AMMONIA EMISSION INVENTORY FOR THE STATE OF WYOMING

Prepared for Susan Caplan
Bureau of Land Management
Department of Interior

by

Thomas W. Kirchstetter
TWKirchstetter@lbl.gov

Colette R. Maser
CRMaser@lbl.gov

Nancy J. Brown, Principal Investigator
NJBrown@lbl.gov

Atmospheric Sciences Department
Lawrence Berkeley National Laboratory
Berkeley, California 94720

ABSTRACT

Ammonia (NH_3) is the only significant gaseous base in the atmosphere and it has a variety of impacts as an atmospheric pollutant, including the formation of secondary aerosol particles: ammonium sulfate and ammonium nitrate. NH_3 preferentially forms ammonium sulfate; consequently ammonium nitrate aerosol formation may be limited by the availability of NH_3. Understanding the impact of emissions of oxides of sulfur and nitrogen on visibility, therefore, requires accurately determined ammonia emission inventories for use in air quality models, upon which regulatory and policy decisions increasingly depend.

This report presents an emission inventory of NH_3 for the state of Wyoming. The inventory is temporally and spatially resolved at the monthly and county level, and is comprised of emissions from individual sources in ten categories: livestock, fertilizer, domestic animals, wild animals, wildfires, soil, industry, mobile sources, humans, and publicly owned treatment works. The Wyoming NH_3 inventory was developed using the Carnegie Mellon University (CMU) Ammonia Model as framework. Current Wyoming-specific activity data and emissions factors obtained from state agencies and published literature were assessed and used as inputs to the CMU Ammonia Model.

Biogenic emissions from soils comprise about three-quarters of the Wyoming NH_3 inventory, though emission factors from soils are highly uncertain. Published emission factors are scarce and based on limited measurements. In Wyoming, agricultural land, rangeland, and forests comprise 96% of the land area and essentially all of the estimated emissions from soils. Future research on emission rates of NH_3 for these land categories may lead to a substantial change in the magnitude of soil emissions, a different inventory composition, and reduced uncertainty in the inventory.

While many NH_3 inventories include annual emissions, air quality modeling studies require finer temporal resolution. Published studies indicate higher emission rates from soils and animal wastes at higher temperatures, and temporal variation in fertilizer application. A recent inverse modeling study indicates temporal variation in regional NH_3 emissions. Monthly allocation factors were derived to estimate monthly emissions from soils, livestock and wild animal waste based on annual emission estimates. Monthly resolution of NH_3 emissions from fertilizers is based on fertilizer sales to farmers. Statewide NH_3 emissions are highest in the late spring and early summer months.

INTRODUCTION

Ammonia (NH_3) is the third most abundant nitrogen gas and is the only significant gaseous base in the atmosphere. NH_3 has a short atmospheric lifetime of hours to days, but has a wide variety of impacts as an atmospheric pollutant. Among them are eutrophication of terrestrial and aquatic ecosystems and soil acidification, which leads to forest decline (Bouwman and Van Der Hoek, 1997). Along with sulfur oxides (SO_x) and nitrogen oxides (NO_x), NH_3 is a major precursor of secondary aerosol particles formed by gas phase reactions in the atmosphere. SO_x and NO_x react with oxidants in the atmosphere and water to form sulfuric and nitric acid aqueous aerosols. Ammonia serves an important role in neutralizing these acids by converting the particles to ammonium sulfate and ammonium nitrate. While lowering atmospheric acidity, these ammoniated aerosol products scatter light efficiently and degrade visibility. Ammonium sulfate and nitrate contribute significantly to fine particle matter ($PM_{2.5}$) mass concentration and visibility reduction in many regions of the United States (Sisler and Malm, 1994). Knowledge and possible curtailment of ammonia emissions is, therefore, important for compliance with the National Ambient Air Quality Standard for $PM_{2.5}$ and the Regional Haze Rule for visibility in Class 1 areas.

The formation of nitrate aerosol may be limited by the availability of NH_3. Ammonia preferentially reacts to form non-volatile ammonium sulfate, and if excess NH_3 is present after reaction with sulfuric acid, NH_3 then reacts with NO_x to form ammonia nitrate (Dentener and Crutzen, 1994). Unlike ammonium sulfate, ammonium nitrate is volatile and the gas/particle partitioning of ammonium nitrate is a strong function of temperature and relative humidity. In regions of high sulfate concentration or low emission of NH_3, the atmosphere may be in an ammonia limited regime in regard to nitrate formation.

Much of the modeling of this inorganic aerosol system has been performed in areas of the country where the concentrations of NH_3 do not limit particle formation, primarily in the Southern California and San Joaquin Valley air basins in California. These conditions may not exist, however, in the inter-mountain west. For example, emissions estimates of NH_3 for San Joaquin Valley County in California are 5.04 tons/year/km^2 while those in Sublette County in Wyoming are approximately 0.069 tons/year/km^2 (EarthTech, 1998; Benjamin, 2001). The EPA estimated that the states of California and Wyoming are the seventh and thirty-third largest emitters in the U.S. (EPA, 2000), respectively, as illustrated in Figure 1.

Understanding the impact of emissions of SO_x and NO_x on visibility in the West requires an accurately determined ammonia emission inventory comprised of a variety of source types. The inventory is essential for predicting concentrations of ammonium sulfate and ammonium nitrate aerosols in visibility models, confirming whether or not the inorganic aerosol system is in equilibrium, and for identifying the limiting reagent if one should exist. Regulatory and policy decisions increasingly depend upon modeling, therefore it is important to ensure that particle formation models perform correctly in this region of the country where emission patterns and chemistry are quite different from the more thoroughly-studied urban areas.

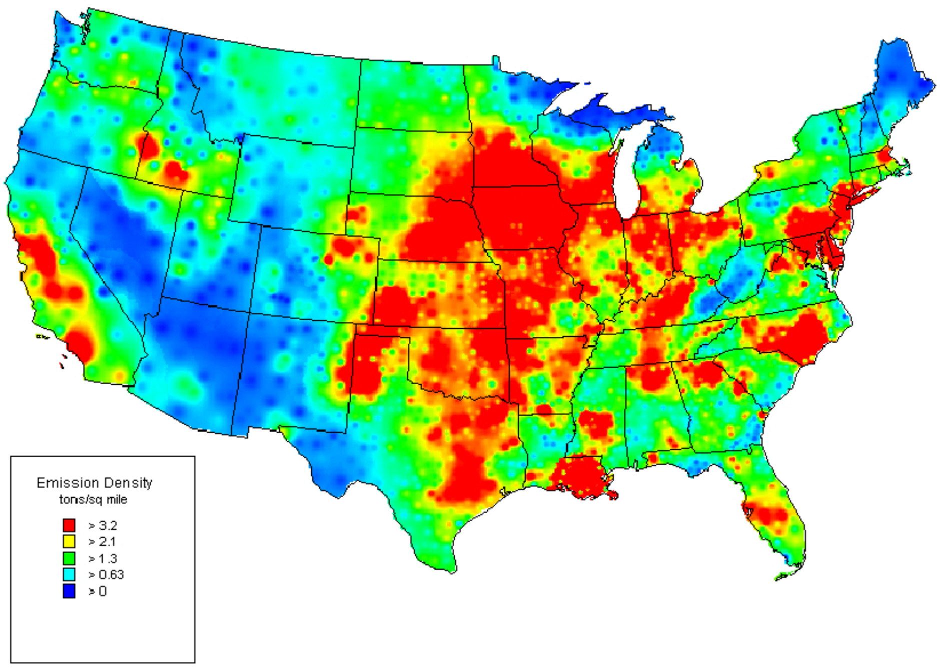

Figure 1. Map of estimated NH_3 emissions in the United States (EPA, 2002).

Ammonia emission inventories contain many more uncertainties than the emission inventories of SO_x and NO_x, which have long been examined with great scrutiny because of their immediate health effects and roles in acid rain and ozone formation. Also, most SO_x and a significant portion of NO_x emissions are from major point sources that are easily monitored, whereas ammonia is emitted from an array of urban and rural sources, many of which are diffuse and/or unregulated. While rural sources may dominate ammonia emissions across large areas, on a smaller scale, urban sources may be more influential since the formation of secondary aerosols requires the coexistence of NH_3 and SO_x or NO_x. Therefore, the accuracy of NH_3 emissions estimates for sources that co-emit SO_x or NO_x, or emit into ambient plums of SO_x or NO_x, is more important than their absolute magnitudes might suggest. For example, livestock and fertilizer application leads to significant NH_3 emissions, but they are generally farther removed from SO_x and NO_x sources than are urban sources.

Little is currently known about ammonia emissions and concentrations in the inter-mountain region. Worldwide, waste from livestock is estimated to be the largest sources of ammonia (Bouwman et al., 1997). Other significant sources include fertilizer use, biomass burning, soils and human wastes (Bouwman et al., 1997). These estimates are based largely on emission factors developed in Europe by Asman (1992), and are understood to contain large uncertainties. An ammonia inventory compiled for a modeling study of Southwest Wyoming includes no estimate of (EarthTech, 1998) emissions from industrial processes, diesel engines, or wood burning – all of which could be substantial sources in some areas. For non-urban, non-agricultural areas, the importance of soil and other biogenic emissions (those not caused by human activities) may also be important for understanding local air quality.

The purpose of this study is to develop an ammonia emission inventory for the state of Wyoming based on the most current information about sources and source activity. To facilitate the development of the inventory, we used the Carnegie Mellon University Ammonia Model (CMU, 2003) as a framework. The CMU model is a downloadable computer program that references user-adaptable emission factor and activity files to create the emission inventory. Other inventories of NH_3 emissions in Wyoming (EPA, 2002; WRAP, 2001) are not user accessible in this manner and therefore do not allow one to make refinements as improved data become available.

This CMU Model has been designed to estimate NH_3 emissions resolved to the county level in each of the continental Unites States. It is recommended that the default emission factor and activity data be evaluated and modified when needed when applying it to individual states (Strader, 2003). In this study, we reviewed all available emission factor and activity level data specific to the state of Wyoming.

The CMU Model accounts for ammonia emissions from 82 individual sources that comprise ten categories: livestock, fertilizer, mobile sources, domestic animals, wild animals, wildfires, soil, industry, humans, and publicly owned treatment works (POTWs). Application of the CMU Model to Wyoming using the default values for emission factors and activity levels yields a statewide emission estimate of 1.20×10^8 kg NH_3 year^{-1}. Biogenic emissions of NH_3 from soils constitute 77% of the inventory, but the developers of the CMU Model and others acknowledge that emission factors from soils are highly uncertain. The estimated inventory total, soil emissions excluded, is 2.81×10^7 kg NH_3 year^{-1}. The distribution of emissions is illustrated in Figure 1. In this case, livestock and fertilizer represent the largest sources, together constituting 83% of the total inventory. Emissions from cattle constitute the overwhelming majority (90%) of emissions from livestock. This is consistent with other inventories for South Korea (Lee and Park, 2002), the United Kingdom (Pain et al., 1998) and the United States (Battye et al., 1994). Emissions associated with three of the thirteen types of fertilizers account for a great majority (86%) of total emissions from this category. Thus, statewide, the emissions distribution is highly skewed. Source categories that contribute less than 2% of total NH_3 emissions are wildfires, domestic animals, humans, and POTWs.

The CMU Model employed in this study (version 3.0 Public Beta) was released in April of 2003. Compared to its predecessor (version 2.1), the default emission factor dataset included with the current version has been updated. Twenty-eight emission factors were revised, which resulted in a 50% decrease in statewide estimated NH_3 emissions in Wyoming. Decreases in emission factors for livestock animals, most notably those of cattle, represented 77% of the decrease in the statewide inventory. Changes to emission factors associated with fertilizer application represented 12% of the decrease in the inventory. This illustrates the skewed nature of NH_3 emissions statewide, wherein emissions from cattle and fertilizer application are dominant, and the inventory is particularly sensitive to large changes in emission factors and activity levels for these sources. In a review of the earlier CMU Model (version 2.1), recommendations were made for updating several of the default emission factors (Chinkin et al., 2003). Notably, the reduced emission factors for cattle incorporated into the present version of the CMU Model are the same as those recommended by Chinkin et al. (2003).

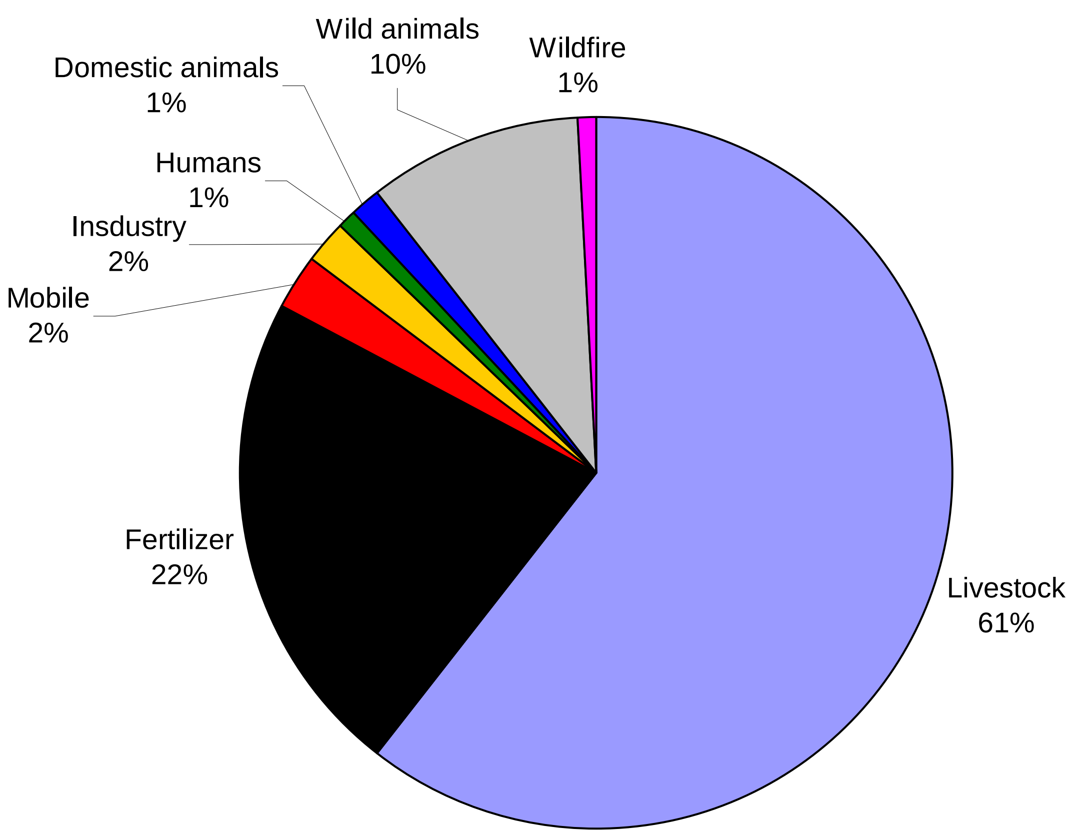

Figure 2. Contributions from different source categories (excluding soils) to the statewide NH_3 emission inventory in Wyoming derived using the CMU Model with default parameters (CMU, 2003).

In the next section of this report, we discuss the emission factors and activity files that we used as inputs to the CMU Model framework. In our review of emission factors, we consider the recent review of Chinkin et al. (2003), the recent updates to the default values in the CMU Model, and other published data. The most recent activity data specific to the counties in Wyoming was incorporated. Tabulated emission factors and activity data are presented in the report Appendices A and B.

