From: Ken Eklund <futureeverything@writerguy.com>
Sent: Wednesday, July 16, 2025 1:32 PM
To: Benton Public Comment
Subject: Testimony in response to Republic-County-Pawlowski written material July 8-9 on dump odor
Attachments: A1 OCA5-abridged-reduced.pdf; A3 Odor complaint form on the Coffin Butte Landfill site Archive of Email chain.pdf; A5 Sunshine landfill ordered to step up actions to address odors .pdf; A6 Many say landfill emits 'invasive' odor into Harrisburg neighborhood – WSOC TV.pdf; A7 Neighbors say landfill smell hasn't improved after state-approved action plan – WSOC TV-reduced.pdf

RE: LU-24-027, the application to expand Coffin Butte Landfill
RECOMMENDATION: Please deny this application

Document ID: This is Part A, Odor.

Dear Chair Fowler, Vice Chair Hamann, and Planning Commissioners Biscoe, Cash, Fulford, Lee, Struthers, and Wilson:

I'm submitting this letter in response to information in four items in the in the "9. New Evidence from July 8-9 Hearings" folder on Munidocs:

1. Republic's slide deck ("25RS1067 Coffin Butte Deck_FINAL")
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Before you begin, please note: my letter has attached evidence A1 through A7. To view these attachments using the County's **Munidocs record** system, look to the Attachments section in this email's header, and double-click to view each one.

Also: for verification of statements made, this letter refers to testimonies in the Munidocs record that relate to the information in the above four items; I've linked to them so that you can quickly and easily refer to them. (And any attachments to *those* must also be double-clicked in their header, respectively, to open.)

I intend to be as succinct as possible here, however fair warning: this letter is only Part A (Odor).

ODOR

Republic presentation, p. 8-9
Staff presentation, p. 17
Pawlowski, p. 3

also
Kleinman p. 2, 8-11, Planning Commission Findings for Denial 2021

Brent Pawlowski brings up the issue of dump odor levels and public experience and expectations about odors and smells in his letter. Republic's presentation cites its odor modeling (odor study) and proposed mitigation. The County presentation also cites the odor study and the County's proposed Conditions of Approval.

The results of the odor study are not sufficient proof that the odor impacts of an expanded landfill will not seriously impact uses adjacent to the landfill (and in its effective "adjacent" impact zone). This is due to the large number of both quantitative and qualitative flaws in the model, omissions, and the readily apparent disconnect between the odor study's theoretical results and the available real-world data. ***Simply put, the odor study fails to explain what's currently happening around the landfill, much less what will happen if the landfill were to expand.***

1. **The odor study is a mishmash of snapshot inputs from 2004 (weather), 2024 (complaints) and 2023 (estimates of landfill gas emissions levels), etc., and results from such a mishmash are clearly insufficient to prove landfill odor impacts from now throughout the proposed life of the expansion.**
    a. The study uses *weather data* from 2004-5 (Munidocs **link** p. 127)
    b. Yet the study is keyed to *complaints* from its odor complaint portal, *which launched sometime after March 4, 2024* (see below), thus rendering the majority of complaints "inconclusive."
    c. The study also uses self-generated emissions estimates (see Munidocs **link** p. 127)

2. **The odor study asserts that its scientific rigor invalidates almost all community odor complaints, but it uses a cherry-picked subset of complaints, obsolete weather data, and self-determined gas emissions levels whose validity is currently being investigated by regulatory authorities, and which are contradicted by real-world data on Coffin Butte's landfill gas emissions. These shortcomings undermine its narrative of being scientifically rigorous.**
    a. Although the study purports to use "all available complaints" from 2022-2024, in fact it does not include the complaints received and compiled each year by the Benton County Disposal Site Advisory Committee in its annual Community Concerns Annual Report (CCAR), which the County then publishes to Oregon DEQ as required by state law. Republic Services has a representative on that committee, who voted on each year's CCAR. Republic's DSAC representative should have then entered those complaints into the study pool, but did not.
    The study has thus knowingly excluded from consideration several hundred community complaints about odor. Those Reports are in the record (see the attachments to p. 102 of this Munidocs **link**).
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d. The study uses Republic's reported emissions levels, but these reports are currently being audited by the EPA, after two EPA inspections revealed large-scale leaks. See my EPA timeline-explainer (the attachment to this Munidocs **link**).

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    i. If a 4,000 ppm concentration of methane were observed at the dump's surface, it would be 8 times the reportable level and trigger a requirement for immediate remedial action.

    ii. According to Table 1 in Republic's odor study, which is reproduced in the **County's Staff Presentation** on p. 17, the D/T value of "anaerobic digester gases" is 100,000 D/T. Anaerobic digester gas is an analogue to landfill gas, which is also largely a product of anaerobic digestion of organic matter, but landfill gas also includes odorifics that result from the breakdown of plastics, construction materials (especially gypsum wallboard), and a host of others generated by the interaction of organic and inorganic materials in the landfill. Since this data visualization shows the landfill gas emerging at somewhere over 6,000 ppm-m methane at its source, and then decreasing to concentrations of around 4,000 to 2,000 ppm-m (only decreasing 33% to 67%) before entering the property of others, we can back-of-envelope estimate that the D/T is in the neighborhood of 33,000 D/T and up when it crosses the property line. This is well above the nuisance threshold of 7, and maps well to the documented community experience, which is that the odor is powerful even miles away from the dump.

f. Both Republic's presentation and the County's presentation characterize odor with the D/T values catalogued in Table 1. This Table of Odor Index Examples is *from an entirely different industry than landfilling* (the wastewater industry).

    i. The table is useful only to wastewater treatment professionals, who may be familiar with what "primary clarifier weir cover exhaust" smells like.

    ii. The odorifics produced by wastewater treatment are only a subset of the odorifics produced by landfilling, as explained above. The quantity of odorifics such as VOCs are generally much lower in wastewater treatment, because that industry has effective odor abatement measures.

    iii. This information is old (2006). Why?

    iv. Why does this table, from another industry entirely, appear in this study, instead of a recent one that's directly relevant to landfills? The use of this table brings up questions about manipulation of the narrative of this study, such as: did the odor consultant cherry-pick this table so as to obscure the D/T of landfill gas, which may be high (higher than 100,000 D/T?)?

3. **Republic has misrepresented its complaint data for the odor study.** The presentation cites the data as coming from its "comprehensive odor management plan, 2022-2024." Ginger Richardson of Republic Services, however, informed the Benton County Board of Commissioners and staff by email on March 4, 2024, that Republic's real-time portal for

complaints (a web form) *had not yet been announced publicly*, “but would be soon” (email thread attached, see attachment **A3**). This was after Commissioner Wyse encountered landfill odor driving with her family on 99W (February 22, 2024) and sought a way to notify Republic of it, but found it notably difficult to do so (see attachment **A4**).

4. **The results of the odor study cited in Republic and County presentations are called into question by a documented real-world case where landfill odor disrupted a sale of land (a vineyard) in 2023.** That case is detailed in a local press article (see Munidocs **link**, p. 8).
5. **The results of the odor study cited in Republic and County presentations are called into question by documented cases where odor from landfills similar to Coffin Butte have caused widespread impacts over their area.** There are many examples; one such case is detailed in recent press articles from California (see Munidocs **link** and attachment **A5**) and another in news reports from North Carolina (see attachments **A6** and **A7**).
6. **The mitigation efforts listed in the Republic presentation *do not actually include any provisos for odor mitigation***. They attempt only to prolong Republic’s fiction that odors might not actually be happening at Coffin Butte Landfill.
7. **Republic has had ample opportunity to voluntarily reduce odors, but has failed to act on them.** There are well-established protocols for landfills to follow to reduce odors, but Republic has not followed any such protocol at Coffin Butte. Such actions would have been, or should have been, supplied to you as evidence – increased monitoring efforts, for example.

   In particular, Republic should have acted on the information provided to them by Carbon Mapper, the climate science nonprofit which is creating the images and data of landfill gas plumes coming off the landfill. Carbon Mapper open-sources this data *specifically so that facility operators such as Coffin Butte’s can access it and act on it*. The plume images show the origin points of the plumes, to aid facility operators in locating these mega-leaks and remediating them. Republic has not acted on these remediation aids; in fact, one mega-leak that Carbon Mapper pinpointed in July 2023 was still there in September 2024.

   If Republic did not undertake voluntary remediations in order to clean up its act and put on a good face for this expansion application, it’s exceedingly unlikely to begin once the company already has what it wants.
8. **The Conditions of Approval for odor listed in the County presentation do not actually include any provisos for controlling odor**.
   a. OP-5, limiting the height of the expanded landfill does not control odor: it is no different than the status quo.
   b. OP-7(A) and (B) also only attempt to prolong the fiction that serious odors might not be actually happening at Coffin Butte Landfill; neither contain any actual mitigation. For example, OP-7B: “Odor complaints which are verified by site personnel shall be remediated where possible” is no different from the status quo.
   c. OP-7(C) appears to be an attempt to derive a real-world operational limit from a mathematical model, which will not actually prevent any odor from occurring.
      i. A quantity of “organic waste” may be assumed in a generalized mathematical model, but there is no reliable operational way on a day-to-day basis to determine how much of incoming waste is “organic.”
      ii. OP-7(C)’s supposed annual limit of 930,000 tons of organic waste seems to be the result of mathematical misunderstanding or error by the County. Never in the dump’s history has it ever taken even half of this amount of organic waste in a year.

         A quick back-of-envelope calculation shows this: “organic” is tricky to define, but if you use the EPA guidance that a typical municipal solid waste stream is roughly 33% "organic," then Coffin Butte's current annual intake is roughly 0.36M tons of organic (33% of 1.05M tons). Allowing the annual intake of organic waste to escalate from 0.36M tons to 0.934M tons, which is what this Condition of Approval would do, is allowing a 250% increase in annual organic waste. This would lead to a corresponding sharp increase in landfill gas emissions, leading to landfill gas emissions that are 250% higher than where we are now. At no time is there any kind of "throttling" effect on landfill gas emissions as a result of OP-7(C).

iii. OP-7(C)'s so-called "limit" of 934,000 tons of organic waste annually also seems to be the result of misunderstanding or error by the County, because the County seems unaware of the drastic change that would have to have occurred for it to be triggered. As shown above, for the 934K/yr limit to come into play, the yearly waste intake would have increased 250%, which means Coffin Butte would have filled its quarry and expansion volumes much more rapidly and the landfill would be closing in the 2030–2035 timeframe.

iv. A simple use case for this Condition would be: the County discovers that Republic has exceeded its organic waste allotment (however "organic" is defined). The County has not identified any realistic mechanism by which it can enforce this Condition, i.e., how it can compel Republic to place less organic waste going forward to make up for its overage, especially since to achieve a one-ton reduction in organic waste, Republic would have to forego two additional tons of non-organic waste.

v. In terms of odor, OP-7(C) is much worse than the status quo: up to 2.5x worse.

d. OP-7(D) just furthers the narrative that the problem is detection and quantification of odors, rather than actual mitigation of them. It continues the current policy of raising procedural obstacles that must be overcome before mitigation will even be attempted, and its mitigation mandate – "Applicant shall immediately take steps to mitigate the odor" – might as well specify the use of a magic wand.

e. OP-11(A-F) – Republic is already subject to these requirements at its existing landfill. Since the County adds no monitoring or enforcement, these Conditions make no effective change to the status quo, and do not mitigate odor.

9. **Qualitative discrepancy: the odor study asserts the qualitative result of "no nuisance," but pays no attention to how the *quality* of an odor affects its *qualitative result*.** Simply put, there are dangerous odors and non-dangerous odors, and numerous testimonies establish that Coffin Butte odor is dangerous-smelling (Munidocs **link1** **link2** **link3** **link4** etc.). "It's OK for me to keep breathing this odor," said no one, ever, upon encountering the smell. This is a fatal flaw in the odor study.

10. **Landfill odors DO actually signal danger.** Landfill gas is known to contain many toxics. The nose knows.

    a. "Nearly 30 organic hazardous air pollutants have been identified in uncontrolled landfill gas, including benzene, toluene, ethyl benzene, and vinyl chloride. Exposure to these pollutants can lead to adverse health effects." – EPA. As an example, Coffin Butte's 2020 Air Toxics Emissions Inventory (the most recent I could find) shows that the landfill is calculated to have emitted over 2 tons of toluene gas that year. Toluene has a sweet or sharp odor, which is how I would describe what landfill gas smells like.

    b. PFAS is a focus of current concern, because the EPA has established that these chemicals are present in landfill gas, and they are known to have a wide range of health impacts even at small concentrations, but these impacts are not yet well known, especially for “non-legacy PFAS” (PFAS variants that are being used to replace the “legacy” PFAS types, which have been phased out due to health impacts). The science on PFAS is emerging, and that has been well documented in prior testimonies to the Planning Commission (see this Munidocs **link and its attachments**).

The current lack of clarity from the EPA about safe levels of PFAS only increases concern and avoidance. *It’s prudent to be alert to, and shield yourself and your family from, a toxic smell if you have no assurance that it’s safe to breathe.*

11. **Odor quantification does not equal proof of non-seriousness.** Republic Services and the County both admit this. According to them, a D/T of 1 means that on the average, half the people encountering it will smell it. Since approximately 8,400 people live within 5 miles of the landfill, there are 4,200 who will smell it regularly at that level.

    Let’s put “D/T” in plain language, in the experience of a person who has a reasonably good sense of smell. They will no longer be able to make use of the E.E. Wilson Wildlife Area – you have testimony to this effect. They will no longer be able to drive 99W with their windows open or the air system not on RECIRC – there’s testimony about this as well. They will no longer be able to freely visit friends or family in the area of the landfill. And if they happen to live within a certain radius of the landfill, they will need to sell and move, but of course they won’t be able to sell if buyers also have a good sense of smell. You have testimony about all this as well.

    Republic’s odor quantification of the number of people involved in this situation is suspect, given the disparity between what the numbers say and what the people say, but the *precise* number is irrelevant, because it is clearly nowhere close to zero.

    We know that **x** number of people are already suffering serious interference **i** from the odor impact of the landfill – so the harm is **x times i**. An expanded landfill would increase this impact on **x**, because as Republic admits, it would extend their time suffering the impact **i** – so, it’s now **x times (i+j)**, where **j** is that impact during that extended time. If the landfill persists for longer, it's also growing **x**, because now there’s more time for more people to suffer the impact. So an expanded landfill means we no longer have **x times i**, we have (**x+y) times (i+j)**, where **y** are the new people suffering the odor impacts. We also have an increase in odor impacts because they are a function of landfill surface area, which an expansion would increase by roughly 33%. So now, where we have **x times i** with no expansion, we have **((x+y) times (i+j)) times 1.33.** Has Republic *convinced* you that **((x+y) times (i+j)) times 1.33** is a small enough number that your criteria can safely ignore it? On the contrary, I would say: you have received no proof of that. Without proof, you cannot find that serious interference will not occur.

Conclusion. As explained in verbal testimony (see Munidocs **link**), a Burden of Proof must both produce *evidence* and create a *convincing narrative*, or it fails. Let’s look at how Republic itself characterizes its evidence, quoting the Supplemental Staff Report:

> “Staff engineering consultants have reviewed and determined the applicant’s odor study follows reasonable assumptions and modeling protocols.” (p. 8)

This is weak tea, narratively speaking. It is damning with faint praise. Any number of studies may be constructed that follow “reasonable assumptions and modeling protocols,” but which *fail to adequately and convincingly model reality*.

The numbered Arguments above create a number of narratives about odor that more than countervail the stories put forward in Republic’s presentation and by Pawlowski in his letter. Here is one such narrative, assembled from the above Arguments:

The dump has an odor problem, and has had one for many years;

Republic has been unwilling or unable to remedy it;

Republic has chosen instead to try to discount community concerns about odor;

Landfill proponents support this by characterizing complainants as NIMBYs;

Republic belatedly realized odor would be a key issue in early 2024, and created an odor complaint portal shortly before filing the expansion application;

The purpose of the portal was to collect data they could use to discount odor as an issue;

Most community members intuited this, and did not use the portal (myself included);

The data did not lend itself to the conclusion Republic wanted, and so it took approximately nine months and many attempts to engineer an odor study that could pass muster as "following reasonable assumptions and modeling protocols" and still have the conclusion that Republic wanted;

Republic knows the odor study is riddled with flaws, but is hoping the public will not be able to bring those forward;

Republic hopes to overcome the weight of hundreds of community concerns about odor by trying to assert, through the gravitas of credentialed consultants, that the action that's needed is monitoring, not mitigation.

I am not under a Burden of Proof, but I believe the evidence available to you, Commissioners, supports this narrative more than Republic's "reasonable assumptions," which is under a Burden of Proof.

I'll close with rebuttal of a point of view which Pawlowski summarizes very well:

> "Many opponents to the landfill are those that live near the landfill site… One should not expect customers of several counties to yield to the few who had the option to buy property elsewhere. The responsibility of having one's property value affected should be pushed back to those who decided to buy residential land nearby. What were they thinking?" (p. 2-3)

I think you Commissioners are aware of the shortcomings of this reasoning from a land-use perspective, so I won't belabor them. Your decision criteria focus on serious interference to other land uses and to the character of the area, not on the interests of customers or the business that serves them. What I focus on here is how this reasoning attempts to divert responsibility for environmental hazards away from the entity causing them and onto the entities suffering them – *victim blaming*, in modern parlance.

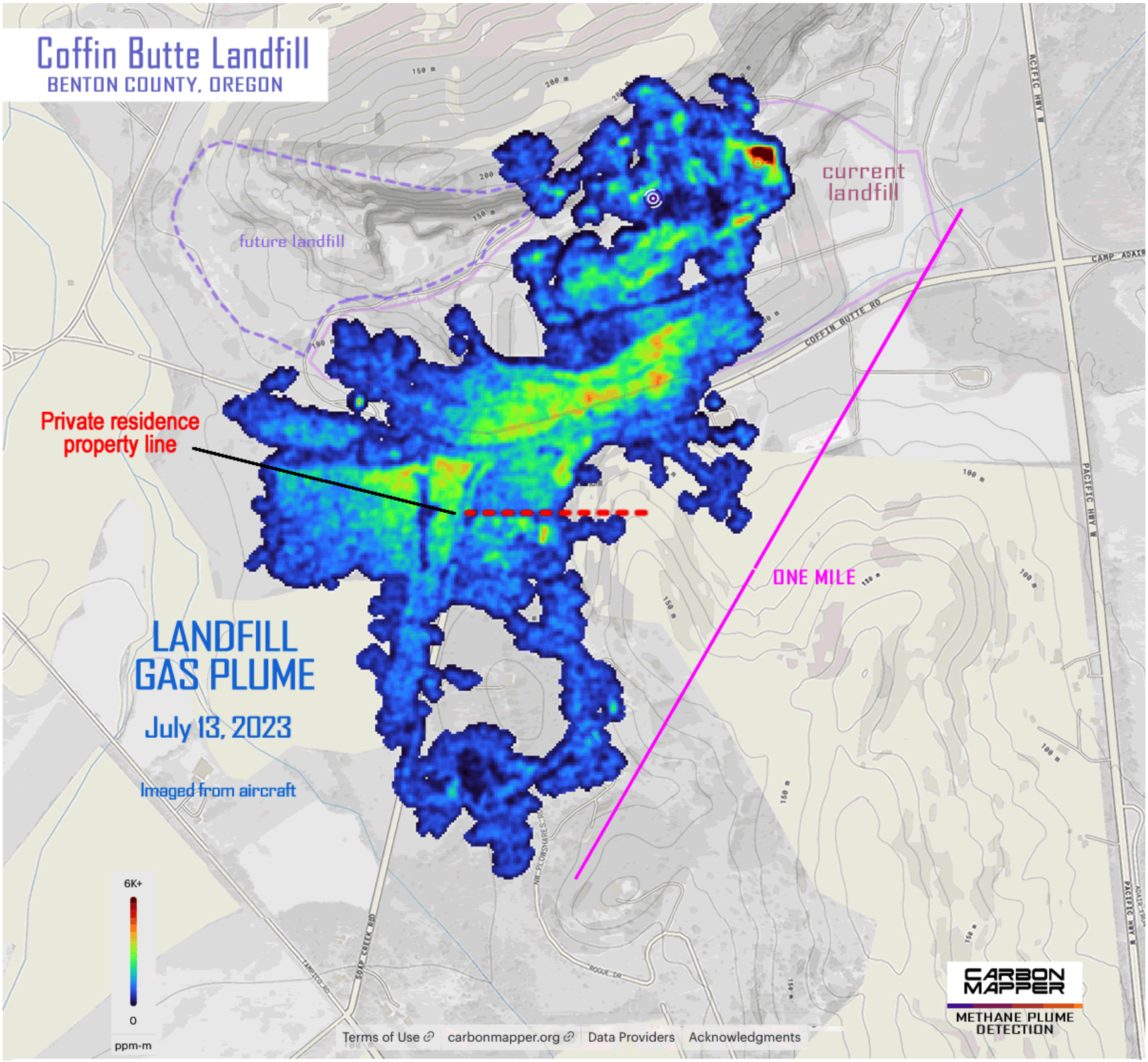
As you have heard in many testimonies, victims of dump odor did not buy, but inherited their land, or bought land when the landfill and its future were much different, or bought land many miles away from Coffin Butte Landfill, never imagining landfill stench could travel that far. Or they don't live here, they just try to visit, or pass through on Highway 99W. No matter: however they came to be where they are, your decision criteria focus on whether or not an expanded landfill will pose serious interference to their enjoyment of their land, or to the character of the area.

Pawlowski is in effect promoting the idea that the area around the landfill should become a *sacrifice zone* – or, I should say, to *continue* becoming a sacrifice zone, because that has been a dark thread in its history so far. The landfill has driven away farms and farmers with well contamination, bought up and deplatted neighborhoods-to-be, degraded wetlands and natural areas, and so on. Attorney Kleinman articulated this process and its future very well in his July 9 testimony, when he evoked an image of the landfill expanding into a new location, which blights surrounding uses, so that it has a new area to expand into, and so on, without end. –Or should I say, instead of landfill, the *Landfill Complex*, because LU-24-027 would establish a precedent of creating new landfills that no longer even physically touch the existing ones.

Every sacrifice zone has an associated *abundance zone* – somebody who profits from the sacrifice zone – and Pawlowski touches on this as well, with his opinion that the needs of Republic's customers and Republic outweigh those of the people in the sacrifice zone. Pawlowski is saying the quiet part out loud.

Commissioners, an Approve decision on this land use application would be a de facto declaration of Sacrifice Zone status, and would have a huge and irrevocable impact on the character of the area that I and many others call home.

And it may have a wider impact, as well. What we're finding in VNEQS is that many Oregonians don't <u>want</u> to benefit from the victimization of others. They'd vote against it, if they could. They'd object to being characterized as customers who are only concerned with low garbage rates. They may not be here to speak for themselves – many don't even know what is being proposed in their name – through no fault of their own, I may add. They're voiceless in this proceeding, but I'll speak up on their behalf, and urge you to deny the application to expand Coffin Butte Landfill. "Not in our names," is what they are saying.


Coffin Butte Landfill
BENTON COUNTY, OREGON
current landfill
future landfill
Private residence property line
ONE MILE
LANDFILL GAS PLUME
July 13, 2023
Imaged from aircraft
6K+
0
ppm-m
COFFIN BUTTE RD
CAMP ADAIR
PACIFIC HWY W
SOAP CREEK RD
Terms of Use
carbonmapper.org
Data Providers
Acknowledgments
CARBON MAPPER
METHANE PLUME DETECTION

☆ **Nancy Wyse**

February 28, 2024 at 8:53 PM

NW

RE: Odor complaint form on the Coffin Butte Landfill site?

To: Ken Eklund

Ken,

I don't recall if the link/online feature was ever formally shared with us (Benton County/Board of Commissioners)… it could have been, but I don't remember. I do remember seeing reports of complaints about the landfill, which included odors. Since I experienced the odors last week it made me think about that report and wonder if others were reporting. I saw your email come in and went to their website to look. It took me a few minutes to find it. I couldn't find a link. I had to do 3 or 4 searches to find it. I *think* the keyword that finally found it was "odor".

We (my family and I) were driving hwy 99W northbound on the 22nd around 5:30/5:45pm-ish. I had a respiratory infection at the time which affected my sense of smell, but just before Adair Village I noticed a "weird" smell and it got stronger right as we passed the landfill.

p.s. not to diminish the focus of your email, but I've not seen a golden eagle in Benton County before… but I'd like to! I'll keep my eyes peeled!

Benton County OREGON

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Creator of
World Without Oil
Ed Zed Omega
FutureCoast
and other storymaking games

From: Ken Eklund
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   e. Both Republic's presentation and the County's presentation are based on the odor study's conclusion that dump odor at the landfill property line is detectable (D/T 0.5) but does not rise above the level of nuisance (defined as D/T 7). This conclusion is called into question by actual observations of landfill gas plumes in 2023, such as one that shows a plume spilling southward and surrounding homes at concentrations of from 2,000 to 4,000 ppm-m of methane (see my attachment **A2**, a July 2023 plume image). Methane is the primary component in Coffin Butte's landfill gas (52%) and is used to track the plume; the odorifics are a host of other organic compounds which landfilling creates along with methane, and which piggyback on methane into the environment.
      i. If a 4,000 ppm concentration of methane were observed at the dump's surface, it would be 8 times the reportable level and trigger a requirement for immediate remedial action.
      ii. According to Table 1 in Republic's odor study, which is reproduced in the **County's Staff Presentation** on p. 17, the D/T value of "anaerobic digester gases" is 100,000 D/T. Anaerobic digester gas is an analogue to landfill gas, which is also largely a product of anaerobic digestion of organic matter, but landfill gas also includes odorifics that result from the breakdown of plastics, construction materials (especially gypsum wallboard), and a host of others generated by the interaction of organic and inorganic materials in the landfill. Since this data visualization shows the landfill gas emerging at somewhere over 6,000 ppm-m methane at its source, and then decreasing to concentrations of around 4,000 to 2,000 ppm-m (only decreasing 33% to 67%) before entering the property of others, we can back-of-envelope estimate that the D/T is in the neighborhood of 33,000 D/T and up when it crosses the property line. This is well above the nuisance threshold of 7, and maps well to the documented community experience, which is that the odor is powerful even miles away from the dump.
   f. Both Republic's presentation and the County's presentation characterize odor with the D/T values catalogued in Table 1. This Table of Odor Index Examples is *from an entirely different industry than landfilling* (the wastewater industry).
      i. The table is useful only to wastewater treatment professionals, who may be familiar with what "primary clarifier weir cover exhaust" smells like.
      ii. The odorifics produced by wastewater treatment are only a subset of the odorifics produced by landfilling, as explained above. The quantity of odorifics such as VOCs are generally much lower in wastewater treatment, because that industry has effective odor abatement measures.
      iii. This information is old (2006). Why?
      iv. Why does this table, from another industry entirely, appear in this study, instead of a recent one that's directly relevant to landfills? The use of this table brings up questions about manipulation of the narrative of this study, such as: did the odor consultant cherry-pick this table so as to obscure the D/T of landfill gas, which may be high (higher than 100,000 D/T?)?
3. **Republic has misrepresented its complaint data for the odor study.** The presentation cites the data as coming from its "comprehensive odor management plan, 2022-2024." Ginger Richardson of Republic Services, however, informed the Benton County Board of Commissioners and staff by email on March 4, 2024, that Republic's real-time portal for complaints (a web form) *had not yet been announced publicly*, "but would be soon" (email thread attached, see attachment **A3**). This was after Commissioner Wyse encountered landfill odor driving with her family on 99W (February 22, 2024) and sought a way to notify Republic of it, but found it notably difficult to do so (see attachment **A4**).
4. **The results of the odor study cited in Republic and County presentations are called into question by a documented real-world case where landfill odor disrupted a sale of land (a vineyard) in 2023.** That case is detailed in a local press article (see Munidocs **link**, p. 8).
5. **The results of the odor study cited in Republic and County presentations are called into question by documented cases where odor from landfills similar to Coffin Butte have caused widespread impacts over their area.** There are many examples; one such case is detailed in recent press articles from California (see Munidocs **link** and attachment **A5**) and another in news reports from North Carolina (see attachments **A6** and **A7**).
6. **The mitigation efforts listed in the Republic presentation** ***do not actually include any provisos for odor mitigation***. They attempt only to prolong Republic's fiction that odors might not actually be happening at Coffin Butte Landfill.
7. **Republic has had ample opportunity to voluntarily reduce odors, but has failed to act on them.** There are well-established protocols for landfills to follow to reduce odors, but Republic has not followed any such protocol at Coffin Butte. Such actions would have been, or should have been, supplied to you as evidence – increased monitoring efforts, for example.
   In particular, Republic should have acted on the information provided to them by Carbon Mapper, the climate science nonprofit which is creating the images and data of landfill gas plumes coming off the landfill. Carbon Mapper open-sources this data *specifically so that facility operators such as Coffin Butte's can access it and act on it*. The plume images show the origin points of the plumes, to aid facility operators in locating these mega-leaks and remediating them. Republic has not acted on these remediation aids; in fact, one mega-leak that Carbon Mapper pinpointed in July 2023 was still there in September 2024.
   If Republic did not undertake voluntary remediations in order to clean up its act and put on a good face for this expansion application, it's exceedingly unlikely to begin once the company already has what it wants.
8. **The Conditions of Approval for odor listed in the County presentation do not actually include any provisos for controlling odor**.
   a. OP-5, limiting the height of the expanded landfill does not control odor: it is no different than the status quo.
   b. OP-7(A) and (B) also only attempt to prolong the fiction that serious odors might not be actually happening at Coffin Butte Landfill; neither contain any actual mitigation. For example, OP-7B: "Odor complaints which are verified by site personnel shall be remediated where possible" is no different from the status quo.
   c. OP-7(C) appears to be an attempt to derive a real-world operational limit from a mathematical model, which will not actually prevent any odor from occurring.
      i. A quantity of "organic waste" may be assumed in a generalized mathematical model, but there is no reliable operational way on a day-to-day basis to determine how much of incoming waste is "organic."
      ii. OP-7(C)'s supposed annual limit of 930,000 tons of organic waste seems to be the result of mathematical misunderstanding or error by the County. Never in the dump's history has it ever taken even half of this amount of organic waste in a year.
         A quick back-of-envelope calculation shows this: "organic" is tricky to define, but if you use the EPA guidance that a typical municipal solid waste stream is roughly 33% "organic," then Coffin Butte's current annual intake is roughly 0.36M tons of organic (33% of 1.05M tons). Allowing the annual intake of organic waste to escalate from 0.36M tons to 0.934M tons, which is what this Condition of Approval would do, is allowing a 250% increase in annual organic waste. This would lead to a corresponding sharp increase in landfill gas emissions, leading to landfill gas emissions that are 250% higher than where we are now. At no time is there any kind of "throttling" effect on landfill gas emissions as a result of OP-7(C).
      iii. OP-7(C)'s so-called "limit" of 934,000 tons of organic waste annually also seems to be the result of misunderstanding or error by the County, because the County seems unaware of the drastic change that would have to have occurred for it to be triggered. As shown above, for the 934K/yr limit to come into play, the yearly waste intake would have increased 250%, which means Coffin Butte would have filled its quarry and expansion volumes much more rapidly and the landfill would be closing in the 2030–2035 timeframe.
      iv. A simple use case for this Condition would be: the County discovers that Republic has exceeded its organic waste allotment (however "organic" is defined). The County has not identified any realistic mechanism by which it can enforce this Condition, i.e., how it can compel Republic to place less organic waste going forward to make up for its overage, especially since to achieve a one-ton reduction in organic waste, Republic would have to forego two additional tons of non-organic waste.
      v. In terms of odor, OP-7(C) is much worse than the status quo: up to 2.5x worse.
   d. OP-7(D) just furthers the narrative that the problem is detection and quantification of odors, rather than actual mitigation of them. It continues the current policy of raising procedural obstacles that must be overcome before mitigation will even be attempted, and its mitigation mandate – "Applicant shall immediately take steps to mitigate the odor" – might as well specify the use of a magic wand.
   e. OP-11(A-F) – Republic is already subject to these requirements at its existing landfill. Since the County adds no monitoring or enforcement, these Conditions make no effective change to the status quo, and do not mitigate odor.
9. **Qualitative discrepancy: the odor study asserts the qualitative result of "no nuisance," but pays no attention to how the** ***quality*** **of an odor affects its** ***qualitative result.*** Simply put, there are dangerous odors and non-dangerous odors, and numerous testimonies establish that Coffin Butte odor is dangerous-smelling (Munidocs **link1 link2 link3 link4** etc.). "It's OK for me to keep breathing this odor," said no one, ever, upon encountering the smell. This is a fatal flaw in the odor study.
10. **Landfill odors DO actually signal danger.** Landfill gas is known to contain many toxics. The nose knows.
    a. "Nearly 30 organic hazardous air pollutants have been identified in uncontrolled landfill gas, including benzene, toluene, ethyl benzene, and vinyl chloride. Exposure to these pollutants can lead to adverse health effects." – EPA. As an example, Coffin Butte's 2020 Air Toxics Emissions Inventory (the most recent I could find) shows that the landfill is calculated to have emitted over 2 tons of toluene gas that year. Toluene has a sweet or sharp odor, which is how I would describe what landfill gas smells like.
    b. PFAS is a focus of current concern, because the EPA has established that these chemicals are present in landfill gas, and they are known to have a wide range of health impacts even at small concentrations, but these impacts are not yet well known, especially for "non-legacy PFAS" (PFAS variants that are being used to replace the "legacy" PFAS types, which have been phased out due to health impacts). The science on PFAS is emerging, and that has been well documented in prior testimonies to the Planning Commission (see this Munidocs **link and its attachments**).
       The current lack of clarity from the EPA about safe levels of PFAS only increases concern and avoidance. *It's prudent to be alert to, and shield yourself and your family from, a toxic smell if you have no assurance that it's safe to breathe.*
11. **Odor quantification does not equal proof of non-seriousness.** Republic Services and the County both admit this. According to them, a D/T of 1 means that on the average, half the people encountering it will smell it. Since approximately 8,400 people live within 5 miles of the landfill, there are 4,200 who will smell it regularly at that level.
    Let's put "D/T" in plain language, in the experience of a person who has a reasonably good sense of smell. They will no longer be able to make use of the E.E. Wilson Wildlife Area – you have testimony to this effect. They will no longer be able to drive 99W with their windows open or the air system not on RECIRC – there's testimony about this as well. They will no longer be able to freely visit friends or family in the area of the landfill. And if they happen to live within a certain radius of the landfill, they will need to sell and move, but of course they won't be able to sell if buyers also have a good sense of smell. You have testimony about all this as well.
    Republic's odor quantification of the number of people involved in this situation is suspect, given the disparity between what the numbers say and what the people say, but the *precise* number is irrelevant, because it is clearly nowhere close to zero.
    We know that **x** number of people are already suffering serious interference **i** from the odor impact of the landfill – so the harm is **x times i**. An expanded landfill would increase this impact on **x**, because as Republic admits, it would extend their time suffering the impact **i** – so, it's now **x times (i+j)**, where **j** is that impact during that extended time. If the landfill persists for longer, it's also growing **x**, because now there's more time for more people to suffer the impact. So an expanded landfill means we no longer have **x times i**, we have **(x+y) times (i+j)**, where **y** are the new people suffering the odor impacts. We also have an increase in odor impacts because they are a function of landfill surface area, which an expansion would increase by roughly 33%. So now, where we have **x times i** with no expansion, we have **((x+y) times (i+j)) times 1.33.** Has Republic *convinced* you that **((x+y) times (i+j)) times 1.33** is a small enough number that your criteria can safely ignore it? On the contrary, I would say: you have received no proof of that. Without proof, you cannot find that serious interference will not occur.

