From: Joel Geier
To: Coffin Butte Landfill Appeals
Subject: LU-24-027 Arsenic issues
Date: Monday, October 20, 2025 3:51:21 PM
Attachments: Arsenic Simple Scoping Calculation 2025-10-20.pdf

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Please add the attached PDF document, discussing arsenic anomalies at the Coffin Butte landfill site and possible explanations, to the public record for LU-24-027. My address is included in the PDF.

Thank you again,
Joel Geier, Ph.D.

Dear Commissioners Wyse, Malone, and Shepherd:

Thank you for your attention to yet another bit of testimony regarding LU-24-027. As stated in previous testimony, my address is 38566 Hwy 99W, Corvallis, 97330, and I work internationally as a consultant specializing in fractured rock hydrogeology, which includes both groundwater flow and solute transport.

One of the most controversial topics regarding the environmental impacts of Coffin Butte landfill, and the proposed expansion to create a new landfill on Tampico Ridge, is whether seepage of leachate into groundwater has occurred, and/or could occur in the future. Unlike air pollution and pollution of rivers by the practice of trucking leachate to municipal wastewater treatment plants that discharge to the Willamette River, groundwater impacts occur mostly "out of sight and out of mind," and are thus more difficult to demonstrate conclusively.

One part of this controversy is the observation of anomalously high levels of arsenic in groundwater monitoring wells on the east side of the existing landfill. High levels of arsenic, exceeding maximum contaminant limits for drinking water set by the US EPA, have been measured in wells on the east side of Coffin Butte Landfill for more than thirty years.[1] These high levels of arsenic in groundwater are highly unusual both in Benton County and for Polk County.[2] Also for more than thirty years, consultants for the applicant have offered a series of shifting excuses, none of which have held up to scientific scrutiny.

In their most recent filings in support of their appeal of the Planning Commission's unanimous decision to deny LU-24-027, the applicant offers a new excuse for the high levels of arsenic. Here I provide you with simple calculations to show why the applicant's newest excuse is not plausible.

1 Arsenic levels for wells on the east side of Coffin Butte landfill have been reported in Annual Environmental Monitoring Reports (AEMRs), submitted by the applicant to Oregon DEQ. The 2023 AEMR is included in the record for LU-24-027.

2 Hinkle, S. and Polette, D. (1999) Arsenic in Ground Water of the Willamette Basin, Oregon. U.S. Geological Survey Water-Resources Investigations Report 98-4205, 27 p. (also included in the record for LU-24-027 and cited in previous testimony).

This is directly relevant to to the review criteria that you are asked to consider, in particular BCC 53.215, because clean water is a fundamental public facility. Access to clean water is internationally recognized as a basic human right[3], and protection of clean water resources is an obligation of governments at all levels. In north Benton County, and adjoining areas of Polk County Clean groundwater resources are particularly vital to residential and agricultural uses of rural areas, and are also part of the <u>character of the area</u>.

The applicant's new excuse for high arsenic on the east side of the landfill, presented in their Exhibit 67, can be stated in simple terms as follows:
They suggest that conditions of low oxygen below the landfill cause arsenic to be released from the sediments. Based on chemical analysis of a few rock samples, they claim that the basalt bedrock contains enough arsenic to account for the high levels observed in monitoring wells.

Does this newest excuse hold up? No, it does not. *This process would need to have started over 7000 years ago, at the very dawn of Sumerian civilization*. This can be demonstrated by simple calculations, as given in the following pages.

There are indeed unresolved scientific issues regarding the anomalous arsenic levels at this site. The best chance of resolving those questions would be to improve the monitoring system. The applicant's reluctance to do so does not portend well for their willingness to address similar issues that could arise from the proposed new landfill. Please uphold the decision of your Planning Commission, to deny this application.

Yours sincerely,
Joel Geier, Ph.D.

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3 United Nations, 2010. Resolution adopted by the general assembly. 64/292. The human right to water and sanitation. A/RES/64/292. New York: United Nations.

Simple calculations of potential arsenic leaching from Coffin Butte basalt

This question can be addressed by some very simple calculations, with the following steps:

1. Estimate the amount of arsenic that groundwater carries out from under the landfill per year.
2. Multiply this by the 30 year time over which these high levels have been observed.
3. Determine what thickness into the surface of the fresh basalt surface would need to be accessed, to extract that much arsenic from the native bedrock.

The result can then be compared to the rate at which such processes are estimated to occur, from independent scientific research on alteration of basalts.