EMISSION FACTORS AND ACTIVITY

Livestock Emissions

Emission of NH_3 from livestock is estimated to be one of the largest sources of ammonia in the U.S. (EPA, 2000) and worldwide (Bouwman, 1997). In this study, we considered emissions from the 16 animal types listed below in Table 1. As mentioned earlier, cattle (milk cows, beef cows, heifers, and steers) comprise the overwhelmingly dominant source of livestock related emission of NH_3.

Table 1. Animals included in the livestock category of the Wyoming NH_3 inventory.

Cattle	Other animals	Fowl
milk cows	hogs and pigs	geese
beef cows	horses	ducks
heifers	angora goats	turkeys
steers	milk goats	broilers
	sheep	pullets, < 13 wks
		pullets, 13 to 20 wks
		layers (pullets > 20 wks)

The emission factors used to estimate NH_3 for most livestock animals (cattle, horses, sheep, goats, and chickens) are those developed by Bouwman et al. (1997) for developed countries. Bouwman et al. developed emission factors for developed and developing countries to account for the regional differences in feeding situations, animal characteristics and management conditions. Bouwman et al. calculated emission rates of NH_3 from domestic animal waste based on average nitrogen excretion from different animals and subsequent NH_3 losses during housing, storage of wastes outdoors, grazing, and application of the wastes to grassland or arable land.

We note that the cattle emission factors recommended by Bouwman et al. and used in this study are the emission factors newly adopted in the CMU Model, recently recommended by Chinkin et al. (2003), and previously suggested to the EPA by Battye et al. (1994). The emission factor for pigs used in this study is the default CMU Model emission factor, and is equal to that recommended by Chinkin et al. and similar to that suggested by Battye et al. The default values given in the CMU Model emission for the remainder of the livestock species (ducks, geese and turkeys) were used in this study. These were adopted from a report by the European Environmental Agency (2001).

The USDA publishes livestock activity data (i.e., population estimates) at the county level in the Census of Agriculture every five years (USDA, 1997). The most recently available data were collected in 1997; year 2002 data are tentatively scheduled for publication in February 2004. Four cattle classifications are reported in the Census of Agriculture and have been incorporated into the CMU model: beef cows, milk cows, heifers, and steers. In addition to the USDA data, the Wyoming Agricultural Statistics Service (WASS) provides county estimates of total cattle population yearly; the most recent available data are for 2002 (WASS, 2002). The total cattle population estimates for 1997 in both reports agree well. We used the more recent population data from WASS to determine the relative change in each county's total cattle population from 1997 to 2002. Using this information, we derived population estimates for 2002 for the four cattle classes based on the 1997 USDA data. The scaling factors are listed below in Table 2. Most scaling factors were less than ±30%. It follows that the resultant activity levels and emission inventory assume that the populations of each of the four cattle classes varied by the same proportion between 1997 and 2002. These activity levels should be modified if needed when the next USDA census report is published. All other livestock activity levels are those of the 1997 Census of Agriculture.

Table 2. Scaling factors derived from Wyoming Agricultural Statistics Service total cattle data (WASS, 2002) and applied to 1997 USDA cattle class populations to estimate 2002 populations.

County	Cattle population ratio, 1997/2002	County	Cattle population ratio, 1997/2002
Albany	0.79	Natrona	0.87
Big Horn	1.02	Niobrara	1.08
Campbell	1.01	Park	0.83
Carbon	0.83	Platte	1.33
Converse	1.18	Sheridan	0.79
Crook	0.70	Sublette	0.63
Fremont	0.91	Sweetwater	0.75
Goshen	1.16	Teton	0.75
Hot Springs	1.08	Uinta	0.70
Johnson	0.81	Washakie	0.76
Laramie	1.32	Weston	1.04
Lincoln	0.79		

Fertilizer Emissions

Ammonia is released into the atmosphere following application of nitrogen containing fertilizers. The volatilization of NH_3 is related to the type of fertilizer, soil properties (e.g., soil pH and moisture content), meteorological conditions and management. Increased temperature, for example, promotes NH_3 emission (Bouwman et al., 1997). Most ammonia emissions are released within a few days after application (Van der Weerden and Jarvis, 1997).

Several NH_3 inventories that include emissions related to fertilizer application have been published. Goebes et al. (2003) developed the most recent inventory for the United States, and reviewed those previously published. Emission factors and activity levels (i.e., amount of fertilizer applied and time of application) developed by Goebes et al. were incorporated into the current CMU Model and used in this study.

The fertilizer emission factors of Goebes et al. (2003) are largely taken from Asman (1992). These have been used in other inventories as well (Bouwman et al., 1997; Battye et al., 1994). Asman's emission factors are based largely on the experiments of Whitehead and Raistrick (1990), who measured emissions during application of different fertilizers to various types of soil. The emission factors are reported in Appendix A of this report. Emission factors are reported for 14 fertilizer types: 13 types that comprise >95% of all fertilizers used (Goebes et al., 2003) and a miscellaneous category that represents lesser-used fertilizers.

Fertilizer application (i.e., activity) is temporally, primarily linked to planting and harvesting in spring and fall, and spatially variable. Goebes et al. (2003) noted emissions might vary greatly within a state, and noted that fertilizer emissions in Wyoming are largely associated with agricultural activity in the southeast and northwest. Activity levels in the CMU Model based on 1995 fertilizer sales to farmers by county and type of fertilizer covering two six-month time periods (January to June and July to December). These data are taken from a report published by the American Plant Food Control Officials (AAPFCO, 1995). AAPFCO published a more recent 2002 Commercial Fertilizers report, however, the data for Wyoming is an estimate based on average usage from surrounding states (Terry, 2003). Therefore we did not modify the default activity levels in the CMU Model.

Wild Animal Emissions

Emissions from black and grizzly bears, deer and elk are included in the CMU Model. In this study we included antelope as well because their statewide population is close to that of deer (WYGF, 2003).

Wildlife NH_3 factors are those of Warn et al. (1990), who presented yearly emission estimates derived from weight normalized emission rates and typical animal weights. Warn et al. reported a weight normalized emission rate for bears but not their weight; thus, they did not present emission factors for bears. We calculated emission factors for bears based on a weight of 550 lbs for grizzly bears (www.bear.org) and 200 lbs for black bears (www.americanbear.org). Our emission factors are compared in Table 3 to the default emission factors of the CMU Model. Also shown are wildlife waste emission factors reported by Benjamin (2003) for development of an NH_3 emission inventory for the state of California.

Table 3. Wildlife animal NH_3 emission factors (kg NH_3 yr^{-1}) used in this study versus the default values in the CMU Model.

Wildlife Animal	This study	CMU Model default values	Benjamin (2003)
Black bear	66.1	4.6	19.1
Grizzly bear	181.8	4.6	
Deer	4.8	4.6	5.1
Elk	17.2	24.5	17.2
Antelope	2.9	n/a	2.9

Estimates of deer, elk and antelope population were available from Wyoming Game and Fish Department (WYGF, 2003) for the end of the 2001 hunting season, which means the data are valid for early 2002. Population estimates were given for herd groups. Herd groups are not defined by county lines but are grouped by hunt area. Therefore, we used a hunt area map (gf.state.wy/wildlife/application/nonres_03.asp) to determine which county or counties a specific herd group occupied. The population of a herd group was divided evenly if it covered two or more counties. Activity levels for black and grizzly bears more recent than those in the default CMU Model files (valid for 1993) were not available from either Wyoming Game and Fish or the American Bear Association. Therefore, no modifications were made to these activity levels.

Mobile Source Emissions

Catalytic converters, designed to reduce NO_x emissions from gasoline-powered vehicles, produce ammonia emissions as a by-product of NO_x conversion. To estimate mobile source emissions of ammonia, it is necessary to distinguish between activity of vehicles equipped and not equipped with catalytic converters. The Wyoming Department of Transportation (WYDOT, 2003) provided us with the number of vehicle miles driven per county in year 2002 for all on-road vehicles, broken down into thirteen classes: motorcycles, passenger cars, two-axle four-tire single units, buses, two-axle six-tire single units, three-axle single units, four or more axle single units, four or less axle single trailers, five-axle single trailers, six or more axle single trailers, five or less axle multi-trailer, six-axle multi-trailer and seven or more axle multi-trailer. We assigned these classes to one of two groups: those that could be catalyst equipped and those not catalyst equipped. Motorcycles were not included in either group. Passenger cars, two-axle four-tire single unit vehicles and two-axle six-tire single unit trucks were assigned to the first category since these vehicle types include light and medium duty gasoline powered vehicles, many of which are catalyst equipped. The remaining ten vehicle classes were assigned to the non-catalyst equipped group.

Durbin et al. (2002) reported NH_3 emission rates for a fleet of 39 in-use light duty gasoline-fueled vehicles consisting of cars and trucks with various levels of emission controls ranging from non-catalyst vehicles to those certified at the ULEV California standard, all of which were driven on dynamometers following the Federal Test Procedure. The emission rate averaged 54 mg mi^{-1}. The factors for pre-1990 and post 1990 (Tier 0 and Tier 1) vehicles were, respectively 12 and 75 mg mi^{-1}. A subset of tests indicated that NH_3 emissions increased with more aggressive driving conditions. NH_3 emissions typically occurred after catalyst light-off when the catalyst approached its equilibrium temperature.

Table 4. Summary of NH_3 emission factors for motor vehicles.

Reference	EF (mg NH_3 mi^{-1})	Vehicle Type
Bouwman et al. 1997	117	catalyst equipped light duty gasoline
	5.9	diesel vehicles
	2.0	non catalyst equipped light duty gasoline
Fraser and Cass, 1998	116	catalyst equipped LD
	98	mixed fleet
	0	diesel (assumed)
Kean et al., 2000	78±5	95% catalyst equipped, 99% gasoline LD
Durbin et al., 2002	54 (range <4 to 177)	mixed LD fleet
CMU default values	97	cars
	27	trucks
This study	80	gasoline catalyst equipped group
	5	non-catalyst group

The tunnel study of Kean et al. (2000) indicated an average 1999 in-use fleet emission rate of 79 mg mi^{-1}. It was estimated that 99% and 95% of the vehicles under study in the Caldecott tunnel were gasoline-powered and catalyst-equipped, respectively. Bouwman et al.

(1997) referenced two European studies for use in their global emission inventory and reported NH_3 emission rates of 2.0, 117, 5.9 mg mi^{-1} for uncontrolled petrol-engine cars, three-way catalyst cars and diesel vehicles, respectively. From the 1993 Van Nuys tunnel study, Fraser and Cass (1998) reported an emission rate of 98.1 mg NH_3/mi for the observed fleet, 91.8% of which were gasoline powered and catalyst equipped. They estimated a value of 116 mg NH_3/mi for the only three-way or dual-bed catalyst equipped vehicles assuming negligible (i.e., zero) emissions from diesel vehicles in the fleet.

The emission factors used in this study are based on the review of Bouwman et al. (1997), Fraser and Cass (1998), Kean et al. (2000) and Durbin et al. (2002) and the factors used by the CMU Model (Table 4). Based on this review, we chose emission factors of 80 and 5 mg mi^{-1} for our catalyst and non-catalyst equipped vehicle groups.

Wildfire Emissions

Emissions of NH_3 from burning biomass are dependent on the nitrogen content of the fuel (Bouwman et al., 1997), which is known to vary from 0.1 to almost 5% by mass and changes significantly over the course of a year as vegetation cures (Yokelson, 2003). Further, the conditions of the fire, whether smoldering or flaming, impact NH_3 emission rates (Yokelson, 2003). NH_3 is produced mainly during the smoldering process whereas NO_x is emitted under flaming fire conditions.

Goode et al. (2000) presented average carbon monoxide (CO) emission factors and NH_3/CO emission rates measured for a large number of fires. Most of the forests in Wyoming are comprised of aspen, Engelmann spruce, Douglas fir, alpine fir, white bark, limber pine and lodge pole pine (WY Tourism, 2003). These biomass types are represented in the studies reviewed by Goode et al. (2000). CO emission factors range from 81.6 to 96.5 g kg^{-1} of wood burned, and NH_3/CO ratios range from 0.0122 to 0.0257 for the studies reviewed. For this study, we chose central values of the molar emission ratio NH_3/CO (0.02) and the CO emission factor (90g kg^{-1}).

Biomass burning activity data employed in this study is the same as in the CMU Model. These data include the number of acres burned, supplied by the National Interagency Fire Center (NIFC, 2000), and the fuel loading per acre (EPA, 2000). More recent data from the Wyoming State Forestry Division are not reconcilable with the data from NIFC and are not available at the county level, and were not used here. However, starting with the 2003 fire season each county will have a computer reporting system, so future data on acreage burned will likely be more reliable.

Industrial Process Emissions

The EPA maintains a database of NH_3 emissions that is part of the Toxic Release Inventory (TRI). States report emissions at the county level. The contribution of industrial emissions to the Wyoming NH_3 inventory was obtained directly from the TRI rather than through multiplication of emission factors by activity levels. The current CMU Model includes industrial emissions for 1995. Rather than use these default values, we used more recent data for 2001 that is published in the online TRI (www.epa.gov/tri). Industrial NH_3 emissions are reported for nine of the 23 Wyoming counties, as shown below in Table 5.

Statewide industrial NH_3 emissions decreased from 606 to 267 metric tons between 1995 and 2001, due in large part to the >60% reduction reported for Laramie county. Carbon and Sweetwater Counties reported increased industrial NH_3 emissions.

Table 5. Year 1995 and 2001 industrial air emissions of NH_3 (kg yr^{-1}) reported in the EPA Toxic Release Inventory.

County	1995	2001
Big Horn	799	5060
Campbell	0	2
Carbon	1637	4396
Goshen	50794	25541
Laramie	475236	169560
Lincoln	17551	1682
Natrona	2550	448
Sweetwater	14535	22818
Washakie	42630	37409
Total:	***605732***	***266916***

Publicly Owned Treatment Work (POTW) Emissions

Municipal sewage treatment plants process sufficient quantities of nitrogen-rich wastes to generate significant ammonia emissions under certain conditions. As of 1996, there were 103 facilities in operation in Wyoming. The volume of wastewater treated (i.e., activity) is compiled by the EPA and available online (EPA, 1996). These are the data in the CMU Model and used in this study. Statewide volume treated in 1996 was 50 million gallons. Newer data may become available as the EPA Office of Wastewater Management modernizes its database. The NH_3 emission factor (19 lb $Mgal^{-1}$) was developed for the National Acid Precipitation Assessment Program (Battye et al., 1994). It is based on influent and effluent NH_3 concentrations from >850 wastewater treatment facilities and research on NH_3 stripping (Warn et al., 1990) from treatment facilities. In their review of the CMU Model, Chinkin et al. (2003) noted that the emission factor is uncertain because of the assumptions made in its derivation.

Human Emissions

Ammonia is released from the breath, sweat, and excretion of humans as a normal metabolic process (Ament et al., 1997; Silvester et al., 1997; Spanel et al., 1998). These emissions generally comprise a minor portion of regional ammonia emissions and are not explicitly included in the EPA's air pollutant emission inventory (EPA, 2000). The CMU Model uses the emission factor recommended by Battye et al. (1994), which is comparable to that suggested by others (Bouwman et al., 1997). We found no basis for changing this emission factor; however, we updated the default CMU Model estimates of 1997 human population to 2002 populations, which the US Census Bureau estimated based on 2000 census data (US Census, 2000).

Domestic Animal Emissions

Emissions from dogs and cats are included in the inventory. They generally contribute negligibly to regional NH_3 emissions. The default values for activity levels and emission factors in the CMU Model, obtained from the American Veterinary Medical Association (AVMA, 1997) and Battye et al. (1994), were not modified.

