**Final Work Plan**

# California Regional $PM_{10}/PM_{2.5}$ Air Quality Study Ammonia Emissions Improvement Projects in Support of CRPAQS Aerosol Modeling and Data Analyses: Draft Ammonia Inventory Development

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# 1. INTRODUCTION

## Background

The California Regional $PM_{10}/PM_{2.5}$ Air Quality Study (CRPAQS) is a multi-year program to study particulate matter (PM) air pollution in Central California and consists of meteorological and air quality monitoring, emissions inventory development, data analysis, and air quality modeling. The primary objectives of the study are to:

- Provide an improved understanding of emissions and atmospheric processes that influence particle formation and transport;
- Develop methods useful to planning agencies in formulating and assessing candidate control strategies for attaining the federal and state PM standards in Central California; and
- Provide reliable tools for estimating the impacts of control strategies for PM on visibility, air toxics, and acidic aerosols and on attainment strategies for other pollutants, specifically ozone.

Chemical reactions of ammonia emissions with airborne oxides of sulfur and nitrogen produce fine ammonium sulfate and ammonium nitrate particulate matter. These reactions, especially those leading to ammonium nitrate, represent a significant percentage of wintertime $PM_{2.5}$ in the San Joaquin Valley (SJV). Thus, ammonia plays a major role in determining secondary aerosol concentrations within the CRPAQS domain. Figure 1-1 displays the San Joaquin Valley study area.

As part of the overall study, grid-based aerosol models are to be applied to simulate particulate matter concentrations in the SJV and to investigate the sensitivity of secondary particulate matter formation to various parameters. A first step in the successful application of air quality models to investigate proposed control strategies is the demonstration of acceptable model performance through comparison of modeled estimates and field study observation data. A key requirement for the credible application of air quality models are accurate input data specifying three dimensional meteorology and ground-level emission rate estimates. Ideally these inputs are to be developed with adequate spatial and temporal resolution in order to accurately represent the complex chemical and transport processes occurring in the atmosphere which contribute to the formation of particulate matter pollution.

Thus, the development of a state-of-the-science ammonia emission inventory for the San Joaquin Valley study area is the subject of this project. Accurate emission inventories based on the best available ammonia emissions information and processing methodologies will be critical in supporting numerous aspects of the CRPAQS activities over the coming years including ambient data analysis and photochemical modeling.

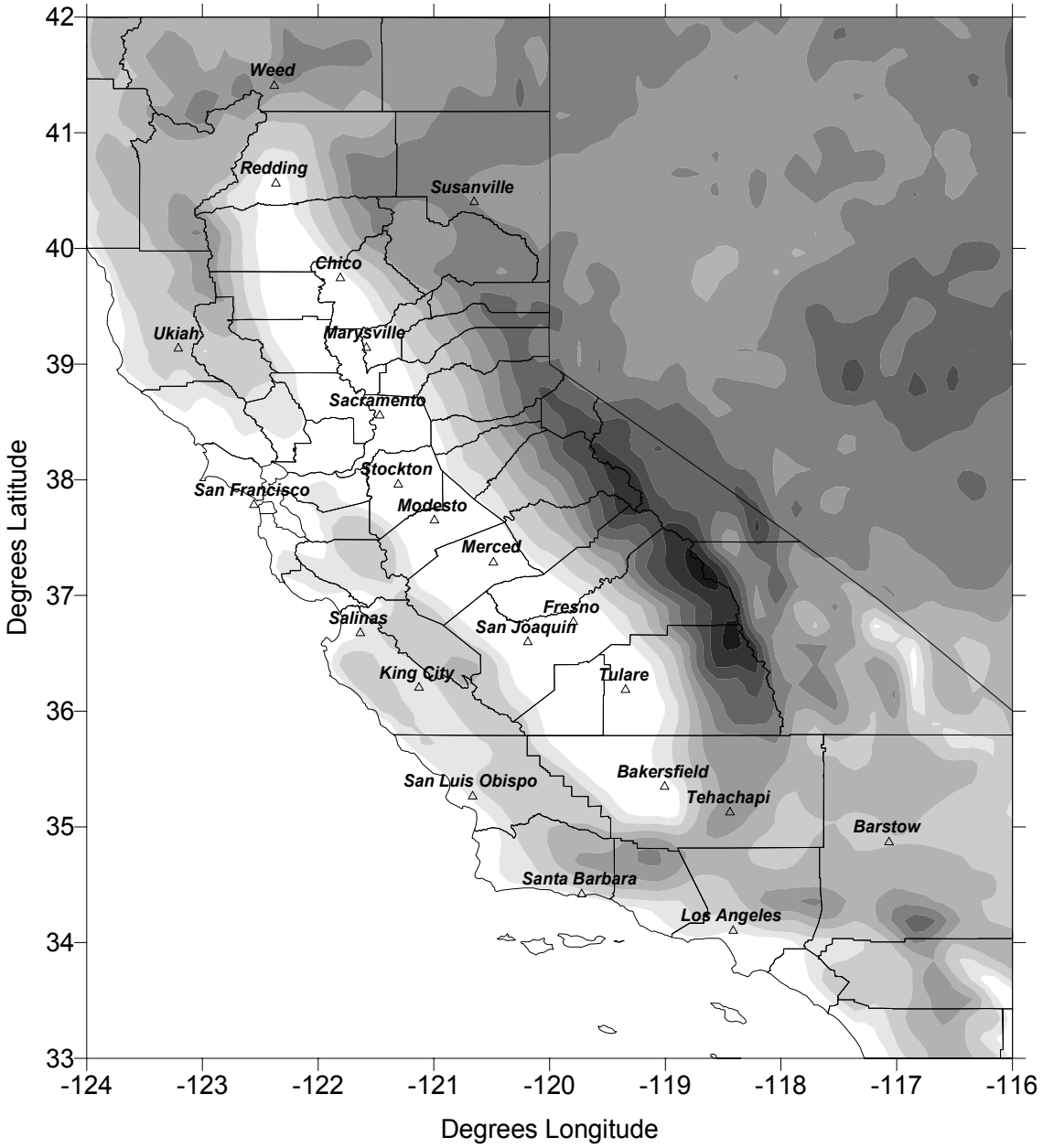


**Figure 1-1.** San Joaquin Valley Study Area.

## Project Goals and Objectives

The primary goal of the project is to develop a draft, ground-level, gridded ammonia emission inventory for use in data analysis and grid-based aerosol modeling for the CRPAQS. The study will take place within California's San Joaquin Valley (SJV) and the draft inventory is to be used to assess the sensitivity of aerosol model estimates to changes in such variables as spatial and temporal resolution, and emissions magnitudes for various source categories of ammonia emissions. The ammonia inventory is to be developed at a spatial resolution of 1-km by 1-km with a temporal resolution of 1-hour using the best available emission source data and processing methodologies. The geographic extent of the gridded inventory will cover the SJV study area, although where feasible, data will be collected for the entire state of California. In addition, a stated objective of the project is to develop a standard input data library and processing procedures in order to facilitate future in-house refinements or revisions to the inventory in a programmatic way.

A secondary goal of the study is the development of an ammonia capable GIS-based emission modeling system. Since for many ammonia emission source categories, emission estimates are intimately linked to land cover/land use (LULC) characteristics, an emissions model which combines the GIS data on LULC distributions with LULC specific emission factors to calculate gridded emissions in a single processing step would be ideal. In addition, the increased efficiency with which the inventory are generated within the GIS-based emission model will facilitate future updates and revisions with a minimal of processing effort.

Finally, it must be emphasized that due to the many on-going field studies and modeling input development projects sponsored by CARB in support of both the Central California Ozone Study (CCOS) and the CRPAQS, numerous sources of information relevant to the development of the ammonia emission inventory are currently either not yet available or in a state of flux. Thus, it will be imperative to maintain on-going coordination with these projects and the associated results. However, due to various scheduling issues and the need to develop a state-of-the-science draft ammonia emission inventory for this project, it may not be possible to rely solely on the availability of pertinent data from these studies. Therefore, where necessary the technical approach to the development of a draft gridded inventory is based on the most current relevant literature and existing sources of data. As the required data processing will be performed programmatically, the resulting inventory may be easily updated and/or modified in the event that more detailed source-specific data and information from these special studies becomes available during the course of the project. Given the current status of existing ARB and CRPAQS contracts, and based on the results of the data collection efforts under Task 2, the technical approach presented here may be subject to revision.

## Work Tasks

Below we briefly summarize the work tasks of the CRPAQS Ammonia Inventory Development Project for addressing the particular goals and objectives of the study.

