ESTIMATES OF AMMONIA EMISSIONS FROM BEEF AND DAIRY CATTLE IN CALIFORNIA

Review Draft

Emissions Estimation Methodology
California Air Resources Board
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CALIFORNIA AIR RESOURCES BOARD
PLANNING AND TECHNICAL SUPPORT DIVISION

Estimates of Ammonia Emissions from Beef and Dairy Cattle in California

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Estimates of Ammonia Emissions from Beef and Dairy Cattle in California

1.1 Background

California is the nation's largest producer of dairy products and is a major contributor to the country's beef cattle production. Several million dairy and beef cattle live in California. These animals, and all livestock, are sources of ammonia emissions due to the biological decomposition of their waste products. For areas with large numbers of livestock animals present, they may be a significant source of regional ammonia emissions. These emissions, when combined in the atmosphere with other pollutants can produce particulate matter that can decrease air quality.

The Air Resources Board (ARB) intends to produce ammonia emission estimates for all major livestock animals including poultry, swine, horses, and sheep. We are producing estimates for the beef and dairy cattle first because of the availability of detailed animal population data and the availability of preliminary emission factor data that provides estimates of ammonia emissions on a per animal basis.

1.2 Methodology Overview

Conceptually, the method for estimating emissions from cattle is simple: count the number of animals, then multiply this by the average emissions per animal, and the resulting value provides the emissions. Unfortunately, the situation is more complex. The number of cattle in California is dynamic. Cattle are brought in from out-of-state in the winter for grazing, animals in feedlots are continually removed and replenished, animals are moved from grazing to feedlot regimens, calves grow up and become dairy producers or beef animals (or hamburgers).

To add further complexity, the estimates of ammonia emissions from cattle are different for beef cattle, dairy cattle, grazing cattle, feedlot cattle, bulls, heifers, and calves. To make matters worse, measuring or estimating ammonia emissions from livestock is a difficult process. Livestock emissions may be substantially affected by many factors such as how many animals are present, what their diet is, how are they housed, what the local air temperature and humidity is, how are the wastes handled, and more. In addition, the available livestock emission estimates were performed by different researchers using different analysis methods and evaluating different animal handling techniques. Some studies were performed in California, some in other states, and several in Europe.

Because of these many potential uncertainties in the number of animals and in the ammonia emissions per animal, it is not possible to produce precise measurements of regional livestock emissions as can be done for individual factories or cars. The ammonia estimates for livestock are based on averages and estimates and using the best available data applicable to the specific situation. These estimates are dynamic, and as additional information becomes available that is relevant to California livestock

operations, it will be included to improve the ammonia emission estimates. However, it is not possible to delay until all uncertainties are understood or quantified prior to producing regional emission estimates.

The remaining sections provide detailed information about how the number of beef and dairy cattle in California were estimated, including what emissions values were used for each major bovine classification, and how these were combined to produce regional emission estimates.

1.3 Emissions Summary

Table 1-1 and Figure 1-1 summarize the estimates of ammonia from beef and dairy cattle in California for 1996. On a statewide basis, the ammonia emissions from dairy operations are about twice as high as emissions from beef cattle operations. This is due to two factors. In 1996, there were an estimated 1.9 million beef cattle in California versus 2.6 million dairy cattle. In addition, the average emission rate for beef cattle is estimated as 19 pounds of ammonia per head per year, versus 30 pounds of ammonia per head per year for dairy cattle.

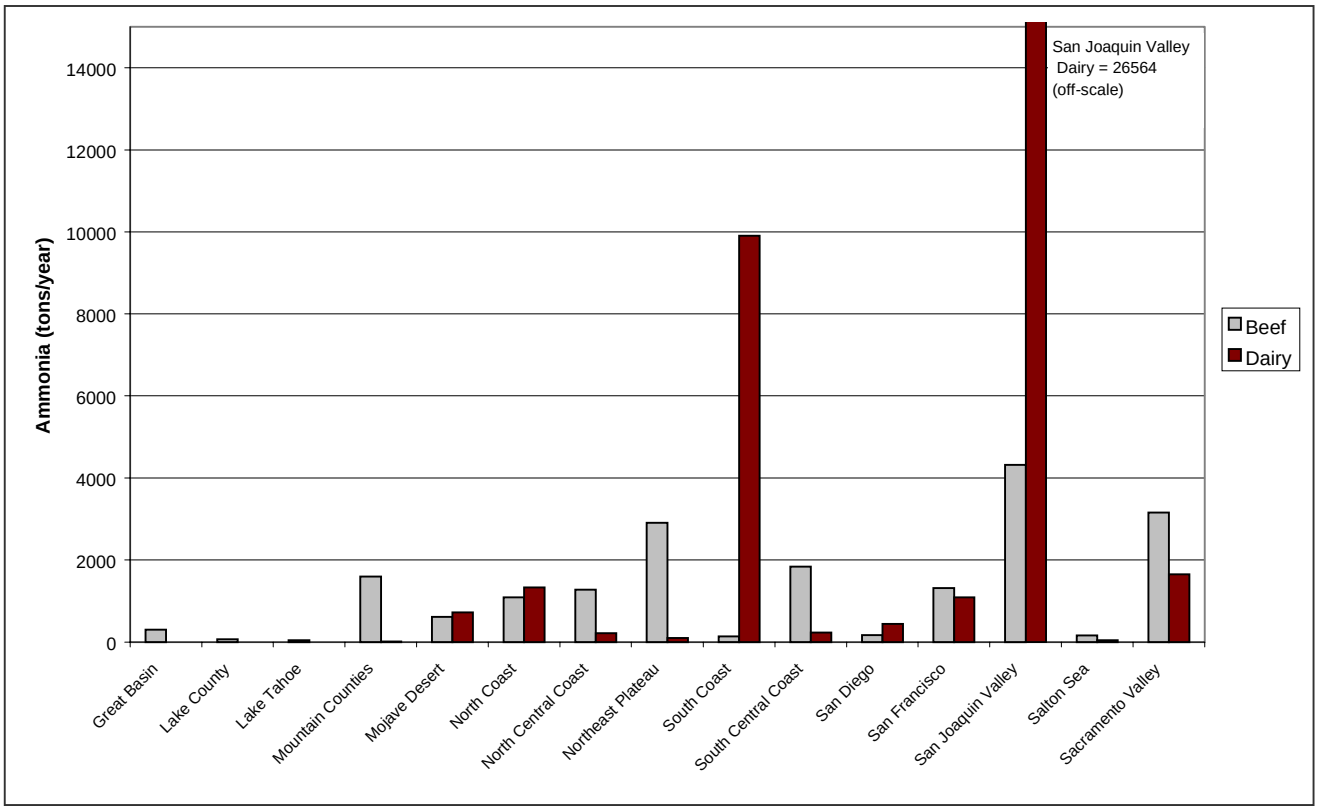
The San Joaquin Valley is by far the largest producer of ammonia emissions from cattle in California, primarily due to dairy cattle. However, there are other specific regions, such as areas in the South Coast Air Basin, in which there are substantial populations of dairy cattle. The detailed sections which follow provide county specific listings of beef and dairy related ammonia emissions.

These emissions estimates are a first draft. Further refinements are needed both in estimating the number of animals as well as the emissions per animal. Also, depending on the significance of regional ammonia emissions, more specific information may be needed to show where populations of animals are located and how their numbers vary seasonally.

Table 1-1.
California Cattle Ammonia Emissions Estimates for 1996.

	Cattle Ammonia Emissions for 1996 (tons/year)		
Air Basin	**Beef**	**Dairy**	**Total**
Great Basin	303	0	303
Lake County	71	0	71
Lake Tahoe	46	2	48
Mountain Counties	1597	9	1606
Mojave Desert	611	478	1089
North Coast	1085	1099	2184
North Central Coast	1270	131	1401
Northeast Plateau	2908	26	2934
South Coast	133	8063	8196
South Central Coast	1838	97	1935
San Diego	172	220	392
San Francisco	1316	863	2179
San Joaquin Valley	4318	26564	30882
Salton Sea	158	82	240
Sacramento Valley	3157	1171	4328
Total	**18983**	**38805**	**57788**

Figure 1-1. Ammonia Emission Estimates for Beef and Dairy Cattle for 1996.



2.0 Beef Cattle Ammonia Estimates

This section includes three major subsections:

- Population of beef cattle (quantity, types, and location of animals)
- Emission factors for beef cattle (emissions assigned to each animal type)
- Emission estimates for beef cattle (county ammonia emissions estimates)

The subsections provide detail about how the beef cattle ammonia estimates were developed and the assumptions and simplifications used in producing the estimates.

2.1 Population of California Beef Cattle

The ultimate objective for this section is to estimate the total number of beef animals in California. This includes determining what they are doing (grazing, feedlots), where they are doing it, how their populations vary by month, and what kind of animals are present (calves, adults). It is also important to know this information for a time as close to the present as possible. With reasonably available information, these objectives can be met with varying degrees of completeness.

For this analysis, two sources of data were used to estimate the number of beef cattle in California. These data were used to assign the cattle populations by county in California and to deduce the types of cattle present both in terms of feeding, age, and time present.

The first reference, *California Livestock Statistics Bulletin*, 1990, published by the California Agricultural Statistics Service, June, 1991 (the CASS report), provides estimates of the number of head of beef cattle in each California county for 1990. The report provides minimal information on the types of cattle present and does not have recent population data.

The second reference, the *California Agricultural Resource Directory*, 1997, published by the California Department of Food and Agriculture, December 1997 (the CDFA report), provides detailed information on the types of cattle present and population counts for the year 1996, but it does not include county specific beef cattle population estimates. The relevant data from these reports are reproduced in Appendix A.

This remainder of this section provides a detailed description of the methods used to estimate the beef cattle populations. Appendix B includes the tabular data, population counts, and detailed notes use to derive this section. Using the method described below, the ARB approach of apportioning the animals differs from the CDFA statewide estimates by about 40 head.

2.1.1 Apportioning by County and Air Basin

To produce the county specific estimates necessary for this analysis, data from the CASS and CDFA reports were combined. The older 1990 CASS data, which are provided by county, were used to distribute the newer CDFA 1996 statewide population data by county (since the 1996 data are not provided by county). This approach has the obvious shortcoming of assuming the relative ratios of beef cattle populations in each county are

the same in 1990 and 1996. For these first estimates it is believed that these values will reasonably reflect relative county distributions, although it is understood that additional, more current, data may be needed for regions with significant ammonia problems.

In addition to distributing the populations by county, they must also be distributed by air basin. Some counties are split by air basin boundaries, so it is necessary to estimate how many cattle are within the portion of the county within each air basin. For beef cattle, the number of animals were subdivided based on the square miles of each county within the air basin. This subdivision is shown in Table 2-1. In the future, more site-specific information will be used to apportion the animal populations for those regions where ammonia is a significant air pollutant. For reference, a map of California counties and air basins are provided in Appendix D.