Conclusion. As explained in verbal testimony (see Munidocs **link**), a Burden of Proof must both produce *evidence* and create a *convincing narrative*, or it fails. Let's look at how Republic itself characterizes its evidence, quoting the Supplemental Staff Report:

> "Staff engineering consultants have reviewed and determined the applicant's odor study follows reasonable assumptions and modeling protocols." (p. 8)

This is weak tea, narratively speaking. It is damning with faint praise. Any number of studies may be constructed that follow "reasonable assumptions and modeling protocols," but which *fail to adequately and convincingly model reality*.

The numbered Arguments above create a number of narratives about odor that more than countervail the stories put forward in Republic's presentation and by Pawlowski in his letter. Here is one such narrative, assembled from the above Arguments:

> *The dump has an odor problem, and has had one for many years;*
>
> *Republic has been unwilling or unable to remedy it;*
>
> *Republic has chosen instead to try to discount community concerns about odor;*
>
> *Landfill proponents support this by characterizing complainants as NIMBYs;*
>
> *Republic belatedly realized odor would be a key issue in early 2024, and created an odor complaint portal shortly before filing the expansion application;*
>
> *The purpose of the portal was to collect data they could use to discount odor as an issue;*
>
> *Most community members intuited this, and did not use the portal (myself included);*
>
> *The data did not lend itself to the conclusion Republic wanted, and so it took approximately nine months and many attempts to engineer an odor study that could pass muster as "following reasonable assumptions and modeling protocols" and still have the conclusion that Republic wanted;*
>
> *Republic knows the odor study is riddled with flaws, but is hoping the public will not be able to bring those forward;*
>
> *Republic hopes to overcome the weight of hundreds of community concerns about odor by trying to assert, through the gravitas of credentialed consultants, that the action that's needed is monitoring, not mitigation.*

I am not under a Burden of Proof, but I believe the evidence available to you, Commissioners, supports this narrative more than Republic's "reasonable assumptions," which is under a Burden of Proof.

I'll close with rebuttal of a point of view which Pawlowski summarizes very well:

> "Many opponents to the landfill are those that live near the landfill site… One should not expect customers of several counties to yield to the few who had the option to buy property elsewhere. The responsibility of having one's property value affected should be pushed back to those who decided to buy residential land nearby. What were they thinking?" (p. 2-3)

I think you Commissioners are aware of the shortcomings of this reasoning from a land-use perspective, so I won't belabor them. Your decision criteria focus on serious interference to other land uses and to the character of the area, not on the interests of customers or the business that serves them. What I focus on here is how this reasoning attempts to divert responsibility for environmental hazards away from the entity causing them and onto the entities suffering them – *victim blaming*, in modern parlance.

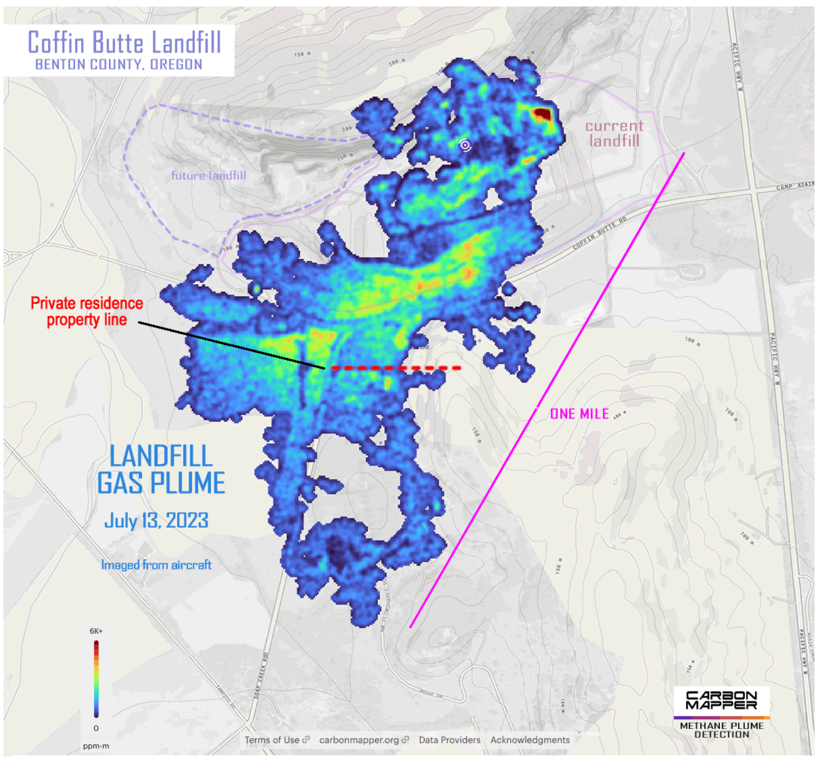
As you have heard in many testimonies, victims of dump odor did not buy, but inherited their land, or bought land when the landfill and its future were much different, or bought land many miles away from Coffin Butte Landfill, never imagining landfill stench could travel that far. Or they don't live here, they just try to visit, or pass through on Highway 99W. No matter: however they came to be where they are, your decision criteria focus on whether or not an expanded landfill will pose serious interference to their enjoyment of their land, or to the character of the area.

Pawlowski is in effect promoting the idea that the area around the landfill should become a *sacrifice zone* – or, I should say, to *continue* becoming a sacrifice zone, because that has been a dark thread in its history so far. The landfill has driven away farms and farmers with well contamination, bought up and deplatted neighborhoods-to-be, degraded wetlands and natural areas, and so on. Attorney Kleinman articulated this process and its future very well in his July 9 testimony, when he evoked an image of the landfill expanding into a new location, which blights surrounding uses, so that it has a new area to expand into, and so on, without end. –Or should I say, instead of landfill, the *Landfill Complex*, because LU-24-027 would establish a precedent of creating new landfills that no longer even physically touch the existing ones.

Every sacrifice zone has an associated *abundance zone* – somebody who profits from the sacrifice zone – and Pawlowski touches on this as well, with his opinion that the needs of Republic's customers and Republic outweigh those of the people in the sacrifice zone. Pawlowski is saying the quiet part out loud.

Commissioners, an Approve decision on this land use application would be a de facto declaration of Sacrifice Zone status, and would have a huge and irrevocable impact on the character of the area that I and many others call home.

And it may have a wider impact, as well. What we're finding in VNEQS is that many Oregonians don't want to benefit from the victimization of others. They'd vote against it, if they could. They'd object to being characterized as customers who are only concerned with low garbage rates. They may not be here to speak for themselves – many don't even know what is being proposed in their name – through no fault of their own, I may add. They're voiceless in this proceeding, but I'll speak up on their behalf, and urge you to deny the application to expand Coffin Butte Landfill. "Not in our names," is what they are saying.



☆ **Nancy Wyse** February 28, 2024 at 8:53 PM NW

RE: Odor complaint form on the Coffin Butte Landfill site?

To: Ken Eklund

Ken,

I don't recall if the link/online feature was ever formally shared with us (Benton County/Board of Commissioners)… it could have been, but I don't remember. I do remember seeing reports of complaints about the landfill, which included odors. Since I experienced the odors last week it made me think about that report and wonder if others were reporting. I saw your email come in and went to their website to look. It took me a few minutes to find it. I couldn't find a link. I had to do 3 or 4 searches to find it. I *think* the keyword that finally found it was "odor".

We (my family and I) were driving hwy 99W northbound on the 22nd around 5:30/5:45pm-ish. I had a respiratory infection at the time which affected my sense of smell, but just before Adair Village I noticed a "weird" smell and it got stronger right as we passed the landfill.

p.s. not to diminish the focus of your email, but I've not seen a golden eagle in Benton County before… but I'd like to! I'll keep my eyes peeled!

Benton County OREGON

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Fifth Oregon Climate Assessment

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We are grateful to the many authors, other contributors, reviewers, and advisors to this Assessment, especially during a year that was extraordinarily difficult for so many. We welcome readers to contact us with ideas for ensuring that the sustained assessment process is relevant to their priorities.

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Executive Summary

Established and emerging understanding of observed and projected climate change in Oregon, and knowledge of the opportunities and risks that climate change poses to natural and human systems, may serve as a resource for actions including but not limited to planning for mitigation of climate-related natural hazards and implementation of Oregon's 2021 Climate Change Adaptation Framework.

State of Climate Science

Temperature. Oregon's annual average temperature increased by about 2.2°F per century since 1895. If greenhouse gas emissions continue at current levels, temperature in Oregon is projected to increase on average by 5°F by the 2050s and 8.2°F by the 2080s, with the greatest seasonal increases in summer.

Precipitation. Precipitation is projected to increase during winter and decrease during summer. The number and intensity of heavy precipitation events, particularly in winter, is projected to increase throughout the twenty-first century. Furthermore, as temperatures warm, the proportion of precipitation falling as rain rather than snow in Oregon is projected to increase, especially at lower to intermediate elevations in the Cascade Range.

Snowpack and runoff. Snowpack throughout Oregon, especially on the west slope of the Cascade Range, is accumulating more slowly, reaching lower peak values, and melting earlier. These trends are likely to continue, and may accelerate, as temperature increases. Concomitantly, runoff is expected to begin and peak earlier in the year, decline in summer, and increase in winter, but will vary geographically.

Science advances. In addition to simulations of future climate from the newest generation of global climate models, advances in climate science have improved the accuracy of climate forecasts one week to one month into the future. Also, it is becoming more feasible to estimate the extent to which human-caused climate change affects the likelihood of some types of extreme weather events.

Climate-Related Natural Hazards

Extreme heat. The frequency and magnitude of days that are warmer than 90°F is increasing across Oregon. During summer, relative increases in nighttime minimum temperatures have been greater than those in daytime maximum temperatures. The frequency, duration, and intensity of extreme heat events is expected to increase throughout the state during the twenty-first century.

Drought. Over the past 20 years, the incidence, extent, and severity of drought in the Northwest increased. These changes partially are attributable to human-caused climate change. As summers in Oregon continue to become warmer and drier, and mountain snowpack decreases, the frequency of droughts, particularly snow droughts such as those in 2014 and 2015, is likely to increase.

Wildfire. Wildfire dynamics are affected by climate change, past and contemporary land management and human activity, and expansion of non-native invasive grasses. From 1984 through 2018, annual area burned in Oregon increased considerably. Over the next 50 to 100 years, area burned and fire frequency are projected to increase substantially, initially east of the crest of the Cascade Range and then in the western Cascade Range. Over the long term, depending on how vegetation and fire weather shift with climatic changes and fuel and fire management, fire severity also may increase.

Floods. Flood magnitudes in Oregon are likely to increase. Heavy precipitation events are expected to become more intense because a warmer atmosphere can carry more moisture. Also, in a warmer climate, the relatively contribution to floods of rainfall will be greater than that of snowmelt. The consequence is larger flood peaks because, for a given amount of precipitation, the peaks of rainfall-driven floods tend to be larger than those of snowmelt-driven floods. Projected increases in wet-season precipitation also are likely to increase winter flood magnitude. Increases in regulated flows from the main stem of the Columbia River during winter appear likely to increase flood risk throughout the Columbia River reservoir system.

Coastal hazards. Sea-level rise, storminess, sediment supply, and human adaptation measures influence whether a given stretch of Oregon's coastline has eroded or built up in recent decades. Therefore, predicting future shoreline change is challenging. As sea level rises, coastal storms and high tides are likely to increase the frequency and severity of flooding along Oregon's coastline. By the year 2050, relative sea level at Newport is very likely to rise between 0.6 and 1.8 feet, and at least one flood is likely to exceed four feet above mean high tide. Accounting for plausible, yet uncertain, estimates of Antarctic ice sheet melt suggests that sea level could rise 2.9 feet by the year 2050, with regular nuisance flooding occurring earlier.

Marine and coastal change. Off the Northwest coast, the open-ocean surface temperature increased by more than 1.2 ± 0.5°F since the year 1900, and is projected to increase by about another 5.0 ± 1.1°F by the year 2080. These changes in temperature have the potential to affect many other drivers of ocean change, such as by accelerating the rate of reduction in dissolved oxygen in the water and increasing the toxicity of harmful algal blooms. Ocean acidity also is projected to change by roughly 100–150%, resulting in a drop in open-ocean pH from 8.1 to 7.8. The change in pH is likely to affect shell formation in diverse species of commercial, recreational, and cultural value.

Adaptation Sectors

Natural systems. Climate change is affecting the timing of seasonal events in the life cycle of some plants and animals, and the viability of some species. Projected decreases in freshwater flows and connectivity are likely to decrease survival and growth of salmon. Projected increases in temperature and changes in precipitation also may have negative effects on some protected species. The ability of Oregon's species to adapt behaviorally, physically, or genetically to climate change in part depends on the speed of climate change, the level of other environmental stressors, and genetic diversity.

Built environment. Climate change is likely to stress Oregon's infrastructure. Projected increases in sea level and precipitation intensities are expected to strain levees, tide gates, and sewer and stormwater infrastructure. Droughts may diminish hydropower production and the effectiveness of water-supply infrastructure. Wildfires may threaten communities directly and indirectly via, for example, landslides and degraded water quality. Urban heat island effects are expected to increase summer electricity demand and risks of heat stress. Opportunities for mitigation and adaptation include wind and solar power, grid integration of electric transportation, and green infrastructure for resilience to flooding. Data-driven, science-based capital planning that engages stakeholders can help to realize these adaptations.

Public health. Racial and economic injustices have created disparities in health outcomes among populations in Oregon. Black, Indigenous, and People of Color; underinvested rural, Tribal, and low-income communities; the young and the old; and those with pre-existing conditions or disabilities are more likely to experience negative health effects of climate extremes. One in two households in Oregon spends 30% or more of their income on rent or a mortgage. These households are less likely to rebuild in the event of home loss or severe damage from an extreme weather event. Displacement and income loss associated with climate impacts will increase the risk of homelessness, food insecurity, and mental health effects.

Tribal cultural resources. Tribes may experience distinct impacts of climate change that relate to their cultures, identities, histories, relations with other governments, and land-holding status. Tribes throughout Oregon are using Traditional Knowledges to prepare for and increase their resilience to climate change. Priority topics include access to first foods, community health, changes in the distributions or status of native species, and wetland alterations. Tribal climate adaptation strategies also help to reassert treaty rights, advocate for equitable investment in civil infrastructure, and reestablish Tribal sovereignty.

Social systems. Social, political, and economic systems mediate the effects of climate change. The costs of adaptations to climate change in the agricultural sector likely will be passed on to consumers, exacerbating the existing challenges some communities face in obtaining affordable produce. Agricultural laborers' incidence of heat-related illnesses and exposure to wildfire smoke are expected to increase as climate changes. In Oregon, 28% of agricultural workers are undocumented immigrants who may be unable or reluctant to seek health care.

The full Fifth Oregon Climate Assessment is available at blogs.oregonstate.edu/occri/oregon-climate-assessments/.

Introduction

Consistent with its charge under Oregon House Bill 3543, the Oregon Climate Change Research Institute (OCCRI) conducts a biennial assessment of the state of climate change science, including biological, physical, and social science, as it relates to Oregon and the likely effects of climate change on Oregon. This fifth Oregon Climate Assessment builds on previous assessments (Dello and Mote 2010; Dalton et al. 2013, 2017; Mote et al. 2019) by continuing to evaluate past and projected future changes in Oregon's climate and hydrology. This Assessment is structured with the goal of serving as a resource for the state's mitigation planning for natural hazards and implementation of the 2021 Oregon Climate Change Adaptation Framework.

The first section of this Assessment, *State of Climate Science*, reflects OCCRI's sustained appraisal of observed trends and future projections of temperature, precipitation, snowpack, and streamflow. New research and insights are consistent with previous key messages about projected changes in Oregon's climate, such as warmer temperatures, drier summers, wetter winters, heavier rains, less snowpack, and associated shifts in the timing and discharge of streamflow. *State of Climate Science* also summarizes the latest research related to simulations of future climate, including preliminary insights on the newest generation of global climate models, subseasonal to seasonal climate prediction, and attribution of extreme events.

The dependence of human communities on their surrounding natural, economic, and social environment is magnified by climate extremes and associated hazards (Guidotti et al. 2016, Martinez-Diaz et al. 2020). The second section of this Oregon Climate Assessment explores how climate change is expected to affect climate-related natural hazards, including extreme heat, drought, wildfire, floods, and coastal hazards, in support of Oregon's 2020 Natural Hazards Mitigation Plan. Furthermore, this Oregon Climate Assessment examines recent observed and projected changes in the physical and biological environment of marine and coastal systems in Oregon and the Northwest. Implicit in the Assessment's treatment of hazards is the fact that disasters may result either from single, major events or from recurrent events that individually are not extreme, but degrade a community's social and economic infrastructure (Field et al. 2012).

The third section of this Assessment addresses six sectors within which Oregon's 2021 Climate Change Adaptation Framework aggregates vulnerabilities and strategic responses: economy, natural world, built environment and infrastructure, public health, cultural heritage, and social systems. The Framework aims to guide state decisions about investment of resources as climate changes and to facilitate collaboration among state agencies. This Assessment dedicates a chapter each to five of the sectors. These chapters describe the latest research in climate science and climate adaptation that is relevant to the sector in Oregon. Economic aspects of climate change are integrated throughout chapters on other sectors rather than treated independently. The economic risks of gradual changes in climate and extreme climate-related events vary among regions. Additionally, given the distinct impacts of climate change on Tribal cultures, identities, histories, relations with other governments, and land-holding status, this Assessment emphasizes Tribal cultural heritage.

Both the Climate Change Adaptation Framework and this Assessment recognize that the myriad interactions and feedbacks among natural and human systems are complex and can be difficult to differentiate. Evidence from Oregon's natural hazards mitigation planning process, the climate science literature, and a sustained assessment process can help indicate the extent to which natural hazards may affect adaptation sectors, and inform selection of actions to maximize resilience.

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State of Climate Science

Meghan Dalton, Heejun Chang, Benjamin Hatchett, Paul Loikith, Philip Mote, Laura Queen, and David Rupp

This chapter synthesizes observed trends and projections of future climate and hydrology from previous Oregon Climate Assessments, provides updates, and reports on new knowledge. In addition, this chapter reports on major advances in the field of climate science that are relevant to Oregon, including simulations of future climate under a new generation of global climate models, prediction of weather conditions three to four weeks into the future, and attribution of extreme weather events.

Observed and Projected Trends in Greenhouse Gases

In 2019, carbon dioxide concentrations measured at the long-term monitoring site on Mauna Loa, Hawaii, averaged 411 parts per million (ppm) by volume (NOAA 2020). Monthly concentrations from January through October 2020 were above 411 ppm. Global carbon dioxide emissions decreased during 2020 due to the COVID-19 pandemic. In April 2020, at the maximum confinement in many countries, carbon emissions dropped by 17% compared to 2019, reducing emissions to 2006 levels. However, by June 2020, carbon dioxide emissions had nearly rebounded to 2019 levels. Estimated 2020 carbon dioxide emissions are four to seven percent lower than those in 2019, similar to the yearly declines of emissions sustained over decades that are necessary to limit global warming to 2.7°F (1.5°C) (Luterbracher et al. 2020). Nevertheless, despite the temporarily lowered emissions, global concentrations of greenhouse gases in the atmosphere continued to increase, albeit at a slower rate.

Projections and analysis of future climate in this and other chapters primarily are based on the suite of global climate models from the fifth phase of the Coupled Model Intercomparison Project (CMIP5; Taylor et al. 2012). The future climate scenarios associated with CMIP5, called representative concentration pathways (RCPs), encompass plausible trajectories of greenhouse gas emissions and concentrations that would lead to different amounts of warming by the end of the twenty-first century (van Vuuren et al. 2011). This assessment references the two most commonly cited future scenarios, RCP 4.5 and RCP 8.5. RCP 4.5, a lower scenario, represents moderate reductions in global greenhouse gas emissions, with a peak near mid-century. RCP 8.5, a higher scenario, represents a continuation of current levels of emissions throughout the twenty-first century. The newest generation of global climate models, which are part of phase six of the Coupled Model Intercomparison Project (CMIP6), simulate future climate under scenarios called shared socioeconomic pathways (SSPs). CMIP6 and SSPs are described in more detail in *Recent Advances in Climate Science*, below.

Observed and Projected Trends in Climate

Temperature

Oregon's average temperature increased at a rate of 2.2°F (1.2°C) per century from 1895–2019 (NCEI 2020). All of the past 20 years (2000–2019) except 2011 were warmer than the twentieth century (1900–1999) average, and all except the two strongest La Niña years in the twenty-first century, 2008 and 2011, were warmer than the 1970–1999 average (NCEI 2020). The year 2015 was Oregon's warmest on record from 1895 through 2019 (NCEI 2020) (Fig. 1a).

	2050s		2080s	
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
Annual	3.6 (1.8, 5.4)	5.0 (2.9, 6.9)	4.6 (2.1, 6.7)	8.2 (4.8, 10.7)
Winter	3.3 (1.6, 5.1)	4.5 (2.4, 6.5)	4.2 (1.8, 6.5)	7.4 (4.2, 9.8)
Spring	3.1 (1.4, 5.0)	4.1 (2.0, 5.9)	3.8 (1.7, 6.0)	6.7 (3.8, 9.2)
Summer	4.5 (2.2, 6.8)	6.3 (3.6, 8.9)	5.5 (2.7, 8.3)	10.2 (6.5, 13.9)
Autumn	3.7 (1.5, 5.4)	5.2 (2.6, 7.0)	4.7 (2.0, 6.9)	8.6 (4.6, 11.4)

Table 1. Projected future changes in mean annual and seasonal temperature (°F) in Oregon from the historical baseline (1970–1999) for the 2050s (2040–2069) and 2080s (2070–2099) under RCP 4.5 and RCP 8.5. Values in boldface are the average changes from 35 global climate models and the 5th to 95th percentile range across those models. Table reproduced from Dalton et al. 2017, with data for Oregon from Rupp et al. 2017. Winter includes December, January, and February; spring includes March, April, and May; summer includes June, July, and August; autumn includes September, October, and November.

Oregon's temperatures are projected to increase in all seasons, particularly summer. Dalton et al. (2017) reported projected average changes in Oregon's annual and seasonal temperatures for the periods 2040–2069 and 2070–2099 relative to 1970–1999 under RCP 4.5 and RCP 8.5 (Table 1). These projections, which were based on 35 global climate models from CMIP5, are still the most current projections for Oregon. Preliminary results from comparisons of CMIP6 with CMIP5 for Oregon, reported in *Recent Advances in Climate Science* (below), suggested slightly greater warming under CMIP6 than CMIP5. Under the CMIP5 models and RCP 8.5, Oregon's annual average temperature is projected to increase by 5°F (~2.8°C) by the 2050s and 8.2°F (~4.6°C) by the 2080s (Dalton et al. 2017) (Fig. 1a, Table 1). Summer temperatures are projected to increase by 6.3°F (~3.7°C) by the 2050s and 10.2°F (~5.7°C) by the 2080s under RCP 8.5 (Table 1). Changes in extreme temperatures and heat events are described in *Extreme Heat* (this volume).

Precipitation

Oregon's annual precipitation varies considerably among years, and has not changed significantly over the observational record (+0.58 inches [1.5 cm] per century from 1895–2019) (NCEI 2020). Some statistically significant increases in heavy precipitation have been documented in Oregon (e.g., Dalton et al. 2017 and reviews therein). However, the relatively small sample sizes and large variability in intense precipitation makes it difficult to detect long-term observed trends, and results often depend on location, time frame, and definition of heavy precipitation (Mote et al. 2013). The maximum consecutive five-day precipitation in October and March in Portland, Oregon, increased from 1977 through 2016 ($p < 0.1$), but not in the intervening months (Cooley and Chang 2020).

	2050s		2080s	
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
Annual	1.9 (-4.9, 9.0)	2.7 (-6.0, 11.4)	3.4 (-5.6, 15.3)	6.3 (-5.2, 19.9)
Winter	4.9 (-6.4, 16.5)	7.9 (-4.7, 24.3)	7.3 (-6.3, 19.9)	14.5 (-2.8, 37.1)
Spring	1.9 (-8.9,12.1)	2.7 (-7.2, 17.4)	3.4 (-7.7, 14.9)	3.6 (-9.4, 15.6)
Summer	-6.3 (-28.5, 16.1)	-8.7 (-33.1, 22.5)	-4.6 (-24.2, 22.3)	-7.7 (-38.7, 33.5)
Autumn	0.5 (-17.0, 14.4)	-0.8 (-17.1, 14.9)	1.5 (-15.0, 18.1)	1.9 (-17.2, 24.2)

Table 2. Projected future relative changes in total annual and seasonal precipitation (%) in Oregon from the historical baseline (1970–1999) for the 2050s (2040–2069) and 2080s (2070–2099) under RCP 4.5 and RCP 8.5. Values in boldface are the average changes from 35 global climate models and the 5th to 95th percentile range across those models. Table reproduced from Dalton et al. 2017, with data for Oregon from Rupp et al. 2017. Winter includes December, January, and February; spring includes March, April, and May; summer includes June, July, and August; autumn includes September, October, and November.

Annual variability is expected to continue to dominate annual precipitation, with a slight increasing trend (Fig. 1b, Table 2). Precipitation is expected to increase during the wet season and decrease in summer in the Columbia River Basin (Rupp et al. 2017) and, on average, for Oregon as a whole

(Table 2). In general, the intensity of heavy precipitation events during the twenty-first century in Oregon is projected to increase, although not uniformly across the state (e.g., Dalton et al. 2017 and reviews therein, Cooley and Chang 2020).

Atmospheric rivers. Atmospheric rivers are long, narrow corridors that transport high amounts of atmospheric water vapor and are important mechanisms for precipitation across the Pacific Northwest (Ralph et al. 2020). Atmospheric rivers are common features of autumn and winter storms in Oregon (Payne and Magnusdottir 2014), and are associated with around 25–30% of precipitation in those seasons over most of the state. The majority of autumn and winter extreme precipitation events, defined on the basis of three-day total precipitation, also are associated with atmospheric rivers, especially in western Oregon (Fig. 2) (Slinskey et al. 2020).

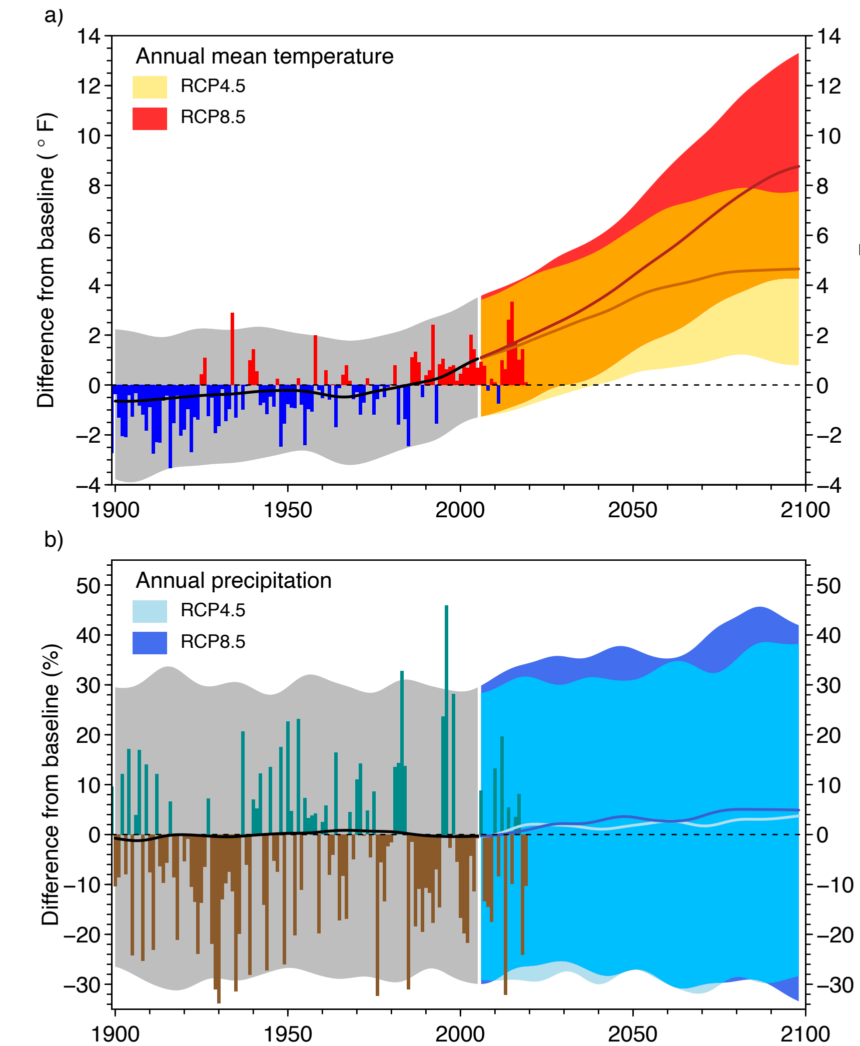

Figure 1. Observed, simulated, and projected changes in Oregon's mean annual (a) temperature and (b) precipitation relative to 1970–1999 (baseline) under RCP 4.5 and RCP 8.5 future scenarios. Colored bars are observed values (1900–2019) from the National Centers for Environmental Information. The thicker solid lines are the mean values of simulations from 35 climate models for the 1900–2005 period, which were based on observed climate forcings (black line), and the 2006–2099 period for the two future scenarios (orange [RCP 4.5] and red [RCP 8.5] lines in the top panel, light blue [RCP 4.5] and darker blue [RCP 8.5] lines in the bottom panel). Shading indicates the range in annual temperatures or precipitation from all models. The mean and range were smoothed to emphasize long-term variability.

Because a warmer atmosphere can hold more water vapor, the intensity of atmospheric rivers, as defined by the amount of water vapor transported, is projected to increase (Gao et al. 2015, Warner and Mass 2017, Espinoza et al. 2018, Ralph et al. 2020), and possibly to penetrate further inland (Mahoney et al. 2018). How this translates into changes to atmospheric river-related precipitation across Oregon and other parts of the west coast is an active area of research (Payne et al. 2020). The number of days with an atmospheric rivers present across Oregon is projected to increase by roughly 5–10% over western Oregon by the end of the twenty-first century under RCP 8.5, although this does not mean that the number of atmospheric rivers, or of the storms with which they are associated, will change (Espinoza et al. 2018, Massoud et al. 2019). The increase in water

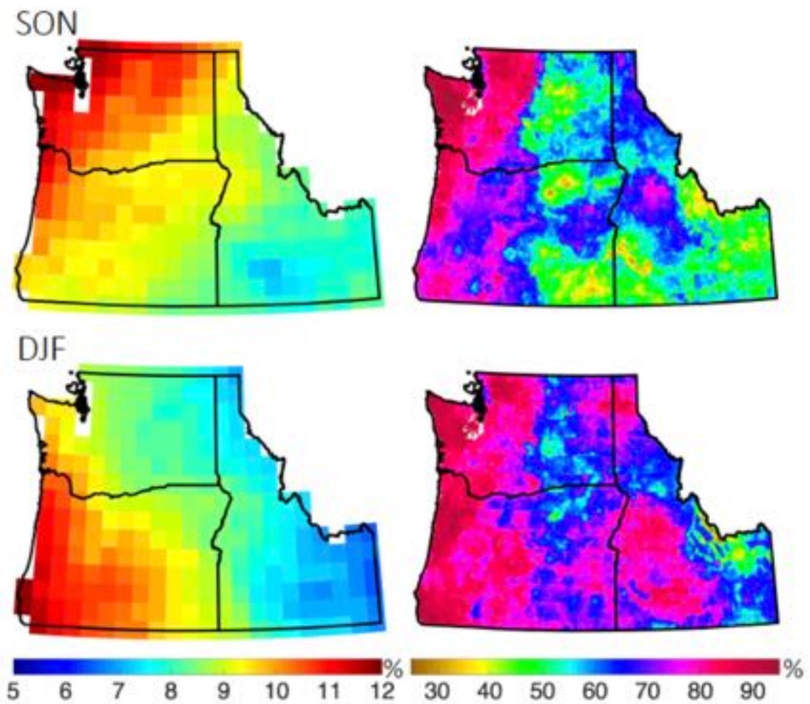

Figure 2. Percentage of days with (left) atmospheric rivers and (right) extreme precipitation that also have an atmospheric rivers, based on data from 1981–2016. Results are for (top row) September, October, and November and (bottom row) December, January, and February. Source: Slinskey et al. 2020 © American Meteorological Society. Used with permission.

vapor-holding capacity of the atmosphere as it warms also is projected to increase the intensity of atmospheric rivers. As reported in Dalton et al. (2017), the latter inference is supported by a projected 250% or greater increase in the number of days with extreme atmospheric river conditions (highest 1% of intensity) by the end of the twenty-first century under RCP 8.5 (Warner et al. 2015). Climate models also project an increase in the contribution of atmospheric river-produced precipitation to total annual precipitation across the region (Gershunov et al. 2019).

Observed and Projected Trends in Hydrology

Snowpack

Snow is a major source of water for natural ecosystems and for human consumption and recreation in Oregon. Snow is most common in Oregon's mountain ranges (Fig. 3), but also occurs at lower elevations, particularly east of the Cascade Range. Many ecosystem processes and human consumptive uses depend on the presence of a seasonal snowpack that accumulates during the cool season and melts during spring and summer, providing streamflow during the warm season and refilling reservoirs. Snowpack, often analyzed in terms of snow water equivalent (SWE)—the amount of water contained in the snowpack—can be classified as seasonal, ephemeral, or non-snowy (Fig. 4) on the basis of a snow seasonality metric (Petersky and Harpold 2018). The snow seasonality metric is based on the duration of seasonal (persisting 60 or more consecutive days) and ephemeral (persisting for fewer than 60 consecutive days) snowpacks compared to the total number of days with snow. Oregon's highest mountain ranges, including the Cascade Range and Wallowa, Blue, Steens, Siskiyou, Trout Creek, and Santa Rosa Mountains, have seasonal snowpacks. Ephemeral snowpacks occur at lower elevations east of the Cascades Range, in the northern Coast Ranges, along the west slope of the Cascade Range, and in the Klamath and Siskiyou Mountains.

