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Out of Order:

An evaluation of the regulatory aspects of Los Alamos National Laboratory's proposal to vent tritium from waste containers

Prepared for Tewa Women United, Santa Cruz, New Mexico

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Preface

Tritium (abbreviated as "T") is a highly radioactive isotope of ordinary, non-radioactive hydrogen, while having essentially the same chemical and biological properties as ordinary hydrogen. Therefore, when it displaces an ordinary, non-radioactive hydrogen atom in water, H_2O, the result is radioactive water, HTO. When both hydrogen atoms are displaced, the water, now T_2O, becomes even more radioactive. One teaspoon of HTO would contaminate about 100 billion gallons of water up to the U.S. drinking water limit of 20,000 picocuries per liter – which is about 740 becquerels per liter (Bq/L). That means 740 beta particles are emitted every second at the drinking water limit. When inside living cells of humans, animals, and plants, each beta particle emitted by tritium can cause biological harm.

I wrote this report because Los Alamos National Laboratory (LANL) has proposed to vent waste containers that have about three times more tritium than would be dumped into the Pacific Ocean from the stricken Fukushima Daiichi nuclear power plant in Japan over the course of thirty years. It is instructive, as a thought experiment, to get an idea of the magnitude of the tritium in those waste containers by calculating what it might do, if in the form of HTO, to the annual flow of the Rio Grande River. It would be enough to contaminate more than half its annual average flow at the nearby Otowi Bridge to the drinking water limit. (The Otowi Bridge crosses the river at the southwestern tip of San Ildefonso Pueblo.) In the lowest flow years, it would be enough to contaminate the entire annual flow to well over the drinking water limit.[1] As a practical matter, HTO would be in the air as water vapor and rain down over a much larger area, contaminating soil and groundwater, and potentially also surface waters to varying degrees.

I have long been concerned about the problem of tritium pollution. Tritium is the most ubiquitous radioactive pollutant associated with nuclear weapons and nuclear power. Tritium, once in the body in the form of water, pervades every cell. It crosses the placenta and impacts the embryo and the fetus at every stage, producing risks of early failed pregnancies, organ malformations, and neurological damage. By ionizing the water in living cells, it disrupts mitochondrial DNA, which is the core of the energy system of essentially all animals, plants, and fungi. Yet, these aspects have not received the scientific attention they deserve. I have been concerned enough to write an entire book on the topic.[2]

I wrote this particular report because it was evident, from the very first meeting with Los Alamos officials to which Tewa Women invited me, that LANL had not done its due diligence in protecting the public. A part of that involves a detailed, quantitative examination of alternatives that would keep exposures to the public as low as reasonably achievable below the allowable maximum regulatory limit. It had not modeled how radioactive the rain that would fall on its neighbors, farm fields, and home

[1] Rio Grande flows at various monitoring stations, including the one at Otowi Bridge, are reported by the United States Geological Survey. The annual average flow during the 1958-2000 period was 1.75 million acre-feet. The minimum flow was 606,000 acre-feet. Perhaps also relevant in the era of climate change and extreme weather events, the lowest, reconstructed (estimated) flow in the 1450-2002 period was just 247,000 acre-feet. The average flow data at Otowi bridge are at https://www.treeflow.info/content/rio-grande-otowi-bridge-nm-natural-flows . Contemporary data at that and other stations in New Mexico are at https://waterdata.usgs.gov/nm/nwis/current/?type=flow

[2] Arjun Makhijani, Exploring Tritium Dangers, Opus Self-Publishing Services, Politics & Prose Bookstore, Washington D.C., 2023. https://ieer.org/wp/wp-content/uploads/2023/02/Exploring-Tritum-Dangers.pdf

gardens might become. LANL had not calculated how much it might contaminate groundwater. As I demonstrate in this report (Chapter 6), this is required by a Department of Energy rule (Order 458.1), given the magnitude of the releases involved.

LANL stated there would be a risk of explosions during transport of the containers without actually making measurements to determine whether there were hydrogen-oxygen mixtures in the headspace of the waste containers sufficient to cause an explosion. Further, LANL has not calculated doses to infants and children in its compliance applications, even though they might get higher doses from the same level of environmental contamination with tritium.

I recommended to Tewa Women United that they commission my colleague Bernd Franke to model the tritium release, verify LANL's calculations, and also to estimate doses to people of various ages and under adverse short-term weather conditions (since the venting is proposed to take place over a few days). An assumption of adverse weather conditions is required, since such an estimate, if properly done, would indicate an upper limit dose. If that estimate is below the regulatory limit, it would ensure that the venting would comply with the Clean Air Act.

I prepared this report for Tewa Women United on compliance based on Bernd Franke's report as well as on my own research. In addition, I also analyzed the requirements of DOE Order 458.1 as it applies to the proposed venting. Having worked for many years on the problem of tritium (among other issues), I prepared this report as a public service, using IEER's general support funds.

It has been privilege to provide technical support to Tewa Women United on this critical issue. I have collaborated with and received comments from Talavi Denipah Cook, Kayleigh Warren, Kathy Sanchez, and Nathana Bird. Two lawyers from the New Mexico Environmental Law Center, Masyln Locke and Kacey Hovden, also provided comments. Bernd Franke provided a scientific review. Their suggestions and reviews have helped improve this report. Any errors or problems that remain are entirely my responsibility.

Arjun Makhijani

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Contents

1. Executive Summary

a. Findings regarding 40 CFR 61.92

Los Alamos National Laboratory's (LANL's) analysis of the impacts of venting is seriously deficient on a number of counts as it concerns estimation of dose to the most exposed receptor:

1. LANL has not calculated potential doses for members of the public of all ages.
2. Adults are not the most exposed members of the public for the proposed activity. Infants are.
3. LANL's use of annual average weather data in the application to vent the FTWCs is not in accord with EPA guidance for use of CAP88.
4. Short-term weather data indicate that doses in adverse weather conditions would be much higher than when annual average weather data are used.
5. LANL has not used conservative estimates for humidity in calculating doses.
6. LANL's assertion that its use of December 1, 2018 daytime data is a "bounding case" for dose is very unlikely to be correct even for adults. The dose factor (dose per curie of release) is likely to be much higher than estimated by LANL even for adults. It is approximately a factor of three higher for infants than for adults.
7. The 3 mrem dose that LANL plans to use as a marker for pausing venting is unsatisfactory, since the 12-month dose limit of 8 mrem set by LANL for the venting operation would be exceeded for infants before the 3 mrem threshold is reached. This problem is directly related to the issue that LANL's compliance-related dose estimates are for adults and not the most exposed member of the public, as required by 40 CFR 61.42 in Subpart H.
8. LANL has incorrectly excluded infants, and children more generally, as members of the public in its application.
9. The EPA incorrectly approved the LANL venting application in 2018 based on annual dose calculations for adults. The necessary estimate should be made using worst-case short-term weather data for infants and one-year olds.
10. Infant and one-year old doses would be exceeded even if annual average weather is used for either of the two most loaded FTWCs. Based on available information, the venting proposal would be in violation of 40 CFR 61, and specifically the dose limit at 40 CFR 61.92, when infant doses are modelled.
11. Under adverse weather conditions, and the assumption that all the tritium is in the form of HTO in the headspace (as LANL has appropriately assumed in its application), even the least loaded FTWC may exceed the 10 mrem dose limit when calculated for infant members of the public.

b. Findings regarding DOE Order 458.1 and ALARA

LANL has not performed the requisite ALARA analysis. LANL's designation of 90 mrem as the ALARA limit is scientifically meaningless in the context of the proposed venting since LANL proposes to limit emissions to keep dose under 8 millirem in a 12-month period.

