# Appendix F

## PRECURSOR DEMONSTRATION

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# Appendix F: Precursor Demonstration for Ammonia, SOx, and ROG

*[This section provided by the California Air Resources Board]*

## F.1 INTRODUCTION

Fine particulate matter (PM2.5) is made up of many constituent particles that are either directly emitted, such as soot and dust, or formed through complex reactions of gases in the atmosphere. Oxides of nitrogen (NOx), sulfur dioxide (SO2), volatile organic compounds (VOCs), and ammonia (NH3) are gases that are precursors to PM2.5, transforming into particles through physical and chemical atmospheric processes.

The United States Environmental Protection Agency (U.S. EPA) finalized a PM2.5 State Implementation Plan (SIP) Requirements Rule[1] (PM2.5 Rule) that identifies the four PM2.5 precursor pollutants—NOx, SO2, VOCs, and ammonia—that must be evaluated for potential control measures in any PM2.5 attainment plan. As described in the PM2.5 Precursor Demonstration Guidance[2] (Guidance) finalized by U.S. EPA in May 2019, the PM2.5 Rule permits air agencies to "submit an optional precursor demonstration designed to show that for a specific PM2.5 nonattainment area, emissions of a particular precursor from sources within the nonattainment area do not or would not contribute significantly to PM2.5 levels that exceed" the national ambient air quality standards (NAAQS). If the agency's demonstration is approved by U.S. EPA, the attainment plan "may exclude that precursor from certain control requirements under the Clean Air Act."

This document includes precursor demonstrations that the California Air Resources Board (CARB) is requesting to be excluded from certain control requirements specified in the Clean Air Act (Act) for three PM2.5 precursors: ammonia (NH3), oxides of sulfur (SOx), and reactive organic gases (ROG). The CARB inventory tracks SOx rather than SO2 specifically, but SOx consists mostly of SO2. ROG is similar, although not identical, to U.S. EPA's term "VOC."[3] CARB's inventory tracks ROG as a subset of total organic gases (TOG). NOx is an important and significant precursor to PM2.5 and is controlled extensively in the SIP. NOx emissions are essential to the attainment strategy for the San Joaquin Valley (Valley).

Following the Guidance, the three precursor demonstrations analyze "the relationship between precursor emissions and the formation of secondary PM2.5 components" using an air quality model, and take into consideration additional relevant factors.

[1] 81 FR 58010 (August 24, 2016)
[2] U.S. EPA. PM2.5 Precursor Demonstration Guidance. 30 May 2019. https://www.epa.gov/sites/default/files/2019-05/documents/transmittal_memo_and_pm25_precursor_demo_guidance_5_30_19.pdf
[3] See: California Air Resources Board. "FACT SHEET #1: Development of Organic Emission Estimates For California's Emission Inventory and Air Quality Models." Aug. 2000. Web. 24 May 2018. www.arb.ca.gov/ei/speciate/factsheetsmodeleispeciationtog082000.pdf

## F.2 U.S. EPA PM2.5 PRECURSOR DEMONSTRATION GUIDANCE

U.S. EPA finalized the Guidance in May 2019 to “assist air agencies who may wish to submit PM2.5 precursor demonstrations.” The Guidance provides recommendations or guidelines, as authorized under the Act, “that will be useful to air agencies in developing the precursor demonstrations by which the U.S. EPA can ultimately determine whether sources of a particular precursor contribute significantly to PM2.5 levels that exceed the standard in a particular nonattainment area.” Recommendations include modeling procedures for conducting the required analysis and contribution thresholds to determine the impact of a precursor on PM2.5 levels. The Guidance also describes an analytical process to perform the precursor demonstration, involving a concentration-based analysis followed by a sensitivity-based analysis and consideration of additional information.

### F.2.1 Concentration-Based Analysis

The evaluation of precursors begins with a concentration-based analysis using ambient data to determine whether precursor emissions contribute to total PM2.5 concentrations. Each precursor’s impact on total PM2.5 mass is compared to contribution thresholds. U.S. EPA recommends values for these thresholds, or air quality concentrations below which air quality impacts are not statistically significantly different from “the inherent variability in the measured atmospheric conditions,” and thus do not contribute to PM2.5 concentrations that exceed the NAAQS. These thresholds are ≥0.2 micrograms per cubic meter (μg/m$^3$) for the annual PM2.5 standard and ≥1.5 μg/m$^3$ for the 24-hour PM2.5 standard.

As shown below in Table F-1, based on this metric, ammonia, SO2, and VOCs contribute to total PM2.5 mass in the Valley in amounts that exceed U.S. EPA’s recommended thresholds.

**Table F-1 Contribution of Ammonia, SO2, and VOCs to Total PM2.5**

| Species | Relevant Precursor | Species Contribution (μg/m$^3$) to PM2.5 Mass* | Over Threshold? |
|---|---|---|---|
| Ammonium nitrate | Ammonia | 4.6 | Yes |
| Ammonium sulfate | SO2 (SOx) | 1.1 | Yes |
| Carbonaceous aerosols | VOCs (ROG) | 6.5 | Yes |

* 2017 annual average for Bakersfield-California

This concentration-based analysis, however, does not accurately capture the impact of reductions of precursor emissions on PM2.5 levels. Since the concentration-based analysis shows the precursors contribute to total PM2.5 mass in amounts over U.S. EPA’s recommended thresholds, CARB proceeded to conduct an optional sensitivity-based analysis to demonstrate that reductions of ammonia, SOx, and ROG will have negligible impact on PM2.5 air quality and be excluded from certain control requirements.

### F.2.2 Sensitivity-Based Analysis

The PM2.5 Rule allows for a sensitivity-based analysis to examine the degree to which PM2.5 levels are sensitive to precursor reductions. According to the Guidance:

> This modeling analysis examines the sensitivity of ambient PM2.5 concentrations in the nonattainment area to decreases in precursor emissions in the area…. Where decreases in emissions of the precursor result in insignificant air quality impacts (i.e., the area is “not sensitive” to decreases), such a small degree of impact can be considered to not “contribute” to PM2.5 concentrations for the purposes of determining whether control requirements should apply.

U.S. EPA notes in the Guidance that, “where air agencies have both base year and future year modeling in support of an attainment demonstration…, precursor demonstration modeling to demonstrate that precursor emissions do not contribute significantly to PM2.5 concentrations in the nonattainment area could be done in either a base year or a future year.”

For each existing PM2.5 monitor location in the area, the first step for estimating PM2.5 impacts from ammonia, SOx, or ROG in the base year is to estimate the average PM2.5 concentration on an annual basis. The second step is to calculate the annual average PM2.5 concentration at each monitor with a specified percent reduction in precursor emissions, still in the base year. The difference between these two calculated PM2.5 values is the impact on PM2.5 levels from precursor emissions reductions. Note that “precursor demonstrations do not examine changes in emissions between a base year and a future year. Instead, the calculation of changes in PM2.5 concentrations occur between a modeled case with all emissions and a modeled case with reduced precursor emissions.” In addition, U.S. EPA recommends in the Guidance modeling reductions of between 30 and 70 percent of precursor emissions since emission reductions need to be large enough to test the interaction of the precursor. In general, the recommended range is reasonable for SO2 and NOx; however, this range is not reasonable for ammonia. As indicated in the Guidance, between 2011 and 2017, the median changes in SO2 and NOx emissions nationally were decreases of 63.6 and 31.8 percent respectively, while, in contrast, the median change in ammonia was a 0.8 percent increase in emissions. The large reductions in SO2 and NOx emissions are in response to reasonable controls that are available and in practice at sources. The slight increase nationally of ammonia is indicative of the lack of controls on ammonia sources across the nation.

The third step in the sensitivity-based analysis is to compare the modeled impact on PM2.5 levels from a decrease in ammonia, SOx, or ROG emissions to contribution thresholds for annual PM2.5. If the calculated PM2.5 impact is greater than 0.2 $\mu g/m^3$ for the 12 $\mu g/m^3$ annual standard, then PM2.5 levels are sensitive to the modeled percent reduction in ammonia, SOx, or ROG emissions.

### F.2.3 Consideration of Additional Information

To supplement modeling analysis, U.S. EPA Guidance also allows an air agency to consider additional information, assessing the significance of a precursor "'based on the facts and circumstances of the area.'" The Guidance states:

> If the estimated air quality impact is greater than or equal to the recommended contribution threshold, this fact does not necessarily preclude approval of the precursor demonstration. There may be cases where it could be determined that precursor emissions have an impact above the recommended contribution thresholds, yet "do not contribute significantly" to levels that exceed the standard in the area.

In these cases, an air agency may provide U.S. EPA with "information related to other factors they believe should be considered in determining whether the contribution of emissions of a particular precursor to levels that exceed the NAAQS is 'significant' or not." Such factors may include trends in emissions of other precursors such as NOx, anticipated growth or loss of emissions sources, and impacts of modeled precursor reductions in a future year rather than the base year. U.S. EPA may also require an evaluation of available emissions controls in support of a precursor demonstration. These factors are discussed in the context of the precursor analyses for the Valley in the subsequent sections.

The following sections contain sensitivity-based analyses and supplemental information demonstrating that ammonia, SOx, and ROG are not significant precursors to PM2.5 in the Valley.

## F.3 AMMONIA ANALYSIS

Ammonium nitrate (NH4NO3) is a constituent of PM2.5, making up about 19 percent of fine particulate matter mass in the Valley in 2017. Ammonium nitrate forms when nitrogen dioxide (NO2) reacts with highly oxidizing species in the atmosphere to form nitric acid (HNO3). Nitric acid then reacts with ammonia (NH3) to yield ammonium nitrate as a particle. Since ammonia reacts chemically in this way to form a particle, ammonia is a precursor to PM2.5.

Lowering PM2.5 concentrations to levels that meet the NAAQS will rely upon an effective control strategy for ammonium nitrate. The amount of ammonium nitrate that can form in the atmosphere is limited by whichever precursor, either NOx or ammonia, is in least supply, and research studies confirm that there are relatively fewer NOx molecules in the air in the Valley than ammonia. This implies that reducing NOx, the limiting precursor in this case, is more effective for reducing ammonium nitrate concentrations and thus improving PM2.5 air quality.

Following the analytical process outlined in the Guidance and summarized above, CARB has evaluated ammonia in the Valley. The results of the sensitivity-based analysis and consideration of additional information are presented below.

### F.3.1 Sensitivity-Based Analysis

CARB staff used an air quality model to estimate the PM2.5 design value for the annual standard in the base year of 2017 at each Valley monitor. Then, CARB staff applied the recommended lower bound of a 30 percent reduction to ammonia emissions and used the air quality model to estimate the PM2.5 design values, as shown in Table F-2. The difference between the two design values represents the modeled impact on PM2.5 levels of a 30 percent reduction in ammonia emissions in 2017. This is the value that is compared to U.S. EPA's recommended contribution threshold for the 12 $\mu g/m^3$ annual standard of 0.2 $\mu g/m^3$ to establish if PM2.5 levels are sensitive to this level of ammonia reduction.

**Table F-2 Base Year 2017 PM2.5 – 30 Percent Ammonia Reduction**

| Site | 2017 Baseline DV | 2017 DV with 30% Ammonia Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 16.97 | 16.69 | 0.28 |
| Hanford | 15.73 | 15.52 | 0.21 |
| Bakersfield-Golden | 15.52 | 15.24 | 0.28 |
| Visalia | 15.43 | 15.23 | 0.20 |
| Bakersfield-California | 15.12 | 14.87 | 0.25 |
| Corcoran | 14.95 | 14.65 | 0.30 |
| Fresno-Hamilton | 13.99 | 13.85 | 0.14 |
| Fresno-Garland | 13.69 | 13.58 | 0.11 |
| Turlock | 12.7 | 12.64 | 0.06 |
| Clovis | 12.69 | 12.47 | 0.22 |
| Merced-SCoffee | 12.28 | 12.17 | 0.11 |
| Stockton | 12.21 | 12.27 | -0.06 |
| Madera | 12.11 | 11.94 | 0.17 |
| Merced-MStreet | 11.73 | 11.63 | 0.10 |
| Modesto | 11.16 | 11.17 | -0.01 |
| Manteca | 10.37 | 10.42 | -0.05 |
| Tranquility | 8.19 | 8.08 | 0.11 |

For completeness, CARB staff repeated this analysis, applying the U.S. EPA-recommended upper bound of a 70 percent reduction to ammonia emissions in the 2017 base year, as shown in Table F-3.

**Table F-3 Base Year 2017 PM2.5 – 70 Percent Ammonia Reduction**

| Site | 2017 Baseline DV | 2017 DV with 70% Ammonia Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 16.97 | 15.93 | 1.04 |
| Hanford | 15.73 | 14.53 | 1.2 |

| Site | 2017 Baseline DV | 2017 DV with 70% Ammonia Reduction | Difference |
|---|---|---|---|
| Bakersfield-Golden | 15.52 | 14.4 | 1.12 |
| Visalia | 15.43 | 14.6 | 0.83 |
| Bakersfield-California | 15.12 | 14.15 | 0.97 |
| Corcoran | 14.95 | 13.49 | 1.46 |
| Fresno-Hamilton | 13.99 | 13.34 | 0.65 |
| Fresno-Garland | 13.69 | 13.1 | 0.59 |
| Turlock | 12.7 | 12.0 | 0.7 |
| Clovis | 12.69 | 11.65 | 1.04 |
| Merced-SCoffee | 12.28 | 11.37 | 0.91 |
| Stockton | 12.21 | 11.71 | 0.5 |
| Madera | 12.11 | 11.1 | 1.01 |
| Merced-MStreet | 11.73 | 11.21 | 0.52 |
| Modesto | 11.16 | 10.59 | 0.57 |
| Manteca | 10.37 | 9.94 | 0.43 |
| Tranquility | 8.19 | 7.57 | 0.62 |

From this analysis, the estimated air quality impact of reducing ammonia emissions by the lower bound of 30 percent in the base year equals or exceeds U.S. EPA's recommended annual threshold of 0.2 µg/m$^3$ at seven Valley monitors. Reducing emissions by the upper bound of 70 percent shows impacts above the threshold at all sites. It is not possible, however, at this point to conclude from this analysis that emissions of ammonia "significantly contribute."

In this case, ammonia emissions have an impact above the recommended contribution thresholds even at the lower bound, but, as the Guidance indicates, this does not necessarily mean the precursor contributes significantly to PM2.5 levels that exceed the NAAQS. Making the appropriate determination about the ammonia emission reduction impact requires further analysis of additional factors.

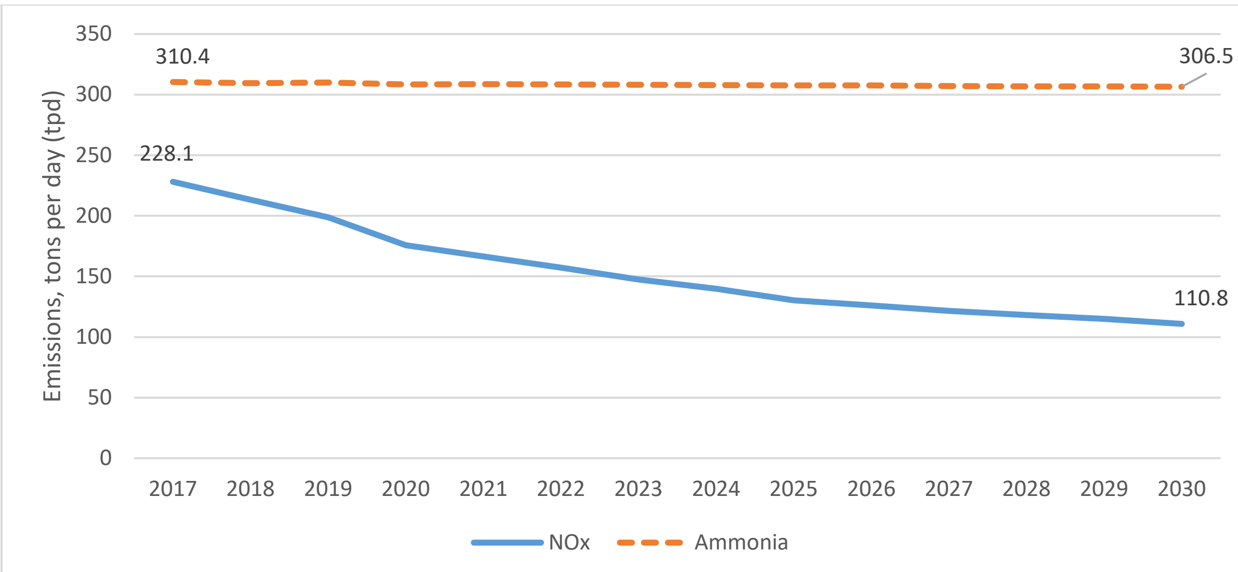
## F.3.2 Consideration of Additional Information

To supplement modeling analysis, the Guidance also allows an air agency to consider additional information, assessing the significance of a precursor "'based on the facts and circumstances of the area.'" CARB staff believes that there are several critical factors that must be considered in determining whether ammonia is a significant precursor to PM2.5 in the Valley.

### F.3.2.1 Emissions Trends and Studies

CARB has an extensive suite of measures in place to reduce NOx emissions from mobile sources that reduce ammonium nitrate. Between 2017 and 2030, total NOx emissions are expected to decline 117 tons per day (tpd) or 51 percent. Meanwhile, total ammonia emissions are expected to remain flat, declining 3.9 tpd or 1 percent, as shown in Figure F-1. The San Joaquin Valley Air Pollution Control District (District) adopted four rules[4] between 2004 and 2011 with measures that provided ammonia emissions reductions in the Valley; however, reductions from these existing control measures are already accounted for in the inventory, prior to the base year of 2017. In the future, emissions from the main sources of ammonia—dairies, fertilizer, and non-dairy livestock operations—are not anticipated to either increase or decrease substantially.

**Figure F-1 NOx and ammonia emission trends in the San Joaquin Valley between 2017 and 2030**




Source: CEPAM 2022 v 1.00

The steep downward trend of NOx emissions and the stability of ammonia emissions between 2017 and 2030 lead CARB staff to conclude that modeling the impact of ammonia emissions reductions in the future, rather than the base year, is appropriate and more representative of the Valley's emissions conditions. The Guidance states that, in some situations, it may be "more appropriate to model future conditions that provide a more representative sensitivity analysis." This approach is applicable in the Valley. After a 30 percent reduction in ammonia emissions, NOx and ammonia are of roughly similar magnitude in the base year, thereby leading to some modeled sensitivity of PM2.5 levels to a 30 percent reduction in ammonia emissions, these conditions do not persist and are not representative in the future.

As early as the 1995 Integrated Modeling Study (IMS95), in situ measurements in the San Joaquin Valley indicated the region was ammonia-saturated, which supports NOx being the controlling precursor to ammonium nitrate formation (Kumar et al., 1998[5];

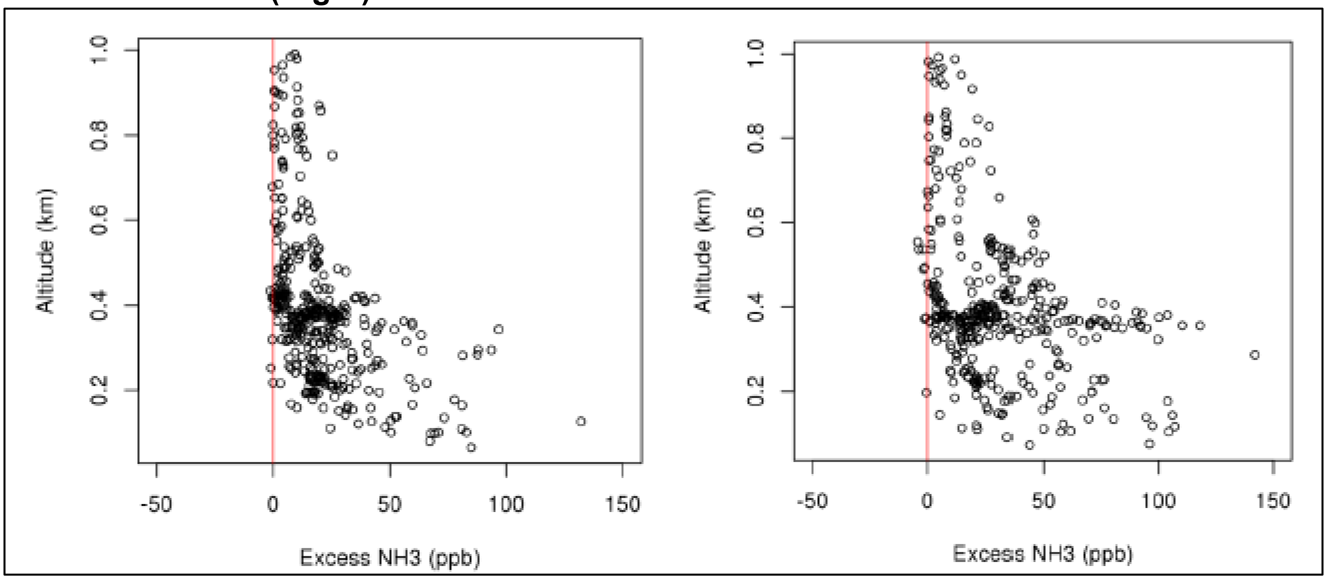
[4] District Rule 4550: Conservation Management Practices (adopted 2004); Rule 4565: Biosolids, Animal Manure, and Poultry Litter Operations (adopted 2007); Rule 4566: Organic Material Composting Operations (adopted 2011); and Rule 4570: Confined Animal Facilities (adopted 2006, amended 2010)

[5] Kumar, N.; Lurmann, F.W.; Pandis, S.; Ansari, A. *Analysis of Atmospheric Chemistry during 1995 Integrated Monitoring Study*; STI-997214-1791-FR; Report prepared for the San Joaquin Valleywide Air Pollution Study Agency, c/o the California Air Resources Board, Sacramento, CA, by Sonoma Technology, Inc.: Petaluma, CA, 1998.

Blanchard et al., 2000[6]). Wintertime measurements five years later during the CRPAQS field study (December 1999 through February 2001) were consistent with the IMS95 findings, where nearly all of the measurements were ammonia-saturated (Lurmann et al., 2006[7]). Lurmann et al. (2006) note that "[t]he consistent excess of NH3 over nitric acid levels indisputably shows that secondary ammonium nitrate formation is more limited by nitric acid availability than NH3 within the SJV and in the foothills."[8]

More recent measurements during the DISCOVER-AQ field campaign in January and February 2013 (Parworth et al., 2017[9]; and Figure F-2), support previous findings of an ammonia-saturated environment, where a small to moderate reduction in ammonia emissions is likely to have little to no effect on ammonium nitrate concentrations.

**Figure F-2 Excess ammonia (NH3) in the San Joaquin Valley on Jan 18 (Left) and Jan 20 (Right) based on NASA aircraft measurements in 2013**




Since ammonium nitrate formation is limited by NOx, reducing NOx emissions is the more effective strategy for reducing ammonium nitrate and PM2.5.

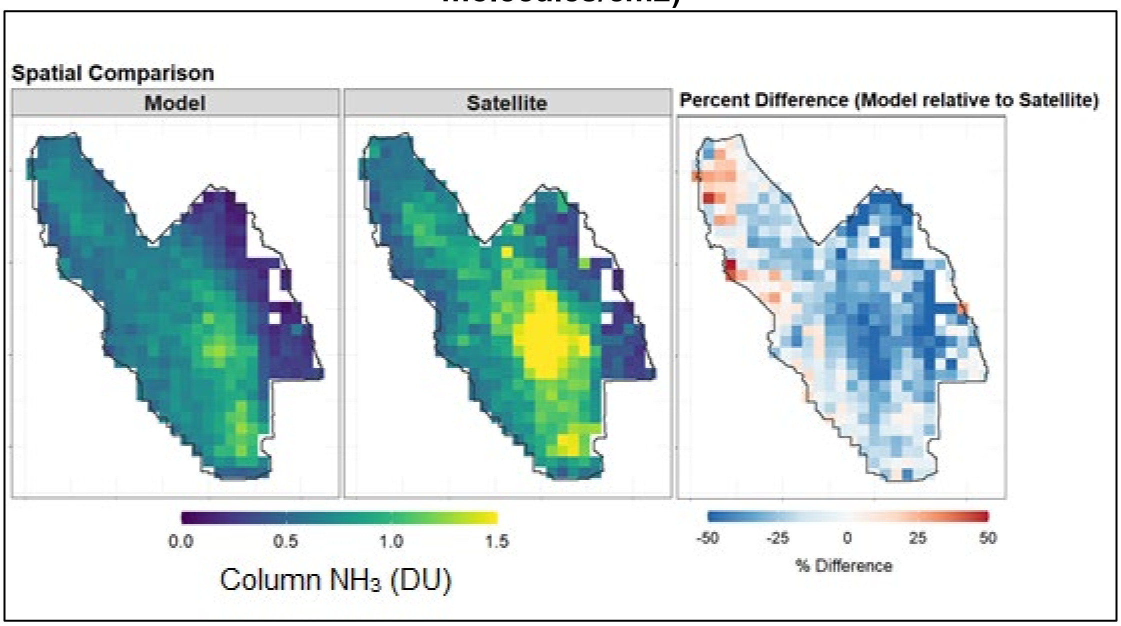
Other research has found that ammonia emission concentrations in the San Joaquin Valley are higher than currently estimated, further confirming that NOx reductions are the most effective path to reducing PM2.5. A 2017 study using satellite data also aligns

[6] Blanchard, C.L.; Roth, P.M.; Tenenbaum, S.J.; Ziman, S.D.; Seinfeld, J.H. The Use of Ambient Measurements to Identify Which Precursor Species Limit Aerosol Nitrate Formation; *J. Air & Waste Manage. Assoc.* 2000, 50, 2073-2084.
[7] Lurmann, F.W.; Brown, S.G.; McCarthy, M.C.; Roberts, P.T. Processes Influencing Secondary Aerosol Formation in the San Joaquin Valley during Winter; J. Air & Waste Manage. Assoc. 2006, 56, 1679-1693, https://doi.org/10.1080/10473289.2006.10464573
[8] Ibid. Page 1688
[9] Parworth, C.L.; Young, D.E.; Kim, H.; Zhang, X.; Cappa, C.D.; Collier, S.; Zhang, Q. Wintertime water-soluble aerosol composition and particle water content in Fresno, California, J. Geophys. Res., 122, 3155-3170, doi:10.1002/2016JD026173

with this previous research. Measurements of column-integrated ammonia[10] taken from the Infrared Atmospheric Sounding Interferometer (IASI), an instrument housed aboard the European Space Agency's MetOP-A satellite which passes over California daily, suggest that CARB's emissions inventory currently underestimates ammonia emissions in the Valley. These results suggest the modeled sensitivity to ammonia reductions is overstated and further reinforces the efforts to develop and deploy ammonia controls would not move the Valley forward on the path to reducing PM2.5 concentrations, and that NOx emissions reductions are the most effective strategy to reduce ammonium nitrate. CARB is continuing to evaluate ammonia emissions and for any updates that are made to the emissions inventory for ammonia in connection with development of future SIPs, CARB staff will hold a public process to solicit public input.

Figure F-3 shows the annual average of column ammonia in 2017 from IASI (Satellite) and Community Multiscale Air Quality (CMAQ) (Model). The model is biased low for column ammonia in the Valley. This bias is most noticeable in Tulare County, where both the model and satellite show an ammonia hotspot, but the model shows about half as much ammonia as the satellite.

**Figure F-3 Maps of annual average ammonia from CMAQ (Model; left), IASI (Satellite; middle), and the percentage difference (DU, 1 DU = 2.69e16 molecules/cm2)**




With these new findings from the 2017 study aligning with previous findings from IMS95, CRPAQS, and DISCOVER-AQ, CARB staff's conclusion based on the scientific analysis available continues to be that focusing on NOx emission reductions is key to improving the health of Valley residents and actions to reduce ammonia will not provide significant PM2.5 air quality improvements.

[10] Column-integrated ammonia is total ammonia in the atmosphere above a specific location, including both surface (ground-level) and aloft. Most column-integrated ammonia is found at the surface.

### F.3.2.2 Future Year Modeling

Analysis of NOx and ammonia emissions trends, discussed above, indicated that modeling the impact of ammonia emissions reductions in the future, rather than the base year, is appropriate and more representative of the Valley's emissions conditions. In accordance with the Guidance, CARB staff repeated the sensitivity-based analysis of ammonia for the future attainment year of 2030. Staff used an air quality model to estimate the PM2.5 design value for the annual standard in 2030 at each Valley monitor. Then, CARB staff applied a 30 percent reduction to ammonia emissions and used the air quality model to estimate the PM2.5 design values in 2030, shown in Table F-4. The difference between the two design values represents the modeled impact on PM2.5 levels of a 30 percent reduction in ammonia emissions in the attainment year. The future-year modeling includes emission reductions from measures in the CARB-adopted 2022 State Strategy for the State Implementation Plan (2022 State SIP Strategy).[11]

**Table F-4 Future Year 2030 PM2.5 – 30 Percent Ammonia Reduction**

| Site | 2030 Baseline DV | 2030 DV with 30% Ammonia Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 14.05 | 13.96 | 0.09 |
| Hanford | 11.17 | 11.01 | 0.16 |
| Bakersfield-Golden | 12.48 | 12.38 | 0.1 |
| Visalia | 12.41 | 12.33 | 0.08 |
| Bakersfield-California | 12.39 | 12.3 | 0.09 |
| Corcoran | 10.71 | 10.54 | 0.17 |
| Fresno-Hamilton | 11.77 | 11.7 | 0.07 |
| Fresno-Garland | 11.55 | 11.49 | 0.06 |
| Turlock | 10.33 | 10.21 | 0.12 |
| Clovis | 9.91 | 9.8 | 0.11 |
| Merced-SCoffee | 9.61 | 9.49 | 0.12 |
| Stockton | 10.7 | 10.59 | 0.11 |
| Madera | 9.17 | 9.06 | 0.11 |
| Merced-MStreet | 9.96 | 9.9 | 0.06 |
| Modesto | 9.3 | 9.19 | 0.11 |
| Manteca | 8.85 | 8.75 | 0.1 |
| Tranquility | 6.37 | 6.29 | 0.08 |

For completeness, CARB staff repeated this analysis, applying instead the U.S. EPA-recommended upper bound of a 70 percent reduction to ammonia emissions in 2030, as shown in Table F-5.

[11] CARB. 2022 State Strategy for the State Implementation Plan. 22 Sept. 2022. https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf

**Table F-5 Future Year 2030 PM2.5 – 70 Percent Ammonia Reduction**

| Site | 2030 Baseline DV | 2030 DV with 70% Ammonia Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 14.05 | 13.75 | 0.30 |
| Hanford | 11.17 | 10.66 | 0.51 |
| Bakersfield-Golden | 12.48 | 12.17 | 0.31 |
| Visalia | 12.41 | 12.15 | 0.26 |
| Bakersfield-California | 12.39 | 12.1 | 0.29 |
| Corcoran | 10.71 | 10.11 | 0.60 |
| Fresno-Hamilton | 11.77 | 11.53 | 0.24 |
| Fresno-Garland | 11.55 | 11.34 | 0.21 |
| Turlock | 10.33 | 9.96 | 0.37 |
| Clovis | 9.91 | 9.58 | 0.33 |
| Merced-SCoffee | 9.61 | 9.23 | 0.38 |
| Stockton | 10.7 | 10.36 | 0.34 |
| Madera | 9.17 | 8.78 | 0.39 |
| Merced-MStreet | 9.96 | 9.76 | 0.20 |
| Modesto | 9.3 | 8.96 | 0.34 |
| Manteca | 8.85 | 8.54 | 0.31 |
| Tranquility | 6.37 | 6.12 | 0.25 |

From this analysis, in 2030, the modeled air quality impact of reducing ammonia emissions by 30 percent falls under U.S. EPA's recommended threshold of 0.2 µg/m$^3$ at all Valley monitor sites. The estimated air quality impact of reducing ammonia emissions by the upper bound of 70 percent in 2030 exceeds U.S. EPA's recommended threshold at all sites.

### F.3.2.3 Available Emissions Controls

Another factor that may be considered as additional information for this analysis is available emissions controls on ammonia. The availability of ammonia emissions controls is relevant to the decision-making process, influencing the extent of reasonable modeled reductions. While U.S. EPA recommends modeling emissions reductions of between 30 and 70 percent to estimate PM2.5 impacts, these percentage were based on the change seen nationally in NOx and SO2 reductions between 2011 and 2017. During that same time, ammonia emissions increased slightly, indicating limited control opportunities. CARB staff, District staff, and the public process also have not identified specific controls that are technologically and economically feasible to achieve reductions at the low end of the recommended sensitivity range (i.e., 30 percent), much less at the upper end of the range.