Table 2-1.
Beef Cattle Population Splits for Counties in Multiple Air Basins.

County	Air Basin	% in Air Basin
El Dorado	Lake Tahoe	12.2
	Mountain Counties	87.8
Kern	Mojave Desert	46.5
	San Joaquin Valley	53.5
Los Angeles	Mojave Desert	33.4
	South Coast	66.6
Placer	Lake Tahoe	10.0
	Mountain Counties	61.1
	Sacramento Valley	28.9
Riverside	Mojave Desert	42.7
	Salton Sea	29.2
	South Coast	28.1
San Bernardino	Mojave Desert	94.4
	South Coast	5.6
Solano	San Francisco	48.2
	Sacramento Valley	51.8
Sonoma	North Coast	60.7
	San Francisco	39.3

2.1.2 Apportioning by Animal Type

In addition to apportioning the cattle by county and air basin, it is also important to estimate the quantity of each major type of beef animal in the county. This is necessary because the emission factors (i.e., pounds of ammonia per animal per year) are specific to different animal types. Also, the different cattle types are resident in the state for different lengths of time, which is not fully reflected in the CASS and CDFA summary head count data. By subdividing the populations by animal type, it is possible to more accurately estimate the number of animals that are actually living in California (versus the total number slaughtered or in feedlots throughout the year).

For beef cattle, information was available which allowed dividing the animals into four categories: cows that have calved, range calves, stocker inshipments, and feedlot feeder

cattle. The following sections describe each of these categories and the methods used to estimate the number of animals present.

2.1.1.1 Cows That Have Calved

Based on the table provided on page 96 of the CDFA California Agricultural Resource Directory for 1997, there were a total of 840,000 head of beef cows that have calved (a copy of this table is provided in Attachment B) for 1996. Using the method described in the previous section, these cattle were apportioned by county using the CASS 1990 county specific population data (which is also provided in Attachment B). For the purposes of estimating emissions, these animals are considered to be range fed adults.

2.1.1.2 Range Calves

Available reports do not include separate estimates of beef calves and calves that are associated with dairy. Therefore, the number of beef calves are estimated based on the proportions of beef and dairy cows that calved. The CDFA table shows a total of 950,000 beef and dairy calves under 500 pounds in California for 1996. The number of beef calves was estimated by allocating the calves based on the proportion of 'beef cows that have calved' to the total number of 'cows that have calved'. The total number of cows that have calved for 1996 is 2,100,000. Of this, 840,000 are beef cows. Therefore, since 40% (i.e., 840,000/2,100,000) of the total cows that have calved are beef cows, it was assumed that 40%, or 380,000 of the calves are beef related (950,000 total calves x 0.4).

Calves were apportioned by county based on the CASS 1990 data for total beef populations. This assumes that the calves are located where the adult 'beef cows that have calved' are located. Note that the CDFA document includes two tables on page 96 (see Appendix A). The upper table shows a calf count of 950,000 head. The lower table shows a calf crop of 1,750,000 head for 1996. The reason these values do not agree and the reason the 950,000 value was used, is because the higher value is the total number of animals born and does not include marketing, death, and slaughter losses. The value of 950,000 better represents the number of calves actually living in California.

Based on information from the California Cattlemen's Association, most beef related calves are range fed, so the emissions estimates are based on the calf specific emission factors most appropriate to this type of feeding. For areas with potential ammonia problems, calf populations could be geographically distributed to those areas with grazing lands to better spatially allocate them.

2.1.2.3 Stocker Inshipments

Stocker inshipments are cattle that are typically brought in from out of state to graze on California grasslands. It is assumed that all stockers/inshipments are beef animals. CDFA shows that there were 820,000 inshipments for 1996. These animals are a distinct population from the 'cows that have calved' which is based on evaluation of the beef cattle totals. Inshipment cattle are present in California for only about 7 months (November through May). Therefore the total inshipment population was scaled using the ration of 7.1898 months/12 months = 0.599, which produces an annual average population of approximately 491,390 head (820,000 x 0.599). The residency time was

adjusted slightly from exactly seven months so that the grand total beef cattle population agrees with the composite CDFA 1996 inventory total which is 1,994,000 head.

The emission rates used for inshipments is the same as that used for the beef cow animals since both are typically range fed.

2.1.2.4 Feedlot Feeder Cattle

Feeders are beef cattle fed in feedlots. Based on the CDFA data (page 94) there were 565,000 head of cattle marked from feedlots in 1996. However, this total number of animals are not present all year because typically animals are not fed in feedlots for a full year. To determine how long the feedlot cattle are resident, information from the CASS report was used (reproduced in Appendix A). Table 12 of the CASS report shows the number of cattle and calves in feedlots. Table 13 of the report provides the number of cattle and calves marketed. Table 2-2 below shows the analysis used to estimate the residence time. From the data, there are roughly twice as many animals marketed annually as there are present at any one time. This indicates that on average, the animals are present in feedlots for approximately six months (ratio of those marketed to those present is about 2 to 1). The residence time in months was computed as:

$$residence\ time = \frac{animals\ present}{animals\ marketed} \quad x \quad 12\ months$$

Table 2-2. Feedlot Residence Time

	1989	1990
Animals present (monthly average)	437	438
Animals marketed (annual)	930	825
Residence time (months)	5.6	6.4
Average residence time (months)	6 months	

As with the other categories, the feedlot cattle are distributed throughout the state based on the 1990 CASS county beef cow inventory. As needed, this can be improved by collecting specific industry information on where the feedlots and associated cattle are located. The emissions for the feedlot animals is based on estimates of ammonia from young cattle for fattening.

2.1.2.5 Additional population information

The CDFA data tables further split cattle into bulls, heifers (females that have not calved), and steers (castrated males). The ARB population counts do not explicitly list these animals in the counts, but they are implicitly included in the inshipment and feedlot categories. To confirm this, note that based on the CDFA data, the number of beef bulls, heifers, and steers is estimated to be 774,000 (Appendix B, Table B-1). Using the ARB methods just described, the number of beef animals in the inshipment and feedlot categories is 773,803 animals. This indicates that the animals included in the CDFA estimates are accounted for in the ARB method.

Currently, there is not clear information to determine which portion of the inshipments or feedlot animals are heifers or steers, and it is not possible to explicitly allocate the bulls.

This is why they are not individually listed. Because these different animals have different emission rates, this limitation slightly affects the final emission estimates, which are slightly lower (about 3%) than if the bulls and others could be explicitly counted and included. However, as is explained in the following emission factor section, this is not a significant issue at this time.

Based on the data and assumptions discussed above, the population data in Table 2-3 were developed. Further details about generating the population estimates are provided in the notes in Appendix B.

Table 2-3. Beef Cattle Population Estimates by Animal Type for 1996

		Ammonia Emissions (tons/yr)				
Air Basin	**County**	**Range**	**Calves**	**Feedlot**	**Total**	**Air Basin Total**
GBV	Alpine	1051	1359	781	5515	
	Inyo	4043	5227	3005	21211	
	Mono	970	1254	721	5091	31816
LC	Lake	1415	1829	1052	7424	7424
LT	El Dorado	419	542	312	2200	
	Placer	510	660	379	2678	4877
MC	Amador	3234	4181	2404	16969	
	Calaveras	5660	7317	4207	29695	
	El Dorado	3017	3901	2243	15830	
	Mariposa	5255	6795	3907	27574	
	Nevada	2223	2875	1653	11666	
	Placer	3088	3992	2295	16200	
	Plumas	4043	5227	3005	21211	
	Sierra	2223	2875	1653	11666	
	Tuolumne	3234	4181	2404	16969	167777
MD	Kern	9775	12638	7267	51287	
	Los Angeles	378	489	281	1984	
	Riverside	483	625	359	2536	
	San Bernardino	1603	2072	1192	8410	64217
NC	Del Norte	404	523	301	2121	
	Humboldt	10915	14112	8114	57269	
	Mendocino	5660	7317	4207	29695	
	Trinity	809	1045	601	4242	
	Sonoma	3926	5076	2919	20600	113927
NCC	Monterey	18596	24042	13824	97569	
	San Benito	6266	8101	4658	32877	
	Santa Cruz	566	732	421	2969	133415
NEP	Lassen	21830	28224	16229	114538	
	Modoc	15766	20384	11721	82722	
	Siskiyou	20617	26656	15327	108174	305434
SC	Los Angeles	754	975	560	3955	
	Orange	1496	1934	1112	7848	
	Riverside	318	411	236	1669	
	San Bernardino	95	123	71	499	13971
SCC	San Luis Obispo	20617	26656	15327	108174	
	Santa Barbara	13340	17248	9918	69995	
	Ventura	2830	3659	2104	14847	193017
SD	San Diego	3436	4443	2555	18029	18029
SF	Alameda	5053	6533	3757	26513	
	Contra Costa	4245	5488	3156	22271	
	Marin	2223	2875	1653	11666	
	Napa	1738	2247	1292	9121	
	San Francisco	0	0	0	0	
	San Mateo	1536	1986	1142	8060	
	Santa Clara	6468	8363	4809	33937	
	Solano	2533	3275	1883	13291	
	Sonoma	2542	3287	1890	13337	138196
SJV	Fresno	12936	16725	9617	67874	
	Kern	11246	14540	8361	59008	
	Kings	1617	2091	1202	8484	
	Madera	5255	6795	3907	27574	
	Merced	15766	20384	11721	82722	
	San Joaquin	13745	17771	10218	72116	
	Stanislaus	13745	17771	10218	72116	
	Tulare	12128	15680	9016	63632	453527
SS	Imperial	2830	3659	2104	14847	
	Riverside	331	427	246	1734	16582
SV	Butte	4649	6011	3456	24392	
	Colusa	6468	8363	4809	33937	
	Glenn	5255	6795	3907	27574	
	Placer	1460	1888	1086	7662	
	Sacramento	12936	16725	9617	67874	
	Shasta	7681	9931	5710	40300	
	Solano	2722	3520	2024	14283	
	Sutter	2223	2875	1653	11666	
	Tehama	13745	17771	10218	72116	
	Yolo	3234	4181	2404	16969	
	Yuba	2830	3659	2104	14847	331621
	Total	380005	491310	282504	1993830	1993830

2.2 Emission Factors for Beef Cattle

Over the past ten years, many researchers have performed tests to quantify the ammonia emissions from cattle. This is an extremely difficult process. Not only do the measured emissions vary by the type of animal, but they also vary based on the type of feed, environmental conditions such as temperature and humidity, how the animals are housed, how the measurements were taken, where they were taken geographically, and the activities measured such as grazing, housing, manure storage, and manure spreading. This report will not significantly examine these issues, however they have been considered in the selection of the factors applied.