Median peak SWE increases as elevation increases. The greatest SWE values, which often exceed 39.4 inches (1000 mm), are in the Cascade Range (Fig. 5a). Along the west side of the Cascade Range, peak SWE increases as the snowpack transitions from low-elevation non-snowy to mid-elevation ephemeral to high-elevation seasonal. On the east side of the northern Cascade Range, peak SWE decreases sharply as elevation decreases. This elevational gradient in SWE is less apparent in the southern Cascade Range. Peak SWE values are lower (less than 7.9 inches [200 mm]) in the Coast Ranges and the Klamath and Siskiyou Mountains. The lower-elevation ranges of eastern Oregon generally have relatively low peak SWE values, whereas the higher-elevation Wallowa Mountains, Steens Mountains, and Strawberry and Elkhorn Mountains within the Blue Mountains have relatively high SWE values. Peak SWE values in the Blue Mountains of east-central Oregon and the Warner, Santa Rosa, and Trout Creek Mountains of southeastern Oregon are relatively low, less than 15.7 inches (400 mm), but colder temperatures facilitate seasonal snowpacks.

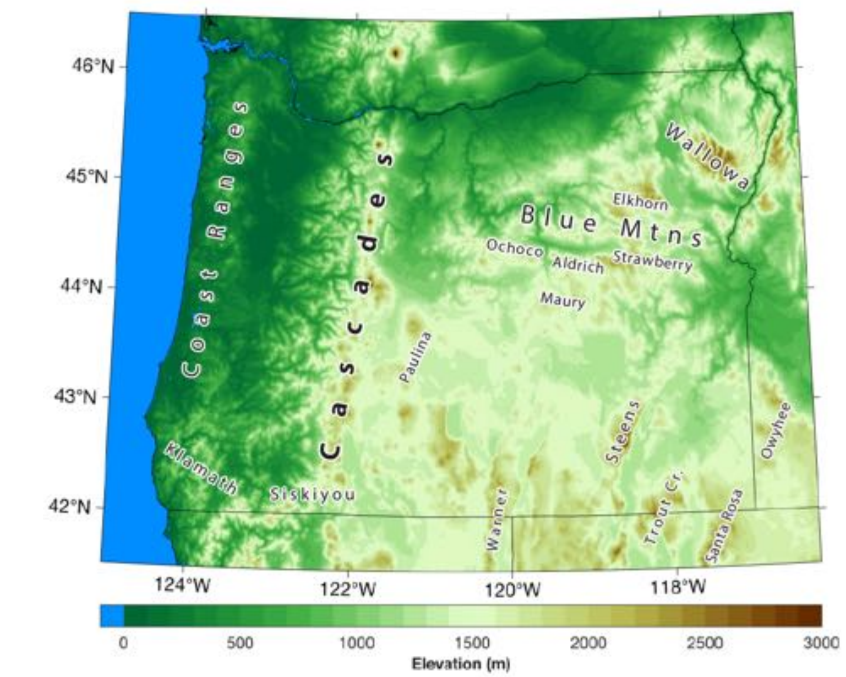

Figure 3. Elevations and major mountain ranges in Oregon.

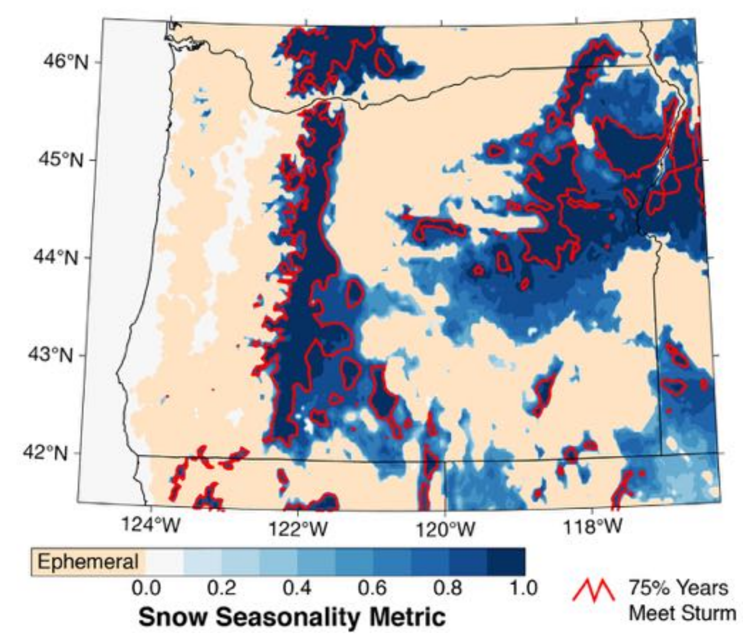

Figure 4. Snow seasonality classified by the median snow seasonality metric (Petersky and Harpold 2018). The metric varies continuously from -1 (ephemeral) to 1 (seasonal). Values greater than zero indicate seasonal snowpack and values less than zero indicate ephemeral snowpack. White indicates non-snowy areas (no days with SWE greater than zero). Red contour denotes the area in which 75% of years meet the Sturm et al. (1995) definition of seasonal snowpack, generally snow seasonality metric values greater than about 0.9.

The median timing of peak SWE in Oregon occurs from February (low elevation, ephemeral snowpacks) through May (high elevation, seasonal snowpacks; Fig. 5b). In the interior mountain ranges, elevated valleys, and plateaus, SWE values are relatively low. Nevertheless, colder winter temperatures, which are typical of inland regions where mountains inhibit the moderating effect of warmer oceanic airmasses, generally correspond to later dates of peak SWE. The latest peak SWE occurs near the crest of the Cascade Range and in the Steens and Wallowa Mountains.

Observed trends. From 1955 through 2016, spring snowpack, in terms of 1 April SWE, decreased at nearly every snow-observing station in Oregon (Mote et al. 2018, 2019). Because computing the area

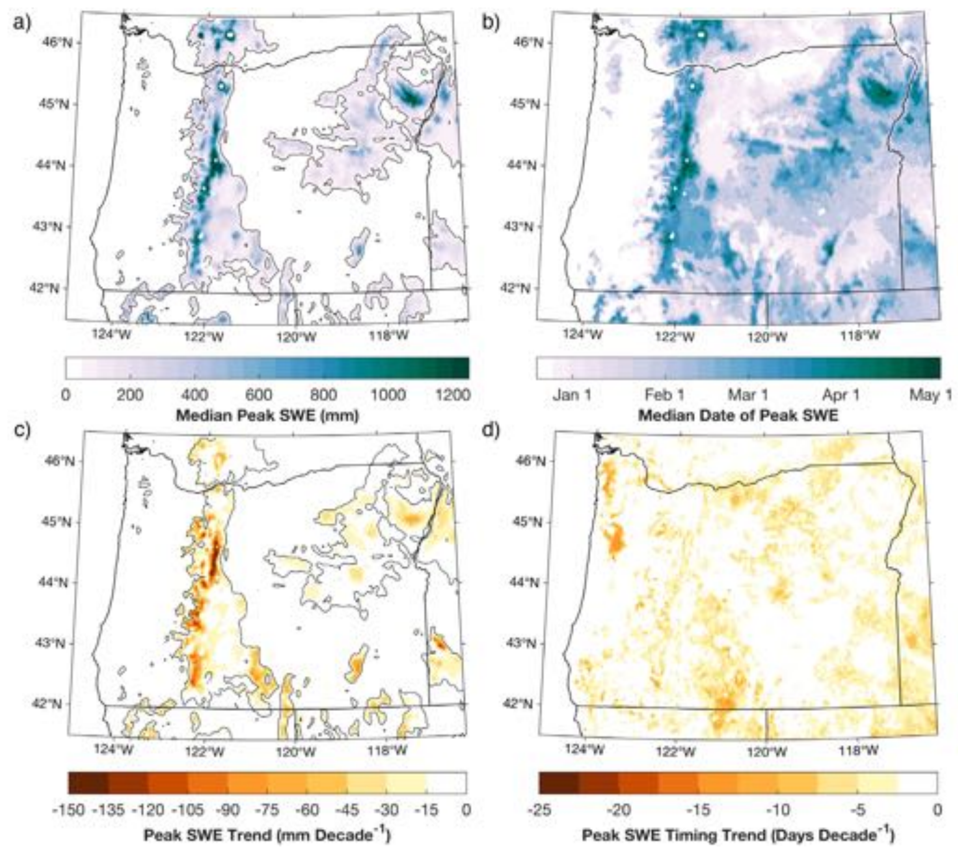

Figure 5. Oregon snowpack characteristics and trends analyzed over the period 1982–2017. (a) Median peak snow water equivalent (SWE; mm) and (b) timing of peak SWE (days past 1 October). (c–d) As in (a–b) but illustrating decadal trends (none statistically significant at p<0.001). Trends were assessed with nonparametric Mann-Kendall tests with lag-1 autocorrelation removed (Hamed and Rao 1998). Black contour lines in (a) and (c) enclose areas exceeding 2 inches (50 mm) median peak SWE.

averages from point observations alone is challenging, Mote et al. (2018) also analyzed gridded outputs from a variable infiltration capacity hydrologic model, and found that 1 April SWE averaged over the western United States decreased by roughly 15–30% since the middle of the twentieth century. The effects of anthropogenic forcing on spring snowpack trends since 1980 may have been mitigated by natural variability forced by large-scale changes in atmospheric circulation. Those changes in circulation, in turn, were driven by Pacific sea surface temperatures, suggesting that once the cycle of natural variability shifts from its current mode, snowpack declines may accelerate (Siler et al. 2019).

This section presents a new examination of trends and characteristics of Oregon's snowpack that was based on a new, gridded data product that interpolates point-based observations and normalizes by prior-year snowfall accumulations to estimate daily SWE and snow depth on a continuous 4 km horizontal grid over water years 1982–2017 (Broxton et al. 2016, Zeng et al. 2018). This gridded product also was used to calculate the snow seasonality metric (Fig. 4). The new exploration described here addressed the amount and timing of peak SWE (Fig. 5), number of days with snow cover, and timing of snowmelt and snow sufficient for recreation (Fig. 6). Results indicated that from 1982–2017, the snowpack throughout all of Oregon's mountains, especially the west slope of the Cascade Range, accumulated more slowly, had lower peak SWE values, and melted earlier.

Peak SWE declined in the southern and central Cascade Range, Warner Mountains, Steens Mountains, Trout Creek Mountains, and Wallowa Mountains (Fig. 5c). The largest declines (on the order of more than 5.3 inches [135 mm] per decade, or a >70% decline over the 36-year period) were observed on the east side of the central Cascade Range near Mt. Jefferson. Declines were greater than 3.5 inches (90 mm) per decade (a 50–80% decline over the 36-year period) along the

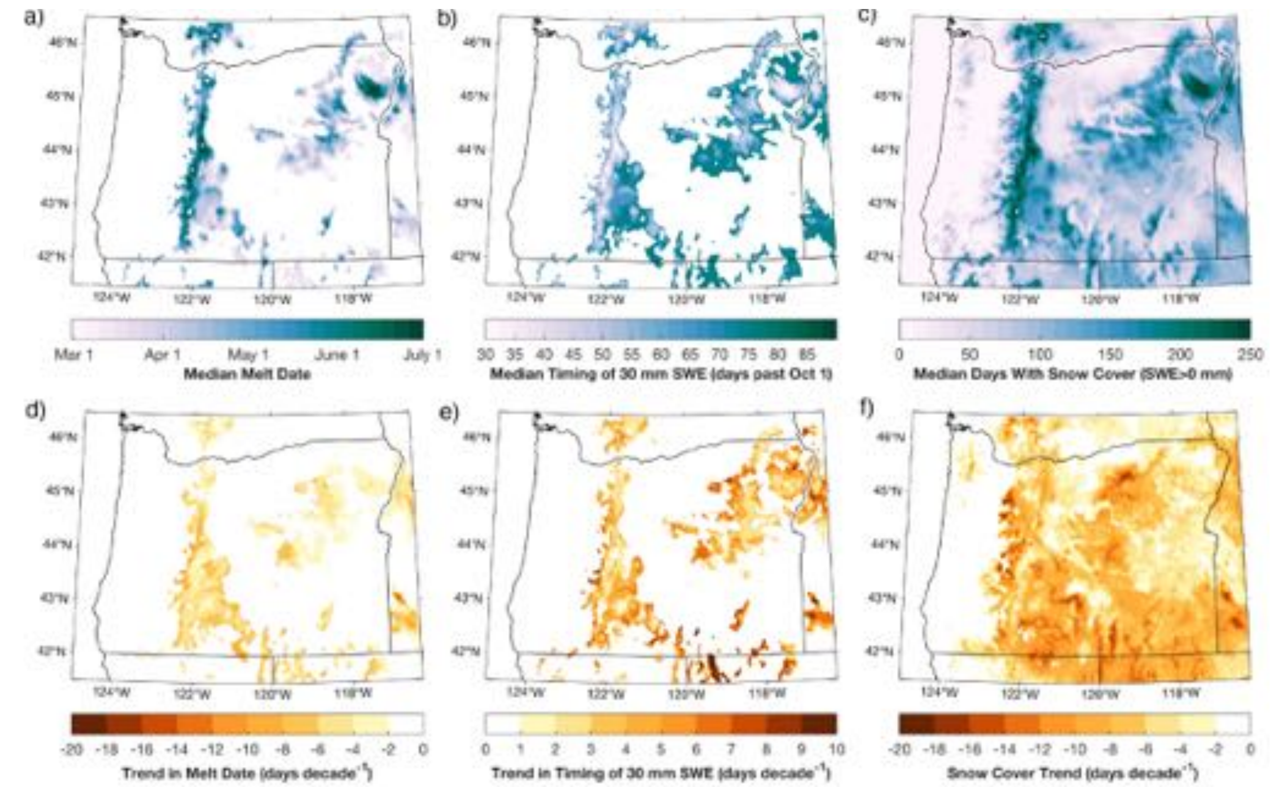

Figure 6. Additional Oregon snowpack characteristics and trends analyzed over the period 1982–2017. (a) Median timing of melt date, (b) median timing of sufficient snow for recreation (1.2 inches [30 mm] snow water equivalent [SWE]; days past 1 October), (c) median days with snow cover (SWE>0); (d–f) As in (a–c) but illustrating decadal trends. Trends were assessed with nonparametric Mann-Kendall tests with lag-1 autocorrelation removed (Hamed and Rao 1998).

west side of the Cascade Range. Trends in other mountain ranges and the easternmost side of the southern Cascades ranged from 0.6–3.5 inches (15–90 mm) per decade (a 20–50% decline over the 36-year period). However, these trends in peak SWE were not statistically significant at the conservative p<0.001 level. Trends in the timing of peak SWE varied (Fig. 5d). The largest negative (earlier) trends, on the order of 5–10 days per decade, were along the southeastern side of the Cascade Range. Negative trends of lower magnitude (2.5–7.5 days per decade) were observed along the west side of the Cascade Range and scattered throughout other mountain ranges in Oregon.

Complete melting of winter snowpack—defined as the day on which SWE decreases to zero—occured in early spring (March) at lower elevations in the interior mountains (Fig. 6a) and progressively later as elevation increased. The highest elevations in the Cascade Range and Wallowa Mountains generally retained snow until late June or early July. Melting trended earlier (albeit not significant at p<0.001) in all mountain regions in Oregon (Fig. 6d), with the greatest changes (more than 16 days earlier per decade) in the northern margins of the Great Basin east of the central Cascade Range, and near the Warner Mountains and high-elevation valleys near the California-Oregon-Nevada border. Changes were smaller (2–10 days earlier per decade) along the western slopes of the Cascade Range, particularly in the central Cascade Range (north of Mt. Jefferson), in the southern and northern Blue Mountains (e.g., the Maury and Elkhorn Ranges), throughout the Steens and Warner Mountains, and along the lower elevations of the Wallowa Mountains.
The first date of sufficient snowpack for recreation was defined as the first date with 1.2 inches (30 mm) SWE (Hatchett and Eisen 2019). This value commonly is used by land managers to open

areas for over-snow vehicle recreation (Hatchett and Eisen 2019). It also is a reasonable benchmark for sufficient snowpack to enjoy backcountry recreation activities. Over the period 1982–2017, snowpack usually was sufficient for recreation by early to mid-November in the higher elevations of Oregon's mountains and by mid-December at lower elevations (Fig. 6b). The timing shifted later by 3–8 days per decade (Fig. 6e), with the largest shifts along the western slope of the Cascade Range, in parts of the eastern slope of northern and central Cascade Range, and throughout the interior mountains (e.g., Blue, Wallowa, and Steens).

Most of Oregon had an average of at least 10 days of snow cover (non-zero SWE) per year from 1982–2017 (Fig. 6c). Despite low peak SWE values, often less than 3.9 inches (100 mm), much of interior southeastern Oregon had an average of 80 or more days of snow cover. However, due to sparse observations in this region, these model-based estimates should be compared against independent data from satellite-based observations or other direct measurements. Duration of snow cover increased as elevation and distance from the Pacific Ocean increased. Many of the highest-elevation and snowiest regions had more than 200 days of snow cover. The Siskiyou Mountains, northern Coast Range, and Klamath Mountains had one to two months of snow cover on average.

The number of days with snow cover decreased throughout much of Oregon (Fig. 6f). The largest declines in snow-cover duration were on the order of 12 or more days per decade and were on the west side of the central Cascade Range, Warner Mountains, and Wallowa Mountains. Widespread declines of 4–12 days per decade were observed in the inland mountain ranges and in the northern regions of the Great Basin. Changes in southeastern Oregon did not appear to be limited to high elevations. It would be quite informative to evaluate the physical drivers of declines in snow cover during the accumulation (autumn) and melting (spring) seasons with different definitions of snow cover and additional data sources.

Future projections. Oregon's snow cover and snowpack are likely to decrease further as the climate becomes warmer, which will cause a greater proportion of precipitation to fall as rain than as snow in many locations that historically received substantial snowfall during winter (Nolin and Daly 2006, Klos et al. 2014, Catalano et al. 2019, Lynn et al. 2020). Catalano et al. (2019) used projected changes in the elevation of the freezing level to quantify how the proportion of wet days with snow to all wet days will change at Snow Telemetry (SNOTEL) stations across the Northwest (Fig. 7). The proportion decreased rapidly at low to intermediate elevations, especially in the Cascade Range. For example, at most SNOTEL stations in the Oregon Cascade Range, fewer than 25% of wet days are projected to be days with snow by the mid-twenty-first century, compared to about 50% at most stations during the late twentieth to early twenty-first centuries. Such a decrease in the proportion of snow days may have a major impact in areas that rely on Cascade Range snowpack for water. The proportion of snow to rain will decrease more slowly at higher elevations and in eastern Oregon; some stations are projected to continue to have snow on at least 25% of wet days.

Runoff

Watersheds in Oregon have one of three distinctive runoff regimes: rainfall dominated, mixed rain and snow, and snow dominated. Distance from the Pacific Ocean, elevation, position on the leeward or windward side of a mountain range, vegetation, and geology affect variability in the temporal distribution of runoff in Oregon (Chang and Jung 2010). Rainfall-dominated systems occur in coastal regions and the Willamette Valley. In these areas, flow closely follows the timing of precipitation, leading to a single, extended runoff peak in winter, populated by multiple local runoff

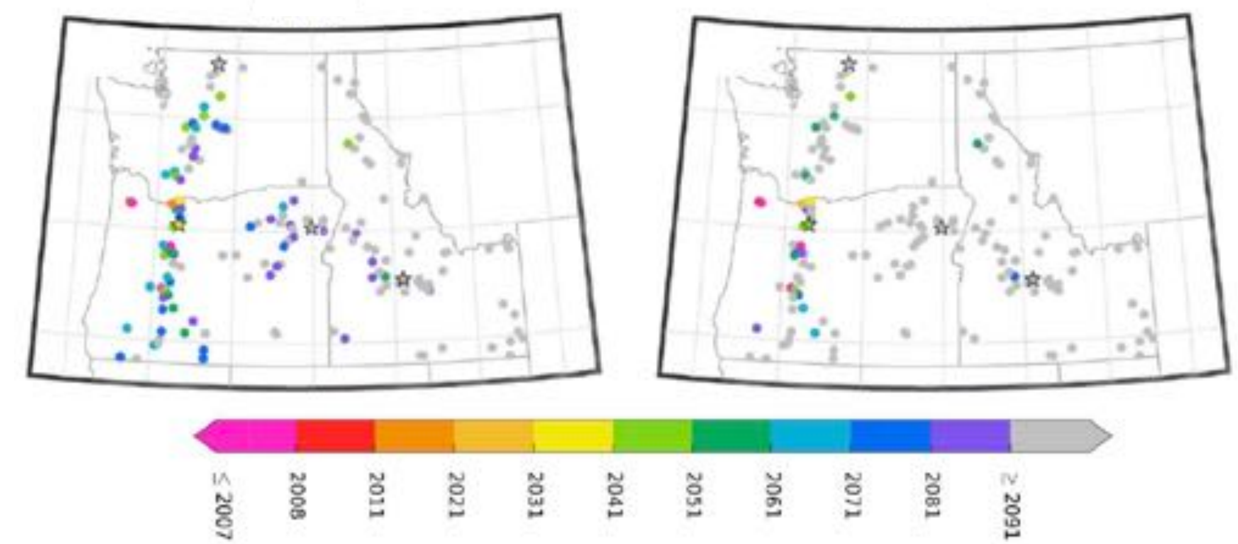

Figure 7. (Left) RCP 8.5 and (right) RCP 4.5 projections of the first decade during which the percentage of wet days that have snow falls below 25% at SNOTEL stations across the Northwest. For example, a circle with color shading corresponding to the year 2041 means that at that station, the 10-year period starting in 2041 is the first decade during which fewer than 25% of wet days will be cold enough for snow to fall. Gray circles indicate that the models do not project that the percentage of snow days will fall below 25% during the twenty-first century. Stations with stars are specific to Catalano et al. (2019), from which this figure is adapted.

maxima corresponding to rainfall events. Mixed rain and snow systems, characterized by two runoff peaks that correspond to rainfall and snowmelt, occur in many watersheds at high elevations in the Cascade Range and mountains to the east. In snow-dominated systems above 4000 feet (1219 m) in south-central and northeast Oregon, runoff peaks in early to mid-summer. Peak flow in streams at higher elevations of the Cascade Range are delayed due to snowmelt and sustained summer flow; their continuous baseflow reflects discharge from groundwater basins with high specific yield (the ratio of the volume of water that the soil can yield by gravity to the total volume of the soil).

Previous Oregon Climate Assessments reported that multiple studies detected trends toward earlier runoff in many snowmelt-dominated watersheds in the Northwest, consistent with a warming climate (e.g., Stewart et al. 2005, Dalton et al. 2017 and reviews therein). Observed changes in the amount and timing of streamflow, especially years with exceptionally early or high midwinter runoff (2015, for example), are eliciting responses from reservoir managers. These managers aim to assess impacts of changes in streamflow on water resources and ecosystems, with the goal of informing management actions (e.g., Cohen et al. 2020, Jones and Hammond 2020). Continued warming is projected to result in earlier streamflow, declining summer flows, and increasing winter flows, particularly for mixed rain and snow and snow-dominated basins (e.g., Dalton et al. 2017 and reviews therein). Three new studies (Burke and Ficklin 2017, Yazzi and Chang 2017, Chen and Chang 2020) projected runoff changes in specific basins in Oregon.

Burke and Ficklin (2017) reported changes in runoff volume and timing in the coastal Siletz watershed, a watershed on the central Oregon coast that provides habitat for Coho salmon (*Oncorhynchus kisutch*). They projected that wet season (November–March) flow will increase by 18% by the end of the twenty-first century under RCP 8.5. The median center timing of flow was projected to shift three days earlier by the middle of the twenty-first century and, in one global climate model, 10 days earlier by the end of the twenty-first century.

Chen and Chang (2020) investigated the effects of climate change on the runoff in the Clackamas River watershed, which provides drinking water to 350,000 people in the Portland metropolitan area. Median summer runoff in the watershed was projected to decline by 50% under the study's warmest scenario (the HadGEM2-ES climate model assuming RCP 8.5). In addition, extreme high flows, defined by the 90th percentile flow volume, were projected to increase by up to 19%, and extreme low flows, defined by the seven-day low flow, were projected to decrease by as much as 20 cubic meters per second by the middle and late twenty-first century (Chen and Chang 2020). The center timing of flow was projected to shift two to three weeks earlier by the 2080s (2070–2099) under the study's warmest scenario. Chen and Chang (2020) also found that land-cover change had minimal impact on watershed-level runoff. Similarly, in the snow-dominated upper Umatilla River in eastern Oregon, which is the main source of irrigation water in that river basin, the center timing of flow was projected to occur nearly one month earlier (Yazzi and Chang 2017).

Projections of future streamflow have several sources of uncertainty, including the selection of climate models, emission scenarios, downscaling methods, and hydrologic model structure and parameters (Praskievicz and Chang 2009). In the Northwest, differences among climate models and representative concentration pathways (RCPs) are the greatest sources of uncertainty in projections of the volume and timing of annual runoff, whereas differences among hydrologic models are the greatest source of uncertainty in projections of low flows in many locations (Fig. 8; Chegwidden et al. 2019). Information about the greatest sources of uncertainty in future hydrological projections for different flow metrics and locations (e.g., Chegwidden et al. 2019) can inform selection of the most appropriate set of hydrological projections for a given application. For the majority of the Columbia River Basin, applications might consider the timing of annual runoff and analyze results among multiple representative concentration pathways, because difference among the latter are the largest source of uncertainty (Fig. 8). In the Willamette Basin, however, it may be sensible to prioritize analysis of results among multiple global climate models, because difference among those models are the greatest source of uncertainty in that geographic area (Fig. 8).

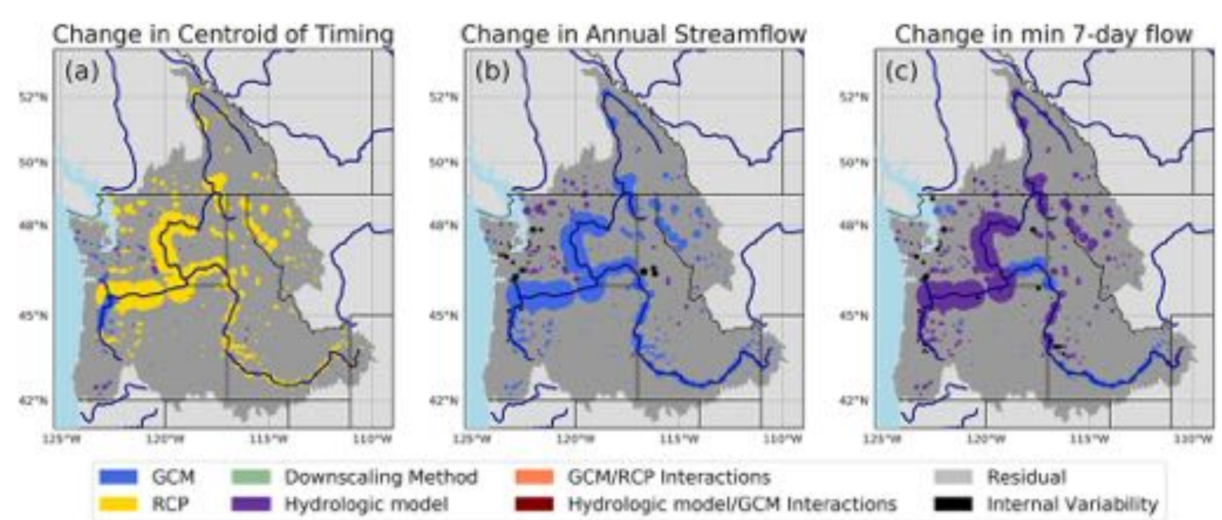

Figure 8. The dominant source of uncertainty in projected changes in the (a) timing and (b) volume of annual runoff and (c) low flows from the 1980s through the 2080s. Marker sizes are scaled by the mean annual historic flows without regulation or irrigation. Source: Chegwidden et al. 2019.

Stream Temperature

Stream temperature is sensitive to changes in air temperature, but also is affected by vegetation cover and water source. In open water, a 1.8°F (1.0°C) increase in air temperature generally leads to 1.1–1.4°F (0.6–0.8°C) increase in water temperature (Morrill et al. 2005), although the sensitivity of stream temperature to air temperature varies on the basis of factors such as water depth, mixing of surface and shallow subsurface water, wind, humidity, and cloud cover. Additionally, riparian vegetation can provide shade that reduces stream temperature. Groundwater input also affects stream temperature because the temperature of groundwater is fairly constant throughout the year, whereas the temperature of surface water fluctuates seasonally. For example, in the upper Middle Fork John Day River in northeast Oregon, a mature riparian forest with 79% effective shade—the percentage of direct solar radiation attenuated and scattered by riparian vegetation before reaching the stream surface—can decrease the seven-day average daily maximum stream temperature (a measure commonly applied in regulation of water temperatures) by ~12.6°F (7.0°C) via changes in air temperature and discharge (Wondzell et al. 2019).

Stream temperature generally is projected to increase across Oregon. Assuming the A1B emissions scenario (an older scenario that falls between RCP 4.5 and RCP 8.5), by the 2080s (2070–2099), relative to the 2000s (1993–2011), August average stream temperature was projected to increase by about 4°F (2.2°C) in most parts of Oregon (Isaak et al. 2017). The increase in stream temperature was projected to be slightly lower in southeastern Oregon.

In the Willamette River Basin, stream temperature was projected to increase by 1.8–7.2°F (1.0–4.0°C) by the 2080s according to three representative climate change scenarios that were based on three global climate models and RCP 8.5. The magnitude of change depended on the climate scenarios and local geology. With the same climate change scenario, the temperature increase was minimal in groundwater-fed streams at high elevations in the Cascade Range, whereas the increase was greatest in low-elevation streams that are fed by surface water (Chang et al. 2018).

In a central Oregon Coast watershed, maximum stream temperature was projected to increase by 5.4°F (3°C) in the mainstem of the North Fork of the Siletz River by the 2080s (2070–2099) under RCP 8.5 as simulated by one global climate model (HadGEM2-ES365) (Lee et al. 2020).

Recent Advances in Climate Science

Three of the areas of climate science that are developing rapidly are simulations of the future climate, prediction of weather conditions three to four weeks into the future (subseasonal-to-seasonal forecasting), and attribution of extreme weather events.

Simulations of Future Climate

For decades, the assessments of the Intergovernmental Panel on Climate Change (IPCC) have been supported by the Coupled Model Intercomparison Project (CMIP). New simulations from CMIP6 (Eyring et al. 2016) have been distributed since 2019 to support development of the IPCC's Sixth Assessment Report, currently scheduled for release in April 2021. In the aggregate, the CMIP6 models estimate a higher equilibrium climate sensitivity (ECS)—the increase in temperature after the climate system reaches equilibrium following a doubling of atmospheric carbon dioxide concentrations—than the CMIP5 models (Fig. 9, Forster et al. 2020). Cloud feedbacks and cloud-aerosol interactions most likely are the primary contributors to the increased ECS (Meehl et al.

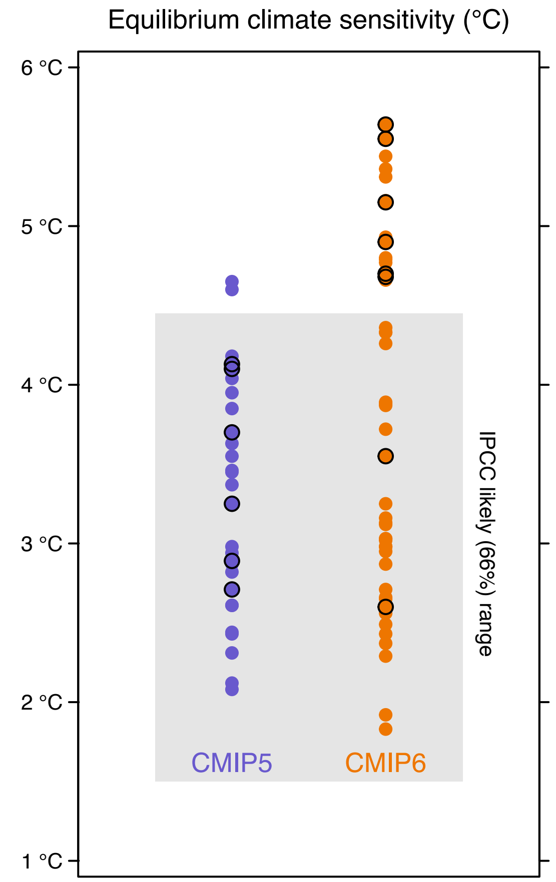

Figure 9. The equilibrium climate sensitivity (ECS) from 30 CMIP5 and 47 CMIP6 global climate models. Black open circles correspond to the models listed in Table 3, except CMCC-CM and HadGEM2-CC, for which ECS values were not found in the literature. Figure adapted from Forster et al. (2020). ECS values from Meehl et al. (2013) and Zelinka et al. (2020).

2020, Zelinka et al. 2020). As of December 2020, a vigorous scientific debate continues about the plausibility of the higher ECS values in the new CMIP6 models. Some scientists argue that the higher ECS values (or the related transient climate response) exceed observational constraints (e.g., Nijsse et al. 2020). Others critique the observational constraint, noting that the warming during 1975–2013 ended with the so-called hiatus, which may have caused the CMIP6 models to overestimate the warming during that period. Regardless, the IPCC long has assessed ECS with a probability distribution. For instance, the grey "likely" range in Fig. 9 means that there is a 66% probability that ECS is within the range of about 1.5–4.5°C, and a 34% probability that ECS is outside that range. The probability that ECS exceeds 4.5°C was not quantified explicitly by the IPCC, but is physically possible. However, it is "very unlikely"—probability less than 10%—that ECS is greater than 6°C (IPCC 2007).

The potential changes in ECS do not affect the scenarios of greenhouse gas concentrations. In the CMIP6 models, the representative concentration pathways (RCPs) that provided estimates of greenhouse gas emissions for CMIP5 have been augmented by shared socioeconomic pathways (SSPs) that describe more explicitly the social and economic scenarios corresponding to each RCP. Here, RCP 4.5 corresponds to SSP2-45, and RCP 8.5 to SSP5-85.

For this Assessment, CMIP6 outputs were obtained from global climate models that most clearly corresponded to those used in the CMIP5-based analysis for the Northwest (Rupp et al. 2017; Fig. 1a). The CMIP5 models within the selected pairs (Table 3) were among the 10 best-performing models as evaluated by Rupp et al. (2013a), or frequently were used in related studies (e.g., the IPSL-CM5A-LR and MIROC5 models). Also, data for both the historical period and the twenty-first century were available for the selected CMIP6 models. Where multiple versions of a model were available, the version that seemed most similar to the CMIP5 version, given readily available documentation, was chosen. The eight CMIP6 models were used to analyze past and future annual mean temperature in Oregon (Fig. 10),

CMIP5	CMIP6
CanESM2	CanESM5
CESM1-BGC	CESM2
CESM1-CAM5	CESM2-WACCM
CMCC-CM	CMCC-CM2-SR5
CNRM-CM5	CNRM-CM6-1
HadGEM2-CC	HadGEM3-GC31-LL
IPSL-CM5A-LR	IPSL-CM6-LR
MIROC5	MIROC6

Table 3. Model pairs from the fifth and sixth phases of the Coupled Model Intercomparison Projects (CMIP5, CMIP6) that were used to create Figure 10.

similar to Figure 1a. The CMIP5 versions of these models have a somewhat higher rate of warming than the 35-member average of Rupp et al. (2017).