At U.S. EPA staff's request, CARB and the District developed a supplemental document on ammonia as a PM2.5 precursor to support the Attainment Plan Revision for the 1997 Annual PM2.5 Standard (15 µg/m$^3$ SIP Revision) which CARB submitted in 2021. The supplemental document—Ammonia: Supplemental Information for EPA in Support of 15 µg/m$^3$ Annual PM2.5 Standard (Ammonia Supplemental Information for the 15 µg/m$^3$

SIP Revision)[12]—expanded on earlier analyses, assessing potential controls on ammonia sources identified by U.S. EPA to analyze the appropriateness of the 30 percent reduction threshold for the precursor analysis, relevant to the 15 µg/m$^3$ annual PM2.5 standard. CARB submitted the Ammonia Supplemental Information for the 15 µg/m$^3$ SIP Revision to U.S. EPA in March 2023. U.S. EPA proposed approval of the 15 µg/m$^3$ SIP Revision, including the precursor demonstration for ammonia, on July 14, 2023.[13] The information in this section of the Precursor Demonstration builds on the analysis and conclusions presented in the Ammonia Supplemental Information for the 15 µg/m$^3$ SIP Revision, relevant here to the 12 µg/m$^3$ annual PM2.5 standard.

It is important to note that not all control measure concepts are appropriate to be submitted into the SIP as rules. Any rules that are submitted into the SIP must meet U.S. EPA requirements, and must:

- Include enforceable emission limitations and other control measures, means, or techniques, as well as schedules and timetables for compliance, as may be necessary to meet the requirements of the Clean Air Act [Act section 110(a)(2)(A)];
- Provide necessary assurances that the State will have adequate personnel, funding, and authority under State law to carry out such SIP (and is not prohibited by any provision of federal or state law from carrying out such SIP) [Act section 110(a)(2)(E)];
- Be adopted by a State after reasonable notice and public hearing [Act section 110(l)]; and
- Not interfere with any applicable requirement concerning attainment and reasonable further progress, or any other applicable requirement of the Act [Act section 110(l)].

The supplemental evaluation of potential controls on ammonia sources identified by U.S. EPA is found below.

#### *F.3.2.3.1 Evaluation of Potential Controls on Ammonia Emissions Sources*

The District and CARB analyzed potential control measures to reduce ammonia emissions in order to evaluate whether a 30 percent reduction in ammonia emissions is feasible. For an effective control measure evaluation, it is necessary to characterize and understand the key sources of ammonia in the Valley.

The three main sources of ammonia emissions in the Valley from stationary and area sources, which account for 93 percent of the Valley's ammonia emissions[14], are the focus of the evaluation. Since the attainment year for this SIP is 2030, data and figures below reflect the projected ammonia inventory for that year. The increased level of

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[12] CARB. Ammonia: Supplemental Information for EPA in Support of 15 µg/m3 Annual PM2.5 Standard. March 2023. https://ww2.arb.ca.gov/sites/default/files/2023-04/AmmoniaSupplementalInformation.pdf

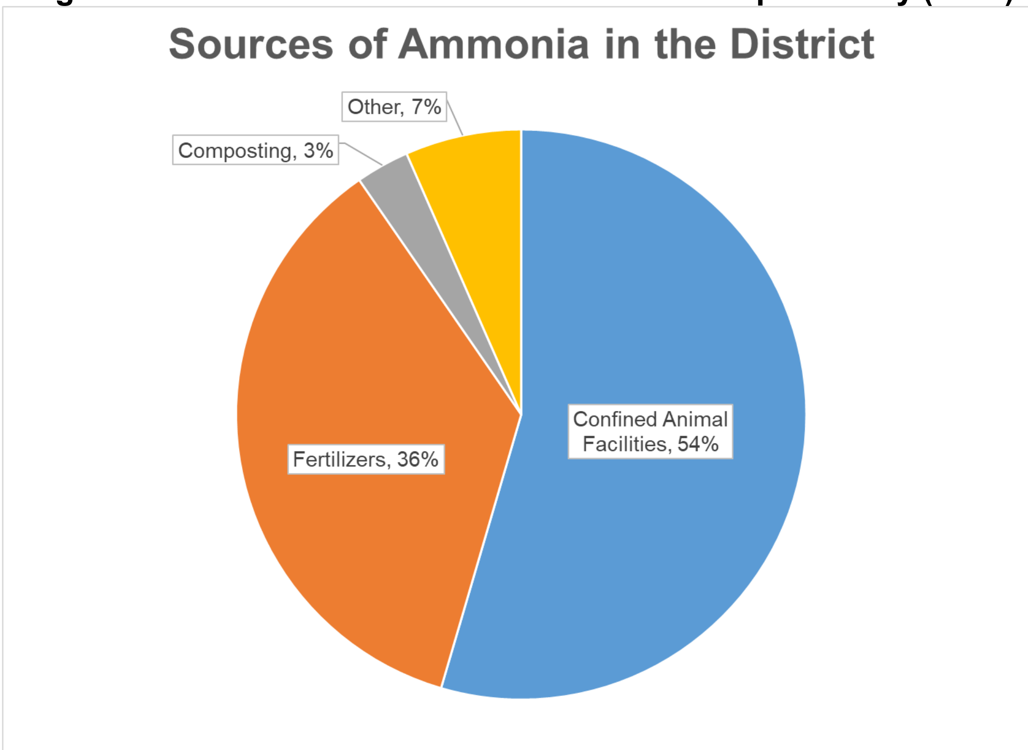
[13] See 88 FR 45276. (July 14, 2023). Retrieved from: https://www.govinfo.gov/content/pkg/FR-2023-07-14/pdf/2023-14687.pdf

[14] Based on CEPAM 2022 v 1.00 Annual Average Emissions Inventory for 2030

control due to the implementation of District rules and regulations is already incorporated into the projected emission inventory.

- Confined Animal Facilities (CAFs) with 167.2 tons per day (tpd);
- Agricultural Fertilizers at 109.9 tpd; and
- Composting Solid Waste Operations at 9.3 tpd.

**Figure F-4 Sources of Ammonia in the San Joaquin Valley (2030)**




Since the primary source of ammonia emissions in the Valley are from CAFs, the District focused its evaluation on the different types of animal operations, specifically dairies, which account for the majority of ammonia emissions.

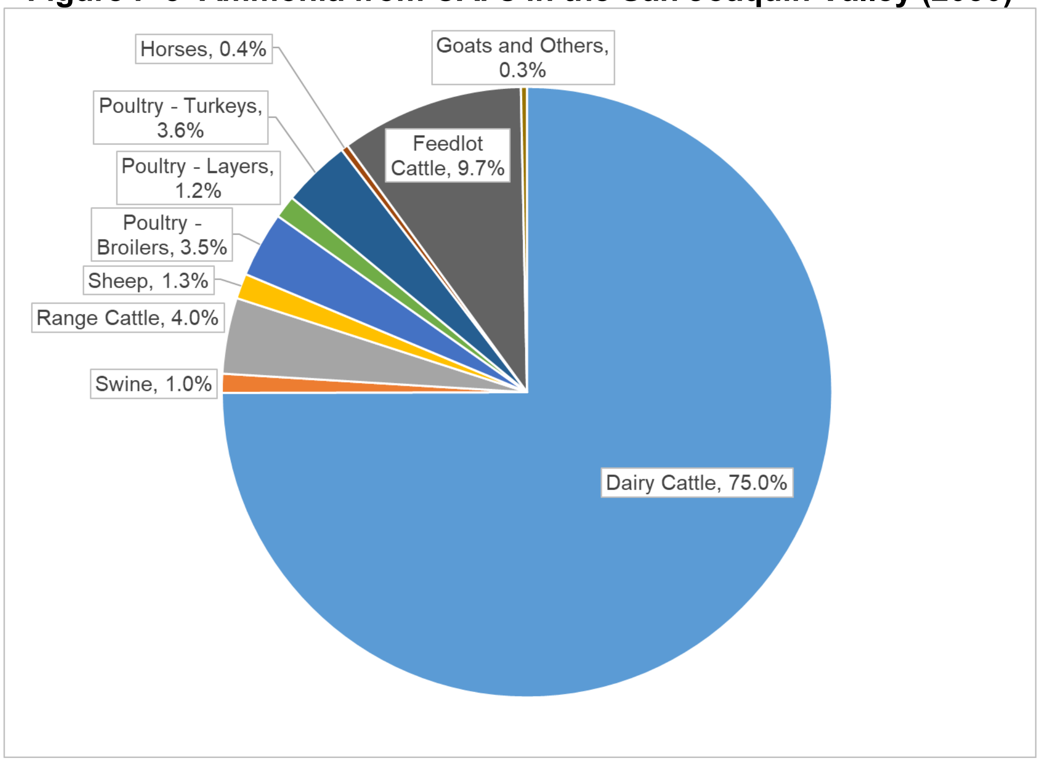
The total ammonia emissions in the Valley in 2030 are 306.5 tons per day. As shown in Table F-6 below, to reduce the total ammonia emissions by 30 percent, 50 percent, and 70 percent, emissions from CAFs would need to be further reduced by 55 percent, 92 percent, and 128 percent respectively. As shown in the evaluation below, the District has only identified a few measures that have the theoretical potential to reduce additional ammonia emissions, which may achieve a total of up to 2 percent reduction in emissions notwithstanding technological and economic feasibility considerations. These reductions are not capable of achieving the lower bound level of 30 percent reductions, and the 50 percent and 70 percent reduction levels are infeasible.

**Table F-6 CAF Emission Reduction Analysis**

| | 30% Reduction | 50% Reduction | 70% Reduction |
|---|---|---|---|
| Theoretical Ammonia Reductions (tpd) | 91.9 | 153.2 | 214.5 |
| % reduction required from CAFs | 55% | 92% | 128% |

As shown below in Figure F-5, dairy cattle emissions account for 75.0 percent of ammonia emissions from CAFs.

**Figure F-5 Ammonia from CAFs in the San Joaquin Valley (2030)**



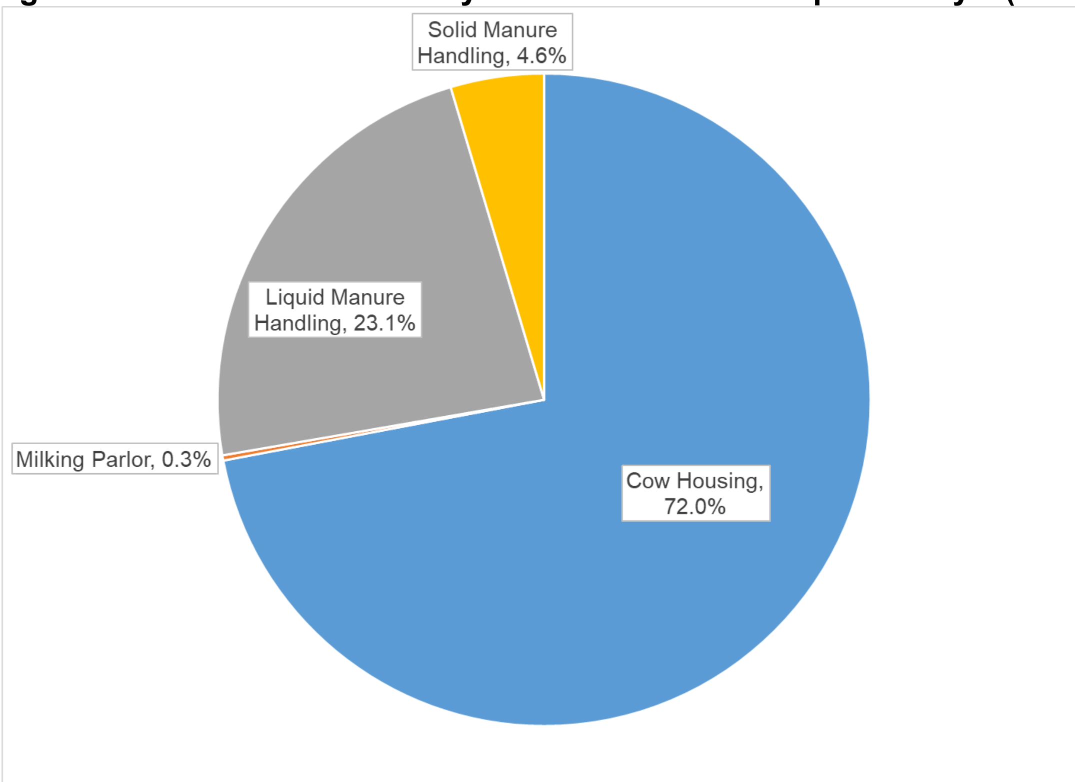

The total ammonia emissions in the Valley in 2030 are 306.5 tons per day. As shown in Table F-7 below, to reduce the total ammonia emissions by 30 percent, 50 percent, and 70 percent, emissions from dairy cattle would need to be reduced by 73 percent, 122 percent, and 171 percent, respectively.

**Table F-7 Dairy Cattle Emission Reductions Analysis**

| | 30% Reduction | 50% Reduction | 70% Reduction |
|---|---|---|---|
| Theoretical Ammonia Reductions (tpd) | 91.95 | 153.24 | 214.54 |
| % reduction required of dairy cattle | 73% | 122% | 171% |

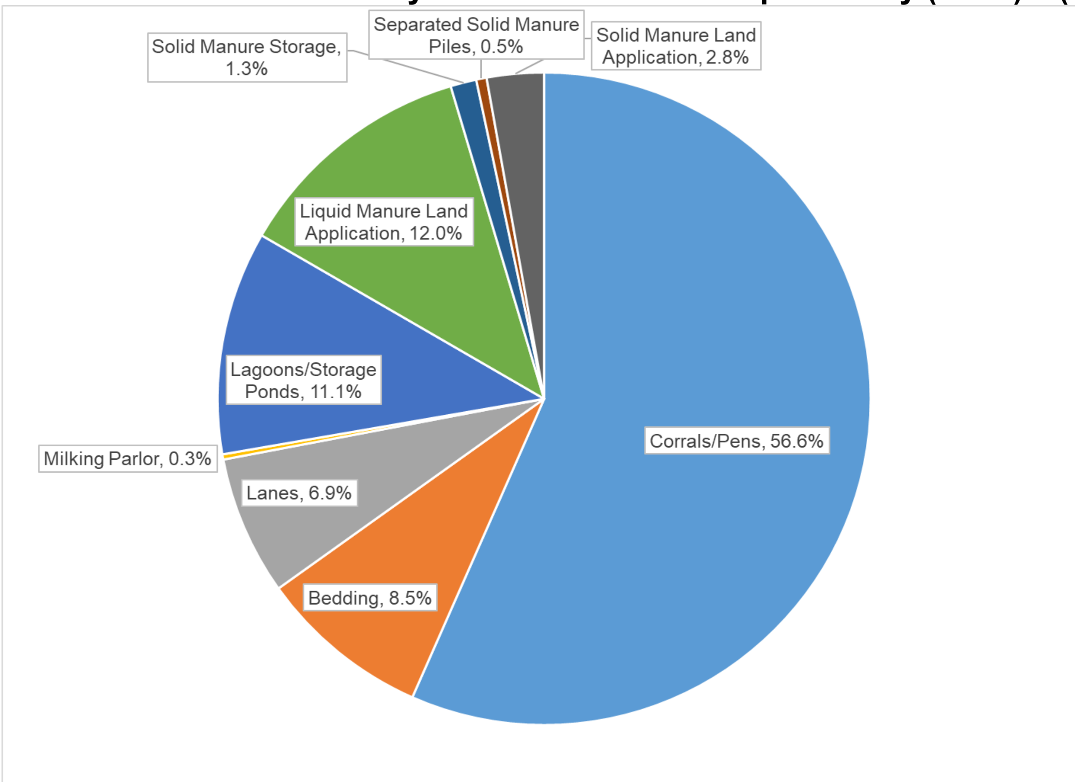
As shown in Figure F-6, the primary source of ammonia emissions from dairy cattle is cow housing (72 percent). Figure F-7 further evaluates ammonia emissions from dairy cattle by illustrating the different categories such as corrals/pens (56.6 percent), liquid manure land application (12 percent), and lagoons/storage ponds (11.1 percent), etc. Accordingly, the District has provided an evaluation of mitigation measures for dairy cattle focusing on housing, land application techniques, and solid and liquid manure handling.

**Figure F-6 Ammonia from Dairy Cattle in the San Joaquin Valley[15] (2030)**




[15] Based on District ammonia emission factors for dairy cattle.

**Figure F-7 Ammonia from Dairy Cattle in the San Joaquin Valley (cont.)[16] (2030)**




Based on the emission inventory analysis above, reducing ammonia emissions by the lower bound precursor demonstration threshold of 30 percent would require eliminating over 50 percent of ammonia emissions from CAFs, or over 70 percent of emissions from only dairy cattle, beyond the ammonia emission reductions already achieved by the requirements of District Rule 4570 (Confined Animal Facilities). A 70 percent reduction of ammonia emissions in the District would require the elimination of all CAFs in the District in addition to other categories that have already achieved significant ammonia reductions.

### *F.3.2.3.2 Inventory of Confined Animal Facilities in the Valley*

The District reviewed current permitted facilities in the Valley. Demonstrated below in Table F-8 is the count of permitted facilities by type that are subject to Rule 4570, and the controlled ammonia emissions from each type of facility.

[16] Ibid.

**Table F-8 Inventory of Confined Animal Facilities in the Valley (2030)**

| Facility Type | # of Facilities Subject to Rule 4570[17] | Ammonia Emissions from Facility Type (tpd) |
|---|---|---|
| Dairies | 859 | 125.3 |
| Beef Feedlots | 6 | 16.2 |
| Other Cattle | 17 | 6.7 |
| Chicken – Broilers | 47 | 5.8 |
| Chicken – Layers | 12 | 2.0 |
| Turkeys | 19 | 6.0 |
| Swine | 1 | 1.7 |

### *F.3.2.3.3 District Rule 4570 (Confined Animal Facilities)*

**Background**

The largest source of ammonia in the Valley is CAFs. The District has implemented Rule 4570 to reduce emissions from this source category, and requires the most stringent requirements for reducing emissions from CAFs in the nation. Rule 4570 was originally adopted on June 15, 2006, and was again amended on October 21, 2010. District Rule 4570 applies to facilities where animals are corralled, penned, or otherwise caused to remain in restricted areas and primarily fed by a means other than grazing for at least 45 days in any twelve-month period. In addition to limiting volatile organic compound (VOC) emissions, District Rule 4570 includes measures that limit ammonia emissions from these operations.

**Evaluation of District Rule 4570**

District Rule 4570 includes multiple mitigation measures that control ammonia emissions from CAFs. Since these facilities generally cover a large area and have different processes, a single mitigation measure or technology is generally not sufficient to control overall emissions from the facility. Due to the varying types of operations and emissions sources at these facilities, each CAF requires a site-specific constellation of measures to achieve overall emission reductions.

District Rule 4570 includes a large number of measures that must be implemented by each CAF and also requires additional measures to be selected from a menu of mitigation measures options to achieve additional emission reductions. The menu approach gives the facilities the flexibility to achieve the required emission reductions by selecting mitigation measures that are most practical and effective for their operation. As discussed in the District staff report for the 2010 amendments to District Rule 4570,[18] the design and operation of each CAF differs depending on animal type, regional climatic conditions, business practices, and the preferences of the owners/operators. Because of this, no two CAFs are identical. In addition to air quality

[17] Review of District permits database (May 2023)
[18] SJVAPCD. *Staff Report for 2010 Amendments Rule 4570 (Confined Animal Facilities).* Available at: http://valleyair.org/Board_meetings/GB/agenda_minutes/Agenda/2010/October/Agenda_Item_7_Oct_21_2010.pdf

regulations, CAFs are subject to other regulations to protect water quality and the environment. These additional regulations often restrict how CAFs can operate.

It is not feasible for all CAFs to implement the same measures due to various factors, such as infrastructure, conditional use permits, water quality regulations, production contracts, and other limitations. The options included in District Rule 4570 provide the owners and operators of CAFs much-needed flexibility to choose the mitigation measures that make the best environmental and economic sense for their facility, while maximizing the amount of emission reductions.

#### *F.3.2.3.4 Other Air District Rules*

The District provided an in-depth review of Rule 4570 in Appendix C of the *2018 Plan for the 1997, 2006, and 2012 PM2.5 Standards* (*2018 PM2.5 Plan*), [19] including a comprehensive analysis of Rule 4570, in which the District compared emissions limits, optional control requirements, and work practices in Rule 4570 to comparable requirements in rules from the following areas:

- South Coast Air Quality Management District (SCAQMD) Rule 223 (Emission Reduction Permits for Large Confined Animal Facilities);
- SCAQMD Rule 1127 (Emission Reductions from Livestock Waste);
- Bay Area Air Quality Management District (BAAQMD) Regulation 2, Rule 10 (Large Confined Animal Facilities);
- Ventura County Air Pollution Control District (VCAPCD) Rule 23 (Exemptions from Permit);
- Sacramento Metropolitan Air Quality Management District (SMAQMD) Rule 496 (Large Confined Animal Facilities);
- Imperial County Air Pollution Control District (ICAPCD) Rule 217 (Large Confined Animal Facilities Permits Required) and Policy Number 38 (Recommended Mitigation Measures for Large Confined Animal Facilities); and
- Idaho Administrative Procedure Act 58.01.01 Sections 760-764 (Rules for the Control of Ammonia from Dairy Farms);

In addition to these rules, the District's *2016 Plan for the 2008 8-hour Ozone Standard* (*2016 Ozone Plan*)[20] included a comparison of District Rule 4570 to requirements from the following:

- Butte County Air Pollution Control District (BCAQMD) Rule 450 (Large Confined Animal Facilities); and
- Yakima Regional Clean Air Agency (Air Quality Management Policy and Best Management Practices for Dairy Operations).

[19] SJVAPCD. *2018 Plan for the 1997, 2006, and 2012 PM2.5 Standards*. Appendix C, pages C-311 – C-339. Available at: https://www.valleyair.org/pmplans/documents/2018/pm-plan-adopted/2018-Plan-for-the-1997-2006-and-2012-PM2.5-Standards.pdf

[20] SJVAPCD. *2016 Plan for the 2008 8-hour Ozone Standard*. Available at: http://valleyair.org/Air_Quality_Plans/Ozone-Plan-2016/Adopted-Plan.pdf

Through the rule comparisons included in the *2022 Ozone Plan*, *2018 PM2.5 Plan*, and the *2016 Ozone Plan*, the District demonstrated that Rule 4570 was more stringent than the above rules in other areas, at the time of each plan's adoption. The areas mentioned above have not changed or amended their respective rules since the District's previous evaluations, except for the Yakima Regional Clean Air Agency, which rescinded their policy for dairies in 2018. The District has found no new requirements in other areas, but has reevaluated the rules above and found that Rule 4570 continues to implement the most stringent requirements for CAFs.

### *F.3.2.3.5 Federal Actions and Guidance*

The evaluation of appropriate practices and measures to reduce emissions from confined animal facilities requires accurate methodologies to estimate emissions. The National Academy of Sciences identified the lack of methodologies to estimate emissions from animal feeding operations (AFOs) in 2002. In response, U.S. EPA announced an opportunity for AFOs to sign a voluntary consent agreement and final order known as the Air Compliance Agreement (2005).[21] The goal of the agreement was to develop scientifically credible methodologies for estimating emission models produced by AFOs. AFOs that chose to participate in the agreement provided the funding for the National Air Emissions Monitoring Study (NAEMS). As part of the agreement, U.S. EPA agreed not to sue participating AFOs for certain violations of the Act, Compensation, and Liability Act (CERCLA), and Emergency Planning and Community Right-to-Know Act (EPCRA), provided that the AFOs comply with the agreement's conditions.

The NAEMS monitored 25 AFOs in various regions of the country to have equipment installed for ammonia, hydrogen sulfide, particulate matter, and VOC emissions monitoring. Separate draft models of swine, poultry, and dairy AFOs emissions were created using the monitoring data and input from the U.S. EPA Science Advisory Board.[22]

While data collection took place from 2007 to 2010, these draft models only became publicly available in August 2020, August 2021, and June 2022 for swine, poultry, and dairy AFOs respectively. U.S. EPA's final models to estimate emissions from AFOs are not yet available. Currently, U.S. EPA projects that finalization of all draft models will occur in late 2023.[23] Though U.S. EPA has not provided final guidance on emission estimation methodologies for CAFs, the District has reviewed information from U.S. EPA and many other sources in order to use the best information available to calculate emissions from CAFs.

[21] See 70 FR 4958. (January 31, 2005). Retrieved from: https://www.epa.gov/sites/default/files/2016-06/documents/afolagooneemreport2012draftappe.pdf
[22] Livestock and Poultry Environmental Learning Community. *NAEMS: How It Was Done and Lessons Learned*. April 20, 2022. Retrieved from: https://lpelc.org/naems/
[23] EPA. *National Air Emissions Monitoring Study*. Retrieved from: https://www.epa.gov/afos-air/national-air-emissions-monitoring-study#naems-status

### F.3.2.3.6 District Efforts

The District first began permitting agricultural sources in 2004, and since that time District staff members have gained a great deal of experience in the evaluation of emissions from agricultural sources through collaborative efforts with other institutions, agencies, and interested stakeholders. The District has also been thoroughly involved in collaborative scientific research efforts to evaluate emissions from agricultural sources. This is particularly true of the agricultural emissions research efforts in California. The District has played an important role in coordination of these efforts through the San Joaquin Valleywide Air Pollution Study Agency (Study Agency) and the Study Agency's Agricultural Air Quality Research Committee (AgTech). The District has also been at the forefront of developing and implementing regulations to reduce emissions from CAFs.

The District will continue to track the development of rules, regulations, research/studies, and practices for CAFs to ensure the best available control measures and most stringent measures are in place in the Valley, in coordination with industry stakeholders, researchers, CARB, and other agencies.

### F.3.2.3.7 Evaluation of Mitigation Measures for Confined Animal Facilities

In the Federal Register posting for the proposed partial approval and partial disapproval of portions of the state implementation plan revisions for the 1997 annual PM2.5 standard,[24] U.S. EPA indicates that further evaluation of potential control measures for ammonia sources is needed. In U.S. EPA's proposed disapproval of portions of the *2018 PM2.5 Plan* for the 2012 annual PM2.5 standard,[25] U.S. EPA refers to several studies that were cited in a Public Justice comment letter[26] that evaluate CAF mitigation measures that have the potential to achieve additional ammonia reductions. In the same proposal, U.S.EPA noted that the United States Department of Agriculture (USDA) National Resources Conservation Service (NRCS) has collaborated to develop a "Reference Guide for Poultry and Livestock Production Systems" (NRCS Reference Guide) [27] that lists 12 measures that may reduce ammonia emissions by more than 30 percent. U.S. EPA also cited a 2011 inventory of mitigation methods by Price et al. prepared for the UK government (UK User Guide) that identifies several ammonia mitigation methods for UK farms.[28]

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[24] See 86 FR 38662. (July 22, 2021). Retrieved from: https://www.govinfo.gov/content/pkg/FR-2021-07-22/pdf/2021-15551.pdf

[25] See 87 FR 60494. (October 5, 2022). Retrieved from: https://www.govinfo.gov/content/pkg/FR-2022-10-05/pdf/2022-21492.pdf

[26] Public Justice, et al. (January 28, 2022). Group Comment Letter *Re: Clean Air Plans; 2012 Fine Particulate Matter Serious Nonattainment Area Requirements; San Joaquin Valley, California*; EPA-R09-OAR-2021-0884. Retrieved from: https://www.regulations.gov/comment/EPA-R09-OAR-2021-0884-0136

[27] EPA-USDA NRCS. "Reference Guide for Poultry and Livestock Production Systems." September 2017. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf

[28] Price et al., "An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture, User Guide," December 2011. Retrieved from: https://repository.rothamsted.ac.uk/download/942687eab7ec4b83751c7e241d62f0fa8472d72adcd25a149bb891b7c30d55d0/1595300/MitigationMethods-UserGuideDecember2011FINAL.pdf

Following the proposed disapprovals and several meetings with U.S. EPA Region 9 staff, the District was provided with a list of mitigation measures generated by EPA Region 9 staff for evaluation, many of which the District has already evaluated over the years. As discussed earlier, it is also important to note that U.S. EPA has been committed to addressing emission from livestock operations under a voluntary "safe harbor" consent agreement put into place by U.S. EPA in 2005. While the San Joaquin Valley has regulated emissions from livestock operations since 2005, U.S. EPA is still in the process of evaluating emissions and establishing the regulatory framework under this consent agreement, and the District will continue supporting the national effort to address emissions from these operations. This list encompassed publications that evaluated potential ammonia emission reductions for either individual mitigation measures or compilations of mitigation measures. The publications provided to the District included a wide variety of mitigation measures such as reducing crude protein content in feed, litter amendments, injection/incorporation of manure, changing land use from arable to woodland, and reducing human consumption of meat and eggs.

Though some of the suggested measures have related studies that appear to demonstrate potential feasibility, it is imperative to consider the conditions under which the studies were performed and how those conditions compare to the Valley. Several of the studies evaluated were conducted in areas outside of California, and many outside of the nation. Notably, CAFs in the Valley face unique challenges, including hot, dry summers, drought conditions, and strict water regulations, which may not have been considered in some of the publications and studies that evaluated these methods. Valley dairies in particular are typically much larger than dairies in other areas. Based on information from the USDA National Agricultural Statistics Service, the average dairy in the Valley has almost 1,600 cows compared to a national average of less than 300 cows per dairy outside of California.[29, 30] The UK User Guide, which contains many of the measures evaluated in this document, indicated that the average UK dairy has 170 cows. The differences in climate, typical management practices, size of operations, and regulatory environment affect the types of mitigation measures that can be applied to each operation.

Many of the mitigation measures for consideration by U.S. EPA were not applicable to the Valley, were unreasonable or unenforceable, or were based on limited applicability in California (e.g., research conducted in other countries with drastically different operating and natural characteristics). The complete list of potential mitigation measures provided by U.S. EPA Region 9 staff can be found in Appendix A of the Ammonia Supplemental Information for the 15 µg/m$^3$ SIP Revision.[31] The District's evaluation of all potential mitigation measures provided by U.S. EPA is included in the following sections.