There is very little published livestock ammonia emissions data which was measured in California, because of this, it was necessary to rely on other data. The source of the emission factors used for this analysis are from a report sponsored by the U.S. EPA titled, Development and Selection of Ammonia Emission Factors, August, 1994 (Battye). This report surveyed the literature for ammonia emission rates and selected the values judged to be most appropriate for use in the United States. Table 2-3 shows the emission factors selected. More detail on the selection of the emission factors is provided in Appendix B in the notes to the emissions calculations.

Table 2-3. Emission Factors Used For Beef Cattle Ammonia Estimates

Category	Ammonia EF (lbs/head/year)	Source*
Range adults & inshipments	18.12	Asman, 1992. Best fit for range
Calves	11.53	Asman, 1992. Best fit for calves
Feedlot animals	33.49	Asman, 1992. Best fit for feedlot

* See the emission calculation notes in Appendix B for further detail on the emission factor selection.

2.2.1 Range adults and inshipments

The emission factor is from the Battye report, which is a summary of data by Asman (see Appendix A, Table 2-1 of Battye). The specific factor used is ‘fattening/grazing cattle > 2 years’. This factor was selected because it does not include stable and manure spreading emissions, and it is the only grazing specific emission factor included. The other emissions in the Battye table include some confinement housing and spreading emissions. For this reason, the recommended composite value for cattle and calves (Battye table 2-9, 50.5 lbs/animal/year) was not used. This emission factor was also applied to inshipments since they are primarily range fed.

2.2.1 Calves

The emission factor for calves is from Table 2-1 of the Battye report, which is a summary of data by Asman. The factor used is for ‘fattening calves’. It appears as if this factor is based on confined animal measurements since it includes stable, storage, and spreading emissions. Although most California beef calves are raised on the range, this is currently the best available emissions value. This value also seems appropriate since it is slightly

lower than the range fed adult value, which is reasonable based on animal weight differences.

2.2.3 Feedlot animals

Feedlots animals. The emission factor for animals in feedlots is from Table 2-1 of the Battye report, which is a summary of data by Asman. The factor used is the 'young cattle for fattening profile'. The other potentially applicable emission rates appeared to be biased towards dairy animals and they also included emissions for grazing, which would not be present in a feedlot. The feedlot cattle emission factor is significantly smaller than the 'dairy & calf cows' factor by Asman (33.5 versus 87.4 lbs/head/year).

2.2.4 Composite emission factor

Composite emission factor. On a statewide basis, based on an estimate 1,993,930 head of beef cattle and total emissions of 18,983 tons/year of ammonia (see next section), the statewide composite emission factor for all beef cattle is 18 pounds of ammonia/head/year. For dairy cattle, the composite value is 30 pounds/head/year.

Future improvements. For those regions which appear to have ammonia concentrations that negatively affect air quality, it may be worthwhile to develop region specific emission rates. This information would better take into account the climate, feeding, soil, and animal handling practices relevant to the region.

2.3 Emission Estimates for Beef Cattle

The previous sections describe how the number of beef cattle were estimated and what emission rates were assigned to each major animal type. The final step in estimating the ammonia emissions from the cattle is to multiply each population type by its respective emission rate. This calculation was performed on a county basis for all of California. The results of this calculation are provided Table 2-4. For the beef cattle, on a statewide and county basis, the adult range cattle are the largest ammonia producers (about 12,000 tons/year), feedlot cattle come in second (about 4700 tons/year), with calves bringing up the rear with about 2200 tons/year. The respective populations are approximately 1,331,000 for grazers, 283,000 for feedlots, and 380,000 for calves.

Table 2-4. Beef Cattle Ammonia Emission Estimates by Animal Type for 1996

		Ammonia Emissions (tons/yr)				
Air Basin	**County**	**Range**	**Calves**	**Feedlot**	**Total**	**Air Basin Total**
GBV	Alpine	33	6	13	53	
	Inyo	128	23	50	202	
	Mono	31	6	12	48	303
LC	Lake	45	8	18	71	71
LT	El Dorado	13	2	5	21	
	Placer	16	3	6	25	46
MC	Amador	103	19	40	162	
	Calaveras	180	33	70	283	
	El Dorado	96	17	38	151	
	Mariposa	167	30	65	263	
	Nevada	71	13	28	111	
	Placer	98	18	38	154	
	Plumas	128	23	50	202	
	Sierra	71	13	28	111	
	Tuolumne	103	19	40	162	1597
MD	Kern	310	56	122	488	
	Los Angeles	12	2	5	19	
	Riverside	15	3	6	24	
	San Bernardino	51	9	20	80	611
NC	Del Norte	13	2	5	20	
	Humboldt	346	63	136	545	
	Mendocino	180	33	70	283	
	Trinity	26	5	10	40	
	Sonoma	125	23	49	196	1085
NCC	Monterey	590	107	231	929	
	San Benito	199	36	78	313	
	Santa Cruz	18	3	7	28	1270
NEP	Lassen	693	126	272	1090	
	Modoc	500	91	196	788	
	Siskiyou	654	119	257	1030	2908
SC	Los Angeles	24	4	9	38	
	Orange	47	9	19	75	
	Riverside	10	2	4	16	
	San Bernardino	3	1	1	5	133
SCC	San Luis Obispo	654	119	257	1030	
	Santa Barbara	423	77	166	666	
	Ventura	90	16	35	141	1838
SD	San Diego	109	20	43	172	172
SF	Alameda	160	29	63	252	
	Contra Costa	135	24	53	212	
	Marin	71	13	28	111	
	Napa	55	10	22	87	
	San Francisco	0	0	0	0	
	San Mateo	49	9	19	77	
	Santa Clara	205	37	81	323	
	Solano	80	15	32	127	
	Sonoma	81	15	32	127	1316
SJV	Fresno	411	75	161	646	
	Kern	357	65	140	562	
	Kings	51	9	20	81	
	Madera	167	30	65	263	
	Merced	500	91	196	788	
	San Joaquin	436	79	171	687	
	Stanislaus	436	79	171	687	
	Tulare	385	70	151	606	4318
SS	Imperial	90	16	35	141	
	Riverside	10	2	4	17	158
SV	Butte	148	27	58	232	
	Colusa	205	37	81	323	
	Glenn	167	30	65	263	
	Placer	46	8	18	73	
	Sacramento	411	75	161	646	
	Shasta	244	44	96	384	
	Solano	86	16	34	136	
	Sutter	71	13	28	111	
	Tehama	436	79	171	687	
	Yolo	103	19	40	162	
	Yuba	90	16	35	141	3157
	Total	12062	2191	4731	18983	18983

3.0 Dairy Cattle

This section includes three major subsections:

- Population of dairy cattle (quantity, types, and location of animals)
- Emission factors for dairy cattle (emissions assigned to each animal type)
- Emission estimates for dairy cattle (county ammonia emissions estimates)

The subsections provide detail about how the dairy cattle ammonia estimates were developed and the assumptions and simplifications used in producing the estimates.

3.1 Population of California of Dairy Cattle

The objective for this section is to estimate the total number of dairy animals in California. This includes determining what kinds of animals are present such as cows, heifers, calves, and bulls, and estimating how many cattle are within each county. This section provides a detailed description of the methods used to estimate the dairy cattle populations. Appendix B includes the tabular data, population counts, and further information used to generate this section. Using the method described below, the ARB approach to apportioning the animals differs by about 200 head from the total estimate provided by the California Department of Food and Agriculture.

For this analysis, dairy cattle population data were taken from the *California Agricultural Resource Directory*, 1997, published by the California Department of Food and Agriculture, December 1997 (the CDFA report). The report provides county specific population estimates and detailed information on the types of dairy cattle present on a statewide basis. The relevant data from this report are reproduced in Appendix A.

3.1.1 Apportioning by County and Air Basin

Two tables from the CDFA report were used to estimate the dairy cow populations. The first table (CDFA, p. 91), provides 1997 population by county; the second (CDFA, p. 96), provides statewide populations by type of animal such as milk cows, heifers, and calves for 1996 and prior. To compute county specific population estimates, the 1996 data were used for the statewide baseline population and animal type data, but the 1997 county data were used to distribute the animals by county. Even though county split data were available for 1996 it was not used because there is a substantial change in the populations between 1996 and 1997 and it was decided it was most important to try to reflect the populations as close to the present as possible. The main change was an increase in the San Joaquin Valley animals by about 70,000 head.

In addition to distributing the populations by county, they must also be distributed by air basin. Some counties are split by air basin boundaries, so it is necessary to estimate how many cattle are within the portion of the county within each air basin. For dairy cattle, the number of animals were subdivided based on the square miles of each county within the air basin. This subdivision is shown in Table 3-1. For reference, Appendix D includes a map of California counties and air basins.

The exception to this approach is for dairy cattle associated with the counties included in the South Coast air basin (Los Angeles, San Bernardino, Riverside), and the Mojave Desert air basin (Los Angeles, San Bernardino, Riverside, Kern). In this case, splits based on square mileage did not make sense based on the known locations of the dairy cattle operations. To better apportion the data, population estimates were obtained from the air districts. This gave a sense of the numbers of cattle in each region, but in the end, assumptions were made to get the populations to fit with the known data. Generally, it was known that the Mojave Desert AQMD has about 18,000 head of dairy cattle, and the South Coast AQMD has about 314,000 head. The cattle were allocated to be consistent with these numbers, which means placing only small percentages of the total county animals in the Mojave Desert regions. This makes sense knowing that the Mojave Desert region is, not surprisingly, mostly desert. For these air basins, Table 3-1 shows the estimated proportion of cattle in each county, and not the land area ratios. In the future, more site-specific information may be used to apportion the animal populations for those regions where ammonia is a significant air pollutant.

Table 3-1
Dairy Cattle Population Splits for Counties in Multiple Air Basins

County	Air Basin	% in Air Basin
El Dorado	Lake Tahoe	12.2
	Mountain Counties	87.8
Kern	Mojave Desert	30.0
	San Joaquin Valley	70.0
Los Angeles*	Mojave Desert	20.0
	South Coast	80.0
Placer	Lake Tahoe	10.0
	Mountain Counties	61.1
	Sacramento Valley	28.9
Riverside*	Mojave Desert	1.0
	Salton Sea	1.0
	South Coast	98.0
San Bernardino*	Mojave Desert	2.0
	South Coast	98.0
Solano	San Francisco	48.2
	Sacramento Valley	51.8
Sonoma	North Coast	60.7
	San Francisco	39.3

* Populations for the counties in the South Coast AQMD and Mojave Desert AQMD were apportioned based on district population estimates provided by the air districts.

3.1.2 Apportioning by Animal Type

In addition to apportioning the cattle by county and air basin, it is also important to estimate the quantity of each major type of dairy animal in the county. This is necessary because the emission factors (i.e., pounds of ammonia per animal per year) are specific to

different animal types. Unlike some of the beef cattle, dairy cattle are assumed to be in the state year around, which simplifies some of the estimates.

