Final Report

Modeling Air Quality Impact Potential of a Nearby Concentrated Animal Feeding Operation for Minidoka National Historic Site

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for
National Park Service

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ABSTRACT

The Minidoka National Historic site (MHS), located in Jerome County, Idaho, has been established to preserve a Japanese internment camp from World War II. However, this site is located within an area that includes several Confined Animal Facility Operations (CAFOs), and is within several km of a new proposed CAFO that is designed to house 8000 to 13000 cows. As a result there is significant concern about the potential impacts at the historic site related to odor, respiratory health, and visibility associated with CAFO emissions. Agricultural livestock operations have been identified as an important source of ammonia (NH_3), methane (CH_4), nitrous oxide (N_2O), volatile organic compounds (VOCs), and particulate matter as well various odorous compounds. To help address the potential environmental impacts of the proposed CAFO, dispersion modeling calculations have been conducted using the US EPA CALPUFF dispersion model. The focus of this work is on NH_3 concentration levels during winter and summer conditions. Estimates for hydrogen sulfide and PM10 concentrations have also been included. The analyses presented here show that simulated concentrations due to CAFO emissions exhibit a very intermittent pattern at MHS due to changes in wind direction during both winter and summer conditions. The plume from the proposed CAFO produced NH_3 concentrations above typical background levels approximately 35% of the time. Peak hourly values were between 0.5 and 1.0 ppm, while mean concentrations were less than 30 ppb. H_2S concentrations were estimated to be much less due to lower estimated emission rates, although peak levels were estimated to be above the odor detection threshold. Peak hourly PM_{10} concentrations were estimated to be in the range of 60 to 78 $\mu g/m^3$ which is less than the 24-hr average air quality standard for PM_{10} of 150 $\mu g/m^3$. The uncertainties in the NH_3 levels and those predicted for H_2S and PM_{10} are quite large due to the large uncertainty in current knowledge about pollutant emissions from CAFOs.

INTRODUCTION

The Minidoka National Historic site (MHS), located in Jerome County, Idaho, has been established to preserve a Japanese internment camp from World War II. However, this site is located within an area that includes several confined animal facility operations (CAFOs), and is within several km of a new proposed CAFO that is designed to house 8000 to 13000 cows. As a result there is significant concern about the potential impacts at the historic site related to odor, respiratory health, and visibility associated with CAFO emissions. Agricultural livestock operations have been identified as an important source of ammonia (NH_3), methane (CH_4), nitrous oxide (N_2O), volatile organic compounds (VOCs), and particulate matter (PM) as well various odorous compounds.

In this report, atmospheric chemical concentration is expressed as mixing ratio of parts-per-million-by-volume, ppmv or ppm, and parts-per-billion-by-volume, ppbv or ppb. One (1.0) ppm equals 1000 ppb.

Ammonia (NH_3) gas is an odorous compound that is also a precursor to the formation of NH_4^+ aerosol in the atmosphere. The NH_3 global atmospheric concentration is less than 1 ppbv, but local, short-term concentrations can be much higher in the vicinity of NH3 sources. Ammonia has an odor detection threshold of approximately 5 ppm. Auvermann has reviewed odor and other health impacts associated with NH_3 and H_2S.

Odors associated with CAFO's are known to be due to a complex array of organic compounds in addition to NH_3 and H_2S. The odor threshold for H_2S is 2 ppb. Auvermann (2001) has reviewed odor and other health impacts associated with NH_3 and H_2S. H_2S occurs at very low levels in the atmosphere except in the vicinity of local sources. In a review of the impact of CAFO's, an Iowa study group (Iowa State University, 2002) summarized findings by recommending that:

- H_2S, measured at the CAFO property line, should not exceed 70 parts per billion (ppb) for a 1-hour average period (Iowa State University, 2002),
- H_2S, measured at a residence or public use area should not exceed 15 ppb, measured in the same manner as the property line,

- NH_3, measured at the CAFO property line, should not exceed 500 ppb for a 1-hour period,
- NH_3, measured at a residence or public use area, should not exceed 150 ppb, measured in the same manner as the property line measurement.

However, there is no national standard for these gases and regulatory requirements are mostly missing among agricultural states.

Ammonia from animal waste is a result of microbiological breakdown of urea and principal sources include the locations, and associated processes, for animal housing, waste storage/treatment, land application of the waste and pasture use. Figure 1 illustrates pathways for animal waste ammonia emission to the atmosphere.