Task 1: Prepare a Detailed Workplan

Under this task, a detailed workplan defining the issues to be addressed and detailing the technical approach to be used for developing inventory improvements and draft modeling inventories will be prepared. Project management, including preparation of monthly progress reports and regularly scheduled conference calls, will also be performed under this task.

Task 2: Collect Data and Create Standard Input Library

Data collection and creation of a standardized input data library is performed as part of this task. As part of the data collection tasks, ammonia emission sources and data sources are reviewed for each emission source category. Specific data elements and formats for each source category will be developed and documented. Procedures for archiving and processing "raw" data into the standardized data library are also developed and documented.

Task 3: Develop Ammonia Emissions Model

The development of an ammonia capable GIS-based emissions model will be investigated in this task. Enhancements to the GLOBEIS model developed by ENVIRON will be performed in coordination with recent GIS-based emission model development currently being performed/sponsored by the ARB. The resulting GIS-based emission model will be fully documented and used in the development of the draft ammonia modeling inventory to performed under Task 4.

Task 4: Produce Draft Ammonia Modeling Inventory

Under this task, a draft gridded ammonia emission inventory will be prepared for approval. The grid-based ammonia inventories will be developed for two periods corresponding to the CRPAQS 1999-2001 field measurement study periods. The inventory will be generated with 1-hour temporal resolution and 1-km by 1-km spatial resolution encompassing the entire San Joaquin Valley study area. The inventory will be developed using the ammonia model developed under Task 3. Alternative emissions processing systems will also be investigated for use in development of the modeling inventory as a fallback position.

Task 5: Documentation

Under this task, a cumulative Draft Final Report documenting all aspects of the work performed under each task during the course of the project is to be prepared and submitted for review. A Final Report incorporating comments received from the project Technical Committee will be prepared for submission. A Users' Guide detailing all processing procedures, data sources, input data library and processing routines used in the development of the ammonia emission inventory will be prepared. Regular system backups of all project data is also conducted under this task.

**Purpose**

This document is the Work Plan for the CRPAQS "Draft Ammonia Inventory Development" study. It describes the technical approach for the completion of the study, including an identification and prioritization of ammonia emission sources within the San Joaquin Valley study domain, identification and review of existing ammonia inventories and relevant literature, spatial surrogates and temporal profile data by source category, and the procedures and methodologies to be used for data archival, processing, emission inventory gridding and documentation and reporting. Where appropriate, the following items are included:

- Identification and review of the sources of ammonia emissions within the San Joaquin Valley study domain;
- Reviews of existing ammonia emissions literature, ammonia inventories and processing techniques, including ongoing emissions-related work sponsored by the Study Agency, the California Air Resources Board (ARB), and the South Coast Air Quality Management District (SCAQMD);
- Identification and recommendation of the most promising and practical processing techniques and data inputs for producing accurate gridded, hourly emissions estimates statewide and within the CRPAQS modeling domain;
- Detailed identification of spatial surrogate and temporal profile data to be collected and/or updated, by emission source category;
- Detailed description of input data, including associated source category, data source, units, file formats, spatial and temporal resolution and accuracy, and geographic and GIS-specific attributes;
- Documentation of the process for creating gridded emissions estimates from collected data;
- Detailed description of quality assurance (QA), quality control (QC) and documentation procedures;
- Specification of all hardware, software, and operating systems to be used, as well as, procedures to be used for providing regular system backups;
- Task-specific resource allocation and costs; and
- Project management, organization and schedule of work to be completed.

# 2. TECHNICAL APPROACH

In this section, the technical approach for the completion of the gridded ammonia emission inventory improvements is presented and discussed. The approach is organized according to the tasks outlined in the Statement of Work (SOW) for the project study. The SOW defines the following five tasks:

- Task 1: Prepare a Detailed Work Plan
- Task 2: Collect Data and Create Standard Input Library
- Task 3: Develop Ammonia Emission Model
- Task 4: Produce Draft Ammonia Modeling Inventory
- Task 5: Documentation and Reporting

## Task 1: Prepare a Detailed Work Plan

The purpose of this task is to develop a detailed Work Plan describing the approach to be used for the completion of the draft ammonia inventory development. As discussed above in Section 1, this document details the technical approach for the completion of the study, including an identification and prioritization of ammonia emission sources within the San Joaquin Valley study domain, identification and review of existing ammonia inventories and relevant literature, spatial surrogates and temporal profile data by source category, and the procedures and methodologies to be used for data archival, processing, emission inventory gridding and documentation and reporting.

## Task 2: Collect Data and Create Standard Input Library

The objective of this task is the collection of data and the creation of a standardized input data library. As part of the data collection efforts, ammonia emission sources and data sources are reviewed for each emission source category and recommendations regarding the most promising processing methodologies are presented and summarized.

<u>Summary of Source Category Prioritization</u>

Through an extensive review of existing ammonia emission inventories, relevant literature and data sources, the most promising processing methodologies and data sources are identified for use in the development of a gridded ammonia emission inventory for the San Joaquin Valley study area. While all the relevant data needed to quantify the relative contribution of each source category in the complete emission inventory has either not yet been collected or is not yet available, a source category prioritization based on emissions magnitude is not possible at this time. Table 2-1 summarizes the methodologies and sources of emissions/activity data, and temporal and spatial allocation proposed for each source category. The table entries are ordered as to reflect the project team's understanding of the relative importance of each source category as well as to reflect the importance of each emission source with respect to potential improvements that may be realized. The team believes that this approach will result in the most accurate and credible ammonia emission inventory given the available project resources.

Finally, it should be noted that are several common sources of temporal and spatial allocation data that have been used in the past for the development of emission inventories. These include the default temporal allocation profiles used in common emission models such as EPS2.0, EMS-95 and SMOKE, as well as the standard USGS LULC databases derived from the 1:100,000 scale (~200 meter resolution) LULC data. However, for the prioritized emission source categories presented in Table 2-1 below, the Team does not believe that any of these do a very good job of allocation, and therefore alternate methods and data sources are described in subsequent sections of this document.

**Table 2-1.** Prioritized source categories and objectives.

| Source Category | Emissions/Activity | Temporal Information | Spatial Information |
|---|---|---|---|
| Fertilizer Application (see Table 2-2 for source classification codes) | Incorporate emissions inventory directly from Krauter and Potter | Temporal extent of category – annual with primary activity in spring and summer; Temporal resolution of inventory – daily (via incorporation of data from Krauter and Potter). | Spatial extent of the category – statewide agricultural areas; Spatial extent/resolution of inventory - specific crop fields using shape files provided by Krauter/Potter for the entire state. |
| Livestock (see Table 2-6 for source classification codes) | Emission factors from James et al; Gharib and Cass; and Battye et al. Activity data from Calif. Cattlemens Assoc., Western Dairymans Assoc., USDA; RWCQBs; American Horse Council Foundation | Diurnal based on Wilkinson et al. and James et al. | To existing land use/land cover data (e.g., NLCD, USGS); Point |
| Natural Soils/Plant Canopies (see Table 2-3 for source classification codes) | Incorporate CAL-CASA derived inventory directly from Krauter and Potter. | Temporal extent of category – annual; Temporal resolution of inventory - Seasonally from CAL-CASA model. | Spatial extent of the category – statewide; Spatial extent/resolution of the inventory – statewide allocation using Krauter and Potter shape files. |
| Agricultural Burning (see Table 2-4 for source classification codes) | Use emission ratios of NH3 to CO from studies by Yokelson and Goode. Activity data from Les Fife/UC Berkeley or surveys of local agricultural extension offices. | Temporal extent of the category – fall and winter seasons; Temporal resolution of the inventory - Monthly – using the activity calendar developed by Fife and/or the Team. | Spatial extent of category – statewide agricultural areas; Spatial extent/resolution of the inventory - specific crop fields using shape files from Krauter/Potter developed for fertilizer application for the San Joaquin Valley only. |
| Prescribed Burning/Wildfires 930-932-0200-000 (47316) | Use emission ratios of NH3 to CO from studies by Yokelson and Goode. Activity data from CDFFP. | Temporal extent of the category – annual with primary activity in summer and fall seasons; Temporal resolution of the inventory - Seasonally. | Spatial extent of the category – statewide; Spatial extent/resolution of inventory – statewide with coverages developed from CDFFP and NIFC data |
| Residential Wood Burning 610-600-0230-000 (82115) 610-602-0230-000 (82123) | Emission and Activity estimates based on EPA's EIIP alternative methods using data from Energy Information Administration's State Energy Data Report and Residential Energy Consumption Survey. NH3 emissions based on ratios of NH3 to CO from studies by Yokelson and Goode. | Temporal extent of the category – fall, winter and spring seasons; Temporal resolution of the inventory - Monthly. | Spatial extent of category – statewide; Spatial extent/resolution of inventory – statewide allocated to the county-level using data from U.S. Bureau of Census on wood-burning households. Weighting of activity between rural and urban areas to be investigated. |
| On-Road Mobile Sources 700-000-0000-000 | Fleet-wide emission factor from Fraser and Cass or Lord et al. Gridded VMT from CARB. | Temporal extent of the category – annual; Temporal resolution of the inventory - | Spatial extent of category – statewide. Spatial extent/resolution of inventory – statewide gridded VMT provided by |