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[29] Hanson, M. (2021) U.S. Dairy Herd Hits 27-year High. *Dairy Herd Management.* Retrieved from: https://www.dairyherd.com/news/dairy-production/us-dairy-herd-hits-27-year-high

[30] Latest USDA Statistics for average size of dairies excluding California, retrieved from: https://downloads.usda.library.cornell.edu/usda-esmis/files/h989r321c/7d279w693/f7624g40c/mkpr0222.pdf (about 270 cows per dairy outside California)

[31] CARB. Ammonia: Supplemental Information for EPA in Support of 15 µg/m3 Annual PM2.5 Standard. March 2023. https://ww2.arb.ca.gov/sites/default/files/2023-04/AmmoniaSupplementalInformation.pdf

## Nutrition and Feed Management (Feeding)

**Table F-9 Nutrition and Feed Management Measures Evaluated**

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| Reducing Crude Protein (Beef) | Influence of Dietary Crude Protein Concentration and Source on Potential Ammonia Emissions from Beef Cattle Manure | Beef | Preece[32] |
| | Reducing Crude Protein in Beef Cattle Diet Reduces Ammonia Emissions from Artificial Feedyard Surfaces | Beef | Todd[33] |
| | Reduce Dietary Crude Protein in Beef Cattle | Beef | Cole (2005)[34] |
| Reducing Crude Protein (Dairy) | Reducing Dietary Protein Decreased the Ammonia Emitting Potential of Manure from Commercial Dairy Farms | Dairy | Hristov[35] |
| Reducing Crude Protein (Swine) | Reduce Crude Protein Content from Finishing Pig Houses | Swine | Hayes[36] |
| Feed Timing | Phase, Group, and Split Sex-Feeding | Beef | Cole (2006)[37] |
| | Group and Phase Feeding | All | NRCS[38] |
| | Phase Feeding | All | Guthrie[39] |

[32] Preece, Sharon L.M. et al., ''Ammonia Emissions from Cattle Feeding Operations,'' Texas A&M AgriLife Extension Service, referring to Cole, N.A., R.N. Clark, R.W. Todd, C.R. Richardson, A. Gueye, L.W. Greene, and K. McBride, ''Influence of Dietary Crude Protein Concentration and Source on Potential Ammonia Emissions from Beef Cattle Manure,'' Journal of Animal Science 83:(3), 722 (2005)
[33] Todd, R.W., N.A. Cole, and R.N. Clark, ''Reducing Crude Protein in Beef Cattle Diet Reduces Ammonia Emissions from Artificial Feedyard Surfaces.'' Journal of Environmental Quality. 35:(2), 404–411 (2006).
[34] Cole, N., et al., Influence of dietary crude protein concentration and source on potential ammonia emissions from beef cattle manure. J. Anim. Sci. 83, 722 (2005).
[35] Hristov, A. N., Heyler, K., Schurman, E., Griswold, K., Topper, P., Hile, M., ... & Dinh, S. (2015). CASE STUDY: Reducing dietary protein decreased the ammonia emitting potential of manure from commercial dairy farms. The Professional Animal Scientist, 31(1), 68-79
[36] Hayes ET, Leek AB, Curran TP, et al. The influence of diet crude protein level on odour and ammonia emissions from finishing pig houses. Bioresource Technology, 2004
[37] Cole NA, Defoor PJ, Galyean ML, Duff GC, Gleghorn JF. "Effects of phase-feeding of crude protein on performance, carcass characteristics, serum urea nitrogen concentrations, and manure nitrogen of finishing beef steers", Journal of Animal Science, 2006
[38] EPA-USDA NRCS. "Reference Guide for Poultry and Livestock Production Systems." September 2017. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf
[39] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| Wet Distillers Grain | Reduce Feeding of Wet Distillers Grain | Beef | Todd[40] |
| Grazing | Increase Grazing Time for Dairy Cattle | Dairy | Guthrie |
| Feed Additives | Feed Additives for Poultry | Poultry | NRCS |

**<u>Reducing Crude Protein Content for Beef Cattle</u> - *(applies to beef cattle only)***

U.S. EPA noted that studies in 2005 and 2006 found that "*decreasing the crude protein concentration of beef cattle finishing diets based upon steam-flaked corn from 13 to 11.5 percent decreased ammonia emissions by 30 to 44 percent.*"

In the 2005 study, steers were randomly assigned to one of nine dietary treatments (three formulated dietary crude protein (CP) concentrations and three supplemental urea: cottonseed meal ratios). Steers were confined to tie stalls, and feces and urine excreted were collected and frozen after approximately 30, 75, and 120 days on feed. As protein concentration in diet increased from 11.5 to 13 percent, in vitro daily ammonia emissions increased 60 to 200 percent, due primarily to increased urinary nitrogen excretion. As days on feed increased, in vitro ammonia emissions also increased.

This study had a small sample size with 54 cattle used for nine dietary treatments (six cattle per treatment). These results are only applicable to the finishing cycle of beef cattle lives (four to six months of age), and not applicable to milk cows and support stock at dairies. There are very few finishing cycle feeder beef cattle in the Valley. Most beef cattle in California are beef calves and stockers, fed through grazing. Most of these cattle are sent outside of California for the finishing cycle.[41, 42]

Notably, beef finishing cattle make up a small part of the overall inventory of cattle in the Valley. The current feedlot cattle inventory includes all feedlot cattle; however, the lives of beef cattle are divided into different phases of production. Cow and calf pairs are raised on rangeland. Weaned yearlings/stockers may continue to be raised on rangeland or be sent to yearling/stocker feedlots until a weight of approximately 800 to 900 pounds. Finally, beef cattle are sent to other feedlots out of California for the finishing phase, in which the cattle are fed for four to six months until they reach the desired finished weight. Because of the higher cost of feeding cattle in California and

[40] Todd, R.W., N.A. Cole, D.B. Parker, M. Rhoades, and K. Casey. 2009. "Effect of Feeding Distillers Grains on Dietary Crude Protein and Ammonia Emissions from Beef Cattle Feedyards." In Proceedings of the Texas Animal Manure Management Issues Conference, 83–90.
[41] Andersen, M.A., Blank, S.C., LaMendola, T, Sexton, R.J., "California's Cattle and Beef Industry at the Crossroads", California Agriculture 56(5),152-156. Retrieved from: https://doi.org/10.3733/ca.v056n05p152
[42] Saitone, T.L., "Livestock and Rangeland in California", Livestock and Rangeland in California. Retrieved from: https://s.giannini.ucop.edu/uploads/giannini_public/94/c1/94c100fd-9626-47d4-8b82-0bfdb1081a57/livestock_and_rangeland.pdf

the lack of sufficient beef processing capacity, most of feedlot cattle in California are yearlings/stockers for which this measure does not apply.[43]

If dietary protein concentrations are decreased to the point that animal performance is adversely affected, then total ammonia emissions could be increased because animals require more days on feed to reach market weight and condition. There was also little change in ammonia between the 13 percent and 14.5 percent CP groups.

In the 2006 study, two groups of steers were fed diets with either 11.5 or 13 percent CP and all urine and feces were collected. Manure from steers fed 11.5 percent CP diet had less urine, less urinary nitrogen, and a lesser fraction of total nitrogen in urine, compared with the 13 percent crude protein diet. Decreasing CP in beef cattle diets from 13 to 11.5 percent significantly decreased ammonia emission by 44 percent in closed chamber experiment, and decreased mean daily ammonia flux by 29 percent, 30 percent, and 52 percent in spring, summer, and autumn field trials, respectively. No difference was observed in winter.

Additionally, National Research Council (NRC) Nutrient Requirements of Beef Cattle states that decreasing the CP concentration in the diet can potentially reduce animal performance, prolonging the time necessary to reach market weight and potentially increasing ammonia emissions over the life of the cattle. Because adequate protein levels are required for optimal growth, decreasing CP levels hinder the ability to meet daily weight gain goals.

The overall effectiveness of this measure is unclear because of the small sample size and short period of the study. NRC Nutrient Requirements of Beef cattle states that decreasing the CP concentration in the diet can potentially reduce animal performance. Higher CP levels may be needed to meet daily weight gain goals.

If decreasing the CP content of the diet adversely affects performance, any short-term ammonia reductions can be negated by the longer time on feed required for animals to reach their target market weight and condition.[44] While there may be ammonia reductions in the short term, longer time on feed will result in additional ammonia emissions for the additional amount of time it takes for the animals to reach the appropriate weight. Thus, overall emissions may ultimately be the same, or possibly even increase. Due to the limited pool of data and only studying emissions for 21 days, more research is needed to show a full-cycle of emissions and full impact to the animals.

[43] Forero, L., Barry, S., Larson, S. (2021). Beef Cattle on California Annual Grasslands: Production Cycle and Economics. *University of California Agriculture and Natural Resources*. Retrieved from: https://anrcatalog.ucanr.edu/pdf/8687.pdf

[44] Cole NA, Defoor PJ, Galyean ML, Duff GC, Gleghorn JF. "Effects of phase-feeding of crude protein on performance, carcass characteristics, serum urea nitrogen concentrations, and manure nitrogen of finishing beef steers", Journal of Animal Science, 2006.

Despite the uncertainties discussed above, the District further evaluated the potential emission reductions of implementing this measure in the Valley. This analysis is provided below.

The feedlot cattle inventory in the Valley includes calves, beef stockers, yearlings, and finishing cattle. This measure is only applicable to beef finishing cattle. It will be conservatively assumed that 50 percent of the feedlot cattle in the Valley are beef finishing cattle. The ammonia emissions from young beef cattle compared to beef finishing cattle will be assumed to be proportional to their nitrogen excretion. Based on information from the American Society of Agricultural and Biological Engineers (ASABE),[45] it is estimated that the average daily nitrogen excretion for beef finishing cattle is 25.7 percent higher than young beef cattle. Therefore, the overall control efficiency for this measure can be estimated as follows:

$$30\% \times 50\% \times 1.257 = 18.9\%$$

No costs for implementation of this measure in the United States could be located. Notably, feed costs are a significant part of the overall costs of raising livestock, often representing as much as 60-70 percent of production costs,[46] and protein is often the most expensive component in livestock feed.[47] As a result, beef cattle producers will generally avoid overfeeding protein to minimize productions costs. Therefore, the actual emission reductions from this measure may be significantly lower to nothing since most beef cattle producers will already try to minimize feeding excess protein whenever feasible.

The District has concluded that the measure requires further research on both the effect on production and overall costs, and therefore is not a viable mitigation option to include in Rule 4570 at this time. The District will continue to evaluate the feasibility of this option as practices evolve and further research is conducted.

**Reducing Crude Protein Content for Dairy Cattle** - ***(applies to dairy cattle only)***

In a compilation by Bittman[48] it was recommended that the average CP content of diets for dairy cattle should not exceed 15-16 percent of the dry matter (DM). Phase feeding can be applied in such a way that the CP content of dairy diets is gradually decreased from 16 percent of DM just before calving and in early lactation to below 14 percent in late lactation and the main part of the dry period.

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[45] American Society of Agricultural and Biological Engineers. (March 2005). ASABE D384.2 Manure Production and Characteristics. Retrieved from: https://elibrary.asabe.org/abstract.asp?aid=32018

[46] Strauch, B.A., Stockton, M.C. (Sep 2013). Feed Cost Cow-Q-Lator. NebGuide. University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources (G2214). Retrieved from: https://extensionpublications.unl.edu/assets/pdf/g2214.pdf

[47] North Dakota State University (NDSU). (Dec 2019). Comparing Value of Feedstuffs (AS1742). Retrieved from: https://www.ag.ndsu.edu/publications/livestock/comparing-value-of-feedstuffs

[48] Bittman, S., Dedina, M., Howard C.M., Oenema, O., Sutton, M.A., (eds). (2014). "Options for Ammonia Mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen," Centre for Ecology and Hydrology, Edinburgh, UK. Retrieved from: http://www.vuzt.cz/svt/vuzt/publ/P2014/037.pdf

A study[49] measured the effect of reducing the CP content of ammonia emitting potential of dairy manure in a controlled environment. Eleven Pennsylvania dairies with gutter-scrape, gravity-flow, or flush manure-management systems participated in the study. In the study, the CP concentration of the feed for cows that were identified as high-producing cows was decreased from an average of 16.5 to 15.4 percent for the dairies included in the study. Fecal and urine samples were collected from the dairies in the fall of 2009, spring of 2010, fall of 2010, and spring of 2011. The study indicated that laboratory ammonia emissions from reconstituted manure was on average 23 percent lower for the low CP diet versus the high CP diet. No difference was seen in milk yield and milk composition during the low CP and the high CP diet, with average milk yields of 32.2 kg/day and 32.5 kg/day. The researchers that conducted the study concluded that the ammonia emitting potential of dairy manure can be reduced by moderately decreasing dietary CP content.

Although effects of reducing the CP content of the feed for dairy cows may merit further research, there are questions related to the applicability of this study to dairy cattle in the Valley. One important question is if the milk production of the cows in the study is comparable to the milk production of cows in the Valley. The average milk production of the high-producing cows included in the study was only 32.2-32.5 kg/day. In comparison, according to information from USDA National Agricultural Statistics Service, on average, milk cows in California produced approximately 36.2 kg/day of milk in 2021, [50] with high-producing cows in the Valley producing at a rate of 44 to over 50 kg/day of milk per dairy cow.[51] Therefore, although the cows in the study were identified as high-producing cows that were expected to produce greater amounts of milk, the average milk cow in California produces more milk than the cows in this study. Higher levels of milk production require higher levels of protein, so it is likely that reducing the CP content of feed will reduce milk yields of cows that produce milk.

In communications with the District, Dr. Peter Robinson, UC Davis Extension Specialist, Dairy Cattle Nutritional Management Department of Animal Science, stated that the optimal CP level for high-producing dairy cows in the Valley is around 16.8 percent, which is the level that dairy typically feed their high-producing cows. He also states that when CP levels are decreased to levels that are a little lower than required, milk production tends to be negatively impacted immediately. Dr. Robinson’s recommended CP content is based on 14 large on-farm studies that he has completed in the Valley from 2005 to the present. [52] Based on the data he provided from these studies, feed with a CP content of approximately 16.9 percent resulted in maximum milk production for high-producing cows in the Valley, which was about 48.5 kg/day of milk, 50 percent

[49] Hristov, A. N., Heyler, K., Schurman, E., Griswold, K., Topper, P., Hile, M., ... & Dinh, S. (2015). CASE STUDY: Reducing dietary protein decreased the ammonia emitting potential of manure from commercial dairy farms. The Professional Animal Scientist, 31(1), 68-79

[50] USDA, National Agricultural Statistics Service. Milk Production (February 2022). https://downloads.usda.library.cornell.edu/usda-esmis/files/h989r321c/7d279w693/f7624g40c/mkpr0222.pdf

[51] Data from studies of dairy cows in the San Joaquin Valley provided by Dr. Peter Robinson, UC Davis Extension Specialist, Dairy Cattle Nutritional Management Department of Animal Science. https://animalbiology.ucdavis.edu/people/peter-robinson

[52] A list of selected scientific publications by Peter Robinson, PhD is available on the UC Davis website at: https://animalscience.ucdavis.edu/people/faculty/peter-robinson/Articles/Scientific-Publications

more than the milk production of the high-producing cows in this study. Therefore, 50 percent more high-producing cows would be needed to produce the same amount of milk, which would negate the ammonia reductions from this measure. Another potential issue with the study is that manure samples of a specific size were used to compare the ammonia emitting potential of the manure, but it is unclear if the changes in feed composition affected manure production, which could also affect ammonia emissions.

As discussed above, California dairy operators typically feed their high-producing cows a diet that has CP content near the optimum level of 16.8 percent, and decreasing the CP content of the diet can have an adverse effect on milk production in dairy cattle. Thus, CP reductions for dairy cattle must be closely managed to avoid impacting productivity (e.g., milk yield, fat corrected yield, milk protein yield). Additionally, Dr. Robinson stated that most cows need to recoup body weight during later lactation and that lowering the CP percentage in the diet during this period could have very negative impacts on both milk yield and body weight recovery.

Because nutrient concentrations in feed and feed ingredients vary considerably, reducing CP in diets will require additional lab analyses of feed to ensure that animals receive sufficient nutrients, which will result in increased costs. Dairy operators have no incentive to overfeed protein since high protein feeds are usually the most expensive ingredients. The percent of CP in the diets fed that California dairy operators feed to dairy cattle has been significantly reduced from previous levels. According to Dr. Robinson, CP in the diets of dairy cows was frequently in excess of 20 percent in the 1980s and 1990s, but that has decreased to the current level of 16.8 percent today. In communication with District staff, Dr. Robert Hagevoort, Extension Dairy Specialist and Topliff Dairy Chair, New Mexico State University, [53] also confirmed similar reductions in the CP content of dairy feed for dairies in the western U.S. compared to previous levels.

In addition, reducing the CP content to the recommended levels is difficult for cattle that graze or are fed a large amount of grass because grass has higher amounts of protein. The NRCS Reference Guide indicates that reduction of CP can also cause deficiency in certain amino acids that can adversely affect animal performance, such as weight gain.

California dairies are expected to continue to try to improve feed efficiency and minimize environmental impacts. However, it is not feasible to require this measure at this time because of questions that remain about the impact on milk production, animal health, and costs on California dairies. Therefore, the District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Reducing Protein Content for Swine** - ***(applies to swine only)***

Research indicates that low-protein diets may result in poorer performance in finishing pigs than conventional diets.[54] The NRCS Reference Guide indicates that changes to

[53] https://dairy.nmsu.edu/faculty-staff/robert-hagevoort.html (accessed March 15, 2023)
[54] Hayes ET, Leek AB, Curran TP, et al. The Influence of Diet Crude Protein Level on Odour and Ammonia Emissions from Finishing Pig Houses. Bioresource Technology, 2004

animal diets generally increase costs because of the time and expense of diet formulation and acquisition of new ingredients, and that the availability of additives and feedstuff fluctuates. Additionally, there are increased costs for low-protein feed due to the need to supplement with amino acids found in protein like crystalline lysine, threonine, tryptophan, methionine and valine. As previously shown, emissions from swine are a small part of the District's ammonia inventory, as there is only one permitted swine facility in the District. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Reduce Feeding of Wet Distillers Grain - *(applies to beef cattle only)***

In another study, U.S. EPA noted that "one feedyard feeding distillers grains averaged 149 grams of ammonia-N per head per day (ammonia–N/head/day) over nine months, compared with 82 g ammonia–N/head/day at another feedyard feeding lower protein steamflaked, corn-based diets." Nominally, this would represent a 45 percent reduction in ammonia emissions from manure by going to a lower protein diet. However, the net ammonia emission reduction either from reducing crude protein levels in feed, or by providing a lower protein steam-flaked, corn-based diet rather than a distiller grain diet is unclear given the role of protein intake on the time for beef cattle to reach market weight or on milk production for dairy cows.[55]

This study involved two years of near-continuous ammonia emission data collections at two feedyards. Cattle were fed either conventional feed or wet distillers grains (WDG). Ammonia emissions were 36 percent higher for cattle that were fed WDG.

This study is only applicable to WDG, a feed byproduct of ethanol production. The study notes that WDG typically contains 20 percent or more of protein. That is higher than the ideal diet protein content of 11.5-13.5 percent for beef cattle. This feed is not common in California, because WDG is sold primarily to dairies or cattle feedlots within the immediate vicinity of an ethanol plant, and California only grows 0.07 percent of the nation's corn[56], and produces 0.8 percent[57] of the nation's ethanol. Since dairies in the Valley do not feed WDG, and there is almost no means for WDG feed to be acquired by Valley dairies, this measure is already being implemented and no further emission reductions can be achieved.

**Phase, Group, and Split Sex-Feeding - *(applies to all CAFs)***

The NRCS Reference Guide and a compilation by Guthrie, Giles, etc.[58] focus on mitigation measures for feed management including group and phase feeding, dietary

[55] Todd, R.W., N.A. Cole, D.B. Parker, M. Rhoades, and K. Casey. (2009). "Effect of Feeding Distillers Grains on Dietary Crude Protein and Ammonia Emissions from Beef Cattle Feedyards." In Proceedings of the Texas Animal Manure Management Issues Conference, 83–90.
[56] United States Department of Agriculture - National Agricultural Statistics Service, 2017 Census of Agriculture
[57] U.S. Energy Information Administration, State Energy Data 2020: Production
[58] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

formulation changes, and feed additives. Controlling the protein content of feed is a key element to lowering nitrogen content of manure. Protein naturally contains nitrogen compounds that are often broken down into simple compounds such as ammonia. Group and phase feeding allows the animal to receive the proper nutrition intake by separating animals by age or sex. This allows for a specific diet tailored to each group in order to reduce manure excretion and nitrogen content. Split sex feeding programs are already included as a mitigation option in District Rule 4570 for swine facilities.

The Reference Guide states that dietary formulation changes involve changes in feed ingredients or ration formulations to provide essential available nutrients to meet animal requirements while minimizing excess amounts of nutrients.

Because feed is one of the most significant costs for confined animal facilities, producers work with nutritionists to design diets to maximize feed efficiency and minimize excess nutrients to reduce overall costs. Confined animal facilities work to continually improve feed formulations to deliver nutrients in the amounts required to meet production goals. Overfeeding is undesirable because it will increase costs and farming operations have overall small margins of profit. Operations that overfeed would not be able to compete and would not remain in business because they would not be able to compete with operations that formulate rations for greater efficiency.

As a result of genetic selection and improved diets, milk production per cow has increased and feed usage has decreased by 77 percent.[59] For poultry, it is estimated that genetic selection and the current feed practices have reduced nitrogen excretion by poultry by up to 55 percent.[60]

Rule 4570 includes mitigation options for feeding animals in accordance with NRC Guidelines. The NRC Guidelines establish different nutrition requirements for animals at different ages and stages of production. Nutritionists formulate diets to meet the requirements at these different ages and stages of production.

As stated above, farms already formulate diets to maximize feed efficiency and minimize excess nutrients. There are many challenges to further dietary changes[61], including:

- Nutrient concentrations in feed and feed ingredients vary considerably; therefore, changing feed formulations of diets will require additional lab analyses of feed resulting in increased costs;

[59] McCabe, C. (2021). How Dairy Milk Has Improved its Environmental and Climate Impact. Clarity and Leadership for Environmental Awareness and Research at UC Davis. Retrieved from: https://clear.ucdavis.edu/explainers/how-dairy-milk-has-improved-its-environmental-and-climate-impact
[60] United States Department of Agriculture - Natural Resources Conservation Service. (2020). Feed and Animal Management for Poultry. Nutrient Management Technical Note No. 190-NM-4. Retrieved from: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=45569.wba
[61] EPA-USDA NRCS. "Reference Guide for Poultry and Livestock Production Systems", pp. 12-13. September 2017. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf

- Changes in dietary formulations increase feed costs due to the time and expense of diet formulation and acquisition of new ingredients;
- Reduction of crude protein nitrogen can cause deficiency in certain amino acids, such as lysine, threonine, and methionine, that can adversely affect animal performance, including growth and milk production; and
- Crude protein reductions for dairy cattle must be closely managed to avoid impacting productivity.

As discussed above, confined animal facilities already formulate diets to maximize feed efficiency and minimize excess nutrients to reduce overall costs and remain competitive. Rule 4570 includes mitigation options for feeding animals in accordance with NRC Guidelines, which includes specific nutrient requirements for different animals. Therefore, this measure is already implemented by the confined animal facilities in the Valley and any ammonia reductions from this measure are already being attained.

Phase feeding and split-sex feeding have been commonly used at confined animal facilities throughout the nation for many years, particularly on larger operations,[62, 63, 64, 65] and are a standard practice for the relatively larger confined animal facilities subject to District permitting requirements in the Valley. Because of the higher cost of production in California, confined animal facilities are larger operations compared to other states to take advantage of economies of scale. The standard practice at these operations is to separate animals by phases, ages, or groups that are fed specific diets. At dairies, calves, young heifers, bred heifers, dry cows, milk cows in different stages of lactation, and sick cattle are placed in separate groups and fed rations that are specifically formulated. Beef cattle are separated into cows and calf pairs raised on rangeland, bulls, yearlings/stockers, and finishing cattle, which are fed a separate diet. Broiler chickens are typically fed three to four different diets during their grow-out period and turkeys may be fed up to six diets during their grow-out period to match the specific age or stage of production.[66] It is estimated that genetic selection and the current feed practices have reduced ammonia reduced nitrogen excretion by poultry by up to 55 percent.

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[62] Carter, S., Sutton, A., Stenglein, R. (2012). Diet and Feed Management to Mitigate Airborne Emissions – Air Quality Education In Animal Agriculture. *USDA National Institute of Food and Agriculture.* Retrieved from: https://lpelc.org/wp-content/uploads/2019/03/Dietand-Feed-FINAL.pdf

[63] Van Heutgen, E. (2010) Growing-Finishing Swine Nutrient Recommendations and Feeding Management. Pork Information Gateway Factsheets Number PIG 07-01-09. https://porkgateway.org/resource/growing-finishing-swine-nutrient-recommendations-and-feeding-management/

[64] USDA Animal and Plant Health Inspection Service (APHIS). Iowa State University (2022) US Poultry Industry Manual - Broilers: brooding. Poultry FAD Preparedness & Response Series. https://www.thepoultrysite.com/articles/fad-broilers-brooding

[65] Miles, R.D., Jacob, J.P. (2000) Feeding the Commercial Egg-Type Laying Hen. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. https://ucanr.edu/sites/placernevadasmallfarms/files/102990.pdf

[66] Moss A, Chrystal P, Cadogan D, Wilkinson S, Crowley T, Choct M. (2021). “Precision feeding and precision nutrition: a paradigm shift in broiler feed formulation?”
*Animal Bioscience*, 2021;34(3):354-362. Retrieved from: https://www.animbiosci.org/journal/view.php?doi=10.5713/ab.21.0034

Phase feeding is the standard practice in the Valley which also allows for reduction in feed costs and meet production goals. In addition, Rule 4570 includes feeding animals in accordance with NRC Guidelines. The NRC Guidelines establish different nutrition requirements for animals at different ages and stages of production. Nutritionists formulate diets to meet the requirements at these different ages and stages of production. Because phase feeding is in practice at the majority if not all of confined animal facilities in the Valley, any ammonia reductions of this practice are currently being achieved. No additional ammonia reductions are expected from the suggested mitigation measure.

**Increase Grazing Time for Dairy Cattle** - ***(applies to dairy cattle only)***

A compilation by Guthrie[67] states that increased grazing time could reduce ammonia from dairy operations by up to 50 percent as distributed urine can be absorbed into soil and broken down before ammonia is released. However, this practice is not feasible in the Valley, as there is not sufficient land to graze cattle and the arid climate generally requires irrigation to grow crops.

The University of California Agricultural and Natural Resources (UC ANR) publication[68] estimates that the long-term carry capacity of rangeland for grazing in Madera County is 15 or 16 acres per 1,000 lb animal unit; therefore, based on the information in this publication approximately 21-22 acres of unirrigated rangeland would be required to allow a typical 1,400 lb mature dairy cow to graze. The University of California Cooperative Extension (UCCE) publication[69] indicates that 15-18 acres of unirrigated rangeland are required to support a 1,200 lb cow in the Sierra Foothills for one year, and that one acre of irrigated pasture would produce enough forage to feed a 1,200 lb cow for six months. Based on the information in these publications, it is estimated that in the San Joaquin Valley 1522 acres of unirrigated land would be required for each mature cow to graze for a year, one acre of irrigated pasture would be required for a mature cow to graze for six months, and two acres of irrigated pasture would be required for a mature cow to graze for one year. The enormous amount of land required to graze cattle on non-irrigated land clearly makes this infeasible. Based on information from the USDA National Agricultural Statistics Service, the average dairy in the Valley has approximately 1,600 milk and dry cows, not including heifers and calves. Therefore, it is estimated the average dairy in the Valley would require 1,600 acres of land to graze its mature cows for 6 months and 3,200 acres of land to graze its mature cows for one year. Because of the often arid conditions in the Valley, this land would need to be regularly irrigated to sustain sufficient forage for grazing. Additionally, this measure

[67] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

[68] George, M., Frost, W., and McDougald, N. (December 2020). Ecology and Management of Annual Rangelands Series Part 8: Grazing Management. University of California Agricultural and Natural Resources Publication 8547. https://anrcatalog.ucanr.edu/pdf/8547.pdf

[69] Macon, D., and Meyer, H. (June 2018). How Many Cows Can My Property Support? - Basics of Carrying Capacity, Stocking Rate, and Pasture Irrigation. University of California Cooperative Extension. *UCCE Placer/Nevada Publication 31 1005.* Retrieved from: https://projects.sare.org/wp-content/uploads/Pub-31-1005-Carrying-Capacity-and-Stocking-Rate.pdf

would be impossible to implement as a result of the ongoing severe drought, the Sustainable Groundwater Management Act (SGMA), and limitations on water usage pose severe challenges to the Valley.

The study Survey of Dairy Housing and Manure Management Practices in California[70] reported that in 2007, the average number of milk and dry cows of dairies that responded to the survey in Tulare County was 1,800 cows and that these dairies had 524 acres on which manure was applied to grow feed. Assuming that the acreage for feed production on a dairy in the Valley is proportional to the number of mature cows, the average dairy in Valley with 1,600 mature cows is estimated to have approximately 466 acres of land used for feed production. If half of this land is maintained for feed production and the mature cows at the dairy are grazed on irrigated pasture for six months, the average dairy would require approximately 1,367 additional acres (1,600 acres – 233 acres). For grazing of mature cows on irrigated pasture for the entire year, the average dairy in the Valley with 1,600 mature cows would require approximately 2,734 additional acres (3,200 acres – 467 acres). Information from the USDA National Agricultural Statistics Service indicates that there are currently 965 dairies and 1.5 million milk and dry cows in the Valley. Therefore, 1.5 million acres of irrigated pasture would need to be available for grazing if dairy cows in the Valley graze for just six months and 3 million acres of irrigated pasture would need to be available for dairy cows in the Valley to graze for the entire year.

Because the amount of land needed is not available, this mitigation measure is not feasible in the Valley. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Feed Additives for Poultry** - ***(applies to poultry only)***

Feed additives such as minerals, antibiotics, and digestive aids are another option to mitigate emissions. These additives can allow for improved nutrient absorption and minimize nitrogen excretion. Feed additives are a mitigation option included in District Rule 4570 for poultry.

Feed additives are more commonly used with poultry than with ruminants, such as cattle, because of the differences in how the digestive system works in ruminants compared to poultry. Additives in the feed of poultry operations can be absorbed by these animals. However, feed and feed additives are pre-digested by rumen bacteria prior to being absorbed in the digestive system of ruminants, which may alter the composition of many feed additives. The use of the rumen bacteria in the digestive system of ruminants that pre-digest feed allows cattle, and other ruminants to utilize various feeds that cannot be digested by non-ruminants.

[70] Meyer, D., Price, P.L., Rossow, H.A., Silva-del-Rio, N., Karle, B., Robinson, P.H., DePeters, E.J., and Fadel, J. (2011) Survey of dairy housing and manure management practices in California. Journal Dairy Sci. 94:4744-4750. https://doi.org/10.3168/jds.2010-3761

Rule 4570 requires owners/operators of a layer CAF to implement at least one of the following feed mitigation measures:

- Feed according to NRC guidelines; or
- Feed animals probiotics designed to improve digestion according to manufacturer recommendations; or
- Feed animals an amino acid supplemented diet to meet their nutrient requirements; or
- Feed animals feed additives such as amylase, xylanase, and protease, designed to maximize digestive efficiency according to manufacturer recommendations.

Feed is one of the most significant costs for confined animal facilities, therefore producers work with nutritionists to design diets that maximize feed efficiency, increase feed adsorption, and reduce costs. For poultry, it is estimated that genetic selection and the current feed practices have reduced nitrogen excretion by poultry by up to 55 percent.

There are challenges to increase usage of feed additives. Feed is one of the most significant costs of production and feed additives will increase feed costs due to the time and expense of diet formulation and feed additive acquisition. Some additives have negative effects and may increase emissions of some pollutants. The use of antibiotics as feed additives has also been subject to greater restrictions because of efforts to combat increasing bacterial resistance to antibiotics.

The Reference Guide states that many feed additives are already “regularly used to improve nutrient absorption from feed ingredients.” Although the Reference Guide suggests that feed additives may improve nutrient absorption and decrease emissions of some pollutants, it does not specify which additives reduce which pollutants for different animals or the amount of each additive required.

Although the suggested measure lacks the specificity needed for a regulation, confined animal facilities already formulate diets to maximize nutrient adsorption, including the use of various feed additives. In addition, Rule 4570 includes feeding animals in accordance with NRC Guidelines, which includes specific nutrient requirements for different animals, and the option to utilize various feed additives. Therefore, because this measure is already used by the confined animal facilities in the Valley and included in Rule 4570, any ammonia reductions from this measure are already being achieved in the District.

It is critical for farmers to have the flexibility to decide the kind of mitigation measures that will work best for their specific operation by taking into consideration animal health and welfare, productivity, food safety and overall bio-security issues. The District’s menu of feeding options in Rule 4570 provides farmers with this flexibility, while also requiring the most stringent measures for controlling emissions from confined animal facilities.