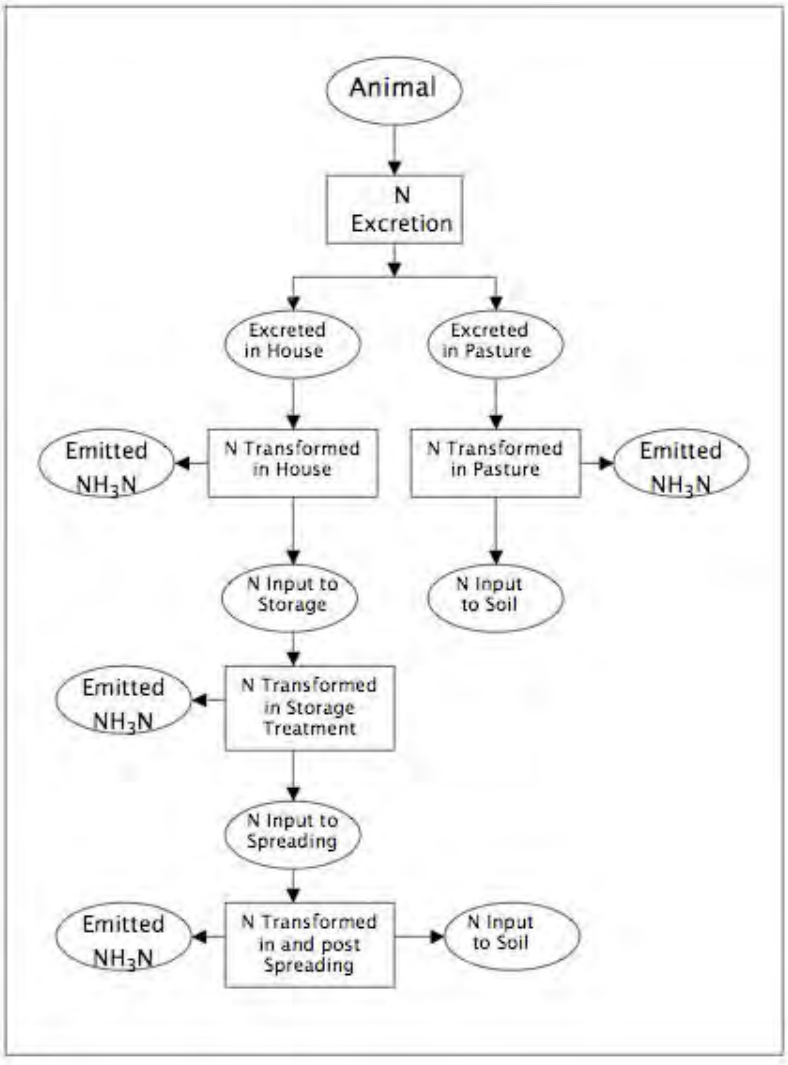

Figure 1. Pathways for animal waste ammonia emission.

In Jerome County, located in south central Idaho, an agricultural group has proposed to build a 'springer' feedlot for raising dairy cattle; a springer is a cow which is about to give birth. The proposed CAFO will occupy a 1200 Ha site with livestock pen areas of 65 Ha (161 acres). Newborn heifers will be brought to the location at 1-2 days of age and will remain on the facility until they are bred and returned to area dairies as 1200-1250 lb springer heifers. The characteristic of animals raised in the CAFO is expected to be as shown in Table 1.

Table 1. Characteristics of animals in the proposed CAFO (distribution by animal weight).

ANIMAL	**Head**	**Lbs**	**Kg**
Bottle Fed calves	1070	105	47.6
Started Heifers	1615	185	83.9
Open Heifer	6071	520	235.9
Bred Heifers	4432	1000	453.6
TOTAL	**13188**		

The CAFO is located ~3 km (~2 miles) from the Minidoka Internment National Monument and approximately ~15 km (~9 miles) from the city of Jerome as shown in Figure 2.