| Source Category | Emissions/Activity | Temporal Information | Spatial Information |
|---|---|---|---|
| | | Allocate based on daily and weekly profiles obtained from CARB. | CARB. |
| Industrial sources (see Table 2-9 for source classification codes) | Emission factor data developed for SCAQMD by ATC; Activity data from major ammonia suppliers in the state. Geothermal source from the ARB CEIDARS database | Temporal extent of the category – annual; Temporal resolution of the inventory – annual (assuming no temporal profile) | Spatial extent of category – statewide. Spatial extent/resolution of inventory – statewide area source spatially allocated by ZIP code coverages. Geothermal sources geo-coded and allocated as point sources |
| Sewage Treatment Plants 130-190-0300-0000 (66713) | Emission and activity data from SWRCB database; local surveys of POTWs | Temporal extent of the category – annual; Temporal resolution of the inventory – annual (assuming no temporal profile) | Spatial extent of category – statewide. Spatial extent/resolution of inventory – statewide; facility addresses geo-coded and allocated as point sources. |
| Composting 140-190-0300-0000 (66714) | Emissions data from Solid Waste Information System database, if available; emission factors developed by ATC for SCAQMD | Temporal extent of the category – annual; Temporal resolution of the inventory – annual (assuming no temporal profile) | Spatial extent of category – statewide. Spatial extent/resolution of inventory – statewide; SWIS-supplied addresses geo-coded and allocated as point sources. |
| Landfills 120-122-0240-0000 (57281) | Emission estimation method – same as existing SJV inventory. Data from SWIS database; California Integrated Waste Management Board; ARB emission inventory database (CEIDARS) | Temporal extent of the category – annual; Temporal resolution of the inventory – annual (assuming no temporal profile) | Spatial extent of category – statewide. Spatial extent/resolution of inventory – statewide, geo-coded and allocated as point sources. |
| Domestic Sources (see Table 2-8 for source classification codes) | Emission factor data from various literature sources (see Table 2-8); Activity data from U.S. Bureau of the Census; California State Board of Equalization | Temporal extent of the category – annual; Temporal resolution of the inventory – annual (assuming no temporal profile) | Spatial extent of category – statewide. Spatial extent/resolution of inventory – statewide; spatial allocation based on urban land use/land cover data from NLCD and USGS LULC databases. |
| Native Animals 950-912-0300-0001 (83288) Deer 950-912-0300-0002 (83289) Bear 950-912-0300-0003 (83290) Pigs | Emission factor data from Warn, et al.; activity data from CDFG. | Temporal extent of the category – annual; Temporal resolution of the inventory – annual (assuming no temporal profile) | Spatial extent of category – statewide. Spatial extent/resolution of inventory – statewide; spatial allocation based on shrubland/forest land use/land cover data from NLCD and USGS LULC databases. Spatial distribution of deer from CDFG. |

Review of Literature, Data Sources and Processing Methodologies

**Fertilizer Application**

The primary objectives for this source category are to better spatially and temporally allocate the emissions. The primary source of information for activity data and spatial allocation will be the GIS shape files produced in the Potter et al (2000) study. According to contacts with technical committee members, these data should be available in May of 2001. After reviewing the information from Potter et al, the Team will develop a set of EIC codes specific to primary crop types. A depiction of how this would look is shown in Table 2-2. The emission factors used by Potter et al will be used in this project. According to Potter et al (2000), the initial ammonia emission estimates were derived by assuming a constant 5.5% loss of fertilizer nitrogen. For the final emission inventory, different methods of application may be assessed (e.g., methods for incorporation of fertilizer into the soil) which lead to lower emission factors (one the order of 0.5 to 1% nitrogen loss).

**Table 2-2**. Emission inventory codes for fertilizer application.

| EIC Description[1] | EIC | CES |
|---|---|---|
| **Existing Code** | | |
| Misc. Agricultural Losses | 420-418-6000-0000 | 47050 |
| **Proposed Codes** | | |
| Fertilization Losses – Grain and Hay | 420-418-6001-0001 | 47051 |
| Fertilization Losses – Truck Crops | 420-418-6001-0002 | 47052 |
| Fertilization Losses – Citrus | 420-418-6001-0003 | 47053 |
| Fertilization Losses – Rice | 420-418-6001-0004 | 47054 |
| Fertilization Losses – Pasture | 420-418-6001-0005 | 47055 |
| Fertilization Losses – Vineyards | 420-418-6001-0006 | 47056 |
| Fertilization Losses – Deciduous Fruit and Nuts | 420-418-6001-0007 | 47057 |
| Fertilization Losses – Field Crops | 420-418-6001-0008 | 47058 |

[1] Crop names and number of categories taken from Potter et al (2000).

The advantages of having the fertilizer application loss emissions disaggregated as shown in Table 2-2 include:

1. The ability to incorporate new emissions data (i.e., emission factors) which will be crop-specific;
2. The ability to allocate emissions temporally based on fertilizer application schedules (as described below);
3. The availability of crop-specific spatial coverages (i.e., from Krauter and Potter).

The information from Krauter and Potter will cover the entire state.

Another possible source of activity and spatial allocation data is the pesticide usage database from the California Department of Pesticide Regulation (CDPR). The Team has ordered a CD-ROM containing preliminary 1999 data (year 2000 data will not be available until 2002), as well as information for the previous 5 years. This database will cover the entire state. According to discussions with CDPR and county agricultural offices, these data should allow the team to develop crop coverages.

This source of data will be considered for use, if the data from Krauter and Potter can not be obtained in time for this study.

Another source of information relative to both activity (mass of fertilizer applied per acre) and temporal allocation is the study being conducted for the California Department of Food and Agriculture (CDFA) by King. According to CDFA, a draft report should have been available by December 2000 and forwarded to one or more members of the technical committee (Cady, 2000). The final report was due by February 28, 2001. The Team requests that a copy of the draft report be forwarded to the Team's Project Manager as soon as it is made available. As with the spatial coverage data mentioned above, the application calendar will cover crops grown within the CRPAQS domain, although it may be representative of the rest of the state.

The Team will evaluate application schedule information from King and Krauter in order to develop temporal allocation factors for each crop type. If sufficient data are found to justify a higher level of temporal resolution (e.g., down to specified weeks of the year), then these factors will be developed.

CARB has developed some temporal allocation factors for agricultural practices and has made them available on the ARB web site. These factors relate to operations generating PM emissions, however, and are not likely to be of much value in this study.

Another source of information for both temporal and spatial allocation will be surveys conducted by Team members to fill in any data gaps found in the information sources described above. These surveys would be conducted with both county agricultural offices and university researchers. Spatial coverage would cover only the CRPAQS domain.

The final source of activity data is the fertilizer sales statistics from the CDFA. These are the same data used in the existing SJV method with the emission factors from Battye et al (1994). Reports of fertilizer sales (over 100 tons) by county are issued twice per year. The entire state is covered. It is not clear how well fertilizer sales data represent actual application, however. Given the availability of the other data sources mentioned above, this information will likely be used to perform a quality assurance check (e.g., by comparing annual sales in the domain to the estimated mass of fertilizer applied that was calculated from information from Krauter, Potter, King, and other sources).

**Agricultural and Natural Soil/Plant Canopy Systems**

As pointed out in the Team's proposal, it is highly uncertain whether natural soils (referred to here as soil/plant canopy systems) are net emission sources over annual time frames. Studies conducted in Europe have shown that the systems studied can be net sources or net sinks of ammonia. This issue is complicated by the interactions of ammonia within the soil/plant canopy system, and should not be simplified by just looking at emissions from the soil. For example, depending on the system, the plant canopy can take up gaseous ammonia directly.

The Team will incorporate the inventory by Potter et al (2000). This inventory should be available by May 2001. One issue with this inventory that should be noted is that it represents the soil component of the system only. Hence, any uptake by the plant canopy is not accounted for. Table 2-3 presents a suggested source categorization scheme for soil/plant canopy systems.

By treating each system separately, future refinements to the inventory will be easier to make (e.g., plugging in new emission factors, adjusting temporal allocation factors).