## Animal Confinement (Housing)

**Table F-10 Animal Confinement Measures Evaluated**

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| Biofilters and Wet Scrubbers | Enclosed Barns with Biofiltration Systems | Dairy | Kresge[71] |
| | Biofilters | All | NRCS[72] |
| | Install Air-Scrubbers or Biotrickling Filters to Mechanically Ventilated Pig Housing | Swine | Price[73] |
| | Air Scrubbing Techniques | All | Guthrie[74] |
| | Wet Scrubbers | All | NRCS |
| Washing Floors/Lanes | Clean Lanes at Dairies | Dairy | Beene[75] |
| | Washing Floors and Other Soiled Areas in Livestock Facilities | All | Guthrie |
| | Scrape/Flush Freestall Lanes | Dairy | Mendes[76] |
| | Washing Down Dairy Cow Collecting Yards | Dairy | Price |
| Corral Management | Constantly Manage Corrals | Dairy | Card[77] |
| | Frequency of Corral Manure Management | Dairy | Schmidt[78] |
| Floor Design | Floor Design Including Slates, Grooves, V-Shaped Gutters and Sloping Floors to Collect and Contain Slurry Faster | Dairy, Swine | Guthrie |
| | Part-slatted Floor Design for Pig Housing | Swine | Price |
| | Adapt Dairy Housing | Dairy | Pinder[79] |

[71] Kresge, L., Strochlic, R. (2007). Clearing the Air: Mitigating the Impact of Dairies on Fresno County's Air Quality and Public Health. California Institute for Rural Studies.
[72] EPA-USDA NRCS. "Reference Guide for Poultry and Livestock Production Systems." September 2017. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf
[73] Price et al., "An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture, User Guide," December 2011. Retrieved from: https://repository.rothamsted.ac.uk/download/942687eab7ec4b83751c7e241d62f0fa8472d72adcd25a149bb891b7c30d55d0/1595300/MitigationMethods-UserGuideDecember2011FINAL.pdf
[74] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html
[75] Beene, M., Krauter, C., Goorahoo, D. (2005). Ammonia Fluxes from Animal Housing at a California Free Stall Dairy. California State University, Fresno. Center for Irrigation Technology and Plant Science Department. Retrieved from: https://www3.epa.gov/ttnchie1/conference/ei15/session6/beene.pdf
[76] Mendes, L.B., Pieters, J.G., Snoek, D., Ogink N.W.M., Brusselman, E., Demeyer, P. (2017). Reduction of Ammonia Emissions from Dairy Cattle Cubicle Houses via Improved Management or Design-Based Strategies: A Modeling Approach, In *Science of The Total Environment*, Volume 574, 2017, Pages 520-531, ISSN 0048-9697. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S0048969716319970?via%3Dihub
[77] Card, T. and Schmidt, C. (May 2006). Dairy Air Emissions Report: Summary of Dairy Emission Estimation Procedures. Final Report to CARB.
[78] Schmidt, C.E., T. Card, P. Gaffney, and S. Hoyt. (2005). Assessment of Reactive Organic Gases and Amines from a Northern California Dairy Using the EPA Surface Emissions Isolation Flux Chamber. Presented at the 14th Annual Emission Inventory Conference of the U.S. Environmental Protection Agency, Las Vegas, NV.
[79] Pinder, R., Adams, P., Pandis, S. (2007). Ammonia Emission Controls as a Cost-Effective Strategy for Reducing Atmospheric Particulate Matter in the Eastern United States. *Environmental Science and Technology*, Volume 41, Pages 380-386. Retrieved from: https://pubs.acs.org/doi/pdf/10.1021/es060379a

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| | Separate Urine/Manure with 3% Floor Slope | Dairy | Braam[80] |
| Additional Straw Bedding | Additional Targeted Straw-bedding for Cattle Housing | All cattle | Price |
| | Straw Bedding for Cattle Housing | All cattle | Guthrie |
| Other Housing | Optimal Barn Acclimatization with Roof Insulation and/or Automatically Controlled Natural Ventilation | All | Guthrie |
| | Oil Spray/Sprinkling | Swine | NRCS |
| | Convert Caged Laying Hen Housing from Deep-Pit Storage to Belt Manure Removal | Poultry | Price |
| | More Frequent Manure Removal from Laying Hen Housing with Belt Clean Systems | Poultry | Price |
| | In-House Poultry Manure Drying | Poultry | Price |

**Biofilters** - ***(applies to all CAFs)***

A biofilter is an air filtration and odor mitigation system that channels building exhaust through a mixture of organic materials that support microbial growth. Biofilters have been identified in several publications as a potential ammonia mitigation method, including the NRCS Reference Guide. The NRCS Reference Guide notes many considerations that must be taken into account when implementing these systems, including that they require careful design, monitoring, and maintenance, and have very high associated costs.

Initial costs and challenges include the replacement of existing ventilation fans in order to provide the necessary airflow and the energy to overcome the added pressure drop caused by the biofilter. Biofilters require increased retention time; however increasing the retention time usually increases the system static pressure, which can compromise the ventilation system performance. It is typically not practical to treat all of the exhaust air during the summer when a large amount of ventilation flow is required to remove excessive heat from the production house. Lower ventilation airflow may also lead to heat stress in the animals.

Different types of biofilters have their own disadvantages. Flat open biofilter beds are easier to construct and generally cost less; however, they require very large footprints. Vertical biofilters are more difficult to construct and are more expensive, and biological material can settle, causing air leaks, which will reduce the performance of the system. In addition, biofilter media will need to be replaced periodically.

[80] Braam, C., Ketelaars, J., Smits, M. (1997). Effects of floor design and floor cleaning on ammonia emission from cubicle houses for dairy cows, *Wageningen Journal of Life Sciences*. Retrieved from: https://library.wur.nl/ojs/index.php/njas/article/view/525

Biofilters require ongoing maintenance to prevent air leakage, dust accumulation, and air constriction in the media to ensure effectiveness of the system performance. Monitoring and maintenance of the filter media moisture is essential to operation of the biofilter, and sprinklers or other wetting systems may be required. Rodents and weeds have also been a problem for some biofilters.

Included in Appendix B of the Ammonia Supplemental Information for the 15 µg/m$^3$ SIP Revision, is a cost-effectiveness analysis that demonstrates the economic infeasibility of biofilters. District Rule 4570 does provide options for facilities to use emissions control devices such as biofilters; however, it is not feasible to require all facilities subject to Rule 4570 to install biofilters as they are not cost-effective or practical for livestock facilities in the Valley. The District has concluded that the measure discussed is not a viable mitigation measure to require in Rule 4570.

**<u>Air-Scrubbers/Wet Scrubbers</u> - *(applies to all CAFs)***

Several compilations of mitigation measures, including the NRCS Reference Guide and UK User Guide, list air scrubbing as a potential method of capturing ammonia from animal housing; however, there are considerable costs and challenges associated with the implementation of scrubbers at animal facilities. One such challenge is that off-the-shelf industrial scrubbers are typically not applicable to animal production systems, due to the variation and dynamic changes of such biological systems (e.g., housing structure variation, changes in ventilation airflow rate/pattern in response to the changes of air temperature, manure management practices, unique PM characteristics).

The practicality of scrubbers is limited due to their potential to compromise the ventilation airflow rate needed to control temperature in production houses to ensure animal health. There are added costs for the replacement of existing ventilation fans in order to provide the necessary airflow and the energy to overcome the added pressure drop because of the scrubber. Additionally, it is typically not practical to treat all of the exhaust air during the summer when a large amount of ventilation flow is required to remove excess heat from the production house and prevent heat stress in the animals.

Additional costs and challenges to scrubbers include the ongoing maintenance required to prevent dust accumulation and air constriction in the media to ensure effectiveness of the system performance. There are also potential dangers in transporting and handling materials such as acid used in the scrubber. Furthermore, wet scrubbers require large supplies of water and special wastewater handling systems that are not typical at animal production operations. This increased water usage is not practical in the Valley because of limited availability of water due to drought and increasing restrictions on the amount of usable groundwater, due to SGMA.

The UK User Guide identifies installing air-scrubbers as a mitigation method specifically for pig housing, however, concludes that the practical application of this method is only to new purpose-built buildings. Included in Appendix B of the Ammonia Supplemental Information for the 15 µg/m$^3$ SIP Revision is a cost-effectiveness analysis of scrubbers for swine facilities. The District found that scrubbers are not cost effective, and are therefore not technologically or economically feasible to require in the Valley. District Rule 4570 does provide options for facilities to use emissions control devices such as scrubbers; however, it is not feasible to require all facilities subject to Rule 4570 to install scrubbers. The District has concluded that the measure discussed is not a viable mitigation measure to require in Rule 4570.

**Washing Floors/Lanes** - ***(applies to all CAFs)***

Several publications include the washing of floors and other soiled areas in livestock facilities as a potential mitigation method to reduce ammonia emissions. The UK User Guide includes a more specific measure involving washing down the concrete areas where dairy cows are collected prior to and after each milking even, through pressure washing or by hosing and brushing.

District Rule 4570 includes the requirement to clean the manure from the lanes, where the majority of manure is excreted, at dairies and other cattle facilities. The majority of cow holding areas at Valley dairies are equipped with sprinkler pens for washing the cows, and are periodically washed throughout the day, rather than scraped once per day.[81] Additionally, Rule 4570 requires constant washing of milking parlor floors to remove manure, which is also standard practice for California dairies. It is essential for all areas of milking parlors, including the milking parlor floors, to be the one of the cleanest parts of the dairy to ensure that the milk from the cows is clean and uncontaminated. There is a constant need for flushing and cleaning of the milking parlor because milk that is contaminated cannot be sold. Therefore, whenever practical, Rule 4570 requires cleaning of areas where the majority of manure accumulates.

Operators of dairy CAFs are required to implement several mitigation measures related to the cleaning of floors/lanes to comply with District Rule 4570, including the following:

Required Measures:

- Flush or hose milking parlor immediately prior to, immediately after, or during each milking;
- Pave feedlanes, where present, for a width of at least 8 feet along the corral side of the feedlane fence for milk and dry cows and at least 6 feet along the corral side of the feedlane for heifers; and
- Flush, scrap, or vacuum freestall flush lanes immediately prior to, immediately after, or during each milking; or flush or scrape freestall flush lanes at least 3 times per day.

[81] Chang, A., T. Harter, J. Letey, D. Meyer, R. D. Meyer, M. Campbell-Mathews, F. Mitloehner, S. Pettygrove, P. Robinson, R. Zhang (2006) Managing Dairy Manure in the Central Valley of California; University of California Committee of Experts on Dairy Manure Management Final Report to the Regional Water Quality Control Board, Region 5, Sacramento, June 2005. https://ucanr.edu/sites/groundwater/files/136450.pdf

Additional Measures (must select at least one of the following):

- Use non-manure-based bedding and non-separated solids based bedding for at least 90 percent of the bedding material, by weight, for freestalls;
- For a large dairy CAF, remove manure that is not dry from individual cow freestall beds or rake, harrow, scrape, or grade freestall bedding at least once every 7 days; or
- For a medium dairy CAF, remove manure that is not dry from individual cow freestall beds or rake, harrow, scrape, or grade freestall bedding at least once every 14 days.

Operators of other cattle CAFs are required to implement the following mitigation measures to comply with District Rule 4570:

- Vacuum, scrape, or flush freestalls at least once every 7 days;
- Pave feedlanes, where present, for a width of at least 6 feet along the corral side of the feedlane; and
- Either use non-manure-based bedding and non-separated solids based bedding for at least 90 percent of the bedding material, by weight, for freestalls; or remove manure that is not dry from individual cow freestall beds or rake, harrow, scrape, or grade bedding in freestalls at least once every seven days.

In conclusion, the District already requires mitigation measures that require CAFs to wash floors and/or lanes inside of cow housing areas. No additional ammonia reductions are expected from the suggested mitigation measure.

**Corral Management** - ***(applies to all cattle)***

Proper management of manure in animal housing areas will stabilize the nitrogen compounds, which will reduce the rate that these compounds are converted to ammonia that can be lost to the atmosphere. Research by Card and Schmidt (2005) supports that management of manure in corrals reduces ammonia emissions from the corrals and points out that of two dairies tested, the ammonia emissions from the dairy with constantly managed corrals had “exceptionally low ammonia emissions.” Follow-up research by Card and Schmidt (2009) at one of the dairies studied indicated that ammonia emissions were significantly reduced (>80 percent reduction comparing 2008 to 2005 reported ammonia emissions) when the frequency of management of the manure in the corrals was increased.

Rule 4570 includes requirements for management of corrals to prevent excessive buildup of manure, designing or managing corrals to prevent excessive moisture, and periodic scraping and removal of manure from corrals. Under Rule 4570, dairy, beef feedlot, and other cattle facilities are required to implement four to six measures for corral management depending on facility type, as well as select one additional mitigation measure as detailed below:

Required Measures

- Pave feedlanes, where present, for a width of at least 8 feet along the corral side of the feedlane fence for milk and dry cows and at least 6 feet along the corral side of the feedlane for heifers (*dairy and other cattle*);
- Clean manure from corrals at least 4 times per year with at least 60 days between cleaning; or clean corrals at least once between April and July and at least once between September and December (*dairy*);
- Scrape corrals twice a year with at least 90 days between cleanings, excluding the removal of in-corral mounds (*beef feedlot and other cattle*);
- Scrape, vacuum or flush concrete lanes in corrals at least once every day for mature cows and every 7 days for support stock; or clean concreted lanes such that the depth of manure does not exceed 12 inches at any point or time (*dairy and other cattle*);
- Inspect water pipes and troughs and repair leaks at least once every 7 days;
- Choose one of the following:
    - Slope the surface of the corrals at least 3 percent where the available space for each animal is 400 square feet or less. Slope the surface of the corrals at least 1.5 percent where the available space for each animal is more than 400 square feet per animal;
    - Maintain corrals to ensure proper drainage preventing water from standing more than 48 hours; or
    - Harrow, rake, or scrape corrals sufficiently to maintain a dry surface; and
- If the CAF has shade structures, they must choose one of the following:
    - Install shade structures such that they are constructed with a light permeable roofing material;
    - Install all shade structures uphill of any slope in the corral;
    - Clean manure from under corral shades at least once every 14 days, when weather permits access into the corral (*dairy*); or
    - Install shade structure so that the structure has a North/South orientation.

Additional Measures

- Manage corrals such that the manure depth in the corral does not exceed 12 inches at any time or point, except for in-corral mounding. Manure depth may exceed 12 inches when corrals become inaccessible due to rain events. The facility must resume management of the manure depth of 12 inches or lower immediately upon the corral becoming accessible.
- Knockdown fence line manure build-up prior to it exceeding a height of 12 inches at any time or point. Manure depth may exceed 12 inches when corrals become inaccessible due to rain events. The facility must resume management of the manure depth of 12 inches or lower immediately upon the corral becoming accessible.
- Use lime or a similar absorbent material in the corral according to the manufacturer's recommendation to minimize moisture in the corrals; or apply

thymol to the corral soil in accordance with the manufacturer's recommendation (*dairy and other cattle*).

In conclusion, the District already requires mitigation measures that minimize emissions from corral housing areas. No additional ammonia reductions are expected from the suggested mitigation measure.

**Floor Design** - ***(applies to dairy cattle and swine only)***

Several publications list different floor design types for collecting and containing slurry that may reduce ammonia emissions that include slats, grooves, v-shaped gutters, and sloping floors. The measures included in these documents are applicable to small dairies in which cows are kept in stables or cubicle-type housing that is common on small European dairies in which manure was allowed to accumulate. These measures are also applicable to manure handled as a slurry, and does not apply to the larger dairies in the Valley that are subject to District permitting, which handle very little manure as a slurry.[82] It should also be noted that most physical changes to existing dairy barns must be incorporated at the design stage, and are not practical for existing structures, resulting in significantly higher capital costs.

Valley dairies have paved lanes to facilitate manure removal, as required by Rule 4570. The lanes on the dairies are sloped to allow manure to be sent to a lagoon system. In addition, Rule 4570 requires that manure must be periodically removed from the lanes where the cattle spend the majority of their time. Therefore, Rule 4570 already incorporates control measures for specialized floor design and this is already being implemented by dairies in the Valley.

Rule 4570 requirements for dairy and other cattle facilities are as follows:

- Pave feedlanes, where present, for a width of at least 8 feet along the corral side of the feedlane fence for milk and dry cows and at least 6 feet along the corral side of the feedlane for heifers and other cattle; and
- For corrals, choose one of the following:
    - Slope the surface of the corrals at least 3 percent where the available space for each animal is 400 square feet or less. Slope the surface of the corrals at least 1.5 percent where the available space for each animal is more than 400 square feet per animal;
    - Maintain corrals to ensure proper drainage preventing water from standing more than 48 hours;
    - Harrow, rake, or scrape corrals sufficiently to maintain a dry surface.

The UK User Guide includes a floor design measure specifically for swine that aims to reduce the overall emitting surface area of slurry by replacing fully slatted floors with

[82] Marklein, A. R., Meyer, D., Fischer, M. L., Jeong, S., Rafiq, T., Carr, M., and Hopkins, F. M. (2021) Facility-scale inventory of dairy methane emissions in California: implications for mitigation, Earth Syst. Sci. Data, 13, 1151–1166, https://doi.org/10.5194/essd-13-1151-2021, 2021.

part-slatted floors. This type of floor design is already a requirement at the only swine facility in the District. The facility has a specific permit condition that states “Permittee shall use a slatted floor system (slatted floors over deep pits or shallow flush alleys), with daily manure removal for shallow flush alleys and weekly removal from deep pits.” Under Rule 4570, swine CAFs are required to implement measures for animal housing that includes the use of a similar slatted floor system, as follows:

- Use a slatted floor system (slatted floors over deep pits or shallow flush alleys), with daily manure removal for shallow flush alleys and weekly removal from deep pits.

In conclusion, the District already requires a mitigation measure for swine CAFs to minimize emissions from animal housing areas through the use of a slatted floor system. No additional ammonia reductions are expected from the suggested mitigation measure.

**Separate Urine/Manure with 3 Percent Floor Slope** - ***(applies to dairy cattle only)***

In one study[83] completed in the Netherlands, ammonia emissions from cubicle housing with a slatted floor, used on small dairies in Europe, were compared with two different solid floor systems: a non-sloped and a 3 percent one-sided sloped floor, combined with a highly frequent or normal removal of manure by a scraper. The study results indicated that the slope of the floor had more impact on reducing ammonia emissions than increasing the scraping frequency. Solid floors with a slope decreased ammonia emissions compared to slatted floors. However, the study indicated that solid floors without a slope may not decrease ammonia emission compared with slatted floors.

Cubicle housing with slatted floors and manure pits under the housing areas are not used for dairy cattle in the Valley. The typical practice is to house cattle in barns or corrals with flushed or scraped lanes. These lanes are sloped to facilitate flushing of the manure to the lagoon system. Additionally, Rule 4570 includes requirements that corrals be sloped, which allows urine to drain away, which reduces the conversion of urea in urine to ammonia since it will have less contact with enzymes in feces that promote this transformation.

District Rule 4570 requires dairy, beef feedlot, and other cattle facilities to implement the following mitigation measure, or an equivalent measure:

- Slope the surface of the corrals at least 3 percent where the available space for each animal is 400 square feet or less. Slope the surface of the corrals at least 1.5 percent where the available space for each animal is more than 400 square feet per animal.

[83] Braam, C., Ketelaars, J., Smits, M. (1997). Effects of floor design and floor cleaning on ammonia emission from cubicle houses for dairy cows, *Wageningen Journal of Life Sciences*. Retrieved from: https://library.wur.nl/ojs/index.php/njas/article/view/525

In conclusion, the District Rule 4570 already includes mitigation measures involving sloped floors for cattle facilities. No additional ammonia reductions are expected from the suggested mitigation measure.

**Additional Targeted Straw-Bedding for Cattle Housing** - ***(applies to dairy and other cattle only)***

This method involves adding extra straw bedding to cattle houses, targeting the wetter and dirtier areas of the house. This measure is applicable to small dairy farms that house cattle indoors and use a solid manure handling system, such as small dairy farms in Europe; however, most dairies in the Valley handle the majority of the manure as a liquid and do not use straw bedding. One study[84] indicated that storage or treatment ponds were found on 95.9 percent of dairies, and another report prepared for CARB states that, "*California dairy effluent often runs 1 percent total solids*."[85] These dairies also use frequent flushing to remove the manure instead of absorbing with straw, thereby reducing emissions through flushing. Beef cattle in the Valley are not housed indoors; therefore, this measure would not apply to beef cattle in the Valley.

For areas of the dairy that would benefit from this method, the use of straw, or other non-manure based bedding for cow housing is included as a menu option for cattle housed in barns, as shown below:

- Use non-manure-based bedding and non-separated solids based bedding for at least 90 percent of the bedding material, by weight, for freestalls (e.g. rubber mats, almond shells, sand, or waterbeds).

In conclusion, the District already has a mitigation measure option to minimize emissions from cow bedding. No additional ammonia reductions are expected from the suggested mitigation measure.

**Optimal Barn Acclimatization with Roof Insulation and/or Automatically Controlled Natural Ventilation** - ***(applies to all CAFs)***

The compilation by Guthrie, et al.[86] includes ammonia mitigation measures that involve specific building design to provide optimal barn acclimatization. This measure was based on information from the United Nations Economic Commission for Europe (UNECE) compilation Framework Code for Good Agricultural Practice for Reducing

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[84] Meyer, D., Price, P.L., Rossow, H.A., Silva-del-Rio, N., Karle, B., Robinson, P.H., DePeters, E.J., and Fadel, J. (2011) Survey of dairy housing and manure management practices in California. Journal Dairy Sci. 94:4744-4750. https://doi.org/10.3168/jds.2010-3761

[85] Meyer, D, Heguy, J., Karle, B. and Robinson, P. (2019) Characterize Physical and Chemical Properties of Manure in California Dairy Systems to Improve Greenhouse Gas Emission Estimates. California Environmental Protection Agency, Air Resources Board. https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/16rd002.pdf

[86] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

Ammonia Emissions.[87] The UNECE publication stated that for cattle cubicle housing was considered the reference and that for cattle housed in cubicles with traditional slats, and claimed that this measure can moderately reduce ammonia by 20 percent compared to conventional cubicle housing.

Cubicle housing with traditional slats is not typically used to house cattle in the Valley; therefore, this measure is not applicable to cattle in the Valley. In cubicle housing with traditional slats, the manure that cattle excrete seeps through the slats and falls to an alley or a storage pit below the housing area. In the Valley, dairy cattle are typically housed in barns or corrals with lanes that are flushed or scraped to remove manure to a separate area for storage. In cubicle housing with traditional slats, a large amount of the ammonia emissions are from the manure stored in an alley or pit below the housing area. Therefore, this measure would not reduce ammonia emissions from cattle housing in the Valley because manure is stored in a different area.

In addition, these measures are not feasible for many existing buildings and must be incorporated in the initial design stage of a new build. For poultry, new houses generally incorporate insulation and controlled ventilation. However, this measure is generally not feasible for implementation at Valley dairies or other cattle facilities. Due to the warm climate in the Valley, barns used for cattle consist of a roof with open sides to allow for adequate airflow and cooling. These structures would need to be completely redesigned and reconstructed to implement this mitigation measure, and there would be substantial cost to enclose the cattle and equip the barns with ventilation systems to supply sufficient airflow for the cattle. Furthermore, the increased airflow from the fans required for ventilation may promote increased emissions from the barns rather than reduce ammonia.

In conclusion, the suggested measure is not applicable to cattle facilities in the Valley and would not result in any additional ammonia reductions.

**Oil Spray/Sprinkling** - ***(applies to swine only)***

Sprinkling of vegetable oil in animal production areas has been demonstrated as an effective measure within swine barns for PM mitigation, with observed smaller reductions of ammonia ranging from 0-30 percent. However, results of research on the effect of this practice on ammonia emissions vary greatly.[88] This practice requires daily labor if applied by hand, and requires additional time during room washing to remove oil residue. Additionally, oil residue can cause ventilation fans to become stuck in on or off positions, preventing them from operating correctly to ensure proper ventilation and cooling of animals. As mentioned above, current research shows considerable

[87] UNECE. 2015. United Nations Economic Commission for Europe Framework Code for Good Agricultural Practice for Reducing Ammonia Emissions. United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution. https://unece.org/environment-policy/publications/framework-code-good-agricultural-practice-reducing-ammonia

[88] Harmon, J., Hoff, S., Rieck-Hinz, A. (2014). Animal Housing – Vegetable Oil Sprinkling Overview. *Air Management Practices Assessment Tool*, Iowa State University. Retrieved from: https://store.extension.iastate.edu/product/Animal-Housing-Vegetable-Oil-Sprinkling-Overview

variability in the potential ammonia emission reductions of this measure; therefore, it is currently uncertain if this measure will reduce ammonia emissions and the magnitude of any potential reductions. Furthermore, the NRCS Reference Guide indicates that this measure is applicable to swine barns, which contribute a very small amount to the District's ammonia inventory with only one permitted facility in the Valley. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Convert Caged Laying Hen Housing from Deep-Pit Storage to Belt Manure Removal - *(applies to poultry only)***

This measure applies to high-rise laying hen housing with deep pit storage. In a deep-pit storage system, laying hens are kept in tiered cages and the manure from laying hens drops into a pit below the cages where it may be stored for months prior to removal. The UK User Guide identifies that replacing this system with a series of belts below each tier of cages, which remove manure from the house, could have the potential to reduce ammonia emissions.

In the United States, the overall trend for farms that produce eggs has been to shift away from high-rise laying hen housing with tiered cages to cage-free housing. In 2018, voters in California approved Proposition 12, also known as the Farm Animal Confinement Initiative.[89] Proposition 12 requires that animals held in buildings, such as laying hens, breeding sows, or veal calves, *"be housed in confinement systems that comply with specific standards for freedom of movement, cage-free design, and minimum floor space."* Implementation of the law began on January 1, 2022, and as a result all eggs produced in California must be procured only from hens in cage-free housing. High-rise hen houses in which egg-laying hens are kept in cages are no longer legal in California. There are significant questions that need to be answered regarding the practicality, cost, and overall ammonia emission reductions of implementing this measure for cage-free hen houses. Therefore, the District has concluded that this measure is not a viable mitigation option to include in Rule 4570 at this time.

**More Frequent Manure Removal from Laying Hen Housing with Belt Clean Systems - *(applies to poultry only)***

This method identified in the UK User Guide increases the frequency of manure removal to twice weekly, and relies on the rapid removal of manure from the house prior to the peak rate of ammonia emission. This measure is only applicable to laying hen houses that are already equipped with belt manure removal systems, and is not feasible for the majority of existing laying hen houses in the Valley given the significant facility reconstruction costs and potential space/infrastructure limitations at existing facilities. In addition, as explained above, all eggs produced in California must be procured only from hens in cage-free housing and there are significant questions that need to be answered regarding the practicality, cost, and overall ammonia emission reductions of implementing this measure for cage-free hen houses. Therefore, the District has

[89] California Proposition 12, Animal Care Program. Retrieved from: https://www.cdfa.ca.gov/AHFSS/AnimalCare/

concluded that this measure is not a viable mitigation option to include in Rule 4570 at this time.

**In-House Poultry Manure Drying** - ***(applies to poultry only)***

In-house poultry manure drying, as identified in the UK User Guide, is applicable to poultry housing, and involves the installation of ventilation/drying systems that reduce the moisture content of poultry litter. The author expects implementation of this method to be low to moderate, due to the practical limitations involved with installing systems in existing buildings. Forced air drying systems are not feasible for houses in which the birds are raised on litter because the litter remains in the houses with the birds until cleaned out to prepare for another flock. Following BACT Guidelines 5.7.1[90] and 5.7.2[91], this practice is evaluated as a potential BACT measure for new or expanding facilities; the required mitigation measure is as follows:

- Completely enclosed mechanically ventilated layer housing with evaporative cooling pads, mixing fans, and a computer control system.

In conclusion, the District already has a mechanism to implement this mitigation measure for expanding or new poultry housing operations. No additional ammonia reductions are expected from the suggested mitigation measure.

**Manure Management (Storage)**

**Table F-11 Manure Management (Storage) Measures Evaluated**

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| Lagoon Management | Replace Lagoons with Deep Tanks | Dairy | Guthrie[92] |
| | Oxygenation of Liquid Manure Lagoons | All | NRCS[93] |
| Storage Bags | Storage Bags | Dairy | Guthrie |
| Manure Storage Covers | Liquid Manure Storage Covers | All | NRCS |
| | | All | Marks[94] |
| | Solid Manure Storage Covers | All | NRCS |

[90] https://ww2.arb.ca.gov/sites/default/files/classic/technology-clearinghouse/bact/BACTID773.pdf?:linktarget=_self&:embed=yes
[91] https://ww2.arb.ca.gov/sites/default/files/classic/technology-clearinghouse/bact/BACTID774.pdf?:linktarget=_self&:embed=yes
[92] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html
[93] EPA-USDA NRCS. "Reference Guide for Poultry and Livestock Production Systems." September 2017. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf
[94] Marks, R. (2001). Cesspools of Shame: How Factory Farm Lagoons and Sprayfields Threaten Environmental and Public Health. *Natural Resources Defense Council and the Clean Water Network.* Retrieved from: https://www.nrdc.org/sites/default/files/cesspools.pdf

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| | | All | Price[95] |
| | | All | Chadwick[96] |
| | Allow Cattle Slurry Stores to Develop a Natural Crust | Dairy | Price |
| Solid-Liquid Separation | Solid-Liquid Separation | All | NRCS |
| Anaerobic Digesters | Anaerobic Digesters | Dairy | NRCS |
| | | Dairy | Marks |
| | | Dairy | Kresge[97] |
| Amendments/Additives | Litter Amendments and Manure Additives | All | NRCS |
| | Acidifying Slurry and Shifting Chemical Balance from Ammonia to Ammonium | All | Guthrie |
| | Acidifying Amendments and Additives for Poultry Litter | Poultry | Price |
| | Urease Inhibitors | All Cattle | Pinder[98] |
| | | All Cattle | Preece[99] |
| Surface Cooling | Surface Cooling of Slurry Manure | All | Guthrie |
| pH of Manure | Lowering pH of Manure | All | Preece |
| On-farm Composting | Composting | All Cattle | NRCS |

**Replace Lagoons with Deep Tanks** - ***(applies to dairy cattle only)***

A compilation[100] indicated that replacing lagoons with deep tanks can reduce ammonia emissions by 30-60 percent. The information from the compilation indicates that this

[95] Price et al., "An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture, User Guide," December 2011. Retrieved from: https://repository.rothamsted.ac.uk/download/942687eab7ec4b83751c7e241d62f0fa8472d72adcd25a149bb891b7c30d55d0/1595300/MitigationMethods-UserGuideDecember2011FINAL.pdf

[96] Chadwick, D.R. (2005). Emissions of Ammonia, Nitrous Oxide and Methane from Cattle Manure Heaps: Effect of Compaction and Covering. *Atmosphere Environment*, Vol. 39, Issue 4: 787-799. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S135223100400994X

[97] Kresge, L., Strochlic, R. (2007). Clearing the Air: Mitigating the Impact of Dairies on Fresno County's Air Quality and Public Health. *California Institute for Rural Studies.*

[98] Pinder, R., Adams, P., Pandis, S. (2007). Ammonia Emission Controls as a Cost-Effective Strategy for Reducing Atmospheric Particulate Matter in the Eastern United States. *Environmental Science and Technology*, Volume 41, Pages 380-386. Retrieved from: https://pubs.acs.org/doi/pdf/10.1021/es060379a

[99] Preece, S., Cole, N., Todd, R., Auvermann, B. (2017). Ammonia Emissions from Cattle Feeding Operations. *Texas A&M AgriLife Extension Service.* Retrieved from: http://baen.tamu.edu/wp-content/uploads/sites/24/2017/01/E-632.-Ammonia-Emissions-from-Cattle-Feeding-Operations.pdf

[100] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

measure is applicable to manure that is handled as a slurry. The reductions in ammonia emissions are a result of the smaller surface area of the manure in contact with the air from which ammonia may be emitted. Storage of manure in deep tanks is not a feasible measure for the District due to the size of dairies in the Valley and the way that manure is typically handled. As previously mentioned, the average dairy in the Valley has almost 1,600 cows compared to a national average of less than 300 cows per dairy outside of California[101, 102] and are larger than the typical European dairies for which this measure was considered. In addition, dairies in the Valley typically handle liquid manure as a dilute liquid rather than a thick slurry. The dilute dairy manure typically handled in the Valley has a solids content of 2 percent or less while slurry manure has a solids content of about 10 percent. As a result, the volume of manure handled would be approximately 27 times greater than the average dairy outside of California that handles dairy manure as a slurry. It is not practical to construct tanks that would contain such large amounts of manure. Notably, the depth of lagoons and storage ponds is limited to protect groundwater because a minimum distance is required between the bottom of the lagoons and storage ponds and the groundwater.[103,104] Therefore, the tanks would need to be constructed aboveground. However, it is not practical to construct tanks aboveground because of the large amount of liquid manure that must be stored. Pumping the manure into aboveground tanks would require larger amounts of energy. Also, it is possible the release of the ammonia conserved in the manure tanks will be delayed until the manure is sent to a storage pond or applied to land. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**<u>Oxygenation of Liquid Manure Lagoons</u> - *(applies to all CAFs)***

The NRCS Reference Guide states that large land footprint of naturally aerobic lagoons is not practical for many farms. This is particularly applicable to the large farms in the Valley. Naturally aerobic lagoons are not feasible in the Valley because the dairies in the Valley would require an extremely large footprint. The design criteria of naturally aerobic lagoons in the USDA-NRCS Practice Standard Code 359 will be used to illustrate the approximate size that would be required for naturally aerated lagoons for confined animal facilities in the Valley. USDA-NRCS Practice Standard Code 359 requires that naturally aerobic lagoons be designed to have a minimum treatment surface area as determined on the basis of daily $BOD_5$ loading per unit of lagoon surface. The standard specifies that the maximum loading rate of naturally aerobic lagoons shall not exceed the loading rate indicated by the USDA-NRCS Agricultural

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[101] Hanson, M. (2021) U.S. Dairy Herd Hits 27-year High. *Dairy Herd Management.* Retrieved from: https://www.dairyherd.com/news/dairy-production/us-dairy-herd-hits-27-year-high

[102] Latest USDA Statistics for average size of dairies excluding California. Retrieved from: https://downloads.usda.library.cornell.edu/usda-esmis/files/h989r321c/7d279w693/f7624g40c/mkpr0222.pdf (about 270 cows per dairy outside California)

[103] California Regional Water Quality Control Board Central Valley Region Order R5-2013-0122 – Reissued Waste Discharge Requirements General Order for Existing Milk Cow Dairies. Retrieved from: https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2013-0122.pdf

[104] California Regional Water Quality Control Board Central Valley Region Order R5-2017-0058 –Waste Discharge Requirements General Order for Confined Bovine feeding Operations. Retrieved from: https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2017-0058.pdf

Waste Management Field Handbook (AWMFH)[105] or the maximum loading rate according to state regulatory requirements, whichever is more stringent.