Another way to parse the CMIP6 data is to draw a direct statistical connection between ECS and temperature change in Oregon (Fig. 11). The CMIP5 projected temperature change for Oregon (Rupp et al 2017) was regressed on each model's ECS value for each RCP and future period. The regression equations then were applied to the ECS values of the CMIP6 models from Zelinka et al. (2020).

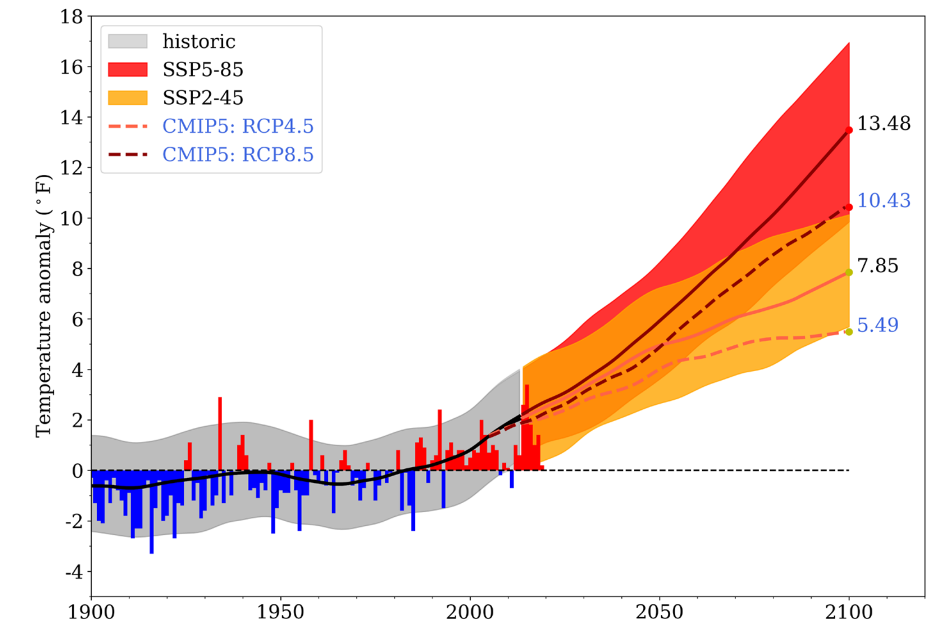

Figure 10. Annual mean temperature in Oregon as observed (blue and red bars; relative to the 1970–1999 average, from NOAA Climate at a Glance) and as simulated by the CMIP6 models for the past (heavy black curve and grey shading). The colored bands and solid curves indicate the average of the two CMIP6 scenarios for 2015–2100, and the dashed curve indicates the corresponding results for CMIP5 (2006–2100). Shaded regions denote the range between the smoothed minimum and maximum annual mean temperature for the eight models. The modeled time series were smoothed with a lowess filter. Mean values for the eight models are printed to the right of the curves and represent the warming relative to 1970–1999.

Consistent with the increase in ECS (Fig. 9), the CMIP6 models suggested higher rates of warming, given either emissions scenario, than their predecessors. Under the RCP 8.5 scenario, the eight CMIP6 models used here, which coincidentally included a disproportionate number with high ECS, led to a 3°F (~1.7°C) greater warming by the end of the twenty-first century than the CMIP5 models. Preliminary estimates that were based on a much larger set of models generally indicated smaller differences in warming between the CMIP5 and CMIP6 models (Fig. 11). Nevertheless, for Oregon and globally, the CMIP6 models suggest that the climate may warm more than expected under the CMIP5 models, if the high ECS values are accurate.

Subseasonal-to-Seasonal Forecasting

Skillful weather forecasts require one to obtain an accurate and thorough estimate of the current state of the atmosphere by assimilating as many observations as possible. Small errors in the initial state of weather propagate, eventually (usually around 10 days) leading to a forecast that is no better than random chance. Seasonal climate prediction, by contrast, aims at a statistical description of the next few months, and rests in large part on the evolving state of the tropical ocean, especially the central and western Pacific Ocean. Between the time scales of skillful weather forecasts and skillful seasonal forecasts are the subseasonal-to-seasonal scales. Recent progress on probabilistic forecasts with some skill on these time scales for the Northwest builds on the work of Bond and Vecchi (2003), who were the first to demonstrate a link between the tropical weather variability known

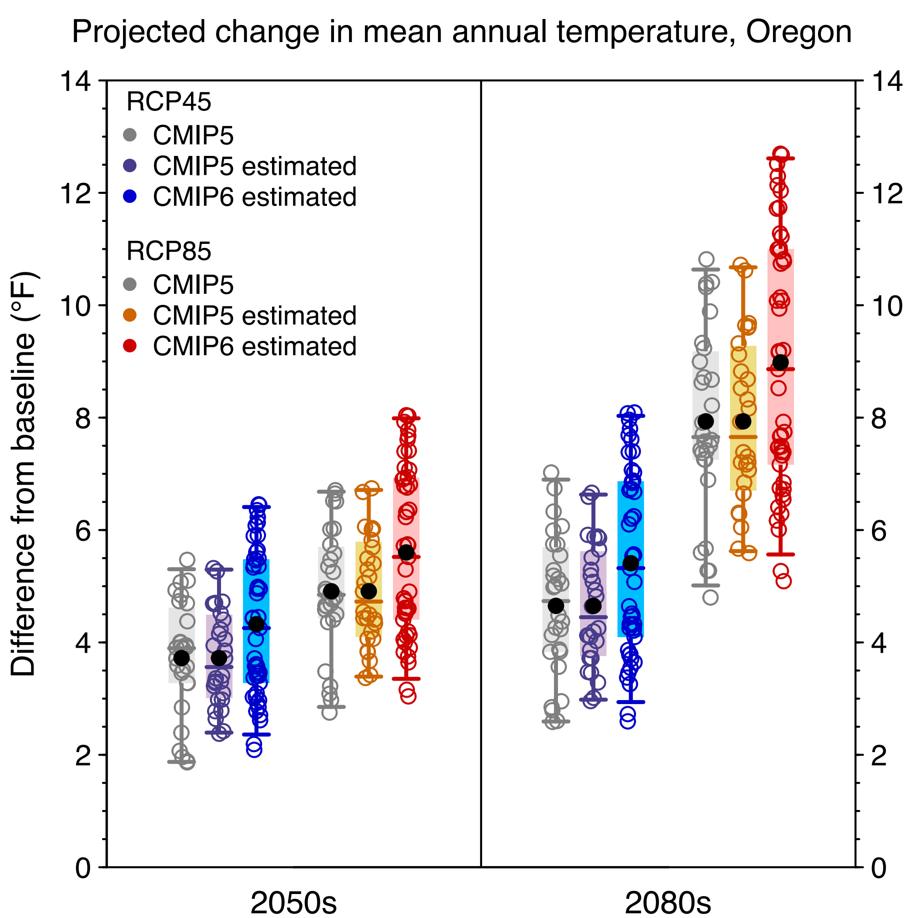

Figure 11. Projected change in Oregon mean annual temperature as the difference between a baseline period (1970–1999) and two future periods (2040–2069, or the 2050s; and 2069–2098, or the 2080s). Estimates were based on direct climate model outputs (gray symbols) or estimates derived from ECS (colored symbols) from CMIP5 (28 models) and CMIP6 (47 models) under RCP 4.5 and RCP 8.5, as described in the text.

as the Madden-Julian oscillation and weather in the Northwest. They discovered that certain phases of the Madden-Julian oscillation corresponded to a heightened risk of flooding in the Northwest. Given the inherent 40- to 50-day duration of the oscillation, their results suggested potential predictability of flooding of at least a few weeks.

Advances in research, observations, and modeling are propelling improvements in the predictability of climate at temporal extents between one week and one month. Perhaps the most comprehensive analysis of subseasonal modeling included seven global atmospheric models (some of which are used in operational weather forecasts) and 17 years of retrospective forecasts. This analysis evaluated forecasts for the third week (the average of days 15 through 21) after the forecasts were made (Pegion et al. 2019). Each of the models made skillful forecasts of Northwest temperature, and the model average was even more skillful. Although similar analysis of precipitation forecast skill was not presented, the models appeared to be capable of forecasting large precipitation anomalies. Pegion et al. (2019) provided an example in which the third week of forecasts of precipitation in October 2018 indicated large wet anomalies. These anomalies coincided with the formation and landfall of Hurricane Michael in the southeastern United States.

Seasonal-to-subseasonal forecasting has the potential to improve climate adaptation. Increasing the advance warning of weather anomalies, such as rapidly developing droughts (Pendergrass et al. 2020) or heat waves, floods, or windstorms, increases preparation time and may improve outcomes. As an example, federal management of reservoirs throughout the year is determined by seasonally dependent reservoir rule curves. These curves describe the desired elevation (amount of water) in each reservoir, and typically are quite low during flood season. However, the rule curves

were developed decades ago, when weather forecasts were accurate only a few days in advance. Incorporating a modern understanding of forecast skill in the 7–10 day (or 15–21 day) time horizon would allow reservoirs to be maintained at higher elevation and avoid a situation in which reservoirs cannot be refilled at the end of flood season (as was the case throughout Oregon in 2015). Such adjustments would help mitigate the stresses of droughts and floods in a changing climate.

Attribution of Climate Events

Attribution of climate phenomena "is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with formal assessment of confidence" (IPCC 2018). Increases in global average temperature since the mid-twentieth century were attributed to human activity by the mid-1990s (e.g., Hegerl et al. 1997). Attribution of seasonal temperature and precipitation in the Northwest suggested that only human activity could account for the warming in each season, but did not indicate that changes in precipitation were attributable to human activity (Abatzoglou et al. 2014). Armal et al. (2018) investigated trends in extreme daily precipitation across the United States. They detected a trend at 35% of Northwest weather stations, and found that most trends could be explained by anthropogenic forcing and natural modes of climate variability.

During the past decade, the focus of attribution research shifted from annual and seasonal means over large areas to human influences on the magnitude or likelihood of specific extreme events or classes of extreme events (e.g., Herring et al. 2020, Swain et al. 2020). NASEM (2016) made highly relevant points about framing questions of attribution, the capabilities for attribution of different types of events, and the fact that basic principles of physics suggest that as climate changes, many types of extreme events will become more likely. Two of these points are discussed here.

First, asking whether climate change caused a certain event is less useful than asking about the change in the likelihood of the event as a result of human activities. Some studies have focused on an individual event and simulated that event under specific meteorological conditions, then created a counterfactual—an alternate simulation or simulations—in which the meteorological conditions were changed to reflect understanding of the physical influence of elevated greenhouse gases. For instance, to study human influence on rainfall intensity in Hurricane Harvey, which deposited as much as 52 inches (1.3 m) of rain over part of Texas, including Houston, in August 2017, van Oldenborgh et al. (2017) subtracted the warming of the ocean surface estimated with the EC-Earth2.3 climate model from the observed ocean temperatures, and ran simulated weather forecasts with a moderately high-resolution atmospheric model. Another approach is to define an extreme event, run numerous simulations, and then compare how often the event occurred with and without greenhouse gas forcing. This approach was applied to the attribution of warm and dry conditions during the 2011 Texas drought (Rupp et al. 2012, 2015), low precipitation in the central United States in 2012 (Rupp et al. 2013b), changes in Northern Hemisphere snow cover in spring (Rupp et al. 2013c), extreme heat in central California (Mera et al. 2015), and exceptionally low spring snowpack in the Northwest in 2015 (Mote et al. 2016).

Second, by considering both the physical effects of climate change on the event type and the confidence in attribution of specific events, NASEM (2016) delineated the capacity for attribution of different types of events on the basis of the expected magnitude of change and the confidence with which models can simulate those events. Attribution is most feasible for cold events, which are becoming less common as concentrations of greenhouse gases increase, followed by heat events, which are becoming more common. Attribution of droughts and extreme rainfall is moderately feasible, and somewhat less feasible for extreme snow and ice storms and tropical cyclones. Attribution of extratropical cyclones, fire, and severe convective storms is difficult.

Previous Oregon Climate Assessments (e.g., Dalton et al. 2017) reported on formal attribution studies in the Northwest, including average and seasonal temperature and precipitation (Abataoglou et al. 2014), fuel aridity related to area burned by wildfire in the western United States (Abatzoglou and Williams 2016), low snowpack in 2015 (Mote et al. 2016), and acidity of coastal ocean water (Feely et al. 2016). Williams et al. (2020) analyzed the contribution of anthropogenic climate change to the particularly dry conditions of the early twenty-first century in an area covering the southwestern United States and most of Oregon. The period 2000–2018 in this geographic region was the second-driest 19 years since 800 CE, and climate model simulations suggested that 47% of the observed dryness in soil moisture was driven by the effect of anthropogenic climate change on temperature, humidity, and precipitation (Williams et al. 2020).

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Extreme Heat

Meghan Dalton and Paul Loikith

Influence of Climate Change on Extreme Heat Events

Warming temperatures are increasing the frequency and intensity of extreme heat events. Extreme heat can include days with maximum temperatures over a threshold, seasons with temperatures well above average, and heat waves, or multiple days with temperature above a threshold. Heat waves occur periodically as a result of natural variability, but human-caused climate change is increasing their severity (Vose et al. 2017). Additionally, 82% of the increase in the frequency of hot summers—average June, July, and August temperatures more than two standard deviations above a baseline—over the western United States from 2000–2010 relative to 1978–1999 may be attributable to anthropogenic climate change (Kamae et al. 2017). Changes in extreme temperatures due to climate change can result directly from increases in temperature. Changes in extreme temperatures also can be an indirect result of changes in the weather patterns that lead to temperature extremes. Atmospheric conditions that drive extreme heat events in Oregon include upper-level ridges of high pressure and offshore flows; the specific atmospheric patterns conducive to heat events vary among the western, central, and eastern portions of the state (Loikith et al. 2017). Previous Oregon Climate Assessments reported on research that projected a weakening of summer atmospheric ridges and fewer days with strong offshore flow events, particularly in western Oregon (Brewer and Mass 2016a, b; Dalton et al. 2017). This suggested that although increases in average temperatures will lead to a larger number of heat events, and more severe extreme heat events, across the state, the increase may be greater in eastern Oregon than in western Oregon (Dalton et al. 2017). However, the degree to which future changes in warm temperature extremes in Oregon and the Northwest will be affected by changes in these weather patterns is still an active area of research.

Observed Trends in Extreme Heat

The frequency and magnitude of very hot days is increasing across Oregon. Very hot temperatures can be defined on the basis of relative thresholds, such as days on which the maximum temperature is above the 90th percentile of some reference period, or absolute thresholds, such as days on which the maximum temperature is above 90°F (32°C). Medford, Pendleton, and Portland, Oregon, have different climates, but annual variability in temperature has been considerable in all three, and the number of days exceeding

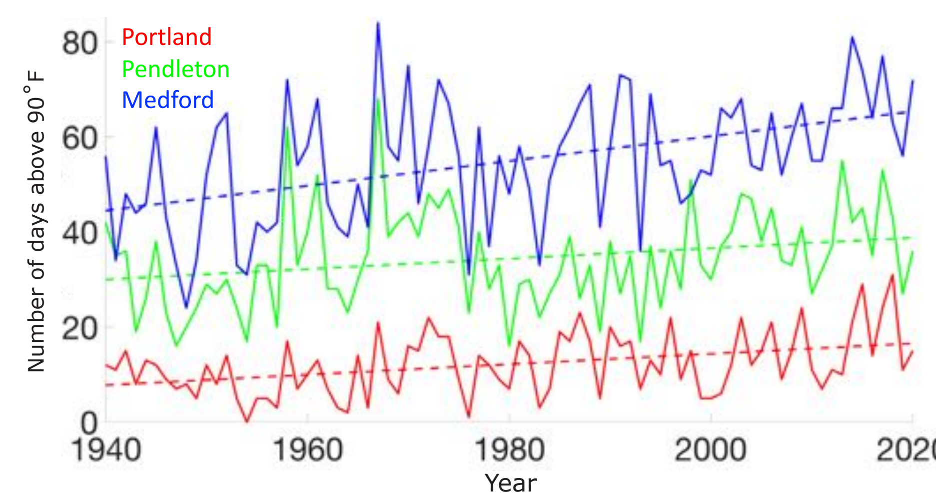

Figure 1. Number of days per year on which the daily high temperature exceeded 90°F at Medford, Pendleton, and Portland. Data source: NOAA National Centers for Environmental Information, www.ncdc.noaa.gov/ghcnd-access.

90°F increased markedly since the mid-twentieth century (Fig. 1). Since 1940, the number of days exceeding 90°F increased by over eight days per year in Portland and Pendleton, and 21 days per year in Medford. The number of 90˚F days in Portland in 2015 (29) and 2018 (31) broke records. These increases are representative of other cities across the state, with the exception of those at the immediate coast and relatively high elevations, where the number of days above 90°F is too small to observe a trend.

Previous Oregon Climate Assessments reported increasing trends in the number of summer extreme heat events as defined by minimum temperature thresholds (Bumbaco et al. 2013, Mote et al. 2013, Oswald and Rood 2014, Dalton et al. 2017). Recent publications are consistent, indicating that trends in summer extreme heat events as defined by nighttime minimum temperatures are stronger than those based on daytime maximum temperatures (Oswald 2018, Thomas et al. 2020). Over the period 1978–2015, the number of summer minimum temperature heat waves increased significantly over most of Oregon, except parts of eastern Oregon (Oswald 2018). The number of summer maximum temperature heat waves over southeastern Oregon also increased significantly (Oswald 2018).

Projections of Future Extreme Heat

Hot summer days are projected to become more frequent in Oregon under continued global emissions of greenhouse gases, and overnight lows will continue to become warmer (Dalton et al. 2017, Mote et al. 2019). The frequency, duration, and intensity of extreme heat events is expected to increase. Not only are summers expected to warm more than annual average temperatures, but the hottest days in summer are projected to warm more than the mean summer temperature over the Pacific Northwest (Dalton et al. 2017). The hot summers of 2015 and 2018 are salient examples of summer temperatures that are expected to become relatively common by the middle of the twenty-first century.

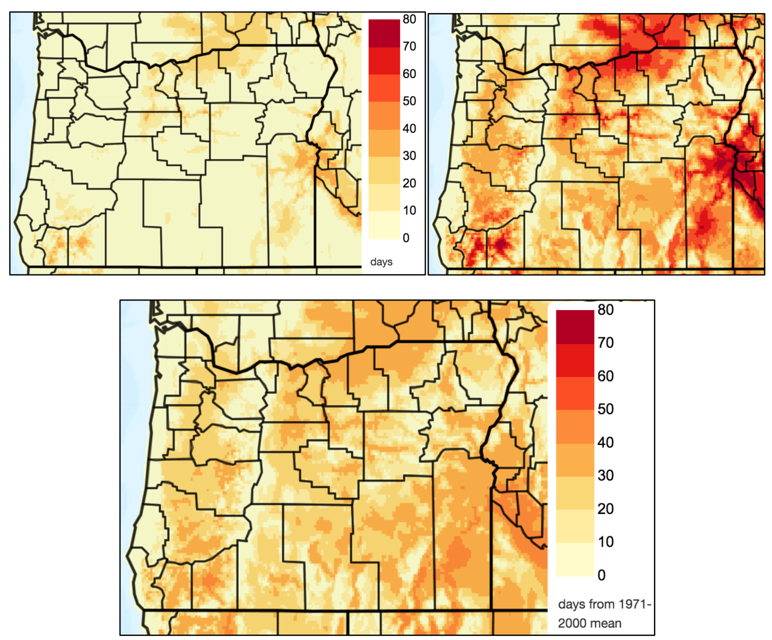

Figure 2. Number of days from April through October with a heat index ≥90°F in historic (1971–2000, top left) and future (2040–2069, top right) periods under RCP 8.5, and the change between those periods (bottom). Data are means of 18 downscaled models from the Coupled Model Intercomparison Project Phase 5. Source: Climate Toolbox, climatetoolbox.org/tool/climate-mapper (Dahl et al. 2019).

The fourth Oregon Climate Assessment reported that by the mid-twenty-first century under RCP 8.5 (a scenario that represents a continuation of current levels of greenhouse gas emissions throughout the twenty-first century, or a relatively high amount of warming), the number of days per year with temperatures above 86°F (30°C) would increase by at least 30 at most locations in Oregon, except at high elevations and the coast (Mote et al. 2019). New research on projected increases in heat index days (Dahl et al. 2019) provides insight on the

human health impacts of extreme heat. The heat index is a measure of perceived heat that reflects both temperature and relative humidity. The National Weather Service issues heat warnings when the heat index exceeds given local thresholds. As relative humidity increases, a given temperature can feel hotter. Across Oregon, heat waves rarely are humid (Rastogi et al. 2020), and the heat index generally is similar to the actual temperature. By the mid-twenty-first century under RCP 8.5, the number of days per year with a heat index greater than or equal to 90°F is projected to increase by at least 15 days across the majority of counties in Oregon (Fig. 2, Table 1).

Effects of Extreme Heat on Public Health and the Built Environment

Increases in the frequency of extreme heat events, and even small increases in average summer temperatures, are expected to increase the incidence of heat-related illnesses and deaths, particularly among the elderly; children; people with chronic illnesses; people with low incomes; Black, Indigenous, and People of Color; and outdoor workers (Ebi et al. 2018; *Public Health*, this volume). Excess mortality from heat waves is likely in cities and countries around the world (Guo et al. 2018). In the United States, without any adaptation, excess heatwave-related deaths were projected to increase by an average of 422% by 2031–2080 relative to 1971–2020 under RCP 8.5 and a median population scenario. With full adaptation measures, including a spectrum of interventions from individual to public policy, excess heatwave-related deaths were projected to increase by 57% (Guo et al. 2018). Increases in projected excess heatwave-related deaths in Portland, Oregon were slightly less than the United States average (Guo et al. 2018).

County	Historical baseline (1971–2000)	Mid-twenty-first century RCP 8.5 (2040–2069)	Change	County	Historical baseline (1971–2000)	Mid-twenty-first century RCP 8.5 (2040–2069)	Change
Baker	5	27	22	Lake	3	24	21
Benton	4	25	21	Lane	4	24	20
Clackamas	2	15	13	Lincoln	1	6	5
Clatsop	1	6	5	Linn	3	22	19
Columbia	2	16	14	Malheur	12	45	33
Coos	1	7	6	Marion	3	20	17
Crook	4	26	22	Morrow	12	38	26
Curry	3	15	12	Multnomah	4	23	20
Deschutes	3	21	18	Polk	4	23	19
Douglas	6	28	22	Sherman	13	42	29
Gilliam	14	43	29	Tillamook	0	4	4
Grant	3	21	18	Umatilla	10	35	24
Harney	4	30	26	Union	3	20	17
Hood River	2	12	10	Wallowa	4	21	18
Jackson	9	33	24	Wasco	9	34	24
Jefferson	9	33	24	Washington	4	21	17
Josephine	13	40	26	Wheeler	7	28	22
Klamath	2	20	17	Yamhill	5	24	19

Table 1. Averaged multiple-model mean values of and changes in the number of days from April through October with a heat index ≥90°F in historical (1971–2000) and future (2040–2069) periods under RCP 8.5. All changes are increases. Data derived from 18 downscaled climate models from the Coupled Model Intercomparison Project Phase 5. Source: Climate Toolbox, climatetoolbox.org/tool/climate-mapper (Dahl et al. 2019).

Increasing access to air conditioning often is touted as a means of increasing resilience to extreme heat events. At present, about 68% of single-family homes and manufactured homes in Oregon have cooling systems, and about 25% of multifamily residences have cooling systems (NEEA 2019). The areas in which extreme heat historically was most common, such as southern and eastern Oregon, have a larger proportion of homes with cooling systems. However, heat also can be extreme in western Oregon, and such extreme heat is becoming more frequent as climate changes. The number of residences in Oregon with air conditioning is increasing, which can improve health outcomes. However, air conditioning also can increase emissions of greenhouse gases that contribute to climate change. Passive survivability in building design can be an alternative to increasing air conditioning (*Built Environment*, this volume). Additionally, heat waves can increase the demands on electric power for cooling, increasing the risk of cascading failures within the electric power network (Clarke et al. 2018). *Built Environment* (this volume) discusses an extreme heat event in summer 2020 that challenged the West Coast's electricity supply. Urban heat islands are addressed in *Built Environment*, *Public Health*, and *Social Systems* (this volume).

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Drought

Larry O'Neill, Benjamin Hatchett, and Meghan Dalton

Introduction

Drought is a natural hazard with significant social, economic, and ecological impacts. Persistent drought is common in the Northwest (Gedalof et al. 2004, Knapp et al. 2004, Bumbaco and Mote 2010, Xiao et al. 2016), and Oregon is among the more drought-prone states (e.g., Cook et al. 1999). Over the last 20 years, the incidence, extent, and severity of drought has increased in both the western United States in general and the Northwest in particular compared with the twentieth century (e.g., Dalton et al. 2017, Williams et al. 2020). These droughts have had numerous adverse impacts on agriculture, water availability, recreation, ecosystems, and wildfire risk. The likelihood of continued increases in drought severity and duration in the twenty-first century raises questions about how best to prepare for and mitigate the impacts of drought and how to better understand drought and its causes. This chapter highlights recent advances in the understanding of drought in Oregon and discusses how climate change is projected to influence drought.

The simplest conceptual definition of drought is "insufficient water to meet needs" (Redmond 2002). Drought broadly may be defined as a sustained imbalance of moisture supply and demand at the surface relative to long-term average conditions. Precipitation supplies moisture, whereas evapotranspiration creates a moisture demand. Drought severity depends on the magnitude and duration of moisture deficiency and the size of the affected area. Four primary classes of drought used widely in monitoring and research distinguish between impacts and physical causes: meteorological, hydrological, agricultural, and socioeconomic (Wilhite and Glantz 1985, Rasmussen et al. 1993). Meteorological drought typically is defined by lack of precipitation, or by evaporative demand that exceeds precipitation. For Oregon, the minimum period of time for consideration of meteorological drought operationally is about 90 days. Hydrological drought occurs when prolonged meteorological drought affects surface or subsurface water supply, such as streamflow, reservoir and lake levels, or groundwater levels. Hydrological drought tends to evolve more slowly than meteorological drought, with extents longer than six months. Agricultural drought occurs when meteorological and hydrological drought impacts agricultural production, and usually reflects precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced availability of irrigation water.

The latter three drought classes largely reflect physical phenomena. Socioeconomic drought, by contrast, occurs when meteorological, hydrological, or agricultural drought reduces the supply of some economic or social good or service. Examples include lower crop yields or reductions in outdoor recreation. Socioeconomic drought often affects state and federal drought declarations. In addition to these primary drought designations, three other drought designations—ecological, flash, and snow—were proposed more recently to reflect more-specific drivers and impacts of drought. Ecological drought is defined as "[a]n episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems" (Crausbay et al. 2017). Like agricultural drought, ecological drought usually is caused by meteorological and hydrological drought. Vegetation and soil types affect likelihood of ecological drought.

Flash drought refers to relatively short periods of warm surface temperatures, low relative humidities and precipitation deficits, and rapidly declining soil moisture. These droughts tend to develop and intensify rapidly within a few weeks (e.g., Otkin et al. 2018, Pendergrass et al. 2020), and may be generated or magnified by prolonged heat waves (e.g., Mo and Lettenmaier 2015, Rupp et al. 2017, Chen et al. 2019).

Snow droughts are defined when snowpack—or snow water equivalent (SWE)—is below average for a given point in the water year, traditionally 1 April (Harpold et al. 2017, Hatchett and McEvoy 2018). Years with low SWE on 1 April often are followed by summers with low river and stream flows. The low flows sometimes lead to or exacerbate water supply deficiencies, especially in snowmelt-dominated basins. Although the idea of snow drought has existed for many years (e.g., Wiesnet 1981), it was further developed in Oregon (Sproles et al. 2017) and the Northwest following the 2015 water year, in which below-average snowpack counterintuitively corresponded with above-average precipitation (Mote et al. 2018). This type of snow drought is classified as warm snow drought. Dry snow drought is classified on the basis of below-average snowpack and precipitation (Harpold et al. 2017).

The dimensionless Standardized Precipitation-Evapotranspiration Index (SPEI) is a key quantitative metric for assessing the occurrence and severity of meteorological and hydrological drought. The SPEI compares the net water balance between precipitation and potential evapotranspiration (evapotranspiration from a large area with uniform vegetation and unlimited soil water) between a recent period of time and a historical period (Vicente-Serrano et al. 2010). The SPEI allows for comparison of drought severity in different locations and times and for identification of different drought types (e.g., Ahmadalipour et al. 2017), including consideration of the role of temperature in drought assessment (Vicente-Serrano et al. 2010). The 12-month SPEI is a reliable predictor of annual streamflow in the Northwest (e.g., Abatzoglou et al. 2014, Peña-Gallardo et al. 2019) and water levels in lakes and reservoirs (e.g., McEvoy et al. 2012).

Meteorological droughts generally build over seasonal or longer periods of time in the Northwest, but they often end relatively abruptly. Precipitation from atmospheric rivers terminates an estimated 60–74% of persistent droughts in the Northwest (Dettinger 2013). Some colloquially refer to atmospheric rivers as drought busters in recognition of their ability to erase large precipitation deficits over a period of time as short as a few days. Along the west coast of the United States, atmospheric rivers are considered critical in terminating droughts. However, atmospheric rivers can create another natural hazard—floods (*Floods*, this volume).

Historical Trends in Drought Severity and Extent

From 2000 through 2020, an average of 37% of Oregon experienced drought of at least moderate intensity, as classified by the U.S. Drought Monitor (USDM), and extreme drought affected nearly 7% of the state (Fig. 1). The USDM provides a consistent overview of drought conditions in the United States. It combines multiple indicators of dryness, including precipitation, snowpack, streamflow, soil moisture, groundwater, and evapotranspiration, at multiple temporal extents, into a single drought severity classification (Svoboda et al. 2002). The total area of Oregon affected by drought varied significantly over the last 20 years, and multiple-year droughts were common (Fig. 1). The impacts of conditions consistent with the USDM's most intense drought categories, extreme (D3) and exceptional (D4), often are widespread and severe across multiple sectors. Major impacts observed in Oregon during these most intense droughts included widespread losses of major crops and pastures, loss of snow- and water-based outdoor recreation, and shortages of water in reservoirs, streams, and wells. In the last 20 years, Oregon experienced exceptional drought only once, from July 2003 through January 2004 in southeast Oregon. This drought affected an average

of 5% of the state. Extreme drought occurred during five distinct episodes: portions of 2001, 2004–2005, 2014–2015, 2018, and 2020 (see Box 1).

The USDM drought categorization has many uses, but is not suitable as an objective definition of drought when analyzing long-term historical conditions or future climate projections. A better metric for the latter applications is the SPEI, which is a key indicator of water supply and demand as reflected in the USDM. In 14 of the last 20 years, the statewide annual SPEI was negative, indicating dry conditions (Fig. 2). In six of these years, SPEI was less than -0.8, indicating widespread, moderate-to-severe meteorological and hydrological drought (Fig. 2). In Oregon and the southwestern United States, the period 2000–2018 was the second-driest 19 years since 800 CE (Williams et al. 2020). Climate model simulations also suggested that 47% of the dryness in soil moisture observed from 2000 through 2018 was driven by the effect of anthropogenic climate change on temperature, humidity, and precipitation (Williams et al. 2020).

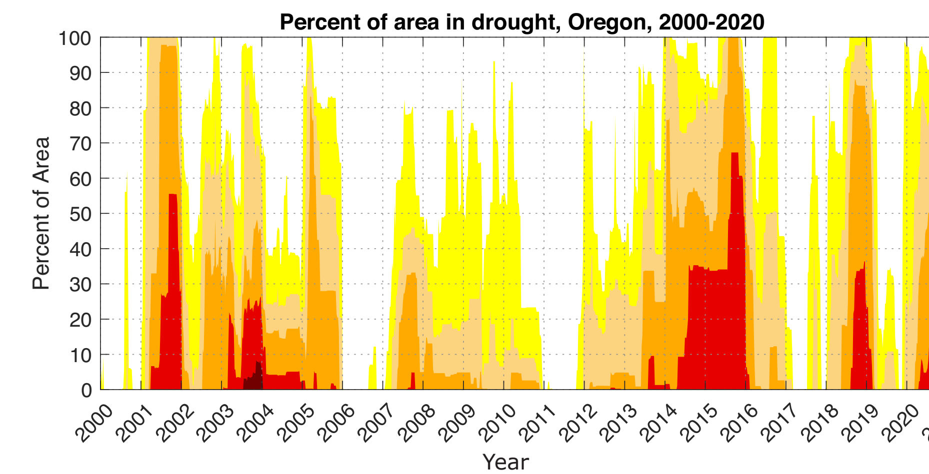

Figure 1. Percentage of Oregon's area in drought according to the U.S. Drought Monitor (droughtmonitor.unl.edu). The five drought classifications are abnormally dry (D0, light yellow), moderate drought (D1, tan), severe drought (D2, orange), extreme drought (D3, red), and exceptional drought (D4, dark red). White corresponds to neutral conditions.

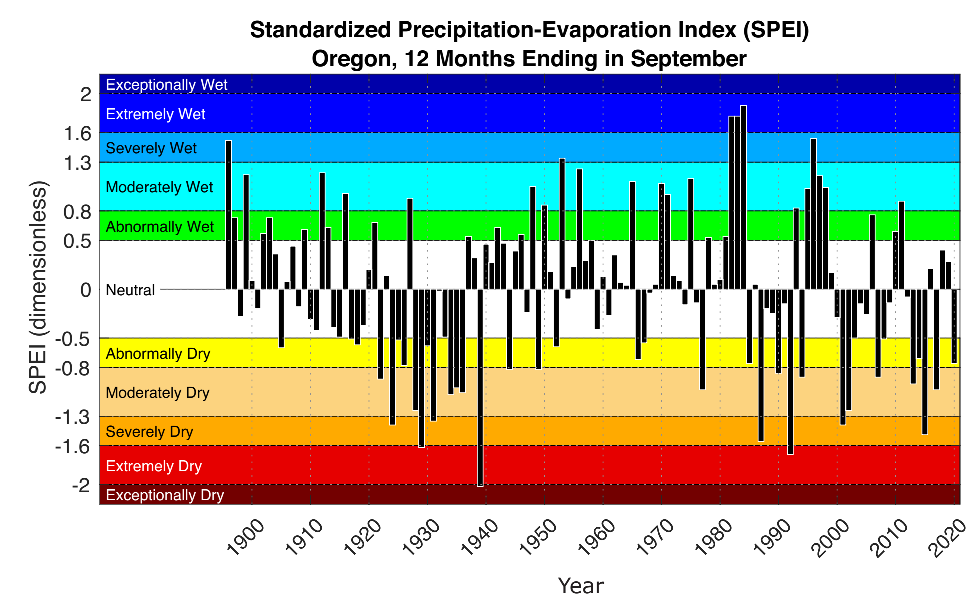

Figure 2. Time series of water year Standard Precipitation-Evapotranspiration Index (SPEI) for Oregon. Negative values follow the U.S. Drought Monitor's drought classifications, and positive values follow the Climate Toolbox U.S. Water Watcher tool (climatetoolbox.org/tool/US-Water-Watcher). Data Source: West Wide Drought Tracker, wrcc.dri.edu/wwdt/time/, with the following selections: Oregon, SPEI, 1895–2020, September, 12-month; accessed 19 December 2020.