**Table 2-3**. Suggested source classification for soil/plant canopy systems.

| EIC Description[1] | EIC | CES |
|---|---|---|
| **Existing Codes** | | |
| Agricultural Biogenics – Day Time | 910-910-0250-0001 | 82255 |
| Agricultural Biogenics – Night Time | 910-910-0250-0002 | 82263 |
| Non-Agricultural Biogenics – Vegetative | 910-912-0250-0000 | 83287 |
| **Proposed Codes** | | |
| Soil/Plant Canopy Systems – Cropland and Semi-Agricultural Land | 910-910-0250-0010 | 82270 |
| Soil/Plant Canopy Systems – Evergreen Needleleaf Forest | 910-912-0250-0010 | 83290 |
| Soil/Plant Canopy Systems – Mixed Forest | 910-912-0250-0011 | 83291 |
| Soil/Plant Canopy Systems – Open Shrubland and Desert | 910-912-0250-0012 | 83292 |
| Soil/Plant Canopy Systems – Grassland | 910-912-0250-0013 | 83293 |
| Soil/Plant Canopy Systems – Bare Soil | 910-912-0250-0014 | 83294 |
| Soil/Plant Canopy Systems – Deciduous Broadleaf Forest | 910-912-0250-0015 | 83295 |
| Soil/Plant Canopy Systems – Woodlands/Wooded Grasslands | 910-912-0250-0016 | 83296 |

[1] System names and number of categories taken from Potter et al (2000).

Coverage will include the entire state and will be based on the GIS shape files provided by Potter et al (2000).

**Biomass Burning (Prescribed Burning/Wildfires, Agricultural Burning, and Residential Wood Burning)**

Each of these categories could be significant during certain episodes (e.g., wildfires in summer, agricultural burning in the fall). Staff at U.C. Berkeley were contacted regarding their ongoing work for CARB in developing spatial coverages and emission inventories of wildfires/prescribed burning and agricultural burning (Scarborough, 2000). For wildfires/prescribed burns, the work completed to date is primarily *a method* for developing 1 kilometer by 1 kilometer spatial coverages and not the actual coverages (or inventories) themselves. For wildfires, some 1998 activity data were collected. Hence, these data are not likely to be of high value for this project (which needs year 2000/2001 data).

Berkeley staff are also looking at methods for developing spatial coverages for agricultural burning from permit data collected by Mr. Les Fife (Scarborough, 2000). According to discussions with Mr. Fife, work completed to date has been a database of calendar year 2000 agricultural burns in the Sacramento Valley. By Spring 2001, Mr. Fife intends to deliver a database covering both the Sacramento and San Joaquin Valleys (i.e., Kern to Shasta counties; Fife, 2000). Temporal resolution is to be down to the day on which these agricultural burns occur. Spatially, the burns will be allocated to specific crop types (e.g., rice, wheat).

For residential wood burning (i.e., wood burned in fireplaces or woodstoves), ideally the amount of wood consumed by households for a given time period would be determined by survey (EPA, 1997). Once wood-burning households are identified, respondents would be asked about the frequency and the amount of wood burned over a certain time period (e.g., per week). Information on the device type (e.g., fireplaces with and without inserts, woodstoves) may also be requested. Performing a survey in the required time frame for the SJV study area is not feasible. U.C. Berkeley staff are currently conducting some residential wood surveys in three areas. The results are not likely to be available in time for this study (projected August 2001 completion). Other alternative approaches are recommended and are discussed below.

*Recommendations for Prescribed Burns/Wildfires*

Due to the uncertainty in the availability of emissions and spatial coverages from Berkeley staff during the period of this study, recommendations are as follows for developing emission estimates. Emissions data are lacking for ammonia from this category, which explains their absence from the current inventory (STI, 1998). Some remote sensing work done by researchers in the early 1990's reported NH3 to NOx ratios of 5:1 using remote sensing methods (Griffith et al, 1991). More recent information includes studies by Yokelson et al (1996, 1999) and Goode et al (1999, 2000). Emissions will be estimated by first determining the total CO emissions using either AP-42 emission factors or emission rates estimated in the studies reviewed above. The CO emissions will be multiplied by the appropriate NH3 to CO emissions ratio to obtain NH3 emissions.

For prescribed burning, activity data (acres burned) will be gathered for the 2000 calendar year from the California Department of Forestry and Fire Protection (CDFFP). However, the CDFFP data do not account for fires occurring on U.S. Forest Service, State Parks, National Parks, and Indian lands. As such, these agencies will need to be contacted separately to determine the availability of statistics on prescribed burning. The team will allocate the activity based on either: allocating the state totals to forested land; or preferably, if data are received by California Region, allocation of the regional totals to forested land in each region. At the same time, the team will gather information from the above agencies on acreage burned by season or month, as available. Steve Shaw of SJV APCD also indicated that prescribed acres burned for the year 2000 might be compiled by the end of January 2001 for counties within SJV APCD jurisdiction. This data set, which will be made available to us, will provide the number of acres burned per county, as well as the day on which the prescribed burns occurred for temporally allocating the activity.

Historically, wildfire emissions have been estimated by ARB, as opposed to the individual air districts. As mentioned above, ARB's most recent data base of wildfire acreage is for 1998. Therefore, wildfire acreage data for California will need to be obtained from the appropriate agencies. CDFFP does track wildfires, and in discussions with CDFFP, they annually publish statistics on wildfire acres, which includes wildfires occurring on all lands, and not CDFFP lands exclusively. A 2000 summary report may not be available in time for this project, but the team will keep apprised of its availability.
If the 2000 CDFFP report is not available, the team would need to supplement CDFFP data with data from other agencies, similar to prescribed burning. Activity data will be obtained from the U.S. Forest Service, and other Federal agencies under the Department of the Interior (e.g., Bureau of Indian Affairs, Department of Fish and Wildlife, Bureau of Land Management). For updating national criteria pollutant emission estimates for this category, the U.S. Forest Service

has provided Pechan with State-level estimates of acres burned due to wildfires on U.S. Forest Service lands, as well as State and private lands, up to the year 1999. The effort to update inventory year 2000 criteria pollutant emissions for the National Emissions Inventory (NEI) will likely occur in mid summer 2001, but any wildfire activity data collected in a timely manner for the NEI could potentially be used for this effort.

Another source for obtaining wildfire and prescribed burning data is the National Interagency Fire Center (NIFC). The NIFC provides year-to-date statistics on the number of acres burned in the southern and northern regions of California via their web-site (data for January 2000 through November 2000 are currently posted). Weekly incident management reports may be useful for temporally allocating the annual activity. The NIFC agency will be contacted to find out if there are any limitations to using these incident report data, and whether any gaps exist in their data (e.g., does it cover all categories of lands including Federal, State and private).

*Recommendations for Agricultural Burning*

As with fertilizer application, the team will disaggregate this category into a number of subcategories by assigning new EIC and CES codes specific to crop type (since activity will vary spatially and temporally by crop type). An example is shown in Table 2-4 below. Spatially, the same coverages developed above for fertilizer application will be used (from shape files developed by Krauter and Potter). As mentioned under the fertilizer application section above, alternate sources of activity and spatial allocation data include the CDPR pesticide usage database and land use/land cover data (e.g., CDWR and USGS).

**Table 2-4.** Suggested EIC/CES codes for agricultural burning.

| EIC Description[1] | EIC | CES |
|---|---|---|
| **Existing Code** | | |
| Agricultural Burning - Field Crops | 670-662-0262-0000 | 47258 |
| **Proposed Codes** | | |
| Agricultural Burning – Crop A | 670-662-0262-0001 | 47259 |
| Agricultural Burning – Crop B | 670-662-0262-0002 | 47260 |
| Agricultural Burning – Crop C | 670-662-0262-0003 | 47261 |
| Agricultural Burning – Crop D | 670-662-0262-0004 | 47262 |

[1] Crop names and number of categories to be determined.

There are no other known sources of activity data for this source category (emissions are not in the current inventory; STI, 1998). EPA currently does not have information for estimating ammonia emissions. We will adopt surrogate emission factors from AP-42 (e.g., for CO) and the information sources noted under prescribed burns/wildfires above.

Temporal allocation will be based on information gathered from Les Fife. Mr. Fife reports that his database will be complete for the Sacramento and San Joaquin Valleys by Spring of 2001 (Fife, 2000). Since his data will not cover the entire CRPAQS domain, the Team will ascertain whether there is a need to adjust the temporal profiles for any crop type to be more representative of the domain. This will be done with telephone contacts to county agricultural extension offices outside of the Sacramento and San Joaquin Valleys.