Biogenic Soil Emissions

Ammonia is produced naturally in soil by bacteria. Natural ecosystems are at equilibrium between atmospheric nitrogen and the nitrogen in the ground and, therefore, NH_3 fluxes are related to the biological activity of the soil (Bouwman et al, 1997). Estimates of NH_3 emissions from soils are debatable because emission factors are scarce and highly uncertain. Some studies suggest that soils can either be a net source or sink of NH_3 (Roe and Mansell, 2001). High pH and low soil moisture content favor soil NH_3 emissions because dry soils exhibit higher gas diffusivity than moist soil and high pH (alkaline soil) shifts the acid-base equilibrium in soil from ammonium ion to ammonia. Anderson et al. (2002) evaluated ammonia emissions in Texas and demonstrated the sensitivity of NH_3 emissions to soil pH by noting a 20-fold reduction in NH_3 emissions occurred when soil pH was reduced from six to five.

When ammonia emissions from soil are presented they often contribute significantly to the inventory. Thus, the fact that there is not a reliable method for estimating ammonia emissions from soil is a significant information gap in ammonia emission inventories. An estimate of NH_3 emissions in the San Joaquin Valley in California (Coe et al., 1998) indicated that natural soils represented 42% of the total of annual inventory. Potter et al. (2001) recently used the NASA/CASA model to estimate native soil ammonia emissions for the entire state of

California. Their yearly estimate of 3.7 Gg is 20% of EPA's estimate of total California NH_3 emissions. Significant seasonal variations in emissions were predicted. As mentioned earlier, when soil emissions are included in the default CMU Model, they comprise 77% of the Wyoming NH_3 inventory; seasonal variation is not incorporated. Soil emissions presented in this study are those of the CMU Model.

The CMU Model soil types (i.e., activity) are based on the United States Geological Survey land use and land cover data (EPA, 1994) that allowed land to be classified using a two-tier system, called the Anderson classification system (Anderson et al., 1976). Anderson land use codes divide land into nine categories: urban, agricultural, rangeland, forest, water, wetland, barren, tundra, and perennial snow and ice. These categories are then divided further into more specific subcategories. As a check of accuracy, we added the total land area reported in the CMU Model for Wyoming and compared it with an independent source of land area (www.50state.com), and found that the figures agreed within 1%.

As shown in Table 6, three soil categories, namely rangeland, forest, cropland/pasture, comprise 96% of the total land area in Wyoming. It follows that the accuracy of the emission rates of NH_3 from soils in these categories will determines the accuracy of not only the soil inventory but also the overall inventory since, as mentioned above, soil emissions of ammonia are usually a significant portion of the total emission inventory.

Table 6. Dominant land uses (i.e., soil types) in Wyoming and published soil emission factors.

		Emission Factors (kg NH_3 km^{-2} yr^{-1})			
Land Use Category, Subcategory	% of Land Area	CMU Model	Chinkin et al., 2003	Bouwman et al., 1997	Potter et al., 2001[a]
Rangeland:	72		14		
herbaceous (19%)		30.8			
shrub/brush (48%)		30.8		50	
mixed (33%)		30.8			
Forest:	18				
deciduous (2%)		11.7	2-400	30	3-13
evergreen 91%)		11.7	1-40		1-16
mixed (7%)		11.7			1-21
Cropland/Pasture	6	100	0	0	9-22

[a] Potter et al. provide two estimates: assuming moderate pH effects (low estimate) and minimum pH effects (high estimate)

Table 6 also presents a comparison of published emission factors, though direct comparison with other data is difficult due to its scarcity. A manuscript is in preparation discussing the CMU Model emission factors (Strader, 2003). Bowman et al. (1997) and Chinkin et al. (2003) suggested omitting NH_3 emissions from cropland and pasture soils to avoid over counting emissions associated with livestock and fertilizer application on these lands. Chinkin et al. concluded that fertilizer NH_3 emissions from cropland are expected to dominate the natural soil emissions. Strader (2003), however, argues that fertilizer emission factors typically capture only the initial NH_3 spike released following fertilizer application, and not the long-term higher baseline emissions from the soil that are a result of the increased nitrogen content. In this regard, it is appropriate to have a non-zero soil emission factor for cropland/pasture, and indeed, it is usually higher than the unfertilized soil emission factor would be due to the increased nitrogen content of the soil. Further, Strader concludes that Chinkin et al. incorrectly interpreted the results of Potter et al. (2001) regarding baseline natural soil emissions for this soil subcategory. Indeed, Potter et al. estimated that NH_3 emissions from native soil in California to be 12-57 Gg yr^{-1} (compared to 12 Gg yr^{-1} from fertilizer application), with cropland emissions comprising 30-60% of the total.

ANNUAL NH_3 EMISSION INVENTORY

Statewide Emissions

The NH_3 emission inventory is tabulated in Appendix C. Figures 3 and 4 illustrate the distribution of statewide emissions by source category when the inventory excludes (Figure3) and includes (Figure 4) emissions from soils. We present results in this manner given the large uncertainty in the soil emissions.

Excluding soil emissions, statewide ammonia emissions for Wyoming are estimated to be 2.98×10^7 kg NH_3 yr^{-1} (Appendix C). This estimate is only slightly larger than that obtained using the default emission factors and activities in the CMU Model, 2.81×10^7 kg NH_3 $year^{-1}$. Emissions from livestock, fertilizer, and wild animals dominate the inventory (Figure 3). Beef cows, heifers and steers contribute 25%, 13% and 12% of these emissions statewide. Fertilizer application is 21% of the statewide total, and a single fertilizer, anhydrous ammonia, represents almost half of all fertilizer emissions. Aside from cattle and fertilizers, only seven other sources contribute more than 1% to the total ammonia emission inventory: deer (8.4%), elk (5.4%), antelope (4.1%), wildfire (2.1%), sheep (1.9%), horses (1.6%), and hogs and pigs (1.5%).

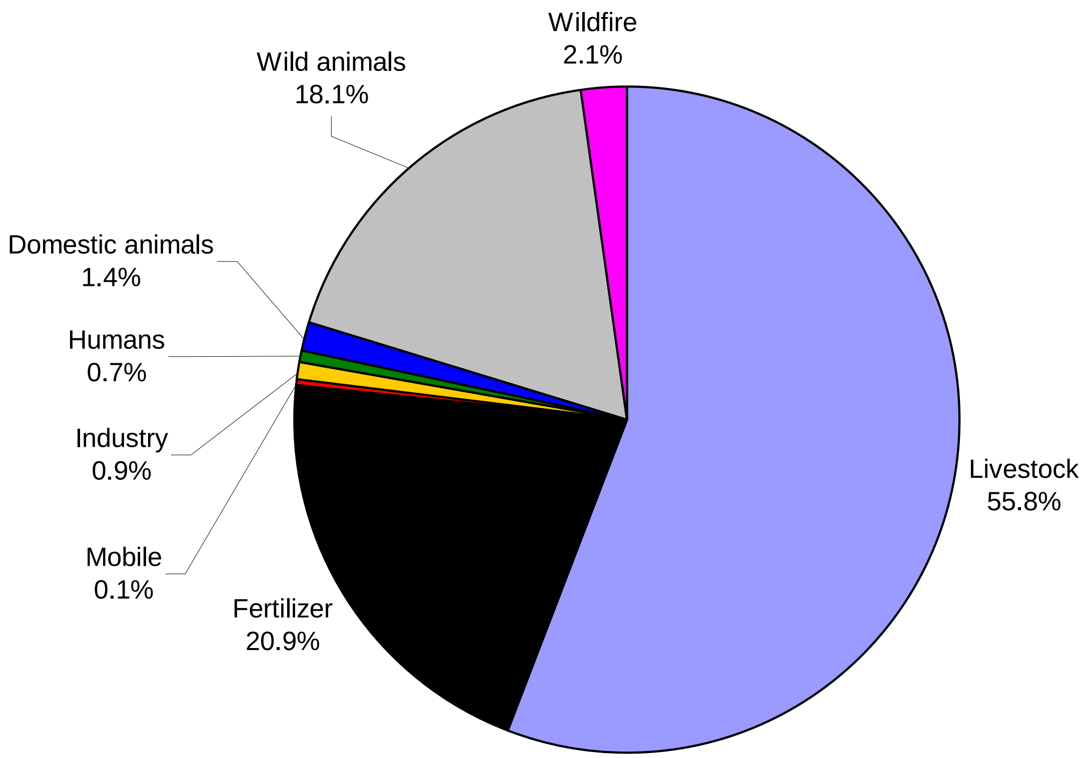

Figure 3. Contributions from different source categories (excluding soils) to the statewide NH_3 emission inventory in Wyoming derived using the CMU Model calculated with the emission factors and activity data tabulated in Appendices A and B.

Inclusion of soil results in a 300% increase in statewide emissions to 1.22 x 10^8 kg NH_3 yr^{-1}. In this case (Figure 4), soil emissions represent three-quarters of the total NH_3 inventory. Emissions from agricultural land, rangeland, and forest comprise all of the NH_3 emissions from soils. Specifically, five soil subcategories contribute substantially to the statewide inventory: shrub/brush rangeland (27%), mixed range land (18%), herbaceous rangeland (10%), cropland/pasture agricultural land (15%), and evergreen forests (5%). Next to soil emissions, livestock, fertilizer and wild animal waste constitute most of the remaining inventory, as shown in Figure 4.

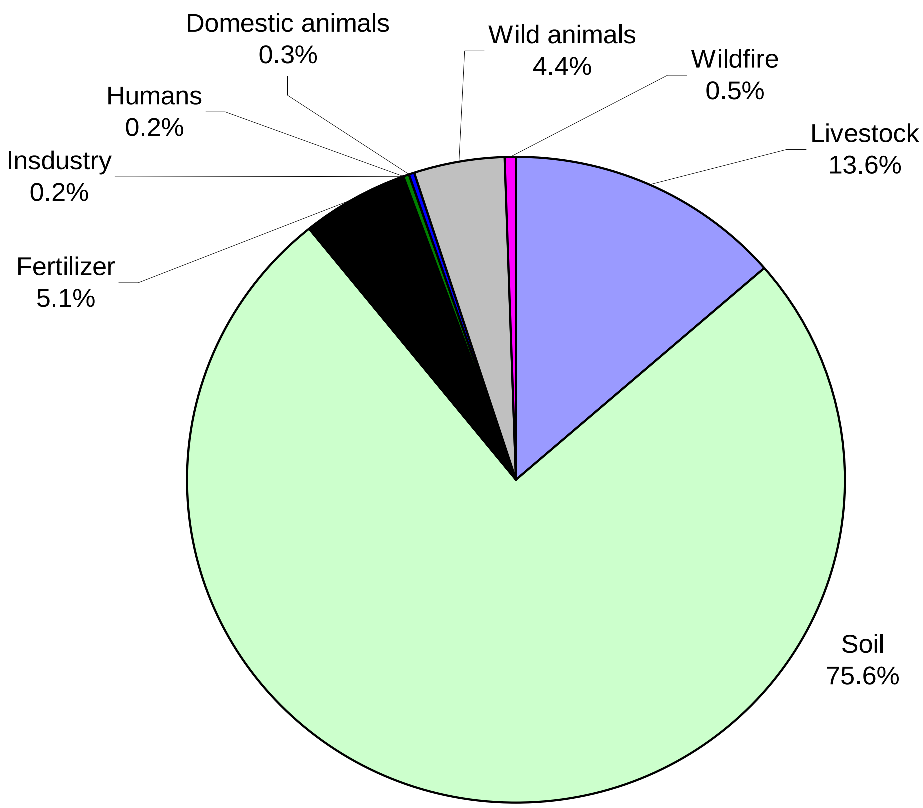

Figure 4. Contributions from different source categories (including soils) to the statewide NH_3 emission inventory in Wyoming derived using the CMU Model calculated with the emission factors and activity data tabulated in Appendices A and B.

County Level Emissions

Figure 5 shows the magnitude of NH_3 emissions from the different source categories at the county level. Similar to the state level, biogenic emission from soil is the largest source of NH_3 in all counties in Wyoming. Barring soil, emissions from livestock represent more than half of the inventory in most counties. Exceptions include Big Horn, Laramie, Sweetwater, and Washakie, where emissions from fertilizer are a major contribution to the county inventory;

Teton, where wildlife emissions are more dominant than those from livestock; and Park, where fertilizer and wildlife emissions together result in more NH_3 emissions than livestock. The contributions of the different source categories to county emission inventories, excluding soil, are reported in Table 7.

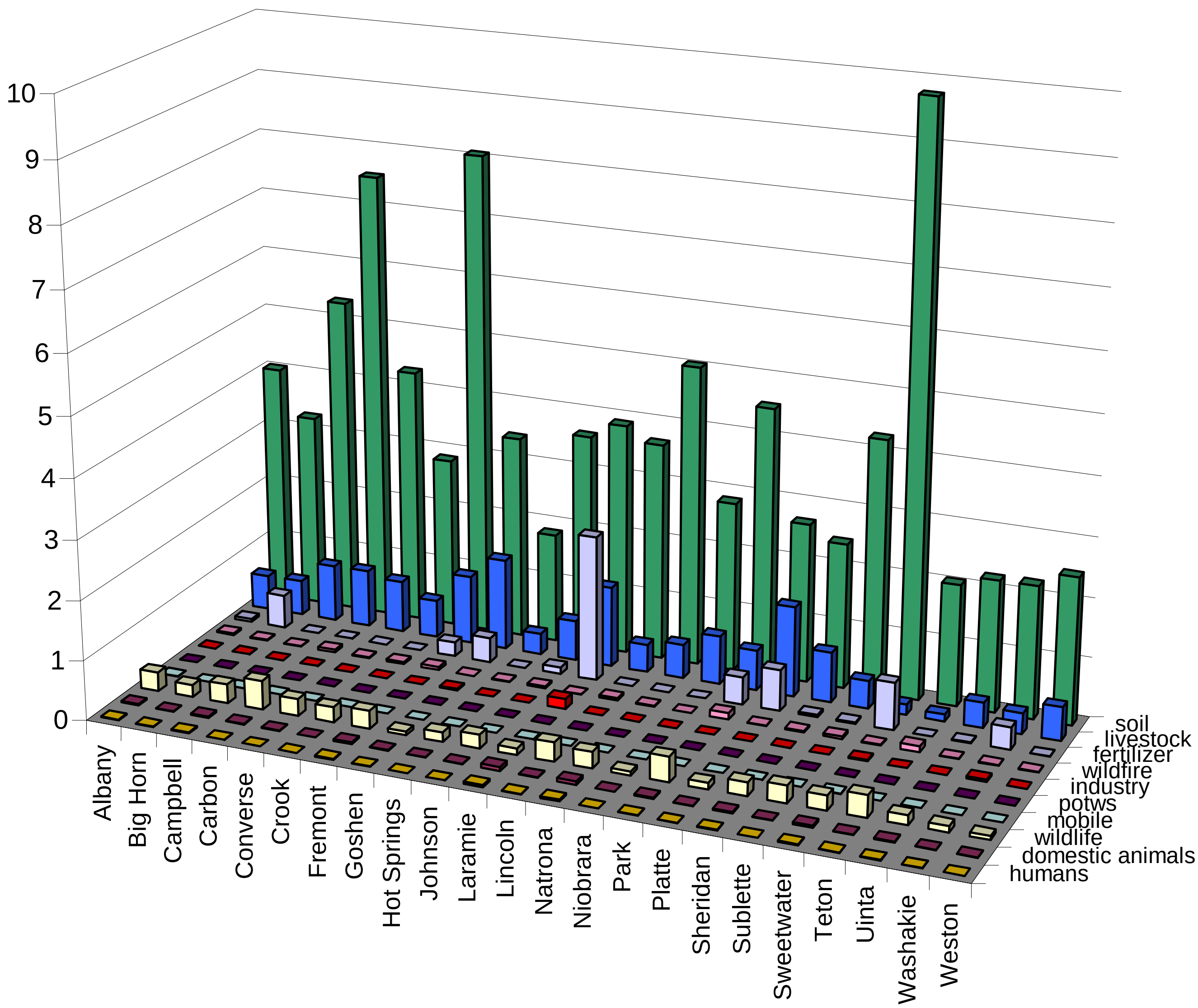

Figure 5. Estimated ammonia emissions (Gg yr^{-1}) from Wyoming Counties by source category.