Persistent and severe drought has been a feature of Oregon's climate over the past 20 years (Fig. 1, 2). These droughts were caused by different conditions, such as low winter precipitation and snowpack (2001), low summer precipitation and high winter temperature (2003), and low snowpack and low winter precipitation (2005) (Bumbaco and Mote 2010). Low

Box 1. Oregon drought during water year 2020

During water year 2020, most of Oregon was in the midst of a historically significant drought (Fig. B1). The exception was northeast Oregon, which received well above average precipitation and flooding associated with a powerful atmospheric river event (*Floods*, this volume). Statewide, water year 2020 was the 13th driest and 10th warmest among the 125 years of record (1895–2020; NCEI 2020).

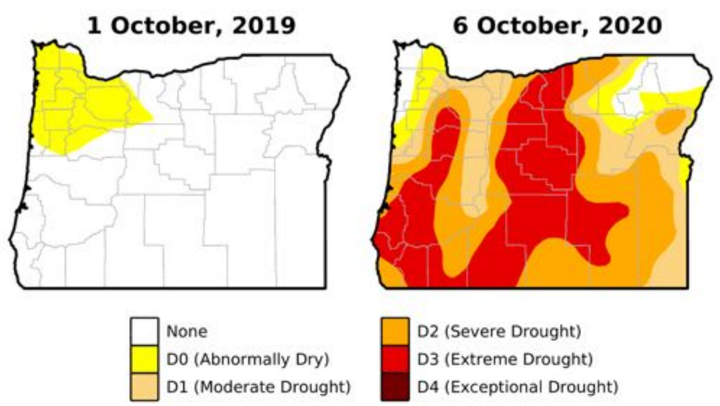

Figure B1. Progression of drought severity throughout water year 2020 as depicted by the weekly U.S. Drought Monitor for (left) 1 October, 2019 and (right) 6 October, 2020.

Fifteen counties in southwest and central Oregon, in which the water year was the 11th driest on record, were granted state-level drought declarations (Fig. B2) due to impacts on surface water availability and agricultural and livestock production.

Although precipitation across much of the state was well below average, snow water equivalent (SWE) in the north and central Cascade Range was only slightly below normal on 1 April. In southern Oregon, by contrast, precipitation and 1 April SWE were well below normal, and therefore the drought in that region had a significant snow drought component. The snowpack melted out one to three weeks early in the Klamath and Rogue River Basins, which elevated streamflows to near normal for a few weeks. Early meltout also occurred in the Willamette River Basin as a result of anomalously high temperatures throughout Oregon from mid-April through mid-May.

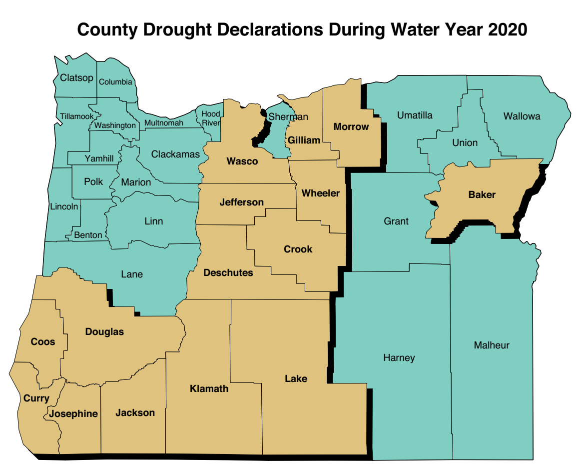

Figure B2. Counties with state-level drought declarations in September 2020 (tan shading). Fifteen counties had governor-approved drought declarations during water year 2020.

see **Water Year 2020**, page 42

precipitation contributed to each drought, but temperature and snowpack also affected drought severity and impacts, including the propagation of meteorological drought to hydrological and agricultural drought (Bumbaco and Mote 2010). Multiple studies have associated cooler sea surface temperatures in the eastern Pacific Ocean during La Niña with the 1998–2004 drought in the western United States (e.g., Hoerling and Kumar 2003, Seager 2007), and with other historical droughts in that region (e.g., Herweijer et al. 2006, Cook et al. 2007).

A number of severe droughts, with different causes, occurred in Oregon since 2010. The most severe of these droughts occurred from 2013–2015 and reflected very low winter precipitation (2014 water year) and snowpack (2015 water year). During water year 2014, SWE was near normal at high elevations and slightly above normal at low elevations (Fig. 3a). During the warm snow drought in water year 2015, precipitation was above normal (Sproles et al. 2016), but SWE was well below normal throughout the state (Fig. 3b), driven by warm temperatures that caused precipitation to fall primarily as rain (Mote et al. 2016) and earlier snowmelt. The water year 2015 drought possibly was accelerated by a snow albedo feedback whereby more sunlight is absorbed by bare ground than by snow, which further increases the surface air temperature and melts the snow (Walton et al. 2017). Water years 2014 and 2015

illustrate two types of snow droughts that may become more common in a warmer climate. First, the snow season may begin later and end earlier, with below-normal peak SWE (e.g., 2014 [Fig. 3a] and, to a lesser extent, 2020). Second, warm temperatures may cause more precipitation to fall as rain and less as snow, resulting in shorter snow-covered durations with smaller peak snowpacks (e.g., 2015, with greater negative SWE anomalies than 2014; Fig. 3b).

Anticipated Impacts of Climate Change on Drought

Climate models project warmer and drier summers for Oregon, and decreases in mountain snowpack due to warmer winter temperatures (*State of Climate Science*, this volume). These factors increase the likelihood of one or more types of drought. Snow drought, for instance, is projected to occur more frequently under a warmer climate as the proportion of precipitation falling as snow decreases. These conditions are projected to increase winter runoff and decrease runoff during spring and summer (e.g., Vano et al. 2015b).

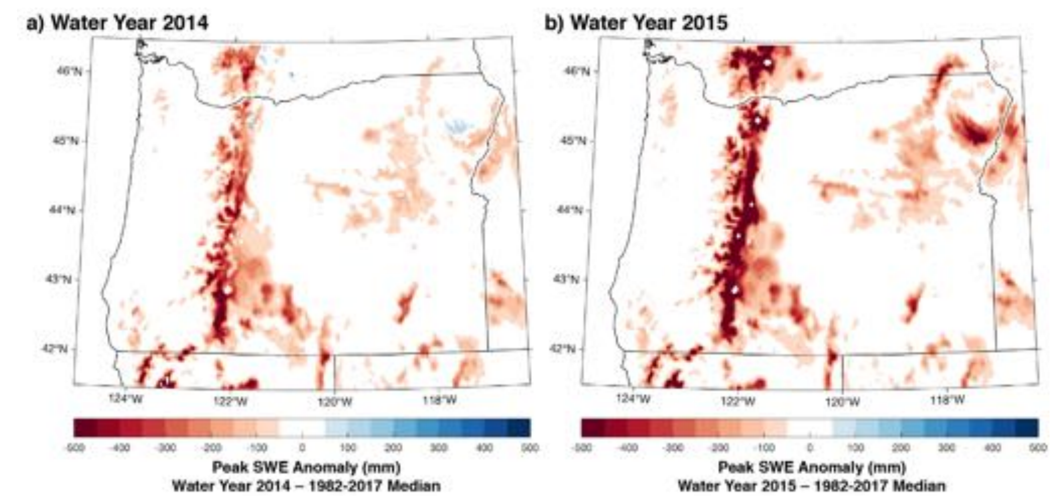

Figure 3. Peak snow water equivalent (SWE) anomalies calculated as differences from the water years 1982–2017 median peak SWE for two recent water years with notable snow drought: (a) water year 2014 and (b) water year 2015. Figure created by Benjamin Hatchett from a 4 km resolution reanalysis of daily SWE from Broxton et al. 2016.

It is still an open question whether conditions similar to the 2015 snow drought may become common by the middle of the twenty-first century (Cooper et al. 2016, Dalton et al. 2017). A sensitivity analysis of historical climate data suggested that for every 1.8°F (1°C) of warming, peak SWE decreases up to 30% (Cooper et al. 2016). Recent work also suggested that effects of anthropogenic forcing on spring snowpack trends since 1980 may have been mitigated by natural variability forced by large-scale changes in atmospheric circulation, which were driven by Pacific sea surface temperatures (Siler et al. 2019). The latter study noted that declines in the snowpack of the western United States may accelerate once the cycle of natural variability shifts from its current mode. Ultimately, projections suggest a decrease in winter snowpack of upwards of 60% by 2050 under RCP 8.5 (a scenario that represents a continuation of current levels of greenhouse gas emissions throughout the twenty-first century, or a relatively high amount of warming) (Fyfe et al. 2017). As climate change reduces mountain snowpack, seasonal drought will become less predictable in the western United States, including Oregon (Livneh and Badger 2020), and snow droughts will increase the likelihood of hydrological or agricultural drought during the following spring and summer (e.g., Koster et al. 2010, Wood et al. 2016).

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Southwest Oregon was first region to experience significant impacts from the drought. Irrigation allocations at the beginning of March were about one-third of normal, leading many producers in the Klamath Basin, for instance, to curtail planting or to rotate to less water-intensive crops. The Oregon Department of Forestry announced an early start of the wildfire season in southwest Oregon due to elevated wildfire risk from dry and warm conditions.

Late spring rainfall was insufficient to alleviate large precipitation deficits across the state, although it delayed drought impacts until mid to late summer across much of western Oregon. Compounding the low winter precipitation east of the Cascade Range was the lack of rainfall during the typical North American monsoon season (July–September). On average, eastern Oregon receives 10–30% of its annual precipitation during these months. The South Central Oregon Climate Division (Fig. B3, CD7) received 0.42 inches (1 cm) of rain from July–September 2020 compared with an average of 1.6 inches (4 cm); this ranks as the fifth driest July–September in the 125-year period of record (NCEI 2020). Additionally, the two-month period August–September 2020 was the third warmest on record for CD7, where average temperatures were 5.0°F (2.8°C) warmer than normal. The low precipitation and high temperatures resulted in extremely dry soil, consistent with flash drought. The most acute impacts were reported in Malheur County. The lack of monsoonal thunderstorms minimized summer lightning activity in eastern Oregon, and lightning did not spark wildfires in the dry vegetation.

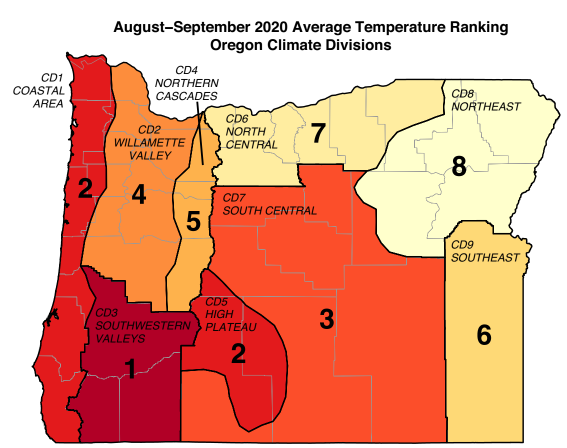

Figure B3. Rank of August–September average temperature over the past 125 years by state climate division (CD). A rank of 1 indicates the warmest average on record. Official rankings from the NOAA National Centers for Environmental Information published December 2020 and retrieved on 19 December 2020.

Conditions consistent with flash drought, driven by near record-high temperatures and dryness, also affected western Oregon during late summer (Fig. B3). The Southwest Oregon Climate Division (CD3) recorded its warmest August–September on record, the Willamette Valley Climate Division (CD4) its fourth warmest, and the Coastal Climate Division (CD1) its second warmest. These conditions contributed to the rapid expansion of wildfires throughout western Oregon during September.

The drought led to a number of very low reservoir levels. Wickiup Reservoir in the central Cascade Range, for instance, was at 1% of capacity by mid-September, a historical low. Delivery of irrigation water from Prineville Reservoir was curtailed in late August due to low water levels and the need to maintain minimum flow requirements on the Deschutes River. Even with irrigation curtailments, reservoirs in southwest Oregon ended water year 2020 at less than 15% of capacity, meaning essentially no carryover into water year 2021.

The social and economic impacts of snow drought may be considerable in basins that rely more heavily on irrigation water derived from snowmelt runoff. In the Columbia River Basin, for example, snowmelt runoff accounts for about 25% of total surface water allocated to irrigation (Qin et al. 2020). The Willamette River Basin also is vulnerable to projected decreases in Cascade Range snowpack and snowmelt runoff, with increased incidence of short-term agricultural drought during summer (Jung and Chang 2012). Short-term drought during the growing season may have major effects on agricultural productivity if water for irrigation becomes limited. Watersheds in the Northwest that receive both rain and snow, and in which snowmelt contributes substantially to streamflow during sprng and summer, are the most sensitive to projected winter warming (Vano et al. 2015a). The frequency of hydrological drought is projected to increase in such watersheds.

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Wildfire

Andrés Holz, Jessica Halofsky, William Nanavati, Laura Platt, and Kelly Gleason

Fire is a natural and recurring ecological disturbance that affects and responds to changes in climate, atmospheric chemistry, vegetation, and human activities, from recreation to industry to housing (Bowman et al. 2009, Flannigan et al. 2009, Archibald et al. 2018). As an ecological process and evolutionary driver, fire affects vegetation structure, plant communities, and species' identities or traits that allow plants to better survive or adapt to different types of fire over time (Agee 1993, McKenzie et al. 2004, Walsh et al. 2015, He et al. 2019, McLauchlan et al. 2020). The total area burned in Oregon during summer and autumn 2020 was among the largest in recorded history. During the 2020 fire season, five wildfires over 100,000 acres (~400 km^2), ignited by lightning and human activity, burned in wildlands and the wildland-urban interface. These and other fires across the western United States led to the displacement of thousands of people and loss of structures and infrastructure, and contributed to hazardous air quality in many parts of Oregon and the Northwest. Given these recent extreme events, this chapter provides historical and scientific context for wildfires in the state and region, and explore projections of wildfire under likely future climate conditions.

Wildfire Regimes in Oregon

Wildfire is driven by nested controls that vary across spatial and temporal scales (Fig. 1). At the finest resolutions, fuel, oxygen, and heat control an ignition or flame. Winds and other weather conditions, fuels, and topography affect expansion of fire and fire intensity (amount of heat; Rothermel 1972, Pyne 1996). Over decades to centuries, fire regimes (attributes of fires over space and time, such as frequency, size, and severity) are influenced by climate, which affects the weight (biomass) and dryness of fuel; vegetation type or species identities of plants; and the frequency, type, and timing of ignitions (Moritiz et al. 2005, Parisien and Moritz 2009) (Box 1). This chapter introduces some foundational terms and concepts in wildfire science and reviews fire trends in Oregon.

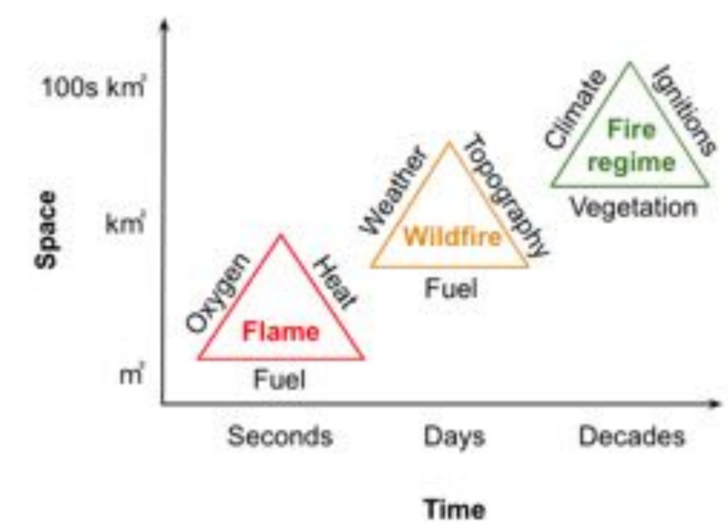

Figure 1. Nested controls on wildfires. Adapted from Moritiz et al. 2005.

Individual wildfires are produced by interactions between fine-scale flame dynamics and larger-scale fire regime dynamics, and are enabled by four factors that are synchronized (Bradstock 2010): sufficient fuel biomass, dry fuels, weather that is conducive to fire expansion, and ignitions. Understanding the interactions among these four factors is necessary to project how wildfires may respond to climate change and to consider whether and where fuels management may be effective.

Across the western United States, a steady increase in fire activity has been observed and linked to climate change (e.g., Westerling et al 2006, Abatzoglou and Williams 2016) and management legacies, such as fire suppression (Haugo et al. 2019) and the introduction of invasive grasses (Kerns et al. 2020). In this region, the number of wildfires ignited by lightning has increased rapidly, whereas human-set fires have increased moderately since the early 1990s (Balch et al. 2017). From 1984 through 2018, annual area burned in Oregon increased (Fig. 2), and projected climate change is expected to greatly increase the occurrence and future risk of large wildfires throughout Oregon, the Northwest, and the western United States (Littell et al. 2010, Stavros et al. 2014, Ager et al. 2017).

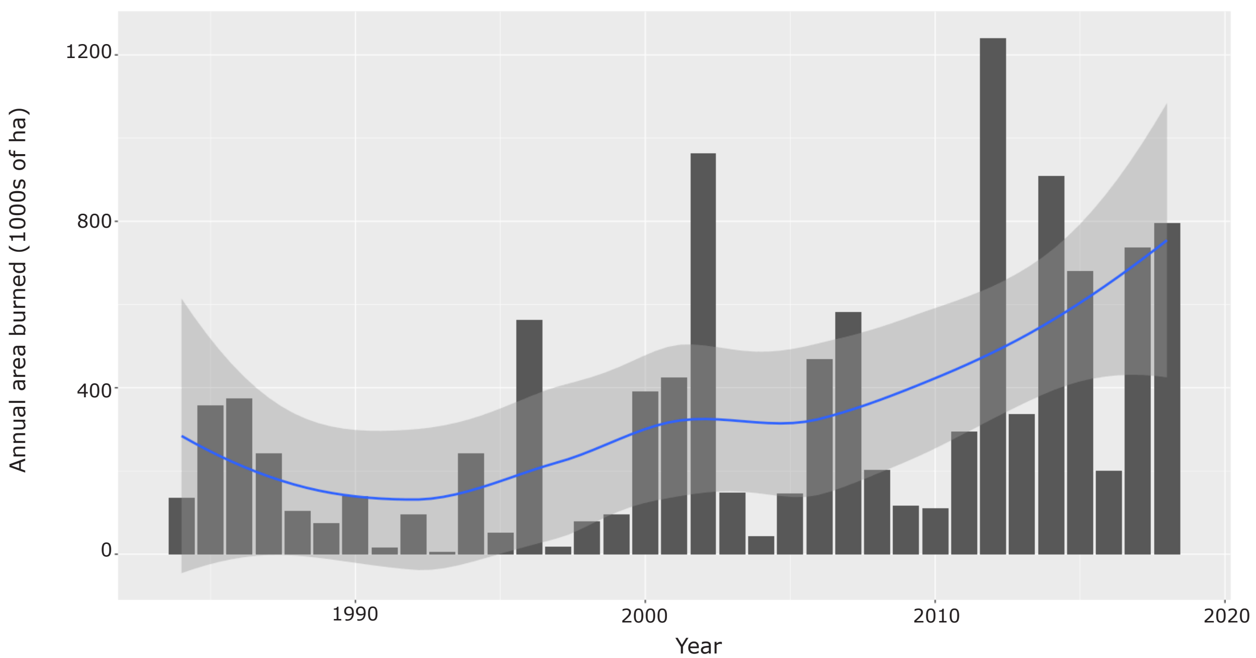

Figure 2. Annual area burned in Oregon from 1984–2018. Fires smaller than 988 acres (400 ha) were omitted. Data source: Monitoring Trends in Burn Severity (Eidenshink et al. 2007).

The concept of fire regimes is useful for characterizing how fire activity varies as precipitation or plant productivity varies along a gradient from low to high. At one end of the gradient are fuel-limited fire regimes, or those in which fire activity is constrained by the amount of contiguous biomass. Fires often are fuel-limited in regions that are dry and have low productivity. For example, fuels usually are limited in sparse shrublands (and some very dry, scattered, and unproductive low-elevation forests) east of the Cascade Range. In contrast, the dense forests of the Coast Range and intermediate to high elevations in the western Cascade Range are flammability-limited: fuels are abundant, but conditions usually are too wet for fire. Forests at intermediate and low elevations in western and southwestern Oregon (e.g., the Willamette Valley), and at intermediate elevations in the Blue Mountains east of the Cascade Range, are characterized by abundant fuels, seasonal aridity, and mixed fire regimes (Perry et al. 2011, Stine et al. 2014, Spies et al. 2018) (Fig. 3).

Limitations to fire activity in both fuel- and flammability-limited ecosystems can be overcome by short-term variability in climate (conditions over a month or longer) and weather (conditions over less than a month). For example, numerous studies in fuel-limited ecosystems have reported that years with above-average precipitation can lead to increased biomass and contiguity of fine fuels and an unusually active fire season. By contrast, in flammability-limited ecosystems, high fire activity often corresponds to extreme heat, spring and summer drought conditions, or strong and dry winds (Littell et al. 2009, Holz et al. 2012, McKenzie et al. 2019).

Conceptually, it is sensible to assume a negative linear relation between fire frequency and severity: as more fires occur in an area, less fuel is available for future fires. Conversely, as the fire-free period becomes longer, fuels can accumulate. However, this assumption ignores nonlinear variation in flammability following fire events. For instance, in the aftermath of a fire, fuel amount might increase rapidly until canopy closure, after which fuel accumulation continues but flammability decreases (Agee and Huff 1987, Spies et al. 1988). Alternatively, succession (long-term development of a plant community) can be interrupted by new and frequent fires (Whitlock et al. 2014, Busby et al. 2020). In dry montane forests, in which the majority of trees that do not require fire for reproduction germinate from seeds, succession can be limited by aridity, and relatively flammable grasses and shrubs can dominate in the early years or decades following wildfire (Davis et al. 2019).

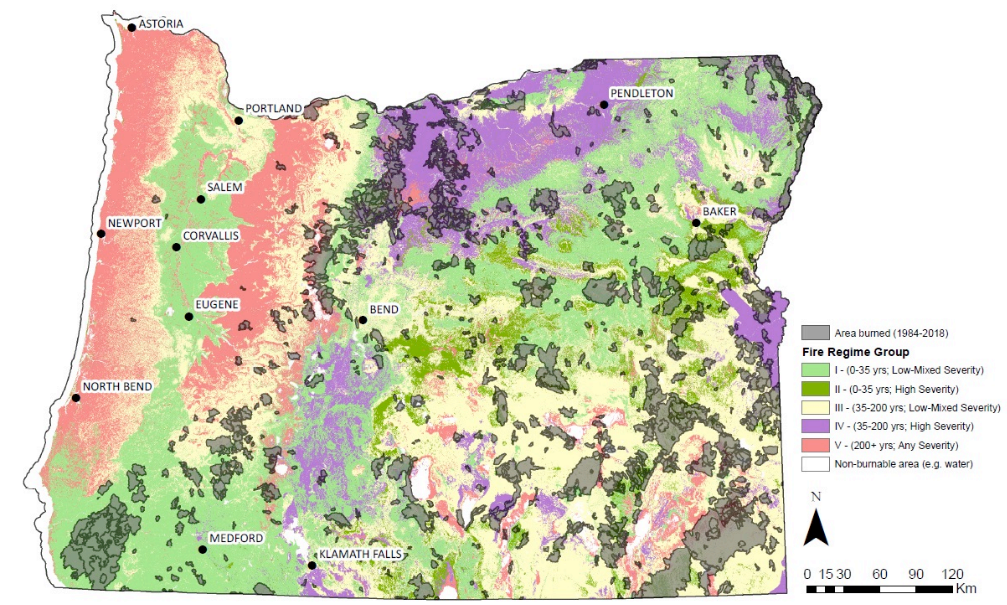

Figure 3. Total area burned in Oregon from 1984–2018 and fire regime groups. Fires smaller than 988 acres (400 ha) were omitted. Data sources: Monitoring Trends in Burn Severity (Eidenshink et al. 2007), LANDFIRE (2010).

Different ecosystems in Oregon have different fire regimes, which can be summarized on the basis of mean fire frequency, size, or seasonality, or other criteria. Below is a summary of Oregon's fire regimes on the basis of burn severity, or the percentage of trees killed by wildfire (Agee 1998): low (less than about 20%), high (more than about 70%), or mixed (about 20–70%). This chapter does not aim to characterize fire regimes in different regions of Oregon in great detail.

Low-severity fires are common at both ends of the precipitation gradient—in both fuel-limited and flammability-limited systems. In fuel-limited ecosystems, fires generally have low severity, cover large areas, and are fairly frequent (Heyerdahl et al. 2019). Years in Oregon in which the area burned was relatively high followed autumns and winters with above-average precipitation, which enabled accumulation of fine fuels, thereby connecting formerly fragmented vegetation and facilitating fire spread. Such climate-vegetation-fire dynamics sometimes are related to the El Niño–Southern Oscillation, as explained below (Heyerdahl et al. 2002, Johnston et al. 2017). Low-severity fires also occur in some moist forests in the Oregon Coast Range (Impara 1997) and western Cascade Range (Reilly and Spies 2016), where only fine fuels in the understory and small trees become dry enough to burn (Keeton and Franklin 2004, Tepley et al. 2013, Meigs et al. 2020).

Following decades of fire suppression that coincided with a relatively cool and wet climate (Higuera et al. 2015), the density and flammability of many low- to mid-elevation dry forests and woodlands in Oregon has increased (Haugo et al. 2019). For example, fire suppression in low elevation,

Box 1. Climate-wildfire relations in Oregon

Characteristics of fire and its ecological effects reflect relations among climate, people, and fire (Whitlock et al. 2010). Paleoecological and dendrological data, ethnographic accounts, and historical observations help elucidate these relations (Table B1). Indirect evidence does not explicitly describe ecological or climate change. Direct evidence includes qualitative and quantitative historical data and remotely sensed observations.

	Spatial resolution	Spatial extent	Temporal resolution	Temporal extent	Ecological inference	Effort needed
Paleoecology	Low	Low	Moderate	Very high	Indirect	High
Ethnographic & historical accounts	Variable	Moderate	Very high	Variable	Variable	Variable
Dendrology	Variable	Low	High	High	Direct	High
Aerial photographs	High	High	Low	Moderate	Indirect	Low
Satellite images	Very high	Very high	Very high	Very low	Indirect	Very low
Historical surveys	Low	High	Low	Low	Indirect	Moderate

Table B1. Forest structure and fire regime reconstruction methods. Adapted from Yokom-Kent 2014, Daniel et al. 2017, and Naficy 2019.

Paleoecological records

Sedimentary pollen and charcoal indicate changes in vegetation and fire activity over tens of thousands of years in the Northwest (Whitlock 1992, Walsh et al. 2015). Following the Pleistocene, about 12,000 years before present (BP), fire activity increased greatly as temperatures increased and forests established. Fire activity was high from 10,000–8000 BP as summer insolation (incoming solar radiation) peaked. Decreases in tree density from 9500–7500 BP may reflect increased fire activity and warm, dry summers. From 8000–4000 years BP, fire activity greatly decreased during a period of lower summer insolation and increased precipitation or lower evapotranspiration. By the end of this period, forest composition was similar to contemporary composition. Fire activity increased after 4000 years BP as a result of continued moisture variability, higher fuel loads, and Indigenous use of fire (Whitlock 1992, Walsh et al. 2015).

Tree-ring records

Tree-ring (dendrological) records can be used to reconstruct the past several hundred years of forest structure and composition, and of wildfires and climate, at seasonal to annual resolution (Table B1). These records suggest that fires were widespread west of the Cascade Range between the 1400s and 1650, possibly associated with warm, dry conditions and Indigenous fire use. Area burned decreased from 1650–1800, likely related to cool, wet conditions and reduction in population sizes of Native Americans, and then increased from 1800–1910, coincident with Euro-American settlement. Then, through the early 2000s, displacement of Native Americans and discontinuation of Indigenous fire use, fire suppression, and cool, wet conditions reduced fire activity (Boyd 1999, Weisberg and Swanson 2003, Noorgard 2014). Exceptions were the large fires during the twentieth century (e.g. Yacolt, 1902; Tillamook, 1933) that resulted from logging operations and extreme easterly winds. Increases in fire incidence since the early 2000s coincided with decreases in fuel moisture (Abatzoglou and Williams 2016).

Most dendrological reconstruction in the eastern Cascade Range has focused on dry, mixed-conifer forests within the Blue Mountains and relatively wet forests at the margins of drier forests. This work assessed variability in fire frequency among forest types and effects of fire suppression on forest structure. Results indicated that fire frequency was about 10–50 years in mixed-conifer forests

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historically open ponderosa pine (*Pinus ponderosa*) forests led to dense fuels and establishment of shade-tolerant tree species, such as grand fir (*Abies grandis*) and white fir (*A. concolor*), throughout the tree canopy, connecting fuels vertically from the ground to the crown. As a result, the intensity and severity of fires in the last three to four decades has increased (Hessburg et al. 2015, Haugo et al. 2019). Due to changes in climate and fire severity (Marlon et al. 2012), some dry forests and woodlands at low to intermediate elevations in eastern Oregon may not be able to reestablish naturally, and could transition to more-flammable shrublands or grasslands (Davis et al. 2019, 2020; Rodman et al. 2020). Fire suppression in wet ecosystems in the western Cascade Range has played a relatively minor role in driving fire patterns in these ecosystems (Spies et al. 2018).

Increases in fire severity also have been observed in arid

shrubsteppe in central and eastern Oregon. In these ecosystems, the rapid expansion of non-native invasive grasses, such as cheatgrass (*Bromus tectorum*) and ventenata grass (*Ventenata dubia*), has increased fine-fuel biomass and spatial continuity of fuels (Balch et al. 2013, Kerns et al. 2020, Tortorelli et al. 2020). Formerly sparse sagebrush ecosystems continue to be colonized by cheatgrass, which has resulted in increases in area burned of up to 200% since 1980 (Bradley et al. 2018). Expansion of cheatgrass leads to a positive feedback loop in which increases in fire frequency and extent facilitate further increases in the distribution and density of cheatgrass. Any ground disturbance, whether from livestock grazing (Williamson et al. 2020), tree thinning, or fire, can facilitate the colonization and increase in abundance of cheatgrass. Expansion of the shade-intolerant cheatgrass tends to be more likely in areas in which native grasses and forbs are sparse, which sometimes reflects a history of intensive livestock grazing (e.g., Kerns and Day 2017). *Ventenata dubia* can colonize relatively bare or open areas in ponderosa pine and mixed conifer forests.

High-severity fires dominate wet, cool forests, including remnant old-growth forests, in Oregon's Coast Range and western Cascade Range. Some shrublands and grasslands in central, eastern, and southwest Oregon also burn at high severity, but more frequently than forests (Fig. 3). High-severity wildfires in wet, cool forests

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(Heyerdahl et al. 2001, 2019; Merschel et al. 2014, 2018; Johnston 2016; Platt 2020). It appears that all dendrological reconstructions of fire history at low to intermediate elevations are consistent with other evidence that fire frequency decreased after 1910–1930 coincident with the federal implementation of fire suppression (Hessburg et al. 1999).

The high temporal resolution of dendrological records also allows for better understanding of the interactions between annual and decadal climate variability and fire activity. Annual variation in the El Niño-Southern Oscillation and decadal variation in the Pacific Decadal Oscillation cause similar changes in climate throughout the Northwest. Relatively warm winters and low snowpack are likely during the positive phases of these oscillations, as are increases in fire activity (Heyerdahl et al. 2002), whereas relatively cool, wet winters and high snowpack are likely during the negative phases (La Niña and PDO-) (Heyerdahl et al. 2008, Littell et al. 2016).

Comparisons to other records

Comparison of paleoecological and dendrological records to past land surveys (e.g., Public Land Surveys); historical and ethnographic records; and time-series of satellite, aerial, and land-based images allows for better understanding of interactions among climate, vegetation, fire, and humans. Fire has been a consistent, major disturbance process in the Northwest. Although changes in vegetation and fire activity following the Pleistocene likely were driven by a warming climate and increased atmospheric concentrations of carbon dioxide, Indigenous fire use likely influenced fire dyamics and vegetation during the past 4000 years. Archaeological, ethnographic, and historical records suggest that Indigenous use of fire led to frequent (less than about 5–35 years), low-severity surface fires in shrubsteppe, grassland, and dry low- to intermediate-elevation forests in central and eastern Oregon, and across the Willamette and Klamath-Siskiyou Basins (Boyd 1999, Steen-Adams et al. 2019).

The reduction in intentional ignition following the displacement of Tribes and fire suppression coincided with cool conditions, resulting in a marked decrease in fire activity and increases in the density of trees and shrubs (Whitlock 1992, Weisberg and Swanson 2003, Hessburg et al. 2007, Walsh et al. 2015). These interpretations and observations are consistent with the hypothesis that the absence of fire from much of the Northwest altered vegetation composition and structure and reduced the frequency of wildfires (Marlon et al. 2012).

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typically are infrequent and large, facilitated by extremely dry and warm springs and summers or high winds (Hemstrom and Franklin 1982, Spies et al. 2018). East of the Cascade Range, most wildfires are ignited by lightning, whereas west of the Cascade Range, most are ignited by human activity (Balch et al. 2017). Dry, cloud-to-ground lightning strikes are rare on the west side of the Cascade Range because of the strong maritime effect of the Pacific Ocean (Spies et al. 2018, Kalashnikov et al. 2020).

In western Oregon (western Cascade Range and Coast Range), extensive clearcutting followed by the planting of Douglas-fir (*Pseudotsuga menziesii*) plantations has reduced the spatial heterogeneity and overall variability in forest structure (Tyler and Peterson 2004, Donato et al. 2020). In older, more-complex stands, the sizes of trees usually are diverse and the understory is shady. In young plantations, by contrast, trees tend to be denser and to have more branches, which allows for greater horizontal and vertical spread of fire (Agee 1993, Stephens et al. 2005). Although the canopies of young plantations are not fully closed, the small-diameter trees readily become dry, which increases their ability to carry fires and elevates the risk of high-severity fires (Thompson et al. 2007, Zald and Dunn 2018). Logging and the post-fire planting of trees have reduced the extent of both mature or old-growth forest and early successional

vegetation in forests west of the Cascade Range in Oregon and Washington (Franklin and Johnson 2013, Swanson et al. 2014). Consequently, the extensive, homogenous patches of young tree plantation and closed-canopy, mid-successional Douglas-fir and western hemlock (*Tsuga heterophylla*) currently present in western Washington and Oregon occupy a larger area than in the past (Davis et al. 2015, DeMeo et al. 2018, Donato et al. 2020). In these historically more heterogeneous forests, the suppression of active fires may be ineffective and considerably more hazardous for fire crews during extremely hot and dry conditions that often are associated with strong easterly winds, such as those that fueled much of the 2020 fire season (Higuera and Abatzoglou 2021).