The rate at which arsenic is carried out from under the landfill can be estimated as:

(arsenic concentration) x (flow rate leaving the east side)

The flow rate is:

(groundwater velocity) x (porosity) x (cross-sectional area)

where "porosity" is the open fraction of the sediments (space between sediment grains). For unconsolidated sediments, porosity is typically in the range 10% to 30%, with 20% as a reasonable average value.

The applicant's consultants have estimated groundwater velocities through sediments at this site to range from 20 to 100 ft/y (feet per year)[4], so 50 ft/y may be taken as a reasonable intermediate value.

The cross-sectional area is the width of the area from which groundwater flows out on the east side, times the thickness of the sediments. From the applicant's ground maps, the width of the discharge area is about 1500 ft.

4 EMCON, 1994, also cited in the applicant's exhibits and AEMRs.

The thickness of sediments is at least 22.7 ft in monitoring well MW-23, 28.0 ft in MW-26, and 35.5 ft in MW-27.[5] As commented in Benton County DSAC's assessment of the monitoring wells at Coffin Butte[6], none of these wells were completed across the sediment/bedrock contact, so the actual sediment depths are greater. A rough value of 30 ft is used here.

Plugging these numbers into the expression for flow rate:

(groundwater velocity) x (porosity) x (cross-sectional area)

gives:

(50 ft/y) x (0.20) x (1500 ft) x (30 ft) = 450,000 cubic feet per year

The arsenic concentration in wells along the east side of the landfill, in areas where groundwater is interpreted as discharging from under the landfill[7], has ranged from around 10 micrograms per liter (µg/L) to as high as 68 µg/L in 2023, as shown in **Figure 1**. For the purpose of this simple calculation, 15 µg/L = 0.015 mg/L is a reasonable average for the 30-year period.

5 From Table 2-1 of the 2024 AEMR.
6 DSAC Groundwater Subcommittee Considerations for Improving the Groundwater/Surface Water Monitoring System, July 9, 2025 (submitted separately to the record).
7 See, for example, Figure 3-5 of the 2023 AEMR.