The minimum requirement for meeting the ALARA requirements of DOE Order 458.1 would be to sample the headspace of each FTWC without venting it. This would allow evaluation of the options for keeping public exposure to the maximum receptor as low as reasonably achievable with corresponding reductions for population dose. It is possible that the level of ALARA level may be zero in case hydrogen (ordinary and tritium) in gaseous form in all FTWCs is found not to pose the risk of an explosion.

c. Recommendations

1. The EPA should require calculations of dose to exposed receptors of all ages, including infants.
2. The EPA should publish a notice in the Federal Register that infants and children and people of all ages are members of the public and that 40 CFR 61.92 (which specifies the 10 millirem limit) will be enforced accordingly for all facilities subject to Subpart H.
3. EPA should reject LANL's application for venting and require calculations in compliance with the guidance for CAP88 as well as other factors. Specifically it should require:
    a. A consistent and transparent analysis using worst-case short-term weather data to estimate dose to the most exposed member of the public, including members of the public of any age.
    b. Sensitivity analysis for humidity, wind speed, and wind direction towards the East-Southeast;
    c. Publication of *all* the weather files and assumptions that LANL uses in its calculations;
    d. Publication of all the quantitative assumptions and weather files (including humidity, lid height, wind speed, and wind direction towards White Rock) used in the "bounding case" claimed for its December 1, 2018 calculations;
    e. Publication of calculations of explosion risk and estimated magnitude of a worst-case explosion for each FTWC based on headspace sampling.
    f. An analysis of options based on sampling of the headspace of each FTWC that is consistent both with Subpart H and with the ALARA requirements of DOE Order 458.1.
4. The DOE should require a full ALARA analysis, based on sampling of the headspace of each FTWC.
5. The value of the tritium, assuming that it is recovered after transportation, should be taken into account in the ALARA cost-benefit analysis.

LANL should also publish the baseline groundwater information and perform an analysis of potential rainwater contamination due to the proposed venting, in accordance with the ALARA environmental requirements of DOE Order 458.1 at paragraph 4.i(2).

2. The venting proposal

In 2007, LANL loaded four containers, known as Flanged Tritium Waste Containers (FTWCs) with tritium-contaminated waste. According to its 2020 public information slide deck, the tritium waste was first put into slender containers, called AL-M1s; four or five AL-M1s were loaded into each 51-gallon FTWC. See Figure 1.

Figure 1: A FTWC is shown at left; an AL-M1 is at right. The center photo shows the FTWC stored in a larger barrel.
Source: LANL 2020[3], Slide 2.

According to LANL, "The tritium in the smaller containers [AL-M1s] will remain"[4]; the tritium in the "headspace", which is the space in the FTWC that is not occupied by the AL-M1s, would be vented. LANL's 2019 (revised) application states the following:

> "The FTWC headspace gas contains hydrogen and oxygen, accompanied by radioactive tritium which will be vented along with the headspace gases. The tritium may be in the form of water vapor or as elemental hydrogen gas."[5]

LANL has not provided data on the mix of ordinary non-radioactive hydrogen (H-1) and tritium (H-3) that the headspace contains. Tewa Women United has filed an FOIA Request with the National Nuclear Security Administration that includes a request for that data for each of the four FTWCs.[6] Tewa Women United also filed a FOIA request to EPA requesting correspondence with LANL on venting-application-related matters.[7]

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[3] Los Alamos National Laboratory, Flanged Tritium Waste Container (FTWC) Project Overview, November 5, 2020. Hereafter LANL 2020.

[4] LANL 2020, Slide 8.

[5] Letter from Enrique "Kiki" Torres and Peter Maggiore (LANL) to George P. Brozowski (EPA Region 6), with Attachment 1 "Application for Pre-Construction Approval under 40 CFR 61 Subparts A and H for Venting of Flanged Tritium Waste Containers (FTWCs) at TA-54", Los Alamos National Laboratory, 17 May 2019, pdf pp. 6-7. Hereafter LANL, 2019.

[6] Tewa Women United, Freedom of Information Act Request to the National Nuclear Security Administration, July 3, 2024.

[7] Tewa Women United, Freedom of Information Act Request to the Environmental Protection Agency, June 14, 2024.

The LANL application does contain data on the tritium loaded into each FTWC. LANL estimated the total amount of tritium (called the "source term") as of June 1, 2019 to be 114,683 curies[8] or about 11.7 grams. Back-extrapolating, one can deduce that about 23 grams of tritium were initially loaded into the FTWCs in 2007. The decay of an atom of tritium (by beta particle emission) produces an atom of (non-radioactive) helium-3 gas; therefore, about 11.3 grams of helium existed in the FTWCs due to the decay of tritium between 2007 and June 1, 2019. The amount of tritium remaining on September 1, 2024 (the reference date used for estimating compliance issues) would be about 8.7 grams; the amount of helium will be about 14.3 grams.

LANL has provided the following rationale for venting:

> "Over time, tritiated water vapor that had been adsorbed onto the media can become liberated into the FTWC headspace. Radiolysis can cause separation of the water vapor, possibly resulting in a hazardous hydrogen-oxygen mixture within the FTWC.
>
> "The Applicants have determined that continued tritium storage in these containers could pose an unsafe condition. To mitigate this hazard, the FTWCs will be vented in-place to remove hazardous gases."[9]

In its October 12, 2023 letter to Dr. Earthea Nance, EPA Region 6 Administrator, the NNSA stated that "the containers likely contain an explosive or flammable hydrogen/oxygen mixture." The specific rationale for venting was that "DOT [Department of Transportation] regulations and worker safety requirements do not allow for handling or movement of the containers in the current configuration. Movement without mitigating the anticipated headspace gas can result in an uncontrolled, unmitigated, and unmonitored release."[10] However, the letter did not cite the specific DOT regulations or worker safety requirements at issue.

LANL sought to demonstrate the compliance of the proposed venting operation by using the CAP88 model that estimates individual and population radiation doses due to release of radionuclides into the atmosphere. This software is specifically authorized for compliance demonstration under the Clean Air Act Regulation 40 CFR Part 61, Subpart H, subject to the limitations specified in the EPA's guidance on the use of the model. LANL and other DOE facilities routinely use the CAP88 model for compliance purposes and file compliance reports. The principal compliance objective is to examine whether the particular activity would by itself, or in combination with other radioactivity releases from the facility, keep the radiation effective dose under the limit of 10 millirem per year (10 mrem/yr.). The specific wording of the rule is as follows:

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[8] LANL 2019, pdf p. 13.

[9] LANL 2019,pdf p. 7.

[10] Letter to Dr. Earthea Nance, EPA Region 6 Administrator, from Frank A. Rose, Principal Deputy Administrator, National Nuclear Security Administration, October 12, 2023. Hereafter NNSA 2023.

> "Emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr."[11]

CAP88 estimates compliance by modeling the dispersion of airborne radionuclides and thereby determining the location of a hypothetical member of the public in the environs where the maximum radiation dose would be received, and estimating the amount of the dose at that location. CAP88 can estimate doses to members of the public of various ages including infants (at 3 months old); 1 year olds, children who are 5, 10, or 15 years old and others all the way up to 75 years old.

Los Alamos reported its modeling approach and results to EPA in its 2019 application. It assumed that

- the entire inventory of tritium would be released;
- the released tritium would all be in the form of tritiated water vapor, HTO (where one of the hydrogen atoms in ordinary water vapor, H_2O, is replaced by tritium, making it radioactive water vapor, HTO).[12]

A number of other inputs are required before CAP88 can compute the location of and dose received by the maximally exposed member of the public:[13]

- **Weather data**: LANL used data from the meteorological tower in Technical Area 54 (TA-54), where the FTWCs are located. It used data for the five-year period 2007 to 2011. These data include typical annual rainfall and humidity data (which must be specified) as well as data on wind speeds and directions, both necessary for estimating the location of the maximally exposed member of the public and the air concentration of the radionuclide, in this case, tritiated water vapor, at that location.
- **Food**: LANL assumed all food consumed would be locally produced.
- **Other technical parameters**: These include height of the source and the momentum with which the radionuclide is released.