Mixed-severity fire regimes are the most complex and least understood across the western United States (Agee 1993, 2005; Tepley et al. 2013). These fire regimes are characterized by local differences in burn intensity and plant mortality (Agee 2005, Naficy 2016). The life histories of the plants that occur in regions with mixed-severity regimes are distinct in terms of fire resistance (Stevens et al. 2020) and vary as a function of water availability, which is affected by topography (Tepley et al. 2015). Fire histories in these systems are difficult to determine because most fire-history reconstruction techniques were developed for low- or high-severity regimes (Agee 2005; but see Hagman et al. 2019, Platt 2020). For example, in systems with infrequent, high-severity fires, the dates of past fires are estimated by pairing individual fire events with data on the ages of trees that colonized and established following that fire (Box 1). In systems with frequent, low-severity fires, fire occurrences typically are evident by scars on individuals of fire-resistant tree species. In contrast, in systems with mixed-severity fire regimes, species with traits that enable resistance or recovery are not uniformly distributed, leaving researchers unable to reconstruct fire activity on the basis of one method alone, and therefore reducing the number of samples from a given site. Additionally, dominant tree species in many areas characterized by mixed-severity fires decay relatively rapidly, limiting the potential use of dendroecology to reconstruct fire histories (Tepley and Veblen 2015). Novel research approaches aim to overcome challenges to reconstruction of fire frequency and severity in dry and cold (Hagman et al. 2019) or moist (Platt 2020) mixed-conifer forests.

Projections of Future Fire Dynamics

Empirical Models

Different types of models are being applied to project future fire dynamics in Oregon. Many empirical models, some reported in previous Oregon Climate Assessments, use the statistical relation between observed climate and area burned over the past 100 years to predict future area burned on the basis of projected temperature and precipitation, which usually are derived from global climate models. Empirical models can be applied at either global (Krawchuk et al. 2009, Moritz et al. 2012) or regional extents, such as the western United States (McKenzie et al. 2004, Littell et al. 2010, Yue et al. 2013, Kitzberger et al. 2017). Empirical models at all extents consistently project that the area burned in Oregon will increase. For example, McKenzie et al. (2004) projected that, with a mean temperature increase of 3.6°F (2°C), the area burned in Oregon will increase more than 200%. Assuming the A1B emissions scenario (medium emission levels), Kitzberger et al. (2017) also projected a 200% increase in median annual area burned in Oregon, including the Cascade Range, from 2010–2039 compared to 1961–2004. Other empirical models for Idaho, Montana, Oregon, and Washington, which were based on projections from two global climate models and the A1B scenario, suggested that area burned will double or triple by the 2080s (Littell et al. 2010).

Results of different empirical models also consistently suggest that the incidence of very large fires, often defined as the largest 5–10% of fires or fires that burn more than 12,350 acres (5000 ha), will

Impact of wildfires on runoff

Wildfires affect water balance, water quality, fluvial and riparian systems, and water infrastructure. Reduction in the extent of the vegetation canopy reduces water interception and storage by the canopy, allowing more precipitation to fall on the soil. In conjunction with reductions in the volume and extent of litter and live vegetation, and therefore evapotranspiration, the additional precipitation increases direct runoff for at least the first few years following a wildfire. In subalpine and alpine watersheds, less canopy interception may lead to greater snow accumulation.

After a wildfire, increased light transmission through the canopy and decreased reflectivity of the snow, a result of deposition of light-absorbing particles such as black carbon and burned debris, increases net shortwave radiation, which drives earlier snowmelt. This is somewhat offset by the decreased net longwave radiation due to the loss of canopy, but overall, wildfire increases the net snowpack energy balance and warms the snowpack (Gleason et al. 2019). In burned forested areas across 11 western states (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming), snow disappeared five days earlier on average, and this shift in snowmelt persisted for more than ten years following fire (Gleason et al. 2019).

Soil hydrophobicity (repelling rather than absorption of water by soil) also is likely to increase after a wildfire, resulting in less infiltration and more direct runoff. Changes in hydrophobicity depend on burn severity and vegetation composition, but overall reduce the lag from snowmelt to streamflow, increase overland flow, and increase peak streamflow. These changes are likely to increase erosion and contribute to earlier drying of soils and vegetation and reductions in late-season flows. As a result, water shortages in the dry season, and differences in seasonal flows in many parts of Oregon, may be exacerbated.

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increase in the future (Barbero et al. 2015). For example, empirical models developed by Barbero et al. (2015) under RCP 8.5 (a scenario that represents a continuation of current levels of greenhouse gas emissions throughout the twenty-first century, or a relatively high amount of warming) suggested that across the western United States, including Oregon, the annual probability of very large fires will increase by 200–400% by 2041–2070 compared to 1971–2000. Models by Davis et al. (2017) suggested that under RCP 4.5 (a lower-emissions and warming scenario), the proportion of forests in which conditions are consistent with large wildfires (more than 100 acres, or 40 ha) will increase by over 20% during the twenty-first century for nearly all major regions in Oregon, although less so for the Coast Range. The largest projected increases were in the Blue Mountains, Klamath Mountains, and eastern Cascade Range.

Future fire severity will depend partly on vegetation composition and structure. In the near term, high tree density may increase fire severity in dry forests (Cassell et al. 2019). Over the long term, fire severity in dry forests may remain similar or increase slightly (Parks et al. 2016).

Mechanistic Models

Mechanistic models use knowledge of physical and biological processes and their interactions to simulate future ecosystem attributes, such as vegetation composition and structure, vegetation productivity, fire frequency and severity, and carbon storage. These models account for potential interactions between vegetation and fire as the climate changes to conditions for which there is no past analog. Thus, they incorporate negative and positive feedbacks between fuel levels and fire frequency, and potential changes in the relation between climate and fire in the future, which are phenomena not captured by the empirical models described above. These models also integrate the potential increase in primary productivity, and in turn fuel loads, as a result of increased atmospheric carbon dioxide concentrations. Examples of process-based models that simulate fire are LANDIS-II (Scheller and Mladenoff 2008) and MC1 (Bachelet et al. 2001) and MC2 (Bachelet et al. 2015).

In an application of the LANDIS-II model to the Oregon Coast Range, area burned over the twenty-first century did not increase substantially relative to historical area as climate changed, but fire severity and the incidence of extreme fire weather increased (Creutzburg et al. 2017). By contrast, LANDIS-II suggested a large increase in fire frequency, size, and severity in dry forests in the southern Blue Mountains of central Oregon (Cassell et al. 2019).

An application of MC1 to the western three-quarters of Oregon and Washington, which assumed an A2 emissions scenario (high emissions), projected a 76–310% increase in annual area burned and a 29–41% increase in burn severity (measured as aboveground carbon released by fire) by 2100, with the degree of increase depending on the climate model used as input (Rogers et al. 2011). As reported in the third Oregon Climate Assessment (Dalton et al. 2017), more-recent simulations with the MC2 model, which incorporated climate scenarios from the fifth phase of the Coupled Model Intercomparison Project, also projected increases in fire frequency across all forest-dominated ecosystems in Oregon, with or without fire suppression (Sheehan et al. 2015).

At the subregional level, MC1 projected increases in fire frequency and extent over approximately 250,000 acres (1 million ha) of forests in central Oregon (Halofsky et al. 2013, 2014). The latter work projected that more than three-quarters of those forests will burn repeatedly from 2070–2100, particularly given hot and dry climate scenarios. The projected fire regime for central Oregon would be a significant change from that of the last century, and likely would result in substantial changes in vegetation. Similarly, MC2 simulations suggested that across south-central Oregon, fire will become more frequent in most vegetation types, especially dry and wet forests, and that fire severity in forests will be similar to or increase slightly compared to historical fire severity (Case et al. 2019).

Turner et al. (2015) projected increased fire frequency in the Willamette Valley under RCP 8.5. Average annual area burned was projected to increase 900% by 2100 relative to 1986–2010, but during the latter period, the total area burned was small (0.2% of the Willamette Valley per year). With smaller temperature increases, average area burned was slightly above historical levels. Mechanistic models consistently suggest that fire frequency and area burned in Oregon will increase. Fire severity also may increase, depending in part on forest composition, structure, and productivity over time. In highly productive ecosystems such as forests west of the Cascade Crest, both fire frequency and severity may increase (Rogers et al. 2011, Halofsky et al. 2018a, McEvoy et al. 2020).

Potential Interactions between Wildfire and Other Disturbances

Fire interacts with other stressors to trees, including drought, insect outbreaks, and pathogens, that can lead to substantial ecological changes (McKenzie et al. 2008). For example, water and vapor-pressure deficits are expected to increase as the climate becomes warmer, indirectly mediating increases in the frequency, extent, and severity of fire (McKenzie et al. 2004, McKenzie and Littell 2017) and insect outbreaks (Logan and Powell 2009). Effects on trees of colonization and herbivory by some insects, such as bark beetles, tend to increase among species during prolonged droughts or warm winters (Logan and Bentz 1999, Carroll et al. 2004, Hicke et al. 2006). Nevertheless, there is little evidence that fire occurrence or severity increases following bark beetle outbreaks in Oregon's forests (especially if trees are needleless when burned) (Agne et al. 2016, Meigs et al. 2016).

Options for Adapting to Fire

Many current management practices, such as manipulation of stand density and efforts to control non-native invasive species, can decrease the magnitude of ecological change following wildfire and

Floods

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Anticipated Effects of Climate Change on Flood Magnitude

Several factors suggest that flood magnitudes in Oregon will increase in a warmer climate. One is that large precipitation events are expected to become more intense (Allen and Ingram 2002, Westra et al. 2014, Warner and Mass 2017). The primary reason for the increase in intensity is simply that warmer air can hold more water, so there may be more moisture in the air available to fall out as rain or snow in a warmer climate. Atmospheric rivers, in particular, often bring heavy precipitation and, consequently, flooding in Oregon (e.g., Konrad and Dettinger 2017). A statewide flood in April 2019 and a flood in northeast Oregon in February 2020 illustrate the manner in which strong atmospheric rivers can result in extensive flooding and damages (Box 1). Atmospheric rivers are projected to bring more water vapor to the Pacific Northwest in the future, again because warmer air can hold more water (*State of Climate Science*, this volume). In general, the intensity of heavy precipitation events over the twenty-first century in Oregon is projected to increase, although not uniformly across the state (e.g., Cooley and Chang 2020; *State of Climate Science*, this volume).

A second factor suggesting that flood magnitudes will increase is that rainfall-driven floods tend to have larger flood peaks than snowmelt-driven floods given the same amount of precipitation (Davenport et al. 2020). Therefore, as rising temperatures cause the proportion of precipitation falling as rain relative to snow to increase, flood magnitudes are projected to increase (Chegwidden et al. 2020).

A third factor is that total wet-season (November–April) precipitation is projected to increase in the Pacific Northwest (Dalton et al. 2017, Easterling et al. 2017, Rupp et al. 2017a, b). Greater precipitation, even after accounting for increases in evaporation (Seager et al. 2014), implies a higher likelihood of wetter soil and reduced depth to ground water—both of which are enabling conditions for flooding—prior to the arrival of heavy precipitation events. Chegwidden et al. (2020) also concluded that rainfall-driven floods are more sensitive to increases in precipitation than snowmelt-driven floods, so the projected increases in total precipitation, and in rain relative to snow, likely will increase flood magnitudes in the region.

Historical Trends in Precipitation Intensity and Extreme River Flows

Relatively small sample sizes and high variability in extreme streamflow events make it difficult to detect long-term trends. Therefore, only large changes in the observational record are detectable. Consistent with the challenges to such analyses, a study of annual maximum daily flows (peak flows) from 1941 through 2015, recorded at 58 gauges in Oregon, found no statistically significant ($p < 0.05$) trends at sites that have little to no reservoir storage upstream (Hodgkins et al. 2019). Statistically significant trends—all decreasing and in western Oregon—only were detected at sites with substantial upstream reservoir storage, suggesting that these decreases could be attributable to reservoir and dam operations since the 1940s.

Projected Changes in Naturalized Extreme Flows

It is standard practice to consider the impact of climate change on naturalized river flows (defined as observed flows that have been adjusted for human regulation and withdrawals). This practice allows for removal of the complicating factor of human activity when assessing effects of climate change on hydrology. Additionally, naturalized flows can be used as inputs when assessing management of the same river systems.

Queen et al. (2021) projected changes in the 10-year and 100-year annual maximum naturalized daily flows at multiple locations in the Columbia River Basin, comparing flows in the second half of the twentieth century (1951–2000) to those in second half of the twenty-first century (2050–2099). The 10-year flow had a 10% likelihood of being exceeded in a given year, whereas the 100-year flow had a 1% likelihood of being exceeded in a given year. They considered 40 hydroclimate scenarios, all assuming RCP 8.5 (a scenario that represents a continuation of current levels of greenhouse gas emissions throughout the twenty-first century, or a relatively high amount of warming), and statistically downscaled meteorological data from ten global climate models as inputs to four hydrological model configurations. The range in changes among the 40 individual scenarios was large, but the average of the 40 scenarios is considered the best estimate of the effect of climate change on these probabilistic flood magnitudes (Table 1). Similar to an earlier study (Maurer et al. 2018), increases of 5% or less in the average of the 10-year and 100-year peak flows were projected along the Columbia River upstream from Vancouver. Much larger increases were projected for other rivers within and adjacent to Oregon. Projected increases for the Willamette River and its tributaries from the Cascades were particularly high, ranging from 39% at Willamette Falls to 63% at Hills Creek Dam on the Middle Fork Willamette for 100-year flows. Changes in flows assuming RCP 4.5 (a scenario that represents moderate reductions in global greenhouse gas emissions, with a peak near the middle of the twenty-first century, or a relatively low amount of warming) were about two-thirds the magnitude of those that assumed RCP 8.5.

River	Location	Projected increase (%)	
		10-year	100-year
Willamette Basin rivers			
Willamette	Willamette Falls to Harrisburg	33–45	39–50
McKenzie	Walterville to Vida	54–56	55–58
Willamette	Eugene	50	54
Middle Fork Willamette	Jasper to Hills Creek Dam	50–57	57–63
Row	Cottage Grove	25	39
Other rivers			
Columbia	Vancouver to McNary Dam	2–3	5
Snake	Ice Harbor Dam to Anatone	19–24	25–29
Snake	Hells Canyon Dam to Nyssa	39–41	52–56
Grande Ronde	Troy	48	68

Table 1. Projected impact of climate change on the magnitude of 10-year and 100-year annual maximum daily flows from 1950–1999 to 2050–2099, assuming RCP 8.5 and averaging over 40 scenarios. Projected changes over a range of locations generally increase from downstream to upstream. Adapted from Queen et al. (2021).

Sampling from the same 40 hydrologic and climate scenarios as Queen et al. (2021), the River Management Joint Operating Committee (RMJOC) analyzed changes in peak 10-day naturalized runoff volumes from large drainage areas of the Columbia Basin, including the Willamette Basin. They considered 10-day runoff volumes because it takes approximately 10 days for water to travel through the Columbia River reservoir system. The RMJOC examined 10-day naturalized runoff volumes preceding the five greatest peak flows at the drainage area outlet in winter (November through March) in each of three 30-year periods: 1976–2005 (historical), 2020–2049 (the 2030s), and 2060–2089 (the 2070s) (RMJOC 2020). The median of 10-day runoff volumes preceding the peak flow events in the Willamette Basin was projected to increase by 11% and 43% by the 2030s and 2070s, respectively, under RCP 8.5. Under RCP 4.5, projected increases were 19% and 37% by the 2030s and 2070s, respectively. In winter, the increases in peak flows from the Willamette River, combined with the shift to more frequent and higher peak flows on the Columbia mainstem, caused projected 10-day runoff volumes at the confluence of the Columbia and Willamette River to increase 15% by the 2030s and 65% by the 2070s under RCP 8.5. Under RCP 4.5, 10-day runoff volumes increased by 22% by the 2030s and 37% by 2070s.

The RMJOC (2020) conducted a similar analysis for large, system-wide spring floods, identifying the five greatest total April–August naturalized runoff volumes in each 30-year period. At the confluence of the Columbia and Willamette Rivers, these runoff volumes were projected to change little under RCP 4.5. Under RCP 8.5, the median of the five greatest runoff volumes decreased by about 5% by the 2070s.

Projected Changes in Flood Risk in Managed River Systems

The heavy management of the Columbia River substantially can impact the magnitude and timing of peak flows and, consequently, flood risk. Two recent studies examined the consequences of climate change on flood risk under the current operations of the Federal Columbia River Power System. In one study, the 13 reservoirs in the Willamette Basin operated by the Willamette Project were characterized as "highly effective at reducing flood risk" under two RCP 8.5 scenarios. Simulated flow at Salem, Oregon, a key control point for the Willamette Project, reached flood stage only once by the year 2099 (Tullos et al. 2020) despite increases in reservoir inflows

Box 1. Two recent flood events in Oregon

Atmospheric rivers in April 2019 and February 2020 illustrated the effects of these storms on Oregon's climate, water supply, and flood risk. The Northwest receives about 25–30% of its total winter precipitation from atmospheric river events (Slinskey et al. 2020; *State of Climate Science*, this volume). The two atmospheric river events in April 2019 and February 2020 also had a significant rain-on-snow component, which contributed to downstream flooding and damage. Runoff from snowmelt during rain-on-snow events compounds runoff from precipitation, amplifying a storm's potential to cause high-impact flooding, landslides, and avalanches. One study of the Santiam River Basin suggested that 74% of peak daily streamflows with a return interval greater than one year were associated with rain-on-snow events (Surfleet and Tullos 2013). This association was highest within the transient rain and snow elevational band, between 1150 feet (350 m) and 3600 feet (1100 m). Recent climate model simulations projected a decreased frequency of high peak flow rain-on-snow events at low to intermediate elevations and an increased frequency of such events at high elevations (e.g., Musselman et al. 2018). The decrease in low to mid-elevation rain-on-snow peak flows is due to projected decreases in snowfall at these elevations. These results were consistent with earlier studies that demonstrated an increased occurrence of rain-on-snow events at high elevations, and decreased occurrence at low elevations, over the last 35 years, which was attributable to the warming climate (McCabe et al. 2007, Ye et al. 2008).

The apparent importance of rain-on-snow to peak flows, however, can depend on how rain-on-snow-affected flows are defined. Although Surfleet and Tullos (2013) considered a peak flow event to be associated with rain-on-snow if any of the existing snowpack melted, Chegwidden et al. (2020) used hydrological modeling to isolate events with a substantial rain-on-snow contribution: more than ~2.5 inches (10 mm) of basin-average soil water equivalent in the existing snowpack and a snowmelt contribution greater than 20% of the total precipitation plus snowmelt. Chegwidden et al. (2020) found that for the North Santiam Basin, and other basins like it in the vicinity, rain-on-snow was an important factor in about 10% of peak daily streamflows with a return interval greater than one year, but may be important in less than 1% of such events by 2100.

April 2019 statewide flood

An unseasonably strong atmospheric river that made landfall in Oregon on 7 April 2019 produced one of the state's historically significant floods. Precipitation and runoff from this event exceeded a number of daily precipitation and streamflow records across Oregon. Due mainly to the rainfall from this event, April 2019 was Oregon's third wettest April on record. The timing of the atmospheric river coincided with the winter maximum snowpack, with snow water equivalent on 1 April at or well above normal for all Oregon mountain basins. Heavy rain and rain-on-snow conditions produced near-record runoff volume and streamflows throughout much of the state (e.g., Fig. B1a). The total April runoff volume set maximum monthly records at 58 streamflow stations across Oregon, and was second-highest at 10 other stations.

At the time of the storm, many reservoirs were drafting higher as operations were switching from flood control to spring and summer filling. The exceptionally high runoff filled many reservoirs, leading operators with no choice but to release water into already full river channels. Widespread flooding ensued across much of the state for the next week, and federal disaster declarations were approved in six

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implied by the projected increases in naturalized flows (Table 1). The resilience of the system was attributed to the current emphasis on flood-risk management in the operating rules and the relatively large volume of storage in the reservoirs compared to projected changes in streamflow (Tullos et al. 2020). However, the study's authors acknowledged that their hydrological model underpredicted peak daily runoff during winter, which could have led to an underestimation of flood risk.

The RMJOC (2020) examined the entire Columbia River reservoir system and determined that the greatest change in flood risk would result from an increase in regulated flows from the Columbia mainstem during winter. Current system operations for minimizing flood risk along the Columbia River largely are designed to manage spring runoff rather than winter runoff, and adaptive management of reservoir operating policies is not anticipated to fully offset potential increases in winter flood risk. As a result, the five largest regulated winter flood events on the lower Columbia River (below the confluence with the Willamette River) occurred when the contribution from the Columbia mainstem, averaged over the five events and relative to the 1976–2005 baseline period, was 44% and 151% larger by the 2030s and 2070s, respectively, under RCP 8.5. Under RCP 4.5, the Columbia contribution increased by 36% and 72% by the 2030s and 2070s, respectively. The substantial projected increase in peak flows from the Willamette River is especially challenging for

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counties as a result of damage associated with the storm. By the end of April, mountain snow water equivalent dwindled to well below average over all Cascade Range basins in Oregon and Washington. The early melt-out of the snowpack preceded below-average summer streamflows on several major rivers draining the Cascades, such as streamflows in May and June along the Willamette (Fig. B1a). Some impacts of this flood were documented in the Oregon Office of Emergency Management's 2019 April Flooding Spotlight: storymaps.arcgis.com/stories/2cfe3ce9706045c585b5f1f3d1c79bb0.

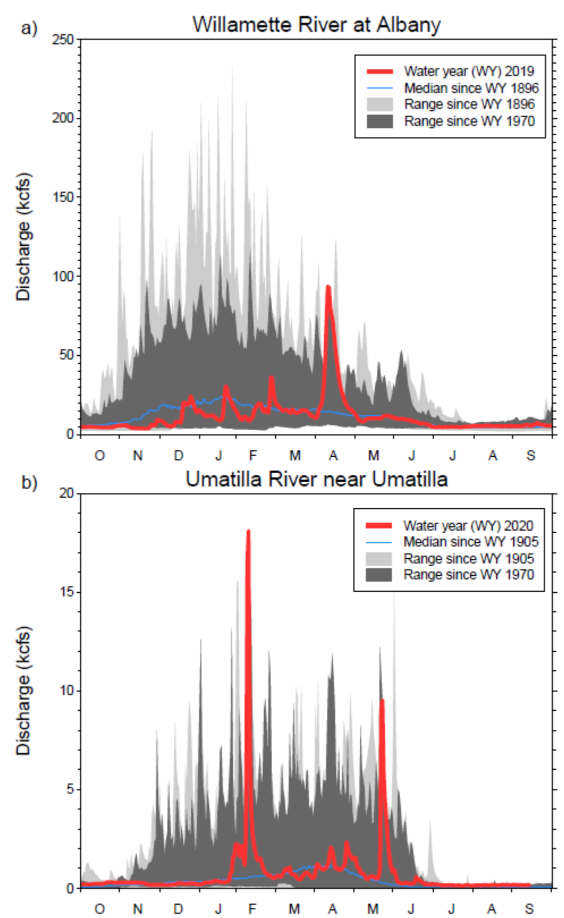

Figure B1. Daily flow (red line) during the water year (1 October–30 September) measured in (a) 2019 at the Willamette River at Albany (USGS gauge 14174000) and (b) 2020 at the Umatilla River near Umatilla (USGS gauge 14033500). The light blue line indicates the median daily flow over the period of record (1896–2020 for the Willamette River, 1905–2020 for the Umatilla River), and the gray shading indicates the full range of daily flows. The darker gray shading includes the water years since 1970, by which nearly all existing flood management infrastructure was completed. The lighter shading covers all years in the period of record.

February 2020 northeast Oregon flood

In early February 2020, while much of Oregon was in drought, a strong atmospheric river affected northeast Oregon. This atmospheric river was extremely unusual: its flow was not the

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flood management on the lower Columbia River, where flow from the Willamette River into the Columbia River further increases water levels on the Columbia above the confluence. For the same five largest winter flood events, the average contributions from the Willamette River were 29% and 39% larger by the 2030s and 2070s, respectively, under RCP 8.5. Under RCP 4.5, the increases in the Willamette contribution area were similar: 29% by the 2030s and 40% by the 2070s.

In the set of simulations conducted by the RMJOC (2020), no major floods (water level greater than 25 feet [7.6 m]) occurred along the Columbia River at Portland and Vancouver during the historical period (1976–2005). However, RMJOC (2020) projected that during 2060–2089, this location would reach major flood stage three times under RCP 4.5 and five times under RCP 8.5. At least one major flood was projected during the 2030s. Moderate flood stage (greater than 20 feet or 6.1 m) was projected to occur in nine and twelve years from 2060–2089 under RCP 4.5 and RCP 8.5, respectively, but only in one to three years (depending on hydrological model used) during 1976–2005. Flood stage (greater than 16 feet [4.9 m]) occurred in at least 20 of those 30 years under either RCP, compared to four to nine years from 1976–2005.

Given the potential for a substantial increase in flood risk on the lower Columbia River, two recent investigations used two-dimensional hydraulic modeling to simulate peak water levels from the mouth of the Columbia River upstream to Bonneville Dam on the Columbia River and Willamette Falls on the Willamette River during plausible future flood events. Helaire et al. (2020) projected flood hazards with the 1996 and 1923 floods (the largest and third largest Willamette River floods since 1900) as baseline events while adjusting runoff and sea level rise to be consistent with climate change projections. A 10% increase in runoff to both the Willamette River and Columbia mainstem was assumed. This change is small relative to the increases even by 2030s given in the RMJOC (2020) study, suggesting that potential changes of this magnitude already may be occurring. With this 10% increase in runoff, water levels in the Portland and Vancouver area increased by 2.56 and 2.69 feet (0.78 and 0.82 m) relative to the 1996 and 1923 floods, respectively. Sea level rise of 2 and 4.9 feet (0.6 and 1.5 m) added 0.3 and 1 feet (0.1 and 0.3 m), respectively, to these water levels. The upper end of the projected range of sea level rise (4.9 feet) is considered very large, with a 1.3% probability of being exceeded by 2100 under RCP 8.5 (*Coastal Hazards*, this volume). The effects of runoff and sea level rise on flood risk varied spatially. Areas near the confluence of the Columbia and Willamette Rivers were most sensitive to runoff changes, whereas coastal regions were most sensitive to sea level rise.

Wherry et al. (2019) also used the 1996 winter flood as a baseline. Roughly consistent with the changes by the 2030s reported in RMJOC (2020), they increased the Willamette River runoff by

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typical southerly or westerly, but curved around an eastern Pacific high and streamed subtropical moisture from the northwest. Due to the unusual orientation of the upstream moisture transport, heavy precipitation began on the cold side of the atmospheric river as snow down to an elevation of 2000 feet (610 m), then transitioned to heavy rain to an elevation of about 5000 feet (1500 m) as the atmospheric river's warm front moved north. As a result, precipitation along the northern Blue and Wallowa Mountains was exceptionally heavy, and quickly drained into the Middle Columbia and Lower Snake River Basins. Similar to the April 2019 event, this atmospheric river featured a fairly significant rain-on-snow component that contributed to the observed high runoff volume.

The peak flow on the Umatilla River at Pendleton set a record high on 6 February at about 19,000 cubic feet per second, surpassing previous high flows from 1965 and 1996 (Fig. B1b). At a number of stations along the Umatilla River, recorded monthly runoff volumes were the second highest on record for February. Some impacts of this flood were documented in the Oregon Office of Emergency Management's 2020 February Flooding Spotlight: oregon-oem-geo.hub.arcgis.com/app/cb570e3df4e14e03a096b0b920534db9.

20% and Columbia River runoff by 40%, assuming that extremely high water levels in the Portland and Vancouver areas are most likely under a scenario in which a major atmospheric river affects western Oregon when winter flows on the Columbia River are moderately high. With this increase in runoff, they modeled two scenarios of sea level rise: 0.8 and 3.3 feet (0.25 and 1.0 m) by 2040 and 2090, respectively. Sea level rise of 3.3 feet has a 17% probability of being exceeded by 2100 under RCP 8.5 (*Coastal Hazards*, this volume) Under such conditions, peak water level increased by 4.1 to 5.4 feet (1.3 to 1.7 m) above the 1996 flood. Wherry et al. (2019) concluded that while critical levees would not be overtopped with these scenarios, most levees along the Columbia Corridor Levee System at Portland (north Portland along the Columbia River) would be "subject to prolonged exposure from water levels that exceed the safe levee height, which is defined by the U.S. Army Corps of Engineers as the highest flood level for which reasonable flood protection is provided."

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From: **Ken Eklund** futureeverything@writerguy.com
Subject: Odor complaint form on the Coffin Butte Landfill site? (Archive of Email chain)
Date: July 13, 2025 at 5:18 AM
To: Public Record for LU-24-027

KE

[chain begins]

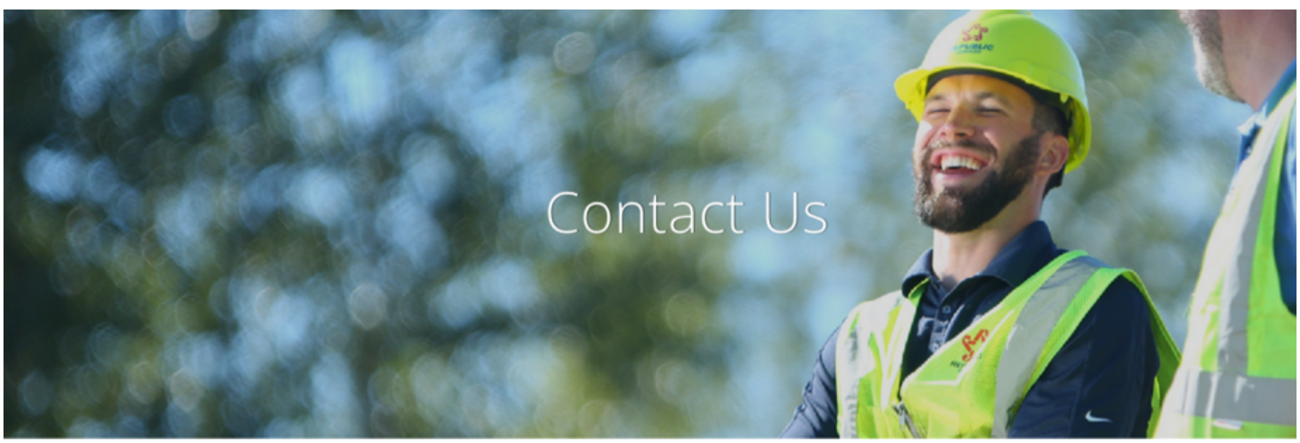
From: Ken Eklund <futureeverything@writerguy.com>
Subject: Odor complaint form on the Coffin Butte Landfill site?
Date: February 28, 2024 at 2:27:21 PM PST
To: Ian Macnab <IMacnab@republicservices.com>
Cc: Xan Augerot <xanthippe.augerot@co.benton.or.us>, Nancy Wyse <nancy.wyse@co.benton.or.us>, Pat Malone <pat.malone@co.benton.or.us>, Rachel MCENENY <rachel.mceneny@bentoncountyor.gov>

Good afternoon Ian,

I heard a report that Coffin Butte Landfill now has an online odor complaint form – which would be exciting news, as I don't believe the landfill has ever had a channel for complaints before. But looking at coffinbuttelandfill.com, I don't find any odor complaint form. I looked on the Contact Us page (see attached) and on the FAQ page (see attached) as well as the home page and several other pages, and found nothing. I also used the website search engine and it came up empty (see attached). Maybe my source was talking about the ODEQ complaint form? I thought I'd check with you.

All best,

Ken



Location

Coffin Butte Landfill 29175 Coffin Butte Road
Corvallis, OR 97330 (541) 745-5792
coffinbutte@republicservices.com

Hours of Operation

8:00 am – 5:00 PM, Monday-Saturday Closed
Sundays and Major Holidays

*If unloading by hand, load must be on scales by 4:30pm on Monday-Saturday.

Drop-off Requirements

Coffin Butte Landfill has a public drop off area on site. Residents may bring loads of trash and clean up debris for disposal. Residents may also bring recyclables such as appliances, e-waste, wood, metals, used motor oil, yard debris, tires, glass, automotive batteries, and cardboard. A fee is charged for disposal based on tonnage and waste type. Call the Landfill at (541) 745-5792 for details and a list of rates. Acceptable forms of payment taken: All major credit cards (Visa, MasterCard, Discover & American Express).

Sign up for updates

How do you control odors?

The Coffin Butte Landfill team takes multiple steps to control odors. We apply a daily cover over the garbage, we have an extensive landfill gas collection and treatment system, and we use geo synthetic covers to help the gas system operate more efficiently. At our Pacific Region Compost site, we use a dry vapor system that neutralizes odors on site.

Nothing Found

Sorry, but nothing matched your search terms. Please try again with some different keywords.

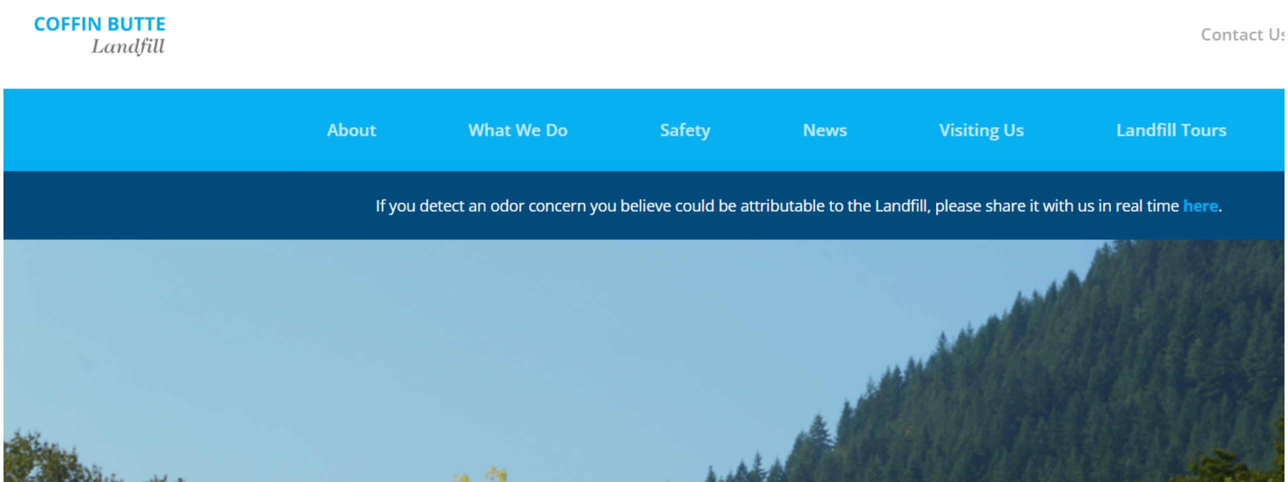
odor complaint

Search

Ken Eklund, writerguy

Creator of
World Without Oil
Ed Zed Omega
FutureCoast
and other storymaking games

> **From:** "Macnab, Ian" <IMacnab@republicservices.com>
> **Subject: RE: Odor complaint form on the Coffin Butte Landfill site?**
> **Date:** February 28, 2024 at 3:34:13 PM PST
> **To:** Ken Eklund <futureeverything@writerguy.com>
> **Cc:** Xan Augerot <xanthippe.augerot@co.benton.or.us>, Nancy Wyse <nancy.wyse@co.benton.or.us>, Pat Malone <pat.malone@co.benton.or.us>, Rachel MCENENY <rachel.mceneny@bentoncountyor.gov>
>
> Hi Ken,
>
> There is a link on the top of the home page on the website:



> Let me know if you have any trouble with it. You may need to clear your browser cache if you're unable to see it.
>
> **Ian Macnab**
> Environmental Manager - Oregon
>
> 28972 Coffin Butte Road
> Corvallis, OR 97330
> **e** imacnab@republicservices.com
> **o** 541-230-5543
> **c** 541-230-4022
> **w** RepublicServices.com
>
> REPUBLIC®

Sustainability in Action

From: Ken Eklund <futureeverything@writerguy.com>
Subject: Re: Odor complaint form on the Coffin Butte Landfill site?
Date: February 28, 2024 at 6:32:18 PM PST
To: "Macnab, Ian" <IMacnab@republicservices.com>
Cc: Xan Augerot <xanthippe.augerot@co.benton.or.us>, Nancy Wyse <nancy.wyse@co.benton.or.us>, Pat Malone <pat.malone@co.benton.or.us>, Rachel MCENENY <rachel.mceneny@bentoncountyor.gov>

Hi Ian,

Thanks for the pointing that out. Excellent to see it. The dark blue bar did appear for me when I entered the coffinbuttelandfill.com URL just now, but it wasn't there earlier today or the day before. When did that dark blue bar/ link go live? And when did that complaint page appear in its current form? Thanks!

