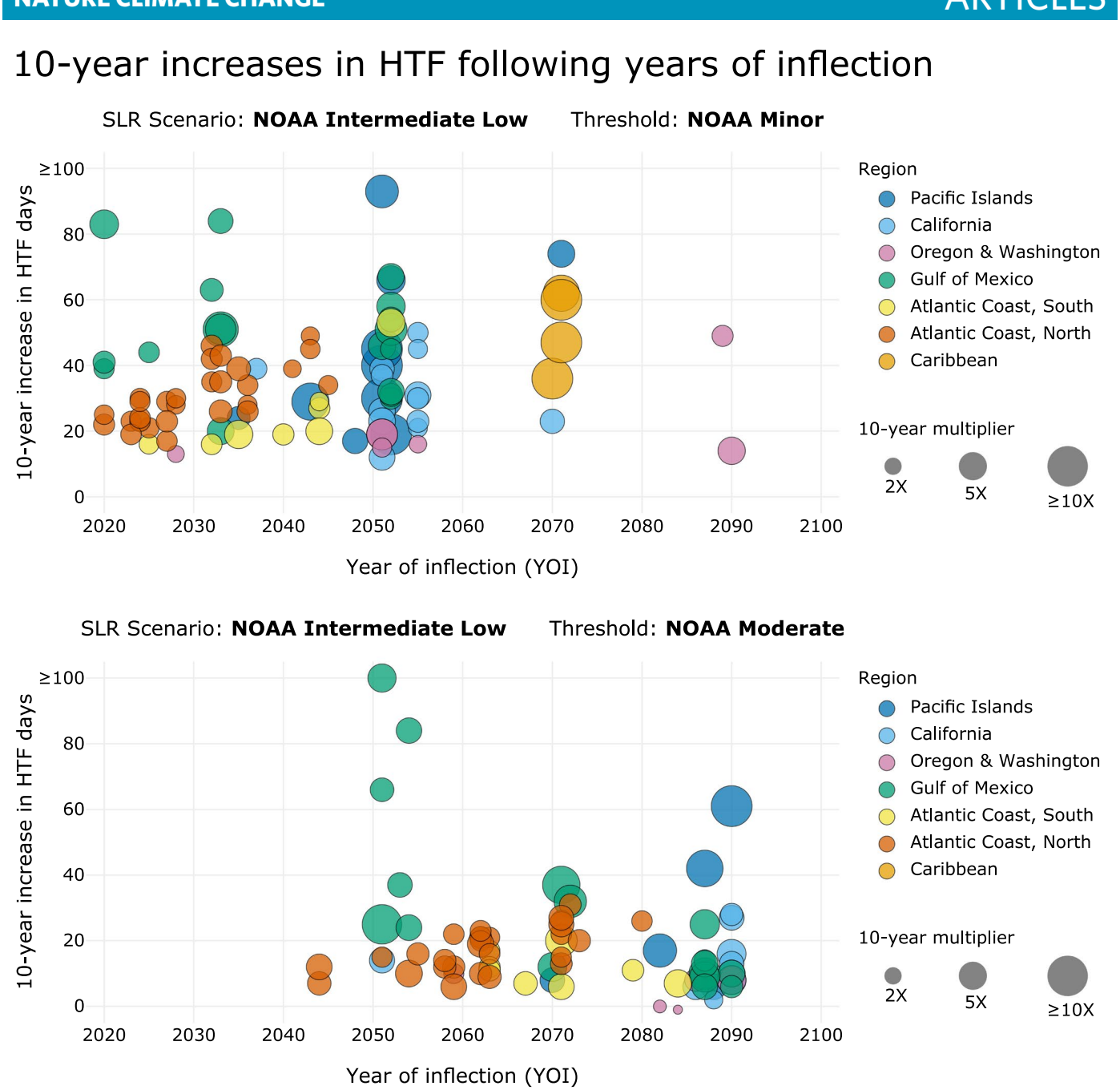