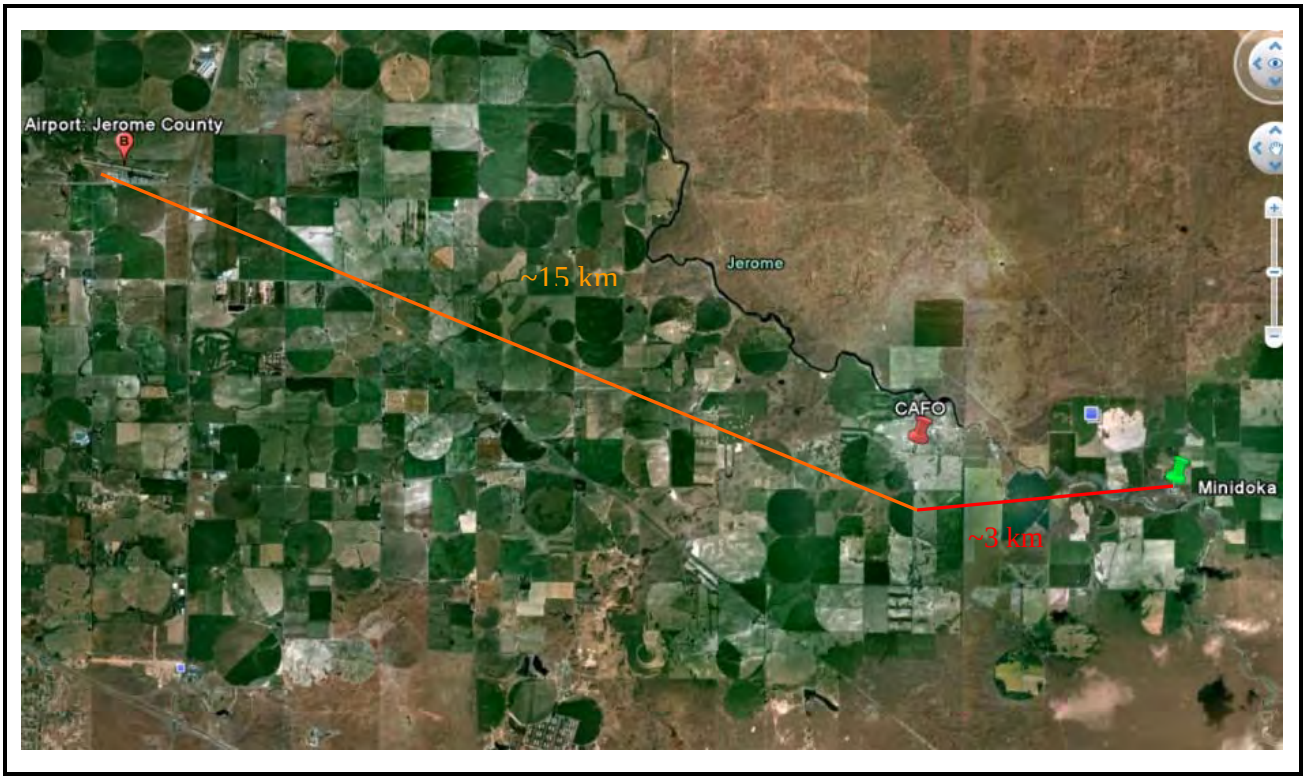

Figure 2. Proposed CAFO relative to the Minidoka National Historic site and to vicinity of Jerome, ID.

To investigate the impact of the proposed CAFO upon the Minidoka area, the CALPUFF dispersion model was selected to estimate ammonia and other pollutant concentrations associated with the CAFO. CALPUFF is an EPA regulatory model that consists of several components: 1) the CALMET meteorological modeling package with diagnostic wind field generation and boundary layer model, 2) Gaussian puff dispersion model and 3) Post-processing programs for analysis of meteorological results, concentration patterns, and deposition fluxes.

The CALPUFF modeling system has been adopted by EPA as a preferred model for assessment of long range transport of pollutants. The model is a non-steady state Lagrangian puff dispersion model that treats multiple species in a detailed 3-d gridded modeling domain. It is able to simulate the effects of time-and space-varying meteorological conditions on pollutant transport, conversion, and removal associated with time-varying pollutant emissions. This software utilizes observed hourly weather data, meteorological and topographic information, land use, and other data, over time periods extending from an hour to as long as a year. Although the situation in this work

does not involve long-range transport, CALPUFF is well suited for use in the short term and our group has considerable experience in using the model.

GOAL and OBJECTIVES

The purpose of this study is to estimate pollutant ambient concentrations downwind of a proposed CAFO in southern Idaho as a basis for assessment of the impact of the CAFO on a nearby National Historic site. Specific objectives include simulation of NH_3, H_2S, and PM_{10} concentrations for selected winter and summer conditions and analysis of these results to estimate the level of impact associated with the CAFO.

METHODOLOGY

The study area encompasses the proposed CAFO location and extends to the west beyond the Jerome airport and to the east beyond the National Historic site. The source and receptor locations were each geo-referenced; then a computational grid was defined and the coordinate of the south-west (lower left) corner (grid-origin) was fixed, as showed in Table 2. Limited meteorological information was available from the Jerome airport, so for this initial step, surface and upper air meteorological data from the Boise airport was obtained in a format suitable for use in CALPUFF. These meteorological data files, based upon observations from 1990 at the Boise airport, were used as input to the CALMET wind processing code which was run to produce 3-d wind fields and boundary layer parameters for the months of January and July, taken to represent winter and summer conditions.

Table 2. Study area coordinates (Idaho).