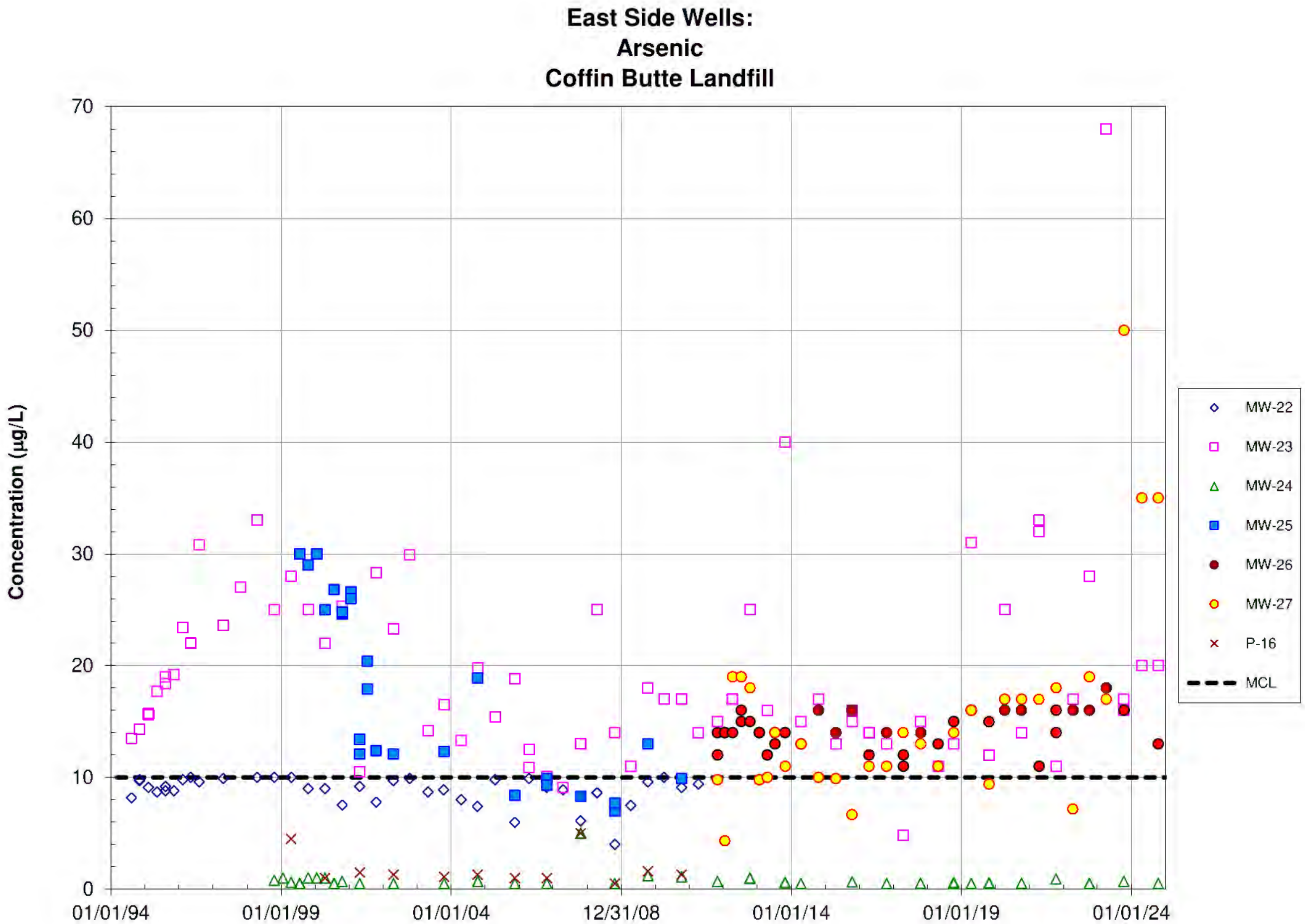

Figure 1. Arsenic in monitoring wells located in the eastern part of the landfill site (figure extracted from the 2024 AEMR). P-16 and MW-24, which have historically had much cleaner water in terms of arsenic, are both uphill of where groundwater flows out from under the landfill, according to the interpretation by the applicant's consultants.

Plugging these numbers into the expression for the rate of arsenic discharge:

(arsenic concentration) x (flow rate leaving the east side)

and converting to metric units gives:

(0.015 mg/L) x (450,000 cu ft / y) x (28.3 L/cu ft) = 191,000 mg/y

So water discharging from below the landfill carries about 191 grams per year of arsenic. Over a 30-year period this adds up to 5.7 kilograms of arsenic discharged from below the landfill, or 5,700,000 milligrams.

Laboratory test results submitted by the applicant show that the arsenic content in some basalt rock samples ranges from below the detection limit (about 1.1 mg per kilogram) up to 1.93 mg per kilogram, with a rough average of 1.5 mg/kg if we assume that all of the samples below the detection limit had arsenic content close to that level.[8]

If it were possible to extract all of the arsenic out of the basalt -- for example, by crushing it to a fine powder and then leaching out the arsenic, the amount of pulverized basalt needed to extract this much arsenic would be:

(5,700,000 mg) / (1.5 mg/kg) = 3,800,000 kg = 3800 metric tons

Since basalt weighs about 2.85 metric tons per cubic meter, that's 1333 cubic meters or 1784 cubic yards of intact basalt.

The footprint of the east side of the landfill has grown over the past 30 years, from about 30 acres to 60 acres recently. Using an average footprint of 45 acres (18 hectares) means this would be equivalent to leaching all of the arsenic out of the uppermost 3 mm of basalt.

For a non-geologist, that might not seem like much. But it would take a very long time for the arsenic to leach out of that thickness of freshly exposed basalt. The pore space in basalt is mostly unconnected, and inaccessible to water. Altered rinds formed by chemical weathering processes are estimated to advance into basalt at a rate of only 0.4 mm per 1000 years.[9] So leaching of all of the arsenic from 3 mm of freshly exposed rock would take on the order of:

(3 mm) / (0.4 mm per 1000 years) = 7500 years

8 The applicant has highlighted some much higher readings which came from "spike" samples. These are samples that were "spiked" by adding arsenic to the sample. This is a standard quality-assurance procedure to ensure that analytical laboratory procedures are working properly, but it was misleading for the applicant to highlight them in this submittal.

9 Navarre-Sitchler, Alexis, Carl I. Steefel, Li Yang, Liviu Tomutsa, and Susan L. Brantley, 2009. Evolution of porosity and diffusivity associated with chemical weathering of a basalt clast, Journal of Geophysical Research: Earth Surface, Volume114, Issue F2. https://doi.org/10.1029/2008JF001060

In other words, this process would need to have started around 5500 BC, at the very dawn of Sumerian civilization, in order to yield as much arsenic as has come out from under Coffin Butte landfill in just the past 30 years.

Possible counterarguments

Two counterarguments from the applicant's consultants can be anticipated, but these can be addressed as follows:

Hypothesis: The arsenic doesn't just come from the fresh basalt surface at the base of the landfill, but also from natural fractures extending to depth in the bedrock.
Rebuttal: These basalts are Eocene in age, which means they are over 30 million years old. Geological descriptions of the Coffin Butte basalts dating back to Allison (1953) note that the natural fractures are weathered, as the result of millions of years of rock-groundwater interaction. This would have included long periods of anoxic conditions under which arsenic could have leached out of the alteration zones adjacent to the fractures. The applicant has not presented any data that would support a hypothesis that relies on significant amounts of arsenic leaching from natural fractures.