Figure 5 and Table 7 indicate that emissions vary greatly within Wyoming. Most notably, fertilizer emissions are large (>0.2Gg) in eight counties and small (<0.01Gg) in ten counties. Fertilizer emissions in Laramie County are 40% of the total fertilizer emissions in the state. Wildfire emissions of NH_3 are also highly skewed; emissions from Park and Teton

Counties equal 34% of the states total NH_3 emissions from wildfires. Ammonia emissions from humans, domestic animals, industry, mobile sources, and publicly owned treatment works are minor. Even when excluding soil emissions, these source categories combined equal 5% or less of NH_3 emissions in all but three Wyoming counties.

Table 7. Source category contributions (rounded to nearest %) to county NH_3 emissions, soil emissions excluded.

	livestock	fertilizer	wildlife	wildfire	dom animal	humans	industry	mobile	POTWs
Albany	57	5	31	3	3	1	0	0	0
Big Horn	42	40	15	1	1	0	0	0	0
Campbell	72	0	24	1	2	1	0	0	0
Carbon	63	0	32	3	1	0	0	0	0
Converse	73	0	24	1	1	0	0	0	0
Crook	68	0	27	4	1	0	0	0	0
Fremont	64	13	17	3	2	1	0	0	0
Goshen	75	20	3	0	1	0	1	0	0
Hot Springs	67	0	30	2	1	0	0	0	0
Johnson	64	11	22	3	1	0	0	0	0
Laramie	32	58	3	0	2	1	4	0	0
Lincoln	55	0	38	5	1	1	0	0	0
Natrona	60	0	29	1	6	3	0	0	0
Niobrara	92	0	7	0	0	0	0	0	0
Park	40	27	25	7	1	1	0	0	0
Platte	65	30	5	0	0	0	0	0	0
Sheridan	72	3	20	2	2	1	0	0	0
Sublette	56	3	35	5	1	0	0	0	0
Sweetwater	13	61	19	1	3	1	2	0	0
Teton	19	0	61	16	2	1	0	0	0
Uinta	67	2	25	1	3	1	0	0	0
Washakie	40	42	12	1	1	0	4	0	0
Weston	87	0	10	2	1	0	0	0	0

TEMPORAL RESOLUTION

The lack of temporal resolution in NH_3 emissions represents an unknown uncertainty in air quality modeling. Assuming annual emissions are uniform in time may lead to errors in predicted $PM_{2.5}$ concentrations. Potter et al. (2001) found that the seasonal pattern in predicted soil NH_3 emission was reasonably consistent with observed seasonality in $PM_{2.5}$ levels in the San Joaquin Valley in California. Seasonality in NH_3 emissions is expected given that fertilizer application occurs more heavily during specific seasons (Goebes et al., 2003), emission from soils is strongly related to soil temperature and moisture (Potter et al., 2001; Roelle and Aneja, 2002), and emission of NH_3 from animal waste is affected by temperature (Dewes, 1996).

As discussed above, Goebes et al. (2003) developed an NH_3 emission inventory for Wyoming based on fertilizer sales to farmers by county. Their inventory illustrates that the seasonality in fertilizer emissions depends on the times of planting and harvesting crops. We report the monthly fraction of yearly amount of fertilizer that is applied in each Wyoming county in Appendix D. These values were computed from the activity data in the CMU Model, which are those of Goebes et al. Figure 6 shows the percentage of total fertilizer amount applied statewide during each month of the year. Fertilizer application peaks in the spring (March and April) and fall (September) and is greater in the summer than in the winter. Thus, monthly emissions associated with each fertilizer in each county can be computed by multiplying the monthly allocation factors reported in Appendix D by the annual emissions of each fertilizer in each county listed Appendix C.

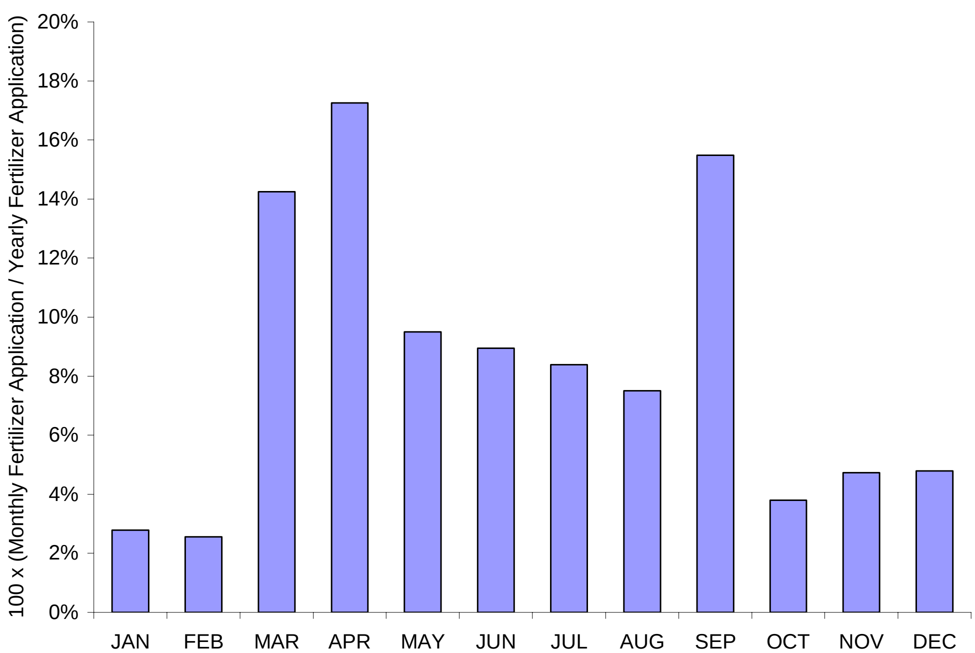

Figure 6. Yearly distribution of application of all fertilizers in Wyoming.

Whereas the seasonality in fertilizer emissions can be approximated using information about fertilizer sales and crop schedules, data on the temporal trend in emissions from other major ammonia sources are very scarce. Perhaps the only comprehensive assessment of the seasonality in regional NH_3 emissions is the recent study of Gilliland et al. (2003). Gilliland et al. found strong seasonal differences in NH_3 emissions in the eastern United States using an inverse modeling technique, measured atmospheric concentrations of ammonium ion, and emission fields acquired from the EPA's national NH_3 emission estimates (EPA, 2000). Gilliland et al. (2003) presented results in the form of scaling factors to be applied to the annual emission estimates to match the seasonal trend in emissions predicted with their model. These scaling factors, which are shown in Figure 7, were reported for eight months. We extrapolated these factors to estimate scaling factors for February, September, November, and December, and then normalized the scaling factors. The normalized scaling factors, also shown in Figure 7, exhibit the same trend as the original scaling factors. When the normalized scaling factors are applied to an annual emission estimate, the sum of the resulting monthly emission estimates equals 100% of the annual estimate.

Chinkin et al. (2003) also recommend using the scaling factors of Gilliland et al. (2003) to estimate the temporal variation in NH_3 emissions. As shown in Figure 7, the trend in the monthly allocation factors derived by Chinkin et al. differs from that of Gilliland et al. Chinkin et al. recommended the use of their monthly allocation factors to estimate the temporal variation in livestock emissions only, presumably because the modeling study of Gilliland et al. is based on the emission estimates of the EPA's national inventory, in which the largest sources are livestock (76% of total emissions) and fertilizer application (10% of total emissions).

We note that national NH_3 emission estimates of the CMU Model indicate a much different composition due to significant soil emissions, which are not explicitly included in the EPA inventory: 55% soil, 25% livestock, and 11% fertilizer application. Emissions from soil, while highly uncertain, may be the dominant contribution to the inventory of NH_3 emissions in Wyoming (Figure 4). For soil, Chinkin et al. recommend use of seasonal profiles developed by Corsi et al. (2002), who measured emissions from pine and oak forests in Texas during the summer. Given that all the forests in Wyoming comprise 20% of the land area (Table 6), the seasonal profile of Corsi et al. may not be applicable to all soils in Wyoming. Using an ecosystem model for soil nitrogen gas emissions, Potter et al. (2001) noted that emissions of soil NH_3 are influenced by air temperature and moisture patterns; peak emissions occurred when soils were predicted to be warm and dry. Similarly, Roelle and Aneja (2002) found that emission from soils in North Carolina was influenced mainly by soil temperature, though it was also noted that soil pH, another controlling variable, remained relatively constant during their research, and that soil moisture also affected emissions.

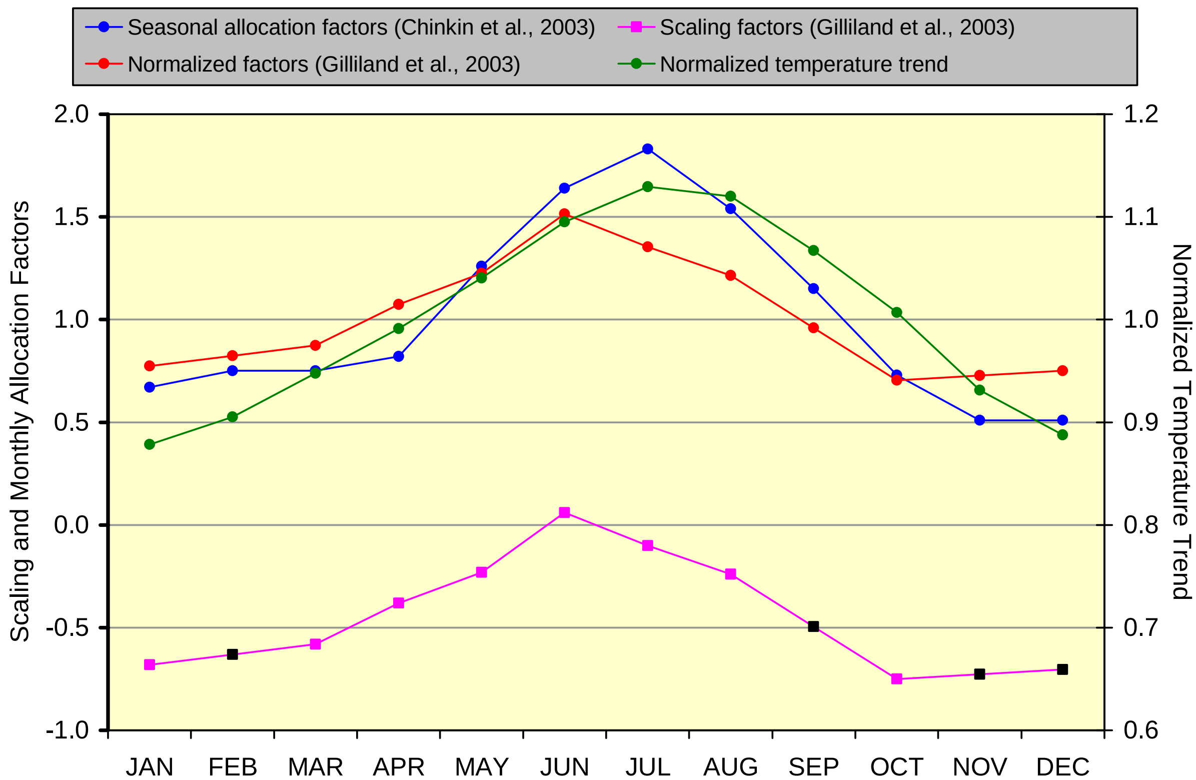

Figure 7. Seasonal scaling factors for NH_3 emissions and normalized temperature trend.

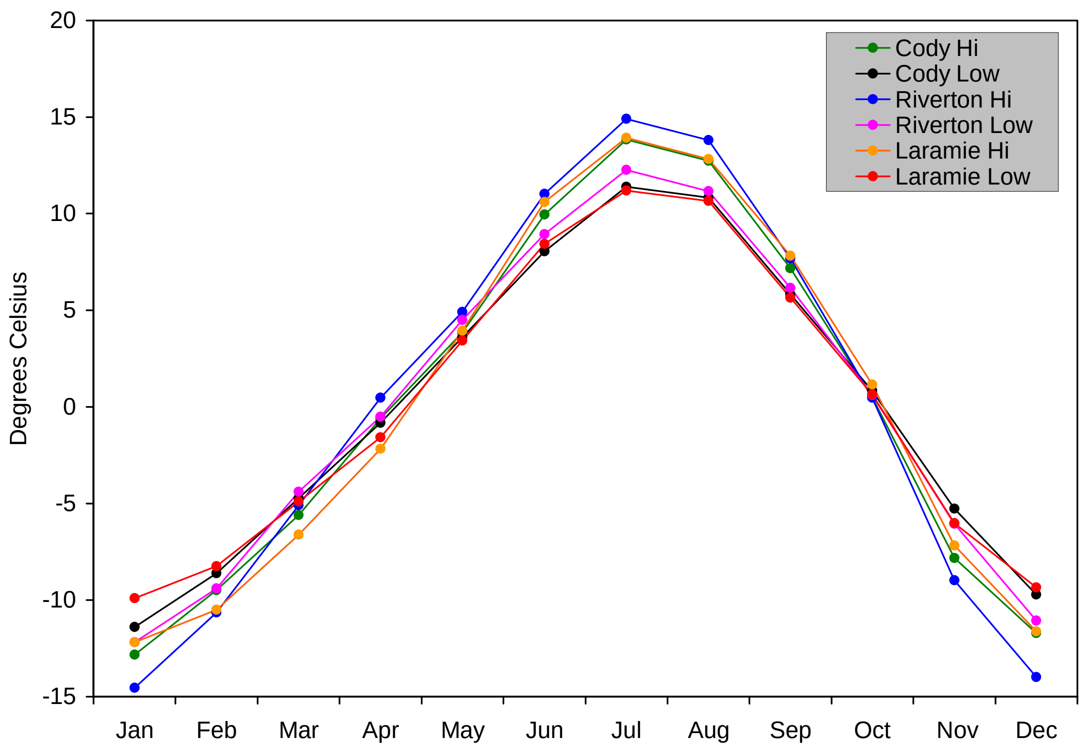

Figure 8. Differences between monthly average maximum (hi) and minimum (low) temperatures and annual average temperature in three Wyoming cities.

Since temperature influences NH_3 emissions from soil and animal waste, we considered the temporal variability in temperature measured at several locations across Wyoming (www.weather.com; >30 yr record). We found that while absolute temperatures vary between locations, differences between monthly and annual average temperatures exhibit similar trends at each location, as illustrated in Figure 8. The average temperature trend was normalized and included in Figure 7 for comparison with the above-mentioned monthly allocation factors. The qualitative features of the temperature and allocation trends generally agree: peak temperatures and peak NH_3 emissions occur during the summer months. This is by no means sufficient evidence to validate use of these monthly scaling factors for Wyoming. Rather, the temperature trend illustrates that temporal variation in emissions is probable.