All best,

Ken

Ken Eklund, writerguy

Creator of
World Without Oil
Ed Zed Omega
FutureCoast
and other storymaking games

> **From:** "Macnab, Ian" <IMacnab@republicservices.com>
> **Subject: RE: Odor complaint form on the Coffin Butte Landfill site?**
> **Date:** February 29, 2024 at 8:15:59 AM PST
> **To:** Ken Eklund <futureeverything@writerguy.com>
> **Cc:** Xan Augerot <xanthippe.augerot@co.benton.or.us>, Nancy Wyse <nancy.wyse@co.benton.or.us>, Pat Malone <pat.malone@co.benton.or.us>, Rachel MCENENY <rachel.mceneny@bentoncountyor.gov>
>
> Ken,
>
> I don't know the exact date, but we added it at the end of last year/beginning of this year.
>
> Thanks

Thanks,

Ian Macnab
Environmental Manager - Oregon

28972 Coffin Butte Road
Corvallis, OR 97330
e imacnab@republicservices.com
o 541-230-5543
c 541-230-4022
w RepublicServices.com

REPUBLIC SERVICES

Sustainability in Action

From: Ken Eklund <futureeverything@writerguy.com>
Subject: Re: Odor complaint form on the Coffin Butte Landfill site?
Date: February 29, 2024 at 10:58:27 AM PST
To: "Macnab, Ian" <IMacnab@republicservices.com>
Cc: Xan Augerot <xanthippe.augerot@co.benton.or.us>, Nancy Wyse <nancy.wyse@co.benton.or.us>, Pat Malone <pat.malone@co.benton.or.us>, Rachel MCENENY <rachel.mceneny@bentoncountyor.gov>

Thanks, Ian. It's confusing, though, what you mean by "it." Does that late '23/early '24 timeline apply to the landfill odor complaint form, and to its link on the home page, or are they on separate timelines? When was the first time the form was used by someone "in the wild," i.e. not connected to Republic/the landfill or Benton County? – Ken

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Ken Eklund, writerguy

Creator of
World Without Oil
Ed Zed Omega
FutureCoast
and other storymaking games

From: "Macnab, Ian" <IMacnab@republicservices.com>
Subject: RE: Odor complaint form on the Coffin Butte Landfill site?
Date: February 29, 2024 at 12:49:24 PM PST
To: Ken Eklund <futureeverything@writerguy.com>

To: Ken Eklund <futureeverything@writerguy.com>
Cc: Xan Augerot <xanthippe.augerot@co.benton.or.us>, Nancy Wyse <nancy.wyse@co.benton.or.us>, Pat Malone <pat.malone@co.benton.or.us>, Rachel MCENENY <rachel.mceneny@bentoncountyor.gov>

Ken,

I reached out to Ginger about this since she was the one in charge of adding it to the website. This is what she sent:

Hi Ken –
Thanks for asking about the odor reporting portal at coffinbuttelandfill.com. The odor link, and the form it links to, were made live on the website morning of January 24. In fairness, we haven't communicated this new function to the public yet, although we did reference it in our recently submitted annual report. Our intent to be more transparent and communicative stems from the BCTT process – you can expect to see more from us on this as we go forward.

I'm happy to talk to you offline/directly about this website feature or other community engagement opportunities. You're always welcome to email me directly atgrough@republicservices.com.

I hope you're well – and look forward to talking again soon,
Ginger

Ian Macnab
Environmental Manager - Oregon

28972 Coffin Butte Road
Corvallis, OR 97330
e imacnab@republicservices.com
o 541-230-5543
c 541-230-4022
w RepublicServices.com

REPUBLIC SERVICES

Sustainability in Action

From: Ken Eklund <futureeverything@writerguy.com>
Subject: Re: Odor complaint form on the Coffin Butte Landfill site?
Date: March 4, 2024 at 2:18:59 PM PST
To: "Rough, Ginger" <GRough@republicservices.com>
Cc: Xan Augerot <xanthippe.augerot@co.benton.or.us>, Nancy Wyse <nancy.wyse@co.benton.or.us>, Pat Malone <pat.malone@co.benton.or.us>, Rachel MCENENY <rachel.mceneny@bentoncountyor.gov>, "Macnab, Ian" <IMacnab@republicservices.com>

<rachel.mceneny@bentoncountyor.gov>, "Macnab, Ian" <IMacnab@republicservices.com>

Hi Ginger,

Good to hear from you. We're all well here, my mother just celebrated her 93rd birthday last Friday.

First, I'd like to continue with the question about when Republic received its first authentic public response on this form? I'm acknowledging that you haven't communicated this new function to the public, and by now the public doesn't expect to find a landfill odor complaint form at coffinbuttelandfill.com, but the dark blue box on the home page should have caught someone's eye. There's been a lot of chatter on social media about smelly days these past months, and questions raised as to how to report it. I think if anyone had found the odor complaint form at coffinbuttelandfill.com that would have appeared in those discussions.

I presume that the reports you get via this form come to the Disposal Site Advisory Committee, to be included in its Community Concerns Annual Report for the year?

I'll just talk briefly on Ian's suggestion that the dark blue bar not appearing for me was a caching issue. This is not a viable scenario, for two reasons. One: it would pose tremendous problems for the Internet if people regularly saw old cached versions of websites instead of updated ones, and so there is a robust system in place to prevent that from happening – etags and so on. Two: If it were a caching issue, it seems odd that after persisting for 35 days it resolved itself a short time after I sent my first email about it.

So some strong pushback from me on the representation that the link on the home page went live on January 24. I would like further evidence about it.

> Our intent to be more transparent and communicative stems from the BCTT process – you can expect to see more from us on this as we go forward.

This is of course very welcome, as I'm sure there is going to be an upswing in demand for transparency and honest answers as this year progresses!

All best,

Ken

Ken Eklund, writerguy

Creator of
World Without Oil
Ed Zed Omega
FutureCoast
and other storymaking games

> **From:** "Rough, Ginger" <GRough@republicservices.com>
> **Subject:** **RE: Odor complaint form on the Coffin Butte Landfill site?**
> **Date:** March 4, 2024 at 7:03:40 PM PST
> **To:** Ken Eklund <futureeverything@writerguy.com>
> **Cc:** Xan Augerot <xanthippe.augerot@co.benton.or.us>, Nancy Wyse <nancy.wyse@co.benton.or.us>, Pat Malone <pat.malone@co.benton.or.us>, Rachel MCENENY <rachel.mceneny@bentoncountyor.gov>, "Macnab, Ian" <IMacnab@republicservices.com>, NICHOLS

<rachel.mceneny@bentoncountyor.gov>; "Machab, Ian" <iMachab@republicservices.com>; NICHOLS Darren <darren.nichols@bentoncountyor.gov>

Good evening Ken –
Congratulations to your mother on another milestone birthday! I hope you were all able to celebrate together. I apologize for the slow response – my mother was in the hospital yesterday, and my sister and I are caring for her today.

I'll do my best to answer your questions, although I am not an IT or technical guru by any means! We've used this odor reporting tool successfully in other communities – and I thought that it might be beneficial in Benton County, following our many discussions during the BCTT process about communication and transparency.

As I mentioned before, we have not announced this tool to the public yet, although we intend to do soon. As such, we not been contacted by anyone in the community via the portal. As for timing – I created the form in December, we did some internal testing, and I requested that it appear on the website beginning the morning of January 24.

Your question about DSAC is a good one. The portal on Coffin Butte website is designed to notify us of a potential concern via email once the individual filling out the form hits "submit." It is designed to be responsive to both mobile and web browsers.

I anticipate there will be discussions in the near future about how to seamlessly share information between all key parties – DEQ, the County, Republic Services and the community. I know during the BCTT process everyone expressed a desire to have greater, and more frequent access to key data. Given DSAC's key role, I welcome input from you and your colleagues on the committee about how best to achieve this.

It is my hope and intent that this portal will be beneficial to this community. I hope you'll understand that its still in its "soft launch" phase. But the goal is driven by the feedback we received during BCTT – and our pledge to be responsive to our customers in Benton County.

I look forward to seeing you again in person – hopefully sooner and not later!

Ginger

☆ **Nancy Wyse** February 28, 2024 at 8:53 PM NW

RE: Odor complaint form on the Coffin Butte Landfill site?

To: Ken Eklund

Ken,

I don't recall if the link/online feature was ever formally shared with us (Benton County/Board of Commissioners)… it could have been, but I don't remember. I do remember seeing reports of complaints about the landfill, which included odors. Since I experienced the odors last week it made me think about that report and wonder if others were reporting. I saw your email come in and went to their website to look. It took me a few minutes to find it. I couldn't find a link. I had to do 3 or 4 searches to find it. I *think* the keyword that finally found it was "odor".

We (my family and I) were driving hwy 99W northbound on the 22nd around 5:30/5:45pm-ish. I had a respiratory infection at the time which affected my sense of smell, but just before Adair Village I noticed a "weird" smell and it got stronger right as we passed the landfill.

p.s. not to diminish the focus of your email, but I've not seen a golden eagle in Benton County before… but I'd like to! I'll keep my eyes peeled!

Benton County OREGON

Nancy V. Wyse *(She/hers)*
Commissioner
Office: 541-766-6754 | **Cell:** 541-760-6067
Email: nancy.wyse@co.benton.or.us
Address: 4500 SW Research Way, Corvallis
www.co.benton.or.us

Sunshine landfill ordered to step up actions to address odors

NEWS RELEASE(HTTPS://SIGNALSCV.COM/AUTHOR/PRESSRELEASE/) MARCH 26, 2025 10:52 AM

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News release

The South Coast Air Quality Management District has issued an order for abatement requiring Sunshine Canyon Landfill to implement stricter and innovative measures to reduce odors that have been impacting the community, the AQMD announced in a news release.

Landfill operations can cause odors, particularly as waste decomposes and if not well controlled, the release said. Since January 2023, South Coast AQMD has received over 4,000 odor complaints from nearby residents and an elementary school regarding Sunshine Canyon Landfill, which is in the Newhall Pass, just west of the Interstate 5 and State Route 14 interchange.

During this period, South Coast AQMD has issued more than 150 notices of violation against the landfill for public nuisance, citing violations of the agency's Rule 402 and California Health & Safety Code Section 41700. Sunshine Canyon Landfill has worked cooperatively with South Coast AQMD to incorporate additional measures and practices to minimize odor impacts, the release said.

The release said the new order, issued this month, requires Sunshine Canyon Landfill to take additional actions including:

• Odor prevention with microbiology: Use aerobic microbiology solutions during waste operations to reduce odors like "fresh trash" and methane.

• Closure turf feasibility: Explore installing gas and leachate systems without disturbing existing closure turfs designed to prevent erosion and emissions.

• Enhanced emissions data: Pilot advanced methods like drones and robotic vehicles to identify potential problem areas and collect more real-time data, including in the evening.

• Odor neutralization: Apply odor neutralizers and microbiology-based solutions at transfer stations to control odors before disposal.

• Gas movement: Test using larger granular materials such as gravel and crushed rock around landfill gas wells to improve gas flow. These larger size materials create more space between particles, allowing gas to move more freely and reducing pressure buildup.

• Daily odor patrols: Perform and document twice-daily patrols to identify odor sources and leachate seeps.

Sunshine Canyon Landfill is owned and operated by Browning Ferris Industries of California Inc. and Republic Services Inc. It is classified as a Class III landfill and can only accept municipal solid waste. No hazardous waste can be accepted at the landfill. Sunshine Canyon Landfill's Solid Waste Facility Permit limit is 12,100 tons per day and the landfill receives roughly 9,000 tons of waste per day, handling approximately one-third of the daily waste of all of Los Angeles County.

In January, Sunshine Canyon Landfill's tonnage limits have been temporarily increased to 15,000 tons per day following approvals and emergency waivers issued by the Sunshine Canyon Landfill Local Enforcement Agency, the Regional Water Quality Control Board and the Los Angeles County Board of Supervisors to address the removal and disposal of fire debris.

More information can be found at: www.aqmd.gov/nav/about/hearing-board/hearing-board/hearing-board-case-documents.

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Sanctuary laws: Where do your legislators stand? (https://signalscv.com/2025/07/sanctuary-laws-where-do-your-legislators-stand/)
JULY 7, 2025

LOCAL

Many say landfill emits ‘invasive’ odor into Harrisburg neighborhood

By **Hannah Goetz, wsoctv.com**

June 29, 2023 at 5:55 pm EDT

NOW PLAYING ABOVE

Many say landfill emits ‘invasive’ odor into Harrisburg neighborhood

By **Hannah Goetz, wsoctv.com**

June 29, 2023 at 5:55 pm EDT

unbearable smell, and they're getting fed up.

ALSO READ: What's that smell? Rare 'corpse flower' blooming at NC State →

"I can't go for a walk," said Luisa Ribeiro, a resident.

"We are worried about our health," said Diane Borkowski.

"It doesn't make us happy. No one wants to be the stinky neighborhood," said December Courtwright.

The residents said the mountain of trash has been releasing a horrific smell for years, and it's not getting any better.

"The odors were so invasive that they would permeate through the houses, where we couldn't even sit in our living rooms, sit in our bedrooms, without being assaulted by the terrible odors," Ribeiro said.

The group said they have filed complaints but they haven't seen any changes made.

"This is our last resort, besides seeking legal," Borkowski said.

ALSO READ: 'Chemical smell' triggers early dismissal for Mooresville HS students →

"The smell was extreme. I couldn't even sit outside with my granddaughter," she added.

In an inspection report from February by the North Carolina Division of Air Quality, both the DAQ and waste management noted receiving several odor complaints about the situation.

Later that month, the DAQ issued a notice requiring an odor management plan, citing the number of complaints and "concerning odorous emissions originating from the solid waste landfill." It gave the owner 60 days to identify the sources and a submit plan to fix the issue.

But neighbors say nothing's changed and they feel like they're being ignored.

New-Indy paper mill says it has reduced foul odor around state line

Hannah Goetz, wsoctv.com

Hannah is a reporter for WSOC-TV.

LOCAL

Neighbors say landfill smell hasn't improved after state-approved action plan

NOW PLAYING ABOVE

Neighbors say landfill smell hasn't improved after state-approved action plan

By **Hannah Goetz, wsoctv.com**

February 20, 2024 at 11:27 am EST

By **Hannah Goetz, wsoctv.com**

February 20, 2024 at 11:27 am EST

CABARRUS COUNTY, N.C. — A strong smell coming from a landfill is tormenting people in a Cabarrus County neighborhood.

It's not the first time Channel 9 has heard complaints. Neighbors first brought their concerns to us **last summer**, but now, they say it's getting worse.

The landfill is located near the Rocky River Crossing community. It's by the Charlotte Motor Speedway just off of Morehead Road.

PREVIOUS: Many say landfill emits 'invasive' odor into Harrisburg neighborhood →

“My daughter and I went outside to play,” Casey Burke said. “And we just had to turn around and go back inside because we were both kind of gagging from the smell.”

Burke said she is fed up with the unbearable smell.

“It’s just gross,” she said.

Her neighbors had similar complaints about the same issue back in June.

“I can’t go for a walk,” Luisa Ribeiro said then.

“We are worried about our health,” said Diane Borkowski.

> **ALSO READ: Cabarrus County company to pursue putting landfill on property →**

“It doesn’t make us happy. No one wants to be the stinky neighborhood,” said December Courtwright.

Channel 9 was told then that the North Carolina Division of Air Quality issued a notice to the

“I think it’s gotten worse,” she said. “I think everybody feels a bit defeated.”

Burke said it’s not just the smell, but the sights and sounds of the landfill she gets from her back windows.

“You can actually see like bags and bags and bags of trash coming out from the dump trucks going into the ground. Just all day,” she said.

She’s begging for help to make a change.

“If there’s anyone out there who can help us or can respond to this, or can help us just sort of deal with what feels like a constant intrusion, we would welcome to help,” she said. “Because it feels like there’s nobody there.”

The last documented smell complaint was from November. The Division of Air Quality did a site visit, but found no violations and noted the landfill appeared to be following the approved odor plan.

Republic Services shared the following statement with Channel 9:

“Charlotte Motor Speedway Landfill investigates all reports of potential off-site odor and conducts daily odor patrols in areas surrounding the landfill. We are utilizing odor misters and have added additional ground cover to the site. We are also in the process of completing more than $1 million in enhancements to the landfill’s infrastructure, including installing new gas collection wells and horizontal gas collection piping.

“Charlotte Motor Speedway is proud to have served this community for more than 30 years, and we continue to work closely with our regulatory partners on the odor management plan and all other aspects of our landfill operations. If residents detect an odor concern they believe can be attributed to the landfill, they can reach out to us in real time at our new odor reporting portal at charlottemotorspeedwaylandfill.com.”

(WATCH BELOW: Neighbors in Anson County upset over plans to expand landfill)

Neighbors in Anson County upset over plans to expand landfill

Hannah Goetz, wsoctv.com

Hannah is a reporter for WSOC-TV.

Read Next

‘Full of life’: Rock Hill rescue helps

Forecast from Chief Meteorologist

John Ahrens

AMS CERTIFIED

NOW	1 AM	4 AM
79°	78°	76°

From: Ken Eklund <futureeverything@writerguy.com>
Sent: Wednesday, July 16, 2025 2:38 PM
To: Benton Public Comment
Subject: Testimony in response to Republic-County-Pawlowski written material July 8-9 on Republic compliance
Attachments: B2 Teamsters declare 'war' with Republic Services, escalating strikes _ Waste Dive.pdf; B3 Coffin Butte mechanics on strike rally with union leaders.pdf; B5 Committee says county staff is stonewalling communications.pdf

RE: LU-24-027, the application to expand Coffin Butte Landfill
RECOMMENDATION: Please deny this application

Document ID: This is Part B, Compliance.

Dear Chair Fowler, Vice Chair Hamann, and Planning Commissioners Biscoe, Cash, Fulford, Lee, Struthers, and Wilson:

I'm submitting this letter in response to information in four items in the "9. New Evidence from July 8-9 Hearings" folder on Munidocs:

1. Republic's slide deck ("25RS1067 Coffin Butte Deck_FINAL")
2. County staff's slide deck ("Staff Slides to Planning Comm LU24027 July 8")
3. Brent Pawlowski's testimony ("07092025 PAWLOWSKI_Brent")
4. Jeff Kleinman's testimony ("07092025 KLEINMAN_Jeff")

Note: my letter has attached evidence A1 through A5. To view these attachments using the County's **Munidocs record** system, look to the Attachments section in this email's header, and double-click to view each one.

Also: for verification of statements made, this letter refers to testimonies in the Munidocs record that relate to the information in the above four items; I've linked to them so that you can quickly and easily refer to them. (And any attachments to *those* must also be double-clicked in their header, respectively, to open.)

I'm *trying* to be succinct, but there'a a lot to respond to. This is Part B: Compliance.

COMPLIANCE
Pawlowski, pp. 1-4
Republic presentation, pp. 2, 8-9, 13-15, 21
Staff presentation, pp. 4, 16-24, 27-28, 38, 40, 44-50
also
Kleinman pp. 3, 8, 11-12, 21, Planning Commission Findings for Denial 2021

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Conclusion. As put forth in law (Munidocs, **Kleinman New Evidence July 9**) and reinforced by common sense, the scheme for compliance laid out for you with the proposed mitigations and Conditions of Approval has to be "possible, likely and reasonably certain to succeed." There is no indications that is the case here. You have no prior examples to look at, because compliance with Conditions of Approval have not been demonstrated to have ever occurred. There's plenty of evidence that they've failed, however. There was (still is, actually) a requirement for Republic to plant trees to screen the landfill from view from Highway 99W, for example. And there are in fact no such trees there.

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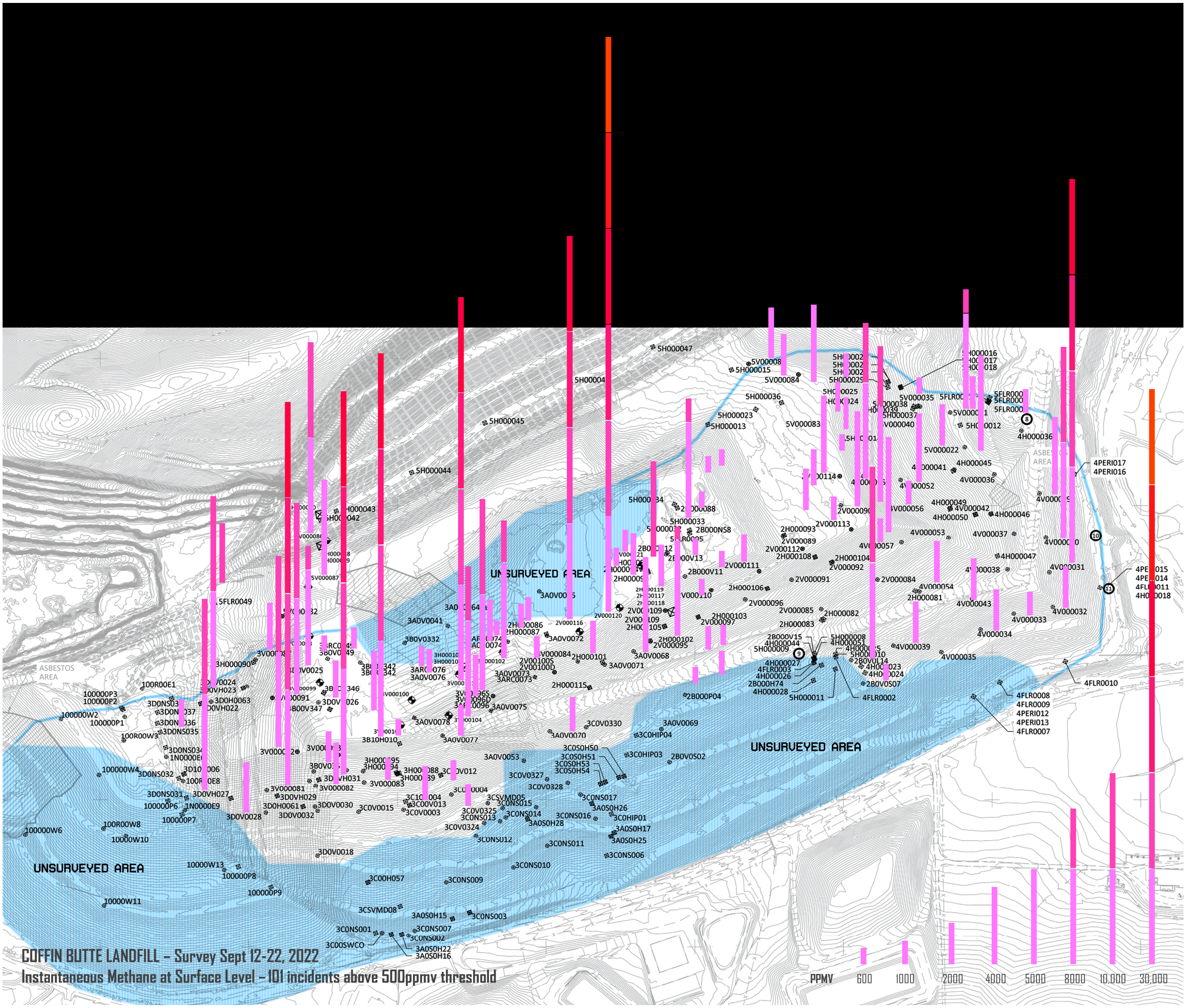
COFFIN BUTTE LANDFILL – Survey Sept 12-22, 2022
Instantaneous Methane at Surface Level – 101 incidents above 500ppmv threshold
UNSURVEYED AREA
UNSURVEYED AREA
UNSURVEYED AREA
ASBESTOS AREA
PPMV
600
1000
2000
4000
5000
8000
10,000
30,000

Ken Eklund, writerguy

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Corvallis OR 97330
408.623.8372

Creator of
World Without Oil
Ed Zed Omega
FutureCoast
and other storymaking games

From: Ken Eklund
To: Benton Public Comment
Subject: Testimony in response to Republic-County-Pawlowski written material July 8-9 on Republic compliance
Date: Wednesday, July 16, 2025 2:39:26 PM
Attachments: B1 Republic on Violation Tracker $162M fines.png
B2 Teamsters declare 'war' with Republic Services, escalating strikes _ Waste Dive.pdf
B3 Coffin Butte mechanics on strike rally with union leaders.pdf
B5 Committee says county staff is stonewalling communications.pdf

RE: LU-24-027, the application to expand Coffin Butte Landfill
RECOMMENDATION: Please deny this application

Document ID: This is Part B, Compliance.

Dear Chair Fowler, Vice Chair Hamann, and Planning Commissioners Biscoe, Cash, Fulford, Lee, Struthers, and Wilson:

I'm submitting this letter in response to information in four items in the "9. New Evidence from July 8-9 Hearings" folder on Munidocs:

1. Republic's slide deck ("25RS1067 Coffin Butte Deck_FINAL")
2. County staff's slide deck ("Staff Slides to Planning Comm LU24027 July 8")
3. Brent Pawlowski's testimony ("07092025 PAWLOWSKI_Brent")
4. Jeff Kleinman's testimony ("07092025 KLEINMAN_Jeff")

Note: my letter has attached evidence A1 through A5. To view these attachments using the County's **Munidocs record** system, look to the Attachments section in this email's header, and double-click to view each one.

Also: for verification of statements made, this letter refers to testimonies in the Munidocs record that relate to the information in the above four items; I've linked to them so that you can quickly and easily refer to them. (And any attachments to *those* must also be double-clicked in their header, respectively, to open.)

I'm *trying* to be succinct, but there'a a lot to respond to. This is Part B: Compliance.

COMPLIANCE
Pawlowski, pp. 1-4
Republic presentation, pp. 2, 8-9, 13-15, 21
Staff presentation, pp. 4, 16-24, 27-28, 38, 40, 44-50
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GOOD JOBS FIRST VIOLATION TRACKER

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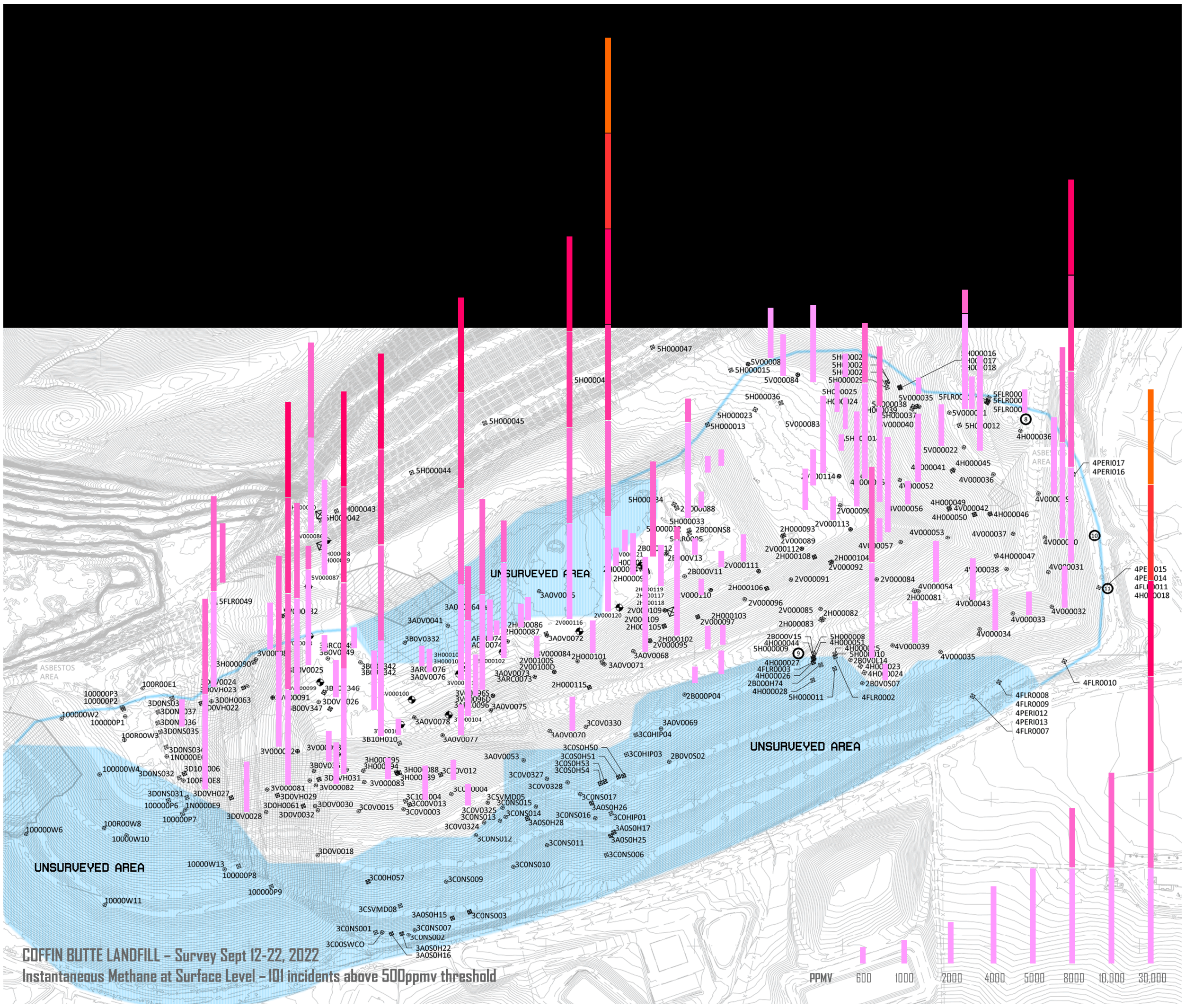

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The escalation comes a week after Local 25 went on strike against Republic Services in the Boston area. The national union claims Republic has not negotiated in good faith.

Published July 10, 2025

Jacob Wallace
Reporter

International Brotherhood of Teamsters Local 25 went on strike against Republic Services on July 1. The union claims Republic Services' proposed compensation package does not match that of other haulers in the area. *Permission granted by Teamsters Local 25*

Listen to the article 4 min

The International Brotherhood of Teamsters says more than 2,000 Republic Services workers represented by the union are either striking or honoring picket lines around the country, a rapid escalation of a dispute that kicked off in the Boston area last week.

The union is accusing Republic, the second largest waste company in the country, of

Services."

"Republic Services has been threatening a war with American workers for years — and now, they've got one," Teamsters General President Sean M. O'Brien said in a statement. "The Teamsters have had it with Republic. We will flood the streets and shut down garbage collection in state after state. Workers are uniting nationwide, and we will get the wages and benefits we've earned, come hell or high water."

The escalation comes after Teamsters Local 25, which serves the greater Boston area, announced it would go on strike on July 1. Since then, other chapters in California, Illinois, Georgia and Washington have announced they are on strike, while picket lines have extended to Seattle and the Bay Area in California.

Twenty-two percent of Republic Services' workers are unionized, the highest rate among large, publicly traded waste companies. Republic has maintained in statements that it is offering workers competitive labor contracts. For the Boston area contract, the company said its most recent contract offer would have included a 39% increase over five years and a 14% increase in the first year.

The company has also claimed striking workers damaged trucks brought in to replace service in the Boston area, a claim the union denies. In a release published Wednesday night, Republic said it was "ready to meet at any time with the Teamsters."

"We call on Teamsters' leadership to immediately stop the instigation, intimidation and criminal acts, and resolve this situation," the company said in a release.

Local 25 has said in statements that wages and benefits for the roughly 450 Republic Services workers it represents don't match those of other haulers in the Boston region, like Capitol Waste Services and Star Waste Systems. The union also claims that Republic has not offered to return to the table since the two sides' last meeting on July 3, nor has the company contacted the federal mediator both sides agreed to bring in to settle the dispute.

The two sides have had a series of disputes in recent years, though this is the largest conflict between Republic and the Teamsters, said Victor Mineros, Teamsters' director of the solid waste and recycling division and Western Region vice president.

"This is such a massive strike and the extensions are constantly growing and are going

Last year, Republic Services and Teamsters Local 104 in the Phoenix area — where the company's corporate headquarters is located — reached a contract agreement after a monthslong dispute. The chapter's members had authorized a strike there, though local leaders ultimately opted not to call one. Republic also paid nearly $300,000 last year to settle a separate dispute with workers represented by Teamsters in California.

The company reported revenue that topped $16 billion last year, up more than 7% year over year. It reported returning $1.18 billion in cash to shareholders in fiscal year 2024, including $490 million of share repurchases.

The Teamsters represent roughly 8,000 Republic Services workers nationwide, and have said the picket line could extend to about 3,500 workers if Republic does not agree to negotiate on the union's terms.

"They're fed up," Mineros said. "This can all end if Republic comes to the table and negotiates."

RECOMMENDED READING
Teamsters expand strike over Republic Services contracts
By Jacob Wallace • Updated July 2, 2025

Filed Under: **Collections & Transfer**

EDITORS' PICKS

Federal grantees reckon with loss of 'generational' recycling funding under Trump

By Jacob Wallace • May 21, 2025

EPA confirms SWIFR, REO grant funding disbursement on track

By Megan Quinn • April 14, 2025

ALERT FEATURED TOP STORY

Union leaders, House Speaker show support for Coffin Butte mechanics at rally

Mechanics, fellow employees, and community members lined the sidewalk in front of Republic Services in support of
Jess Hume-Pantuso, Mid-Valley Media

Kosiso Ugwuede

Striking Coffin Butte mechanics were joined by several union leaders, elected officials and concerned community members at a rally on Thursday, Sept. 12, in front of the Corvallis Republic Services office.

Carrying placards, with an inflatable "Scabby the Rat" mascot standing guard, a small group came out in support of the seven heavy duty mechanics **who have been striking**

since Sept. 11 at various locations around the Coffin Butte Landfill.