Based on these inputs, LANL calculated the dose to an adult and determined the location of the maximally exposed individual to be 2,195 meters East-South-East of the location of the FTWCs in Building 2018 in TA-54. That location is in the town of White Rock, which borders on LANL. The maximum dose that LANL calculated was 20.2 millirem, a little more than double the limit specified at 40 CFR 61.92, cited above. Most of the parameters and assumptions used in the calculation, including the assumption that the entire inventory would be released in the form of tritiated water vapor and that there would be no capture of the HTO before release are conservative, as LANL has noted, and as is appropriate for demonstrating compliance with a regulatory limit through modeling. In the absence of sampling the headspace to determine how much tritium would be released, an assumption of complete

[11] Environmental Protection Agency, Title 40 - Protection of Environment, Chapter I - Environmental Protection Agency, Subchapter C - Air Programs, Part 61 - National Emission Standards for Hazardous Air Pollutants, 2022, Subpart H, at 40 CFR 61.92,

[12] LANL 2019, pdf p. 13. LANL also did calculations in case the vented tritium was in the form of tritium gas.

[13] LANL 2019,pdf p. 20.

release as HTO is reasonable and conservative. It should be noted that that does not mean that venting is a reasonable and appropriate approach for addressing the problem.

Since LANL's dose estimate was that the venting would exceed 10 millirem dose limit, it devised a new approach to the venting, where it would monitor the releases and stop the operation if the release was estimated to cross certain dose thresholds. In addition, some venting was also thought possible during transportation of the FTWCs from Building 1028 to the Weapons Engineering Tritium Facility, known as WETF. The new approach was described in a March 2020 amendment to the venting application.[14]

The original application had envisioned venting one FTWC at a time and then transporting that to WETF, prior to venting the next one. In the new protocol, all four FTWCs would be vented and then transported to WETF. A provision for emissions during transportation was also included.

According to this new approach, the venting of each FTWC would be monitored and, potentially phased as follows:[15]

- **3 mrem pause**: If the dose estimated by LANL is 3 mrem, LANL proposed to pause the operation. The dose would be determined by measuring the release in terms of radioactivity and applying a factor for dose per curie vented. This factor was estimated by LANL to be 0.000266 mrem/curie. The release would be the actual measured release after any tritium was captured in mitigation devices. The amount of tritium corresponding to this dose and estimated procedure, as estimated by LANL, would be 11,300 curies (rounded)
- **6 mrem pause**: There would be a second pause for approval if the estimated dose reached 6 mrem. The curie release amount, according to the LANL estimation procedure, at this pause would be 22,500 curies.
- **8 mrem maximum dose:** A maximum dose estimated in the same way would mean that the maximum release allowed would be about 30,000 curies. The dose based on the same emission factor would be 8.0 mrem (rounded).

This procedure would leave emissions amounting to a dose of 2 mrem per year from all other operations at LANL for the laboratory to be in compliance with the 10 CFR 61.92 limit of 10 mrem/year. This allowance was deemed to be adequate in view of the maximum annual estimated dose from all air emissions over a 10-year period, starting in 2009, of 1.09 mrem/yr.

3. Evaluation of LANL's compliance calculations and claims

Based on the above inputs, assumptions, and calculations, LANL claims the venting operation would be in compliance with the dose limit of 10 mrem/yr. specified at 40 CFR 61.92. In order to verify LANL's approach and calculations, Tewa Women United commissioned an independent assessment of air pathway doses. This assessment was prepared by Bernd Franke, a director of a scientific NGO in

[14] David Fuehne, Notification of Operational Scope Change for the FTWC Venting Project at Los Alamos National Laboratory (LANL), LA-UR-20-22148, Los Alamos National Laboratory, 2020-03-12, pdf p. 20; hereafter Fuehne 2020.
[15] Fuehne 2020, op cit. pdf p. 23.

Heidelberg, Germany, for Tewa Women United.[16] The institute specializes in performing environmental and energy evaluations including for Germany's environment ministry and the European Union agencies. This section dealing with LANL's use of CAP88 and its compliance claims is based on Franke 2024, except as noted.

Franke 2024 attempted to reproduce LANL's calculations in its 2019 application (LANL 2019) using LANL's assumptions, as a preliminary verification measure. It is important to consider the LANL 2019 modeling since that was the basis on which the EPA had previously approved the pre-construction application on that basis. Franke 2024 did calculations with annual weather data for each year from 2018 to 2022, inclusive. Using the same assumptions about source term, and release conditions, such as moisture in the air, Franke 2024 concluded that, given LANLs assumptions, the 20.2 dose estimate was correct. We consider LANL's modified dose estimation proposal separately (Section 4).

Franke 2024 also examined other scenarios. They are not described here in detail, since the results for 16 scenarios are available in that report. These scenarios addressed three basic questions:

- *Is an adult the most exposed member of the public or is a member of the public of some other age more exposed, all else, including weather assumptions, being equal?* Franke 2024 included calculations for members of the public who were infants (3 months old), 1 year-olds, 5-year olds, 10-year olds, 15-year olds, and adults.
- *Does using short-term weather data make a difference?* LANL's calculations of compliance were based on using weather data averaged over a five-year period. The venting would be carried out over a period of days. There are many short periods were the wind blows far more frequently than the annual average in the direction of the most exposed receptor at White Rock, East-South-East of the FTWCs.
- *Does the assumption about humidity make a difference?* LANL assumed that the moisture content of air would be 5.5 grams per cubic meter (g/m3) of air.[17] While this is in the range of humidities observed in the area, the range is wide and the specific humidity assumption significantly impacts the dose calculation. This is especially relevant since the release would be over a short period of time when the humidity might be substantially different than a monthly or an annual average.

a. Age of the receptor

The comparisons in this section are for venting of the FTWC with the largest source term decay corrected to September 1, 2024. Since doses are directly proportional to the source-term when all other factors are held constant, a simple age-dependent comparison of the estimates in Franke 2024 and LANL 2019 is possible.

[16] Bernd Franke, Review of LANL radiation dose assessment for the Venting of Flanged Tritium Waste Containers (FTWCs) at TA-54 of Los Alamos National Laboratory, ifeu, September 14, 2024, prepared for Tewa Women United. Hereafter Franke 2024.

[17] A teaspoon would contain about 5 grams of water.

Table 1 shows emissions from the FTWC with the most tritium in it – 32,000 curies, decay-corrected to September 1, 2024. The Franke 2024 results for 2020 weather data are compared with the LANL dose estimate in LANL 2019.

Table 1: Franke 2024 doses by age using annual 2020 weather data compared to LANL adult estimate using five-year (2007 to 2011) weather data

	mrem dose, 32,000 curie HTO release			
	Infant	1-year-old	5-year-old	Adult
2020 weather data	15.7	14.8	8.0	4.9
LANL estimate	N/A	N/A	N/A	5.6

Source: Franke 2024, Table 4.1

The Franke adult dose estimate using 2020 weather data was 4.9 mrem; this is very comparable to the estimate of 5.6 mrem derived using the LANL dose factor of 0.000176 mrem/curie (LANL 2019). The small difference can be attributed to the different weather data. (Franke 2024 did not have access to the five-year, 2007-2011 average data used by LANL).

LANL did has not published dose estimates for any other age group. But it is clear that the dose to an infant (3 months old) and a one-year old from the venting of just one FTWC would exceed the annual limit of 10 mrem in 40 CFR 61.92 (in Subpart H of the regulation) by roughly 50%, even without taking account of more adverse weather conditions that might prevail on the day of the venting.