*Recommendations for Residential Wood Combustion*

The Team recommends generating year 2000 estimates based on the EPA's Emission Inventory Improvement Program (EIIP) alternative method for this category (EPA, 1997). This method specifies the use of State-level estimates of the amount of wood consumed for California according to the Energy Information Administration's (EIA's) State Energy Data Report. This State estimate is then allocated to the county level using the number of wood-burning households in each county, as reported by the 1990 United States Census. Since these data represent 1990, the Team will determine whether newer information will be available for this study from the 2000 census. As mentioned above, U.C. Berkeley is conducting research in estimating emissions from this category, however the results are not expected to be available for inclusion in this study.

For the NEI, residential wood combustion activity was estimated for the year 1990 by running the County Wood Consumption Estimation Model. For each year since 1990 up to 1999, county-level activity estimates (i.e., cords of wood) were updated using the national total for residential wood consumption and heating degree days. For most States, monthly heating degree days are obtained from one representative meteorological station in the State. For California, 2 stations, one in Northern California and one in Southern California, are used for Northern and Southern California counties, respectively. Heating degree data for 2000 from the National Climatic Data Center (NCDC) are likely to be available by June 2001.

ARB estimates emissions for all air districts within the State. For fireplaces, ARB multiplies an average wood consumption per fireplace estimate (0.28 cords per year) by the estimated number of houses with active fireplaces. The estimated number of houses with active fireplaces is derived by subtracting the estimated number of wood heating houses (available from the 1990 Census of Population and Housing-Summary Tape File 3A) from the total number of wood burning houses. The total number of wood burning houses is estimated by multiplying the fraction of houses burning wood by the total number of houses. The 1988 report, *The California Residential Wood Consumption Survey, Draft*, lists the percentage of wood burning households by Air Basin. ARB estimates emissions for wood stoves differently than emissions for fireplaces, since wood stove activity is believed to correlate more closely with temperature (i.e., heating degree days). For wood stoves, a model equation was developed that estimates energy consumption using inputs such as number of households burning wood, housing design characteristics, heating degree days, and fuel heating values.

In discussions with ARB, year 2000 estimates for residential wood combustion are likely to be grown from 1999 estimates, using the annual change in population as a growth factor. ARB last used the method described above for the inventory year 1997, and has grown the estimates using county-level population for each year since then.

Because the same NH3 emission factors would likely be applied to all activity data, regardless of whether the activity corresponds to fireplaces or wood stoves, a method that distinguishes between the activity from these two types of devices may not add value. If, in the process of researching this issue, it is found that emission factors or seasonal profiles are available by device type, the Team will make an effort to distinguish the activity among the various devices separate EIC/CES codes will be used for each). This distinction could be made using data from EIA's *Housing Characteristics 19xx*, which is part of its Residential Energy Consumption Survey. This publication has information to estimate the percent of households in the Western region that use fireplaces versus wood stoves.

Most residential wood burning occurs during the cold season (typically in the fall, winter and early spring). Temporal allocation profiles have been developed by ARB to apply to annual estimates of wood burned by households. Both Statewide profiles and profiles specific for the SJV APCD have been developed (ARB, 1997). Heating degree-day data for 2000 can also be obtained from National Climatic Data Center and used to update these profiles specifically for the inventory year in question, if warranted. Other factors, such as the price of electricity, may also affect the wood-burning activity for a specific time period during the inventory year being modeled. The Team will examine potential factors and will determine if information is available (e.g., from the literature or from State agency contacts) to improve the activity data or temporal allocation factors.

As with prescribed burning and wildfires, contacts with EPA staff and searches of the literature to date have not yielded NH3 emission factors specific for residential wood combustion. Consistent with ARB's current approach, NH3 emissions may be estimated based on ratios of NH3 to CO emission rates from other biomass combustion sources (e.g., wildfires). Care must be taken in the use of these ratios, however since NH3 emissions from sources such as wildfires can come from the underlying soil as well as the burned biomass.

Based on other ongoing work for this source category, it is clearly important to be able to distinguish between urban and rural residential wood burning activity. Per unit household, activity in urban areas is lower than in rural areas (where wood can be an important primary or supplemental fuel source; Houck, 1997). The team will develop weighting factors to account for this issue from the U.S. Department of Energy household energy consumption surveys (e.g., DOE, 1993) and the U.S. Bureau of Census American Housing Survey.

**Livestock**

The ENVIRON team will attempt to improve on the current limitations in the Livestock ammonia emissions inventory. We believe that significant improvements can be made in the spatial and especially the temporal allocation of livestock emissions.

The ENVIRON team will use the emission factors from the study by James et al (1997) to estimate emissions for confined operations (dairies and beef feedlots. For range cattle, the grazing emission factor presented in Battye et al (1994) will be used (based on the work of Asman in Europe). The team will use methods similar to those used by CARB in 1999 to spatially allocate populations to California air basins. Emission factors for goats will be from Bouwman et al. (1997); emission factors for rabbits will be from Gharib and Cass (1984). All other emission factors will be from Battye at al. (1994). Livestock emission factors are shown on Table 2-5. Proposed emission inventory codes are given in Table 2-6.

**Table 2-5**. Livestock emission factors.

| Livestock | Emission Factor, lbs/animal/yr | Emission Factor Source |
|---|---|---|
| Beef Cows (confined operations) | 74 | James et al. (1997) |
| Milk Cows (confined operations) | 74 | James et al (1997)[e] |
| Manure Spreading | 5.6 | Battye et al. (1994) |
| Range Cattle | 1.54 | Battye et al. (1994) |
| Hogs and Pigs | 20.3 | Battye et al. (1994)[b] |
| Sheep and Lambs | 7.43 | Battye et al. (1994)[b] |

| | | |
|---|---|---|
| Layers and pullets | 1.00 | Battye et al. (1994)[b] |
| Broilers and other meat type chickens | 0.37 | Battye et al. (1994)[b] |
| Horses | 26.90 | Battye et al. (1994)[b] |
| Mules, Burros and Donkeys | 26.9 | Battye et al. (1994)[b] |
| Goats | 1.28 | Bouwman, et al. (1997)[d] |
| Rabbits | 0.37 | Gharib and Cass (1984)[e] |

We will investigate in detail the basis for proposed diurnal variations in dairy related ammonia emissions (Muck and Steenhuis, 1982; Wilkinson et al., 1998; James et al., 1997; and Schmidt and Winegar, 1996). We will specifically concentrate on algorithms which describe the emissions in terms of commonly available environmental parameters (i.e., wind speed, temperature and solar radiation) because they will provide a sound basis for future refinement of the inventory. The current understanding of the biological and physical processes accounting for the creation of emission of ammonia from animal excreta is insufficient to develop a theoretically based temporal model. However, an understanding of these processes will be used to validate an empirical model like the one presented in Wilkinson et al. (1998). That model assumes wind speed, temperature, solar radiation, and relative humidity are the independent variables. Because models like that presented in Wilkinson et al. (1998) require significant amounts of local environmental data, processing constraints may require a more general approach. We believe that several regional profiles can be produced which would represent diurnal and seasonal variation of ammonia emissions. These profiles would be compiled from the results of a model like Wilkinson et al. (1998). The authors of Wilkinson et al. (1998) and James et al. (1997) will be contacted to obtain any newly developed information.

Other temporal variations may occur because of management practices regarding manure removal, feed cycles and seasonal population fluctuations. The ENVIRON team will consult with the California Cattleman's Association and the Western Dairy Association to determine how these practices may affect seasonal ammonia emissions and recommend a seasonal temporal profile if it can be supported.

**Table 2-6.** Suggested EIC/CES Codes for Livestock Operations

| EIC Description | EIC | CES |
|---|---|---|
| **Existing Code** | | |
| Livestock Wastes | 630-618-0262-0000 | 66605 |
| **Proposed Codes** | | |
| Cattle - Confined Dairy Operations | 630-618-0262-0001 | 66606 |
| Cattle - Confined Beef Operations | 630-618-0262-0002 | 66607 |
| Cattle - Grazing | 630-618-0262-0003 | 66608 |
| Cattle - Manure Spreading | 630-618-0262-0004 | 66609 |
| Poultry - Broiler Chickens | 630-618-0264-0001 | 66612 |
| Poultry - Layer and Pullet Chickens | 630-618-0264-0002 | 66613 |
| Poultry - Turkeys | 630-618-0264-0003 | 66614 |
| Hogs and Pigs | 630-618-0266-0001 | 66618 |
| Goats | 630-618-0268-0001 | 66620 |
| Rabbits | 630-618-0270-0001 | 66622 |
| Sheep and Lambs | 630-618-0272-0001 | 66624 |
| Mules, Burros and Donkeys | 630-618-0274-0001 | 66626 |
| Horses | 630-618-0276-0001 | 66628 |

The temporal profiles discussed above were all developed for dairies and may not be applicable for other livestock. However, because test data to determine temporal profiles for other livestock are lacking, the profiles developed for dairies could be used. This method is assumed to be appropriate because excreta from other animals are assumed to react similarly to dairy cow excreta.