According to Figure 10-30 (August 2009) of the latest version of the AWMFH, the maximum aerobic lagoon lading rate for the Valley is 45 - 55 lb-$BOD_5$/acre-day. Based on information from the USDA National Agricultural Statistics Service, the average dairy in the Valley has approximately 1,600 milk and dry cows. Based on a typical dairy herd composition, the average dairy in the Valley is estimated to have approximately 1,348 milk cows, 252 dry cows, and 1,153 heifers and calves. According to Table 4-5 (March 2008) of the USDA-NRCS AWMFH, the total daily manure produced by each milk cow, dry cows, and 970 lb heifer will have an average BOD loading of 2.9 lb-$BOD_5$/day, 1.4 lb-$BOD_5$/day, and 1.2 lb-$BOD_5$/day, respectively. The average BOD loading of manure produced by smaller heifers and calves is estimated based on manure volatile solids excretion rates. Assuming that 80 percent of the manure will be flushed to the lagoon system, the minimum lagoon surface area required for a naturally aerobic lagoon treating manure from an average size dairy in the Valley with 1,600 milk and dry cows can be calculated as follows:

$BOD_5$ loading (lb/day)

1,348 milk cows x 2.9 lb-$BOD_5$/cow-day x 0.80 = 3,127 lb-$BOD_5$/day

252 dry cows x 1.4 lb-$BOD_5$/cow-day x 0.80 = 282 lb-$BOD_5$/day

457 heifers (15-24 months) x 1.2 lb-$BOD_5$/heifer-day x 0.80 = 439 lb-BOD5/day

366 heifers (7-14 months) x 0.83 lb-$BOD_5$/heifer-day x 0.80 = 243 lb-$BOD_5$/day

182 heifers (4-6 months) x 0.47 lb-$BOD_5$/heifer-day x 0.80 = 68 lb-$BOD_5$/day

148 calves (0-3 months) x 0.27 lb-$BOD_5$/heifer-day x 0.80 = 32 lb-$BOD_5$/day

Total BOD loading = 3,127 lb-$BOD_5$/day + 282 lb-$BOD_5$/day + 439 lb-$BOD_5$/day + 243 lb-$BOD_5$/day + = 68 lb-$BOD_5$/day + 32 lb-$BOD_5$/day = 4,191 lb-$BOD_5$/day

Minimum Surface Area Required for a Naturally Aerobic Lagoon for an Average San Joaquin Valley Dairy

Minimum Surface (acres) in areas with a maximum loading rate of 55 lb-$BOD_5$/acre-day = 4,191 lb-$BOD_5$/day ÷ 55 lb-$BOD_5$/acre-day = 76.2 acres

Minimum Surface (acres) in areas with a maximum loading rate of 45 lb-$BOD_5$/acre-day = 4,191 lb-$BOD_5$/day ÷ 45 lb-$BOD_5$/acre-day = 93.1 acres

[105] United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), Agricultural Waste Management Field Handbook (AWMFH). Retrieved from: https://directives.sc.egov.usda.gov/viewerfs.aspx?hid=21430

As shown above the minimum surface area required for a naturally aerobic lagoon treating manure from an average size dairy in the Valley would range from approximately 76.2 – 93.1 acres. This amount of land is not typically available and would require the removal of land that is currently used to produce feed or other crops. Construction of a lagoon over 76 acres in size would be a massive project that would have numerous challenges and high costs for both design and construction. For example, the expense of lining a lagoon of this size would be extremely high. To comply with the requirements of the Central Valley Regional Water Quality Control Board, new lagoons and ponds that store dairy manure in the Valley have generally needed to comply with the Central Valley Regional Water Quality Control Board Tier 1 design standards, which require a lagoon or pond with a double liner constructed of high density polyethylene (HDPE) or material of equivalent durability with a leachate collection and removal system. The Capital Press article[106] indicated that the cost for the installation of double-liner for an existing lagoon at a dairy near Sunnyside, Washington in 2016 was roughly $500,000 for each lagoon and the lagoons averaged 78,000 square feet each. Based on this information, the cost of a double liner for a lagoon storing dairy manure is estimated to be about $7.88 per square foot and $343,253 per acre in 2022. Therefore, the cost for the liner for a lagoon only with an area of 76.2 to 93.1 acres would be $26,555,879 to $31,956,854.

In addition to construction costs, there would also be an increase in expenses for designing and maintaining lagoons of such a large size. To comply with the requirements of Regional Water Quality Control Board and Mosquito Abatement District the lagoon would need to be regularly cleared of any dead algae, vegetation, and floating debris that could create a habitat for mosquitos and other vectors that carry diseases. Therefore, as a result of the large size of the lagoons, the maintenance required to comply with these regulations would be difficult and there would also be increased costs. Finally, ammonia emissions may increase from naturally aerobic lagoons because of the large surface in contact with the atmosphere.

The NRCS Reference Guide states that the energy required at an animal production operation to introduce enough oxygen for complete aerobic treatment using mechanical aeration is very expensive and aeration of the surface of the liquid manure is more common.

The Government of Ontario publication[107] states that there are several disadvantages for on-farm use of mechanical aeration and specifically lists the following:

- High initial costs;
- High energy costs;
- High maintenance costs;

[106] Wheat, D. (2018). Dairy Installs Double Liner in Its Lagoon. Capital Press. Updated December 13, 2018. Retrieved from: https://www.capitalpress.com/state/washington/dairy-installs-double-liner-in-its-lagoon/article_9ded077e-db11-5cc5-adb7-aa7ebee6e5b9.html

[107] Government of Ontario. (2006). “Aeration of Liquid Manure”. Retrieved from: https://www.ontario.ca/page/aeration-liquid-manurehttps://www.ontario.ca/page/aeration-liquid-manure

- Effectiveness is reduced in cold weather;
- The introduction of antibiotics and sanitizers can upset or destroy the required aerobic bacteria; and
- Nitrogen loss to the atmosphere is increased with mechanical aeration.

This publication cautions that improperly designed mechanical aeration systems may contribute more odor than what is reduced through the mixing of air into the liquid, which indicates that mechanical aeration of manure can increase emissions.
The very high cost of complete mechanical aeration makes this option infeasible for farms. For complete aerobic treatment of a lagoon, sufficient oxygen must be delivered into the lagoon and the oxygen delivered must be completely mixed throughout the lagoon. A report by the University of California (UC) Davis[108] states, "*Mixing is important to ensure uniformity of temperature and composition throughout the volume, e.g., continuous bulk turnover is needed to eliminate quiescent zones or sludge layers where anaerobic conditions persist. Also, relatively vigorous mixing (high turbulence) prevents clumping of organisms/substrate, and reduces diffusion resistance by thinning the film thickness through which dissolved oxygen must migrate (diffuse) to reach substrate particles and organisms.*" Delivery of oxygen and mixing of the oxygen throughout a lagoon requires substantial amounts of energy. The cost of electricity for complete aeration can be estimated based on the amount of oxygen that needs to be supplied and the energy required for complete mixing of oxygen throughout a lagoon. The Government of Ontario publication indicates that for complete aeration of manure, oxygen must be supplied in an amount equal to twice the BOD in the manure.

A publication[109] indicates that approximately 1.5 to 2.5 pounds of oxygen is required to digest one pound of Biological Oxygen Demand ($BOD_5$) with additional oxygen required for conversion of ammonia to nitrate (NO3-) (nitrification). In this publication, Dr. Ruihong Zhang of UC Davis estimated that 2.4 lbs (1.1 kg) of oxygen ($O_2$) per cow must be provided each day for removal of BOD and an additional 3 lbs (1.4 kg) per cow for oxidation of 70 percent of the nitrogen, which is a ratio of approximately 2.25 lb of oxygen per lb of BOD. It will be estimated that 2 lb of oxygen per 1 lb of $BOD_5$ is required for nitrification of ammonia.

As discussed above, the lagoons for an average size dairy in the Valley with 1,600 mature cows will have a BOD loading rate of approximately 4,191 lb-$BOD_5$/day. Based on the data gathered in the UC Davis report, aeration efficiencies for mechanical aerators ranged from 0.10 to 0.68 kg of oxygen provided per kW-hr of energy utilized.[110] The most efficient aerator tested installed in dairy lagoons had an aeration efficiency of 0.49 kg-$O_2$/kW-hr. These efficiency tests were performed in clean water. The efficiency

[108] Williams, R.B., Elmashad, H., Kaffka, S. (2020). Research and Technical Analysis to Support and Improve the Alternative Manure Management Program Quantification Methodology. *University of California, Davis, California Biomass Collaborative*, CARB Agreement No. 17TTD010. Retrieved from: https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/ucd_ammp_qm_analysis_final_april2020.pdf
[109] San Joaquin Valley Dairy Manure Technology Feasibility Assessment Panel. (2005) An Assessment of Technologies for Management and Treatment of Dairy Manure in California's San Joaquin Valley. California Air Resources Board
[110] Zhang, R., Sun, H., Kamthunzi, W.M., Collar, C.A., Mitloehner, F.M. (2007) Aerator Performance for Wastewater Lagoon Application, ASABE. https://elibrary.asabe.org/abstract.asp?aid=23832

of the aerators will be lower in liquid manure because of the higher amount of solids that it contains compared to clean water. The yearly energy requirement for a mechanically aerated lagoon treating flushed manure an average size dairy in the Valley is calculated as follows:

Oxygen Requirement for Average Size Dairy in the Valley

4,191 lb-$BOD_5$/day x 1 kg/2.2046 lb = 1,901 kg-$BOD_5$/day x 2 = 3,802 kg-$BOD_5$/day

Electricity for High Efficiency Aerator

3,802 kg-$BOD_5$/day ÷ (0.68 kg-$O_2$/kW-hr) x (365 day/year) = 2,040,779 kW-hr/year

Electricity for Low Efficiency Aerator

3,802 kg-$BOD_5$/day ÷ (0.10 kg-$O_2$/kW-hr) x (365 day/year) = 13,877,300 kW-hr/year

Electricity for Complete Mixing of Air

The UC Davis report estimates that mixing for complete aeration of a dairy lagoon would require 3,300 kW-hr per milk cow per year. The energy required for mixing for complete aeration for an average sized dairy in the Valley is calculated as follows:

1,348 milk cows x 3,300 kW-hr/milk cow-year = 4,448,400 kW-hr/year

Total Electricity Required for Complete Aeration with High Efficiency Aerator

2,040,779 kW-hr/year + 4,448,400 kW-hr/year = 6,489,179 kW-hr/yr

Total Electricity Required for Complete Aeration with Low Efficiency Aerator

13,877,300 kW-hr/year + 4,448,400 kW-hr/year = 18,325,700 kW-hr/yr

Cost of Electricity for Complete Mechanical Aeration of a Lagoon Treating Manure from an Average Size Dairy in the Valley:

The cost for electricity will be based upon the average price for industrial electricity in California for the year December 2021 through November 2022, as taken from the Energy Information Administration (EIA) website:

Average Cost for electricity = $0.1685/kW-hr

The electricity costs for complete aeration are calculated as follows:

Low Cost Estimate (High Efficiency Aerator)

6,489,179 kW-hr/year x $0.1685/kW-hr = $1,093,427/year

High Cost Estimate (Low Efficiency Aerator)

18,325,700 kW-hr/year x $0.1685/kW-hr = $3,087,880/year

As shown above, the estimated cost for only the electricity for a mechanically aeration to reduce ammonia emissions from an average size dairy in the Valley ranges from nearly $1.1 million per year to nearly $3.1 million per year. This cost does not include the design and construction of the mechanical aeration system or any additional operational costs. However, it is clear that the cost of electricity alone would make this system economically infeasible, especially when considering that the price of electricity is expected to continue to increase.

Although the NRCS Reference Guide states that surface aeration of manure is more common because of the difficulty and expense of complete mechanical aeration, the amount of oxygen provided by aeration of the surface of liquid manure would not be sufficient to oxidize ammonia. Any ammonia oxidized would be converted to nitrite and nitrate. Increased concentrations of nitrite and nitrate in the liquid manure may require treatment to protect water quality or increase emissions of NOx or nitrous oxide (N2O). Although surface aeration may sometimes reduce odors of some compounds, surface aeration may actually increase ammonia emissions because it accelerates the release of carbon dioxide (CO2), an acidic gas, which increases the pH of the manure promoting increased ammonia emissions.[111, 112] Additionally, low levels of aeration will not provide sufficient oxygen for treatment, but can increase the transfer of emissions from the manure to the air because of the increased disturbance at the surface of the liquid manure.

Naturally aerated lagoons are not feasible in the Valley because of the large land requirements, fully mechanically aerated lagoons are not practical because of the high energy requirements and costs, and surface aeration is not expected to reduce ammonia emissions; therefore, this is not a feasible measure to reduce ammonia emissions from liquid manure in the Valley.

The District is unaware of any instances in which oxygenation demonstrates to be a practical technology on any farm to decrease ammonia emissions from liquid manure and has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

[111] Zhao, B., Chen, S. (2003). Ammonia Volatilization from Dairy Manure under Anaerobic and Aerated Conditions at Different Temperature. Paper number 034148, 2003 American Society of Agricultural and Biological Engineers Annual Meeting. Retrieved from: https://elibrary.asabe.org/abstract.asp?aid=13892

[112] Kaffka, S., Barzee, T., El-Mashad, H., Williams, R., Zicari, S., Zhang, R. (2016). Evaluation of Dairy Manure Management Practices for Greenhouse Gas Emissions Mitigation in California. Final Technical Report to the State of California Air Resources Board Contract #14-456. Retrieved from: https://biomass.ucdavis.edu/wp-content/uploads/ARB-Report-Final-Draft-Transmittal-Feb-26-2016.pdf

**Storage Bags** - ***(applies to dairy cattle only)***

Manure storage bags have primarily been used to store manure from pig farms in Europe and Canada. They have also recently started to be used to store manure on some dairy farms that are relatively small compared to the typical dairies in the Valley. The storage of manure in bags is only suitable for small dairies that handle manure as a slurry. Manure storage bags are not suitable for large dairies that handle dilute liquid manure because of the large volumes of manure that must be stored until it can be applied to cropland. The majority of dairies in the Valley are large flush dairies in which liquid manure mixed with water is stored in large earthen lagoons or ponds until it can be applied to cropland. Dairies that handle manure as a slurry without the addition of water are extremely rare in the Valley. [113] In addition, lagoons and storage ponds that hold manure are required to be lined in order to reduce the chances of manure contaminating the groundwater. Manure storage bags may not be allowed because there is a high possibility that something may puncture the bag causing manure to leak, which could degrade groundwater.

The District is unaware of any dairies in the Valley that are currently using storage bags to store manure. Manure storage bags are not suitable for the typical size dairies in the Valley and there are questions about if these bags would comply with existing California regulations, including water regulations. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Liquid Manure Storage Covers** - ***(applies to all CAFs)***

The NRCS Reference Guide includes manure storage covers as a potential measure to reduce emissions from the storage of manure. Manure can be handled and stored in the form of a thick slurry, a dilute liquid, or as a solid. A study[114] notes that placing a cover over a lagoon can reduce emissions, however the different cover types have both benefits and drawbacks. Such covers include, natural or synthetic and they may be flexible or rigid, which vary in cost. The type of cover that is appropriate for each operation depends on the size and type of manure storage, environmental factors, and the goals of the farm. Manure storage covers limit emissions by slowing diffusion of gases and reducing the effects of wind on the surface of the manure. Although manure storage covers may reduce pollutants directly emitted from the manure, they do not destroy or eliminate pollutants such as ammonia. Rather, concentrations of these pollutants increase in the stored manure and additional measures would be required to prevent their release when the manure is removed from storage.

[113] Marklein, A. R., Meyer, D., Fischer, M. L., Jeong, S., Rafiq, T., Carr, M., and Hopkins, F. M. (2021) Facility-Scale Inventory of Dairy Methane Emissions in California: Implications for Mitigation, Earth Syst. Sci. Data, 13, 1151–1166, https://doi.org/10.5194/essd-13-1151-2021, 2021.
[114] Marks, R. (2001). Cesspools of Shame: How Factory Farm Lagoons and Sprayfields Threaten Environmental and Public Health. *Natural Resources Defense Council and the Clean Water Network.* Retrieved from: https://www.nrdc.org/sites/default/files/cesspools.pdf

As previously mentioned, Valley dairies that handle manure as a slurry without the addition of water are extremely rare and therefore certain types of manure covers are generally not applicable. The NRCS Reference Guide notes that concrete covers cannot be used on earthen or steel manure storages and natural covers (e.g. straw, barely, cornstalks) are impractical if the surface area of the storage is very large. Dairies in the Valley primarily store liquid manure with low solids content in large earthen lagoons or ponds,[115] therefore concrete covers and natural covers cannot feasibly be used to cover liquid manure in the Valley. Additionally, the Valley regulations from the Regional Water Quality Control Board[116] and mosquito abatement districts[117] generally require the removal of any materials that would form natural covers in order to decrease the chances for the proliferation of mosquitos and other vectors.

Although covers made of rigid plastic, such as HDPE, may be a potential option to cover lagoons and ponds that store liquid manure in the Valley, they would be very prohibitively expensive because of the large area that would need to be covered. As previously mentioned, the average dairy in the Valley has almost 1,600 cows compared to a national average of less than 300 cows per dairy outside of California. Since the Valley dairies are larger compared to other dairies in the nation, the lagoons and ponds that store liquid manure are also several times larger compared to the national average dairy that stores mostly undiluted slurry manure.

Moreover, manure covers do not destroy ammonia, rather they create a barrier that suppresses emissions of ammonia from the manure and air space above the manure. This leads to increased concentrations of ammonia and other air contaminants in the manure and air space above the manure, which will just delay the release of ammonia until it is sent to a different pond or applied to land. The increase concentration of ammonia in the manure will also increase the pH and subsequently increase the potential for ammonia emissions. Furthermore, because of the warm climate of the Valley, covering a lagoon with a plastic cover would turn the lagoon into an anaerobic digester. The majority of anaerobic digesters operating on dairies in the Valley are already covered lagoon digesters. The NRCS Reference Guide also states that gases will build up under impermeable covers that must be flared or utilized in another way. Flaring or combusting these gases would produce $NO_X$, which is the primary precursor for PM2.5 in the Valley, as well as direct PM2.5 emissions.

The District has permitted several facilities to construct and operate a covered lagoon. However, in each case, the covered lagoon was part of a digester system to capture biogas/digester-gas, and the cost of the system was funded by grants from the California Department of Food and Agriculture (CDFA) Dairy Digester Research and Development Program.

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115 Meyer, D., Price, P.L., Rossow, H.A., Silva-del-Rio, N., Karle, B., Robinson, P.H., DePeters, E.J., and Fadel, J. (2011) Survey of Dairy Housing and Manure Management Practices in California. Journal Dairy Sci. 94:4744-4750. https://doi.org/10.3168/jds.2010-3761
116 California Regional Water Quality Control Board Central Valley Region. Order R5-2013-0122. Retrieved from: https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2013-0122.pdf
117 The Fresno County Mosquito Control Districts. Retrieved from: https://fresnocountymosquito.org/

In conclusion, it is not reasonable to require covers to reduce ammonia emissions from liquid manure storage in the Valley given the high expense associated to the practice and the fact that the practice is not expected to result in any overall reductions of ammonia emissions in the Valley, but could increase emissions of other pollutants.

**Solid Manure Storage Covers** - ***(applies to all CAFs)***

U.S. EPA identified Method 62 (Cover solid manure sources with sheeting) from the UK User Guide, noting that it could result in ammonia emission reductions up to 90 percent. Method 62 involves covering solid manure stores with sheeting, which provides a physical barrier preventing the release of ammonia to the air. U.S. EPA acknowledged that this method "would increase ammonium content of the slurry, potentially leading to higher ammonia emissions during storage and spreading." District Rule 4570, U.S. EPA acknowledges, contains mitigation measure options for the covering of dry manure piles, and in most cases, facilities are required to cover manure and separated solids or else remove them from the facility.[118]

Storage of solid manure/separated solids contributes a very small amount of total ammonia emissions in the Valley, by making up less than 2 percent of the total ammonia emissions from dairies. Nonetheless, covering for solid manure/separated solids during the months of October through May is included in Rule 4570 and required for most dairies during these 8 months of the year, which include the District's PM2.5 season.

Based on District permitting records covering solid manure or separated manure solids during October through May is required by 729 dairies, 84 percent of the dairies are subject to Rule 4570, and a larger percentage of the total dairy cattle since this measure is required for all dairies that are classified as large confined animal facilities under the rule.

Covers for solid manure/separated solids is not required during the summer because solid manure is primarily composed of organic material that is combustible and during the hot summers in the Valley, elevated temperatures increase the chances of spontaneous combustion of manure piles.[119] Therefore, for safety reasons manure covers cannot be required during the hotter summer months. However, through District Rule 4570, the District requires CAFs to cover solid manure/separated solids during the colder winter months, as shown below:

- Cover dry manure outside the housing with a weatherproof covering from October through May, except for times when wind events remove the covering, not to exceed 24 hours per event; and

[118] Chadwick, D.R. (2005). Emissions of Ammonia, Nitrous Oxide and Methane from Cattle Manure Heaps: Effect of Compaction and Covering. *Atmosphere Environment*, Vol. 39, Issue 4: 787-799. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S135223100400994X
[119] Westendorf, M. L. "Animal Science Update: Spontaneous Combustion". New Jersey Farmer. August 15, 2016. Page 6. https://plant-pest-advisory.rutgers.edu/spontaneous-combustion/

- Cover separated solids outside the housing with a weatherproof covering from October through May, except for times when wind events remove the covering, not to exceed 24 hours per event.

In conclusion, the District already has a mechanism to implement this mitigation measure for solid manure/separated solid stored onsite. No additional ammonia reductions are expected from the suggested mitigation measure.

**Allow Cattle Slurry Stores to Develop a Natural Crust** - ***(applies to dairy cattle only)***

This measure identified in the UK User Guide involves retaining a surface crust on slurry stores, composed of fiber and bedding material present in cattle slurry, for as long as possible. This practice is applicable to thick slurry manure, which differs from the typical liquid manure stored in the Valley. The dilute liquid manure handled in the Valley is stored in ponds and lagoons much larger than storages used for slurry manure in other regions, and does not contain enough solids to form a natural crust.

Additionally, this practice is more applicable to cooler climates, while in the Valley’s warm climate, floating debris on liquid manure create a habitat for mosquitos and other vectors that carry diseases, including West Nile virus, zika, dengue, chikungunya, and St. Louis encephalitis.[120] To reduce the potential for the propagation of mosquitos and other disease carrying vectors, Regional Water Quality Control Board[121] and Mosquito Abatement District regulations require the removal of any dead algae, vegetation, and floating debris, including those that would form a natural crust on the surface of a lagoon or pond.[122] Thus, this practice is not allowed in the Valley. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Solid-Liquid Separation** - ***(applies to all CAFs)***

The NRCS Reference Guide states that for manure streams handled as a slurry, separation of the solid and liquid portions prior to storage, additional treatment, and/or land application may reduce odor and other gaseous emissions, particularly for undersized lagoons. Various solid separation technologies are used for these purposes, including screens, rotary drums, centrifugal tanks, earthen pits, weeping walls, settling basins and screw-presses.

Dairies in the Valley primarily handle liquid manure that has been diluted with water, rather than slurry manure, and the effluent from dairies in California often has a total

[120] The Fresno County Mosquito Control Districts. Retrieved from: https://fresnocountymosquito.org/
[121] California Regional Water Quality Control Board Central Valley Region. Order R5-2013-0122. Retrieved from: https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2013-0122.pdf
[122] Collar, C. (2005). West Nile Virus – How Dairies Can Help ‘Fight the Bite. *University of California, Davis, Cooperative Extension.* Retrieved from: https://cemerced.ucanr.edu/newsletters/September_200523148.pdf

solids content of only 1 percent;[123] therefore this measure is not directly applicable to most dairies in the Valley. The NRCS Reference Guide indicates that solid-liquid separation does not work well for manure streams with very low or very high solids content, unless advanced technologies or multiple separation stages or screen sizes are used to remove large and small solids from the manure stream separately. These technologies will have additional challenges and increased costs. Additionally, some studies indicate that the majority of ammonia nitrogen in dilute manure streams remains in the liquid portion and are not removed by solid-liquid separation. The NRCS Reference Guide indicates that some separator designs may increase emissions of gases or particles during the separation process. Dried separated solids may also increase the potential for PM emissions.

As mentioned above, this control measure is applicable to manure handled as a slurry rather than the dilute liquid manure that is typically handled on dairies in the Valley. Therefore, this practice is not directly applicable to dairies in the Valley. However, for cattle facilities that handle liquid manure, Rule 4570 does allow the facilities to choose the option to remove solids from the waste system with a solid separator system prior to the waste entering the lagoon. This option has been chosen by the vast majority cattle facilities that handle liquid manure, including over 90 percent of dairy cattle facilities subject to Rule 4570.[124] The option in Rule 4570 is as follows:

- Remove solids from the waste system with a solid separator system, prior to the waste entering the lagoon.

In conclusion, the District already has a mitigation measure option to minimize emissions from solid-liquid manure separation. No additional ammonia reductions are expected from the suggested mitigation measure.

**Anaerobic Digesters** - ***(applies to dairy cattle only)***

Anaerobic digesters are storage or treatment lagoons that are undergoing anaerobic reactions, primarily located at dairies. Digesters are outfitted with roofs and covers that enclose all anaerobic emissions within the system and vent to a gas collection system that eliminates undesired methane emissions. The microbes performing anaerobic reactions in lagoons convert nitrogen to form various new compounds, including ammonia. Through the implementation of its Short-Lived Climate Pollutant Strategy and SB 1383,[125] the State of California has funded the installation of over 120 dairy digester

[123] Meyer, D, Heguy, J., Karle, B. and Robinson, P. (2019) Characterize Physical and Chemical Properties of Manure in California Dairy Systems to Improve Greenhouse Gas Emission Estimates. California Environmental Protection Agency, Air Resources Board. Retrieved from: https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/16rd002.pdf

[124] EPA-USDA NRCS. "Reference Guide for Poultry and Livestock Production Systems." September 2017. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf

[125] CARB. Analysis of Progress toward Achieving the 2030 Dairy and Livestock Sector Methane Emissions Target. (March 2022). Retrieved from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiayMXd4af9AhXWrmoFHYf2BNsQFnoECBAQAQ&url=https%3A%2F%2Fww2.arb.ca.gov%2Fsites%2Fdefault%2Ffiles%2F2022-03%2Ffinal-dairy-livestock-SB1383-analysis.pdf&usg=AOvVaw32GB5_r8-3GsSd57-XTnyo

systems throughout the state to reduce methane emissions, with the majority of installations in the San Joaquin Valley. Through the generation of vehicle renewable natural gas, some dairy digester systems have the potential of reducing vehicle-related NOx, PM2.5, air toxics, and greenhouse gas (GHG) emissions.

Some forms of energy conversion from biogas (e.g., burning biogas in an engine to produce electricity) may increase emissions of NOx, a precursor for PM2.5 and ozone, and direct PM2.5 emissions. These emissions can have a negative impact in the Valley, which is designated as nonattainment for PM2.5 and ozone This technology is very expensive, due to capital costs, operation, and maintenance expenses. It also requires significant addition of water, and may not be feasible in water-limited areas.

The NRCS Reference Guide includes anaerobic digesters as a measure to reduce VOCs and GHG emissions, but does not indicate that it reduces ammonia. Some of the information discussed in the NRCS Reference Guide about anaerobic digestion indicates a potential for increased ammonia emissions. The results of some studies also indicate that there is a potential for increased ammonia emissions following digestion.[126] There is limited information regarding the potential and scale of ammonia emissions impacts associated with digester, and California does not currently attribute any increased ammonia impacts from the implementation of dairy digester systems.

At this time there are significant uncertainties about the overall effect of anaerobic digesters on ammonia emissions from manure and additional research is needed to better understand this, particularly for digesters in the Valley. Because of this and the very high costs associated with installation of anaerobic digesters, they are not a feasible option to implement into Rule 4570 at this time. However, this practice would be evaluated as a potential BACT measure for any new or expanding operations; the required mitigation measure from BACT Guideline 5.8.6[127], is as follows:

- Anaerobic treatment lagoon designed according to NRCS Guideline 359.

In conclusion, the District already has a mechanism to implement this mitigation measure for expanding or new confined animal facilities. No additional ammonia reductions are expected from the suggested mitigation measure.

**<u>Manure Additives</u> - *(applies to all CAFs)***

Manure amendments are not practical for manure handled as a dilute liquid, which is typical for Valley dairies, because the large volume of water mixed with the manure greatly increases the amount of an amendment required to change the properties of liquid manure, such as pH. The addition of certain amendments also increases the risk

[126] Koirala, K., Ndegwa, P.M., Joo, H.S., Frear, C., Stockle, C.O., Harrison, J.H. (2013). Impact of Anaerobic Digestion of Liquid Dairy Manure on Ammonia Volatilization Process. *American Society of Agricultural and Biological Engineers,* Vol. 56(5): 1959-1966. Retrieved from: https://labs.wsu.edu/ndegwa/documents/2016/09/Article-57.pdf/
[127] CARB BACT Guidelines Tool. Retrieved from: https://ww2.arb.ca.gov/sites/default/files/classic/technology-clearinghouse/bact/BACTID781.pdf?:linktarget=_self&:embed=yes

of foaming in liquid manure, which can damage pumps.[128] For slurry and liquid manure, it is difficult and costly to apply a sufficient amount of amendments to change the pH of the manure because of its natural buffering capacity, or resistance to changes in pH due to its chemical properties.

The NRCS Reference Guide states, *"It is often difficult to establish microbiological additives due to competition from naturally-occurring bacteria in manure."* The microbes in microbial additives are often out-competed by the naturally occurring microorganisms, because of the abundance of diverse microorganisms that are naturally present in manure that can multiply rapidly when favorable conditions are present. As a result, microbial additives are often ineffective or must be continually added to the manure. A study[129] conducted by Iowa State University, clearly demonstrates that many questions remain unanswered about the general effectiveness of microbial additives used to reduce emissions. The study evaluated 12 commercial microbial additives that were marketed for their ability to reduce emissions of odorous VOCs, H2S, ammonia, GHG, and odors. The results indicated that emissions from the treated manure were not statistically significant to the untreated manure for any of the 12 products tested. Thus, the ability of microbial additives to reduce emissions from manure remains unproven. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Acidifying Slurry and Shifting Chemical Balance from Ammonia to Ammonium - *(applies to all CAFs)***

This mitigation method mentioned in the compilation by Guthrie, et al.[130] involves the use of manure amendments to minimize ammonia emissions. Manure amendments are not practical for manure handled as a dilute liquid, which is typical for Valley dairies, because the large volume of water mixed with the manure greatly increases the amount of an amendment required to change the properties of liquid manure, such as pH. The addition of certain amendments also increases the risk of foaming in liquid manure, which can damage pumps. For slurry and liquid manure, it is difficult and costly to apply a sufficient amount of amendments to change the pH of the manure because of natural buffering capacity. Notably, some additives can even increase emissions of certain pollutants and can be toxic to handle.