The dose to an infant from tritiated water vapor is estimated at over three times greater than the dose to an adult. All intake factors (including breathing rate and food and water intake) and dose coefficients used in the calculation are internal to CAP88-PC. The inputs were the same as those used by LANL except the weather data (2020 instead of the 2007-2011 average) as was the location of the receptor (hypothetical individual) who would be the most exposed member of the public (at a church in White Rock, 2,195 meters East-Southeast of LANL Area G).

The Clean Air Act and other regulations protect public health, among other things, by limiting the exposures to "any member of the public." For the purposes of radiation protection, this generally means everyone except when they are working in an installation that is part of the nuclear industry. For instance, 40 CR 190, the EPA regulation governing emissions from nuclear fuel cycle facilities, defines a "member of the public" as follows:

> *Member of the public* means <u>any</u> individual that can receive a radiation dose in the general environment, whether he may or may not also be exposed to radiation in an occupation associated with a nuclear fuel cycle. However, an individual is not considered a member of the public during any period in which he is engaged in carrying out any operation which is part of a nuclear fuel cycle.[18]

Children are not "engaged in" carrying out operations that are "part of a nuclear fuel cycle". Therefore, by EPA's own definition, children are members of the public. Children born in the United States are

[18] 40 CFR § 190.02(k) (emphasis added).

defined as citizens from the moment they are born.[19] Finally, all people under the jurisdiction of the United States are entitled to equal protection of laws. Section 1 of the 14th Amendment to the United States Constitution states:

> All persons born or naturalized in the United States, and subject to the jurisdiction thereof, are citizens of the United States and of the State wherein they reside. No State shall make or enforce any law which shall abridge the privileges or immunities of citizens of the United States; nor shall any State deprive any person of life, liberty, or property, without due process of law; nor deny to any person within its jurisdiction the equal protection of the laws.

Since the doses to infants would exceed 10 mrem even if annual weather data are used (that is, without taking adverse weather conditions into account), the LANL venting proposal does not, on the face of it, appear to be compliant with the 10 mrem dose limit specified at 40 CFR 61.92.

b. Critical issues: duration of release, humidity, and wind speed

The calculations discussed so far are based on the use of annual weather data in Franke 2024 and a five-year (2007 to 2011) average in LANL (2019). However, LANL's proposal is to vent each container in about one day (LANL 2020).

Weather on a single day is much more variable than on average. For instance, in 2020, the wind blew about 7% of the time from the West-Northwest – the direction that would carry the radioactivity from the FTWC storage in Building 1028, Area G toward White Rock, which is East-Southeast of Area G. But in the most adverse 24-hour period, the wind blew towards White Rock (East-Southeast) from the West-Northwest direction about 42% of the time – that is, about six times more frequently than the annual average.

Humidity is also a major factor in the case of a tritium release. This is mainly because CAP88 assumes that HTO, being water, achieves equilibrium with the water content of food instantly. LANL used a humidity assumption of 5.5 g/m3 of air.[20] When the humidity is lower, the same amount of tritiated water vapor will produce a higher concentration in atmospheric water vapor. This higher concentration of tritium in water vapor would result in more contaminated food and water, since these are assumed to be in equilibrium. As a result, *the amount of tritium inhaled and ingested, and hence the radiation dose, will be inversely proportional to humidity: the lower the humidity the higher the dose, and vice versa.*

LANL's choice of 5.5 g/m3 is within the range of recorded relative humidity at the TA-54 is within the range of atmospheric water vapor loading in the region, since humidity at LANL varies from less than 1 g/m3 to more than 10 g/m3. But 5.5g/m3 is far from the worst case. None of the LANL dose estimates we have seen has a sensitivity analysis for humidity, despite the fact that it is a principal factor in the dose estimate due to tritium venting.

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[19] 8 U.S.C. § 1401; U.S. Constitution amendment XIV, § 1.

[20] LANL 2019, pdf p. 20. 5.5 grams of water vapor, if condensed, would be about a teaspoon of water.

Finally, wind speed is also critical. Calm weather – low wind speed, means that air pollution remains in a particular area for longer, other things being equal, since the dispersion factor, X/Q is inversely proportional to the wind speed and air concentration is directly proportional to X/Q. Conversely, a higher windspeed means a lower dose since the wind passes by faster. For instance, other things being equal a 5 meter/second wind speed during the release would result in half the dose of a wind speed of 2.5 m/s. Wind speeds during the day of release may higher or lower than the annual average.

A worst case combination of the above factors would be low wind speed, low humidity, and high proportion of wind direction toward White Rock on the day of the release relative to annual average weather. While all three factors may not simultaneously be at the values that would give the very highest dose, there are many periods, especially over short periods, such as a day or several hours, where the combination of factors leads to substantially higher doses than average factors. This is illustrated in the Section c. below and in Chapter 4.

c. Overall combined impact of the various factors

This section compares LANL's compliance calculation in the 2019 application (LANL 2019) with Franke 2024.

Franke 2024 did a sensitivity analysis for all four critical parameters – age of the receptor, duration of release, humidity, and wind speed. Table 2 shows the results for an infant (who is the maximally exposed member of the public) and an adult, the member of the public at the same location in White Rock for which LANL did its compliance calculations in its 2019 application. This approach allows an assessment of how much LANL would be out of compliance on the grounds of use of meteorological data alone and how much when proper account is taken of all members of the public, including infants and children.

All doses are calculated for a 32,000 curie release of HTO. This would be the source term in the FTWC with the largest amount of tritium, decay-corrected to September 1, 2024. LANL's dose estimate was for all four FTWCs with the source term as of June 1, 2019. The dose estimated by LANL was therefore reduced by a factor of 0.279, which is the ratio of the source term used by LANL to the decay-corrected inventory in the FTWC with the most tritium.

Table 2 shows the comparison. This is a heuristic comparison designed to illustrate the range of doses that could plausibly be calculated using local data on wind speed, wind direction frequency, and humidity. They are not to be read as estimates that could be used for compliance. Indeed, as discussed in Section 5, LANL's calculations, as they stand, cannot be used to demonstrate compliance with Subpart H. The doses as calculated in Franke 2024 for short-term releases indicate non-compliance by wide margins.

Table 2: Estimated doses in mrem to the most exposed member of the public: LANL 2019 compliance calculation compared to Franke 2024 (Notes 1, 2, and 3)

	mrem dose, 32,000 Ci release	**Ratio most exposed case**

					Franke 2024 to LANL 2019
	LANL five yr avg. weather	24-hour , worst case towards ESE, avg humidity	24-hour, worst case towards ESE, low humidity	24- hour release, worst case + low wind speed	**Ratio: Franke 2024 to LANL adult**
Adult receptor	5.6	28	160	257	**46**
Infant receptor	N/A	92.8	527	848	**152**

Source: Franke 2024

Notes: 1. Source term: 32,000 curies, the amount of tritium estimated to be in the most loaded FTWC, decay-corrected to September 1, 2024.

2. Franke 2024 scenarios are all for a 24-hour release, with a worst case estimate of wind blowing ESE towards White Rock for 42% of the day. Franke 2024 only estimated infant doses for these scenarios since the infant receptor is the most exposed. The adult doses were estimated for this table by dividing the infant dose by a factor of 3.3 for purposes of comparison with the LANL estimate shown in the table. (The infant dose to adult dose ratio varies somewhat according to humidity, but this does not affect the overall comparison materially.) The three scenarios differ as follows:

i. Average humidity = 5.5 g/m3, the same value used by LANL, for purpose of comparison.
ii. Low humidity = 1 g/m3, a plausible value, given the range of relative humidity measured at TA-54.
iii. "Worst case + low-wind speed" assumes calm weather during the release, specifically a wind speed averaging less than 3 knots (about 3.5 miles per hour).