For spatial allocation, the ENVIRON team will pursue data from California Cattleman's Association, Western Dairy Association, local Regional Water Quality Control Boards (RWQCBs), county vector control offices and/or county health departments, and the Department of Water Resources land use database. We will identify as many dairy facilities, with populations, as possible, filling in data from multiple data sources if required. These facilities will be distributed as point sources. If spatial location data is not available from the relevant data source it will be determined by geo-coding the facility address. The ENVIRON team will focus on identifying the largest facilities, especially large poultry facilities, in order to pinpoint the majority of these emissions.

The same approach will be used for poultry operations. Using primarily data from the county vector control offices and/or county health departments, the ENVIRON team will geo-code facility addresses to allocate these emissions as point sources.

Beef cattle will be allocated to the grasslands/herbaceous classification, code 71, in the National Land Cover Data (NLCD) database. Half of the horses, mules, burros and Donkey emissions will be allocated to the pasture/hay classification, code 81. These emissions represent commercial operations. Half of the emissions will be allocated to low intensity residential classification, code 21, representing home stabled animals. Half of the hogs, rabbits, sheep and goats will be allocated to pasture/hay classification, code 81, and half will be allocated to grasslands/herbaceous classification, code 71. Following a review of the animal population data, the team will consult with local agricultural extension offices to determine the best allocation of these emissions.

Activity data for dairies will be pursued through California Cattleman's Association, Western Dairyman's Association, the RWQCBs, Branch, the Department of Agriculture's 1997 Agricultural Census (USDA 1999a). Activity data for horses will be pursued from the Department of Agriculture's Equine Study (USDA 1999b), Department of Agriculture's 1997 Agricultural Census (USDA 1999a), and American Horse Council Foundation. On farm horse populations will be taken from the Agricultural Census (USDA 1999a), non-farm horse populations will be developed based on the ratio of non-farm to farm horses reported at the state level in the American Horse Council Survey.

In some cases data from multiple sources will be reconciled to produce the best estimate of animal population.

**Wastewater Treatment**

The ENVIRON team will identify a preliminary list of wastewater treatment plants (POTWs) from the California State Water Resources Control Board (SWRCB) Database of Waste Dischargers. Because past researchers have noted that not all POTWs are listed on the SWRCB database, the ENVIRON team will contact local sanitation district's within the study area to identify any additional facilities. The ENVIRON team will survey POTWs to determine the extent to which sludge drying occurs at the facilities or off-site within the study domain or outside of the study domain and to determine flow rates if not available from the SWRCB database. We will assign emissions specific to sludge drying to those facilities where sludge drying occurs. Emissions for sludge drying will be estimated from field data collected at the Visalia Plant by STI (1998). Emissions from water treatment will be estimated using the emission factor developed for STI (1998) from a regression analysis of self reported ammonia emissions and flow rates. This emission factor is consistent with the emission factor developed by ATC (2000) from source test results at two POTWs. The activity data, flow rates, will be from the SWRCB database or telephone survey for unlisted facilities. Facility addresses will be geo-coded and the emissions allocated as point sources.

**Composting**

The ENVIRON team has reviewed the Solid Waste Information System (SWIS) Database of the California Integrated Waste Management Board to determine the extent of current composting operations in the San Joaquin Valley and throughout the State. The database includes almost 200 composting facilities statewide. The database does not contain the relevant activity data, amount of waste composted, to develop ammonia emissions estimates for significant portion of these facilities. The ENVIRON team will use activity data from the database, if available, and will contact facilities within the study area to obtain activity data for those facilities for which data is lacking in the database. The emission factors developed by ATC (2000) from source test results from facilities composting several different waste types will be used to estimate emissions

Composting emissions will be allocated as point sources based on the latitude/longitude information from the SWIS database. Ammonia emissions information from composting operations is insufficient to develop a temporal profile for this source.

**Landfills**

The ENVIRON team has reviewed the Solid Waste Information System (SWIS) Database of the California Integrated Waste Management Board to identify landfills in the Study Area. Activity data, the amount of methane produced, will be developed from data reported in California Air Resources Board emission inventory database (CEIDARS). This data is reported as total organic gases (TOG) and reactive organic gases (ROG). Total methane is calculated as the difference of TOG minus ROG. No new emissions data for ammonia was found during the literature search. The team will adopt the same weight ratio of 0.7 NH3 to methane used in the previous inventory (STI, 1998) in order to estimate emissions.

The ENVIRON team will fill in data for large landfills identified in the SWIS database which are not reported in CEIDARS. Data for similar sized landfills will be used to fill in this data. Previous researchers have found this source category to be minor (ATC 2000, Radian 1991, STI 1998), therefore, the ENVIRON team will not expend significant resources in contacting facilities to produce the most comprehensive database possible or filling in data lacking from the CEIDARS database

Landfill emissions will be allocated as point sources based on the latitude/longitude information from the SWIS database. Because of the scarcity of emissions data, and the relatively minor contribution from this source, no temporal profiles will be developed.

**Native Animals**

This source category is considered a minor source. Native animals were not included in the most recent inventory for the San Joaquin Valley (STI 1998). Native animals accounted for only 0.01% of the recent South Coast Air Basin inventory (ATC 2000). The ENVIRON team will develop emissions estimates for this category without expending an unwarranted amount of effort for this minor source.

Emissions from small and ubiquitous animals (e.g., rodents and birds) are assumed accounted for in the soil emissions estimates.

Emission factors for several wild animals have been presented, however these factors vary considerably. The ENVIRON team will use emission factors developed for the South Coast Air Basin inventory (ATC 2000). These emission factors, developed from a generic herbivore emission factor from Warn et. al., (1990). Are shown on Table 2-7.

**Table 2-7**. Native animal emission factors.

| Game | Total | Warn et. al. (1990) Emission Factor, lb/kg-head-yr | Weight[a] kg | Adjusted Warn et al. Emission Factor[b], lb/head-yr |
|---|---|---|---|---|
| Deer | 13,500 | 0.14 | 79.4 | 11.1 |
| Bear | 0.25/ sq. mile[c] | 0.14 | 300 | 42.0 |

[a] Warn T.E., Zelmanowitz S., and Saeger M. (1990): Development and Selection of Ammonia Emission Factors for 1985 NAPAP Emissions Inventory. EPA-600/7-90-014. Final Report Prepared for Office of Research and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance Technologies Corporation, Chapel Hill, N.C., EPA Contract No. 68-02-4374, Work Assignment No. 43 , June.

[b] Weight of white-tail deer taken from http://www.thewildones.org/CHA.Animals97/deer.html. Weight of bears taken from http://www.bearden.org/blkbear.html.

[c.] Bear Density from Department of Fish and Game, Black Bear Management Plan, July 1998.

Activity data for bears and deer will be collected from the California Department of Fish and Game (CDFG). Activity data for bears will be based on the 0.25 bear per square mile density estimate from the CDFG black bear management plan (CDFG 1998). Activity data for game animals will be pursued through the most recent game take hunter survey report by the CDFG. Past researchers, however, have found this data to be too sparse to develop good population estimates (ATC 2000, STI 1998.) In addition, a relatively large population of wild pigs are present within the state and contribute about as much ammonia emissions as do bears. Therefore, activity data for wild pigs will be obtained from the CDFG and used to estimate emissions based on emission factors developed by Warn et al.

Emissions from native animal waste will be allocated to shrub land, code 51 and forest land, codes 41, 42, and 43. In the case of deer, the CDFG has spatial distribution information within the state by district, which will be used to better spatially allocate emissions from this source. Because of the scarcity of emissions data, and the relatively minor contribution from this source, no temporal profiles will be developed.

**Domestic Sources**

Domestic sources include ammonia emissions associated with pets, cigarette smoke, untreated human waste, perspiration, respiration and household ammonia use. The ENVIRON team will use emission factors developed for the South Coast Air Basin inventory (ATC 2000.) This recent study provides the most comprehensive analysis of literature for these sources. Emission factors for domestic sources are shown in Table 2-8.