Given the evidence for temporal NH_3 emissions and the importance of including realistic emission profiles in air quality models, and because seasonality data specific to Wyoming do not presently exist, we applied the normalized scaling factors of Gilliland et al. (2003) to the annual emission estimates (Appendix D) to estimate monthly NH_3 emissions from livestock, wild animals, and soil. We note, however, that the profile developed by Gilliland et al. applies to the eastern United States (nominally for livestock only), and the appropriate profile for Wyoming needs to be determined. The profile data illustrated in Figure 7 are reported in Table 8.

Table 8. Monthly allocation factors derived from Gilliland et al. (2003).

Month	Factor	Month	Factor
Jan	0.77	Jul	1.35
Feb	0.82	Aug	1.21
Mar	0.87	Sep	0.96
Apr	1.07	Oct	0.70
May	1.22	Nov	0.73
Jun	1.51	Dec	0.75

Application of the monthly allocation factors in Table 8 to soil, livestock, and wild animal emissions, and in Appendix C to fertilizer activity, yields the temporal trend in statewide emissions shown in Figure 9. Estimated NH_3 emissions peak in June and are greater in the late spring and early summer than in the fall and winter. When soil emissions are not included in the inventory, emissions are more evenly distributed throughout the spring and summer seasons, in addition to being considerably smaller in magnitude, as shown in Figure 10.

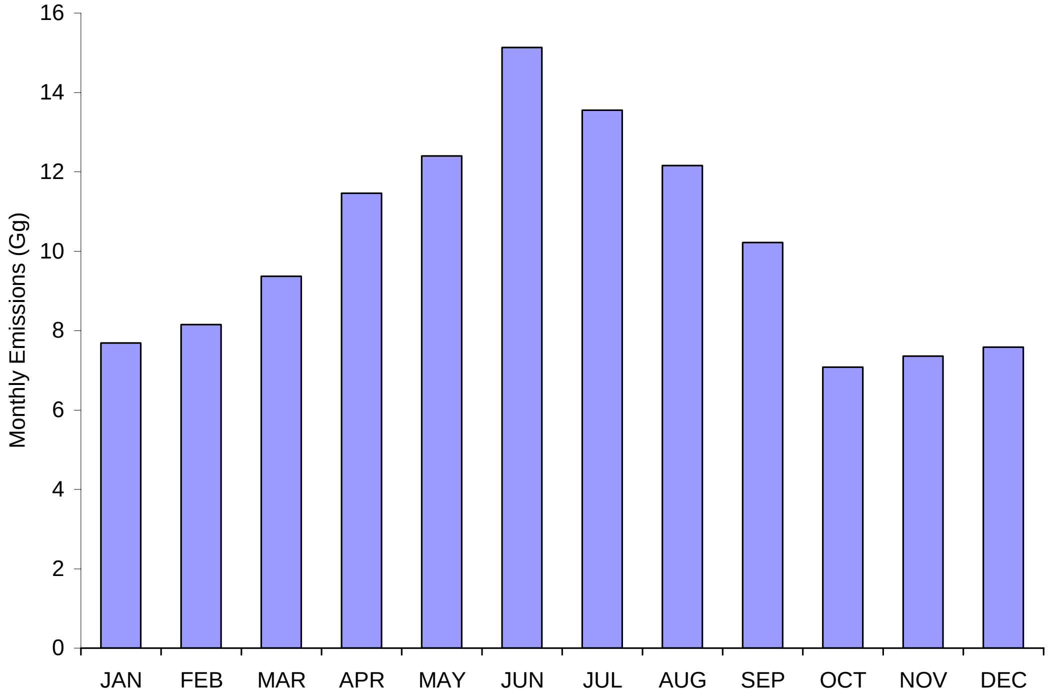

Figure 9. Monthly emissions of NH_3 in Wyoming assuming temporally dependent fertilizer application and soil, livestock, and wild animal emissions, as discussed in the text.

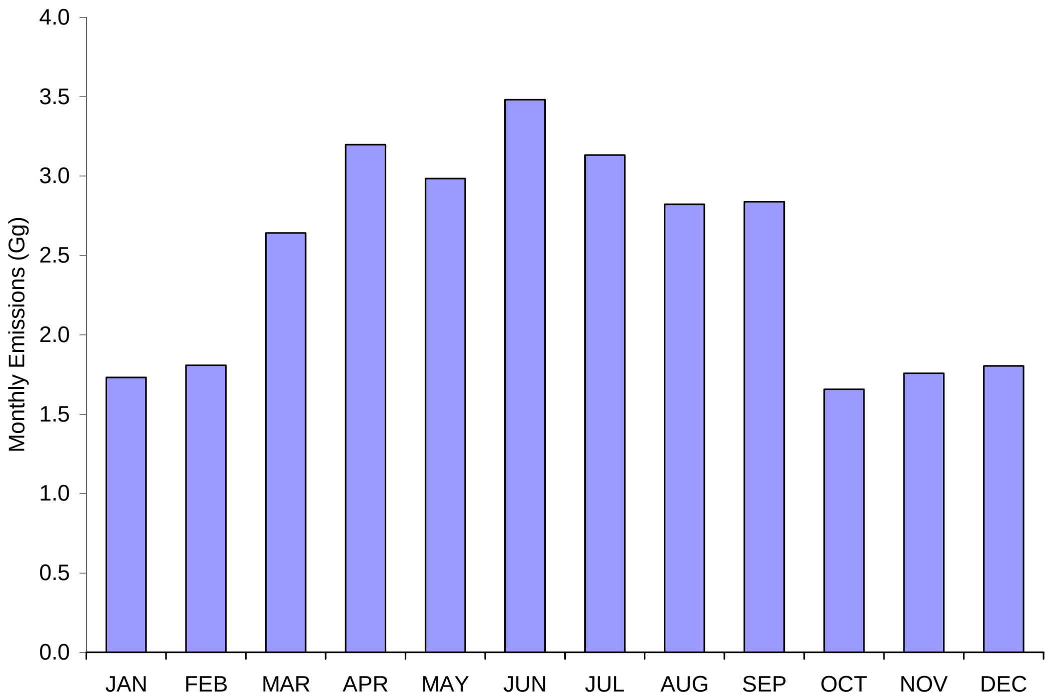

Figure 10. Monthly emissions of NH_3 in Wyoming assuming temporally dependent fertilizer application and livestock and wild animal emissions (soil emissions excluded), as discussed in the text.

CONCLUSION

An NH_3 emission inventory was developed for the state of Wyoming using the CMU Ammonia Model, which can be used to estimate NH_3 emissions nationwide. Default emission factors and, in particular, activity levels were updated for specific application of the CMU Model to Wyoming. The emission inventory is spatially and temporally resolved to the county and monthly level.

The largest portion of the NH_3 inventory is biogenic emission from soils, for which emission factors are highly uncertain. Published emission factors are scarce and based on limited measurements. In Wyoming, agricultural land, rangeland, and forests comprise 96% of the land area and essentially all of the estimated emissions from soils. Thus, future research on emission rates of NH_3 for these land categories may lead to a substantial change in the magnitude of soil emissions, a different inventory composition, and reduced uncertainty in the inventory.

While many NH_3 inventories include annual emissions, air quality modeling studies require finer temporal resolution. Published studies indicate higher emission rates from soils and animal wastes at higher temperatures, and temporal variation in fertilizer application. A recent inverse modeling study indicates temporal variation in regional NH_3 emissions. In this study, derived monthly allocation factors were applied to annual emission estimates to calculate monthly emissions from soil, livestock and wild animal waste. Monthly resolution of NH_3 emissions from fertilizers is incorporated into the CMU Model, and is based on fertilizer sales to farmers. Results from this study indicate that statewide NH_3 emissions are largest in the late spring and early summer months.

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APPENDICIES

Appendix A: Emission factors.

Appendix B: Annual activity levels by county.

Appendix C: Annual Ammonia Emissions (kg of NH_3 per year per county).

Appendix D: Monthly allocation of fertilizers generated with the CMU Ammonia Model (CMU, 2003) and discussed by Goebes et al. (2003).

Appendix A

SOURCE	UNITS	VALUE	REFERENCES
Livestock			
Beef cows	kg $head^{-1}$ yr^{-1}	9.44	Bouwman et al., 1997
Heifers	kg $head^{-1}$ yr^{-1}	9.44	Bouwman et al., 1997
Steers	kg $head^{-1}$ yr^{-1}	9.44	Bouwman et al., 1997
Milk cows	kg $head^{-1}$ yr^{-1}	24.8	Bouwman et al., 1997
Boilers	kg $head^{-1}$ yr^{-1}	0.242	Bouwman et al., 1997
Layers	kg $head^{-1}$ yr^{-1}	0.242	Bouwman et al., 1997
Pullets 13 to 20 weeks	kg $head^{-1}$ yr^{-1}	0.242	Bouwman et al., 1997
Pullets younger than 13 weeks	kg $head^{-1}$ yr^{-1}	0.242	Bouwman et al., 1997
Hogs and pigs	kg $head^{-1}$ yr^{-1}	4.84	Bouwman et al., 1997
Horses	kg $head^{-1}$ yr^{-1}	9.20	Bouwman et al., 1997
Milk goats	kg $head^{-1}$ yr^{-1}	0.701	Bouwman et al., 1997
Sheep	kg $head^{-1}$ yr^{-1}	0.774	Bouwman et al., 1997
Fertilizer			
Ammonium Nitrate	% N volatilized as NH_3	1.0	CMU, 2003; Goebes et al., 2003
Ammonium Sulfate	% N volatilized as NH_3	5.0	CMU, 2003; Goebes et al., 2003
Ammonium Thiosulfate	% N volatilized as NH_3	2.5	CMU, 2003; Goebes et al., 2003
Anhydrous Ammonia	% N volatilized as NH_3	4.0	CMU, 2003; Goebes et al., 2003
Aqueous Ammonia	% N volatilized as NH_3	4.0	CMU, 2003; Goebes et al., 2003
Calcium ammonium Nitrate	% N volatilized as NH_3	1.0	CMU, 2003; Goebes et al., 2003
Diammonium Phosphate	% N volatilized as NH_3	5.0	CMU, 2003; Goebes et al., 2003
Liquid Ammonium Polyphosphate	% N volatilized as NH_3	5.0	CMU, 2003; Goebes et al., 2003
Miscellaneous	% N volatilized as NH_3	7.0	CMU, 2003; Goebes et al., 2003
Mix	% N volatilized as NH_3	7.0	CMU, 2003; Goebes et al., 2003
Monoammonium Phosphate	% N volatilized as NH_3	5.0	CMU, 2003; Goebes et al., 2003
Nitrogen Solutions	% N volatilized as NH_3	8.0	CMU, 2003; Goebes et al., 2003
Potassium Nitrate	% N volatilized as NH_3	1.0	CMU, 2003; Goebes et al., 2003
Urea	% N volatilized as NH_3	15	CMU, 2003; Goebes et al., 2003
Wild Animals			
Black bear	kg $head^{-1}$ yr^{-1}	66.1	Warn et al., 1990
Grizzly bear	kg $head^{-1}$ yr^{-1}	182	Warn et al., 1990

Appendix A

SOURCE	UNITS	VALUE	REFERENCES
Deer	kg head^{-1} yr^{-1}	4.76	Warn et al., 1990
Elk	kg head^{-1} yr^{-1}	17.2	Warn et al., 1990
Antelope	kg head^{-1} yr^{-1}	2.86	Warn et al., 1990
Motor Vehicles			
Vehicles with catalysts	mg mi^{-1}	80	Bouwman et al, 1997; Fraser & Cass, 1998; Kean et al, 2000; Durbin et al, 2002
Vehicles without catalysts	mg mi^{-1}	5	Bouwman et al, 1997; Fraser and Cass, 1998; Durbin et al., 2002
Wildfires			
Wildfire CO	kg CO/ton wood burned	90	Goode et al., 2000
Wildfire ratio of NH3 to CO	mole NH_3/ mole CO	0.02	Goode et al., 2000
POTWs			
POTWs	kg 10^{-6} gal^{-1}	0.054	CMU, 2003
Humans			
Human population	kg person^{-1} yr^{-1}	0.44	CMU, 2003
Domestic Animals			
Dogs	kg dog^{-1} yr^{-1}	2.18	CMU, 2003
Cats	kg cat^{-1} yr^{-1}	0.69	CMU, 2003
Biogenic Soil			
Unknown (0)	kg km^{-2} yr^{-1}	30.8	CMU, 2003
Urban or built upland (11-17)	kg km^{-2} yr^{-1}	13.3	CMU, 2003
Agricultural land	kg km^{-2} yr^{-1}	0	CMU, 2003
21-Cropland and pasture	kg km^{-2} yr^{-1}	100	CMU, 2003
22-Orchards, groves, nurseries	kg km^{-2} yr^{-1}	108	CMU, 2003
23-Confined feeding operations	kg km^{-2} yr^{-1}	0	CMU, 2003
24- Other agricultural land	kg km^{-2} yr^{-1}	100	CMU, 2003
Rangeland(31-33)	kg km^{-2} yr^{-1}	30.8	CMU, 2003
Forestland (41-43)	kg km^{-2} yr^{-1}	11.7	CMU, 2003
Water (51-54)	kg km^{-2} yr^{-1}	0	CMU, 2003
Wetland (61-62)	kg km^{-2} yr^{-1}	30.8	CMU, 2003
Barren land (71-77)	kg km^{-2} yr^{-1}	0	CMU, 2003
71-Dry salt flats	kg km^{-2} yr^{-1}	0.56	CMU, 2003
72- Beaches	kg km^{-2} yr^{-1}	0	CMU, 2003

Appendix A

SOURCE	UNITS	VALUE	REFERENCES
73- Sandy areas not beaches	kg km^{-2} yr^{-1}	0	CMU, 2003
74- Bare exposed rock	kg km^{-2} yr^{-1}	0	CMU, 2003
75- Strip mines, quarries, gravel	kg km^{-2} yr^{-1}	0	CMU, 2003
76-Transitional areas	kg km^{-2} yr^{-1}	30.8	CMU, 2003
77- Mixed barren land	kg km^{-2} yr^{-1}	5	CMU, 2003
Tundra (81-85)	kg km^{-2} yr^{-1}	0	CMU, 2003
Perennial snow or ice (91-92)	kg km^{-2} yr^{-1}	0	CMU, 2003

Appendix B

SOURCE	UNITS	REFERENCE
Livestock		
Beef cows	number	USDA, 2003; WASS, 2002
Heifers	number	USDA, 2003; WASS, 2002
Steers	number	USDA, 2003; WASS, 2002
Milk cows	number	USDA, 2003; WASS, 2002
Boilers	number	CMU, 2003
Layers	number	CMU, 2003
Pullets 13 to 20 weeks	number	CMU, 2003
Pullets younger than 13 weeks	number	CMU, 2003
Hogs and pigs	number	CMU, 2003
Horses	number	CMU, 2003
Milk goats	number	CMU, 2003
Sheep	number	CMU, 2003
Fertilizer		
Ammonium Nitrate	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Ammonium Sulfate	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Ammonium Thiosulfate	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Anhydrous Ammonia	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Aqueous Ammonia	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Calcium ammonium Nitrate	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Diammonium Phosphate	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Liquid Ammonium Polyphosphate	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Miscellaneous	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Mix	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Monoammonium Phosphate	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Nitrogen Solutions	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Potassium Nitrate	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Urea	tons yr^{-1}	CMU, 2003; Goebes et al., 2003
Wild Animals		
Black bear	number	CMU, 2003
Grizzly bear	number	CMU, 2003
Deer	number	WYGF, 2003
Elk	number	WYGF, 2003
Antelope	number	WYGF, 2003
Motor Vehicles		
Vehicles with catalysts	mi yr-1	WYDOT, 2003
Vehicles without catalysts	mi yr-1	WYDOT, 2003
Wildfires		
Wildfire	tons wood burned	CMU, 2003
Industry		
Industry	kg NH_3 yr^{-1}	CMU, 2003
POTWs		