The following conclusions can be arrived at from the estimates in Table 2:

- Even if the receptor is an adult and releases were from one FTWC at a time to ensure compliance with the Subpart H 10 mrem dose limit, the worst case weather conditions would result adult doses greatly in excess of the 10 mrem Clean Air Act limit.
- Infant doses would be greater than the allowable 10 mrem limit even with annual weather data. When short-term weather and adverse humidity are factored in, the infant dose would exceed the dose limit by well over one hundred times.
- Using annual weather data to estimate the dose to the maximally exposed member of the public for the proposed FTWC venting is scientifically incorrect.

It is important to remember that the above dose calculations are for a single FTWC, the most loaded one. The overall inventory is about 2.67 times higher than the single FTWC with the highest tritium loading. The weather conditions on the days of venting the other would differ, so a simple proportionality would be inappropriate for estimating overall dose. Even so, the estimate of total dose due to venting all four FTWCs at the White Rock receptor would be greater than the values in Table 2.

4. LANL's use of December 1, 2018 data

In its March 2020 supplement, LANL also modified its dose calculation procedure (LANL 2020). That modified procedure was reiterated in 2022.[21] This revised LANL procedure, in effect, acknowledges that the dose calculation for the proposed tritium should use conservative short-term weather data to demonstrate compliance – one of the main conclusions that is evident from the analysis in Franke (2024). But whether LANL's calculation represents a conservative compliance calculation is quite another matter.

LANL published its modified approach as a "bounding case" for dose by using weather data "during daylight hours of Dec 1, 2018, when the wind blew steadily from Area G towards the White Rock town site". On this basis, LANL calculated dose factor of 0.000266 mrem/curie (2.66E-4 mrem/Ci in exponential notation). Using this factor, a 30,000 curie release would give a dose of about 8 mrem, the limit chosen by LANL for venting the FTWCs in any twelve-month period.[22] As before, LANL calculated the dose for an adult receptor. Under the same conditions assumed by LANL, the dose factor for an infant would be about 8.5E-4 mrem/Ci to 8.8E-4, depending on humidity, ***yielding an infant dose of about 26 millirem for a 30,000 curie venting – far in excess of the 8 mrem stop point proposed by LANL for any particular year. In fact, the infant dose would exceed 8 mrem annual limit for the venting operation even before the first 3 mrem stop in the revised venting operation proposed by LANL.***

We also question LANL's estimate of 2.66E-4 mrem/Ci for an adult is a "bounding case" even apart from the issue of the age of the receptor.

LANL's dose factor for the 10-hour sunrise to sunset period is only 57% higher than the LANL estimate of 1.76E-4 mrem/Ci that it estimated using five-year average weather data (LANL 2019). LANL has not published the details of its calculations, but stated the following about the assumptions for venting at TA-54:[23]

- "Wind file" – "Dec 1, 2018 daylight wind (bounding case) for planning Area G ventilation limits";
- "Other Meteorological parameters: Precipitation, Temperature, Lid Height, Humidity" – "Lid height should be selected for actual month of venting operations; other parameters use annual averages described in procedure EPC-ES-TP-501."

The use of annual average humidity combined with wind speed for a 10-hour period on a single day is scientifically inappropriate for a bounding case, since there are many days within the year when humidity is lower, which would result in a higher dose estimate, all other factors being kept the same. In the specific instance of the 10-hour daylight period on December 1, 2018, the measured humidity, based on TA-54 met tower data, was 2.4 g/m3 (Franke 2024). Neither LANL 2020 or LANL 2022 state the value used for annual average humidity. The average value in 2018

[21] David Patrick Fuehne, Supplemental Information Regarding the Application for Remediation of the Flanged Tritium Waste Containers at Los Alamos National Laboratory, LA-UR-21-31397, February 22, 2022.
[22] LANL 2020, pdf p. 23.
[23] LANL 2020, pdf p. 21.

as well as that used by LANL in its 2019 application are both much higher than the 10-hour December 1, 2018 average. This means that LANL's dose factor is correspondingly underestimated. We cannot estimate the amount of this underestimation since LANL has not provided the value to humidity it used. Franke 2024 estimated the annual average humidity for 2018 as 3.7g/m3. If LANL used this value for its December 1, 2018 dose factor calculation (as indicated by the above quote), the supposedly "bounding case" would underestimate the dose for a December 1 venting by about 50% on account of this factor alone. LANL's default annual average value is 4.3 g/m3;[24] if LANL's used its usual default factor, it would mean an underestimation of the dose by about 80%.

Franke 2024 estimated the doses for a 32,000 curie release (the inventory on September 1, 2024 of the FTWC with the largest tritium loading) for annual average 2024 data at 2.4 g/m3 humidity using CAP88 and then adjusted for the wind speed and wind direction frequency for the 10-hour daytime period on December 1:

- The wind speed in the 10-hour period was approximately double the annual average, reducing the annual dose estimate by half when translated to the 10-hour December 1 daytime period.
- The frequency of wind blowing towards the ESE (White Rock) from Area G was 63% in the 10-hour December 1 daytime period compared to the annual average of 7%. This increases the dose estimate by a factor of nine.

The lid height – the column of the atmosphere in which mixing takes place was assumed to be 1,600 meters, the same as in all the other model runs by Franke 2024 cited above and also used in LANL 2019. Neither LANL 2020 nor LANL 2022 provide the value for lid height used to estimate the dose factor of 2.66E-4 for the daytime hours of December 1, 2018. However, monthly lid heights estimates are in a LANL 2021 document that Tewa Women United obtained via an FOIA request; the mid-afternoon lid height for December is estimated by LANL to be 620 meters.[25] A run of CAP88-PC with a 620-meter lid height instead of 1,600 meters indicated no material difference in the dose estimate.[26]

Figure 1 compares the LANL 2019 annual dose and LANL 2020 revised "bounding" dose for December 1 with the results in Franke 2024 using 2018 annual and December 1 daytime data.

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[24] Los Alamos National Laboratory, Dose Assessment Using CAP-88, Revision 0, Document number EPC-CP-QP-0501, November 30, 2021. Part of a set of documents obtained by Tewa Women United as part of a Freedom of Information Request, p. 11 (pdf p. 26 of the combined FOIA document as sent). Hereafter LANL Dose Assessment 2021.

[25] LANL Dose Assessment 2021, p. 11 (pdf p. 26 of the FOIA document set cited in Footnote 24 above).

[26] This is due to the near-ground-level release with a nearby receptor. Bernd Franke to Arjun Makhijani, personal email correspondence, October 29, 2024.

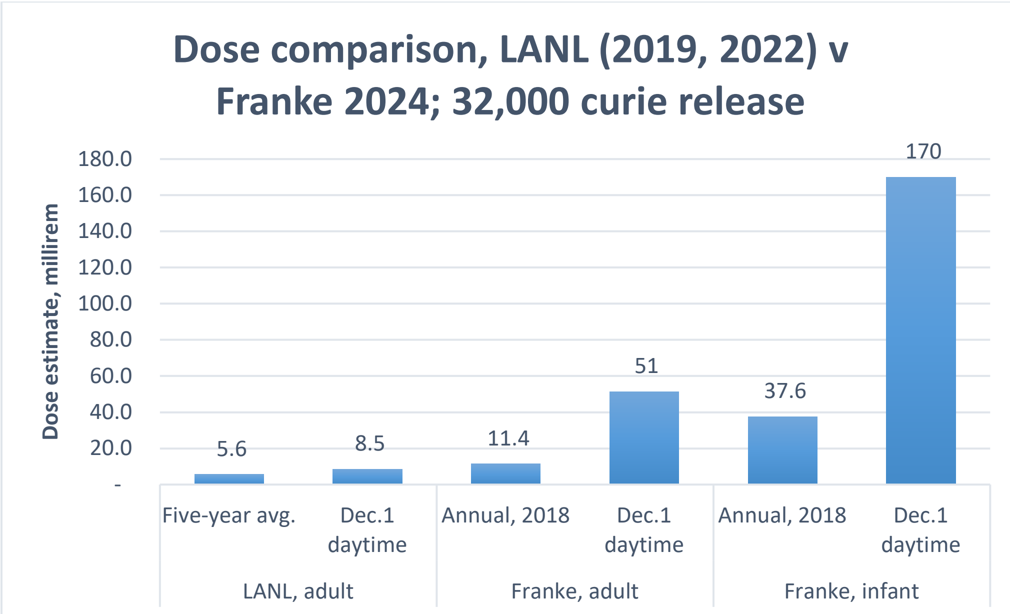

Figure 1: Comparison of LANL 2019, LANL 2020, and Franke 2024 dose estimates for a 32,000 curie release at the White Rock receptor location with long-term and December 1, 2018 daytime weather data.
Sources: LANL 2019, LANL 2020 dose factor applied to 32,000 curies, and Franke 2024