For dairy cattle, information was available which allowed dividing the animals into four categories: cows that have calved, milk calves, milk heifers, and dairy bulls. The following sections describe each of these categories and the methods used to estimate the number of animals present.

3.1.2.1 Cows that Have Calved

Based on the table provided on page 96 of the CDFA California Agricultural Resource Directory for 1997, there were a total of 1,260,000 head of dairy cows that have calved in 1996 (a copy of this table is provided in Appendix A). Using the method described in the previous section, these cattle were apportioned by county using the CDFA 1997 county specific population data (which is also provided in Appendix A). For the purposes of estimating emissions, these animals are considered to be milk cows.

3.1.2.2 Calves

Available reports do not include separate estimates of calves that are associated with dairy operations. Therefore, the number of dairy calves are estimated based on the relative proportions of beef and dairy cows that calved. The CDFA table shows a total of 950,000 dairy and dairy calves under 500 pounds in California for 1996. The number of dairy calves was estimated by allocating the calves based on the proportion of 'dairy cows that have calved' to the total number of 'cows that have calved'. The total number of cows that have calved for 1996 is 2,100,000. Of this, 1,260,000 are dairy cows. Therefore, since 60% (i.e., 1,260,000/2,100,000) of the total cows that have calved are dairy cows, it was computed that 60%, or 570,000 of the calves are dairy related (950,000 total calves x 0.6).

Calves were apportioned by county based on the CDFA 1997 data for total dairy populations. This assumes that the calves are located where the adult 'dairy cows that have calved' are located. Note that the CDFA document includes two tables on page 96 (see Appendix A). The upper table shows a calf count of 950,000 head. The lower table shows a calf crop of 1,750,000 head for 1996. The reason these values do not agree and the reason the 950,000 value was used, is because the higher value is the total number of animals born and does not include marketing, death, and slaughter losses. The value of 950,000 better represents the number of calves actually living in California.

For emissions estimation purposes, the emissions estimates for calves are based on values for the 'fattening calves' category. This value is substantially smaller than the values used for adult animals.

3.1.2.3 Heifer

Heifers are cows that have not yet calved. This population is provided by CDFA for 1996. The report shows 600,000 milk cow heifers, 160,000 beef cow heifers, and 170,000 other heifers. These animals are considered replacement animals. To assign all of the cattle for emission estimates, 79% (or 134,000 head) of the 'other' heifers were distributed to the milk cow heifer inventory. This percentage is based on the calculation

that of the total milk and beef heifers, 79% are milk heifers (i.e., 600,000/760,000). It is assumed that these animals are present for a full year.

The statewide number of heifers were apportioned by county based on the proportions of 'cows that have calved' in each county, from the 1997 CDFA data. The emission rates used for heifers is based on an emission profile specific to heifers over 500 pounds. The emission rate is smaller than the value used for producing milk cows.

3.1.2.4 Dairy bulls

Dairy bulls are male animals associated with dairy operations. Page 96 of the CDFA report shows 70,000 bulls in California. Based on the proportion of dairy cows that have calved to all cows (1,260,000 dairy to 2,100,000 total), sixty percent of the bulls were allocated to the dairy industry

As with the other categories, the bulls are distributed throughout the state based on the 1997 CDFA county dairy cow inventory. This method can be improved by collecting specific industry information on where dairies and associated cattle are located. The emissions for the bulls are based on estimates of ammonia for breeding bulls over two years old.

Based on the data and assumptions discussed above, the population data in Table 3-2 were developed. Further details about generating the population estimates are provided in the notes in Appendix B.

Table 3-3. Dairy Cattle Population Estimates by Animal Type for 1996.

		Ammonia Emissions (tons/year)					
Air Basin	**County**	**Cow**	**Calves**	**Heifer**	**Bulls**	**Total**	**Air Basin Total**
GBV	Alpine	0	0	0	0	0	
	Inyo	0	0	0	0	0	
	Mono	0	0	0	0	0	0
LC	Lake	0	0	0	0	0	0
LT	El Dorado	0	0	0	0	0	
	Placer	50	22	29	2	103	103
MC	Amador	0	0	0	0	0	
	Calaveras	0	0	0	0	0	
	El Dorado	0	0	0	0	0	
	Mariposa	0	0	0	0	0	
	Nevada	0	0	0	0	0	
	Placer	301	136	175	10	622	
	Plumas	0	0	0	0	0	
	Sierra	0	0	0	0	0	
	Tuolumne	0	0	0	0	0	622
MD	Kern	11034	4991	6427	368	22820	
	Los Angeles	276	125	161	9	571	
	Riverside	1108	501	645	37	2291	
	San Bernardino	3104	1404	1808	103	6421	32103
NC	Del Norte	2755	1246	1605	92	5698	
	Humboldt	14503	6561	8448	483	29995	
	Mendocino	1427	646	831	48	2952	
	Trinity	0	0	0	0	0	
	Sonoma	17002	7691	9904	567	35164	73809
NCC	Monterey	3021	1366	1760	101	6247	
	San Benito	999	452	582	33	2067	
	Santa Cruz	225	102	131	8	466	8780
NEP	Lassen	0	0	0	0	0	
	Modoc	0	0	0	0	0	
	Siskiyou	850	385	495	28	1759	1759
SC	Los Angeles	1103	499	643	37	2282	
	Orange	0	0	0	0	0	
	Riverside	108569	49114	63246	3619	224548	
	San Bernardino	152119	68816	88615	5071	314620	541450
SCC	San Luis Obispo	323	146	188	11	669	
	Santa Barbara	2815	1274	1640	94	5822	
	Ventura	0	0	0	0	0	6491
SD	San Diego	7152	3235	4166	238	14792	14792
SF	Alameda	0	0	0	0	0	
	Contra Costa	2518	1139	1467	84	5208	
	Marin	12330	5578	7182	411	25501	
	Napa	304	137	177	10	628	
	San Francisco	0	0	0	0	0	
	San Mateo	0	0	0	0	0	
	Santa Clara	1173	531	683	39	2426	
	Solano	703	318	410	23	1454	
	Sonoma	11008	4980	6413	367	22767	57984
SJV	Fresno	70545	31913	41095	2352	145905	
	Kern	25738	11644	14994	858	53234	
	Kings	98757	44676	57530	3292	204254	
	Madera	23940	10830	13946	798	49514	
	Merced	154137	69729	89791	5138	318795	
	San Joaquin	81638	36931	47557	2721	168848	
	Stanislaus	132019	59723	76906	4401	273048	
	Tulare	275770	124753	160647	9192	570363	1783959
SS	Imperial	1560	706	909	52	3227	
	Riverside	1108	501	645	37	2291	5518
SV	Butte	585	264	341	19	1209	
	Colusa	133	60	77	4	275	
	Glenn	13729	6211	7998	458	28394	
	Placer	142	64	83	5	294	
	Sacramento	14937	6757	8702	498	30894	
	Shasta	118	53	69	4	244	
	Solano	755	342	440	25	1563	
	Sutter	460	208	268	15	952	
	Tehama	3935	1780	2292	131	8139	
	Yolo	491	222	286	16	1016	
	Yuba	2726	1233	1588	91	5637	78616
	Total	1259994	569997	733996	42000	2605987	2605987

3.2 Emission Factors for Dairy Cattle

Over the past ten years, many researchers have performed tests to quantify the ammonia emissions from cattle. This is an extremely difficult process. Not only do the measured emissions vary by the type of animal, but they also vary based on the type of feed, environmental conditions such as temperature and humidity, how the animals are housed, how the measurements were taken, where they were taken geographically, and the processes measured, such as grazing, housing, manure storage, storage ponds, and manure spreading. This report will not significantly examine these issues, however they have been considered in the selection of the factors applied.

There is very little published livestock ammonia emissions data based on California specific measurements. Because of this, it is necessary to rely on other data. The source of the emission factors used for this analysis are from a report sponsored by the U.S. EPA titled, Development and Selection of Ammonia Emission Factors, August, 1994 (Battye). This report surveyed the literature for ammonia emission rates and selected the values judged to be most appropriate for use in the United States. The table below shows the emission factors selected. The original data tables used for selecting these data are included in Appendix A.

Especially for the dairy cattle, it is not possible to conceal that some relatively arbitrary decisions were made to assign emission rates. The rationale for these decisions is provided below, but it is acknowledged that another person could produce different, equally valid, emission factor selections. The emission factors will be updated as needed based on industry expert analysis and if accepted California specific data become available.

Table 3-2. Emission Factors Used For Dairy Cattle Ammonia Estimates

Category	Ammonia (lbs/head/year)	Source*
Dairy cow	37.58	Asman, 1990. Dairy cattle
Milk calves	11.53	Asman, 1992. Fattening calves
Milk heifers	28.75	Asman, 1992. Heifers over 500 lbs
Dairy bulls	61.53	Asman, 1992. Bulls over 500 lbs

* See the emission calculation notes in Appendix B for further detail on the emission factor selection.

3.2.1 Dairy cow

Dairy cow. This emission factor was the most difficult to select. Published emission factors for dairy cows range from 17 to over 87 lbs per head per year. Based on some (somewhat controversial) tests in Southern California, a value of 20 lbs/year was developed. Based on European tests, the values are as high as 87 lbs/animal (which likely includes different animal handling and housing practices than California). Because of the tremendous variability, a value somewhat in the low range of possibilities was

selected for these first estimates. This factor is comparable with the feedlot animal factor, so it puts the confined, non-range, animal operations on similar footings. In addition, in terms of magnitude, this value fits in well relative to the other factors for the calves, heifers, and bulls. California specific factors will be incorporated if they become available.

3.2.2 Calves

The emission factor for calves is from Table 2-1 of the Battye report, which is a summary of data by Asman. The factor used is for 'fattening calves'. It appears as if this factor is based on confined animal measurements since it includes stable, storage, and spreading emissions. This value also seems appropriate since it is lower than the range fed adult value, which is reasonable based on animal weight differences.

3.2.3 Milk heifers

The emission factor for animals in feedlots is from Table 2-1 of the Battye report, which is a summary of data by Asman. The factor used is from the young cattle profile for heifers that are 500 pounds and over in weight. The factor includes emission components from stable and storage, spreading, and grazing activities. This value is somewhat smaller than that used for the producing milk cows (28.75 vs 37.58).

3.2.4 Dairy Bulls

Dairy Bulls. The big boys. The emission factor for these animals is based on a factor specific to breeding bulls over 500 pounds from Table 2-9 of the Battye report (from Asman). The factor includes stable, storage, and spreading emission components. The factor for bulls is larger than for the other dairy related animals.