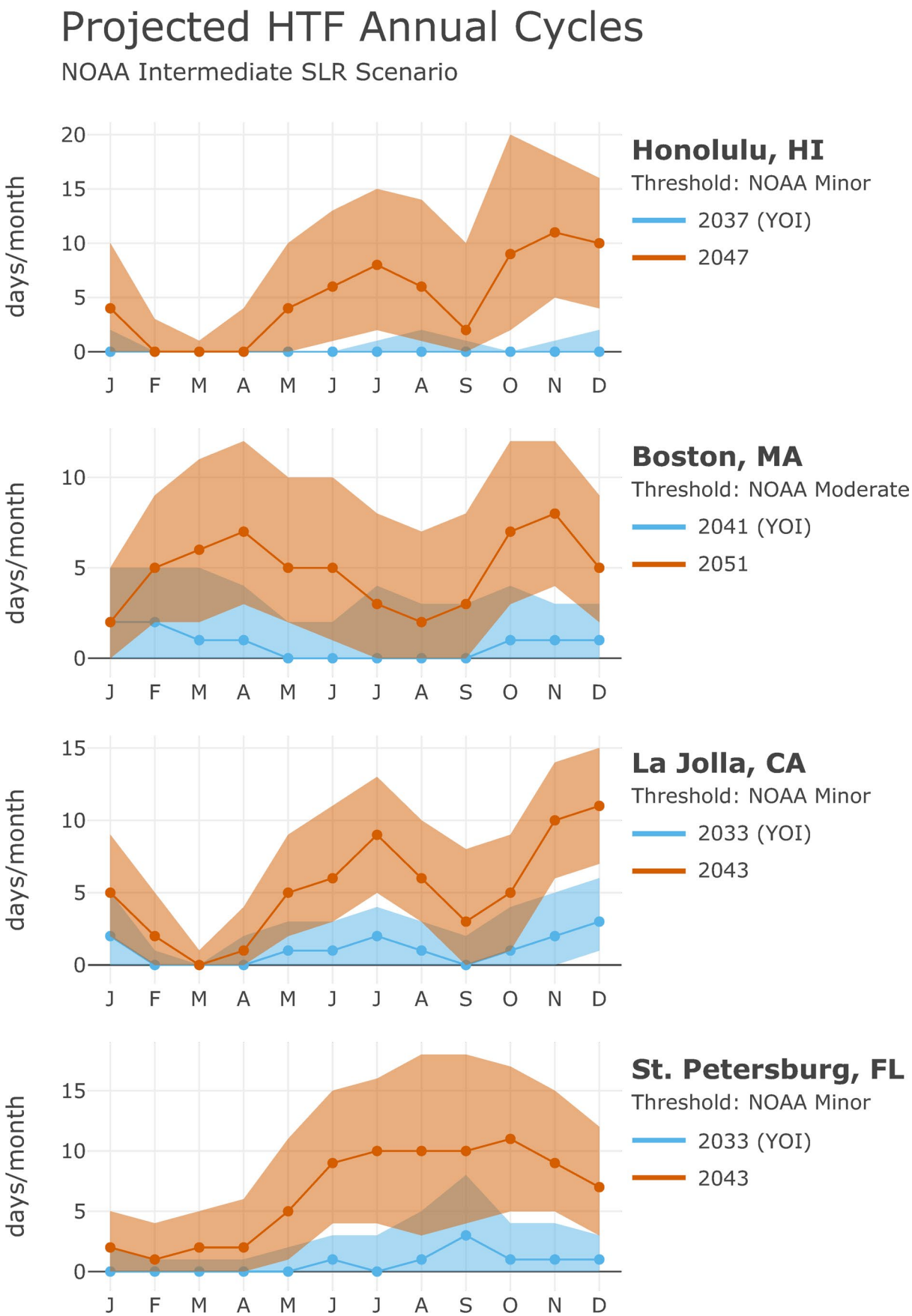