Place	**Coordinates** (UTM)		**Elevation** (m)
	X (km)	**Y** (km)	
Minidoka Historic site	725.3	4728.26	1204.9
CAFO –Livestock	722.26	4728.00	1198.9
Jerome Airport	708.1	4733.92	1140
Grid Origin	703.98	4710.74	

UTM: Universal Transverse Mercator coordinate system; UTM Zone 11.

The modeling domain was defined to cover 50 km by 50 km with 1 km x 1 km grids cells and with 10 vertical layers extending to 3000 m. The vertical model levels were fixed at 0.0, 20, 30, 60, 120, 300, 500, 1000, 1500, 2000 and 3000 meters.

Topographic and land use digital data were also obtained for the modeling area and processed to match the gridded modeling domain using the CALPUFF processing tools.

The air pollutants selected for modeling was NH_3, H_2S, and PM_{10}. Dry deposition was calculated, but for this initial study, wet deposition was not included due to a lack of readily available precipitation data. Ammonia is the principal pollutant emission from CAFO operation, and its principal source is located in the livestock pen area where the animals are housed. Therefore, the livestock pens were identified as an "area source" within CALPUFF. Figure 3 shows the livestock pens relative to the Minidoka Historic site.

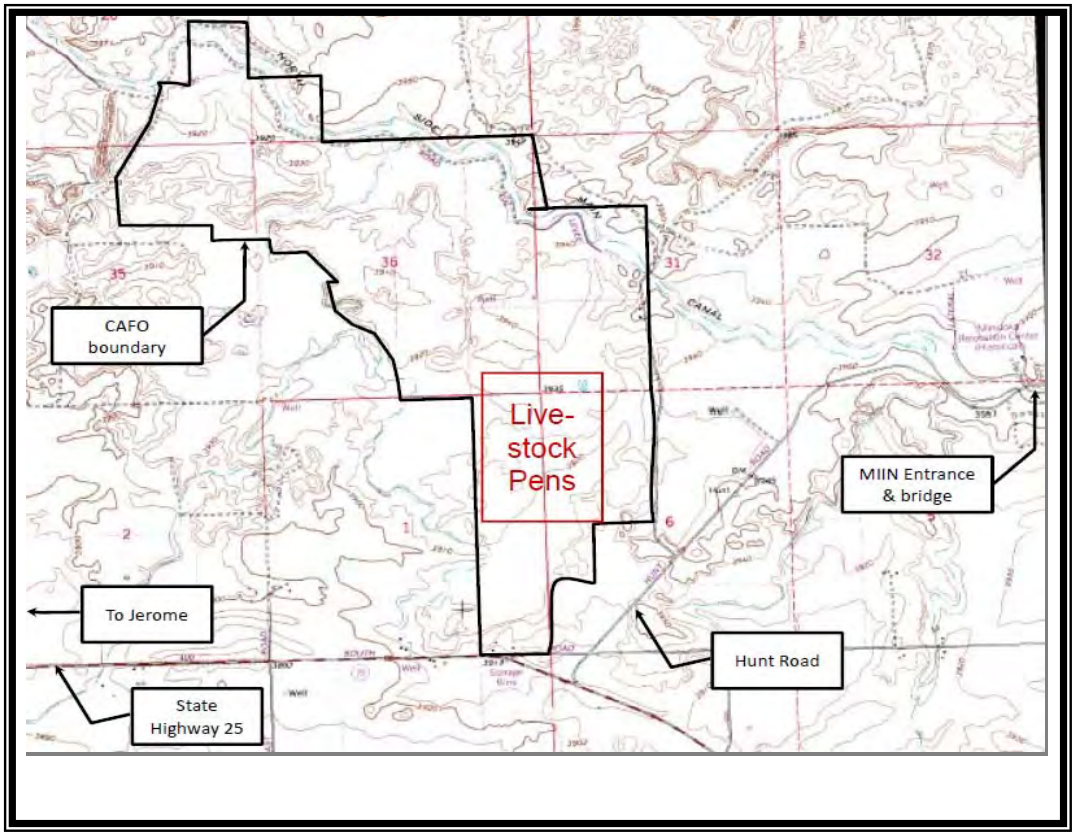

Figure 3. Livestock pens location within the proposed CAFO.