3.2.5 Composite emission factor

On a statewide basis, based on an estimate of 2,606,000 1,993,930 head of dairy cattle and total emissions of 38,805 tons/year of ammonia (see next section), the statewide composite emission factor for all dairy cattle is 30 pounds of ammonia/head/year. For beef cattle, the composite value is 18 lbs/head/year.

Future improvements. For those regions which appear to have ammonia concentrations that negatively affect air quality, it may be worthwhile to develop region specific emission rates. This information would better take into account the climate, feeding, soil, and animal handling practices relevant to the region.

3.3 Emission Estimates for Dairy Cattle

The previous sections describe how the number of beef cattle were estimated and what emission rates were assigned to each major animal type. The final step in estimating the ammonia emissions from dairy cattle is to multiply each population type by its respective

emission rate. This calculation was performed on a county basis for all of California. The results of this calculation are provided Table 3-3. For dairy cattle, on a statewide and county basis, the adult cows are the largest ammonia producers (about 24,000 tons/year), heifers cattle come in second (about 10,000 tons/year), calves come in at 3,300 tons/year, with bulls bringing up the rear with about 1,300 tons/year. The respective populations are approximately 1,260,000 head for adult cows, 734,000 for heifers, 570,000 for calves, and 42,000 head for bulls.

Table 3-3. Dairy Cattle Ammonia Emission Estimates by Animal Type for 1996.

		Ammonia Emissions (tons/year)					
Air Basin	**County**	**Cow**	**Calves**	**Heifer**	**Bulls**	**Total**	**Air Basin Total**
GBV	Alpine	0	0	0	0	0	
	Inyo	0	0	0	0	0	
	Mono	0	0	0	0	0	0
LC	Lake	0	0	0	0	0	0
LT	El Dorado	0	0	0	0	0	
	Placer	1	0	0	0	2	2
MC	Amador	0	0	0	0	0	
	Calaveras	0	0	0	0	0	
	El Dorado	0	0	0	0	0	
	Mariposa	0	0	0	0	0	
	Nevada	0	0	0	0	0	
	Placer	6	1	3	0	9	
	Plumas	0	0	0	0	0	
	Sierra	0	0	0	0	0	
	Tuolumne	0	0	0	0	0	9
MD	Kern	207	29	92	11	340	
	Los Angeles	5	1	2	0	8	
	Riverside	21	3	9	1	34	
	San Bernardino	58	8	26	3	96	478
NC	Del Norte	52	7	23	3	85	
	Humboldt	273	38	121	15	447	
	Mendocino	27	4	12	1	44	
	Trinity	0	0	0	0	0	
	Sonoma	319	44	142	17	524	1099
NCC	Monterey	57	8	25	3	93	
	San Benito	19	3	8	1	31	
	Santa Cruz	4	1	2	0	7	131
NEP	Lassen	0	0	0	0	0	
	Modoc	0	0	0	0	0	
	Siskiyou	16	2	7	1	26	26
SC	Los Angeles	21	3	9	1	34	
	Orange	0	0	0	0	0	
	Riverside	2040	283	909	111	3344	
	San Bernardino	2858	397	1274	156	4685	8063
SCC	San Luis Obispo	6	1	3	0	10	
	Santa Barbara	53	7	24	3	87	
	Ventura	0	0	0	0	0	97
SD	San Diego	134	19	60	7	220	220
SF	Alameda	0	0	0	0	0	
	Contra Costa	47	7	21	3	78	
	Marin	232	32	103	13	380	
	Napa	6	1	3	0	9	
	San Francisco	0	0	0	0	0	
	San Mateo	0	0	0	0	0	
	Santa Clara	22	3	10	1	36	
	Solano	13	2	6	1	22	
	Sonoma	207	29	92	11	339	863
SJV	Fresno	1326	184	591	72	2173	
	Kern	484	67	216	26	793	
	Kings	1856	258	827	101	3041	
	Madera	450	62	200	25	737	
	Merced	2896	402	1291	158	4747	
	San Joaquin	1534	213	684	84	2514	
	Stanislaus	2481	344	1106	135	4066	
	Tulare	5182	719	2309	283	8493	26564
SS	Imperial	29	4	13	2	48	
	Riverside	21	3	9	1	34	82
SV	Butte	11	2	5	1	18	
	Colusa	2	0	1	0	4	
	Glenn	258	36	115	14	423	
	Placer	3	0	1	0	4	
	Sacramento	281	39	125	15	460	
	Shasta	2	0	1	0	4	
	Solano	14	2	6	1	23	
	Sutter	9	1	4	0	14	
	Tehama	74	10	33	4	121	
	Yolo	9	1	4	1	15	
	Yuba	51	7	23	3	84	1171
	Total	23675	3286	10551	1292	38805	38805

4.0 All California Cattle – Emissions Summary

Table 4-1 summarizes the estimated beef and dairy cattle ammonia emissions for California counties and air basins. Figure 4-1 maps these data by county/air basin, and indicates ammonia emissions from beef cattle, dairy cattle, and total cattle. Note that the scales are different for each map. Also note that the emission ranges for each color on the map are not based on equal intervals such as 10 to 20, 20 to 30, and so on. Instead, the splits are based on natural breaks in the data. This provides a better comparison of emissions magnitudes than using equal intervals. For reference, Appendix D includes a California map with the districts and counties labeled.

The beef cattle map shows that beef ammonia emissions are relatively low per county, and they are also spread widely throughout the state. The map of dairy emissions shows high ammonia emissions in the San Joaquin Valley and a portion of Southern California, but relatively low emissions throughout the remainder of the state. Because of the dominance of the dairy emission levels, the areas in the state with the highest overall cattle ammonia emissions are also in the San Joaquin Valley and parts of Southern California.

Based on need, data could be obtained to provide more detailed spatial resolution of the sources of cattle ammonia emissions based on land use data and industry information on locations of dairies, feedlots, and typical grazing regions. Future research may also provide information to show how these ammonia emissions with time so it can be understood if the emissions are relatively consistent throughout the year, or are there times of the year when either there are more cattle brought in (such as with spring grazers) or when conditions are more conducive to ammonia generation.

Table 4-1. All California Cattle – Ammonia Emissions Summary for 1996

		Ammonia Emissions (tons/year)			
Air Basin	**County**	**Beef**	**Dairy**	**Total**	**Basin Total**
GBV	Alpine	53	0	53	
	Inyo	202	0	202	
	Mono	48	0	48	303
LC	Lake	71	0	71	71
LT	El Dorado	21	0	21	
	Placer	25	2	27	48
MC	Amador	162	0	162	
	Calaveras	283	0	283	
	El Dorado	151	0	151	
	Mariposa	263	0	263	
	Nevada	111	0	111	
	Placer	154	9	163	
	Plumas	202	0	202	
	Sierra	111	0	111	
	Tuolumne	162	0	162	1607
MD	Kern	488	340	828	
	Los Angeles	19	8	27	
	Riverside	24	34	58	
	San Bernardino	80	96	176	1089
NC	Del Norte	20	85	105	
	Humboldt	545	447	992	
	Mendocino	283	44	327	
	Trinity	40	0	40	
	Sonoma	196	524	720	2184
NCC	Monterey	929	93	1022	
	San Benito	313	31	344	
	Santa Cruz	28	7	35	1401
NEP	Lassen	1090	0	1090	
	Modoc	788	0	788	
	Siskiyou	1030	26	1056	2934
SC	Los Angeles	38	34	72	
	Orange	75	0	75	
	Riverside	16	3344	3360	
	San Bernardino	5	4685	4690	8196
SCC	San Luis Obispo	1030	10	1040	
	Santa Barbara	666	87	753	
	Ventura	141	0	141	1934
SD	San Diego	172	220	392	392
SF	Alameda	252	0	252	
	Contra Costa	212	78	290	
	Marin	111	380	491	
	Napa	87	9	96	
	San Francisco	0	0	0	
	San Mateo	77	0	77	
	Santa Clara	323	36	359	
	Solano	127	22	148	
	Sonoma	127	339	466	2179
SJV	Fresno	646	2173	2819	
	Kern	562	793	1354	
	Kings	81	3041	3122	
	Madera	263	737	1000	
	Merced	788	4747	5535	
	San Joaquin	687	2514	3201	
	Stanislaus	687	4066	4752	
	Tulare	606	8493	9099	30882
SS	Imperial	141	48	189	
	Riverside	17	34	51	240
SV	Butte	232	18	250	
	Colusa	323	4	327	
	Glenn	263	423	685	
	Placer	73	4	77	
	Sacramento	646	460	1106	
	Shasta	384	4	387	
	Solano	136	23	159	
	Sutter	111	14	125	
	Tehama	687	121	808	
	Yolo	162	15	177	
	Yuba	141	84	225	4328
	Total	18983	38805	57788	57788

5.0 Comparison of ARB Estimates with Other Estimates

This is the first time the ARB has prepared a statewide estimate of ammonia emissions for beef and dairy cattle. Various other studies have developed regional estimates of ammonia emissions. This section compares the ARB values with the other studies and provides reasons for the differences. [to be completed]

6.0 Future Improvements to Methodology

As complex as it is, this emissions estimation methodology is only a starting point for performing a comprehensive ammonia estimates for beef and dairy cattle. However, before committing substantial resources to improving this method on a statewide basis, it is more important to perform initial ammonia estimates for all of the major ammonia source categories. This data can then be combined with ambient air quality data to determine which regions are negatively impacted by ammonia emissions. With this information available, the regions with significant ammonia related problems can then be targeted for more comprehensive and specific ammonia estimates.

For those areas with high particulate levels associated with ammonia in the air, there are several inputs to the emission estimates which can be further refined. Some of these issues are discussed in letters written by the California Cattlemen's Association and the University of California at Davis. The letters are provided as attachments to this methodology.

Population, Spatial, and Seasonal Data. Through working closely with industry groups, more recent, and more location and time specific population data can be developed. This would include when animals of each type tend to be present throughout the year to improve seasonal estimates, as well as much more detailed animal siting information. beyond the county level now used.

Emission Factors. This is the area in which additional work is most needed for better refined emission estimates. None of the emission factors used in this methodology are based on measurements made in California with California climatic conditions and California animal handling practices. The current emission factors are also based on a per animal basis derived from either field measurements or calculations of ammonia potential based on nitrogen input/output calculations. These provide some apportioning of emissions between grazing, stable, and manure spreading, but substantial improvements could be made on developing more process specific emission rates. Improved factors will assist in identifying and applying the most cost effective control strategies for regions negatively affected by ammonia emissions.

Other Cattle Related Pollutants. With the information provided by this methodology, it is possible to develop estimates of volatile organic compounds (VOC's) and methane produced by cattle livestock operations. The information could also be used to produce estimates for the particulate matter dust emissions that can be produced by large numbers

of confined animals. The Air Resources Board is beginning to collect emission factor information which will allow emission estimates for these pollutants.