**Table 2-8**. Domestic sources emission factors.

| Source | Proposed EIC Codes | Emission Factor, lbs/person/year | Emission Factor Reference |
|---|---|---|---|
| Respiration | 690-995-0000-0001 | 0.004 | e |
| Perspiration | 690-995-0000-0002 | 0.550 | e |
| Household Use | 690-995-0000-0003 | 0.050 | a |
| Untreated Human Waste | 690-995-0000-0004 | 0.050 | e |
| Cigarettes | 690-995-0000-0005 | 0.000 | c,d |
| Infant - Cloth Diapers | 690-995-0000-0006 | 6.900 | b |
| Infant - Disposable Diapers | 690-995-0000-0007 | 0.360 | b |
| Cats | 690-995-0000-0008 | 0.029 | e |
| Dogs | 690-995-0000-0009 | 0.265 | e |
| Homeless | 690-995-0000-0010 | 11.000 | b |

[a] Census of Population and Housing, U.S. Bureau of the Census, Current Population Reports, Series P23-194, Population Profile of the United States: 1997. U.S. Government Printing Office, Washington, D.C., 1998.

[b] Radian, 1987 Ammonia Emission Inventory (1991), September.

[c] California State Board of Equalization, "Table 30B - Cigarette Distributions and Per Capita Consumption, 1959-60 to 1997-98." 1997 Annual Report, A-41

[d] Warn T.E., Zelmanowitz S., and Saeger M. (1990): Development and Selection of Ammonia Emission Factors for 1985 NAPAP Emissions Inventory. Final Report Prepared for Office of Research and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance Technologies Corporation, Chapel Hill, N.C., PB90-235094, EPA-600/7-90-014, June.

[e] Sutton, M.A., C.J. Place, M. Eager, D. Fowler, and R.I. Smith (1995): Assessment of the Magnitude of Ammonia Emissions in the United Kingdom, Atmospheric Environment, (29):1393-1411.

Activity data for pets will be developed based on the ratio of pets per capita developed for the 1991 South Coast Air Basin inventory (Radian 1991) and 2000 census data from the U.S. Bureau of the Census. These ratios are specific to the urban and suburban settings. A determination of the setting, urban or suburban, will be made for each county, based on the predominant setting within each county.

Activity data will be based on per capita cigarette consumption data from the most current annual report on cigarette distribution and per capita consumption from the California State Board of Equalization in conjunction with 2000 census data from the U.S. Bureau of the Census.

Activity data for untreated human waste includes the population of homeless people and the population of infants of diaper wearing age. Most counties have a service department responsible for the homeless population. The ENVIRON team will survey the States most populous counties to determine an appropriate ratio of homeless to total population for each county. Infant population will be calculated as the sum of the under one year old population , the one to two year old population, the two to three year old population and half of the three to four year old population from the 2000 census data from the U.S. Bureau of the Census.

Activity data for respiration and perspiration will be the total population from the 2000 census data from the U.S. Bureau of the Census.

All domestic sources will be allocated based on total population from the 2000 census data from the U.S. Bureau of the Census except for infants, which will be distributed based on the diaper wearing population described above.

**Industrial sources**

Industrial sources have traditionally been inventoried based on reported emissions such as the SARA 313 Toxic Release Inventory (TRI) or the Air Resources Boards Air Toxics Database (ATEDS). This method allows emissions allocations as point sources, and, in the case of ATEDS, the assignment of appropriate release parameters. Reporting to ATEDS is based on facility size, as determined by criteria pollutant emissions. Reporting under SARA 313 has a very large threshold and excludes facilities with certain SIC codes. Therefore, many facilities that may have significant ammonia emissions are not included in these databases. Additionally, the number of individual facilities (Several thousand facilities were identified in the 1991 South Coast Air Basin inventory (Radian 1991) requires an unwarranted strain on resources.

The ENVIRON team will obtain data from major ammonia suppliers in the State, including UNOCAL, LaRoche Industries Incorporated and Hill Brothers Chemical Corporation for ammonia usage. This data will be aggregated to zip codes to protect the proprietary nature of the supplier data. Supplier data will be segregated by use for selective catalytic reduction, refrigeration, metal treating, blueprinting and wastewater treatment. Emission factors for each category are reported in the recent South Coast Air Basin inventory (ATC 2000). Suggested EIC/CES codes are presented in Table 2-9. Emission factors are:

- Refrigeration – Fugitive emissions from ammonia refrigeration occur as a result of system leaks. Therefore, by mass balance, each pound of ammonia supplied is also emitted. The emission factor is 100 percent of usage.

- $NO_x$ Control – Ammonia is injected into the exhaust of boilers, gas turbines and other process equipment to reduce $NO_x$ emissions. The injected ammonia reacts on a 1:1 molar ratio of $NH_3$ to NOx. Excess ammonia is added to attempt to react all NOx. Good engineering practice results in approximately 10 ppm of unreacted $NH_3$ released from the stack (BACT requirement) by reducing NOx from 100 ppm to 10 ppm. The 10 ppm of excess ammonia that does not react to reduce NOx, but is emitted directly to the atmosphere is called ammonia slip. The 10 ppm ammonia slip can be correlated to 10% of the ammonia injected. The emission factor is 10 percent of usage.

- Metal Heat Treating – Ammonia is used in the nitriding process to heat treat steel. Based on minimal escape during the nitriding process, approximately 10% of ammonia supplied is emitted. The emission factor is 10 percent of usage.

- Waste Water Treatment – Ammonia is used in wastewater treatment for neutralization. Based on minimal losses during transfer, upsets and improper operation, approximately 15% of ammonia supplied is emitted because ammonia is highly soluble in water. The emission factor is 15 percent of usage.

- Blueprinting – Ammonia is used in blueprint processing. By mass balance, each pound of ammonia supplied is also emitted. The emission factor is 100 percent of usage.

Industrial source emissions will be allocated as area sources based on the ZIP code coverage. In addition to those industrial source listed above, the CEIDARS database includes ammonia emission from geothermal sources which comprised approximately 1% of the statewide ammonia emission inventory. Emission form geothermal sources will be obtained form the ARB and included in the inventory as point sources.

**Table 2-9.** Suggested EIC/CES Codes for Industrial Sources.

| EIC Description | EIC | CES |
|---|---|---|
| Refrigeration | 499-995-0020-0001 | 47085 |
| $NO_x$ Control | 499-995-0020-0002 | 47086 |
| Metal Heat Treating | 499-995-0020-0003 | 47087 |
| Waste Water Treatment | 499-995-0020-0004 | 47089 |
| Blueprinting | 499-995-0020-0005 | 47089 |

**Mobile Sources**

Two strategies are often used for mobile sources, namely link based or county level emissions. County level emissions are processed essentially as area sources. Processing mobile source emissions as individual links from a transportation model preserves the maximum possible information on spatial distribution, temporal allocation and vehicle fleet characteristics from the transportation model. EPS2, EMS-95 and SMOKE can all handle link based emissions, but frequently a specialized program such as DTIM is used instead. DTIM is widely used in California, but it is not configured to handle ammonia emissions directly. This limitation can be circumvented by processing the ammonia emissions through DTIM as if they are PM emissions**.** The decision whether to process on-road mobile ammonia emissions on links or at the county level is a compromise between the extra precision and additional cost of link-based processing. The previous SJV ammonia inventory estimated mobile source emissions at the county level and allocated the emissions using spatial surrogates and temporal profiles (i.e., like an area source).

The Team will assess the latest emissions data (e.g., Fraser and Cass, 1998; Lord et al, 2000) to determine the most appropriate data for use in a statewide mobile inventory. The Lord et al study provide results that indicated that emissions from on-road vehicles may be underestimated (this study was conducted in the South Coast Air Basin). The current SJV estimates are taken from Pechan's 1990 National Particulates Inventory (STI, 1998). The emission factor used by Pechan for those estimates is close that obtained by Fraser and Cass [72 milligrams per kilometer (mg/km)]. The value obtained in the Lord et al study was 138 mg/km. The Team will contact these researchers to gather additional underlying data for this emission factor.

The ARB is currently developing statewide gridded VMT in support of the Central California Ozone Study (CCOS). The Team will obtain these gridded VMT data and, with the appropriate emission factors for ammonia, will develop the gridded on-road mobile inventory as the product of the VMT and a fleet-wide emission factor. Depending on the spatial resolution of the gridded VMT, the resulting gridded mobile emission inventory may require re-allocation to the 1 km resolution of the final inventory.