Appendix B

SOURCE	UNITS	REFERENCE
POTWs	10^6 gal day^{-1}	CMU, 2003
Humans		
Human population	number	US Census Bureau, 2002
Domestic Animals		
Dogs	number	CMU, 2003
Cats	number	CMU, 2003
Biogenic Soil		
County Land Area	km^2	CMU, 2003
Unknown (0)	km^2	CMU, 2003
Urban or built upland (11-17)	km^2	CMU, 2003
Agricultural land		
21-Cropland and Pasture	km^2	CMU, 2003
22-Orchards, groves, nurseries	km^2	CMU, 2003
23-Confined feeding operations	km^2	CMU, 2003
24- Other agricultural land	km^2	CMU, 2003
Rangeland(31-33)	km^2	CMU, 2003
Forestland (41-43)	km^2	CMU, 2003
Water (51-54)	km^2	CMU, 2003
Wetland (61-62)	km^2	CMU, 2003
Barren land		
71-Dry salt flats	km^2	CMU, 2003
72- Beaches	km^2	CMU, 2003
73- Sandy areas not beaches	km^2	CMU, 2003
74- Bare exposed rock	km^2	CMU, 2003
75- Strip mines, quarries, gravel	km^2	CMU, 2003
76-Transitional areas	km^2	CMU, 2003
77- Mixed barren land	km^2	CMU, 2003
Tundra (81-85)	km^2	CMU, 2003
Perennial snow or ice (91-92)	km^2	CMU, 2003

Appendix B

SOURCE	ALBANY	BIG HORN	CAMPBELL	CARBON	CONVERSE	CROOK
Livestock						
Beef cows	29652	31383	57433	54742	51877	34214
Heifers	15234	13841	20247	23131	17848	14782
Steers	14215	10079	15317	19050	14915	12398
Milk cows	74	271	36	12	209	65
Boilers	54	90	44	0	54	79
Layers	384	439	643	202	415	394
Pullets 13 to 20 weeks	206	67	88	206	49	28
Pullets younger than 13 weeks	0	37	0	0	0	37
Hogs and pigs	681	2220	194	122	48	881
Horses	2020	2200	3180	2080	1400	2470
Milk goats	18	61	99	18	24	18
Sheep	6710	36400	59900	34200	68700	29100
Fertilizer						
Ammonium Nitrate	103240	1475400	0	68960	0	0
Ammonium Sulfate	0	0	0	5548	0	0
Ammonium Thiosulfate	0	4622	3370	0	529	0
Anhydrous Ammonia	0	0	0	0	0	0
Aqueous Ammonia	0	0	0	0	0	0
Calcium ammonium Nitrate	0	0	0	0	0	0
Diammonium Phosphate	0	600300	0	198	0	0
Liquid Ammonium Polyphosphate	16539	0	0	110	0	0
Miscellaneous	178	66870	914	0	265	0
Mix	10193	2302	8184	2357	30	0
Monoammonium Phosphate	50930	452960	0	21610	0	0
Nitrogen Solutions	435500	476000	0	0	0	0
Potassium Nitrate	0	0	0	0	0	0
Urea	0	1612400	0	0	0	0
Wild Animals						
Black bear	23	16	25	43	23	14
Grizzly bear	7	5	8	14	7	4
Deer	22261	24230	42372	39008	31872	44562
Elk	4889	4533	342	10081	2249	0
Antelope	43047	4385	38891	42990	31019	13316
Motor Vehicles						

Appendix B

SOURCE	ALBANY	BIG HORN	CAMPBELL	CARBON	CONVERSE	CROOK
Vehicles with catalysts	777136	251123	630549	966138	443275	355992
Vehicles without catalysts	289058	93405	234534	359357	164878	132411
Wildfires						
Wildfire	2257	1454.1	688.2	3367	1180.3	2682.5
Industry						
Industry	0	5060	2	4400	0	0
POTWs						
POTWs	3.99	0.993	3.55	2.5	1.15	0.346
Humans						
Human population	31742	11212	36110	15346	12433	5929
Domestic Animals						
Dogs	8720	3220	9150	4460	3430	1650
Cats	10300	3810	10800	5270	4050	1950
Biogenic Soil						
County Land Area	11200	8230	12400	20700	11000	7370
Unknown (0)	0	0	0	0	0	0
Urban or built upland (11-17)	49	16	35	64	31	16
Agricultural land						
21-Cropland and Pasture	527	727	1090	847	606	916
22-Orchards, groves, nurseries	0	0	0	0	0	0
23-Confined feeding operations	0	0	0	0	0	0
24- Other agricultural land	2	1	6	6	2	2
Rangeland(31-33)	8290	5840	10600	16300	9200	3760
Forestland (41-43)	2180	1410	667	3250	1140	2590
Water (51-54)	82	35	4	135	13	44
Wetland (61-62)	20	68	10	77	1	0
Barren land						
71-Dry salt flats	0	0	5	0	2	0
72- Beaches	0	0	0	0	0	0
73- Sandy areas not beaches	0	0	0	28	0	0
74- Bare exposed rock	0	0	0	0	1	0
75- Strip mines, quarries, gravel	4	8	7	36	20	31
76-Transitional areas	2	0	5	7	2	3
77- Mixed barren land	0	0	0	0	0	0
Tundra (81-85)	34	130	0	11	0	0

Appendix B

SOURCE	ALBANY	BIG HORN	CAMPBELL	CARBON	CONVERSE	CROOK
Perennial snow or ice (91-92)	0	0	0	0	0	0
SOURCE	**FREMONT**	**GOSHEN**	**HOT SPRINGS**	**JOHNSON**	**LARAMIE**	**LINCOLN**
Livestock						
Beef cows	61687	46435	19306	37249	40588	20607
Heifers	25504	45843	10584	15644	29576	9066
Steers	24272	67735	6045	9815	27398	7552
Milk cows	192	86	6	20	351	2188
Boilers	221	114	54	54	178	54
Layers	1030	1120	186	321	544	1030
Pullets 13 to 20 weeks	100	118	206	206	76	47
Pullets younger than 13 weeks	37	37	0	37	80	37
Hogs and pigs	224	112	111	56	75500	1970
Horses	6760	1390	1290	2460	1720	2980
Milk goats	34	74	18	18	20	18
Sheep	40500	4800	1180	74200	47900	29400
Fertilizer						
Ammonium Nitrate	960200	195840	0	373	754200	19486
Ammonium Sulfate	122860	38280	0	0	86374	0
Ammonium Thiosulfate	0	81220	0	132	54860	0
Anhydrous Ammonia	238050	1463800	0	0	30947000	0
Aqueous Ammonia	0	28070	0	0	0	0
Calcium ammonium Nitrate	0	0	0	0	0	0
Diammonium Phosphate	602300	218020	0	198	397	0
Liquid Ammonium Polyphosphate	10034	39268	0	0	2802	0
Miscellaneous	47012	322150	265	179	14421	0
Mix	151	12032	1422	0	69880	0
Monoammonium Phosphate	371980	250750	0	16640	174430	0
Nitrogen Solutions	285250	1978200	0	0	8737000	0
Potassium Nitrate	0	0	0	0	0	0
Urea	318190	293550	0	452690	137430	0
Wild Animals						
Black bear	46	9	11	22	12	21
Grizzly bear	15	3	3	7	4	7
Deer	16566	9150	18479	26524	17918	43439
Elk	9338	100	3325	652	0	3973

Appendix B

SOURCE	FREMONT	GOSHEN	HOT SPRINGS	JOHNSON	LARAMIE	LINCOLN
Antelope	19212	5238	3569	30382	8487	15607
Motor Vehicles						
Vehicles with catalysts	648515	226882	108467	448133	1263819	416606
Vehicles without catalysts	241218	84387	40344	166684	470079	154957
Wildfires						
Wildfire	3959	136.16	728.9	2164.5	83.99	3030.3
Industry						
Industry	0	25500	0	0	170000	1680
POTWs						
POTWs	3.31	0.505	0.5	0.708	8.42	0.934
Humans						
Human population	36113	12244	4701	7374	82894	14890
Domestic Animals						
Dogs	10300	3610	1300	1910	22600	4000
Cats	12100	4270	1540	2260	26700	4730
Biogenic Soil						
County Land Area	24100	5780	5130	10700	7140	10400
Unknown (0)	1	0	0	0	0	0
Urban or built upland (11-17)	131	14	59	36	124	35
Agricultural land						
21-Cropland and Pasture	942	1580	165	249	1570	626
22-Orchards, groves, nurseries	0	0	0	0	0	0
23-Confined feeding operations	0	1	0	0	0	0
24- Other agricultural land	8	3	4	2	6	1
Rangeland(31-33)	17100	4030	4120	8150	5350	6610
Forestland (41-43)	3820	131	704	2090	81	2930
Water (51-54)	198	9	0	22	3	44
Wetland (61-62)	203	11	6	2	0	77
Barren land						
71-Dry salt flats	0	0	0	0	0	0
72- Beaches	0	0	0	0	0	0
73- Sandy areas not beaches	25	0	0	0	0	2
74- Bare exposed rock	85	0	7	0	0	47
75- Strip mines, quarries, gravel	19	0	2	4	4	16
76-Transitional areas	17	1	2	1	3	12

Appendix B

SOURCE	FREMONT	GOSHEN	HOT SPRINGS	JOHNSON	LARAMIE	LINCOLN
77- Mixed barren land	0	0	0	0	0	0
Tundra (81-85)	1540	0	60	187	0	32
Perennial snow or ice (91-92)	42	0	0	0	0	0
SOURCE	**NATRONA**	**NIOBRARA**	**PARK**	**PLATTE**	**SHERIDAN**	**SUBLETTE**
Livestock						
Beef cows	33391	39211	27472	64614	43581	24538
Heifers	11793	20421	19489	44871	23096	11566
Steers	7950	22828	14536	45877	17980	9275
Milk cows	36	27	627	885	154	53
Boilers	54	0	65	188	48	54
Layers	251	152	636	448	1110	392
Pullets 13 to 20 weeks	206	0	68	26	206	193
Pullets younger than 13 weeks	0	0	37	0	0	37
Hogs and pigs	179	1970	466	1970	104	123
Horses	2080	1170	3380	1440	3140	3020
Milk goats	18	16	18	18	18	16
Sheep	60200	16400	57000	1950	15700	17000
Fertilizer						
Ammonium Nitrate	586	0	1648800	372800	389550	323000
Ammonium Sulfate	0	0	210270	0	5582	0
Ammonium Thiosulfate	0	0	32993	0	0	6477
Anhydrous Ammonia	0	0	72180	11023000	0	0
Aqueous Ammonia	0	0	0	0	0	0
Calcium ammonium Nitrate	0	0	14426	0	0	0
Diammonium Phosphate	0	0	1201200	0	113690	0
Liquid Ammonium Polyphosphate	9	0	42251	2830	0	0
Miscellaneous	1761	0	487630	0	42560	17
Mix	26697	0	4713	2789	2423	175310
Monoammonium Phosphate	0	0	406720	258650	128840	2534
Nitrogen Solutions	0	0	1471700	119290	45970	43420
Potassium Nitrate	0	0	0	0	0	0
Urea	0	0	285370	471000	0	0
Wild Animals						
Black bear	29	14	33	10	13	23
Grizzly bear	9	4	11	3	4	7

Appendix B

SOURCE	NATRONA	NIOBRARA	PARK	PLATTE	SHERIDAN	SUBLETTE
Deer	13964	8197	22600	6737	37567	17350
Elk	1856	124	17311	1825	2231	10125
Antelope	61047	7756	5150	15294	4059	12282
Motor Vehicles						
Vehicles with catalysts	816184	136812	424552	419016	416091	202710
Vehicles without catalysts	303585	50887	157912	155855	154765	75398
Wildfires						
Wildfire	1076.7	234.95	8547	518	1742.7	3293
Industry						
Industry	448	0	0	0	0	0
POTWs						
POTWs	7.2	0.168	3.89	0.604	2.06	1.35
Humans						
Human population	67336	2357	25773	8752	26678	5969
Domestic Animals						
Dogs	18100	754	7250	2400	7230	1600
Cats	21400	891	8570	2840	8540	1900
Biogenic Soil						
County Land Area	13900	6800	17900	5530	6600	12800
Unknown (0)	0	0	1	0	0	0
Urban or built upland (11-17)	102	4	35	38	40	76
Agricultural land						
21-Cropland and Pasture	239	462	715	937	475	788
22-Orchards, groves, nurseries	0	0	0	0	0	0
23-Confined feeding operations	0	0	1	1	0	0
24- Other agricultural land	2	3	2	1	1	1
Rangeland(31-33)	12400	6100	6650	4000	4390	7430
Forestland (41-43)	1040	227	8250	499	1690	3180
Water (51-54)	56	2	71	55	2	121
Wetland (61-62)	7	0	82	1	0	294
Barren land						
71-Dry salt flats	0	0	0	0	0	0
72- Beaches	0	0	0	0	0	0
73- Sandy areas not beaches	1	0	1	1	0	16
74- Bare exposed rock	2	1	187	0	0	56

Appendix B

SOURCE	NATRONA	NIOBRARA	PARK	PLATTE	SHERIDAN	SUBLETTE
75- Strip mines, quarries, gravel	3	0	0	3	5	4
76-Transitional areas	8	0	0	2	1	7
77- Mixed barren land	0	0	0	0	0	0
Tundra (81-85)	0	0	1930	0	4	847
Perennial snow or ice (91-92)	0	0	20	0	0	13
SOURCE	**SWEETWATER**	**TETON**	**UINTA**	**WASHAKIE**	**WESTON**	
Livestock						
Beef cows	9891	5347	21554	13814	31511	
Heifers	3212	2519	8099	7548	12034	
Steers	3654	1786	8257	10610	13964	
Milk cows	14	118	186	10	6	
Boilers	0	0	76	54	54	
Layers	58	58	340	314	434	
Pullets 13 to 20 weeks	206	0	112	206	173	
Pullets younger than 13 weeks	0	0	92	37	37	
Hogs and pigs	64	1970	50	1970	118	
Horses	975	1500	1810	777	1320	
Milk goats	18	18	18	41	23	
Sheep	11100	1180	50500	44100	4890	
Fertilizer						
Ammonium Nitrate	513	0	145970	1877800	0	
Ammonium Sulfate	10417	0	42420	231	0	
Ammonium Thiosulfate	0	0	0	1389	0	
Anhydrous Ammonia	16161000	0	0	253600	0	
Aqueous Ammonia	0	0	0	0	0	
Calcium ammonium Nitrate	0	0	0	0	0	
Diammonium Phosphate	0	0	0	746300	0	
Liquid Ammonium Polyphosphate	0	0	0	22136	0	
Miscellaneous	1922	295	8624	28311	23630	
Mix	7688	966	28907	328	225	
Monoammonium Phosphate	16607	0	4972	178970	0	
Nitrogen Solutions	0	0	0	437820	0	
Potassium Nitrate	0	0	0	0	0	
Urea	36125	0	0	789800	0	
Wild Animals						