Many of the methodology refinements listed here require significant resources and some substantial changes to current methodology. For that reason, again, it is recommended that the more detailed information be gathered and applied only for those areas in which ammonia emissions not only contribute significantly to regional air pollution, but where control of the ammonia might be a significant tool in improving air quality. For example, some regions might have such pervasive ammonia levels that control of other pollutants, such as automotive exhaust and other combustion products, would provide more inexpensive and effective control strategies. [to be completed]

7.0 References

(1) California Livestock Statistics Bulletin, 1990. Published by California Agricultural Statistics Service, June, 1991.
(2) California Agricultural Resource Directory, 1997. Published by California Department of Food and Agriculture, December 1997.
(3) Memo from George Gough, Director Government Relations, California Cattlemen's Association. RE: San Joaquin Valley Beef Cattle Statistics, February 25, 1998
(4) Development and Selection of Ammonia Emission Factors, Final Report, August 1994. By R. Battye, W. Battye, C. Overcash, and S. Fudge, of EC/R Incorporated, Durham, North Carolina 27706. EPA Contract Number 68-D3-0034, EPA/600/R-94/190, William Benjey, contract manager.

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September, 1999

APPENDIX A

Estimates of Ammonia Emissions from Beef and Dairy Cattle in California

Selected Excerpts from References

- California Agricultural Statistics Service
- California Department of Food and Agriculture
- Development and Selection of Ammonia Emission Factors, Battye, 1994

APPENDIX B

Detailed Beef and Dairy Ammonia Emissions Estimation Spreadsheets

Review Draft

Emissions Estimation Methodology
California Air Resources Board

Detailed Beef and Dairy Ammonia Emissions Estimation Spreadsheets

The following tables were used to generate the emission estimates developed in this methodology. The beef tables are first followed by the dairy tables. The notes which follow the tables are an important part of this appendix. The notes provide the assumptions and decisions made in estimating populations, selecting emission factors, and estimating the ammonia emissions. Excerpts of the references listed in notes are provided in Appendix A.

The titles of the tables in this appendix are:

Table B-1. California Beef Cattle Population Estimates by County
Table B-2. Beef Cattle Ammonia Emission Estimates by Animal Type for 1996
Table B-3. Summary Data used for Beef Population Estimates
Table B-4. Emission Factors used for Beef Cattle

Table B-5. California Dairy Cattle Population Estimates by County
Table B-6. Dairy Cattle Ammonia Emission Estimates by Animal Type for 1996
Table B-7. Summary Data used for Dairy Population Estimates
Table B-8. Emission Factors used for Diary Cattle

Table B-1. California Beef Cattle Population Estimates by County

		Population Input Data			Population Data					
Air Basin	County	(a) 1991* Beef Cow Data (temp)	(b) Air Basin Scaling	(c) 1991 Range Beef Cows	(d) 1996 Cows that Calved	(e) 1996 Range Calves	(f) 1996 Range Stockers Inshipment	(g) 1996 Feedlot Feeder	(h) 1996 Beef Cattle Total	Air Basin Total Populations
GBV	Alpine	2600	1	2600	2323	1051	1359	781	5515	
	Inyo	10000	1	10000	8936	4043	5227	3005	21211	
	Mono	2400	1	2400	2145	970	1254	721	5091	31816
LC	Lake	3500	1	3500	3128	1415	1829	1052	7424	7424
LT	El Dorado	8500	0.122	1037	927	419	542	312	2200	
	Placer	12500	0.101	1262	1128	510	660	379	2678	4877
MC	Amador	8000	1	8000	7149	3234	4181	2404	16969	
	Calaveras	14000	1	14000	12511	5660	7317	4207	29695	
	El Dorado	8500	0.878	7463	6669	3017	3901	2243	15830	
	Mariposa	13000	1	13000	11617	5255	6795	3907	27574	
	Nevada	5500	1	5500	4915	2223	2875	1653	11666	
	Placer	12500	0.611	7637	6825	3088	3992	2295	16200	
	Plumas	10000	1	10000	8936	4043	5227	3005	21211	
	Sierra	5500	1	5500	4915	2223	2875	1653	11666	
	Tuolumne	8000	1	8000	7149	3234	4181	2404	16969	167777
MD	Kern	52000	0.465	24180	21608	9775	12638	7267	51287	
	Los Angeles	2800	0.334	935	836	378	489	281	1984	
	Riverside	2800	0.427	1196	1068	483	625	359	2536	
	San Bernardino	4200	0.944	3965	3543	1603	2072	1192	8410	64217
NC	Del Norte	1000	1	1000	894	404	523	301	2121	
	Humboldt	27000	1	27000	24128	10915	14112	8114	57269	
	Mendocino	14000	1	14000	12511	5660	7317	4207	29695	
	Trinity	2000	1	2000	1787	809	1045	601	4242	
	Sonoma	16000	0.607	9712	8679	3926	5076	2919	20600	113927
NCC	Monterey	46000	1	46000	41106	18596	24042	13824	97569	
	San Benito	15500	1	15500	13851	6266	8101	4658	32877	
	Santa Cruz	1400	1	1400	1251	566	732	421	2969	133415
NEP	Lassen	54000	1	54000	48255	21830	28224	16229	114538	
	Modoc	39000	1	39000	34851	15766	20384	11721	82722	
	Siskiyou	51000	1	51000	45574	20617	26656	15327	108174	305434
SC	Los Angeles	2800	0.666	1865	1666	754	975	560	3955	
	Orange	3700	1	3700	3306	1496	1934	1112	7848	
	Riverside	2800	0.281	787	703	318	411	236	1669	
	San Bernardino	4200	0.056	235	210	95	123	71	499	13971
SCC	San Luis	51000	1	51000	45574	20617	26656	15327	108174	
	Santa Barbara	33000	1	33000	29489	13340	17248	9918	69995	
	Ventura	7000	1	7000	6255	2830	3659	2104	14847	193017
SD	San Diego	8500	1	8500	7596	3436	4443	2555	18029	18029
SF	Alameda	12500	1	12500	11170	5053	6533	3757	26513	
	Contra Costa	10500	1	10500	9383	4245	5488	3156	22271	
	Marin	5500	1	5500	4915	2223	2875	1653	11666	
	Napa	4300	1	4300	3843	1738	2247	1292	9121	
	San Francisco	0	1	0	0	0	0	0	0	
	San Mateo	3800	1	3800	3396	1536	1986	1142	8060	
	Santa Clara	16000	1	16000	14298	6468	8363	4809	33937	
	Solano	13000	0.482	6266	5599	2533	3275	1883	13291	
	Sonoma	16000	0.393	6288	5619	2542	3287	1890	13337	138196
SJV	Fresno	32000	1	32000	28596	12936	16725	9617	67874	
	Kern	52000	0.535	27820	24860	11246	14540	8361	59008	
	Kings	4000	1	4000	3574	1617	2091	1202	8484	
	Madera	13000	1	13000	11617	5255	6795	3907	27574	
	Merced	39000	1	39000	34851	15766	20384	11721	82722	
	San Joaquin	34000	1	34000	30383	13745	17771	10218	72116	
	Stanislaus	34000	1	34000	30383	13745	17771	10218	72116	
	Tulare	30000	1	30000	26809	12128	15680	9016	63632	453527
SS	Imperial	7000	1	7000	6255	2830	3659	2104	14847	
	Riverside	2800	0.292	818	731	331	427	246	1734	16582
SV	Butte	11500	1	11500	10277	4649	6011	3456	24392	
	Colusa	16000	1	16000	14298	6468	8363	4809	33937	
	Glenn	13000	1	13000	11617	5255	6795	3907	27574	
	Placer	12500	0.289	3612.5	3228	1460	1888	1086	7662	
	Sacramento	32000	1	32000	28596	12936	16725	9617	67874	
	Shasta	19000	1	19000	16979	7681	9931	5710	40300	
	Solano	13000	0.518	6734	6018	2722	3520	2024	14283	
	Sutter	5500	1	5500	4915	2223	2875	1653	11666	
	Tehama	34000	1	34000	30383	13745	17771	10218	72116	
	Yolo	8000	1	8000	7149	3234	4181	2404	16969	
	Yuba	7000	1	7000	6255	2830	3659	2104	14847	331621
	Totals	1067100*		940012	840011	380005	491310	282504	1993830	1993830

*not population total

Table B-2. Beef Cattle Ammonia Emission Estimates by Animal Type for 1996

		Ammonia Emissions (tons/year)				
		(i)	(j)	(k)	(l)	Air Basin
Air Basin	County	Range	Calves	Feedlot	Total	Total
GBV	Alpine	33	6	13	53	
	Inyo	128	23	50	202	
	Mono	31	6	12	48	303
LC	Lake	45	8	18	71	71
LT	El Dorado	13	2	5	21	
	Placer	16	3	6	25	46
MC	Amador	103	19	40	162	
	Calaveras	180	33	70	283	
	El Dorado	96	17	38	151	
	Mariposa	167	30	65	263	
	Nevada	71	13	28	111	
	Placer	98	18	38	154	
	Plumas	128	23	50	202	
	Sierra	71	13	28	111	
	Tuolumne	103	19	40	162	1597
MD	Kern	310	56	122	488	
	Los Angeles	12	2	5	19	
	Riverside	15	3	6	24	
	San Bernardino	51	9	20	80	611
NC	Del Norte	13	2	5	20	
	Humboldt	346	63	136	545	
	Mendocino	180	33	70	283	
	Trinity	26	5	10	40	
	Sonoma	125	23	49	196	1085
NCC	Monterey	590	107	231	929	
	San Benito	199	36	78	313	
	Santa Cruz	18	3	7	28	1270
NEP	Lassen	693	126	272	1090	
	Modoc	500	91	196	788	
	Siskiyou	654	119	257	1030	2908
SC	Los Angeles	24	4	9	38	
	Orange	47	9	19	75	
	Riverside	10	2	4	16	
	San Bernardino	3	1	1	5	133
SCC	San Luis Obispo	654	119	257	1030	
	Santa Barbara	423	77	166	666	
	Ventura	90	16	35	141	1838
SD	San Diego	109	20	43	172	172
SF	Alameda	160	29	63	252	
	Contra Costa	135	24	53	212	
	Marin	71	13	28	111	
	Napa	55	10	22	87	
	San Francisco	0	0	0	0	
	San Mateo	49	9	19	77	
	Santa Clara	205	37	81	323	
	Solano	80	15	32	127	
	Sonoma	81	15	32	127	1316
SJV	Fresno	411	75	161	646	
	Kern	357	65	140	562	
	Kings	51	9	20	81	
	Madera	167	30	65	263	
	Merced	500	91	196	788	
	San Joaquin	436	79	171	687	
	Stanislaus	436	79	171	687	
	Tulare	385	70	151	606	4318
SS	Imperial	90	16	35	141	
	Riverside	10	2	4	17	158
SV	Butte	148	27	58	232	
	Colusa	205	37	81	323	
	Glenn	167	30	65	263	
	Placer	46	8	18	73	
	Sacramento	411	75	161	646	
	Shasta	244	44	96	384	
	Solano	86	16	34	136	
	Sutter	71	13	28	111	
	Tehama	436	79	171	687	
	Yolo	103	19	40	162	
	Yuba	90	16	35	141	3157
	Total	12062	2191	4731	18983	18983

Table B-3. Summary Data used for Beef Population Estimates

Statewide data used to compute county apportioned data		
Data	Value	Source
1991 state beef cow inventory, by county	940000	from CASS report, Table 14 (ref. 1)
1996 state beef cow inventory, statewide	840000	from CDFA, p. 96 (ref. 2)
1996/1991 ratio	0.894	calculated value
1996 beef calf estimate	380000	calculated value, see note (e)
1996 statewide stocker total	820000	from CDFA, p. 96, plus modifications
1996 statewide feedlot estimate	282500	calculated value, see notes
1996 statewide beef total estimate	1993789	calculated from CDFA, p. 96, based on dairy & beef splits (see Table A-3 calc.)