A part of the reason for the lower December 1 LANL dose estimate is very likely due to a higher humidity assumption made by LANL. But this does not explain most of the discrepancy.

While a definitive comparison between the LANL 2020 "bounding case" estimate and Franke 2024 is not possible because LANL has not published the complete information needed to do that, the following conclusions can be drawn:

- **Dose limit**: Even if LANL's dose factor of 2.66E-4 mrem/Ci is accepted, the 40 CFR 61.92 dose limit would be violated for an infant member of the public as well as children who are older – for instance, for one- and five-year olds.
- **Humidity**: The LANL use of annual average humidity is scientifically incorrect for a "bounding case." LANL's use of long-term average 2018 humidity means that its "bounding case" dose would underestimate the dose by 50% or more (depending on which year it used).
- **Dose factor**: The LANL dose factor for an adult for the 10-hour period on December 1, 2018 is likely to be significantly underestimated.
- **Bounding case**: Given the above analysis, LANL's dose factor of 2.66E-4mrem/Ci is unlikely to be a bounding case for adults; it is not the bounding case when all members of the public, including children, are considered.

5. Compliance aspects of the use of the CAP88 model

This section examines two issues relating to the use of CAP88 for the purpose of demonstrating compliance with 40 CFR 61, Subpart H:

- Are there weather-data-related limitations on its use?
- Are there any specific issues concerning the age of the receptor associated with CAP88?

a. CAP88 and weather data

In this section we examine the issue of whether annual weather data use is allowable for LANL's venting proposal for compliance calculations. This is important because EPA Region 6 approved a LANL application with five-year average weather data. That permit has expired. As noted above, LANL has proposed a different "bounding case;" EPA has not, to our knowledge, ruled on its appropriateness, or lack thereof.

Subpart H of 40 CFR 61 explicitly allows the use of CAP88 to demonstrate compliance in paragraph 61.93(a). However, as with all methods, such use must be in keeping with the limitations within which the model is scientifically valid. The EPA has issued guidance concerning the use of CAP88 that specifically addresses this issue:

> "Dose and risk estimates from CAP88-PC are applicable only to low-level chronic exposures, since the health effects and dosimetric data are based on low-level chronic intakes. *CAP88-PC should not be used for either short-term or acute high-level radionuclide intakes*."[27]

"Short-term" is, of course, a relative concept. In the context of contaminant transport in air, the relevant metric is whether the time frame of the release and the period of the weather dataset are commensurate. LANL proposes to release the tritium in days – roughly two orders of magnitude less than the time frame of an annual dataset. The use of annual or multi-year weather data is incompatible with the time frame of the release. There a sound scientific basis for the limitation on CAP88 use. For instance, in 2018, the wind was blowing towards White Rock from TA-54 only about 7% of the time on average. But on December 1 of that year it was blowing that way 31% of the time; during daylight hours (about 7 am to 5 pm), the fraction was even higher: 63%.

The estimates in Franke 2024 for a release from the most loaded FTWC in the 10-hour period of 7 am to 5 pm with December 1, 2018 weather data are much higher than estimated by LANL. This means that the dose factor would also be much higher than that claimed to be a "bounding case" by LANL. However, it should be noted that the calculations are not strictly comparable since LANL has not published all of the relevant data and weather files.

b. Age of the receptor

Early versions of CAP88, up to and including Version 2, did not contain dose conversion factors for people of various ages. Subpart H went into effect in 1990. Therefore, entities such as LANL

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[27] Trinity Engineering Associates, CAP88-PC Version 4.1 User Guide, prepared for the EPA Office of Radiation and Indoor Air, Washington, DC 20460, 2019, pdf p. 8; hereafter Trinity Engineering 2019; italics added.

that were subject to the rule were, in effect, being told to demonstrate compliance by calculating doses to adults. However, that changed about two decades ago when Version 3 of CAP88 was issued, since that version contained dose factors for people of various ages.[28]

However, the EPA does not appear to have issued any guidance that people of all ages, specifically including infants and children, are members of the public, even though, as noted above, this is clear from its own definition of the term in 40 CFR 190.02(k). In the absence of such guidance, LANL has continued to use adults as the members of the public even though in some cases, including the LANL venting proposal, children would suffer high doses for the same level of environmental contamination. They also have higher cancer risk per unit dose, with females being much more at risk than males for most cancers as well as when all cancers are considered together.

None of the correspondence between LANL and EPA Region 6 indicates that either organization raised the issue of the age of the receptor in the issuance of the 2018 permit. (The permit has expired; LANL's request for an authorization to vent is pending, as of the date of this report.)

By allowing LANL to use adults as the maximally exposed receptors when infants and other children have higher doses, the EPA is violating 40 CFR 61.92 of Subpart H. LANL is also violating it by not calculating doses to infants and children of other ages.

Dose conversion factors for people of various ages, including infants, have been available for about three decades. They have been part of CAP88 for about two decades. By failing to require a calculation for and to calculate doses for the member of the public who is most exposed LANL and EPA have effectively disregarded infants and children as members of the public.

6. ALARA

Besides being required to comply with the EPA regulation at 40 CFR 61, Subpart H, including the annual dose limit via the air pathway of 10 mrem, LANL, as a Department of Energy facility, is also subject to DOE Order 458.1.[29] Among other things, this DOE order requires protection of the public beyond the dose limit, so long as it is technically feasible and is practicable. This feature of public and environmental protection goes under the rubric of keeping impacts "as low as reasonably achievable", often abbreviated as "ALARA".

The EPA dose limit of 10 millirem per year via the air pathway to the most exposed member of the public and the ALARA rule are very different in concept. The 10 millirem is a hard cap on exposure. It is mandatory and shall not be exceeded in any year. Measurements and models in some combination can be used to demonstrate compliance; suitable conservative calculations are appropriate to ensure the limit is not exceeded. Specifically, because the 10 millirem is a mandatory upper limit, it suffices to show

[28] Trinity Engineering 2019, pdf p. 9.

[29] Department of Energy, "Radiation Protection of the Public and the Environment" (Change 4), (September 20, 2020) at https://www.directives.doe.gov/directives-documents/400-series/0458.1-BOrder-chg4-ltdchg/@@images/file (Hereafter "DOE Order 458.1")

that a *hypothetical* member of the public located at the place with the worst radioactive air pollution year would not receive a dose above the limit were they present there throughout the year. For this purpose, estimating air concentrations of radionuclides in a conservative way (that is, by ensuring modeling parameters will yield doses higher than would be expected under actual conditions) is sufficient. If the dose limit is met with conservative estimates of the amounts of radionuclides to be released and conservative assumptions about meteorological conditions, compliance is effectively demonstrated. When properly done, there is reasonable assurance that no member of the public would receive a radiation dose via the air pathway above 10 mrem in any given year.