Defining an emission rate to use for NH_3 from a CAFO is highly uncertain. We examined a number of sources of information and found NH3 emissions ranging from approximately 5 kg/head/yr to more than 300 kg/head/yr, but this included estimates for dairies and beef feedlots. At these rates, the area source emissions rate (for 10400 head in 65 ha) ranges from approximately 3 $\mu g/m^2/s$ to 150 $\mu g/m^2/s$. Baum and Ham (2009) recently developed a unique relaxed eddy accumulation method for directly measuring NH_3 emissions from feedlots and reported emission fluxes from their measurements and other recent studies (Todd et al., 2008; Flesch et al., 2007) ranging from 36 to 360 $\mu g/m^2/s$ for mid-western beef feedlots during spring, summer and fall conditions. At WSU, we have made similar measurements at a beef feedlot during spring conditions and found an average flux of 142±87 $\mu g/m^2/s$ over a period of approximately two weeks. Feedlot operators have recently been required to report estimated emissions to EPA. The feedlot operators association developed a worksheet for this purpose where the recommended emission rates ranged from 0.16 to 0.48 lb/head/day. For the proposed CAFO, this converts to approximately 15 to 43 $\mu g/m^2/s$. Because of this wide range of estimates and the lack of any direct measurements for a springer operation similar to the proposed CAFO, we have used an approximate emission rate of 100 $\mu g/m^2/s$ as a starting place for the CALPUFF simulations. It should be emphasized that any change in this estimated emission rate would cause a linear, corresponding change in predicted concentrations.

For H_2S, there is even less information available for estimating emissions. Auvermann reported in a presentation on feedlot emissions that measured H_2S emissions from a feedlot that were highly variable, but averaged approximately 2 $\mu g/m^2/s$. We have taken this value as a starting place for estimating H_2S concentrations. For PM_{10}, there is also a lack of information. The California Air Resources Board settled on an estimate of 29 lb/1000 head/day which converts to 12 $\mu g/m^2/s$. An important missing factor is that PM_{10} emissions from a feedlot are highly dependent upon livestock activity levels. Generally, emissions tend to be higher in the evenings when the cattle are more active. We neglect these daily changes and assume a constant emission rate for all conditions.

RESULTS

Model results covering January and July are shown in Figure 4 in terms of ambient NH_3 levels predicted at the Minidoka Historical site.

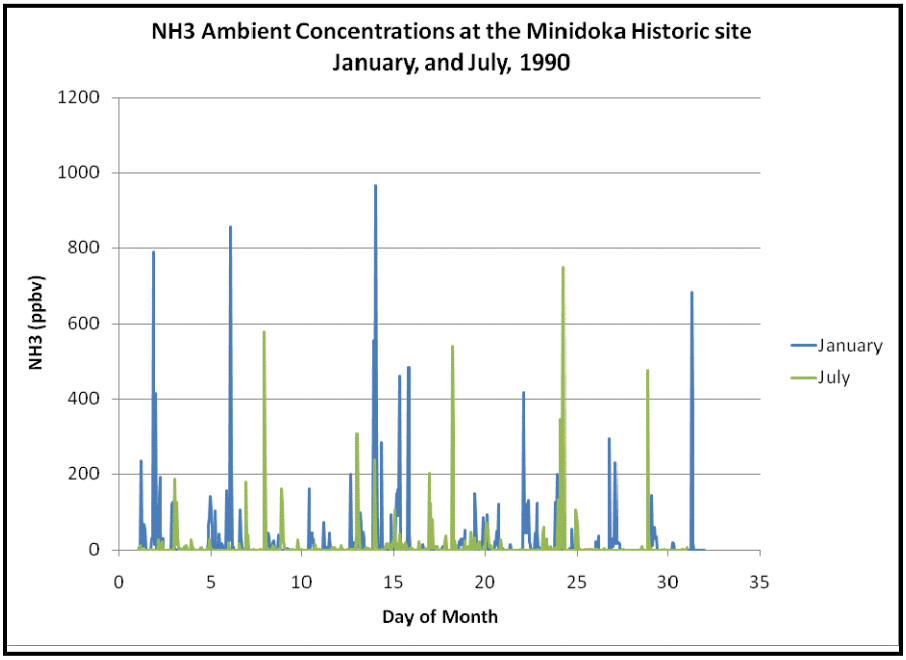

Figure 4. Ammonia mixing ratio during January and July estimated with the CALPUFF model at the Minidoka Historic Site

The modeling results (Table 3) show that the CAFO intermittently impacts the MHS, and these intermittent impacts can produce concentrations reaching as high as 750 ppbv. During these two months, the mean hourly concentration was 22 and 12 ppbv, respectively. Maximum concentrations reached 966 in January and 747 in July. Because of variable wind directions, the CAFO impacts the MHS only intermittently. To quantify plume impact at the site, we considered plume impact to occur when the predicted concentration exceeded 0.5 ppbv, approximately the detection limit for NH_3 measurements. For each month, impacts greater than 0.5 ppbv occurred approximately 35% of the time; during these times when concentrations were greater than 0.5 ppbv, the mean concentrations were 59 ppbv and 187 ppbv, respectively, for January and July. These results are summarized in Table 3. Based upon these two months, it does not appear that there is a significant difference in the winter vs. summer impact since the mean is greater in winter, but the mean during plume impacts is greater in summer.