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[128] USDA NRCS/EPA (2017) Agricultural Air Quality Conservation Measures Reference Guide for Poultry and Livestock Production Systems. https://www.nrcs.usda.gov/sites/default/files/2022-06/Ag_AQ_Conservation_Measures_Poultry_and_Livestock_September_2017.pdf

[129] Koziel, J., Chen, B., Andersen, D., Parker, D., Bialowiec, A., Banik, C., Lee, M., O'Brien, S., Ma, H., Meiirkhanuly, Z., Wi, J., Li, P., Iowa State University. (2021). Evaluating Manure Additives for Odor Mitigation. *National Hog Farmer.* Retrieved from: https://www.nationalhogfarmer.com/agenda/evaluating-manure-additives-odor-mitigation

[130] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

Moreover, any additives to the manure require approval of the Regional Water Quality Control Board.[131] The Regional Water Quality Control Board has determined that increased salinity is a threat to water quality in the Valley.[132] As a result, in many cases the application of amendments and additives that use salts to change pH will not be allowed.

For reasons discussed above, manure amendments are not practical for most operations in the Valley. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Acidifying Amendments and Additives for Poultry Litter** - ***(applies to poultry only)***

This method involves the application of aluminum to poultry litter to reduce the pH of the litter. However, poultry operations have already reduced nitrogen excretion by 55 percent and are not a significant source of ammonia in the Valley. Use of acidifying litter amendments is more common for poultry litter however, any additives to the manure require approval of the Regional Water Quality Control Board. The Regional Water Quality Control Board has determined that increased salinity is a threat to water quality in the Valley.[133, 134] As a result, in many cases the application of amendments and additives that use salts to change pH will not be allowed.

Notably, some additives can increase emissions of certain pollutants and can be toxic to handle. For example, the litter in poultry houses in the Valley are drier than many other parts of the country and therefore aluminum would need to be applied as a liquid. Nevertheless, liquid aluminum is an acid that is dangerous to handle and requires a certified applicator to be hired which results in higher costs.

Despite the uncertainties above, the District further evaluated the potential emission reductions of implementing this measure in the Valley. This analysis is provided below.

Ammonia is a weak base and reducing the pH of litter binds ammonia and reduces its volatilization. Aluminum sulfate, also known as alum, is a common compound used to treat poultry litter to reduce ammonia emissions and bind phosphorous to prevent runoff. The typical recommended application rate for aluminum sulfate is 0.1 to 0.2 lb of

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[131] California Regional Water Quality Control Board Central Valley Region. (March 2017). Resolution R5-2017-0031 (Accepting the Salt and Nitrate Management Plan). Retrieved from: https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/resolutions/r5-2017-0031_res.pdf

[132] California Regional Water Quality Control Board Central Valley Region. (May 2006). Salinity in the Central Valley. Retrieved from: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/CDWA%20et%20al/SDWA_206.pdf

[133] California Regional Water Quality Control Board Central Valley Region. (May 2006). Salinity in the Central Valley. Retrieved from: https://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/california_waterfix/exhibits/docs/CDWA%20et%20al/SDWA_206.pdf

[134] California Regional Water Quality Control Board Central Valley Region. (March 2017). Resolution R5-2017-0031 (Accepting the Salt and Nitrate Management Plan). Retrieved from: https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/resolutions/r5-2017-0031_res.pdf

aluminum sulfate per broiler placed.[135] The higher the aluminum sulfate application rate, the higher the ammonia control and phosphorus binding ability of aluminum sulfate. The lower recommended application rate will control ammonia emissions for about half the time as the higher recommended application rate.[136, 137] Young chicks are more vulnerable to higher ammonia concentrations in the houses; however, ammonia emissions are lower because of the lower amount of manure produced by the smaller birds. These recommended application rates are based on broilers with a finished weight of approximately four pounds. Larger birds will require correspondingly larger application rates to achieve the same control of ammonia.[138]

A study published in 2020 found that an application rate of 98 kg of aluminum sulfate per 100 square meters incorporated into litter reduced overall ammonia emissions from broilers by 35 percent.[139] In the study, the birds were placed in 2.1 m by 1.8 m pens with 50 birds per pen to evaluate different treatments. Therefore, the application rate of alum on a per bird basis was calculated as follows:

98 kg/100 $m^2$ x 2.1 m × 1.8 m ÷ 50 bird = 0.074 kg/bird

The application rate of 0.074 kg/bird is equivalent to an application rate 0.16 lb-aluminum sulfate per bird. Therefore, it will be assumed that this is the application rate required to reduce ammonia emissions by 35 percent. The District's current ammonia emission factor for broiler chickens is 0.0958 lb-NH3/bird-year. Thus, the ammonia emission reductions for this practice can be calculated as follows:

0.0958 lb-NH3/bird-year x 35% = 0.0335 lb-NH3/bird/year

The cost of the emission reductions is based on the cost of the purchase and application of aluminum sulfate. Because of the typically dry conditions in the Valley, liquid aluminum sulfate is preferred because moisture is required for aluminum sulfate to react with ammonia. A USDA-ARS publication[140] indicates that one ton of aluminum sulfate is equivalent to 370 gallons of liquid aluminum sulfate. Based on a web search, the price of aluminum sulfate is estimated to be $1,155 per 55 gallon drum.[141] The customer applicator rate is assumed to be $100 for each broiler house housing 20,000

[135] See Moore, P. Treating Poultry Litter with Aluminum Sulfate. USDA ARS. Developed by Livestock GRACEnet. https://www.ars.usda.gov/ARSUserFiles/np212/LivestockGRACEnet/AlumPoultryLitter.pdf
[136] Moore, P., Watkins, S. Treating Poultry Litter with Alum. University of Arkansas (U of A) Division of Agriculture Cooperative Extension Service. https://www.uaex.uada.edu/publications/PDF/FSA-8003.pdf
[137] Moore, P., Miles, D., Burns, R. (March 2019). Reducing Ammonia Emissions from Poultry Litter with Alum. Livestock and Poultry Environmental Learning Community (LPELC). https://lpelc.org/reducing-ammonia-emissions-from-poultry-litter-with-alum/
[138] Anderson, K.; Moore, P.A., Jr.; Martin, J.; Ashworth, A.J. (2020) Effect of a New Manure Amendment on Ammonia Emissions from Poultry Litter. *Atmosphere*, *11*, 257. https://doi.org/10.3390/atmos11030257
[139] Penn, C., Zhang, H (April 2017) Alum-Treated Poultry Litter as a Fertilizer Source. Oklahoma State University Extension. https://extension.okstate.edu/fact-sheets/alum-treated-poultry-litter-as-a-fertilizer-source.html#nitrogen-content-of-alum-treated-litter
[140] See Moore, P. Treating Poultry Litter with Aluminum Sulfate. USDA ARS. Developed by Livestock GRACEnet. https://www.ars.usda.gov/ARSUserFiles/np212/LivestockGRACEnet/AlumPoultryLitter.pdf
[141] Alliance Chemical, Price of Aluminum Sulfate 50%. Retrieved from: https://alliancechemical.com/product/aluminum-sulfate-50/?attribute_pa_size=55-gallon&attribute_pa_packaging-type=drum&gclid=EAIaIQobChMIurHTv9WT_QIVMRPUAR1c5QvKEAQYASABEgJ5__D_BwE

birds. Therefore, the total cost for each application of aluminum sulfate on a per bird basis is calculated as follows:

0.16 lb-aluminum sulfate/bird x 1 ton/2,000 lb x 370 gal-aluminum sulfate/ton-aluminum sulfate x $1,155/55 gal-aluminum sulfate + $100/20,000 bird = $0.63/bird

Approximately 6.7 broiler flocks are produced each year and aluminum sulfate must be applied prior to placing each flock; therefore, the annual cost of this measure on a bird capacity basis is 6.7/year x $0.63/bird = $4.22/bird capacity-year.

The cost effectiveness of the ammonia reductions from this measure are calculated as follows:

$4.22/bird-year ÷ 0.0335 lb-NH3/bird-year x 2,000 lb/ton = $251,940/ton-NH3 reduced

As demonstrated above, the potential reductions from this measure are not cost effective, with a cost effectiveness of $251,940 per ton of ammonia reduced. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Urease Inhibitors** - ***(applies to all cattle)***

A study[142] indicates that the information for this control measure was taken from AirControlNet, a software tool previously used by EPA to estimate the cost of emission reductions. The AirControlNET v.4.1 Documentation Report[143] indicates that the specific chemical additive that this measure refers to was N-(n-butyl) thiophosphoric triamide (NBPT), which was being sold under the trade name Conserve-Nr. NBPT is a type of urease inhibitor. The cost information was provided by a supplier of the chemical and appears to be an underestimate.

Urease inhibitors inhibit the action of the enzyme urease. Urease, which is present in feces and produced by soil microorganisms, converts urea into ammonia, which can then volatilize. Although there are many compounds that can inhibit urease, only a few are non-toxic, effective at low concentrations, and chemically stable. Urease inhibitors have shown promising results for reducing nitrogen emissions from urea-based fertilizers, but some studies indicate that there remain questions about their effectiveness in reducing ammonia from manure.[144]

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[142] Pinder, R., Adams, P., Pandis, S. (2007). Ammonia Emission Controls as a Cost-Effective Strategy for Reducing Atmospheric Particulate Matter in the Eastern United States. *Environmental Science and Technology*, Volume 41, Pages 380-386. Retrieved from: https://pubs.acs.org/doi/pdf/10.1021/es060379a
[143] E.H. Pechan & Associates, Inc. (September 2005). AirControlNET v.4.1 Documentation Report. Retrieved from: https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1012ZYW.TXT
[144] Lasisi, A.A., Akinremi, O.O., and Kumaragamage, D. "Ammonia emission from manures treated with different rates of urease and nitrification inhibitors," Canadian Journal of Soil Science 100(3), 198-205, (25 February 2020). Retrieved from: https://doi.org/10.1139/cjss-2019-0128

Urease inhibitors appear to reduce ammonia emissions for relatively short periods of time and must be reapplied, and the buildup of urea in the pen surface may require that the NBPT additions increase with time to continue to control ammonia. Because of the need to re-apply increasing amounts of urease inhibitors as manure and urea accumulate, there will be increased costs.

Additionally, there is evidence that urease inhibitors may alter plant metabolism and lead to accumulation of urea in plant tissue,[145] which can have negative effects on crops. Urea inhibitors will also increase the amount of nitrogen in the manure, and to comply with Regional Water Quality Control Board Regulations, some farms would need to acquire additional cropland to apply the manure or identify ways to export the manure to ensure that nitrogen is not over-applied.

It appears that the treatment of animal manure with urease inhibitors has not yet been commercialized. This is likely because of the limited chemical stability of the inhibitors, the need for reapplication, the lack of efficient and automated application systems, and a subsequent increase in the cost for the farmer. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Surface Cooling of Slurry Manure** - ***(applies to all CAFs)***

The publication by Guthrie, et al.[146] suggests this measure for CAFs with a slurry manure handling system. The measure involves lowering the temperature of the slurry in the channels by pumping a coolant (e.g., groundwater) through a series of fins floating on the slurry. This measure appears to be largely theoretical, and the District is not aware of any instances in which cooling of liquid or slurry manure has been used to reduce emissions from animal production operations. Furthermore, there are high costs for installation of piping and pumping coolant and circulation of coolant through manure, and recycling groundwater may not be permitted in some regions. For these reasons, this measure is unproven and not feasible to implement in the Valley.

**Feeding Strategies to Lower the pH of Manure** - ***(applies to all CAFs)***

Livestock feeding strategies can influence the pH of manure and urine. The pH of manure can be lowered by increasing the fermentation in the large intestine. This increases the volatile fatty acids (VFA) content of the manure and causes a lower pH. The pH of urine can be lowered by lowering the electrolyte balance of the diet. Furthermore, the pH of urine can be lowered by adding acidifying components to the diet. A low pH of the manure and urine excreted also results in a low pH of the slurry/manure during storage even after a certain storage period. This pH effect can

[145] Zanin L, Venuti S, Tomasi N, Zamboni A, De Brito Francisco RM, Varanini Z, Pinton R. (2016) Short-Term Treatment with the Urease Inhibitor N-(n-Butyl) Thiophosphoric Triamide (NBPT) Alters Urea Assimilation and Modulates Transcriptional Profiles of Genes Involved in Primary and Secondary Metabolism in Maize Seedlings. Front Plant Sci. 2016 Jun 22;7:845. doi: 10.3389/fpls.2016.00845. PMID: 27446099; PMCID: PMC4916206.
[146] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

reduce ammonia emissions from slurries during storage and also following application. This measure is primarily for non-ruminants, such as poultry and pigs and is not recommended for cattle.

The pH of freshly excreted urine mainly depends on the electrolyte content of the diet. The pH of urine will eventually rise towards alkaline values due to the hydrolysis of urea irrespective of initial pH; however, the initial pH and the pH buffering capacity of urine affect the rate of ammonia volatilization from urine immediately following urination. Lowering the pH of urine of ruminants is theoretical possible. However, it has not been demonstrated to be feasible on actual farms. Lowering the pH of cattle manure is also theoretically possible, but this might easily coincide with disturbed rumen fermentation and is therefore not recommended. Since this measure has not been demonstrated for cattle and remains theoretical, it is premature to consider it as part of any regulatory efforts.

The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Land Application of Manure**

**Table F-12 Land Application of Manure Measures Evaluated**

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| Timing of Land Application | Timing of Land Application | All Cattle | NRCS[147] |
| | Optimal Weather Conditions for Spreading | All Cattle | Guthrie[148] |
| Injection | Injection | All Cattle | NRCS |
| | Use Slurry Injection Application Techniques | All Cattle | Price[149] |
| | Injector | All Cattle | Guthrie |
| | Open-slot Injection | All Cattle | Webb[150] |
| | Injector | All Cattle | Eory[151] |

[147] EPA-USDA NRCS. "Reference Guide for Poultry and Livestock Production Systems." September 2017. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf

[148] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

[149] Price et al., "An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture, User Guide," December 2011. Retrieved from: https://repository.rothamsted.ac.uk/download/942687eab7ec4b83751c7e241d62f0fa8472d72adcd25a149bb891b7c30d55d0/1595300/MitigationMethods-UserGuideDecember2011FINAL.pdf

[150] Webb, J., Pain B., Bittman, S., Morgan J. The impacts of manure application methods on emissions of ammonia, nitrous oxide and on crop response—a review. Agric. Ecosyst. Environ. 137, 39–46 (2010). Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S0167880910000046?via%3Dihub

[151] Eory, V., Rees, B., Topp, K., Dewhurst, R., et al. ClimateXChange, "On-farm technologies for the reduction of greenhouse gas emissions in Scotland," March 2016. Retrieved from: https://www.climatexchange.org.uk/media/1927/on-farm_technology_report.pdf

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| | Injection Techniques | All Cattle | Bittman[152] |
| | Injection into the Soil | All Cattle | Preece[153] |
| Incorporation of Liquid and Solid Manure | Incorporation | All Cattle | NRCS |
| | Incorporate Manure into the Soil | All Cattle | Price |
| | Incorporation of Manure | All Cattle | Guthrie |
| | Incorporation of Surface-Applied Solid Manure and Slurry into Soil | All Cattle | Bittman |
| | Incorporation into the Soil | All Cattle | Preece |
| | Incorporate Manure into the Soil | All Cattle | Atia[154] |
| | Immediate Incorporation of Applied Manure | All Cattle | Pinder[155] |
| Band Spreading | Banding | All Cattle | NRCS |
| | Slurry Band Spreading Application Techniques | All Cattle | Price |
| | Band Spreading | All Cattle | Guthrie |
| | Band Spreading Slurry | All Cattle | Bittman |
| Other Land Application | Slurry Dilution | All Cattle | Bittman |
| | Transport Manure to Neighboring Farms | All Cattle | Price |

**Timing of Land Application** - ***(applies to all cattle)***

This measure requires operators to apply the correct amount of necessary nutrients to crops when they are most in demand and in locations where they can be accessed by specific plants. Applying nutrients in spring prior to planting, when crops are ready to utilize the nitrogen, can reduce ammonia emissions compared to applying in fall. Applying at lower soil temperatures can also help to reduce near-term ammonia emissions due to reduced microbial activity in cooler soils. Split application to better time the nutrient application to crop needs can also be beneficial.

Although not specifically included in Rule 4570, the measure is already required for confined animal facilities in the Valley that apply manure to land. Regional Water Quality Control Board Regulations[156] require that manure may only be applied to land at

[152] Bittman, S., Dedina, M., Howard C.M., Oenema, O., Sutton, M.A., (eds), 2014, "Options for Ammonia Mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen," Centre for Ecology and Hydrology, Edinburgh, UK. Retrieved from: http://www.vuzt.cz/svt/vuzt/publ/P2014/037.pdf

[153] Preece, Sharon L.M. et al., ''Ammonia Emissions from Cattle Feeding Operations,'' Texas A&M AgriLife Extension Service, referring to Cole, N.A., R.N. Clark, R.W. Todd, C.R. Richardson, A. Gueye, L.W. Greene, and K. McBride, ''Influence of Dietary Crude Protein Concentration and Source on Potential Ammonia Emissions from Beef Cattle Manure,'' Journal of Animal Science 83:(3), 722 (2005)

[154] Atia, A. (2008). Ammonia volatilization from manure application. Alberta Agriculture, Food and Rural Development. Retrieved from: https://open.alberta.ca/dataset/b115d4b8-982d-43d5-97a6-1d987bf8ba01/resource/863253f1-22f1-4a7b-950a-c424ef5cc9e5/download/2008-538-3.pdf

[155] Pinder, R., Adams, P., Pandis, S. (2007). Ammonia Emission Controls as a Cost-Effective Strategy for Reducing Atmospheric Particulate Matter in the Eastern United States. *Environmental Science and Technology*, Volume 41, Pages 380-386. Retrieved from: https://pubs.acs.org/doi/pdf/10.1021/es060379a

[156] California Regional Water Quality Control Board Central Valley Region. Order R5-2013-0122. Retrieved from: https://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2013-0122.pdf

agronomic rates in accordance with an approved nutrient management plan, and that nutrients, including nitrogen, may only be applied at times when plants can utilize these nutrients. The rate of application of manure and process wastewater for each crop in each land application area (also considering sources of nutrients other than manure or process wastewater) to meet each crop's needs without exceeding the application rates is specified in the Regional Water Quality Control Board Technical Standard.

The NRCS Reference Guide estimates that this measure will reduce ammonia emissions from land application by 65-70 percent. Because this measure is already required, as an industry standard, these reductions have already been achieved in the Valley.

**Injection** - ***(applies to all cattle)***

Applying manure to the soil surface without incorporation can lead to significant emissions of ammonia and other odorous gases. Several of the mitigation measure compilations evaluated by the District included injection of liquid or slurry manure as an option to reduce ammonia emissions from land application. However, this method is more applicable to slurry manure than the dilute liquid manure applied to land in the Valley. Additionally, the equipment needed to transport and inject the dilute liquid manure, which is not typically used in the Valley, would have high costs for fuel and would increase emissions of NOx and PM2.5.

Estimated ammonia emissions reductions from the injection of liquid manure are based on the assumption that surface broadcasting of liquid manure is the typical practice. Broadcasting of liquid manure results in higher emissions because of the larger amount of surface area of the liquid manure that will be in direct contact with the atmosphere. However, nearly all liquid manure in the Valley is diluted and applied via surface gravity irrigation systems, such as flood and furrow irrigation. Because of the much lower concentration of ammonia in the diluted liquid manure typically applied in the Valley, and the reduced surface area of liquid manure in furrow and flood irrigation systems compared to broadcasting, ammonia emissions from the application of liquid manure in the Valley is already much lower than traditional surface broadcasting. A report prepared by the University of California Division of Agricultural and Natural Resources Committee of Experts on Dairy Manure Management[157] indicates that in California, "nearly all" manure from lagoons is diluted with irrigation water and applied via surface gravity irrigation systems and that "during irrigations, farmers commonly dilute lagoon water with 5 to 10 parts of fresh source water." The report goes on to state that "in systems with frequent, but well diluted manure water applications, ammonia losses from the ground surface will commonly be minimal during the irrigation (10 percent or less)."

[157] Chang, A., T. Harter, J. Letey, D. Meyer, R. D. Meyer, M. Campbell-Mathews, F. Mitloehner, S. Pettygrove, P. Robinson, R. Zhang (2006) Managing Dairy Manure in the Central Valley of California; University of California Committee of Experts on Dairy Manure Management Final Report to the Regional Water Quality Control Board, Region 5, Sacramento, June 2005. https://ucanr.edu/sites/groundwater/files/136450.pdf

The Ammonia Volatilization from Manure Application fact sheet,[158] estimates that ammonia losses from unincorporated manure to be 66 percent in the spring and early fall; this the standard practice in the Valley of applying manure by gravity flow irrigation is already estimated to reduce ammonia emissions by at least 85 percent compared to broadcasting of manure.

Furthermore, to avoid damaging growing crops, injection of liquid manure can only be performed prior to planting the crop, typically a maximum of two times per year. Additionally, the amount of nitrogen that can be applied to cropland is limited to protect water quality. Many agricultural areas in the Valley already have nitrate levels in the groundwater that are above acceptable limits, and many dairies are required to reduce the amount of nitrogen applied to land. Injection of manure reduces the amount of nitrogen emitted to the air, but the retained nitrogen is placed in the soil. Thus, injection of manure into the soil will increase the amount of nitrogen in the cropland and may not be feasible for some dairies, or will require additional land in order to comply with their nutrient management plans.

District Rule 4570 includes the requirement to minimize the amount of emissions from applying liquid manure to the soil. These mitigation measures include an option to inject liquid manure, as shown below:

- Apply liquid/slurry manure via injection with drag hose or similar apparatus.

In conclusion, the District already has mitigation measures for liquid manure injection. No additional ammonia reductions are expected from the suggested mitigation measures.

**Incorporation of Liquid Manure** - ***(applies to all cattle)***

Many mitigation measure compilations included incorporation of slurry and liquid manure into soil as an option to reduce ammonia emissions.[159] However, as discussed above, nearly all liquid manure in the Valley is diluted and applied via surface gravity irrigation systems, such as flood and furrow irrigation. Because of the of the much lower concentration of ammonia in the diluted liquid manure typically applied in the Valley, ammonia emissions from the application of liquid manure in the Valley is already much lower than the emissions from broadcasting slurry manure.

Slurry manure is not typically applied in the Valley and liquid manure in the Valley is diluted prior to application. However, District Rule 4570 includes a mitigation option to minimize the amount of emissions from incorporating liquid manure to the soil, as shown below:

[158] Atia, A. (2008). Ammonia volatilization from manure application. Alberta Agriculture, Food and Rural Development. Retrieved from: https://open.alberta.ca/dataset/b115d4b8-982d-43d5-97a6-1d987bf8ba01/resource/863253f1-22f1-4a7b-950a-c424ef5cc9e5/download/2008-538-3.pdf

[159] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

- Allow liquid manure to stand in the fields for no more than 24 hours after irrigation.

In conclusion, the District already has mitigation measures for the incorporation of liquid manure. No additional ammonia reductions are expected from the suggested mitigation measures.

**Incorporation of Solid Manure** - ***(applies to all cattle)***

The NRCS Reference Guide and UK User Guide include methods for incorporation of solid manure that involve mixing manure with surface soil to reduce the exposed surface area of the manure. The NRCS Reference Guide advises that incorporation should occur as soon as possible after the manure is applied, or at least within 24 hours, to reduce ammonia emissions. In the Valley, solid manure land application accounts for less than 3 percent of total ammonia emissions from dairies and incorporation of solid manure within 72 hours is already required for over 80 percent of cattle facilities that apply manure to land.

To avoid damaging growing crops, incorporation of solid manure can only be performed prior to planting the crop, typically a maximum of two times per year. Almost all dairies in the Valley use a double-crop farming system for their cropland to maximize the amount of manure that can be applied and increase the amount of feed produced for the cattle, with some dairies using a triple-crop system. In the typical double-crop system used on Valley dairies, corn for silage is planted in late April through June to be harvested in September, and winter forage (e.g. wheat, oats, barley, etc.) is planted in late September to be harvested in April or May.[160,161] Because of the very short time frame available between crops, the standard practice in the Valley is to incorporate applied solid manure as soon as practical so the land can be prepared for the next crop.

Solid manure applied to cropland is often incorporated immediately after application; however, additional time may sometimes be required due to unforeseen circumstances, such as difficult weather conditions, equipment breakdowns, or the unavailability of the contractors that perform the work since they may be busy at other farms that are also preparing to plant the next crop. With this under consideration, Rule 4570 gives additional time to account for the unforeseen circumstances that may unexpectedly delay incorporation of manure into cropland within 24 hours, as shown below:

- Incorporate all solid manure within 72 hours of land application.

[160] University of California, Davis. UC Drought Management – Corn. Retrieved from: https://ucmanagedrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/Corn/
[161] Ag Proud – Progressive Dairy. 12-Month Forage Pays. Retrieved from: https://www.agproud.com/articles/30676-12-month-forage-pays

The District is further evaluating requiring solid manure applied to cropland to be incorporated within 24 hours. An analysis of this measure, including the control efficiency and estimated costs, is below.

The control efficiency for incorporation is estimated based on information from the Chesapeake Bay Program Watershed Model report.[162] This report includes estimations of ammonia emission reductions for low-disturbance incorporation and high-disturbance incorporation of manure. The report gives vertical tillage as an example of low-disturbance incorporation and states that for high-disturbance incorporation, chisel plowing followed by secondary tillage with a disk harrow or field cultivator is expected to be the most common practice. Information in the report indicates that with low-disturbance incorporation, ammonia emissions are reduced 34 percent when manure is incorporated within 72 hours and 50 percent when manure is incorporated within 24 hours. The report also indicates that with high-disturbance incorporation, ammonia emissions are reduced 50 percent when manure is incorporated within 72 hours and 75 percent when manure is incorporated within 24 hours. Based on this information, the ammonia ($NH_3$) emissions from incorporation of solid manure within 72 hours and 24 hours are estimated as follows:

<u>Low-Disturbance Incorporation of Solid Manure within 72 Hours</u>

Control Efficiency: 34%

Percent $NH_3$ emissions of manure that is not incorporated: 66%

<u>Low-Disturbance Incorporation of Solid Manure within 24 Hours</u>

Control Efficiency: 50%

Percent $NH_3$ emissions of manure that is not incorporated: 50%

<u>High-Disturbance Incorporation of Solid Manure within 72 Hours</u>

Control Efficiency: 50%

Percent $NH_3$ emissions of manure that is not incorporated: 50%

<u>High-Disturbance Incorporation of Solid Manure within 24 Hours</u>

Control Efficiency: 75%

Percent $NH_3$ emissions of manure that is not incorporated: 25%

[162] Chesapeake Bay Phase 6.0 Manure Incorporation And Injection Expert Review Panel: Dell, C., Allen, A., Dostie, D., Meinen, R., Maguire, R (December 2016) Manure Incorporation and Injection Practices for Use in Phase 6.0 of the Chesapeake Bay Program Watershed Model. Prepared for Chesapeake Bay Program, Annapolis, MD 21403. CBP/TRS-309-16. EPA Contract No. EP-C-12-055. https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/phase_6_final_mii_final_report.pdf

The ammonia control efficiency for incorporation of solid manure within 24 hours rather than 72 hours, compared to the ammonia emissions from solid manure that is not incorporated is estimated as follows:

<u>Low-Disturbance Incorporation of Solid Manure within 24 Hours</u>

66% - 50% = 16%

<u>High-Disturbance Incorporation of Solid Manure within 24 Hours</u>

75% - 50% = 25%

The ammonia emissions from solid manure land application are approximately 2.8 percent of the ammonia emissions from dairies and other cattle facilities; therefore, the overall control efficiency of this measure is estimated to be:

<u>Low-Disturbance Incorporation of Solid Manure within 24 Hours</u>

17% x 2.8% = 0.48% of total NH3 emissions from cattle

<u>High-Disturbance Incorporation of Solid Manure within 24 Hours</u>

25% x 2.8% = 0.7% of total NH3 emissions from cattle

The incremental ammonia control efficiency for incorporation of solid manure within 24 hours compared to incorporation of solid manure within 72 hours is calculated as follows.

<u>Low-Disturbance Incorporation of Solid Manure within 24 Hours</u>

1 – (50%/66%) = 24.2%

<u>High-Disturbance Incorporation of Solid Manure within 24 Hours</u>

1 – (50%/75%) = 33.3%

This control efficiency is just for the application of solid manure to cropland, which is a very small portion of the total emissions from cattle facilities.

The cost of more rapid incorporation varies greatly, depending whether a farm already has the required equipment available or if the farm requires an additional tractor and must contract with a custom farm service to implement this practice. For farms for which the required equipment for more rapid incorporation is available, it will be assumed that the primary cost of this measure will be the additional labor required to operate the equipment, to ensure that the manure is incorporated within the required timeframe. For other farms for which the required equipment is not available, it will be assumed that they must hire a custom farm service to ensure that manure is incorporated within the required timeframe. The labor costs for incorporation of solid manure and the costs for hiring a custom farm service will be estimated based on information from the University of California Cooperative Extension.[163, 164] The costs for labor and hiring a custom farm service for low-disturbance incorporation of solid manure are assumed to be similar to finish discing of a field, and the costs for labor and hiring a custom farm service for high-disturbance incorporation of manure are assumed to be similar to chiseling a field followed by discing.

Based on the University of California Cooperative Extension publications, the incremental cost for low-disturbance incorporation of solid manure is estimated to be approximately $2.64 per acre if only additional labor is required, and $15.37 per acre if a custom farm service must be used. At dairies in the Valley, solid manure is typically applied to land twice per year so the overall cost for low-disturbance incorporation of solid manure is as follows:

Incremental Labor Cost for Low-Disturbance Incorporation of Solid Manure within 24 Hours

$2.64/acre x 2 time/year = $5.28/acre-year.

Incremental Cost for Custom Farm Service for Low-Disturbance Incorporation of Solid Manure within 24 Hours

$15.37/acre x 2 time/year = $30.74/acre-year.

Based on the University of California Cooperative Extension publications, the incremental cost for high-disturbance incorporation of solid manure is estimated to be approximately $6.60 per acre if only additional labor is required, and $64.21 per acre if a custom farm service must be used. As mentioned above, at dairies in the Valley solid manure is typically applied to land twice per year so the overall cost for high-disturbance incorporation of solid manure is as follows:

Incremental Labor Cost for High-Disturbance Incorporation of Solid Manure within 24 Hours

$6.60/acre x 2 time/year = $13.20/acre-year.

[163] University of California Cooperative Extension, Agriculture and Natural Resources, Agricultural Issues Center (2016) 2016 Sample Costs to Establish and Produce Alfalfa, Tulare County, Southern San Joaquin Valley, 300 Acre Planting. https://coststudyfiles.ucdavis.edu/uploads/cs_public/1c/e2/1ce256d0-957e-4bd4-b17e-18fef4efcedd/16alfalfasjv300acfinal_41916.pdf

[164] University of California Cooperative Extension, Agriculture and Natural Resources, Agricultural Issues Center (2016) 2016 Sample Costs to Establish and Produce Alfalfa, Tulare County, Southern San Joaquin Valley, 50 Acre Planting. https://coststudyfiles.ucdavis.edu/uploads/cs_public/24/b6/24b68b4a-4c04-4853-b127-d3461e1a248f/16alfalfasjv50ac_final_4192016.pdf

Incremental Cost for Custom Farm Service for High-Disturbance Incorporation of Solid Manure within 24 Hours

$64.21/acre x 2 time/year = $128.42/acre-year.

Estimated ammonia emissions from unincorporated manure will be based on measurements included in the 2008 Dairy Emission Study report by Schmidt.[165] Based on measurements in this study, ammonia emissions from unincorporated solid manure are estimated to be approximately 4 lb-NH3/acre-year.