A Place to Sleep, episode 2: Albany, part II

Mid-Valley Media

The mechanics — who operate and maintain machinery used in moving and compacting the landfill — are protesting alleged unfair labor practices and unsafe work environment by Valley Landfills Inc. a subsidiary of the waste management company, Republic Services, which operates the Benton County-owned facility.

Since November 2022, the mechanics, who unanimously voted to join the International Union of Operating Engineers Local 701, have been in negotiations with the company to review their working conditions and wages.

According to one mechanic, Troy Paul, the negotiations were productive until conversations shifted into economic benefits, including pensions, wages and health insurance, which remains the knottiest issue on the table.

Jacob Stallings, attorney for Local 701, said last month that the company is rejecting the mechanics' proposal which would allow them to access insurance provided by the union. The plan offers them and their families more benefits for less money, an obvious win-win, he said.

An inflatable rat wielding a large banner highlighting the differences between the EPO900 United Healthcare Family Plan and I.U.O.E Family Healthcare Plan

Jess Hume-Pantuso, Mid-Valley Media

So far, Valley Landfills has responded to the demands of the mechanics with union-busting behavior, including intimidation, retaliation and canceled bargaining sessions, Stallings said last month.

"These workers have been demanding adequate and affordable health care, while being exposed to toxic chemical and dangerous machinery," Graham Trainor, Oregon chapter president of the AFL-CIO, said at the Thursday rally.

"It is our duty as Oregon labor to stand strong, shoulder-to-shoulder with them in this fight for however long it takes," Trainor said. "Whether it’s a group of seven workers or 7,000, their fight matters."

Republic Services, when contacted repeated its earlier statement to Mid-Valley Media, saying via email: "Republic Services is in contract negotiations with the union representing six maintenance technicians at our landfill in Benton County.

"We respect the rights of our employees to engage in collective bargaining and look forward to reaching a fair and competitive contract that is beneficial for our employees, our customers, and our company."

Graham Trainor, Oregon chapter president of the AFL-CIO, speaks at a rally for striking mechanics was held outside of the Republic Service office building, 110 NE Walnut Blvd. in Corvallis on Thursday, Oct. 12, 2023.

Jess Hume-Pantuso, Mid-Valley Media

Questions about the tenuous health insurance negotiations went unanswered.

Ed Eby, another mechanic who has been with the company for three years and on the maintenance unit for a year, said that so far, it has felt like the company wants to look the other way and ignore the mechanics.

"Stuff we're exposed to is just terrible, and then we take it home to our families who then get sick," said Lorne Nash, another mechanic who joined the company about a half-month before the strike began.

Rob Perdue gives a quick interview about the rally regarding Republic Services and what comes next for the mechanics on strike.

Jess Hume-Pantuso, Mid-Valley Media

"We don't have the compensation to be able to afford to go to the doctor and when we have to go, it'll just cripple us," Nash said.

He said he believes the pushback from the company stems from a lack of appreciation as well as a show of power. Without the backing of the union, Valley Landfills can exert control over the mechanics and keep them working in unsafe conditions, he added.

"We all understand that there is risk involved with our job, but some of that risk can be mitigated. But they refuse to," Nash said.

"Whether we're breathing it in or laying down in it, we're always exposed to something," said Logan Carter, who has been at the company for a year.

The mechanics, who work 10-hour shifts, said that they were exposed to all kinds of contaminants one might imagine results from a dump. Without a decontamination facility, the mechanics work only with basic personal protective equipment.

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Paul accused the company of valuing profits over people and being solely focused on attracting more trash to the landfill.

"As long as the money is flowing in then they don’t really care, and that needs to change," Paul said at the Thursday rally.

Oregon House Speaker Dan Rayfield, who was at the rally, expressed his support for the striking mechanics.

"It can feel alone being on the picket line," Rayfield, D-Corvallis, said during brief remarks. "As someone who lives in this community, we appreciate what you do for this community, and we appreciate what you’re fighting for."

Rayfield and a few colleagues have written to Republic Services in support of the mechanics’ demands.

"Because having a fair contract is not an option and having safe workplace conditions especially in Oregon is not an option," Rayfield said.

Other elected officials at the event included state Sens. James Manning, D-Eugene, and Deb Patterson, D-Salem. Representatives and leaders from local chapters of the AFL-CIO and United Auto Workers were also at the rally.

"It’s incredible to see the support that we have," Carter said about the turnout.

"Labor has to support labor, that’s what it's all about," Rob Perdue, UAW Local 492 president, said. "An injury to one is an injury to all."

Perdue and Local 492 have been striking in Beaverton for 21 days after UAW President Shawn Fain asked the unit to join the ongoing auto worker strike against Detroit car makers Stellantis, Ford and GM.

"It’s kind of sad but it seems to be the norm over the last 20 or 30 years," Perdue said of the manner in which billion-dollar companies treat their workers.

"We’ve seen that companies have their investors and interests in mind more than their workers," Perdue said.

- **Coffin Butte landfill mechanics on strike**
- **Who repressed speech at Coffin Butte event?**
- **Benton County commission unanimously rejects Coffin Butte landfill expansion plan**
- **Republic Services appeals county decision on Coffin Butte landfill expansion**

- **Republic Services pulls appeal on Coffin Butte landfill expansion**
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Kosisochukwu Ugwuede (she/her) covers the cities of Corvallis, Philomath & Millersburg. She can be reached via e-mail at [illegible] or by phone at 541-812-6091

[illegible]

ALERT FEATURED TOP STORY

Disposal site advisory committee says county staff is stonewalling communications

Birds surround the peak of Coffin Butte Landfill, looking for food scraps, while machinery works to compact the curre

Jess Hume-Pantuso, Mid-Valley Media

Kosiso Ugwuede

About a month after its resumption, several members of the Benton County Disposal Site Advisory Committee are concerned by what chair Ken Eklund has called a "stonewall" with the county's community development department staff.

The advisory board resumed meeting in October after two long breaks, first between September 2022 and May 2023 as a result of the **then-ongoing Benton County Trash**

Talks, and again from June to October 2023 for no clear reasons, according to Eklund.

Eklund says the committee is concerned that its recent interactions with county staff have stalled its advisory role as required by state law and impeded it from addressing important landfill issues.

But community development director Darren Nichols says the committee "has not been effectively gathering public insights for the past two years" adding, via email, that "the conversation has dwindled to a handful of passionate committee members operating with a narrower agenda."

[illegible]

To **"keep discussions at one table"** in relation to the Coffin Butte Landfill, the activities of the Disposal Site Advisory Committee as well as the Solid Waste Advisory Council were paused as the county turned all **of its attention to the Trash Talks taskforce**.

According to Nichols, the county's one-table policy was instituted upon the advice of Oregon Consensus (whose principal is Sam Imperati), the county's facilitator for the task force's fact-finding activities, because it is a typical feature of consensus building processes.

The goal, Nichols said, was to provide "one supported and coordinated space to share information and address the full range of issues around solid waste."

With the plan in place, the county will then "establish a new governance structure around solid waste and sustainable materials," according to Nichols, and the state's Department of Environmental Quality was in support of this policy.

The advisory committee fought its way into meeting for an hour during that time, according to Eklund, although they could only discuss issues that pertained to the taskforce and **the report it was compiling** on the Coffin Butte Landfill. It was in no way like its regular meetings — which, according to state law, must be held at least four times in a calendar year — and the committee did not set its own agenda.

Then SWAC was dissolved.

According to Nichols, SWAC's dissolution simply had to do with the county's long-term and wide-ranging trash plans.

"Benton County is replacing the earlier version of the Solid Waste Advisory Council (SWAC) with a more appropriate regional advisory committee during the development of a sustainable materials management plan," Nichols said via email.

At the committee's meeting on Oct. 25, Nichols said an ad-hoc committee was being formed in the interim to fill in for the dissolved council pending the development of the county's sustainable materials management plan.

Members of the disposal site advisory committee are not buying these reasons.

Joel Geier, also a member of the dissolved council, said he found the county's one-table policy "absurd."

In an email to county commissioners dated Nov. 2, Geier said this was especially so because the county "has systematically excluded and removed voices from the 'one table,' ever since the start of the BCTT process."

Regarding the long-term trash plans, Geier said it was concerning that pertinent issues like the **EPA'S methane gas emission warning**, **leachate being sent to treatment plans not designed to remove hazardous chemicals** and recorded groundwater contamination captured in the Trash Talks report were not being captured in what ought to be a long-term waste management plan.

"These are disposal site issues, and thus are appropriate topics for the Disposal Site Advisory Committee," Geier wrote.

"Recent actions by county staff to restrict the scope of meetings and to schedule meetings arbitrarily, without consulting DSAC members, have been a step in the opposite direction," the email further said.

Mark Yeager, another member of the committee, said during the Oct. 25 meeting that SWAC's dissolution was **in violation of county code** and there were still unanswered questions about what responsibilities this proposed interim committee could handle to fill in for the dissolved council. If a conditional use permit request arose, for instance, before the sustainable material plan process was completed and a new advisory body instituted, could the interim committee make standing decisions on it?

It was also concerning, according to Yeager, that members of the disposal site committee had not been asked to be on the interim council being formed.

Nichols said at the meeting that the committee could nominate a member, a topic the group agreed to discuss at the next meeting that was to be held Nov. 16.

On Nov. 9, Nichols emailed the committee to announce the meeting was cancelled. The email said the meeting date was not suitable for multiple members and no comment was made about rescheduling it to a later date in November.

The disposal site advisory committee exists based on state law.

The law (ORS 495.320) mandates every county where a regional landfill is proposed or exists to institute a disposal advisory committee comprising the disposal site's neighbors, property owners as well as employees of the operator. The committee's role is to review the siting, operation, closure and long-term monitoring of said site.

According to the county's 2020 DSAC by-laws, the chair of the committee develops the agenda for the meeting with assistance from the community development director or their designee.

Nichols says the state law does "give the Board of Commissioners authority to schedule committee meetings, set committee agenda topics, appoint ex-officio members and amend the committee bylaws."

One such amendment, which came after a Sept. 5 board of commissioners meeting, was a motion moved by Commissioner Nancy Wyse and seconded by Xan Augerot "to direct staff to schedule monthly DSAC meetings and create meeting agendas to fulfill Benton County's statutory responsibilities in October, November and December 2023."

Nichols said the chair and committee were informed of this revision.

Eklund said that after he'd received the staff's agenda, which he considered preliminary, he prepared one as chair of the committee incorporating the staff's agenda as dictated by the by-laws and shared with staff a week ahead of the meeting. He received no response.

But at the Oct. 25 meeting, both staff and committee members spent more than half an hour in a tense exchange trying to determine which agenda will guide the deliberations. A non-committee member who joined the meeting made a threatening remark to one of the community development staff, exacerbating the already tense meeting.

The staff's agenda for the Oct. 25 meeting listed six items, key of which were (in time allotment): the community concerns about the annual report for 2021, community comments and review of minutes for nine meetings prior.

Eklund's agenda included items he believed were more important to the committee, like setting a regular meeting schedule and reviewing language on the DSAC's web page. He also reallotted time frames to the county staff's agenda.

In his agenda, Eklund allotted the first 25 minutes to "regrounding the committee" since this was the first regular meeting to be held in over a year and, according to the agenda, the meeting was "reconvening in an environment that is much different in terms of staff support."

"For some reason, the agenda prepared by staff had basically an hour allotted for an item where, where we're at with the item is waiting for staff to supply us with documents and so there's nothing to report, there's nothing to do," Eklund said on a call.

According to Eklund, this control over the agenda is a key struggle about the sovereignty of the committee and who decides what they can or can’t discuss at the meetings.

Another committee member, Marge Popp, **who participated in the Trash Talks workgroup**, said she "encountered similar tendencies to control subcommittee process and output by the same staff responsible for liaison with DSAC."

As soon as the committee was directed to resume its meetings, Eklund said he made a public request to the community development staff on Sept. 15 to better understand SWAC’S dissolution. By Oct. 6, the request had not been acknowledged, causing Eklund to flag the request to Nichols citing the Freedom of Information Act as governing the request, which seemed to move it along.

Other records requests he’d made that were not yet responded to at the time of this interview included requests for public comments reports to assist in the compilation of the community concerns annual report for 2021 and 2022.

Every year, county staff collect community concerns and comments regarding the landfill and compile it into a report that is then presented to the committee for review and editing before it is sent off to the state’s Department of Environmental Quality, as required by law.

"The prior reports are posted and publicly accessible on the committee’s website, so they don’t require a public request," Nichols said.

Solid waste and water quality program coordinator Daniel Redick developed a draft of the 2021 report and brought it to the committee last July. But Eklund said they’d failed to include material related to the landfill expansion which the committee believed was a significant omission.

Conversations about the landfill’s expansion began in late 2021. Following an approval recommendation by the solid waste advisory council, the application went to the Planning Commission who held public hearings in November where an overwhelming amount of opposition to its expansion was received.

Eklund said all of that feedback was supposed to be in the 2021 community concerns report. Before the committee could reconvene in October (meetings are held once every quarter), their activities were paused for the Trash Talks taskforce.

Eklund says that in his interpretation of the state law, the committee may not make the four regular meetings per year required of them.

However, Nichols said the committee refuses to acknowledge the staff's community comments report.

The staff report acknowledges that it "does not detail each of the community member concerns received throughout that public hearing process," but it listed concerns culled from the process in a table which included concerns about out-of-county waste, groundwater quality, air quality, odor and greenhouse gas emissions, among other concerns.

"Some members have repeatedly resisted the Board's direction to complete the committee's basic responsibilities, which are to read and approve the 2021 and 2022 reports which then needs to be filed with the Oregon DEQ," Nichols said.

In retrospect, Eklund says he wishes he had put his foot down regarding control over the committee's schedule and agenda before they were suspended last year.

"I believe it is surprisingly difficult for county staff to appreciate the harm a landfill exacts on the environment, and balance that cost against the revenue generated by the franchise fee," Popp said via email.

Eklund thinks the stonewalling goes beyond current or potential franchise fee revenue.

"It seems like there's something else also that has to do with discouraging essentially very active participation in the process from my point of view so far," Eklund said.

Popp said she understands the task of the county staff is tough, but she wishes "they would at least try to do it. And elicit help from residents, not waste time fighting them."

In spite of staff's cancelation of the scheduled November meeting, Eklund has called for a committee meeting on Nov. 27 standing on state and county law, set an agenda which includes discussing a steadier meeting schedule, and has asked the community development staff to respond if it has any concerns.

Related stories:

- **EPA: Methane gas levels at Coffin Butte landfill are concerning**
- **Benton County trash report: Next step is charting a new plan**
- **Union leaders, House Speaker show support for Coffin Butte mechanics at rally**
- **Republic Services appeals county decision on Coffin Butte landfill expansion**

Kosisochukwu Ugwuede (she/her) covers the cities of Corvallis, Philomath & Millersburg. She can be reached via e-mail at [illegible] or by phone via 541-812-6091

[illegible]

From: Ken Eklund
To: Benton Public Comment
Subject: Testimony in response to Republic-County-Pawlowski written material July 8-9: Odor addendum
Date: Wednesday, July 16, 2025 4:19:47 PM
Attachments: 5_001-condensed KE.pdf

RE: LU-24-027, the application to expand Coffin Butte Landfill
RECOMMENDATION: Please deny this application

Document ID: This is a late-breaking Addendum to Part A, Odor (submitted previously).

Dear Chair Fowler, Vice Chair Hamann, and Planning Commissioners Biscoe, Cash, Fulford, Lee, Struthers, and Wilson:

I'm submitting this Addendum in response to information in three items in the in the "9. New Evidence from July 8-9 Hearings" folder on Munidocs, on the subject of dump odor:

1. Republic's slide deck ("25RS1067 Coffin Butte Deck_FINAL") Republic presentation
2. County staff's slide deck ("Staff Slides to Planning Comm LU24027 July 8") Staff presentation
3. Brent Pawlowski's testimony ("07092025 PAWLOWSKI_Brent") Pawlowski

Please note: my letter has evidence attached as a PDF. To view this attachment using the County's **Munidocs record** system, look to the Attachments section in this email's header, and double-click to view the PDF.

To be brief: I've just now received a response to a Freedom Of Information Act request submitted to the EPA, for documents related to EPA Enforcement's Section 114 Information Request filed in January. I thus have a new document relevant to my Part A: Odor testimony, filed earlier today. That document is attached.

The Section 114 IR asked Republic to:

5. Provide information regarding citizen complaints that the Landfill has knowledge of between January 1, 2022, and the date of this request. The information should include:

a. *Date and time;*
b. *Location at or near the Landfill which.is the subject of the complaint;*
c. *Copy or description of complaint;*
d. *Corrective action or monitoring done as a result; and*

e. *Name and contact information for the person who submitted the complaint.*

Republic responded:

> *The PDF provided in Folder 5 includes the information that the site has regarding citizen complaints from January 2022 to January 2025. Persons who responded to this request include Paul Koster, Environmental Manager.*

I've attached "the PDF provided in Folder 5" with blank pages removed for file size/conciseness. **I thought you might appreciate receiving Republic's raw data, which you can compare to how it is portrayed in the Applicant's Odor Study. You can now read actual comments about the odor made by the community members, for example, and where they were relative to the landfill when they smelled the odor.**

You'll also note that Republic apparently does not receive or retain complaints expressed to Benton County, including those expressed to the Disposal Site Advisory Committee.

Note: the gray "(B) (6)" blocks are EPA redacting personal information – i.e., they are instances when a community member contacted Republic directly. (Most people contacted DEQ rather than Republic. I'm not sure Republic *ever* publicized their complaint portal?)

Thank you all for your diligence and contribution to our community!

Ken Eklund

Ken Eklund, writerguy

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Creator of
World Without Oil
Ed Zed Omega
FutureCoast

and other storymaking games

Month: **Feb-2022**

#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
	2/22		DEQ informed us of 25 odor complaints they had received between 11/18/21 and 2/7/22. No additional details provided	N/A					N/A

#	Month: Aug-2022 Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	8/17	N/A	DEQ	assorted via DEQ					
	7/1	10am	via DEQ	n/a	"The usual stench from the landfill. Once again occuring at my location as the marine clouds lift and the day warms.				N/A
	7/26	8am	via DEQ	n/a	"odors from the Coffin Butte Landfill. Quite noticeable this morning while we had a high pressure system and no wind", complex toxic chemical slew				N/A
	7/30	8am	via DEQ	n/a	Coffin Butte Landfill by Republic. Sulfur, dump odor				N/A
	8/15	9:13 AM	via DEQ	n/a	"the Coffin Butte Dump smell is noticeable on occasion. Today it is really bad. To the point of making me sick to my stomach when I walk around outside", methane				N/A

	Month: Sep-2023								
#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	9/28		N/A (forwarded from DEQ) 2/7/24		"overpowering and pervasive to my nostrils and eyes"				

Month: **Nov-2023**

#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	11/21	N/A	(b) (6)	Writsman Creek Dr	"dump smell"				
2	11/29	12:40pm	(b) (6)	Writsman Creek Dr					

Month: Dec-2023									
#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	12/1	3:36pm	(b) (6)	Writsman Creek Dr					
2	12/12	1:35pm	(b) (6)	Writsman Creek Dr					
3	12/16	2:00pm		Writsman Creek Dr	"overwelming stench this morning"				
4	12/14		N/A (forwarded from DEQ) 2/7/24		"particularly nasty"	N/A	N/A	N/A	N/A
5	12/15	12:00 PM	N/A (forwarded from DEQ) 2/7/24	highway 20 at independence highway	"absolutely overpowering"				
6	12/25		N/A (forwarded from DEQ) 2/7/24		"like rotten garbage, some sort of gas"				

	Month:	Jan-2024							
#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	1/12	12:15pm	N/A (forwarded from DEQ)	"apx 3 miles from Cof	"horrible smell of the landfill"	6-Apr	NE	41	
2	1/18	12:00 PM	N/A (forwarded from DEQ) 2/7/24						
3	1/18	1:30 PM	N/A (forwarded from DEQ) 2/7/24	"several miles south of Coffin Butte landfill"	"incredibly intense"				
4	1/18	12:00 PM	N/A (forwarded from DEQ) 2/7/24		"odor was very obvious"				
5	1/18	4:00 PM	N/A (forwarded from DEQ) 2/7/24	"town of Corvallis"	"hits you like a wet blanket and permeates into the home as well"				
6	1/18	3:30 PM	N/A (forwarded from DEQ) 2/7/24		"really bad"				
7	1/19	8:00 AM	N/A (forwarded from DEQ) 2/7/24		"very apparent"				

	Month: Feb-2024								
#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	2/3	3:00 PM	N/A (forwarded from DEQ) 2/7/24		"Chemical type smell, Horrible"				
2	2/3	10:00 AM	N/A (forwarded from DEQ) 2/7/24		"Strong smell of methane"				
3	2/3	9:00 AM	N/A (forwarded from DEQ) 2/7/24		"foul chemical odor"				
4	2/3	1:00 PM	N/A (forwarded from DEQ) 2/7/24	"apx 3 miles from the landfill"	"nasty, horrible and probably not good for anyone to breathe"				
5	2/3		N/A (forwarded from DEQ) 2/16/24	"south end Tampico Rd"	"so strong"				
6	2/8	12:46 PM	N/A (forwarded from DEQ) 2/16/24		"strong"				
7	2/10	7:30 AM	N/A (forwarded from DEQ) 2/16/24	"soap creek rd"	"awful stench"				
8	2/10	8:30 AM	N/A (forwarded from DEQ) 2/16/24	"soap creek valley"	"stinky air" "especially bad"				
9	2/10	9:29 AM	N/A (forwarded from DEQ) 2/16/24	"by the landfill"					
10	2/13		N/A (forwarded from DEQ) 2/16/24	"above 800ft elevation, along Vineyard Mountain Ridge"	"the usual Coffin Butte stench"				
11	2/14	8:30 AM	N/A (forwarded from DEQ) 2/16/24		"very bad"				
12	2/14	11:00 AM	N/A (forwarded from DEQ) 2/23/24	"my home, Soap creek rd, Tampico rd, Adair Village"	"usual rotting garbage odor"				
13	2/15	10:51 PM	N/A (forwarded from DEQ) 2/23/24		"extremely strong"				
14	2/20	3:37 PM	N/A (forwarded from DEQ) 2/23/24		"malodorous chemical smell"				
15	2/20	9:00 AM	N/A (forwarded from DEQ) 2/23/24		"rotting garbage"				
16	2/20	3:00 PM	N/A (forwarded from DEQ) 2/23/24	700-800 ft elevation	"usual landfill stench"				
17	2/22	10:48 AM	N/A (forwarded from DEQ) 3/1/24	7 miles south of the landfill					
18	2/24	1:00 PM	N/A (forwarded from DEQ) 3/1/24		"Rotting stench"				
19	2/24		N/A (forwarded from DEQ) 3/1/24	3 miles south of landfill	"sour, reeking stench"				

#	Month: Mar-2024 Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	3/6	7:30 AM	forwarded from DEQ	"South of Landfill"	"Reeking Stench"	0	SSE	27.6	unknown
2	3/8	1:00 PM	(b) (6)	(b) (6)	"5"	3	W	45	unknown
3	3/8	8:30 AM	(b) (6)		"rotting garbage plus acrid chemical smell", level 8	0	SSE	32	unknown
4	3/12	2:30 PM	forwarded from DEQ	E.E. Wilson State Wildlife Area	"landfill odor with a noxious chemical component"	9	SSW	50	unknown
5	3/23	8:00 AM	(b) (6)	White Fir and Trillium Lane, also Robison road	"foul/gassy, for two hours"	0-6	SSW	45	unknown

#	Month: Apr-2024 Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	4/1	8:00 AM	(b) (6)		10	0	SSW	40	N/A
2	4/1	9:00 AM	(b) (6)		"incredibly bad", 10	0	SSW	42	N/A
3	4/1	11:30 PM	(b) (6)		10, "smells like rotten eggs. But worse. More chemically."	0	SE	51	N/A
4	4/12	7:00 AM	forwarded from DEQ	"my house"	"overpowering landfill stench"	0	SSW	38	N/A

Month: **May-2024**

#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	5/2	7:00 PM	forwarded from DEQ		"Strong odors"	7	NE	76.6	
2	5/23	7:30 AM	forwarded from DEQ		"smell of Garbage" overwhelming	4	SW	55	
3	5/23	7:50 AM	forwarded from DEQ	5 miles from the dump	smell the dump	3	SW	56	
4	5/23	9:30 AM	forwarded from DEQ	5 miles south, adair	"coffin Butte's effluence"	5	SW	42	
5	5/23	6:00 PM	forwarded from DEQ	"near coffin Butte"	"trash and rotten egg"	5	NE	85	

Month: Jul-2024

#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	7/12	12:06am	forwarded from DEQ	"south of the landfill"	"landfill smell"				
2	7/24	1:00 PM	forwarded from DEQ	near SE corner of Landfill buffer property	Noticeable unpleasant methane odor	6	S	78.3	
3	7/30	5:30 PM	forwarded from DEQ	4 miles SE of landfill	"landfill dump smell"				

Month: Aug-2024

#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	8/8	7:40 AM	(b) (6)	Oak Grove Drive & Powers	"dump smell, like driving by", "10"	0		58.6	N/A
2	8/8	7:45 AM	(b) (6)	Palestine & Oak Grove	"9"	0		58.6	
3	8/18	7:30am	(b) (6)	Oak Grove Drive & Powers	"smells like driving by the dump", 8	0	S	57.8	
	8/9	3:15 PM	forwarded from DEQ		Piercing garbage smell				
	8/9	5:53 PM	forwarded from DEQ	"miles away"	"terrible smell"				
	8/4	8:30 AM	forwarded from DEQ (8/26)	SW of Landfill or driving by	dump stench				
	8/23	6:30 PM	forwarded from DEQ	South of Landfill	"landfill chemical stink"				

Month:	Nov-2024								
#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	11/26	11:30 AM	forwarded from DEQ	N/A	"Coffin Butte dump stench"				
2	11/27	7:15 AM	forwarded from DEQ	N/A	"went outside with my cup of coffee. Hit with the smell of the landfill"				
3	11/30	10:00 AM	forwarded from DEQ	7 miles S of landfill	"sitting at my dest, when I stared to smell it. It lasted for a about 3 hours"				
4	11/30	12:00 PM	forwarded from DEQ	"passing by the… landfill"	"a terrible odor that we could smell from our car for about a mile north				

Month: **Dec-2024**

#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	12/1	10:00 AM	forwarded from DEQ	"near Coffin Butte"	"odor is so bad"	1	SSW	30.3	
2	12/1	10:00 AM	forwarded from DEQ	n/a	"sometimes unbearable"	1	SSW	30.3	
3	12/1	11:52 AM	forwarded from DEQ	"soap creek valley"	"toxic landfill gases"	3	N	33.2	
4	12/1	8:30 AM	forwarded from DEQ	Soap Creek/Writsman Brook	"some sort of chemical", "rotten garbage"	0	SSW	28.2	
5	12/6	9:45 AM	forwarded from DEQ	n/a	"landfill stench"	0	NNE	30	
6	12/14	1:30 PM	forwarded from DEQ	Coffin Butte Road	"like a cross between a putrid low tide and an auto repair garage".	3	SSW	47	
7	12/20	3:00 PM	forwarded from DEQ	4 miles SSE of the Landfill	"odor" "far worse than usual"	0	W	50.2	
8	12/23	2:00 PM	(b) (6)		landfill smell, 5	0	NE	44.9	
9	12/23	9:30 AM	forwarded from DEQ	6.3 miles away	"stench very noticeable"				
10	12/29	9:29 AM	(b) (6) (also received forwarded from DEQ)	"driving past dump"	"stench", "not one type of aroma"	2	SSE	46.4	
11	12/29	4:45 PM	forwarded from DEQ	n/a	"strong methane odor"	2	S	44.1	
12	12/31	3:45 PM	forwarded from DEQ	n/a	"stink"	3	S	38.3	

Month: **Jan-2025**

#	Date	Time	Complainant	Location of Odor	Description/ Rating Scale	Wind Speed	Wind Direction	Temp	Odor Source
1	1/1	12:00 AM	forwarded from DEQ	5 miles from landfill	very strong odor				
2	1/5	11:50 AM	forwarded from DEQ	n/a	"to much methane and garbage"				
3	1/7	3:30 PM	forwarded from DEQ	n/a	"methane odor"				
4	1/9	1:30 PM	forwarded from DEQ	south of landfill	"somewhat sulfurous and sickening"				
5	1/9	6:00 PM	forwarded from DEQ	SE side of Vineyard Mtn	"smell the landfill"				
6	1/9	all day	forwarded from DEQ	"south of Landfill"	garbage-landfill odor				
7	1/11	n/a	forwarded from DEQ	n/a	"very overwhelming"				
8	1/12	11:00 AM	forwarded from DEQ	n/a	"Very Potent"				
9	1/14	n/a	forwarded from DEQ	Tampico Road	"odor of landfill gas"				
10	1/21	10:30 AM	forwarded from DEQ						
	1/21	10:30 AM	forwarded from DEQ	Soap Creek Valley					
	1/21		forwarded from DEQ						
	1/21	4:00 PM	forwarded from DEQ		Unpleasant smell, overpowering stench				
	1/29	10:30 AM	(b) (6)		"smells bad outside", level 5				

From:	Ken Eklund
To:	Benton Public Comment
Subject:	Testimony in response to Republic-County-Pawlowski written material July 8-9: PFAS
Date:	Wednesday, July 16, 2025 4:58:25 PM
Attachments:	writerguy-cube2.png

RE: LU-24-027, the application to expand Coffin Butte Landfill
RECOMMENDATION: Please deny this application
ID: This is Part C: Concentrating PFAS.

Dear Chair Fowler, Vice Chair Hamann, and Planning Commissioners Biscoe, Cash, Fulford, Lee, Struthers, and Wilson:

This is testimony in response to the July 8, 2025, slide presentation made by Republic Services. It also refers to evidence and testimonies previously submitted, and provides links to articles of evidence and testimonies in the Munidocs record, to help you locate them.

CONCENTRATING PFAS
Republic (RS) presentation, p. 26
Staff presentation by reference
Pawlowski by reference

Slide 16 of the RS presentation addresses the comment "*Coffin Butte landfill leachate contains PFAS*".

RS comment - *PFAS concentrations measured in Coffin Butte Landfill leachate samples are similar to PFAS concentrations measured in a study of landfill leachate and leachate samples collected from California MSW landfills.*

- I notice that RS carefully doesn't say what the PFAS load is – so we can't actually verify their assertion. Why is that?
- Landfill leachate is known for its PFAS load. Saying that the PFAS levels in Coffin Butte Landfill (CBL) leachate are no worse than that of other landfills is not helpful in addressing the seriousness of the concern. Other landfills are concerned too: even low levels of PFAS are of great concern.
- How leachate is treated and where those PFAS (and other toxic components) end up is critical to completing the picture. So, let's talk about that:
    - Somewhere around 35 million gallons of CBL leachate is processed with municipal wastewater at municipal wastewater treatment plants (WWTPs) every year. Currently, those are WWTPs in Corvallis and Salem.
    - As described in Pam Castle's 6/11/2025 written testimony (https://library.municode.com/or/benton_county/munidocs/munidocs?nodeId=8135d7834e2c8), **municipal wastewater treatment plants (WWTPs) do not treat PFAS**. PFAS removal requires specific processes that are not

included in WWTP process, so the PFAS entering the municipal wastewater plant with leachate are not removed during treatment. Instead, they are:

    - Released into the Willamette River with WWTP effluent
    - Distributed into the air as aerosolized droplets generated during aeration steps of wastewater treatment. PFAS levels are higher around WWTPs.
    - Spread with biosolids onto soils in the region.

  - **Aeration at WWTPs converts precursor molecules in landfill leachate into PFAS.** In other words, treatment at WWTPs makes the landfill leachate PFAS problem worse.

- A comparison of PFAS concentrations (provided by Clean Water Services) in leachate from three western Oregon landfills – Riverbend, Hillsboro and Coffin Butte – refutes the applicant's statement claiming that the PFAS concentrations in CBL leachate are similar to those of other landfills. Of the six PFAS compared in a plot of this data (submitted to the record by Dr. Joel Geier) **three were present in much higher concentrations in CBL leachate**. The PFBS concentration in CBL leachate was approximately **4 times** that of Riverbend landfill leachate and over **10 times** that of Hillsboro landfill leachate.
  - This is particularly concerning given the findings in the recently released Waterkeepers PFAS Phase II study of sites downstream from 22 U.S. WWTPs nationwide. The Rock Creek WRRF receives Hillsboro landfill leachate and releases its effluent into the Tualatin River. This waterway was in the top 6 for number of PFAS found to be elevated downstream of the effluent release. It tied for 4th place with two other landfills.
  - In addition, the increase in total PFAS concentration in the Tualatin River downstream from where the Rock Creek WRRF effluent is released was the 5th highest increase of the 22 waterways studied.

RS comment – *No PFAS have ben detected in City drinking water.*

- It is important to note that the intake for the city of Corvallis' drinking water is UPSTREAM of the City of Corvallis' WWTP effluent discharge into the Willamette River. Because of this, we would wouldn't expect the PFAS in WWTP effluent to affect the Corvallis drinking water.
  - It could, however, affect the Adair Village drinking water supply since their intake is downstream of the release of the Corvallis WWTP effluent. And it could affect other communities further downstream.
- A more appropriate measure of the effect of PFAS on the area would be the PFAS concentration in Corvallis WWTP effluent. Those PFAS are released into the Willamette River.

RS comment – *Currently there is no formal requirement to monitor PFAS in leachate or groundwater.*

- This does not lessen the concern about or the need for monitoring PFAS. Government agencies are slow to adopt and enforce rules. Waiting until CBL is forced to stop spreading PFAS in the environment does not fit with their “good community member” descriptor.

- As very recently reported by The Guardian newspaper, the U.S. government has pulled $15 million in funding earmarked to study the effects of PFAS contamination of agricultural land, contamination primarily due to spreading of biosolids from WWTPs. These studies were designed to determine how PFAS move into and accumulate in crops and livestock and enter our food supply.
    - This is an example of why we cannot wait on agencies to police this issue. They aren’t going to be able to do that for a long time. Meanwhile, PFAS-laden WWTP biosolids continue to be spread onto our fields. A good neighbor would monitor their leachate’s PFAS and stop sending it to the WWTP where those PFAS go on to contaminate our environment.

RS comment – *The amount of leachate treated at the City of Corvallis’ WWTP represents 0.0058% of the water treated by the WWTP.*

- This is a 100-fold underestimate. If the WWTP processed 4 billion gallons total and 23 million gallons of that was landfill leachate, the leachate accounted for 0.0058 of total. Multiply that by 100 and you get a total percentage of 0.58%, rather than the 0.0058% reported.
- Trace quantities of PFAS are of concern for human and environmental health.
- PFAS are persistent in the environment, landfill leachate has an outsized PFAS load compared to municipal wastewater, and repeated, long-term exposure to PFAS cause harm making seemingly small volumes of leachate of importance.

Please deny LU-24-027, for findings that it has not been proven not to risk the health of its neighbors and area.

Ken Eklund, writerguy

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Creator of
World Without Oil
Ed Zed Omega
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and other storymaking games