Table B-4. Emission Factors used for Beef Cattle

Category	NH_3 (lbs/head)	Source
Range adults	18.12	Asman, 1992. Best fit for range, see note (l)
Calves	11.53	Asman, 1992. Best fit for calves, see note (j)
Feedlot animals	33.49	Asman, 1992. Best fit for feedlot, see note (k)

Notes for Tables B-1, B-2, B-3, and B-4

The notes below reference documents from the California Agricultural Statistics Service and the California Department of Food and Agriculture. Excerpts from these documents relevant to the notes are provided in Appendix A.

(a) Beef cow inventory from Table 14, California Livestock Statistics Bulletin, CASS 1990. This report includes all beef cattle, and shows the head of cattle in each county (which is not included in more recent reports). The purpose of this section (columns a,b,c) is to apportion cattle by county, and to split the populations by air basin where a county is in more. than one air basin. Column is intermediate data only.
The column (a) total does not match final total in the CASS source table because each county that is part of more than one air basin county is assigned the total county value in this column. This method was used due to lack of more detailed information available to subdivide the beef cattle populations by county for later years.
Values do not agree with California Cattle by Class table on page 96 of California Agricultural Resource Directory, prepared by CDFA. CASS 1991 total = 940,000; CDFA total = 900,000 for 1991; 840,000 for 1996.
Beef cows are generally range fed grazers.

(b) Used to apportion cattle across split air basins. Split based on land acreage in each basin (possibly use pasture lands in future).

(c) Computed county/air basin beef cow populations for 1991 based on air basin scaling proportions. This column is only used to apportion the statewide population totals available for 1996 between the counties.

Notes for Tables B-1, B-2, B-3, and B-4 (continued)

(d) County specific information is not available for 1991. Use 1996 CDFA, p.96 beef cow statewide totals (840,000 head) and 1991 county splits (column c) population to compute grazers by county for 1996. This calculation assumes that the 1991 county population data represents the relative proportion of animals in each county during 1996.

(e) Available reports do not include separate estimates of beef calves and calves that are associated with dairy. Therefore, the number of calves are estimated based on the proportions of beef and dairy cows that have calved (CDFA p. 96). The CDFA report shows that there were 950,000 calves under 500 lbs during 1996. The CDFA table shows populations of 840,000 beef cows that have calved and 1,260,000 dairy cows that have calved. Therefore the 40% of the total cows are beef cows, so the beef calves total = 950,000 x 0.40 = 380,000. Most beef calves are range fed (ref. CA Cattlemen's Assoc.) Note: The calf under 500 lbs inventory (p. 96) does not agree with the calf crop inventory on p. 96 (950,000 vs 1,750,000). This appears to be because the calf crop is the number of animals born and does not include marketing, death, and slaughter losses. The under 500 category seems to include only the live animals. With additional data could also possibly distribute calves by range lands in each county.

(f) Apportion 820,000 stockers/inshipments (CDFA p. 96) by county populations and apply residency time correction. Stockers are based on inshipments and are generally cattle brought in from out of state to graze on grasslands. It is assumed that all stockers/inshipments are beef animals. Stockers are currently apportioned based on the beef cow grazing population in each county (future refinements to allocation could be made based on pasture lands and industry info on county grazing). Inshipments are a distinct population from the cows that have calved (column (d)). Inshipment cattle are present for about 7 months (Nov-May); therefore the inshipment population was scaled as (7.1898 months/12 months) x 820,000 = 491,300 The residency time was adjusted slightly so the computed beef cattle total agrees with the composite CDFA beef cattle total inventory (= 1,994,000)

(g) Feeders are beef cattle fed in feedlots, total based on CDFA, p. 94 (= 565,000 head marketed). Based on data in Table 12 & 13 of CASS report, the ratio of animals present to animals marketed = 0.5. This means that the marketed animals are, on average, only present for six months, or that only half the marketed animals are present at any one time. From this data the statewide number of feedlot cattle present in CA are estimated at 565,000 * 0.5 = 282,500 head on an average day. The animals are apportioned to counties based on beef cow population (can improve based on industry county feedlot data).

(h) Total population of beef cattle including range adults, calves, stockers, and feedlot cattle.

Note on bulls, heifers and steers:
The CDFA California Cattle by Class table, p. 96, provides information to estimate beef related bull, heifer, and steer populations. The ARB population estimate does not explicitly include estimates for these animals, however, they are implicitly included in the inshipment and feedlot categories. Based on the CDFA data, the number of beef bulls, heifers, and steers is estimated to be 774,000. Using the ARB method, the number of beef animals in the inshipment and feedlot categories is 773, 803 animals. This indicates that the animals included in the CDFA data are accounted for by the ARB method.

Currently there is not clear information to determine which portion of the inshipments or feedlot animals are heifers or steers, and it is not possible to explicitly allocate the bulls. This is why they are not individually listed. For this analysis, it is assumed that grazing heifers and steers have the same emission characteristics as grazing cows. It is also assumed that feedlot heifers and steers have the same emission rates as feedlot cows. Based on currently available emission factors it does appear that bulls do have higher emission rates than the other cattle. Incorporating bull-specific emission rates into the feedlot and stocker categories increases emissions by 588 tons per year, or an overall increase of 3%. Because of the relatively small change and the

uncertainty in the emission factors and to keep the calculations relatively simple, at this time, emissions from bulls are assumed to be the same as other cattle in the respective stocker or feedlot categories.

References for Notes

(1) California Livestock Statistics Bulletin, 1990. Published by California Agricultural Statistics Service, June, 1991.
(2) California Agricultural Resource Directory, 1997. Published by California Department of Food and Agriculture, December 1997.
(3) Memo from George Gough, Director Government Relations, California Cattlemen's Association, RE: San Joaquin Valley Beef Cattle Statistics, February 25, 1998.

Table B-5. California Dairy Cattle Population Estimates by County

		Population Input Data			Population Data					
Air Basin	County	(a) 1997 Dairy Cow Data (temp)	(b) Air Basin Scaling	(c) 1997 Dairy Cow Population	(d) Dairy Cows	(e) Estimated Milk Calves	(f) Milk Heifers	(g) Dairy Bulls	(h) 1996 Dairy Cow Total	Air Basin Total Populations
GBV	Alpine	0	1	0	0	0	0	0	0	
	Inyo	0	1	0	0	0	0	0	0	
	Mono	0	1	0	0	0	0	0	0	0
LC	Lake	0	1	0	0	0	0	0	0	0
LT	El Dorado	0	0	0	0	0	0	0	0	
	Placer	522	0	53	50	22	29	2	103	103
MC	Amador	0	1	0	0	0	0	0	0	
	Calaveras	0	1	0	0	0	0	0	0	
	El Dorado	0	1	0	0	0	0	0	0	
	Mariposa	0	1	0	0	0	0	0	0	
	Nevada	0	1	0	0	0	0	0	0	
	Placer	522	1	319	301	136	175	10	622	
	Plumas	0	1	0	0	0	0	0	0	
	Sierra	0	1	0	0	0	0	0	0	
	Tuolumne	0	1	0	0	0	0	0	0	622
MD	Kern	39011	0	11703	11034	4991	6427	368	22820	
	Los Angeles	1463	0	293	276	125	161	9	571	
	Riverside	117509	0	1175	1108	501	645	37	2291	
	San Bernardino	164645	0	3293	3104	1404	1808	103	6421	32103
NC	Del Norte	2922	1	2922	2755	1246	1605	92	5698	
	Humboldt	15383	1	15383	14503	6561	8448	483	29995	
	Mendocino	1514	1	1514	1427	646	831	48	2952	
	Trinity	0	1	0	0	0	0	0	0	
	Sonoma	29710	1	18034	17002	7691	9904	567	35164	73809
NCC	Monterey	3204	1	3204	3021	1366	1760	101	6247	
	San Benito	1060	1	1060	999	452	582	33	2067	
	Santa Cruz	239	1	239	225	102	131	8	466	8780
NEP	Lassen	0	1	0	0	0	0	0	0	
	Modoc	0	1	0	0	0	0	0	0	
	Siskiyou	902	1	902	850	385	495	28	1759	1759
SC	Los Angeles	1463	1	1170	1103	499	643	37	2282	
	Orange	0	1	0	0	0	0	0	0	
	Riverside	117509	1	115159	108569	49114	63246	3619	224548	
	San Bernardino	164645	1	161352	152119	68816	88615	5071	314620	541450
SCC	San Luis	343	1	343	323	146	188	11	669	
	Santa Barbara	2986	1	2986	2815	1274	1640	94	5822	
	Ventura	0	1	0	0	0	0	0	0	6491
SD	San Diego	7586	1	7586	7152	3235	4166	238	14792	14792
SF	Alameda	0	1	0	0	0	0	0	0	
	Contra Costa	2671	1	2671	2518	1139	1467	84	5208	
	Marin	13078	1	13078	12330	5578	7182	411	25501	
	Napa	322	1	322	304	137	177	10	628	
	San Francisco	0	1	0	0	0	0	0	0	
	San Mateo	0	1	0	0	0	0	0	0	
	Santa Clara	1244	1	1244	1173	531	683	39	2426	
	Solano	1547	0	746	703	318	410	23	1454	
	Sonoma	29710	0	11676	11008	4980	6413	367	22767	57984
SJV	Fresno	74827	1	74827	70545	31913	41095	2352	145905	
	Kern	39001	1	27301	25738	11644	14994	858	53234	
	Kings	104751	1	104751	98757	44676	57530	3292	204254	
	Madera	25393	1	25393	23940	10830	13946	798	49514	
	Merced	163493	1	163493	154137	69729	89791	5138	318795	
	San Joaquin	86593	1	86593	81638	36931	47557	2721	168848	
	Stanislaus	140032	1	140032	132019	59723	76906	4401	273048	
	Tulare	292509	1	292509	275770	124753	160647	9192	570363	1783959
SS	Imperial	1655	1	1655	1560	706	909	52	3227	
	Riverside	117509	0	1175	1108	501	645	37	2291	5518
SV	Butte	620	1	620	585	264	341	19	1209	
	Colusa	141	1	141	133	60	77	4	275	
	Glenn	14562	1	14562	13729	6211	7998	458	28394	
	Placer	522	0	151	142	64	83	5	294	
	Sacramento	15844	1	15844	14937	6757	8702	498	30894	
	Shasta	125	1	125	118	53	69	4	244	
	Solano	1547	1	801	755	342	440	25	1563	
	Sutter	488	1	488	460	208	268	15	952	
	Tehama	4174	1	4174	3935	1780	2292	131	8139	
	Yolo	521	1	521	491	222	286	16	1016	
	Yuba	2891	1	2891	2726	1233	1588	91	5637	78616
	Totals	1808908*		1336474	1259994	569997	733996	42000	2605987	2605987

*not population total

Table B-6. Dairy Cattle Ammonia Emission Estimates by Animal Type for 1996.