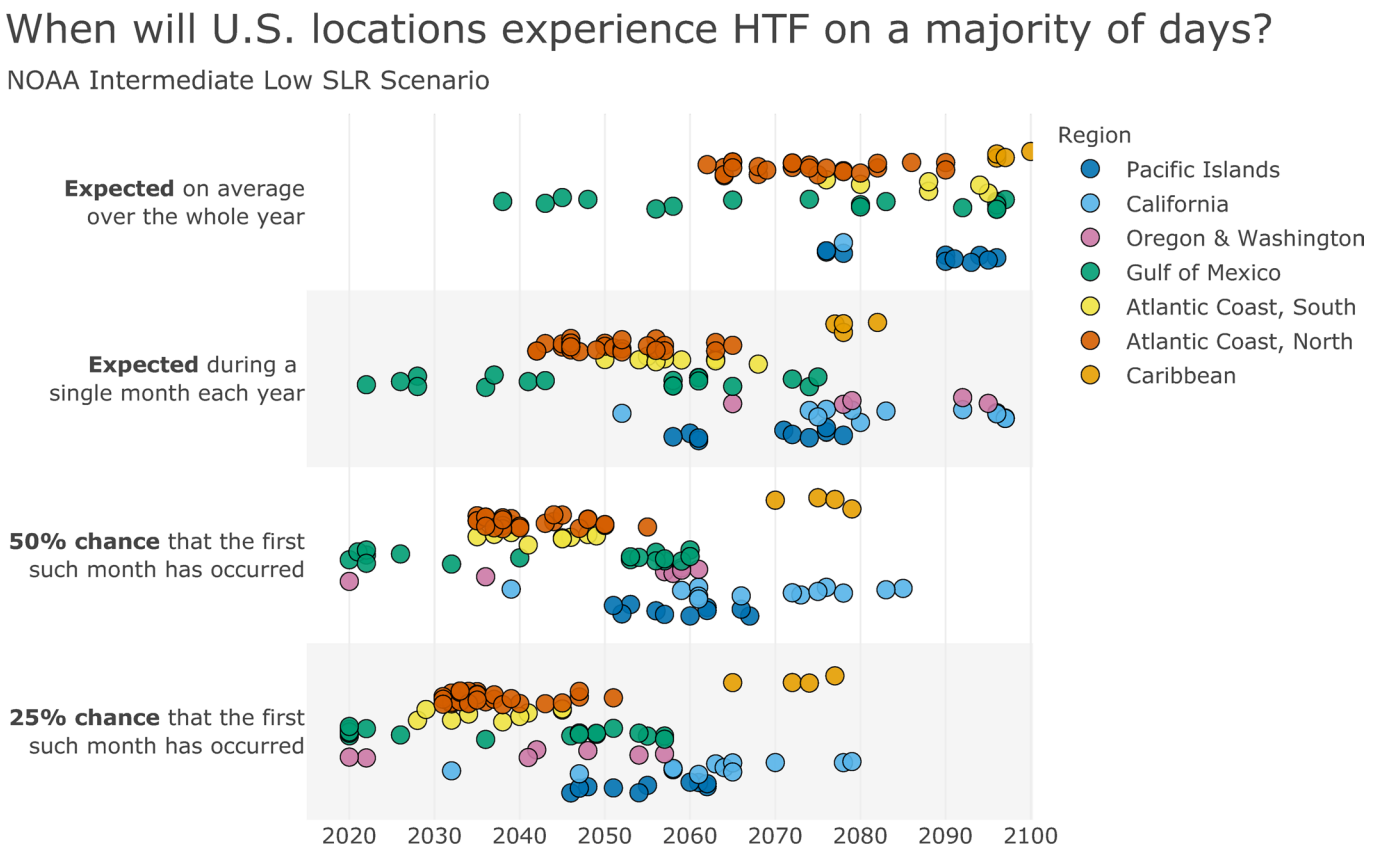
Extended Data Fig. 1 | Projections of annual counts of high-tide-flooding (HTF) days compared to expectations from SLR and tides alone. The four ensemble projections (blue) are identical to Fig. 1. The simple projection of HTF frequency based only on the SLR scenario and predictions of astronomical tides (gray) underestimates the frequency of HTF due to the exclusion of local mean sea level variability across a variety of time scales from high-frequency surge to decadal climate variability.