The cost effectiveness of the potential ammonia reductions for low-disturbance incorporation of solid manure with 24 hours compared to incorporation with 72 hours are estimated as follows:

NH3 Emissions for Low-Disturbance Incorporation of Solid Manure within 72 hours:

4 lb-NH3/acre-year x 66% = 2.64 lb-NH3/acre-year

NH3 Emissions for Low-Disturbance Incorporation of Solid Manure within 24 hours:

4 lb-NH3/acre-year x 50% = 2.0 lb-NH3/acre-year

Potential NH3 Emission Reductions for Low-Disturbance Incorporation within 24 hours

= 2.64 lb-NH3/acre-year - 2.0 lb-NH3/acre-year = 0.64 lb-NH3/acre-year

Cost Effectiveness if Only Additional Labor is Required

Cost of NH3 reductions: $5.28/acre-year ÷ 0.64 lb-NH3/acre-year x 2,000 lb/ton = $16,500/ton-NH3

Cost Effectiveness if Custom Farm Service is Required

Cost of NH3 reductions: $30.74/acre-year ÷ 0.64 lb-NH3/acre-year x 2,000 lb/ton = $96,063/ton-NH3

The cost effectiveness of the potential ammonia reductions for high-disturbance incorporation of solid manure with 24 hours compared to incorporation with 72 hours are estimated as follows:

NH3 Emissions for High-Disturbance Incorporation of Solid Manure within 72 hours:

4 lb-NH3/acre-year x 50% = 2.0 lb-NH3/acre-year

[165] Schmidt, C., Card, T. (August 2009) 2008 Dairy Air Emissions Report: Summary of Dairy Emission Estimation Procedures. Prepared for the San Joaquin Valleywide Air Pollution Study Agency

NH3 Emissions for High-Disturbance Incorporation of Solid Manure within 24 hours:

4 lb-NH3/acre-year x 25% = 1.0 lb-NH3/acre-year

Potential NH3 Emission Reductions for High-Disturbance Incorporation within 24 hours

= 2.0 lb-NH3/acre-year - 1.0 lb-NH3/acre-year = 1.0 lb-NH3/acre-year

Cost Effectiveness if Only Additional Labor is Required

Cost of NH3 reductions: $13.20/acre-year ÷ 1.0 lb-NH3/acre-year x 2,000 lb/ton = $26,400/ton-NH3

Cost Effectiveness if Custom Farm Service is Required

Cost of NH3 reductions: $128.42/acre-year ÷ 1.0 lb-NH3/acre-year x 2,000 lb/ton = $256,840/ton-NH3

As explained above, cattle facilities that apply solid manure to cropland incorporate the manure as quickly as possible in order to prepare for planting of the next crop; so this is already an industry standard, therefore, many cattle facilities are already attaining the potential ammonia emission reductions of this practice, except when conditions make this impractical.

In conclusion, the District already has mitigation measures for incorporation of solid manure. No additional ammonia reductions are expected from the suggested mitigation measures.

**Band Spreading** - ***(applies to all cattle)***

This practice[166] reduces volatilization of ammonia by using low-pressure application near the ground. Band spreading of manure can only be done during very limited periods immediately prior to planting of a crop, a maximum of two times per year. This practice is primarily applicable to slurry manure rather than flush manure, and has limited applicability to the Valley in which most manure is applied as a liquid or a solid. Band spreading is generally a slower operation (with lower application rates), so there may be some issues with labor availability. Additionally, there are high costs due to the initial investment of new machines, as well as the costs of ongoing maintenance and fuel.

As previously discussed, nearly all liquid manure in the Valley is diluted and applied via surface gravity irrigation systems, such as flood and furrow irrigation, which allows

[166] Chang, A., T. Harter, J. Letey, D. Meyer, R. D. Meyer, M. Campbell-Mathews, F. Mitloehner, S. Pettygrove, P. Robinson, R. Zhang (2006) Managing Dairy Manure in the Central Valley of California; University of California Committee of Experts on Dairy Manure Management Final Report to the Regional Water Quality Control Board, Region 5, Sacramento, June 2005. https://ucanr.edu/sites/groundwater/files/136450.pdf

manure to flow on the ground without using pressure to apply liquid manure. Due to the much lower concentration of ammonia in the diluted liquid manure typically applied in the Valley, and the reduced surface area of liquid manure in furrow and flood irrigation systems compared to broadcasting, ammonia emissions from the application of liquid manure in the Valley is already much lower than traditional surface broadcasting and also expected to be lower than emissions from liquid manure applied with band spreading. Moreover, trucks used for these methods would damage growing crops and directly emit NOx and PM, hindering the District's efforts to attain the PM2.5 and ozone NAAQS. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Slurry Dilution** - ***(applies to all cattle)***

This method involves the dilution of slurry with water to decrease the ammonium-N concentration, as well as increase the rate of infiltration into the soil following spreading on land. For undiluted slurry, dilution must be at least 1:1 (one part slurry to one part water) to reduce emissions by at least 30 percent.

This practice is applicable to manure handled as a slurry. The slurry manure would be diluted by 50 percent so it can be infiltrated into soil more quickly. The ammonia reductions for this measure are proportional to the extent of dilution. The majority of dairies in the Valley are large flush dairies in which liquid manure mixed with water is stored in large earthen lagoons or ponds until it can be applied to cropland. The typical practice in the Valley is to dilute manure with irrigation water when it is applied to cropland. The liquid handled on Valley dairies typically has a DM content of 2 percent or less. This manure is then commonly further diluted with 5 to 10 parts of fresh source water during irrigation. Because of this, ammonia emissions from the typical application of liquid manure can be estimated to be more than 90 percent lower than the ammonia emissions from this practice (4.5 percent DM applied, compared to 0.2 percent DM applied). The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Transport Manure to Neighboring Farms** - ***(applies to all cattle)***

This mitigation measure does not result in overall decreases in ammonia emissions. Although ammonia emissions are reduced from the exporting farm, these emissions are transferred to the receiving farm.

Regional Water Quality Control Board Regulations prohibit the over-application of nutrients from manure in the Valley and already only allow manure to be applied at agronomic rates in accordance with an approved nutrient or waste management plan. Nutrient management plans require that farms transport excess manure to other fields or identify other uses for excess manure. Transporting manure would increase emissions of NOx and PM2.5 from fuel use, and these emissions would hinder the District's efforts to attain the PM2.5 and ozone NAAQS. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

### Other Mitigation Measures

**Table F-13 Other Mitigation Measures Evaluated**

| Method | Measure | CAF Type | Reference |
|---|---|---|---|
| Other | Pasture and Range Management: Stocking Density | Other Cattle | NRCS[167] |
| | Improved Livestock Genetics | All | Price[168] |
| | Planting a Tree Shelter Belt | All | Guthrie[169] |
| | Using Plants with Improved Nitrogen Use Efficiency | All Cattle | Guthrie |
| | Changing Land from Arable to Woodland | All | Guthrie |
| | Reduced Consumption of Meat and Eggs by Humans | All | Guthrie |

**Pasture and Range Management: Stocking Density** - ***(applies to grazing cattle only)***

The NRCS Reference Guide lists managing animal stocking density at grazing-based livestock operations as a mitigation method for ammonia emissions. However, the District does not have authority to regulate animals on pasture or rangeland, as they are not confined. This measure also does not recommend a specific stocking density; however, cattle that graze on pastureland and rangeland in California generally require low stocking densities to provide sufficient forage for cattle. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Improved Genetics** - ***(applies to all CAFs)***

A publication prepared for use in the United Kingdom includes genetic selection of useful traits to improve animal health and fertility as a potential mitigation measure to increase the efficiency of animals and reduce environmental impacts. Farmers select animal breeds that have improved genetics that increase efficiency as feasible to reduce overall costs and increase yield. The publication notes that use of animals with improved genetics "*is generally good in the poultry, dairy and pig industries*." Improvements in genetics and management practices to increase efficiency have already significantly reduced the environmental footprint of production from animal agriculture compared to previous years. As a result of genetic selection and improved

[167] EPA-USDA NRCS. "Reference Guide for Poultry and Livestock Production Systems." September 2017. Retrieved from: https://www.epa.gov/sites/default/files/2017-01/documents/web_placeholder.pdf
[168] Price et al., "An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture, User Guide," December 2011. Retrieved from: https://repository.rothamsted.ac.uk/download/942687eab7ec4b83751c7e241d62f0fa8472d72adcd25a149bb891b7c30d55d0/1595300/MitigationMethods-UserGuideDecember2011FINAL.pdf
[169] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

diets, milk production per cow has increased and feed usage has decreased by 77 percent and water use has decreased by 65 percent.[170] GHG emissions from California dairy cattle per amount of milk produced have also decreased by over 45 percent in the 50 years from 1964 to 2014.[171] For poultry, it is estimated that genetic selection and the current feed practices have reduced nitrogen excretion by poultry by up to 55 percent, primarily due to the reduced time from egg to market age.[172]

Farmers are expected to continue to use animals with improved genetics that will increase efficiency and reduce production costs. However, there are several issues that cause this measure to be unsuitable as a requirement in a regulation. The study does not specify the genetic traits that need to be improved. The measure is largely theoretical and requires extensive research and funding to develop new breeds with the desired traits. It would take generations of each breed to evaluate the effectiveness of the breeds as it pertains to reducing ammonia emissions and any potential adverse impacts on the environment. There are also potential ethical concerns regarding if animals were to be genetically modified to accelerate selection of specific traits. Therefore, the District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Planting a Tree Shelter Belt - *(applies to all CAFs)***

This measure involves planting tree shelterbelts around livestock housing and manure slurry storage facilities to disrupt airflow around these sites. The effectiveness of tree shelterbelts as a measure to reduce particulate matter from facilities depends on the shelterbelt height, canopy density, and the prevailing environmental conditions. While some evidence demonstrates effectiveness for PM2.5 emissions reductions, there is little to no evidence for ammonia emissions reductions. Effective tree shelterbelts are expensive and difficult to establish due to the large size of the facilities, severe water limitations, soil conditions, and the number of trees needed to protect these areas.

Irrespective of the lack of available data on the potential ammonia emissions reductions, implementation of this measure requires additional consideration with respect to animal health. Cattle facilities in the Valley depend on natural airflow to cool cattle and provide them with fresh air. Disrupting natural airflow can adversely affect cattle that depend on the natural flow of air, particularly during summer months where large numbers of heat-related animal mortalities occur in the San Joaquin Valley. Tree shelterbelts also require sufficient space to be effective, thus, dairies would need either to remove crops or acquire additional land for a shelterbelt. Furthermore, a shelterbelt of sufficient height to

[170] McCabe, C. (2021). How Dairy Milk Has Improved its Environmental and Climate Impact. Clarity and Leadership for Environmental Awareness and Research at UC Davis. Retrieved from: https://clear.ucdavis.edu/explainers/how-dairy-milk-has-improved-its-environmental-and-climate-impact

[171] Naranjo A., Johnson A., Rossow H., Kebreab E. (2020) Greenhouse Gas, Water, and Land Footprint per Unit of Production of the California Dairy Industry Over 50 years. J Dairy Sci. 2020 Apr;103(4):3760-3773. doi: 10.3168/jds.2019-16576. Epub 2020 Feb 7. PMID: 32037166.

[172] United States Department of Agriculture - Natural Resources Conservation Service. (2020). Feed and Animal Management for Poultry. Nutrient Management Technical Note No. 190-NM-4. Retrieved from: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=45569.wba

be effective would take a number of years to establish. In many cases in the Valley, where the soil has high salinity, conditions are unsuitable for planting tree shelterbelts.

In several cases, permitted CAFs proposed to grow shelterbelts to satisfy District BACT requirements, however, the shelterbelts were not sustainable. Agronomic land surveys of the facilities confirmed the poor soil quality would not sustain the tree shelterbelts. As a result, the District eliminated this option as a BACT requirement for these specific CAFs and allowed an alternative mitigation measure to be implemented.

For the reasons listed above, it is infeasible to require planting tree shelterbelts at animal facilities; however, the trees and plants in the agricultural fields and orchards that surround Valley animal facilities already capture a portion of emissions from these facilities and remove some of the ammonia by deposition. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Using Plants with Improved Nitrogen Use Efficiency - *(applies to all cattle)***

This measure involves developing new plant varieties with improved genetic traits for the capture of soil nitrogen, which would allow reduced fertilizer application. New plant varieties could also be developed with improved nutritional characteristics. This measure is theoretical and requires extensive research and funding to develop new plant varieties with the desired traits. Years of testing would be required to evaluate the effectiveness of new plant varieties for reducing ammonia emissions and any adverse impacts of the new plant varieties. Furthermore, capturing additional soil nitrogen would primarily benefit water quality rather than reducing ammonia emissions. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Changing Land Use from Arable to Woodland - *(applies to all CAFs)***

This measure involves changing land use from agricultural land to permanent woodland. However, many areas in the Valley are dry and often affected by droughts, and thus not suitable for the establishment of permanent woodlands. The District does not have authority to require that agricultural land be converted to forests. Moreover, conversion of agricultural land to farmland would result in total loss of income for the farmers and an associated loss in tax revenue. The District has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

**Reduced consumption of meat and eggs by humans by 63 percent - *(applies to all CAFs)***

The District does not have authority to regulate what people eat and has concluded that the measure discussed is not a viable mitigation option to include in Rule 4570.

## Evaluation of Potential Emissions Reductions from CAFs

As demonstrated in the evaluation above, the District has only identified a few measures that have the theoretical potential to reduce additional ammonia emissions beyond the practices currently enforced through Rule 4570. These measures are reducing CP content in feed for beef finishing cattle, incorporation of solid manure within 24 hours, and acidifying amendments for poultry litter and manure. Despite the technological and economic feasibility issues of these mitigation measures, the District evaluated the potential emission reductions and the impact they might have on the Valley's total ammonia emissions inventory if these measures were to be implemented. This was calculated as follows.

- Control efficiency of reducing CP content in feed for beef finishing cattle, applied to beef cattle emissions inventory:

  18.9% x 16.2 tpd = 3.1 tpd

- Control efficiency of incorporation of solid manure within 24 hours, applied to beef and dairy cattle emissions inventory:

  0.48% x 141.5 tpd = 0.7 tpd

- Control efficiency of acidifying amendments for poultry litter and manure, applied to broiler and layer emissions inventory:

  35% x 7.8 tpd = 2.7 tpd

The emissions reductions from the measures above total 6.5 tpd, which would be reduced from the total ammonia emissions inventory of 306.5 tpd:

6.5 tpd ÷ 306.5 tpd = 2.1%

Overall, ammonia emissions from CAFs in the Valley can only be reduced by 2 percent by implementing the mitigation measures above. This demonstrates that additional reductions in the EPA-recommended range of 30-70 percent are infeasible.

## Fertilizers

Ammonia emissions from agricultural fertilizers are 109.9 in 2030. Emissions growth from agricultural fertilizers are estimated by farmland acreage projection data developed by the Farmland Mapping & Monitoring Program (FMMP) of the California Department of Conservation.

The California Department of Food and Agriculture (CDFA) Feed, Fertilizer and Livestock Drugs Regulatory Services (FFLDRS) Branch primary focus is to ensure in every way possible a clean and wholesome supply of meat and milk, and to promote environmentally safe and agronomically sound use and handling of fertilizer materials. This is performed through regulating manufacturing, labeling, and use of fertilizing materials, feed and livestock drugs.

The CDFA Fertilizer Research and Education Program (FREP) funds and facilitates research to advance the environmentally safe and agronomically sound use and handling of fertilizing materials. FREP is voluntary and serves growers, agricultural supply and service professionals, extension personnel, public agencies, consultants, and other interested parties.

The Fertilizer Inspection Advisory Board (FIAB) is a statutory body that is advisory to the CDFA secretary on matters pertaining to fertilizer issues, including FREP activities. The Board consists of nine persons appointed by the secretary of agriculture, one of whom shall be a public member and eight of whom shall be licensed with CDFA to manufacture or distribute fertilizing materials, including organic inputs. The FIAB established the Technical Advisory Subcommittee (TASC) to advise the FIAB on matters related to the funding of FREP projects. The TASC serves as an expert scientific panel on matters concerning plant nutrition and on environmental effects related to fertilizing materials use. TASC assists in setting research priorities, reviews research proposals, and makes recommendations on projects for funding.

The composition of the TASC is determined by the FIAB. There should be at least nine members representing the major segments of the fertilizer industry, certified crop advisors, technical experts, farming community, public, and governmental agencies. Members have to demonstrate knowledge, technical and scientific expertise in the fields of fertilizing materials, agronomy, plant physiology, principles of experimental research, production agriculture, and environmental issues related to fertilizing materials use. One member can satisfy more than one of the criteria stated above. At minimum, one member shall be appointed from the membership of the FIAB, and one member on the TASC shall be from CDFA.

The TASC meets at least two times per year-once in spring to evaluate concept proposals and once in summer to evaluate full proposals. Additional meetings are necessary for special initiatives. Meetings typically last all day and alternate between Sacramento and other locations throughout the State. Serving on the TASC requires a time commitment in addition to participating in meetings. Members must read and critically evaluate all concept proposals (typically around 35 two-page proposals) and full proposals (typically at least ten 15-page proposals). In addition, TASC members are responsible for reviewing final research reports for FREP funded projects and may be asked to participate in conferences and special initiatives.

CARB has not found an ammonia emission reduction measure for fertilizers that meets U.S. EPA requirements for SIP submittal. CARB staff reached out to the National Association of Clean Air Agencies (NACAA) to ascertain whether other air pollution control agencies across the United States had any experience or regulations reducing ammonia emissions from fertilizers. NACAA reached out to all of their members and CARB staff did not receive any existing rules or regulations controlling ammonia emissions from fertilizers. CARB staff also reached out to EPA Region 9 staff whether they were aware of any rules or regulations controlling ammonia emissions from fertilizers and they were not aware of any. EPA Region 9 staff did ask CARB to review some practices per Table F-14.

**Mitigation Measures**

**Table F-14 Fertilizer Mitigation Measures Evaluated**

| Method | Measure | Reference |
|---|---|---|
| Fertilizer | Optimizing or minimizing use of fertilizer | Guthrie |
| | Adding a Urease Inhibitor | Guthrie |
| | Mixing and injecting fertilizer into the soil quickly | Guthrie and Eory |
| | Applying fertilizer during optimal weather conditions | Guthrie and Eory |

**<u>Optimize or minimize use of fertilizer</u>**

The San Joaquin Valley is a part of Central Valley Water Board of the California Water Board, which is an expansive region extending south from the Oregon border to the northernmost portion of Los Angeles County. The California Legislature passed Senate Bill 390 in 1999, which required Water Boards to develop programs that regulate agricultural lands in accordance with the Porter-Cologne Water Quality Control Act (California Water Code Division 7). In 2003, the Central Valley Irrigated Lands Regulatory Program (ILRP) was established, regulating agricultural discharges to surface waters. The Central Valley Water Board extended the regulations in 2012 to include discharges to ground waters. With the exclusion of lands that are never-irrigated or are covered under a separate Central Valley Water Board program, all commercial irrigated lands are required to obtain regulatory coverage under the ILRP.[173] In accordance with the ILRP, growers are required to prepare farm management plans – which includes an Irrigation Nitrogen Management Plan Summary Report – that comply with the approved upon Waste Discharge Requirements (WDR). Using information from the Reports, inferences can be made about nitrogen management based on estimates that compare nitrogen applied (A) to the nitrogen removed (R) from a field: A/R ratio and A-R difference. Included in the nitrogen fraction is any nitrogen proactively added to a field such as organic amendments, synthetic fertilizers, manure, and irrigation water, whereas nitrogen removed refers to the nitrogen in the materials removed from the field.[174]

Though growers do not have an immediate requirement under ILRP to use nitrogen efficient strategies, growers that are deemed outliers in A/R ratio and A-R difference would be required to employ enhanced strategies to lower these estimates. CDFA

[173] Central Valley Water Board. *Irrigated Lands Regulatory Program (ILRP) FAQs*. Available at: https://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/ilrp_faq.pdf
[174] California State Water Resources Control Board. *State of California State Water Resources Control Board, Order WQ 2018-0002.* Available at: https://www.waterboards.ca.gov/board_decisions/adopted_orders/water_quality/2018/wqo2018_0002_with_data_fig1_2_appendix_a.pdf

FREP offers an Irrigation and Nitrogen Management training program[175] for this purpose among others. A subset of the Irrigation and Nitrogen Management training program is dedicated to nitrogen efficiency, including overviews of the “4 R’s” of nitrogen management, and of efficient nitrogen practices.[176] The 4 R’s principles are founded on applying the “Right source” of nitrogen at the “Right rate”, “Right time”, and “Right place”. The right rate principle is with the identified measure, as it promotes strategies for providing nitrogen in rates that do not go beyond the crop demand for nitrogen. Examples of how this can be accomplished include adjusting the rate of application based on expected crop yield and adjusting season application rates based on soil and plant-tissue testing.

Guthrie et al. (2018) describe how minimizing the amount of fertilizer applied to an level that is optimal for crop can reduce ammonia emissions.[177] This measure and associated findings were not well described by both Guthrie et al. (2018) and the publications they referenced, nor were any specific regulations identified.[178,179,180,181] Additionally, the viewpoints of Guthrie et al. (2018) were prepared in the context of Europe and United Kingdom. There is therefore a probability that the conditions and farming practices described by Guthrie et al. (2018) are consistent with those present and employed in California. This, combined with the lack in strong evidence demonstrating the emission reduction potentials, demonstrates the need for additional research be completed under conditions consistent with those of the San Joaquin valley before this measure can be considered.

## Urease Inhibitor

When combined with urease enzyme present in plants, urea present in urea-based fertilizers can be converted into ammonia, which can then volatilize. Urease inhibitors are a class of nitrogen stabilizer designed to minimize volatilization from applied nitrogen sources by inhibiting the action of the urease, thereby reducing the formation of ammonia.

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[175] CDFA. *Fertilizer Research and Education Program*. Available at: https://www.cdfa.ca.gov/is/ffldrs/frep/

[176] CDFA. *Irrigation and Nitrogen Management Training for Grower Self-Certification*. Available at: https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/training/inmtp_workbook.pdf

[177] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). Impact of ammonia emissions from agriculture on biodiversity: An evidence synthesis. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

[178] UNECE. 2015. United Nations Economic Commission for Europe Framework Code for Good Agricultural Practice for Reducing Ammonia Emissions. United Nations Economic Commission for Europe Convention on Long-range Transboundary Air Pollution. https://unece.org/environment-policy/publications/framework-code-good-agricultural-practice-reducing-ammonia

[179] Zhang, Y., A.L. Collins, J.I. Jones, P.J. Johnes, A. Inman, J.E. Freer. (2017). The potential benefits of on-farm mitigation scenarios for reducing multiple pollutant loadings in prioritised agri-environment areas across England. Environmental Science & Policy 73, 100-114. https://doi.org/10.1016/j.envsci.2017.04.004

[180] Collins, A.L., Y.S. Zhang, M. Winter, A. Inman, J.I. Jones, P.J. Johnes, W. Cleasby, E. Vrain, A. Lovett, L. Noble. (2016). Tackling agricultural diffuse pollution: What might uptake of farmer-preferred measures deliver for emissions to water and air? Science of The Total Environment 547, 269-281. https://doi.org/10.1016/j.scitotenv.2015.12.130

[181] Dalgaard, T., J. F. Bienkowski, A. Bleeker, U. Dragosits, J. L. Drouet, P. Durand, A. Frumau, N. J. Hutchings, A. Kedziora, V. Magliulo, J. E. Olesen, M. R. Theobald, O. Maury, N. Akkal, P. Cellier. (2012). Farm nitrogen balances in six European landscapes as an indicator for nitrogen losses and basis for improved management. Biogeosciences 9, 5303–5321. https://doi.org/10.5194/bg-9-5303-2012

Nitrogen stabilizers are regulated by federal and State regulatory agencies. At the federal level, The Federal Insecticide, Fungicide, and Rodenticide Act requires that nitrogen stabilizers sold and distributed in the United States be registered with U.S. EPA.[182] At the state level, both the California Department of Pesticide Regulations (DPR) and CDFA maintain regulatory authorities over nitrogen stabilizers. While DPR requires all nitrogen stabilizers to be registered,[183] CDFA regulates licensing, registration, labeling, tonnage reporting, and inspection of only a subset of commercial nitrogen stabilizers.[184] In coordination with 4R Nutrient Stewardship and UC Davis Land and Water Resources, CDFA FREP also encourage growers to use enhanced-efficiency sources such as Urease Inhibitors, identifying these sources as possible “Right Source” through their 4 R’s principles.[185]

Although urease inhibitors have shown tremendous promise in reducing ammonia emissions, some studies indicate potential occurrences of pollution swapping through increasing of NOx emissions which must be critically considered and explored prior to further considering the measure.[186,187] Additionally, although there are numerous identified benefits associated with the use urease inhibitors, there is little existing knowledge about their potential to enter the food chain and impact food safety.[188] Further research is needed which demonstrates that there are no food safety-related issues prior to this measure being viable for consideration.

According to Guthrie et al. (2018), the addition of a urease inhibitor has the potential to reduce ammonia emissions by 40-70 percent.[189] Though this has the potential to hold remarkable mitigation potential, their estimates along with those of the original experiments, were prepared under European and United Kingdom conditions. As these findings were based outside of California where environmental and climatic conditions may differ, further research is needed that explores the reduction potentials of urease inhibitors in conditions consistent with those of the San Joaquin Valley. In addition to

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[182] US EPA. *Nitrogen Stabilizer Products that Must Be Registered under FIFRA*. Available at: https://www.epa.gov/pesticide-registration/nitrogen-stabilizer-products-must-be-registered-under-fifra
[183] CDPR. *A Guide to Pesticide Regulation in California 2017 Update*. Available at: https://www.cdpr.ca.gov/docs/pressrls/dprguide/dprguide.pdf
[184] CDFA. *California Fertilizer Laws and Regulations*. Available at: https://www.cdfa.ca.gov/is/docs/Fertilizer_Law_and_Regs.pdf
[185] CDFA FREP. *California Crop Fertilization Guidelines.* Available at: https://www.cdfa.ca.gov/is/ffldrs/frep/FertilizationGuidelines/Adjustments.html#h11
[186] Drury, C.F., X. Yang, W.D. Reynolds, W. Calder, T.O. Oloya, A.L. Woodley. (2017). Combining Urease and Nitrification Inhibitors with Incorporation Reduces Ammonia and Nitrous Oxide Emissions and Increases Corn Yields. Journal of Environmental Quality 46:5, 939-949. https://doi.org/10.2134/jeq2017.03.0106
[187] Mirkhani, R., C. Resch, G. Weltin, L. K. Heng, J. Mitchell, R. Clare Hood-Nowotny, G. Dercon. (2023). Effect of urease inhibitor and biofertilizer on nitrous oxide emission, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-11242, https://doi.org/10.5194/egusphere-egu23-11242
[188] Byrne M.P., J.T. Tobin, P.J. Forrestal, M. Danaher, C.G. Nkwonta, K. Richards, E. Cummins, S.A. Hogan, T.F. O’Callaghan. (2020). Urease and Nitrification Inhibitors—As Mitigation Tools for Greenhouse Gas Emissions in Sustainable Dairy Systems: A Review. Sustainability 12:15, 6018. https://doi.org/10.3390/su12156018
[189] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). Impact of ammonia emissions from agriculture on biodiversity: An evidence synthesis. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

this, Guthrie et al. (2018) merely identified the measures but did not reference or identify any specific regulations.

## Quick mixing and injecting into soil

The identified measure would involve rapid incorporation of fertilizers into soils after the fertilizers have been applied. As previously described, with the implementation of ILRP and WDRs by the Central Valley Water Board growers are required to prepare and management plans. The 4 R's of nitrogen management serve as guiding nitrogen efficiencies principles that growers are recommended to follow when developing their management plans. The identified measure is addressed through two of the four principles. The "Right time" principle refers to timed application of nitrogen to ensure availability to the plant during periods of greatest demand. The measure is also addressed through the "Right place" principle, which considers targeted application of fertilizer in the crop's effective rootzones to facilitate and enhance the uptake of nitrogen by the crop.

As described by Guthrie et al. (2018), ammonia emissions can be reduced by 50-90 percent through this measure, should the fertilizer be mixed in or injected into the soil within 4-6 hours of their application.[190] Though they do not touch on the speed of the process, Eory et al. (2016) likewise identified fertilizer injection as a candidate ammonia emission mitigation measure.[191] However, the publications referenced in Guthrie et al. (2018) and Eory et al. (2016) focus solely on manure application methods and do not provide estimates for commercial fertilizers. [192,193] We cannot assume the mitigation potential of fertilizers to be consistent with that of manure sources. We therefore proceed with caution with the identified measure and will not be considering it at this moment. In addition to this, research from a California-context is profoundly limited,[194] resulting in uncertainty regarding the ammonia reduction potentials under California-specific conditions. Consistent with the previously mentioned fertilizer measures, Guthrie et al. (2018) and Eory et al. (2016) merely identify the measure, and do not reference any specific regulations.

[190] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). Impact of ammonia emissions from agriculture on biodiversity: An evidence synthesis. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html
[191] Eory, V., Rees, B., Topp, K., Dewhurst, R., et al. ClimateXChange, "On-farm technologies for the reduction of greenhouse gas emissions in Scotland," March 2016. Retrieved from: https://www.climatexchange.org.uk/media/1927/on-farm_technology_report.pdf
[192] Loyon, L., C.H. Burton, T. Misselbrook, J. Webb, F.X. Philippe, M. Aguilar, M. Doreau, M. Hassouna, T. Veldkamp, J.Y. Dourmad, A. Bonmati, E. Grimm, S.G. Sommer. (2016). Best available technology for European livestock farms: Availability, effectiveness and uptake. Journal of Environmental Management 166, 1-11. https://doi.org/10.1016/j.jenvman.2015.09.046
[193] Webb, J., B. Pain, S. Bittman, J. Morgan. (2010). he impacts of manure application methods on emissions of ammonia, nitrous oxide and on crop response—A review. Agriculture, Ecosystems & Environment 137:1-2, 39-46. https://doi.org/10.1016/j.agee.2010.01.001
[194] Krauter, C., D. Goorahoo, C. Potter, S. Klooster. (2014). *Ammonia Emissions and Fertilizer Applications in California's Central Valley*. Available at: https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/completedprojects/00-0515Krauter2006.pdf

## Application during optimal weather conditions

Weather conditions (i.e., air temperature, precipitation, and wind speed) have a demonstrated effect on ammonia fluxes.[195] The identified measure would involve rapid incorporation of fertilizers into soils after the fertilizers have been applied. The 4 R's "Right time" principle covers the issue that this measure aims to address. The principle is based on timed nitrogen application in order to ensure the availability of nitrogen to the plant during the more nutrient demanding periods. This period is during vegetative growth in annual crops, and during early fruit and nut development in mature trees and vines.[196]

While describing the fertilizer injection measure, Eory et al. (2016) convey that additional work is needed to determine the emission benefits related to fertilizer application with respect to weather.[197] They however do not provide any additional or specific information regarding a measure or identify the reduction potential of its application. Guthrie et al. (2018) identified weather as affecting ammonia emissions by up to 5 percent and provided the recommendation that growers refrain from using urea-based fertilizers during warm, dry, and windy conditions.[198] After reviewing the two publications referenced in Guthrie et al. (2018) for this measure, Zhang et al. (2017)[199] and Newell et al. (2011)[200], no information regarding concerning weather-related conditions was found. Other publications have demonstrated a link between weather conditions and ammonia emissions, though it is unclear which environmental factors are most appropriate for the various fertilizer types.[201,202] It is particularly important for further research to address the impact of weather and fertilizer application timing under conditions specific to the San Joaquin Valley. Lastly, as has been described previously,

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[195] Li, Q., X. Cui, X. Liu, M. Roelcke, G. Pasda, W. Zerulla, A.H. Wissemeier, X. Chen, K. Goulding, F. Zhang. (2017). A new urease-inhibiting formulation decreases ammonia volatilization and improves maize nitrogen utilization in North China Plain. Scientific Reports 7, 43853. https://doi.org/10.1038/srep43853, https://doi.org/10.1038/srep43853

[196] CDFA. *Irrigation and Nitrogen Management Training for Grower Self-Certification*. Available at: https://www.cdfa.ca.gov/is/ffldrs/frep/pdfs/training/inmtp_workbook.pdf

[197] Eory, V., Rees, B., Topp, K., Dewhurst, R., et al. ClimateXChange, "On-farm technologies for the reduction of greenhouse gas emissions in Scotland," March 2016. Retrieved from: https://www.climatexchange.org.uk/media/1927/on-farm_technology_report.pdf

[198] Guthrie, S., Giles, S., Dunkerley, F., Tabaqchali, H., Harshfield, A., Ioppolo, B., Manville, C. (2018). The Impact of Ammonia Emissions from Agriculture on Biodiversity. *Rand Europe, The Royal Society.* Retrieved from: https://www.rand.org/pubs/research_reports/RR2695.html

[199] Zhang, Y., A.L. Collins, J.I. Jones, P.J. Johnes, A. Inman, J.E. Freer. (2017). The potential benefits of on-farm mitigation scenarios for reducing multiple pollutant loadings in prioritised agri-environment areas across England. Environmental Science & Policy 73, 100-114. https://doi.org/10.1016/j.envsci.2017.04.004

[200] Newell Price, J.P., D. Harris, M. Taylor, J.R. Williams, S.G. Anthony, D. Duethmann, R.D. Gooday, E.I. Lord, B.J. Chambers, D.R. Chadwick, T.H. Misselbrook. "An Inventory of Mitigation Methods and Guide to their Effects on Diffuse Water Pollution, Greenhouse Gas Emissions and Ammonia Emissions from Agriculture," December 2011. Retrieved from: https://repository.rothamsted.ac.uk/download/942687eab7ec4b83751c7e241d62f0fa8472d72adcd25a149bb891b7c30d55d0/1595300/MitigationMethods-UserGuideDecember2011FINAL.pdf

[201] V Venterea, R.T., A.D. Halvorson, N. Kitchen, M.A. Liebig, M.A. Cavigelli, S.J. Del Grosso, P.P. Motavalli, K.A. Nelson, K.A. Spokas, B. Pal Singh, C.E. Stewart, A. Ranaivoson, J. Strock, H. Collins. (2012). Challenges and opportunities for mitigating nitrous oxide emissions from fertilized cropping systems. Frontiers in Ecology and the Environment 10:10, 562-570. https://doi.org/10.1890/120062

[202] Grahmann, K., N. Verhulst, A. Buerkert, I. Ortiz-Monasterio, B. Govaerts. (2013). Nitrogen use efficiency and optimization of nitrogen fertilization in conservation agriculture. Cabi Reviews 8:053. https://doi.org/10.1079/PAVSNNR20138053

Guthrie et al. (2018) and Eory et al. (2016) do not refer to any specific regulations when identifying the measure.