Hypothesis: Leaching of arsenic from basalt is enhanced by fragmentation during landfill construction, including fresh fractures created by blasting, and use of crushed rock below the liner system. The increase in fresh rock surface area would allow faster production of arsenic under the landfill.

Rebuttal: If this is in fact happening, then **that in itself would be an impact of landfill development and operation.** Resort to this argument would be an acknowledgment that the landfill is the source of an arsenic plume.

The applicant's consultant has discounted this possibility in the past.[10] If they invoke this explanation at this point, they will also need to accept liability for causing a plume, but refusing to investigate its spread and potential impact on the Willamette basin fill aquifers. It follows that any expansion of the landfill footprint, including the proposed expansion, would increase the net generation of arsenic by this mechanism.

Inconsistency with other measurements of major dissolved species

In Exhibit 67 the applicant has pointed to the lack of a strong signal of other major components of leachate, specifically chloride, in the monitoring wells where high arsenic levels are found. I agree that this may point to a more complex situation than a simple plume where all components of leachate move in unison. The two compliance boundary wells that register high arsenic (MW-26 and MW-27) also show high concentrations of manganese and iron, bumping up against or occasionally exceeding site-specific limits (SSLs) that were set by DEQ based on the recognition that these were also in excess of standard EPA criteria.

As the applicant's consultants note, arsenic may move more slowly in groundwater than ions such as chloride, due to its tendency to form complexes with other compounds found in soil, depending on oxygen levels and redox conditions. Some of the other substances that they sample for, particularly organic chemicals such as hydrocarbons, have tendencies to sorb to organic carbon in sediments, so these may also move at different rates.

As a further complicating factor, the landfill's footprint has changed dramatically over the past 30 years, and the height of the landfill has grown. With the piling up of some 20 million tons of garbage, sediments under the landfill have undoubtedly been compressed, resulting in a reduction both of their porosity and

10 I raised this possibility in a DSAC meeting in late 2021 or early 2022 (a recording should be on file with Benton County), but VLI's consultant, Eric Tuppan, dismissed the possibility.

their permeability. During that period, portions of Coffin Butte have been excavated and liners installed which – if they function properly – will divert seepage from the excavated facets of the butte.

All of this means that the direction and rate of flow out from under the landfill has been changing over time. If in fact there is a plume resulting from a leak under the landfill, its direction could reasonably be expected to shift over time. Substances that form complexes in the soil, or sorb to organic carbon, may persist in some areas even if the main plume has since shifted elsewhere.

The recent DSAC groundwater subcommittee report (submitted to the record separately) identified two major problems with the monitoring system on the east side of the landfill:

1. The two compliance-boundary wells are too widely spaced and leave gaps where a plume might go undetected, and
2. The wells are not completed in bedrock, but instead stop short of the sediment-bedrock interface, and might not sample the most permeable strata below the levels at which they are screened.

In other words, the main plume from a leak might be missed.

Landfill leachate is also denser than meteoric water (water from rain or snow), due to high concentrations of dissolved solids. Leachate samples from the ponds leachate at Coffin Butte have TDS (total dissolved solids) concentrations as high as 2400 milligrams per liter (mg/L).[11] Although the density contrast is small, it can be enough to cause a leachate plume to angle downward from a landfill, as shown by the modeling results in Figure 2. Note that the TDS concentrations in Coffin Butte leachate are comparable to the middle plot (b) in this figure,which exhibits complex dispersion (plume spreading) behavior. When combined with the insufficient depths of MW-26 and MW-27, density effects may increases the

11 From the 2024 Annual Environmental Monitoring Report, data from L-Pond.

likelihood that the main plume of mobile ions such as chloride could "submarine" below these wells.