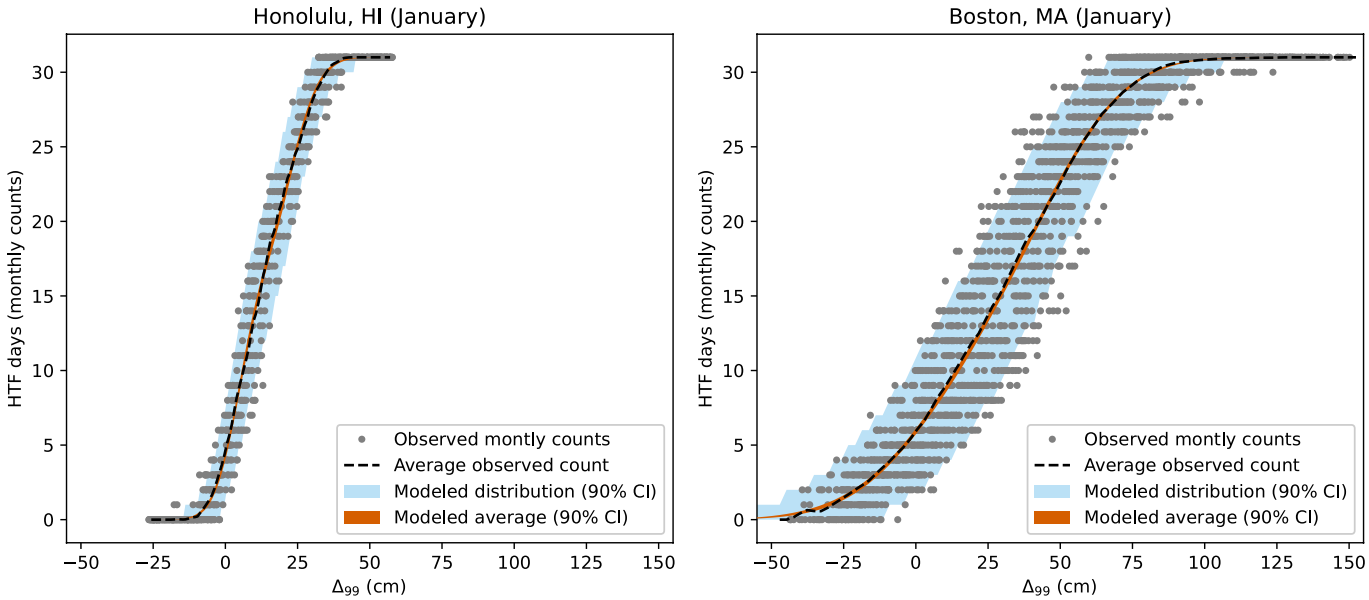
Extended Data Fig. 2 | Years of inflection (YOIs) for the NOAA Intermediate Low SLR scenario. The upper and lower panels correspond to the NOAA Minor and Moderate flooding thresholds, respectively. Position along the horizontal axis corresponds to the timing of the YOI. The vertical axis is projected ten-year increases in annual counts of HTF days following YOIs. Marker size corresponds to ten-year multipliers following the YOIs. Color denotes geographic region.