Appendix B

SOURCE	SWEETWATER	TETON	UINTA	WASHAKIE	WESTON
Black bear	58	21	11	12	13
Grizzly bear	19	7	3	4	4
Deer	17035	22035	21500	12196	8500
Elk	3660	13379	1900	2302	0
Antelope	33600	11925	8232	2194	7756
Motor Vehicles					
Vehicles with catalysts	1730221	416688	707382	126363	138875
Vehicles without catalysts	643555	154986	263112	47002	51617
Wildfires					
Wildfire	1080.4	7733	521.7	610.5	791.8
Industry					
Industry	22800	0	0	37400	0
POTWs					
POTWs	2.6	1.34	1.87	1.14	0.558
Humans					
Human population	36777	18499	19536	8082	6642
Domestic Animals					
Dogs	11400	3920	5770	2450	1860
Cats	13500	4630	6820	2890	2190
Biogenic Soil					
County Land Area	27200	11000	5370	5790	6250
Unknown (0)	0	0	0	0	0
Urban or built upland (11-17)	96	35	32	11	7
Agricultural land					
21-Cropland and Pasture	171	173	446	266	401
22-Orchards, groves, nurseries	0	0	0	0	0
23-Confined feeding operations	0	0	0	0	0
24- Other agricultural land	2	0	0	2	2
Rangeland(31-33)	25400	1950	4360	4920	5060
Forestland (41-43)	1050	7490	504	589	767
Water (51-54)	99	516	9	0	5
Wetland (61-62)	100	169	22	1	1
Barren land					
71-Dry salt flats	2	0	0	0	0
72- Beaches	0	0	0	0	0

Appendix B

SOURCE	SWEETWATER	TETON	UINTA	WASHAKIE	WESTON
73- Sandy areas not beaches	263	22	0	0	0
74- Bare exposed rock	20	84	0	0	0
75- Strip mines, quarries, gravel	13	2	2	1	13
76-Transitional areas	14	1	1	0	0
77- Mixed barren land	0	0	0	0	0
Tundra (81-85)	0	573	0	0	0
Perennial snow or ice (91-92)	0	0	0	0	0

Appendix C

SOURCE	ALBANY	BIG HORN	CAMPBELL	CARBON	CONVERSE	CROOK	FREMONT	GOSHEN
Livestock								
milk_cows	1820	6700	900	289	5170	1600	4750	2120
beef_cows	282000	298000	544000	518000	492000	324000	584000	440000
heifers	144000	131000	191000	218000	168000	139000	241000	432000
steers	134000	95400	144000	180000	140000	117000	229000	640000
hogs_and_pigs	3290	10700	938	590	232	4260	1080	541
horses	18600	20300	29300	19100	12800	22700	62200	12700
sheep	5230	28400	46700	26600	53600	22700	31600	3740
angora_goats	115	16	115	115	115	115	6	115
milk_goats	13	43	69	13	17	13	24	52
pullets_lt_13	0	9	0	0	0	9	9	9
pullets_13_to_20	50	16	21	50	12	7	24	29
layers	93	106	156	49	101	96	250	271
broilers	13	22	11	0	13	19	54	28
turkeys	6	23	23	23	23	23	76	23
geese	36	61	120	12	24	67	29	23
ducks	11	10	78	11	11	35	130	19
Fertilizer								
mix	371	84	298	86	1	0	6	438
anhydrous_ammonia	0	0	0	0	0	0	11600	71100
aqueous_ammonia	0	0	0	0	0	0	0	1360
ammonium_nitrate	3760	53800	0	2510	0	0	35000	7120
ammonium_sulfate	0	0	0	1010	0	0	22400	6970
ammonium_thiosulfate	0	140	102	0	16	0	0	2460
calcium_ammonium_nitrate	0	0	0	0	0	0	0	0
nitrogen_solutions	42300	46300	0	0	0	0	27700	192000
urea	0	392000	0	0	0	0	77300	71300
diammonium_phosphate	0	36400	0	12	0	0	36600	13200
monoammonium_phosphate	3090	27500	0	1310	0	0	22600	15200
liquid_ammonium_polyphosphate	1000	0	0	7	0	0	609	2390
potassium_nitrate	0	0	0	0	0	0	0	0
miscellaneous	17	6500	89	0	26	0	4570	31300
Wild Animals								
grizzly_bears	1330	923	1440	2500	1320	814	2680	529
black_bears	1510	1050	1630	2820	1500	919	3040	600

Appendix C

SOURCE	ALBANY	BIG HORN	CAMPBELL	CARBON	CONVERSE	CROOK	FREMONT	GOSHEN
elk	83900	77800	5870	173000	38600	0	161000	1720
deer	106237	115289	201994	185796	151972	212474	79082	43591
antelope	122000	12500	111000	122000	88600	38000	54800	15000
Motor Vehicles								
cars	746	241	606	928	425	342	623	218
trucks	1740	560	1420	2160	990	792	1450	506
Wildfires								
wildfire	29600	19100	9020	44200	15500	35200	52000	1790
Industry								
industry	0	5060	2	4400	0	0	0	25500
POTWs								
potws	79	20	70	49	23	7	65	10
Humans								
humans	13900	4930	15800	6740	5460	2620	15800	5380
Domestic Animals								
cats	7100	2630	7450	3640	2800	1340	8350	2950
dogs	19100	7030	20000	9740	7490	3600	22400	7880
Biogenic Soil								
lu0 –unknown	22	0	86	17	0	0	288	0
lu11 – residential	2570	1310	1030	1680	1490	316	3920	1130
lu12 – commercial and services	1030	458	899	586	421	78	1340	422
lu13 – industrial	217	238	484	3140	431	52	12400	115
lu14 – transportation, utilities	3110	388	2960	3780	2170	1920	1150	232
lu16 – mixed urban or built-up	126	121	13	460	154	22	682	164
lu17 – other urban or built-up	827	88	179	628	230	85	1400	173
lu21 – cropland and pasture	632000	872000	1310000	1020000	727000	1100000	1130000	1900000
lu22 – orchards, groves, nurseries	0	0	125	0	0	0	0	0
lu24 – other agricultural land	2480	1110	7120	7320	2340	2120	9340	3320
lu31 – herbaceous rangeland	1050000	3620	2000000	87600	1810000	950000	12100	1200000
lu32 – shrub and brush rangeland	102000	282000	91000	4920000	148000	3520	4360000	0
lu33 – mixed rangeland	1920000	1870000	1820000	990000	1440000	436000	1930000	287000
lu41 – deciduous forest land	263	2820	1540	46200	4280	1430	5020	3730
lu42 – evergreen forest land	296000	192000	92200	353000	154000	362000	486000	14800
lu43 – mixed forest land	9440	2530	0	58900	2280	0	44300	0
lu61 – forested wetland	2060	22300	0	19600	0	0	20000	3460

Appendix C

SOURCE	ALBANY	BIG HORN	CAMPBELL	CARBON	CONVERSE	CROOK	FREMONT	GOSHEN
lu62 – non forested wetland	5470	2800	3620	8800	318	0	55100	418
lu71 – dry salt flats	0	0	32	0	11	3	3	0
lu76 – transitional areas	791	18	1960	2560	673	1080	6100	299
lu77 – mixed barren land	0	0	0	0	0	0	0	0

SOURCE	HOT SPRINGS	JOHNSON	LARAMIE	LINCOLN	NATRONA	NIOBRARA	PARK	PLATTE
Livestock								
milk_cows	160	497	8680	54100	880	670	15500	21800
beef_cows	182000	353000	385000	196000	317000	372000	260000	612000
heifers	100000	148000	280000	85700	111000	193000	184000	424000
steers	57000	92600	259000	71300	75100	215000	137000	433000
hogs_and_pigs	536	271	365000	9530	865	9530	2260	9530
horses	11900	22600	15800	27400	19100	10800	31100	13200
sheep	920	57800	37300	22900	46900	12800	44500	1520
angora_goats	115	115	115	115	30	115	115	115
milk_goats	13	13	14	13	13	11	13	13
pullets_lt_13	0	9	19	9	0	0	9	0
pullets_13_to_20	50	50	19	11	50	0	16	6
layers	45	78	132	250	61	37	154	109
broilers	13	13	43	13	13	0	16	46
turkeys	0	23	18	23	11	0	87	0
geese	14	12	29	21	25	12	30	12
ducks	6	6	15	15	10	11	33	53
Fertilizer								
mix	52	0	2550	0	972	0	172	102
anhydrous_ammonia	0	0	1500000	0	0	0	3500	535000
aqueous_ammonia	0	0	0	0	0	0	0	0
ammonium_nitrate	0	14	27500	710	21	0	60100	13600
ammonium_sulfate	0	0	15700	0	0	0	38300	0
ammonium_thiosulfate	0	4	1670	0	0	0	1000	0
calcium_ammonium_nitrate	0	0	0	0	0	0	526	0
nitrogen_solutions	0	0	849000	0	0	0	143000	11600
urea	0	110000	33400	0	0	0	69200	114000
diammonium_phosphate	0	12	24	0	0	0	72900	0
monoammonium_phosphate	0	1010	10600	0	0	0	24700	15700
liquid_ammonium_polyphosphate	0	0	170	0	1	0	2570	172

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SOURCE	HOT SPRINGS	JOHNSON	LARAMIE	LINCOLN	NATRONA	NIOBRARA	PARK	PLATTE
potassium_nitrate	0	0	0	0	0	0	0	0
miscellaneous	26	17	1400	0	171	0	47400	0
Wild Animals								
grizzly_bears	614	1310	694	1220	1720	804	1920	572
black_bears	695	1480	787	1390	1930	912	2170	649
elk	57100	11200	0	68200	31900	2120	296000	31400
deer	88134	126246	85276	206758	66696	39065	107666	32109
antelope	10200	86900	24200	44500	174000	22200	14800	43700
Motor Vehicles								
cars	104	430	1210	401	784	132	408	402
trucks	242	1000	2820	930	1820	305	948	936
Wildfires								
wildfire	9560	28400	1100	39700	14200	3080	112000	6790
Industry								
industry	0	0	170000	1682	448	0	0	0
POTWs								
potws	10	14	166	18	142	3	77	12
Humans								
humans	2060	3240	36500	6560	29600	1010	11400	3840
Domestic Animals								
cats	1060	1560	18500	3260	14800	614	5920	1960
dogs	2840	4180	49300	8740	39500	1640	15800	5240
Biogenic Soil								
lu0 –unknown	0	9	0	14	110	0	234	3
lu11 – residential	474	551	6670	862	5810	352	1490	1080
lu12 – commercial and services	185	137	4100	352	2270	42	1000	391
lu13 – industrial	8260	203	416	2330	3520	44	1880	686
lu14 – transportation, utilities	99	4550	6320	1100	3250	72	594	3200
lu16 – mixed urban or built-up	386	232	446	506	420	124	253	328
lu17 – other urban or built-up	64	144	1800	388	980	80	401	344
lu21 – cropland and pasture	198000	299000	1880000	751000	287000	554000	858000	1120000
lu22 – orchards, groves, nurseries	0	0	0	0	0	0	0	442
lu24 – other agricultural land	4370	2240	7270	1730	2050	3380	2210	1700
lu31 – herbaceous rangeland	226	19300	1700000	3020	677	1900000	143000	492000
lu32 – shrub and brush rangeland	1110000	647000	14600	2380000	2170000	13300	906000	35300

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SOURCE	HOT SPRINGS	JOHNSON	LARAMIE	LINCOLN	NATRONA	NIOBRARA	PARK	PLATTE
lu33 – mixed rangeland	414000	2350000	258000	69500	2410000	344000	1420000	950000
lu41 – deciduous forest land	1140	10400	0	7270	1510	5880	3300	494
lu42 – evergreen forest land	87700	280000	11400	280000	140000	25900	1140000	69600
lu43 – mixed forest land	9970	4020	0	125000	4400	0	12400	0
lu61 – forested wetland	2100	108	0	7180	0	0	11200	0
lu62 – non forested wetland	294	544	0	21500	2580	178	19100	400
lu71 – dry salt flats	0	0	0	0	3	0	2	0
lu76 – transitional areas	769	484	1060	4510	3110	0	172	625
lu77 – mixed barren land	28	0	0	0	0	0	14	0

SOURCE	SHERIDAN	SUBLETTE	SWEETWATER	TETON	UINTA	WASHAKIE	WESTON	WYOMING
Livestock								
milk_cows	3800	1320	334	2920	4600	245	155	139010
beef_cows	413000	233000	93700	50800	205000	131000	299000	7584500
heifers	218000	110000	30400	23800	76400	71300	113000	3832600
steers	170000	87600	34400	16900	78000	100000	132000	3638300
hogs_and_pigs	503	595	310	9530	242	9530	571	440434
horses	28900	27700	8960	13800	16700	7140	12100	464900
sheep	12200	13300	8660	920	39400	34400	3820	555910
angora_goats	115	115	115	115	115	115	115	2352
milk_goats	13	11	13	13	13	29	16	450
pullets_lt_13	0	9	0	0	22	9	9	131
pullets_13_to_20	50	47	50	0	27	50	42	677
layers	269	95	14	14	82	76	105	2643
broilers	12	13	0	0	19	13	13	385
turkeys	9	25	0	0	16	23	6	462
geese	33	12	10	12	12	12	12	630
ducks	11	11	11	11	39	11	11	559
Fertilizer								
mix	88	6390	280	35	1050	12	8	12995
anhydrous_ammonia	0	0	784000	0	0	12300	0	2917500
aqueous_ammonia	0	0	0	0	0	0	0	1360
ammonium_nitrate	14200	11800	19	0	5320	68400	0	303874
ammonium_sulfate	1020	0	1900	0	7730	42	0	95072
ammonium_thiosulfate	0	197	0	0	0	42	0	5631
calcium_ammonium_nitrate	0	0	0	0	0	0	0	526

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SOURCE	SHERIDAN	SUBLETTE	SWEETWATER	TETON	UINTA	WASHAKIE	WESTON	WYOMING
nitrogen_solutions	4460	4220	0	0	0	42500	0	1363080
urea	0	0	8780	0	0	192000	0	1067980
diammonium_phosphate	6900	0	0	0	0	45300	0	211348
monoammonium_phosphate	7820	154	1010	0	302	10900	0	141896
liquid_ammonium_polyphosphate	0	0	0	0	0	1340	0	8258
potassium_nitrate	0	0	0	0	0	0	0	0
miscellaneous	4140	2	187	29	838	2750	2300	101761
Wild Animals								
grizzly_bears	773	1370	3400	1210	618	702	743	29206
black_bears	880	1540	3850	1380	701	793	840	33066
elk	38300	173000	62800	230000	32600	39500	0	1616010
deer	179126	82894	80988	104808	102426	58121	40494	2497241
antelope	11600	35200	96000	34000	23500	6250	22200	1213150
Motor Vehicles								
cars	400	194	1660	401	679	121	133	11588
trucks	930	452	3860	930	1580	282	310	26963
Wildfires								
wildfire	22800	43200	14200	101000	6840	8000	10400	627680
Industry								
industry	0	0	22818	0	0	37409	0	267319
POTWs								
potws	41	27	51	26	37	23	11	979
Humans								
humans	11800	2750	16400	8200	8720	3540	2950	219200
Domestic Animals								
cats	5890	1310	9310	3190	4700	1990	1510	111834
dogs	15800	3490	24800	8560	12600	5350	4070	299150
Biogenic Soil								
lu0 –unknown	84	68	74	42	0	82	18	1151
lu11 – residential	2860	749	2280	2620	1390	624	439	41697
lu12 – commercial and services	1160	232	920	1380	358	137	202	18100
lu13 – industrial	164	10200	4150	0	736	512	204	50382
lu14 – transportation, utilities	1520	287	6000	253	2350	204	139	45648
lu16 – mixed urban or built-up	401	143	811	103	150	260	49	6354
lu17 – other urban or built-up	248	466	1070	1210	182	75	8	11070