Peak concentrations were similar in both months. It should be noted that the constant emission rate was used in modeling for both months and probably doesn't reflect actual changes in emissions due to temperature and moisture effects in the CAFO. We might expect higher emissions during the summer when NH_3 volatility would be enhanced due to warmer conditions. Note that background NH_3 levels were not modeled, just emitted NH_3.

Table 3. Summary of NH_3 concentrations estimated for the MHS during January and July, 1990.

NH3 (ppbv)	**January**	**July**
Mean	22	12
Max	966	747
St. dev.	81	55
Hourly occurrences	273	259
Intermittency	0.37	0.35
Mean with C > 0.5 ppbv	59	187

Another aspect of these model results is the indication that higher concentrations tend to occur during nighttime conditions as illustrated in Figure 5 where the diurnal average NH_3 concentrations profiles for each month are shown. For this graph, the diurnal average concentrations were based only on hours when there was plume impact at the MHS. Concentrations are variable, but significantly higher during nighttime hours compared to daytime hours for both months. This is a clear reflection of the effects of stable nighttime conditions upon plume dilution rates.

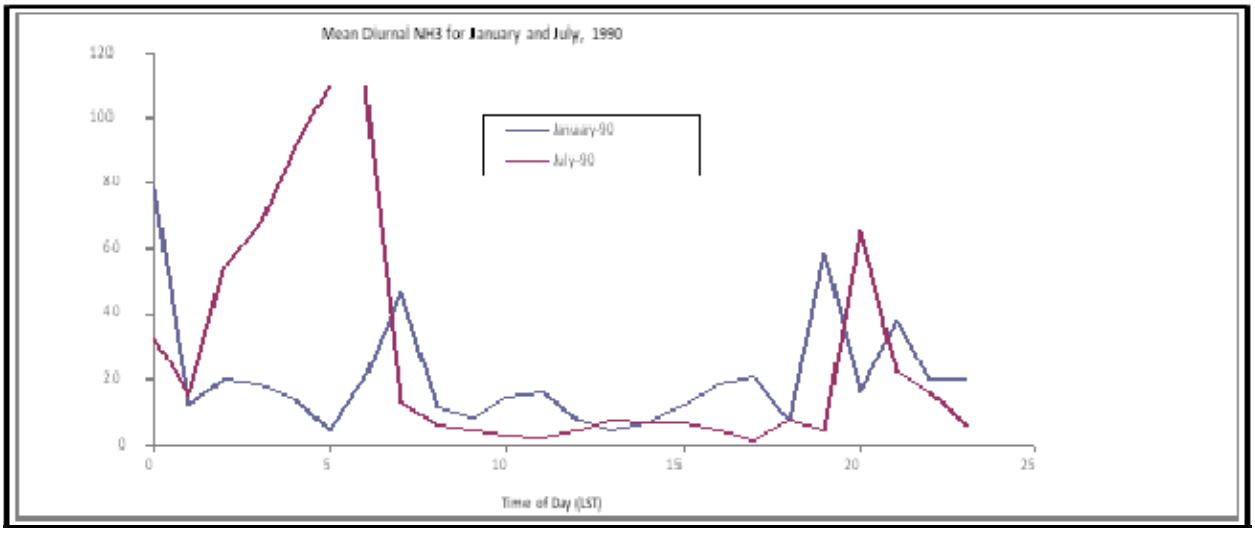

Figure 5. Diurnal average NH_3 concentrations at the Minidoka Historic Site (MHS) during January (blue line) and July (violet line).

These averages are based only upon hours when plume impact at MHS occurred. Examples of the spatial distribution of predicted NH_3 are shown in Figure 6. These hourly dispersion patterns show how the plume transport patterns change with time of day; and also illustrate the variability in concentration that can occur at any given location.