The ALARA provisions of DOE Order 458.1 are very different. The starting point is the presumption that the facility or activity in question would be in compliance with regulatory limits. ALARA then poses the question: what more can be done to further protect the public and the environment from the harm that would accompany the proposed activity or set of activities? It requires an assessment of how much the harm can be reduced below the maximum allowable regulatory exposure. In addition, it also has features requiring protection of the environment that are not necessarily encompassed by dose limits set for members of the public.

DOE Order 458.1, by requiring analyses and corresponding actions that would keep radiation doses and environmental impact as much below regulatory limits as reasonable, implies that any exposure that above an ALARA determined amount is, in effect, an unnecessary and excessive exposure, even if the activity that is compliant with the relevant regulatory dose limit.

Paragraph 4.d(1) of DOE Order 458.1 states:

> "A documented ALARA process must be implemented to optimize control and management of radiological activities so that doses to members of the public (both individual and collective) and releases to the environment are kept as low as reasonably achievable. The process must be applied to the design or modification of facilities and conduct of activities that expose the public or the environment to radiation or radioactive material."

It applies to all planned radiological activities, including routine releases and releases during recovery in the aftermath of unplanned or accidental releases. Accidental radioactivity releases are exempted. As a DOE facility, LANL is subject to DOE Order 458.1 and its ALARA requirements. As such, LANL files periodic reports about its ALARA compliance with DOE.

DOE Order 458.1 also includes an overall dose limit to the public from all pathways and sources of 100 mrem per year, including the air pathway.

LANL did not refer to ALARA in its 2019 venting application to the EPA. However, the 2020 modification of the venting plan (LANL 2020) states the following:[30]

> "The environmental ALARA administrative limit under DOE O 458.1 criteria is set at 90 millirem. Curie limits and hold points established for Radionuclide NESHAP compliance

[30] LANL 2020, pdf p. 20.

> will be shared with EPC-ES Dose Assessment personnel for evaluation relative to this DOE O 458.1 all-pathway administrative limit."

LANL 2020 provided no rationale for the 90 mrem value selected. Since the same document sets a 12-month limit of 8 mrem from the venting and the rest of the air pathway doses have been less than 2 mrem/year (as discussed above), a 90 mrem limit for ALARA for the proposed venting is meaningless. Indeed, any value above 8 mrem for the proposed venting would be meaningless. This is because meeting the 8 mrem 12-month limit for the venting action would automatically satisfy any "ALARA" limit above 8 mrem for the operation.

ALARA considerations specific to the venting would require consideration of how much LANL could keep the maximum dose below 8 mrem (the 12-month limit). Email correspondence provided by LANL in response to a Freedom of Information Act request indicates that ALARA considerations specifically aimed at reducing doses from the planned venting may have been reconsidered after the ALARA issue was raised in the meetings that LANL and EPA Region 6 had with Tewa Women United in late 2022. This is mentioned in an email from David Fuehne, LANL's Team Lead for air emissions of radioactivity:[31]

> After the meeting in late 2022 between Region 6 and the Tewa Women United organization, a few questions were forwarded to the NNSA Los Alamos Field Office. These questions were related to different operational alternatives considered for the FTWC remediation project, how the alternatives were weighed, and how ALARA was considered and addressed in this project.
>
> NNSA staff worked with LANL/Triad operations and environmental compliance personnel to assemble answers to these questions. Attached you will find a Word document addressing the alternatives considered and a summary of the ALARA process. Also attached is a PowerPoint slide, excerpted from the Nov 2020 public presentation, which addresses the considered alternatives.

Tewa Women United has not received the Word document alluded to in the above email. However, an ALARA-related list appears to have been prepared in response to the FOIA; this is uncertain because the document is undated, unsigned, and not even on a letterhead.[32] The full statement about ALARA in the statement is quoted below:

> "ALARA goals are being achieved for the FTWC project through the following methods:
>
> - "use of a tritium vapor collection system in the gas line to capture as much of the tritium as possible;
> - "monitoring of emissions in real time;
> - "only processing one drum at a time, with incremental venting actions to allow control and tracking of emissions throughout the process;

[31] David Fuehne, LANL, email to Michael Feldman, EPA, and others, January 27, 2023, obtained by Tewa Women United pursuant to an FOIA request.

[32] The only identification on the document is a number stamp in the bottom left corner "ED_014865_00000254-00001", which indicates it is part of the series of documents released in response to Tewa Women United's FOIA request.

- "establishment of emissions thresholds and associated pause points & stop points to ensure regulatory limits are not exceeded;
- "using bounding/worst case conditions to establish these emissions & dose thresholds;
- "performing daily emissions calculations and dose assessments to public receptors in all sectors and in nearby communities; and
- "enhanced downwind monitoring of tritium to better track public exposure at receptor locations."

Only the first item in this list relates to reducing doses. But stating that "as much of the tritium as possible" would be captured is not a quantitative assessment or even an analysis; a quantitative ALARA analysis is required given the specifics of the proposed venting (see below). The rest of the list consists of monitoring and compliance items that LANL has put in place to ensure that its 8 mrem limit would not be exceeded in a 12-month period. They are not expressly related to reducing dose to keep it "as low as reasonably achievable."

To determine how much public exposure could be reduced below the regulatory limit requires a quantitative assessment. DOE Order 458.1 does not mandate such an estimation in all cases. It adopts a "graded approach" to ALARA. A quantitative assessment is not required when the dose to the "maximally exposed person…is much less than 1 mrem"; a qualitative approach suffices in such cases.[33] however, it is required when the estimated dose would be in excess of 1 mrem. When doses are near 1 mrem or above it or "near reference levels" a "semi-quantitative" or fully quantitative approach is required.[34] The distinction between "semi-quantitative" and "quantitative" is not sharp; both require a detailed, *quantitative* investigation. In any case, the proposed venting could have maximum doses near the regulatory limit, and indeed, well above the regulatory limit.

As discussed above, the estimated dose from the proposed venting is well in excess of 1 mrem by LANL's calculations, even for adults. When adverse weather conditions are considered with infants as the maximum receptor, the doses could be in the hundreds of millirem from the venting of a single FTWC. A detailed quantitative ALARA investigation is therefore required. LANL has not done the required ALARA analysis. In August 2024, Tewa Women United sent a letter to LANL asking for an ALARA analysis in conformity with DOE Order 458.1.[35]

Besides keeping individual doses as low as reasonably achievable, ALARA also requires keeping population dose as low as reasonably achievable as well as requiring that environmental impact be

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[33] U.S. Department of Energy, DOE Handbook: Optimizing Radiation Protection of the Public and the Environment for Use with DOE O 458.1 ALARA Requirements, DOE-HDBK-2014, October 2014, Reaffirmed 2022at https://www.standards.doe.gov/standards-documents/1200/1215-hdbk-2014-cn1-2022-reaff-2022 (hereinafter "DOE ALARA Handbook"; p. 2-2.
[34] DOE ALARA Handbook, p.2-3 and Figure 2-1 on p. 2-4.
[35] The Tewa Women United, Letter to Thomas Mason, Director of Los Alamos National Laboratory, and others, regarding LANL's Proposed Flanged Tritium Waste Venting Project and its Obligations under DOE Order 458.1, August 2, 2024.

minimized. A specific aspect of the latter relates to the proposed venting; paragraph 4.i(2) of the Order states:[36]

> 2. "Ground water must be protected from radiological contamination to ensure compliance with dose limits in the Order and consistent with ALARA process requirements. To this end, DOE must ensure that:
>
> (a) "Baseline conditions of the ground water quantity and quality are documented;
>
> (b) "Possible sources of, and potential for, radiological contamination are identified and assessed;
>
> (c) "Strategies to control radiological contamination are documented and implemented;
>
> (d) "Monitoring methodologies are documented and implemented; and
>
> (e) "Ground water monitoring activities are integrated with other environmental monitoring activities."