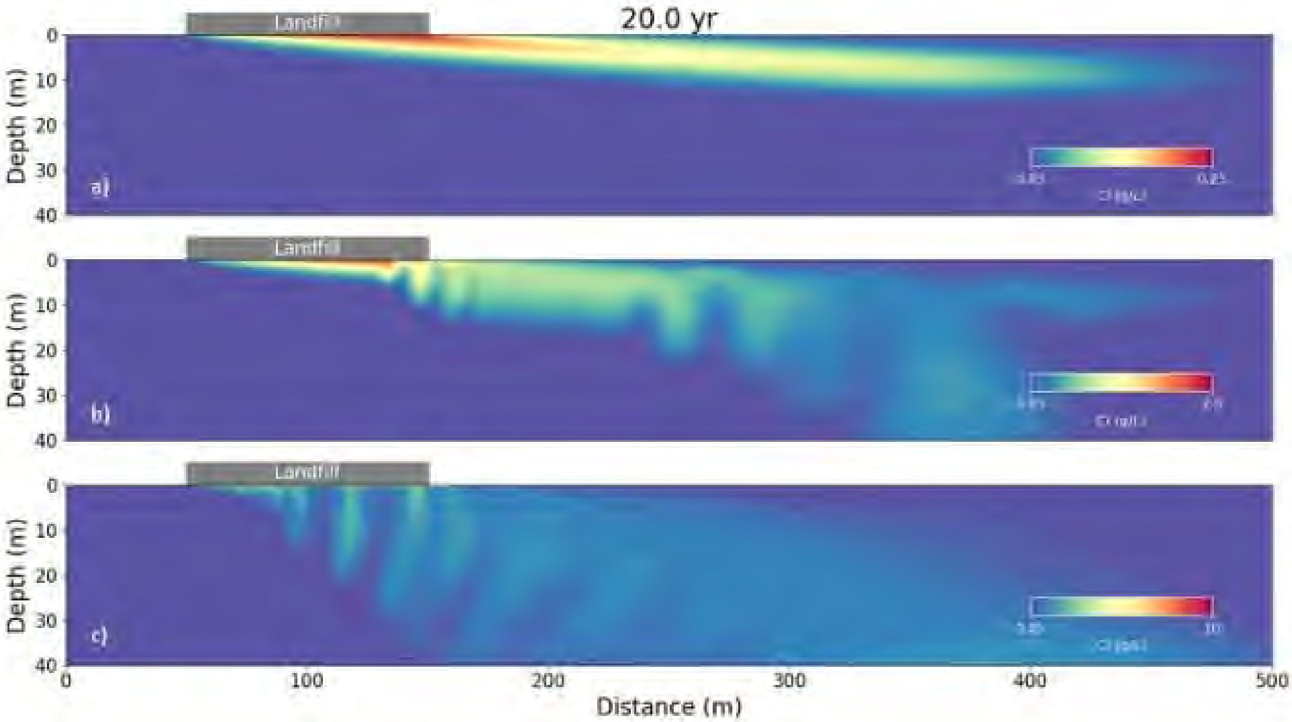

Figure 2. Three different snapshots of numerical simulations showing the concentration distribution of a landfill leachate plume with chloride concentrations for the low-, medium- and high-density cases of: a) 250 mg/L; b) 2500 mg/L; and, c) 10000 mg/L after 20 years of continuous leaching. Figure and caption text from Section 4,4 of Post and Simmons (2022)[12]

Overall, the issues are complex and the remaining scientific questions cannot be fully answered with the available data. **If the applicant is motivated to help to resolve these issues, they could install deeper and additional east-side monitoring wells, in response to the recommendations of the DSAC subcommittee.**

12 Post, Vincent E.A. and Craig T. Simmons, 2022. *Variable-Density Groundwater Flow*. The Groundwater Project, Guelph, Ontario, Canada, 92 pages. https://doi.org/10.21083/978-1-77470-046-4

Arsenic from soil samples in upper Marys River watershed

For reasons that are not clear, the Applicant also refers to soil samples from a 2013 Portland State University master's thesis.[13] The applicant claims that this study "found arsenic at concentrations of 2.62 to 2.68 mg/kg in samples collected from the Siletz River Volcanics." This claim is inaccurate, since Ricker sampled soils which were not necessarily derived from the local bedrock. The sampling site (identified by Ricker as C13) was near Wren along the Marys River in western Benton County.

Floodplain soils at that location (described as clay/sandy loam) could be derived from the marine sedimentary Tyee formation which outcrops less than 5 miles to the west, upstream near Blodgett. Thus the two samples from this single pit sample has no clear relevance for the situation at Coffin Butte. Coffin Butte is in a different watershed, with sediments of different provenance.

Furthermore Ricker concluded: "*soils sampled from above the Marine Sediments and Sedimentary Rocks ... have statistically distinguishable, and higher, arsenic levels when compared to other lithologic groups,*" with the latter category including basalts. **Thus Ricker's main conclusions contradict the applicant's claims.**

13 The applicant's citation of "Ryan Rickard, Tracy" was incorrect, but presumably they meant: Ricker, Tracy Ryan, "Arsenic in the Soils of Northwest Oregon" (2013). Dissertations and Theses. Paper 927. https://doi.org/10.15760/etd.927