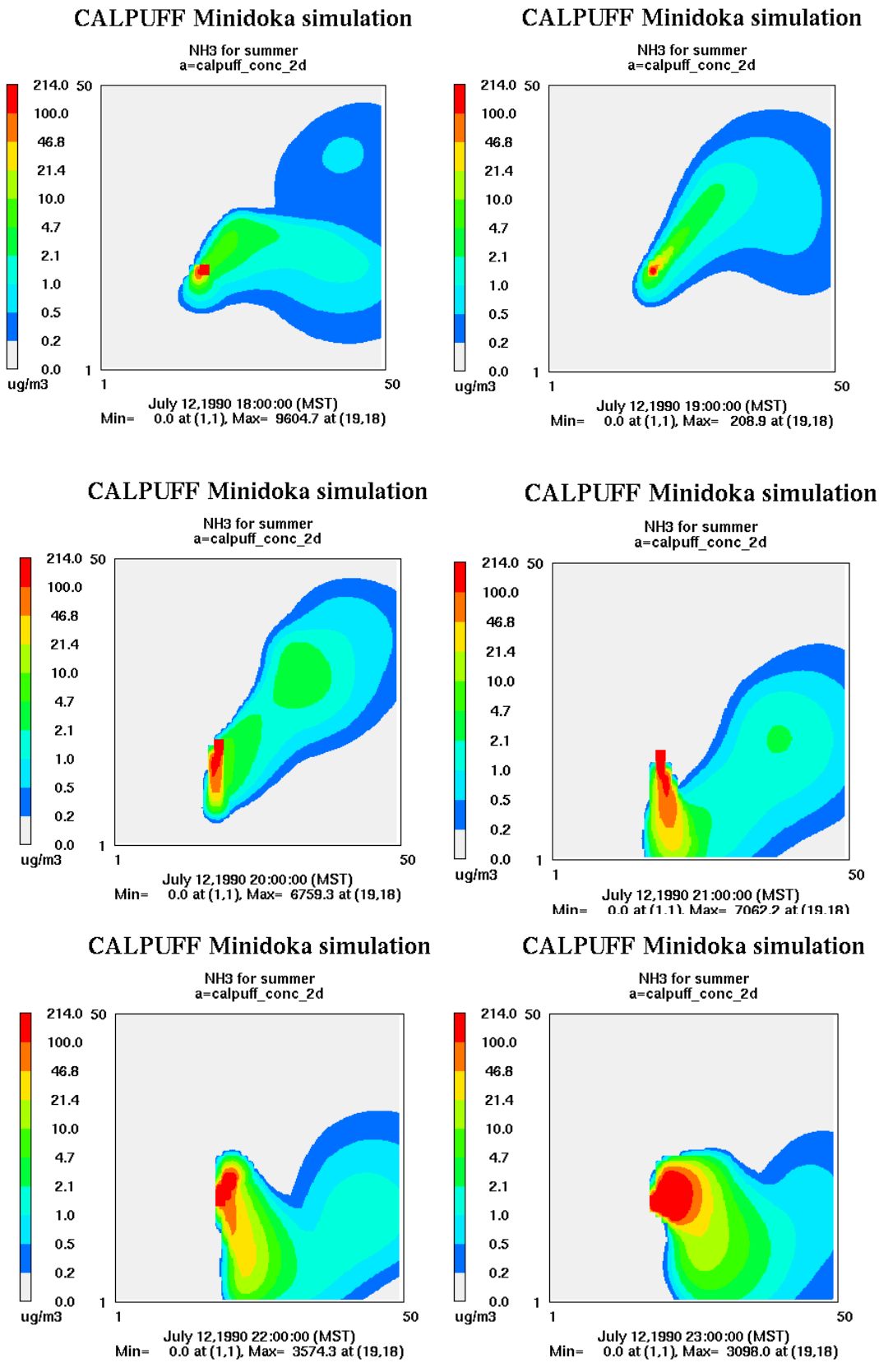

Figure 6. Sequence of hourly dispersion patterns for NH_3

The results for H_2S mirror the patterns predicted for NH_3 since the meteorology and dispersion conditions are identical. Given an estimated emission rate of 2 µg/m^2/s, predicted peak H_2S concentrations will be in the range of 15 to 19 ppb and mean concentrations will be less than 5 ppb during periods with plume impact. These results are summarized in Table 4.

Table 4. Summary of estimated H_2S concentrations

H2S (ppbv)	**January**	**July**
Mean	0.4	0.2
Max	19	15
St.dev.	1.6	1.1
Mean with C > 0.5 ppbv	1.2	3.7

For PM_{10}, using an estimated emission rate of 12 µg/m^2/s, the corresponding range in peak concentrations is estimated to be from 60 to 78 µg/m^3 as summarized in Table 5. The peak and average values are less than the 24-hr average air quality standard for PM_{10} (150 µg/m^3).

Table 5. Summary of estimated PM_{10} concentrations.

PM10 (µg/m3)	**January**	**July**
Mean	1.8	1.0
Max	78	60
St.dev.	6.5	4.4
Mean with C > 0.5 ppbv	4.7	15

SUMMARY

The ammonia results summarized in this report show substantial variability in concentration during winter and summer days. Concentrations of NH_3 estimated to occur at the MHS reach as high as 966 ppbv (0.966 ppm) which is much higher than typical rural background levels, but less than the odor threshold for NH_3 at 5 ppm.