Extended Data Fig. 3 | Projected changes in the seasonal cycle of HTF frequency. Projections correspond to the YOI (blue) and 10 years later (orange) for the four US locations in Fig. 1 assuming the NOAA Intermediate SLR scenario. Shading shows the 10th–90th percentile intervals for each year and month.



Extended Data Fig. 4 | Years for which U.S. coastal locations will experience HTF on a majority of days during annual and monthly windows. Calculations assume the Intermediate Low SLR scenario. Years for which HTF is expected to occur on a majority of days on average during annual and monthly periods (top two rows) are compared to years for which flooding will first occur on a majority of days during a single month (bottom two rows). Marker colors denote station region. The vertical position of each marker within the rows is an arbitrary vertical offset to allow visual distinction between regions and individual locations.



Extended Data Fig. 5 | Relationships between Δ_{99} and monthly counts of HTF days. Examples correspond to the observed (gray and black) and fitted (orange and red) relationships for the month of January in (a) Honolulu and (b) Boston.

COMMENTS ON THE RECIRCULATED DRAFT INITIAL STUDY AND NEGATIVE DECLARATION FOR THE CANNABIS ORDINANCE SUBMITTED ON BEHALF OF THE FORT BRAGG CEQA GROUP

The Fort Bragg CEQA Group (FBCG) submits the following written comments and objections to the City of Fort Bragg's (City) current draft Initial Study and Negative Declaration (IS/ND) concerning the City's proposed updates to the Inland Land Use and Development Code (ILUDC) about commercial cannabis regulations. In our opinion, the draft IS/ND prepared by the City fails to meet applicable requirements and must be revised (again) prior to adoption. FBGC would first like to explicitly incorporate by reference all prior comments and objections to the adequacy of the CEQA review for this project as renewed objections to the adequacy of the revised and recirculated IS/ND as if they were fully set forth herein because many of them still apply even though the City revised the CEQA document in an attempt to address at least some of those concerns and objections. Second, and more specifically, there are several fundamental problems that are evident throughout the recirculated CEQA document, including the following:

1. Failure to identify and analyze potentially significant impacts in several study areas (i.e., Land Use and Planning, and Utilities and Service Systems) that are directly and indirectly implicated by the revisions to existing commercial cannabis regulations.
2. Failure to incorporate actual thresholds of significance for all impact areas under review.

Failure to Identity and Analyze Potentially Significant Impacts:

Of the various study areas covered by the Initial Study checklist, Land Use and Planning presents the most serious issue based on the inconsistency between the City's Inland General Plan and the inclusion of "wholesale and distribution" as accessory uses to cannabis retail within the City's commercial districts. As discussed in the public hearings and meetings for the development of the new ordinance updating the commercial cannabis regulations, potentially permitting those industrial uses in the City's commercial districts rather than limiting them to the industrial districts as they are now, is not consistent with the Inland General Plan's descriptions of the purpose and intent of the commercial land use designations and their corresponding zoning districts and would thus require a prior or concurrent general plan amendment in order to maintain consistency with the Inland General Plan. No such general plan amendment has been proposed and that creates a significant environmental impact in Land Use and Planning because that aspect of the proposed ordinance is in direct conflict with a plan (the Inland General Plan) that was adopted, in part, to protect the environment.

The other major area study area that is deficient as currently written is Utilities and Service Systems. As discussed in separate comments and below concerning the lack of appropriate thresholds of significance in this area, the City does not have adequate water supply to support the reasonably foreseeable development that will be an indirect consequence of the City adopting the proposed ordinance. This primarily applies to the checklist question "Have sufficient water supplies available to serve the project and reasonably foreseeable future

development during normal, dry and multiple dry years?" The current discussion in the IS/ND attempts to defer this necessary analysis into the future on a project-by-project basis on the assertion that because those projects will all require discretionary permit reviews (i.e., Minor Use Permits), we do not currently have to analyze the impacts of making indoor commercial cannabis cultivation permissible as part of this ordinance project. That is incorrect and contrary to applicable legal requirements concerning CEQA review because of the indirect physical development that is reasonably foreseeable to occur as a result of the City's adoption of the proposed ordinance. The City needs to perform city-wide water use and supply analysis based on a buildout analysis for the property currently zoned for industrial land uses where indoor cultivation will be permissible as a direct result of the adoption of the proposed ordinance. In fact, the City already performed such analysis, or at least began to do so, under the former staff who were first assigned to this project when it was initiated as an applicant-funded ILUDC amendment rather than a City-sponsored project. The literal purpose of this project was to update the code to allow for commercial cannabis cultivation as a permissible use so specific development projects would be possible after the amendments, including a large cannabis facility in the industrial zoned parcels north of Pudding Creek and Airport Road. That project and the others like it that justified this project to update the commercial cannabis regulations are indirect but reasonably foreseeable consequences of adopting the proposed ordinance that justify analyzing the projected water supply impacts of adding a whole new land use and class of water users. That analysis needs to be updated in the IS/ND because there is substantial evidence to support a reasonable argument that the City does not have sufficient water supplies available to serve the project and reasonably foreseeable future development during normal, dry and multiple dry years, which are present at the time of this review and projected to continue to the extent that the City's Public Work's Director (and Acting Community Development Director) has stated that there is a reasonable possibility the City will run out of water even with our raw water storage and supplemental desalination unit this coming summer or fall.