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SOURCE	SHERIDAN	SUBLETTE	SWEETWATER	TETON	UINTA	WASHAKIE	WESTON	WYOMING
lu21 – cropland and pasture	570000	946000	205000	208000	535000	319000	481000	17902000
lu22 – orchards, groves, nurseries	0	0	0	0	0	0	0	567
lu24 – other agricultural land	667	1050	2110	149	199	2990	2230	69495
lu31 – herbaceous rangeland	12700	23200	1220	36700	264	592	1370000	12816219
lu32 – shrub and brush rangeland	52100	2530000	9240000	632000	1580000	1200000	31000	32447820
lu33 – mixed rangeland	1560000	190000	117000	51700	19700	620000	476000	21942900
lu41 – deciduous forest land	4100	8090	1850	377	12200	1050	1240	124184
lu42 – evergreen forest land	221000	329000	142000	998000	45600	79900	106000	5906100
lu43 – mixed forest land	11600	110000	2590	52900	13000	1880	0	465210
lu61 – forested wetland	0	39100	4550	26800	7940	50	296	166744
lu62 – non forested wetland	167	69100	32400	35500	0	174	0	258463
lu71 – dry salt flats	0	0	16	0	0	0	0	71
lu76 – transitional areas	384	2650	5210	193	436	0	0	33084
lu77 – mixed barren land	0	0	0	0	0	0	0	41

Appendix D

COUNTY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Urea												
Big Horn	0.030	0.027	0.151	0.183	0.100	0.095	0.078	0.069	0.143	0.035	0.044	0.044
Fremont	0.022	0.020	0.113	0.137	0.075	0.071	0.106	0.094	0.195	0.048	0.059	0.060
Goshen	0.035	0.033	0.182	0.220	0.121	0.114	0.056	0.050	0.102	0.025	0.031	0.032
Johnson	0.039	0.036	0.198	0.239	0.132	0.124	0.044	0.039	0.081	0.020	0.025	0.025
Laramie	0.024	0.022	0.121	0.146	0.080	0.076	0.100	0.090	0.184	0.045	0.056	0.057
Park	0.024	0.022	0.122	0.148	0.081	0.077	0.099	0.088	0.182	0.045	0.056	0.056
Platte	0.029	0.026	0.146	0.177	0.097	0.092	0.082	0.073	0.150	0.037	0.046	0.046
Sweetwater	0.017	0.015	0.086	0.104	0.057	0.054	0.125	0.112	0.231	0.057	0.071	0.071
Washakie	0.030	0.027	0.152	0.184	0.101	0.095	0.077	0.069	0.142	0.035	0.044	0.044
Nitrogen Solutions												
Albany	0.048	0.043	0.243	0.294	0.161	0.152	0.011	0.010	0.020	0.005	0.006	0.006
Big Horn	0.024	0.022	0.124	0.150	0.083	0.078	0.097	0.087	0.180	0.044	0.055	0.056
Fremont	0.027	0.025	0.137	0.166	0.091	0.086	0.088	0.079	0.162	0.040	0.050	0.050
Goshen	0.033	0.030	0.170	0.206	0.113	0.107	0.064	0.057	0.118	0.029	0.036	0.037
Laramie	0.031	0.028	0.158	0.191	0.105	0.099	0.073	0.065	0.134	0.033	0.041	0.042
Park	0.023	0.021	0.119	0.144	0.079	0.075	0.101	0.090	0.186	0.046	0.057	0.058
Platte	0.027	0.024	0.136	0.164	0.091	0.086	0.089	0.079	0.163	0.040	0.050	0.051
Sheridan	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Sublette	0.041	0.037	0.207	0.251	0.138	0.130	0.037	0.033	0.068	0.017	0.021	0.021
Washakie	0.018	0.017	0.093	0.112	0.062	0.058	0.120	0.108	0.222	0.055	0.068	0.069
Monoammonium Phosphate												
Albany	0.027	0.025	0.137	0.166	0.091	0.086	0.088	0.079	0.162	0.040	0.049	0.050
Big Horn	0.024	0.022	0.121	0.147	0.081	0.076	0.099	0.089	0.183	0.045	0.056	0.057
Carbon	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Fremont	0.019	0.018	0.099	0.120	0.066	0.062	0.116	0.104	0.213	0.052	0.065	0.066
Goshen	0.034	0.031	0.174	0.211	0.116	0.109	0.061	0.055	0.112	0.028	0.034	0.035
Johnson	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Laramie	0.027	0.025	0.138	0.167	0.092	0.087	0.087	0.078	0.161	0.040	0.049	0.050
Park	0.036	0.033	0.185	0.223	0.123	0.116	0.053	0.048	0.098	0.024	0.030	0.030
Platte	0.031	0.028	0.157	0.191	0.105	0.099	0.073	0.065	0.135	0.033	0.041	0.042
Sheridan	0.025	0.023	0.129	0.156	0.086	0.081	0.094	0.084	0.173	0.043	0.053	0.054
Sublette	0.051	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Sweetwater	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Uinta	0.034	0.032	0.176	0.213	0.117	0.110	0.060	0.053	0.110	0.027	0.034	0.034

Appendix D

COUNTY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Washakie	0.026	0.024	0.135	0.163	0.090	0.085	0.089	0.080	0.165	0.041	0.050	0.051
Mix												
Albany	0.035	0.032	0.177	0.214	0.118	0.111	0.059	0.053	0.109	0.027	0.033	0.034
Big Horn	0.031	0.028	0.159	0.192	0.106	0.099	0.072	0.065	0.133	0.033	0.041	0.041
Campbell	0.044	0.040	0.225	0.272	0.150	0.142	0.024	0.021	0.044	0.011	0.013	0.014
Carbon	0.008	0.007	0.042	0.050	0.028	0.026	0.157	0.141	0.290	0.071	0.089	0.090
Converse	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Fremont	0.033	0.030	0.167	0.202	0.111	0.105	0.066	0.059	0.122	0.030	0.037	0.038
Goshen	0.000	0.000	0.002	0.002	0.001	0.001	0.186	0.167	0.343	0.085	0.105	0.106
Hot Springs	0.006	0.005	0.029	0.035	0.019	0.018	0.167	0.149	0.307	0.076	0.094	0.095
Laramie	0.025	0.023	0.127	0.153	0.085	0.080	0.095	0.085	0.176	0.043	0.054	0.054
Natrona	0.045	0.041	0.230	0.278	0.153	0.144	0.020	0.018	0.038	0.009	0.012	0.012
Park	0.045	0.042	0.231	0.280	0.154	0.145	0.019	0.017	0.036	0.009	0.011	0.011
Platte	0.051	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Sheridan	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Sublette	0.008	0.008	0.042	0.051	0.028	0.027	0.157	0.140	0.289	0.071	0.088	0.090
Sweetwater	0.046	0.043	0.237	0.287	0.157	0.148	0.015	0.014	0.028	0.007	0.009	0.009
Teton	0.013	0.012	0.069	0.084	0.046	0.043	0.138	0.123	0.254	0.062	0.078	0.078
Uinta	0.042	0.039	0.216	0.262	0.144	0.136	0.030	0.027	0.056	0.014	0.017	0.017
Washakie	0.009	0.008	0.044	0.053	0.029	0.027	0.156	0.139	0.288	0.071	0.088	0.089
Weston	0.027	0.025	0.137	0.166	0.092	0.086	0.088	0.078	0.162	0.040	0.049	0.050
Miscellaneous												
Albany	0.034	0.031	0.174	0.211	0.116	0.110	0.061	0.054	0.112	0.028	0.034	0.035
Big Horn	0.035	0.032	0.179	0.217	0.119	0.112	0.057	0.051	0.105	0.026	0.032	0.033
Campbell	0.007	0.006	0.036	0.043	0.024	0.023	0.162	0.144	0.298	0.073	0.091	0.092
Converse	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Fremont	0.050	0.046	0.257	0.313	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Goshen	0.024	0.022	0.120	0.146	0.080	0.075	0.100	0.090	0.185	0.045	0.056	0.057
Hot Springs	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Johnson	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Laramie	0.002	0.002	0.011	0.014	0.008	0.007	0.180	0.160	0.331	0.081	0.101	0.103
Natrona	0.037	0.034	0.190	0.230	0.127	0.119	0.049	0.044	0.091	0.022	0.028	0.028
Park	0.043	0.039	0.219	0.267	0.146	0.138	0.028	0.025	0.051	0.013	0.016	0.016
Sheridan	0.026	0.024	0.132	0.160	0.088	0.083	0.092	0.082	0.169	0.042	0.052	0.052
Sublette	0.050	0.046	0.258	0.312	0.171	0.162	0.000	0.000	0.000	0.000	0.000	0.000

Appendix D

COUNTY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Sweetwater	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Teton	0.043	0.039	0.218	0.264	0.145	0.137	0.029	0.026	0.053	0.013	0.016	0.016
Uinta	0.034	0.031	0.173	0.209	0.115	0.108	0.062	0.055	0.114	0.028	0.035	0.035
Washakie	0.042	0.038	0.212	0.257	0.141	0.133	0.033	0.030	0.061	0.015	0.019	0.019
Weston	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Liquid Ammonium Polyphosphate												
Albany	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Carbon	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.108
Fremont	0.042	0.039	0.215	0.260	0.144	0.136	0.031	0.028	0.057	0.014	0.017	0.018
Goshen	0.026	0.024	0.133	0.161	0.089	0.084	0.091	0.081	0.168	0.041	0.051	0.052
Laramie	0.002	0.002	0.010	0.012	0.007	0.006	0.180	0.161	0.333	0.082	0.102	0.103
Natrona	0.040	0.037	0.206	0.250	0.138	0.130	0.038	0.034	0.069	0.017	0.021	0.021
Park	0.022	0.020	0.112	0.135	0.074	0.070	0.106	0.095	0.196	0.048	0.060	0.061
Platte	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Washakie	0.029	0.027	0.149	0.180	0.099	0.094	0.080	0.071	0.146	0.036	0.045	0.045
Diammonium Phosphate												
Big Horn	0.035	0.032	0.177	0.213	0.118	0.111	0.059	0.053	0.109	0.027	0.033	0.034
Carbon	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Fremont	0.029	0.027	0.148	0.179	0.099	0.093	0.080	0.071	0.147	0.036	0.045	0.046
Goshen	0.026	0.023	0.131	0.158	0.087	0.082	0.093	0.083	0.171	0.042	0.052	0.053
Johnson	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Laramie	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.345	0.085	0.106	0.107
Park	0.031	0.028	0.157	0.190	0.105	0.098	0.074	0.066	0.136	0.033	0.041	0.042
Sheridan	0.028	0.026	0.143	0.173	0.095	0.090	0.084	0.075	0.154	0.038	0.047	0.048
Washakie	0.027	0.024	0.135	0.163	0.090	0.085	0.089	0.080	0.165	0.040	0.050	0.051
Calcium Ammonium Nitrate												
Park	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Aqueous Ammonia												
Goshen	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Anhydrous Ammonia												
Fremont	0.034	0.031	0.172	0.209	0.115	0.108	0.062	0.055	0.115	0.028	0.035	0.036
Goshen	0.030	0.028	0.154	0.187	0.103	0.097	0.075	0.067	0.139	0.034	0.042	0.043
Laramie	0.016	0.015	0.081	0.099	0.054	0.051	0.128	0.115	0.237	0.058	0.072	0.073
Park	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000

Appendix D

COUNTY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Platte	0.050	0.046	0.255	0.308	0.170	0.160	0.002	0.002	0.004	0.001	0.001	0.001
Sweetwater	0.028	0.026	0.144	0.175	0.097	0.091	0.082	0.074	0.152	0.037	0.046	0.047
Washakie	0.025	0.023	0.126	0.153	0.084	0.079	0.096	0.086	0.177	0.043	0.054	0.055
Ammonium Thiosulfate												
Big Horn	0.048	0.044	0.242	0.294	0.162	0.153	0.011	0.010	0.020	0.005	0.006	0.006
Campbell	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Converse	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Goshen	0.030	0.027	0.151	0.183	0.101	0.095	0.077	0.069	0.143	0.035	0.044	0.044
Johnson	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Laramie	0.024	0.022	0.121	0.146	0.080	0.076	0.100	0.089	0.184	0.045	0.056	0.057
Park	0.041	0.037	0.207	0.251	0.138	0.130	0.037	0.033	0.068	0.017	0.021	0.021
Sublette	0.050	0.046	0.258	0.312	0.171	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Washakie	0.036	0.033	0.184	0.223	0.122	0.116	0.054	0.048	0.099	0.024	0.030	0.031
Ammonium Sulfate												
Fremont	0.028	0.026	0.143	0.173	0.095	0.090	0.084	0.075	0.154	0.038	0.047	0.048
Goshen	0.041	0.038	0.211	0.255	0.141	0.132	0.034	0.031	0.063	0.015	0.019	0.019
Laramie	0.044	0.040	0.225	0.272	0.149	0.141	0.024	0.022	0.044	0.011	0.014	0.014
Park	0.029	0.027	0.149	0.180	0.099	0.093	0.079	0.071	0.146	0.036	0.045	0.045
Sheridan	0.033	0.030	0.169	0.204	0.112	0.106	0.065	0.058	0.120	0.029	0.037	0.037
Sweetwater	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.108
Uinta	0.030	0.028	0.155	0.188	0.103	0.097	0.075	0.067	0.138	0.034	0.042	0.043
Washakie	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Ammonium Nitrate												
Albany	0.045	0.042	0.231	0.280	0.154	0.145	0.019	0.017	0.035	0.009	0.011	0.011
Big Horn	0.033	0.030	0.167	0.202	0.111	0.105	0.066	0.059	0.122	0.030	0.037	0.038
Carbon	0.045	0.041	0.231	0.280	0.154	0.145	0.020	0.018	0.036	0.009	0.011	0.011
Fremont	0.028	0.026	0.145	0.175	0.096	0.091	0.082	0.074	0.152	0.037	0.046	0.047
Goshen	0.047	0.043	0.240	0.291	0.160	0.151	0.013	0.012	0.024	0.006	0.007	0.007
Johnson	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Laramie	0.039	0.036	0.198	0.240	0.132	0.124	0.044	0.039	0.080	0.020	0.025	0.025
Lincoln	0.050	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Natrona	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.168	0.346	0.085	0.106	0.107
Park	0.037	0.034	0.188	0.227	0.125	0.118	0.051	0.046	0.094	0.023	0.029	0.029
Platte	0.050	0.046	0.258	0.311	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Sheridan	0.026	0.024	0.131	0.159	0.087	0.082	0.092	0.083	0.170	0.042	0.052	0.053

Appendix D

COUNTY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Sublette	0.050	0.046	0.258	0.313	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Sweetwater	0.051	0.046	0.258	0.312	0.172	0.162	0.000	0.000	0.000	0.000	0.000	0.000
Uinta	0.031	0.028	0.156	0.189	0.104	0.098	0.074	0.066	0.136	0.034	0.042	0.042
Washakie	0.033	0.031	0.170	0.207	0.113	0.107	0.063	0.057	0.117	0.029	0.036	0.036