		Ammonia Emissions (tons/year)					
Air Basin	**County**	(i) **Adult Cow**	(j) **Calves**	(k) **Heifer**	(l) **Bulls**	(m) **Total**	**Air Basin Total**
GBV	Alpine	0	0	0	0	0	
	Inyo	0	0	0	0	0	
	Mono	0	0	0	0	0	0
LC	Lake	0	0	0	0	0	0
LT	El Dorado	0	0	0	0	0	
	Placer	1	0	0	0	2	2
MC	Amador	0	0	0	0	0	
	Calaveras	0	0	0	0	0	
	El Dorado	0	0	0	0	0	
	Mariposa	0	0	0	0	0	
	Nevada	0	0	0	0	0	
	Placer	6	1	3	0	9	
	Plumas	0	0	0	0	0	
	Sierra	0	0	0	0	0	
	Tuolumne	0	0	0	0	0	9
MD	Kern	207	29	92	11	340	
	Los Angeles	5	1	2	0	8	
	Riverside	21	3	9	1	34	
	San Bernardino	58	8	26	3	96	478
NC	Del Norte	52	7	23	3	85	
	Humboldt	273	38	121	15	447	
	Mendocino	27	4	12	1	44	
	Trinity	0	0	0	0	0	
	Sonoma	319	44	142	17	524	1099
NCC	Monterey	57	8	25	3	93	
	San Benito	19	3	8	1	31	
	Santa Cruz	4	1	2	0	7	131
NEP	Lassen	0	0	0	0	0	
	Modoc	0	0	0	0	0	
	Siskiyou	16	2	7	1	26	26
SC	Los Angeles	21	3	9	1	34	
	Orange	0	0	0	0	0	
	Riverside	2040	283	909	111	3344	
	San Bernardino	2858	397	1274	156	4685	8063
SCC	San Luis Obispo	6	1	3	0	10	
	Santa Barbara	53	7	24	3	87	
	Ventura	0	0	0	0	0	97
SD	San Diego	134	19	60	7	220	220
SF	Alameda	0	0	0	0	0	
	Contra Costa	47	7	21	3	78	
	Marin	232	32	103	13	380	
	Napa	6	1	3	0	9	
	San Francisco	0	0	0	0	0	
	San Mateo	0	0	0	0	0	
	Santa Clara	22	3	10	1	36	
	Solano	13	2	6	1	22	
	Sonoma	207	29	92	11	339	863
SJV	Fresno	1326	184	591	72	2173	
	Kern	484	67	216	26	793	
	Kings	1856	258	827	101	3041	
	Madera	450	62	200	25	737	
	Merced	2896	402	1291	158	4747	
	San Joaquin	1534	213	684	84	2514	
	Stanislaus	2481	344	1106	135	4066	
	Tulare	5182	719	2309	283	8493	26564
SS	Imperial	29	4	13	2	48	
	Riverside	21	3	9	1	34	82
SV	Butte	11	2	5	1	18	
	Colusa	2	0	1	0	4	
	Glenn	258	36	115	14	423	
	Placer	3	0	1	0	4	
	Sacramento	281	39	125	15	460	
	Shasta	2	0	1	0	4	
	Solano	14	2	6	1	23	
	Sutter	9	1	4	0	14	
	Tehama	74	10	33	4	121	
	Yolo	9	1	4	1	15	
	Yuba	51	7	23	3	84	1171
	Total	23675	3286	10551	1292	38805	38805

Table B-7. Summary Data used for Dairy Population Estimates

Statewide data used to compute county apportioned data		
Data	Value	Source
1997 state milk cow inventory, by county	1336480	from CDFA, p. 91
1996 state Dairy cow inventory, statewide	1260000	from CDFA, p. 96, cows that have calved
1996/1991 ratio	0.943	calculated value
1996 dairy calf estimate	570000	calculated value, see notes
1996 dairy heifer estimate	734000	from CDFA, p. 96, calculated value
1996 dairy related bulls	42000	from CDFA, p. 96, calculated value
1996 dairy cattle total	2606211	calculated from CDFA, p. 96, based on

Table B-8. Emission Factors used for Beef Cattle

Emission factors used for ammonia estimates		
Category	NH_3 (lbs/head)	Source
Milk cows	37.58	Asman, 1990. Table 2-4, Battye Report, Dairy Cattle
Calves	11.53	Asman, 1992. Table 2-1, Battye Report, Fattening Calves
Heifers	28.75	Asman, 1992, Table 2-9, Battye Report, Heifers Over 500 lbs
Bulls	61.53	Asman, 1992, Table 2-9, Battye Report, Bulls Over 500 lbs

Notes for Tables B-5, B-6, B-7, and B-8

(a) Milk cow inventory from Page 91, California Agricultural Resource Directory, 1997.
This includes all Dairy cattle. Column is temporary data used for calculations only. Column total does not match actual total because each split county is assigned the total county value. The California Agricultural Statistics Service values such as those used for beef were not used because the CDFA data are more recent. Both the CASS and CDFA data appear to be based not on actual head counts, but estimates based on total production and the average milk output per cow.

(b) Used to apportion cattle across split air basins. Split based on land acreage in each basin and other data where available.

(c) Computed county/air basin emissions for 1997 based on air basin scaling proportions. Scaling by acreage. See beef method for more details.

(d) To keep the dairy and beef cattle counts consistent, 1996, and not 1997 total population data were used (CDFA, p.96 dairy cow statewide totals (1,260,000 head)).
These data were apportioned by county using 1997 population data (column c), the most recently available data, to compute dairy cows by county for 1996.
Although 1996 data could have been used consistently throughout the estimates, it was decided to use the 1997 data for the county splits since they would most accurately reflect the current populations. Additionally, between 1996 and 1997, there is an increase of over 70,000 head to the San Joaquin Valley and it is important to reflect this substantial change in the inventory estimates.

Notes for Tables B-5, B-6, B-7, and B-8 (continued)

(e) Available reports do not include separate estimates of beef calves and calves that are associated with dairy. Therefore, the number of calves are estimated based on the proportions of beef and dairy cows that have calved (CDFA p. 96).
- The CDFA report shows that there were 950,000 calves under 500 lbs during 1996.
- The CDFA table shows populations of 840,000 beef cows that have calved and 1,260,000 dairy cows that have calved.
- Therefore the 60% of the total cows are beef cows, so the beef calves total = 950,000 x 0.60 = 570,000.
- Most beef calves are range fed (ref. CA Cattlemen's Assoc.)
- Note: The calf under 500 lbs inventory (p. 96) does not agree with the calf crop inventory on p. 96 (950,000 vs 1,750,000). This appears to be because the calf crop is the number of animals born and does not include marketing, death, and slaughter losses.
- The under 500 category seems to just include the live animals. With additional data could also possibly split calves by range lands in each county.

(f) CDFA p. 96 shows 600,000 milk heifers and 170,000 other heifers. Based on beef and milk heifer ratios, 79% of the other heifer category was assigned to the milk heifer category (134,000 head).

(g) Page 96 of the CDFA report shows 70,000 bulls in California. Sixty percent of these bulls were allocated to the dairy industry based on the proportion of dairy cows that have calved to all cows (60%, which is 42,000 head). Apportioned to counties based on dairy cow population

(h) Total population of dairy cattle including cows, calves, heifers, and bulls

(i) Adult dairy cow emissions = dairy cow population (column d) x milk cow emission factor
Emission factor is from Table 2-4 (Asman) of Battye report. Emission factors for dairy cows range from 17 to 87 lbs per animal per year. The lower factor was selected somewhat arbitrarily. Based on (somewhat controversial) tests in Southern California, an emission factor of 20 lbs per animal was developed. Based on data from mostly European tests, values may be as high as 87 lbs per animal (which probably includes animals that are housed differently than California animals). Because of the tremendous variations, the factor shown was selected for the first round of estimates. California specific factors will be incorporated when they are available. The factor selected also is comparable with the feedlot animal factor, so it puts the confined non-range animal operations on similar footings.

(j) Calf emissions = calf population (column e) x calf emission factor
Emission factor is from Table 2-1 of the Battye report (from Asman). It is the 'fattening calves' emission factor. This factor is primarily for confined animals. It is the current best fit value and it is significantly lower than adult value, which is reasonable based on the differences in the animal's weights.

(k) Heifer emissions = heifers (column f) x heifer (500 lbs and over) emission factor
Emission factor is from Table 2-9 and Table 2-1 of the Battye report (from Asman). It is the 'young cattle profile' for heifers that are 500 lbs and over. This factor includes emission components from stable and storage, spreading, and grazing. This value is somewhat smaller than that used for the producing milk cows (28.75 versus 37.58).

(l) Bull emissions = bulls (column g) x bull emission factor
Emission factor is from Table 2-9 and 2-1 of the Battye report (from Asman). It is specific to breeding bulls 500 lbs and over.

(m) Total of Adult Range, Calves, and Feedlot animals

References for notes

(1) California Agricultural Resource Directory, 1997. Published by California Department of Food and Agriculture, December 1997.
(2) California Livestock Statistics Bulletin, 1990. Published by California Agricultural Statistics Service, June, 1991.
(3) Memo from George Gough, Director Government Relations, California Cattlemen's Association. RE: San Joaquin Valley Beef Cattle Statistics, February 25, 1998.

APPENDIX C

Comments Received on the Draft Ammonia Emission Estimation Methodology by the San Joaquin Valley Unified Air Pollution Control District

Emissions Estimation Methodology
California Air Resources Board

APPENDIX D

California Counties and Air Basins