No groundwater protection analysis in relation to the proposed venting has been done even though venting of HTO would make rainfall radioactive, should it rain in the environs during the venting. Based on LANL's statements at meetings with Tewa Women United, LANL has not done rainwater modeling, which is essential for estimating the impact on groundwater and on drinking water for those who used groundwater wells. In addition, there would be a longer term impact on food for those who might use groundwater for irrigation and those who collect rooftop rainwater for irrigation.

a. Minimum requirements for ALARA assessment

The first and most fundamental issue for a quantitative ALARA analysis is factual, quantitative knowledge of the source term and the risks it poses of public exposure. Specifically, LANL should have quantitative knowledge of

- The amounts of tritium in each FTWC headspace;
- The chemical form of tritium – i.e., how much of it is in the form of hydrogen gas (T_2) or tritiated water vapor (HTO);
- How much ordinary, non-radioactive hydrogen is present in the headspace;
- How much helium-3 there is in the headspace due to decay of tritium;
- How much oxygen is present in the headspace.

These measurements together would allow an assessment of whether any explosive risk exists at all. LANL has based its risk assessment on modeling: [37]

[36] DOE Order 458.1 4.i(2).

[37] Frank A. Rose, Principal Deputy Administrator, National Nuclear Security Administration. Letter to Dr. Earthea Nance, EPA Region 6 Administrator, October 12, 2023. Hereafter Rose 2023; italics added.

> "While not directly measurable in the current configuration, modeling indicates an *explosive or flammable* hydrogen/oxygen mixture within the FTWCs; each FTWC atmosphere can be *slightly different*."

Therefore, by LANL's own account, it is not certain that any particular FTWC poses the risk of an explosion. There may be a risk of a fire instead of an explosion. It is also possible that there may not be enough hydrogen (non-radioactive and radioactive forms combined) to pose an explosion risk at all. LANL's statement that hydrogen is "not directly measurable in the current configuration" of the FTWCs is disingenuous. LANL could sample the headspace once the necessary equipment is installed; *it has chosen not to do so*, apparently as a matter of regulatory and bureaucratic convenience, as indicated by LANL's response to a question from EPA Region 6 about sampling:[38]

> "Sampling is included in the operational plan and procedures, throughout all operational phases. Opening the FTWCs for headspace sampling requires the same level of ventilation, emissions monitoring, and regulatory permitting/approval that is needed for full venting."

Indeed, based on LANL's own statements there may be little or no tritium in the headspace at all. The November 5, 2020 LANL presentation to the public about the proposed venting stated that the tritium is contained in slender containers, called AL-M1s, that were put inside the FTWCs. Each FTWC contains "four to five AL-M1s holding tritium….The *tritium remains in AL-M1s*".[39] Therefore, in a properly functioning and packed FTWC, there should be no tritium from the AL-M1s in the headspace at all. LANL put items in the FTWCs outside the AL-M1s, but it unclear how much tritium they might contain and what the risk might be.

Moreover, the content of tritium in the four FTWCs was quite different at the time of loading. LANL 2019 provides the following values for the tritium content of the four FTWCs, decay-corrected to June 1, 2019.

Table 3: Tritium content of FTWCs as of June 1, 2019

FTWC	Curies	% of total
225	41,845	36.5%
226	43,017	37.5%
227	12,325	10.7%
228	17,498	15.3%

Source: LANL 2019, pdf p. 13

[38] Rose 2023.

[39] Los Alamos National Laboratory, "Flanged Tritium Waste Container Project Overview," slide 2, November 5, 2020, italics added.

Given these data, "slightly different" is a very misleading characterization of the possible state of the headspace atmospheres in the FTWCs. The two most loaded FTWCs have more than three times the tritium content of the least loaded one (#227) and more than double that of the next one (#228). Further, LANL has provided no data on the content of non-radioactive hydrogen in the FTWCs or the actual gas mixture in terms of its actual fire or explosion risk. It is quite possible one or two of the FTWCs may pose no explosion risk at all even if the other two do.

We should also not that the actual amounts of tritium in the headspaces of the FTWCs may also vary by much more than the initial loading since the tritium was supposed to be in sealed internal AL-M1s. The amounts that would have leaked out, if any, could be very variable from one FTWC to the next. Only sampling can enable an assessment, which is necessary for a quantitative ALARA analysis. A worst-case analysis for demonstrating compliance with Subpart H is reasonable since the public and the EPA would be assured that doses would be below the regulatory limit in practice. In contrast, ALARA requires a realistic assessment of the source-term, dose, and risk so that options to reduce dose and environmental impact can be reasonably assessed. That assessment requires headspace sampling without venting.

From an ALARA analysis point of view, the following is a non-exhaustive set of possibilities based on present knowledge – that is, information in the absence of actual sampling:

1) None of the FTWCs have hydrogen (ordinary and tritium) and oxygen gas mixtures to pose the risk of an explosion;
2) One or more of the FTWCs have hydrogen (ordinary and tritium) and oxygen gas mixtures to pose the risk of a fire, but conditions for an explosion might not exist;
3) There may or may not be an explosion risk sufficient to breach the FTWC, which is certified to withstand 300 pounds per square inch of pressure, in those cases where there is any explosion risk.
4) Where the explosion risk may generate pressures in excess of 300 psi, is safe repackaging in explosion-proof containers possible?

The ALARA option for any FTWC that does not pose an explosion risk is simple: it can be transported without venting. The options for the rest would be more complex and need to be analyzed.

The tritium in the FTWCs is also valuable. The approximately nine grams of tritium (decay-corrected) could be worth a quarter-of-a-million dollars or more. ALARA requires a cost-benefit analysis.

The following steps are indicated at a minimum for ALARA analysis:

1. Sampling the headspace of each FTWC without venting.
2. Determining which FTWCs, if any, pose fire or explosion risks.
3. Analyzing fire versus explosion risks.
4. Evaluating transport issues and risks in light of sampling results;
5. Evaluating repackaging in explosion proof containers in case that is indicted, including costs and risks in light of headspace sampling;
6. Analyzing population dose under various scenarios based on headspace sampling;
7. Establishment of groundwater baselines in the appropriate places;

8. Calculation of rainwater concentrations due to venting and the consequent impact on groundwater;
9. A review of original packaging of AL-M1s and whether done in compliance with AL-M1 container specifications;
10. A review of FTWC packaging and whether it was compatible in technical, safety, and regulatory terms with putting AL-M1s in the same FTWCs.

The above is not meant to be an exhaustive list.

7. Conclusions

- Both LANL and EPA Region 6 have ignored the fact that infants and children are members of the public and, as such, need to be included as members of the public.
- LANL's use of annual weather data in its initial application, which was approved by the EPA, was not in conformity with the guidance on the use of the CAP88 model. The proposed venting operation is to be conducted over days; the use of annual data to estimate dose to the most exposed member of the public is also scientifically incorrect.
- The use of annual weather data systematically underestimates the dose under adverse weather conditions. For instance, low humidity and a higher frequency of wind blowing in the direction of the maximally exposed receptor could result in doses many times higher than those estimated by LANL and far in excess of the allowable 10 mrem per year limit of Subpart H, 40 CFR 61.42.
- LANL has not done the ALARA analysis required by DOE Order 458.1. LANL's brief ALARA statement is meaningless, since it sets an ALARA limit far higher than LANL's estimated dose for the activity. In any case, a detailed quantitative analysis of options is required in the present instance by DOE Order 458.1 and the associated DOE guidance.