Plume impacts at MHS occur approximately 35% of the time in both winter and summer months. Mean concentrations for January and July were 22 ppb and 12 ppb respectively, while mean concentrations for periods with concentrations greater than 0.5 ppbv were 59 ppbv and 187 ppbv, respectively. For H_2S, peak concentrations approach 20 ppbv and are well above the odor threshold of 2 ppb (but well below reported irritant levels). For both NH_3 and H_2S, concentrations modeled for MHS appear to violate the recommendations of the Iowa study group for public spaces, of 150 ppb and 15 ppb respectively. For PM10, estimated peak concentrations were between 60 to 78 $\mu g/m^3$, but average concentrations were less than 15 $\mu g/m^3$, is below the 24-hr ambient standard levels for PM_{10}.

A major aspect of these predictions is the uncertainty in emission rates for NH_3, H_2S, and PM_{10}. Until better emissions data are available for feedlots of this type, a more refined analysis of the CAFO impact upon the surroundings will be very limited.

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Comments from reviewers Mike Barna and Ellen Porter with responses:

Comments by Mike Barna, an air quality modeler at CIRA, Colorado State University, Fort Collins, CO. *Replies are shown in italics.*

This is pretty simple modeling, but the approach is sound for getting a first-order approximation of what's going on.

The particulate numbers looked pretty high, with hourly peaks at 60-78 $\mu g/m^3$. This is reported as PM_{10}, and is presumably due to coarse PM from cows stomping around, and not from reactions involving NH_3 that result in ammonium sulfate or ammonium nitrate. This should be clarified. Also, these numbers would obviously cause a lot of haze, but this isn't a class 1 area (in fact, this site is right in the middle of the Snake River Valley, so presumably it's getting hammered all the time by agricultural emissions).

> *This project's CALPUFF modeling only addresses dispersion of emissions and no chemistry contributes to the results in this study. As notes elsewhere, the CALPUFF results do not include background values.*

The NH_3 and H_2S numbers are also high, and it's noted that 'concentrations modeled for MHS appear to violate the recommendations of the Iowa study group for public spaces, of 150 ppb and 15 ppb respectively.' So it's going to be pretty 'whiffy' out there (but it must be pretty bad anyway, as noted above). If the H_2S numbers get up to, say, 100 ppm, then people will be dropping dead in the parking lot.

One thing to keep in mind is that it is entirely possible that the NH_3 could be increased by a factor a 2 or 3, given the uncertainty in feedlot emissions. The authors make a reasonable assumption regarding emission rates, and chose 100 $\mu g/m^2/s$, but that's on the low side of what's in the literature. So ammonia odor impacts could be worse. Is there any provision here for stipulating 'best management practices' to reduce ammonia emissions?

> *The emissions factor of 100 $\mu g/m^2/s$ is not at either extreme of the feedlot studies WSU reviewed, although it is true that values in the literature vary widely and that more research is needed. Possible the wide range of values in the literature truly reflects emission rates that in fact differ substantially due to differences in ambient conditions during measurement, stock genetics, different feeds and feeding practices, and perhaps differences in stock gut fauna.*

Comments by Ellen Porter, DENVER/NPS.

NPS is funding Edie Allen from UC Riverside to investigate N impacts to grasslands at CRMO (particularly in relation to cheatgrass invasion); John Apel at CRMO is coordinating for the park. Edie Allen has started monitoring N deposition with passive samplers (including gaseous NH_3) at CRMO, HAFO, and CIRO. Those 3 sites bracket Minidoka. She also plans to locate samplers near CAFO's and other sites. Here's an excerpt from her plan:

> With the assistance of NPS personnel, we propose to identify approximately eight sample locations along the N-S axis of CRMO to sample N in air, soil, and vegetation. A distance of 56 mi is more than sufficient to generate a N deposition gradient, as we have shown a gradient over 100 km (40 mi) at Joshua Tree National Park ranging from 3 to 12 kg N/ha/yr (Allen et al. 2009). These sites should be as similar as possible in soil type, vegetation, elevation, and fire history. Much of the Monument is sagebrush-steppe, but the north end has higher elevations and juniper woodland. Lower elevation sites in sagebrush-steppe will be chosen as available so sites will be comparable. Since much of the interior of the Monument is inaccessible by road, the sample sites will be located no more than 1 mile walk from perimeter roads. The sites should be along roads that are infrequently traveled to avoid additional sources of air pollution. In addition to the eight sample locations at CRMO, we propose to establish at least one site each at Hagerman Fossil Beds and City of Rocks. We also propose an additional six sites near or downwind potential sources of air pollution, such as CAFO's, agricultural fields, and a fertilizer manufacturing company, for a total of 16 sample sites. All sample sites will be located with assistance from Monument Resource managers and staff.