Failure to Incorporate Thresholds of Significance in Critical Impact Areas:

Some areas of inquiry include appropriate thresholds of significance, like Air Quality, which incorporates the standards set by applicable regulatory agencies as the City's thresholds of significance for Air Quality impacts, and uses those thresholds in the analysis for that section. Other study areas include absolutely no thresholds of significance but still assert the (unsupported) conclusion that there is no potentially significant impact in that study area. The conclusion that a particular study area does not have a significant impact or could not have a significant impact requires supporting analysis that includes an explicit threshold of significance but several important areas with a strong likelihood of an actual significant impact lack any threshold at all. A threshold of significance requires a qualitative or quantitative metric that can be used to determine if an impact is significant or not. That is, if you are below the threshold, the impact area can be determined to not be significant but if you are at or above the threshold, the impact area is determined to be significant and then you need to consider

potential mitigation. There are not many impact areas that are implicated by this particular proposed ordinance, which is limited in scope, but some areas remain with a strong likelihood of potentially significant impacts. Each of those areas requires a series of thresholds of significance associated with each Initial Study checklist question as well as any additional questions that are particular to this project, if any arguably apply.

The most glaring example of an area of inquiry and checklist questions that do not include an actual threshold of significance but need one is the issue of adequate water supply. As evidenced by substantial evidence in the form of the numerous drought declarations and City-created materials and documents concerning the City's water supply situation and projected worsening drought conditions, the City is facing unprecedented challenges to ensuring an adequate water supply for existing development, let alone additional development that will increase the need and use of municipal water. Unfortunately, this IS/ND proclaims that this area has less than significant impact without actually ever creating a threshold metric to establish how an impact in that study area might or might not be significant.

Based on our community's projected serious drought conditions that are already underway this year, our drastically diminished water supply, the City's recent history of declaring water emergencies and imposing draconian conservation measures and water use prohibitions, it is clear that the appropriate threshold of significance to evaluate a project's impacts to the municipal water supply and infrastructure needs to be a very low threshold, perhaps even any additional contribution to the City's water use needs should be considered significant. The City completely failed to establish any threshold of significance in this study area despite the mountain of evidence concerning the City's dire water supply and infrastructure situation that has and will be submitted as part of the hearing process for this ordinance.

The City's own water model demonstrates that, with diminishing flows in our raw water sources and rising tides and sea level rise due to climate change and other factors, we do not have enough projected water supply for our current development let alone any new development or significant water uses like commercial cannabis cultivation. Yet none of that is adequately addressed in the draft IS/ND in large part because there is absolutely no threshold of significance incorporated into the analysis. That needs to be remedied.

This project likely contributes, in a cumulatively considerable way, to our existing water supply and infrastructure problems and that would amount to a significant impact if the City actually performs adequate analysis evaluating if that contribution is cumulatively considerable based on a reasonable threshold of significance. Moreover, the City has not even tried to consider potential mitigation measures to address this impact area and potentially reduce the likely impacts to less than significant because it fails to acknowledge (within this document) that there is a problem in need of a solution. That is reversible error and the recirculated draft IS/ND requires revision and will likely need to be an MND or even an EIR because of this serious impact area.