CARB has not identified effective mechanisms within its authority to regulate air emissions of ammonia from livestock, which overwhelmingly come from the decomposition of manure, or from fertilizers, the second largest category of emissions in the Valley. CARB's main source of authority is the California Health and Safety Code. CARB's authority is primarily over mobile sources, consumer products, and air toxics, as well as methane from livestock (see Cal. Health & Saf. Code §§ 43013, 39666, 39730.7, 41712).

Estimated feasible reductions in ammonia from this emissions source in the Valley are zero tons.

**Composting and Other Sources**

The District already regulates ammonia emissions from composting operations through District Rules 4565 and 4566. Based on the mitigation measures in practice at facilities subject to Rule 4565 and 4566, ammonia emissions are already being reduced by 44 percent. With these controls in place, composting accounts for only 3 percent of the District's ammonia emissions; therefore, the District will not be further evaluating this source category at this time.

The other source category consists of ammonia emissions primarily from mobile sources and fuel combustion, which are heavily controlled. Therefore, the District will not be further evaluating this source at this time.
Estimated feasible reductions in ammonia from these emissions sources in the Valley are zero tons.

**Research**

CARB is working to fill knowledge gaps on feasible and effective ammonia controls. Development of effective air pollution mitigation strategies for ammonia requires additional spatiotemporal understanding of atmospheric ammonia emissions that are currently lacking as a result of limited data. CARB is conducting research, both in-house and with external partners, to characterize gaseous ammonia emissions from agricultural activities in the San Joaquin Valley. The results of these studies will help future development of CARB's ammonia emission inventory, SIP, Short-Lived Climate Pollutant Reduction Strategy, and community air protection program (AB 617). Findings from these research projects will help CARB better characterize ammonia emissions in the Valley, as a necessary prerequisite to identifying potential effective measures to achieve additional emissions reductions.

Ammonia emissions in general are not well quantified Statewide and further focused study is needed to facilitate quantification and potential further control strategies that are effective and cost-effective. As an example of the agency's work in this area, CARB's

Research Division has developed a new mobile measurement platform equipped with a state-of-the-science ammonia analyzer and other advanced analytical instruments to improve the understanding of various ammonia sources in California. In September and October 2018, CARB staff collaborated with researchers from the University of California, Davis, to quantify emissions from several dairies in the Valley as part of the ongoing projects funded by the California Department of Food and Agriculture, CARB, and industry. Methane, oxides of nitrogen, and other air pollutants and meteorological parameters were measured at or near dairies in addition to ammonia. The major objective is to evaluate the effectiveness of various alternative manure management practices (AMMP) with respect to emission reductions as CARB staff will revisit these dairies after they implement the selected AMMP technologies. This effort is a direct response to Senate Bill 1383 requirements and goals. The AMMP is designed to identify air pollution sources and estimate their emission rates. Its mobility makes it ideal for field measurements that require large spatial coverage, such as mapping ammonia mixing ratios with an emphasis on determining the magnitude of emissions, characterizing spatial variability of emissions, and identifying dominant sources of emissions.

In addition, CARB is undertaking a suite of projects that address research needs. Many projects focus on emissions from dairies, while others, including those with a satellite or remote sensing component, can offer insight into ammonia emissions in the Valley from all source categories. CARB staff is also working with academic researchers and industry representatives to explore potential opportunities to reduce the emissions of ammonia and other air pollutants from dairy manure lagoons which are one of the largest contributors to ammonia in California. Preliminary experiments have been conducted, and further investigation is underway at some Valley dairies with the support from farmers. Additionally, CARB staff is planning to analyze existing satellite data to refine the spatial resolution and allocation of ammonia in California. This may also help evaluate the impact of major wildfires on surface ammonia levels in recent years, and can be used to compare with the estimation methodology in the current ammonia emission inventory associated with wildfires.

Due to research which indicates California is underestimating ammonia emissions in the air, CARB is reviewing and will reassess ammonia estimates in recognition of this research. This effort will help us update our understanding about modeled sensitivity of PM2.5 formation to changes in ammonia emissions.

### F.3.3 Conclusion

CARB has followed the Guidance to evaluate whether ammonia contributes significantly to PM2.5 levels that exceed the 12 $\mu g/m^3$ annual PM2.5 NAAQS. Considering relevant contextualizing information such as emissions, research, and available controls, along with performing sensitivity-based analysis for the future attainment year, CARB determined that emissions of ammonia do not contribute significantly to PM2.5 levels that exceed the 12 $\mu g/m^3$ annual NAAQS in the area. Therefore, CARB has excluded ammonia from control requirements in the SIP.

While the Guidance recommends modeling emissions reductions of PM2.5 precursors of between 30 and 70 percent to evaluate if precursor emissions reductions have a significant impact on PM2.5 levels, CARB and the District have determined that the 30 percent reduction in ammonia emissions is not achievable. Moreover, CARB and the District have not identified methods within its authority to control air emissions of ammonia that achieve an overall 30 percent reduction in ammonia emissions. In practice, the District has implemented the best available control measures on livestock operations that have already achieved approximately 25 percent reduction from this source. CARB is not aware of controls that would achieve greater reductions on the order needed to achieve an overall 30 percent reduction of ammonia emissions in the Valley; nevertheless, CARB is pursuing further research specific to California and the Valley to improve our understanding of ammonia emissions from various sources as a necessary prerequisite to identifying potential effective measures to achieve additional emissions reductions.

The District and CARB analyzed potential control measures to reduce ammonia emissions from key source categories in order to evaluate whether a 30 percent reduction in emissions is feasible. Specific to the confined animal facility category, the District conducted a new, extensive evaluation of potential measures to control sources of ammonia emissions. EPA provided the list of measures to CARB and the District and requested that the measures and studies referenced be addressed specifically for the Valley. In this evaluation, the District has identified only a few measures that have the theoretical potential to reduce additional ammonia emissions beyond the practices currently enforced through District Rule 4570. These measures are reducing crude protein content in feed for beef finishing cattle, incorporation of solid manure within 24 hours, and acidifying amendments for poultry litter and manure. Despite the technological and economic feasibility issues of these mitigation measures, the District evaluated the potential emission reductions and the impact they might have on the Valley's total ammonia emissions inventory if these measures were to be implemented. Overall, ammonia emissions in the Valley can only be reduced from the confined animal facilities source category by 2 percent by implementing these mitigation measures. For the fertilizer category, CARB has not identified effective mechanisms within its authority to regulate air emissions of ammonia from livestock, which overwhelmingly come from the decomposition of manure, or from fertilizers. Furthermore, CARB and the District are unaware of any other jurisdictions with rules for the source. In addition, CARB and the District did not identify feasible control measures for composting or other emissions sources.

Based on the extensive evaluation which identified feasible reductions of only approximately 2 percent, as summarized below in Table F-15, CARB and the District conclude that a 30 percent reduction in ammonia emissions is not achievable.

**Table F-15 Estimated Feasible Emission Reductions**

| Emissions Category | Emissions (tpd, 2030) | Identified Controls | Feasible Ammonia Reductions |
|---|---|---|---|
| Confined Animal Feeding | 167.2 | • Reducing crude protein content in feed for beef finishing cattle<br>• Incorporation of solid manure within 24 hours<br>• Acidifying amendments for poultry litter and manure | 6.5 tpd |
| Fertilizers | 109.9 | No authority or feasible controls identified | 0 |
| Composting | 9.3 | No feasible controls identified | 0 |
| Other sources | 20.2 | No feasible controls identified | 0 |
| Total Ammonia | 306.5 | | 6.5 tpd |

Numbers may not add up due to rounding.

A 2 percent reduction is consistent with the national trend identified in U.S. EPA guidance which stated that ammonia changes ranged nationally from an increase of six percent to a decrease of nine percent.[203] Moving forward, updated national guidance on ammonia emission reductions achievable in practice is needed, as well as guidance on available and feasible control measures.

[203] EPA. *PM2.5 Precursor Demonstration Guidance*. May 2019. https://www.epa.gov/sites/production/files/2019-05/documents/transmittal_memo_and_pm25_precursor_demo_guidance_5_30_19.pdf

## F.4 SULFUR DIOXIDE ANALYSIS

Ammonium sulfate ([NH4]2SO4) is a constituent of PM2.5, making up about 12 percent of fine particulate matter mass in the Valley in 2017. Sulfur oxides (SOx) emitted from stationary and mobile combustion sources, mostly as sulfur dioxide (SO2), are oxidized in the atmosphere to ultimately form sulfuric acid (H2SO4). Sulfuric acid then combines with ammonia to form ammonium sulfate. Since SOx reacts chemically in this way to form a particle, SOx is a precursor to PM2.5.

Following the analytical process outlined in the Guidance and summarized above, CARB has evaluated SOx in the Valley. The results of the sensitivity-based analysis and consideration of additional information are presented below.

### F.4.1 Sensitivity-Based Analysis

CARB staff used an air quality model to estimate the PM2.5 design value for the annual standard in the base year of 2017 at each Valley monitor. Then, CARB staff applied the recommended lower bound of a 30 percent reduction to SOx emissions and used the air quality model to estimate the PM2.5 design values, as shown in Table F-16. The difference between the two design values represents the modeled impact on PM2.5 levels of a 30 percent reduction in SOx emissions in 2017. This is the value that is compared to U.S. EPA's recommended contribution threshold of 0.2 $\mu g/m^3$ for the 12 $\mu g/m^3$ annual standard to establish if PM2.5 levels are sensitive to this level of SOx reduction.

**Table F-16 Base Year 2017 PM2.5 – 30 Percent SOx Reduction**

| Site | 2017 Baseline DV | 2017 DV with 30% SOx Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 16.97 | 16.94 | 0.03 |
| Hanford | 15.73 | 15.91 | -0.18 |
| Bakersfield-Golden | 15.52 | 15.51 | 0.01 |
| Visalia | 15.43 | 15.39 | 0.04 |
| Bakersfield-California | 15.12 | 15.11 | 0.01 |
| Corcoran | 14.95 | 15.10 | -0.15 |
| Fresno-Hamilton | 13.99 | 13.99 | 0 |
| Fresno-Garland | 13.69 | 13.72 | -0.03 |
| Turlock | 12.7 | 12.88 | -0.18 |
| Clovis | 12.69 | 12.88 | -0.19 |
| Merced-SCoffee | 12.28 | 12.50 | -0.22 |
| Stockton | 12.21 | 12.48 | -0.27 |
| Madera | 12.11 | 12.30 | -0.19 |
| Merced-MStreet | 11.73 | 11.75 | -0.02 |
| Modesto | 11.16 | 11.39 | -0.23 |
| Manteca | 10.37 | 10.60 | -0.23 |
| Tranquility | 8.19 | 8.33 | -0.14 |

For completeness, CARB staff repeated this analysis, applying instead the recommended upper bound of a 70 percent reduction to the SOx emissions in the base year, as shown in Table F-17.

**Table F-17 Base Year 2017 PM2.5 – 70 Percent SOx Reduction**

| Site | 2017 Baseline DV | 2017 DV with 70% SOx Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 16.97 | 16.92 | 0.05 |
| Hanford | 15.73 | 15.90 | -0.17 |
| Bakersfield-Golden | 15.52 | 15.49 | 0.03 |
| Visalia | 15.43 | 15.32 | 0.11 |
| Bakersfield-California | 15.12 | 15.10 | 0.02 |
| Corcoran | 14.95 | 15.12 | -0.17 |
| Fresno-Hamilton | 13.99 | 13.93 | 0.06 |
| Fresno-Garland | 13.69 | 13.66 | 0.03 |
| Turlock | 12.7 | 12.87 | -0.17 |
| Clovis | 12.69 | 12.97 | -0.28 |
| Merced-SCoffee | 12.28 | 12.49 | -0.21 |
| Stockton | 12.21 | 12.46 | -0.25 |
| Madera | 12.11 | 12.31 | -0.20 |
| Merced-MStreet | 11.73 | 11.72 | 0.01 |
| Modesto | 11.16 | 11.37 | -0.21 |
| Manteca | 10.37 | 10.58 | -0.21 |
| Tranquility | 8.19 | 8.35 | -0.16 |

From this analysis, the estimated air quality impact of reducing SOx emissions in the base year by the lower bound of 30 percent is well under U.S. EPA's recommended threshold at all Valley monitors. In fact, in some cases, the estimated air quality impact is negative, implying that a reduction in SOx emissions would in fact increase PM2.5 levels at certain sites. Reducing emissions by the upper bound of 70 percent also shows impacts below the recommended threshold at all Valley sites.

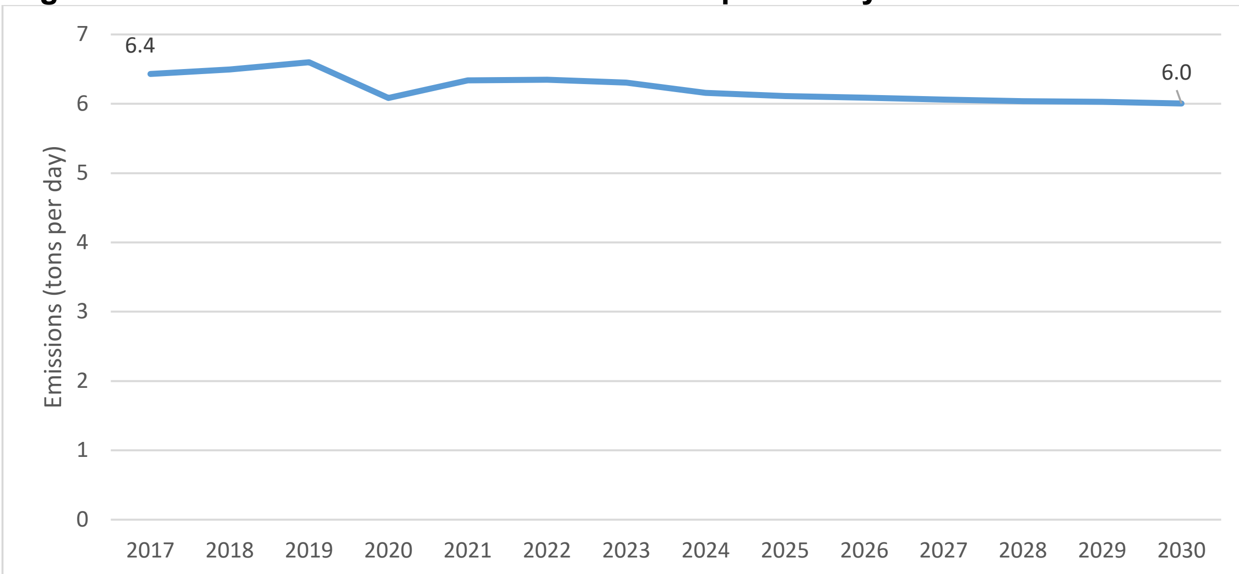
### F.4.2 Consideration of Additional Information

To supplement modeling analysis, the Guidance also allows an air agency to consider additional information. Accordingly, CARB evaluated the trend of SOx emissions in the Valley to support the sensitivity-based analysis.

#### F.4.2.1 Emissions Trend

CARB's SOx inventory indicates that emissions remain roughly constant between 2017 and 2030, dropping 0.4 tpd or 6.7 percent, as shown in Figure F-8. Ammonia emissions also remain flat over the same time frame, as shown above in Figure F-1. Thus, conditions for ammonium sulfate formation are similar in the base and future years, with relative levels of ammonia and SOx remaining the same.

**Figure F-8 SOx emission trend in the San Joaquin Valley between 2017 and 2030**




Source: CEPAM 2022 v 1.00

### F.4.2.2 Future Year Modeling

Analysis of SOx and ammonia emissions trends, discussed above, indicates that the sensitivity-based analysis performed for 2017 in Table F-16 and Table F-17 above is representative into the future with the Valley's emissions conditions remaining similar to the base year.

For completeness, however, CARB staff repeated the sensitivity-based analysis of SOx for the future attainment year of 2030 in accordance with the Guidance. Staff used an air quality model to estimate the PM2.5 design value for the annual standard in 2030 at each Valley monitor. Then, CARB staff applied a 30 percent reduction to SOx emissions and used the air quality model to estimate the PM2.5 design values in 2030, shown in Table F-18. The difference between the two design values represents the modeled impact on PM2.5 levels of a 30 percent reduction in ammonia emissions in the attainment year. The future-year modeling includes emission reductions from measures in the CARB-adopted 2022 State SIP Strategy.

**Table F-18 Future Year 2030 PM2.5 – 30 Percent SOx Reduction**

| Site | 2030 Baseline DV | 2030 DV with 30% SOx Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 14.05 | 13.99 | 0.06 |
| Hanford | 11.17 | 11.11 | 0.06 |
| Bakersfield-Golden | 12.48 | 12.42 | 0.06 |
| Visalia | 12.41 | 12.32 | 0.09 |
| Bakersfield-California | 12.39 | 12.33 | 0.06 |
| Corcoran | 10.71 | 10.68 | 0.03 |
| Fresno-Hamilton | 11.77 | 11.7 | 0.07 |
| Fresno-Garland | 11.55 | 11.49 | 0.06 |
| Turlock | 10.33 | 10.3 | 0.03 |
| Clovis | 9.91 | 9.88 | 0.03 |
| Merced-SCoffee | 9.61 | 9.59 | 0.02 |
| Stockton | 10.7 | 10.68 | 0.02 |
| Madera | 9.17 | 9.14 | 0.03 |
| Merced-MStreet | 9.96 | 9.92 | 0.04 |
| Modesto | 9.3 | 9.27 | 0.03 |
| Manteca | 8.85 | 8.82 | 0.03 |
| Tranquility | 6.37 | 6.37 | 0 |

For completeness, CARB staff repeated this analysis, applying instead the recommended upper bound of a 70 percent reduction to the SOx emissions in 2030, as shown in Table F-19.

**Table F-19 Future Year 2030 PM2.5 – 70 Percent SOx Reduction**

| Site | 2030 Baseline DV | 2030 DV with 70% SOx Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 14.05 | 13.94 | 0.11 |
| Hanford | 11.17 | 11.05 | 0.12 |
| Bakersfield-Golden | 12.48 | 12.38 | 0.10 |
| Visalia | 12.41 | 12.23 | 0.18 |
| Bakersfield-California | 12.39 | 12.28 | 0.11 |
| Corcoran | 10.71 | 10.66 | 0.05 |
| Fresno-Hamilton | 11.77 | 11.62 | 0.15 |
| Fresno-Garland | 11.55 | 11.42 | 0.13 |
| Turlock | 10.33 | 10.27 | 0.06 |
| Clovis | 9.91 | 9.88 | 0.03 |
| Merced-SCoffee | 9.61 | 9.56 | 0.05 |
| Stockton | 10.7 | 10.66 | 0.04 |
| Madera | 9.17 | 9.11 | 0.06 |
| Merced-MStreet | 9.96 | 9.88 | 0.08 |
| Modesto | 9.3 | 9.24 | 0.06 |
| Manteca | 8.85 | 8.79 | 0.06 |
| Tranquility | 6.37 | 6.38 | -0.01 |

From this analysis, the estimated air quality impact of reducing SOx emissions by 30 percent and by 70 percent in 2030 continues to fall under U.S. EPA's recommended threshold of 0.2 µg/$m^3$ for the 12 µg/$m^3$ annual PM2.5 standard at all sites.

### F.4.3 Conclusion

CARB has followed the Guidance to evaluate whether SOx contributes significantly to PM2.5 levels that exceed the NAAQS. Using sensitivity-based analysis in the base year and future year, CARB determined that emissions of SOx do not contribute significantly to PM2.5 levels that exceed the 2012 NAAQS in the area. Therefore, CARB has excluded SOx from control requirements in the SIP.

## F.5 REACTIVE ORGANIC GAS ANALYSIS

Following the analytical process outlined in the Guidance and summarized above, CARB has evaluated Reactive Organic Gas (ROG) in the San Joaquin Valley. The results of the sensitivity-based analysis and consideration of additional information are presented below.

### F.5.1 Sensitivity-Based Analysis

CARB staff used an air quality model to estimate the PM2.5 design value for the annual standard in the base year of 2017 at each Valley monitor. Then, CARB staff applied the recommended lower bound of a 30 percent reduction to ROG emissions and used the air quality model to estimate the PM2.5 design values, as shown in Table F-20. The difference between the two design values represents the modeled impact on PM2.5 levels of a 30 percent reduction in ROG emissions in 2017. This is the value that is compared to U.S. EPA's recommended contribution threshold of 0.2 $\mu g/m^3$ for the 12 $\mu g/m^3$ annual standard to establish if PM2.5 levels are sensitive to this level of ROG reduction.

**Table F-20 Base Year 2017 PM2.5 – 30 Percent ROG Reduction**

| Site | 2017 Baseline DV | 2017 DV with 30% ROG Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 16.97 | 16.89 | 0.08 |
| Hanford | 15.73 | 15.89 | -0.16 |
| Bakersfield-Golden | 15.52 | 15.49 | 0.03 |
| Visalia | 15.43 | 15.35 | 0.08 |
| Bakersfield-California | 15.12 | 15.08 | 0.04 |
| Corcoran | 14.95 | 15.09 | -0.14 |
| Fresno-Hamilton | 13.99 | 13.94 | 0.05 |
| Fresno-Garland | 13.69 | 13.68 | 0.01 |
| Turlock | 12.7 | 12.82 | -0.12 |
| Clovis | 12.69 | 12.8 | -0.11 |
| Merced-SCoffee | 12.28 | 12.46 | -0.18 |
| Stockton | 12.21 | 12.44 | -0.23 |
| Madera | 12.11 | 12.24 | -0.13 |
| Merced-MStreet | 11.73 | 11.72 | 0.01 |
| Modesto | 11.16 | 11.35 | -0.19 |
| Manteca | 10.37 | 10.56 | -0.19 |
| Tranquility | 8.19 | 8.3 | -0.11 |

For completeness, CARB staff repeated this analysis, applying instead the U.S. EPA-recommended upper bound of a 70 percent reduction to ROG emissions in the base year, as shown in Table F-21.

**Table F-21 Base Year 2017 PM2.5 – 70 Percent ROG Reduction**

| Site | 2017 Baseline DV | 2017 DV with 70% ROG Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 16.97 | 16.74 | 0.23 |
| Hanford | 15.73 | 15.82 | -0.09 |
| Bakersfield-Golden | 15.52 | 15.38 | 0.14 |
| Visalia | 15.43 | 15.19 | 0.24 |
| Bakersfield-California | 15.12 | 14.97 | 0.15 |
| Corcoran | 14.95 | 15.04 | -0.09 |
| Fresno-Hamilton | 13.99 | 13.8 | 0.19 |
| Fresno-Garland | 13.69 | 13.55 | 0.14 |
| Turlock | 12.7 | 12.71 | -0.01 |
| Clovis | 12.69 | 12.7 | -0.01 |
| Merced-SCoffee | 12.28 | 12.39 | -0.11 |
| Stockton | 12.21 | 12.34 | -0.13 |
| Madera | 12.11 | 12.14 | -0.03 |
| Merced-MStreet | 11.73 | 11.64 | 0.09 |
| Modesto | 11.16 | 11.25 | -0.09 |
| Manteca | 10.37 | 10.47 | -0.10 |
| Tranquility | 8.19 | 8.29 | -0.10 |

From this analysis, the estimated air quality impact of reducing ROG emissions in the base year by the lower bound of 30 percent is below U.S. EPA's recommended annual threshold of 0.2 μg/m$^3$ at all sites. Reducing emissions by the upper bound of 70 percent shows impacts above the threshold at two of the sites.

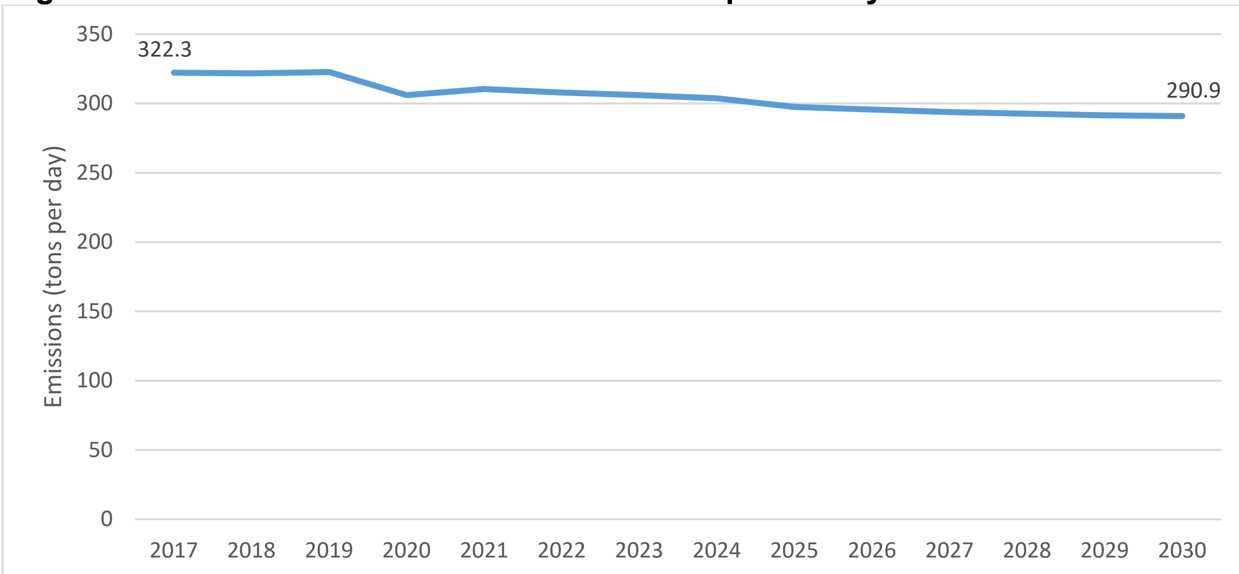
### F.5.2 Consideration of Additional Information

To supplement modeling analysis, the Guidance also allows an air agency to consider additional information. Accordingly, CARB evaluated the trend of ROG emissions in the Valley to support the sensitivity-based analysis and conducted future year sensitivity modeling.

#### F.5.2.1 Emissions Trend

CARB has an extensive suite of measures in place to reduce ROG emissions, particularly in the area of regulating consumer products. In addition, the District has numerous rules that provide ROG emissions reductions in the Valley. CARB's ROG inventory indicates that these existing controls reduce emissions by 18.4 tpd, or 5.7 percent, between 2017 and 2030, as shown in Figure F-9. Considering the change and that CARB's 2022 State SIP Strategy provides additional ROG reductions beyond the base year, it is important to evaluate the role ROG plays in PM2.5 formation and whether it may differ in the base and future years, as the sensitivity-based analysis performed for 2017 may not be representative into the future.

**Figure F-9 ROG emission trend in the San Joaquin Valley between 2017 and 2030**




Source: CEPAM 2022 v.1.00

### F.5.2.2 Future Year Modeling

Analysis of ROG emission trends, discussed above, indicates that the sensitivity-based analysis performed for 2017 in Table 20 and Table 21 above is representative into the future with the Valley's emissions conditions remaining similar to the base year.
For completeness, however, CARB staff repeated the sensitivity-based analysis of ROG for the future attainment year of 2030 in accordance with the Guidance. Staff used an air quality model to estimate the PM2.5 design value for the annual standard in 2030 at each Valley monitor. Then, CARB staff applied a 30 percent reduction to ROG emissions and used the air quality model to estimate the PM2.5 design values in 2030, shown in Table F-22. The difference between the two design values represents the modeled impact on PM2.5 levels of a 30 percent reduction in ROG emissions in the attainment year. The future-year modeling includes NOx and PM2.5 emission reductions from measures in the CARB-adopted 2022 State SIP Strategy.

**Table F-22 Future Year 2030 PM2.5 – 30 Percent ROG Reduction**

| Site | 2030 Baseline DV | 2030 DV with 30% ROG Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 14.05 | 14.01 | 0.04 |
| Hanford | 11.17 | 11.19 | -0.02 |
| Bakersfield-Golden | 12.48 | 12.45 | 0.03 |
| Visalia | 12.41 | 12.38 | 0.03 |
| Bakersfield-California | 12.39 | 12.36 | 0.03 |
| Corcoran | 10.71 | 10.73 | -0.02 |
| Fresno-Hamilton | 11.77 | 11.71 | 0.06 |
| Fresno-Garland | 11.55 | 11.50 | 0.05 |
| Turlock | 10.33 | 10.32 | 0.01 |

| Site | 2030 Baseline DV | 2030 DV with 30% ROG Reduction | Difference |
|---|---|---|---|
| Clovis | 9.91 | 9.89 | 0.02 |
| Merced-SCoffee | 9.61 | 9.61 | 0 |
| Stockton | 10.7 | 10.69 | 0.01 |
| Madera | 9.17 | 9.16 | 0.01 |
| Merced-MStreet | 9.96 | 9.94 | 0.02 |
| Modesto | 9.3 | 9.28 | 0.02 |
| Manteca | 8.85 | 8.83 | 0.02 |
| Tranquility | 6.37 | 6.38 | -0.01 |

For completeness, CARB staff repeated this analysis, applying instead the recommended upper bound of a 70 percent reduction to ROG emissions in 2030, as shown in Table F-23.

**Table F-23 Future Year 2030 PM2.5 – 70 Percent ROG Reduction**

| Site | 2030 Baseline DV | 2030 DV with 70% ROG Reduction | Difference |
|---|---|---|---|
| Bakersfield-Planz | 14.05 | 13.96 | 0.09 |
| Hanford | 11.17 | 11.23 | -0.06 |
| Bakersfield-Golden | 12.48 | 12.42 | 0.06 |
| Visalia | 12.41 | 12.34 | 0.07 |
| Bakersfield-California | 12.39 | 12.32 | 0.07 |
| Corcoran | 10.71 | 10.77 | -0.06 |
| Fresno-Hamilton | 11.77 | 11.63 | 0.14 |
| Fresno-Garland | 11.55 | 11.44 | 0.11 |
| Turlock | 10.33 | 10.3 | 0.03 |
| Clovis | 9.91 | 9.88 | 0.03 |
| Merced-SCoffee | 9.61 | 9.62 | -0.01 |
| Stockton | 10.7 | 10.67 | 0.03 |
| Madera | 9.17 | 9.15 | 0.02 |
| Merced-MStreet | 9.96 | 9.9 | 0.06 |
| Modesto | 9.3 | 9.26 | 0.04 |
| Manteca | 8.85 | 8.81 | 0.04 |
| Tranquility | 6.37 | 6.38 | -0.01 |

From this analysis, in 2030, the modeled air quality impact of reducing ROG emissions by 30 percent and 70 percent falls under U.S. EPA's recommended threshold at all sites.

### F.5.3 Conclusion

CARB has followed the Guidance to evaluate whether ROG contributes significantly to PM2.5 levels that exceed the 12 µg/m$^3$ annual NAAQS. Using sensitivity-based analysis in the base and future years, CARB determined that emissions of ROG do not contribute significantly to PM2.5 levels that exceed the 2012 NAAQS in the area. Therefore, CARB has excluded ROG from control requirements in the SIP.