Development of Standard Input Library

As part of this task, a standard input data library will be developed and documented. The purpose of the data library is to provide an efficient means of archiving data as well as to facilitate future update and revisions to the inventory in a systematic way. The data will be stored in a GIS format with appropriate attributes to specify activity data for each source category, data units, spatial and temporal extent of the data, allocation factors and citations of data sources. Processing procedures will be developed to convert and/or reformat the "raw" data into an appropriate form for input to the GIS-based data library. The ARC/Info Macro Language (AML) will be used for processing and importing "raw" emission data into the GIS. Since most data used in the development of the emission inventory will likely be available, or can be easily re-formatted into, a spreadsheet format the AML programs will be developed to ingest a general ASCII format (e.g., a comma-delimited spreadsheet export file) into the appropriate GIS coverage type (i.e., polygon, point, or line coverages). This approach provides several advantages with respect to future revisions or updates of the data, as well as portability of the data library. As the general ASCII format can be developed and modified using a variety of software tools and text editors, the data will be platform, or operating system, independent and thus portable and easily modified. In addition, the modification of data would not require any specific software tools, computer programming languages, scripts or operating systems. As the details of the AML processors and GIS-based data library are not yet fully defined, nor are the specific formats of the "raw" ASCII input data files finalized, we refer to these simple formats in general terms as spreadsheets. All data and processing routines will be fully documented in detail and provided to the Technical Committee for future in-house processing.

*Point Sources*

For point sources, inventory data will be compiled into an EPS work file format (AFS). Note that the AFS format is essentially a spreadsheet format and as such will be readily imported to the GIS through use of the AML processors. The point source file in this format can be used for direct input into EPS, and the data could be used for input into other emissions models (EMS-95 or SMOKE). In consultation with the Technical Committee, additional fields will be added to the database, such as ARB EIC codes.

For several source categories, part of the standard input library will include underlying spreadsheets that contain emissions data. An example source category would be cattle (both beef and dairy). As part of this inventory effort, the Team will attempt to identify dairies and feedlots that can be modeled as point sources (the remaining population would be modeled separately as area sources). The data in the spreadsheets include source classification codes, emission factors, activity data, release parameters, and temporal allocation data (including data, such as meteorological data used to estimate or allocate emissions). The spreadsheets will also include citations for the origin of each data field. For future updates to the inventory, these spreadsheets can be easily revised (e.g., with new activity data or emission factors) and the data exported into the AFS point source file. All point source data will be imported into the GIS-based data library as ARC/Info point coverages.

*Area Sources*

For on-road sources, the emission estimation method will be to apply the appropriate emission factor to the gridded VMT, provided by the ARB, to obtain the final ammonia emission estimates. The standard input library will be a spreadsheet that contains the identification of each grid cell, the grid-based VMT, the emission factors, weekly and daily cycles (consistent with the

gridded inventory). As mentioned above for the point source files, the spreadsheets used for area sources will contain citations of the source of each data element. On-road mobile source data will be imported into ARC/Info using appropriate AML's as polygon coverages.

For area sources where the spatial coverage is not used as the activity data (e.g., livestock, residential wood, POTWs), spreadsheets will be developed much like those for the point sources. Data will include the source classification codes, emission factor, activity data (e.g., county-level population), temporal allocation factors, citations of reference sources and spatial surrogates and imported into the GIS-based data library as polygon coverages.

For area sources where the spatial surrogate is used as the activity data (e.g., fertilizer application, wildfires, soil/plant canopy systems), the spreadsheets will not contain the activity data. All of the other data elements will be included along with a citation of the source of the spatial surrogate and the land cover type assigned for estimating emissions for each source category. These data will be imported into the GIS-based data library as polygon coverages.

Spatial Surrogates

The spatial allocation of county-level ammonia emissions is accomplished with the aid of gridded spatial surrogate data for each emission source category or groups of source categories. Spatial surrogates are typically based on the proportion of a known region-wide characteristic variable which exists within the modeling domain grid cells (e.g. land use categories, population, socioeconomic data, etc.). The development of an accurate gridded ammonia emission inventory at a spatial resolution of 1-km by 1-km requires surrogate data at a comparable resolution. In addition, in the case of land use data, the ability to distinguish between various land cover characteristics is necessary to properly allocate the county-level emission estimates for certain source categories, particularly for fertilizer application and soil emissions. Other desirable features of the underlying surrogate databases are the currentness of the data (i.e., for what year are the data based on and how often are they updated) and the availability and quality of the data.

There are numerous Land Use/Land Cover (LULC) databases available from a variety of sources. These datasets provide for various spatial resolutions and geographic extent as well as a variety of LULC classification schemes. In addition, a limited number of special study datasets are in development for generating spatial surrogates for other CRPAQS studies as well as for the CCOS. The following LULC databases have been identified for possible use in development of gridded spatial surrogates:

- USGS 1:100,000 scale (~200 m resolution) Land Use/Land Cover (LULC)
- USGS Land Cover Characteristics (LCC) (~1 km resolution)
- USGS National Land Cover Data (NLCD) (~30 m resolution)
- California Gap Analysis Land Cover/Vegetation Data (~50 m resolution)
- California Department of Conservation Farmland Mapping and Monitoring Program Agricultural and Urban Land Use data
- Department of Water Resources Land Use Survey Data
- Various Special Study Databases (e.g., Potter, 2000; California Department of Pesticide Regulation databases, ARC/Info ZIP Code coverages)

Each of these datasets were evaluated for appropriateness in developing surrogate indicators for ammonia emission sources. Evaluations were made with respect to availability, completeness,

accuracy, spatial resolution, land cover characterization in relation to ammonia emission source categories, currentness, and processing resource requirements.

**USGS 1:100,000 Scale Land Use/Land Cover (LULC)**

The USGS 1:100,000 scale Land Use/Land Cover (LULC) database were developed as part of the U.S. Geological Survey National Mapping Program and provide land cover characteristics for most of the contiguous U.S. and Hawaii. The data describe the vegetation, water, natural surface and cultural features on the land surface. The data is available in several formats including the Geographic Information Retrieval and Analysis System (GIRAS), Composite Theme Grid (CTG) and ARC/Info export interchange (E00) formats, all of which are easily imported into a GIS system. The data are developed from aerial photographs acquired from NASA high-altitude missions as well as other ancillary data sources. Manual interpretation of the aerial photographs with additional input from field surveys and other land cover data was used to digitize and classify the maps and the land cover data using an Anderson Level 2 classification scheme. Table 2-10 presents the 36 LULC categories defined for this database. The data files are organized by quadrangle, each of which may be based on different representative dates. The dates of data acquisition range from the mid 1970's through the 1980's with the final datasets corresponding to a nominal 1990 base year. The data is presented in a Universal Transverse Mercator (UTM) projection coordinate system at a spatial resolution of approximately 200 meters. The data are freely available from several sources, particularly the EPA's anonymous FTP site, ftp.epa.gov/pub/spdata/ .

The USGS LULC database has been used extensively in the past for the development of gridded surrogate indicators. ENVIRON and ATC have recently completed an updated gridded ammonia inventory for the South Coast Air Basin (SCAB) using these data and have developed efficient processing techniques within ARC/Info for applications involving the generation of regional scale datasets from multiple LULC quadrangles. However, during the development of the SCAB surrogate database, a number of LULC data errors were discovered which required manual corrections. In addition, as the data is based on aerial photographs and other land cover surveys which are at least, and in some cases more than, 10 years old, it was determined that the data would not be a strong candidate for use as a base dataset for the development of statewide gridding surrogates.

**Table 2-10.** USGS Land Cover/Land Use Codes (Anderson Level 2 Classification Scheme).

| Code | Description |
|---|---|
| 1 | Urban or Built-up Land |
| 11 | Residential |
| 12 | Commercial and Services |
| 13 | Industrial |
| 14 | Transportation/Communication/Utilities |
| 15 | Industrial and Commercial Complexes |
| 16 | Mixed Urban or Built-up Land |
| 17 | Other Urban or Built-up Land |
| 2 | Agricultural Land |
| 21 | Cropland and Pasture |
| 22 | Orchards/Groves/Vineyards/Nurseries/Ornamental Horticultural |
| 23 | Confined Feeding Operation/Other Agricultural Lands |
| 24 | Other Agricultural Land |
| 3 | Rangeland |
| 31 | Herbaceous Rangeland |
| 32 | Shrub and Brush Rangeland |
| 33 | Mixed Rangeland |
| 4 | Forest Land |
| 41 | Deciduous Forest Land |
| 42 | Evergreen Forest Land |
| 43 | Mixed Forest Land |
| 5 | Water Bodies |
| 51 | Streams and Canals |
| 52 | Lakes |
| 53 | Reservoirs |
| 54 | Bays and Estuaries |
| 6 | Wetlands |
| 61 | Forested Wetlands |
| 62 | Nonforested Wetlands |
| 7 | Barren Land |
| 71 | Dry Salt Flats |
| 72 | Beaches |
| 73 | Sandy Areas not Beaches |
| 74 | Bare Exposed Rock |
| 75 | Strip Mines/Quarries/Gravel Pits |
| 76 | Transitional Areas |
| 8 | Tundra |
| 81 | Shrub and Brush Tundra |
| 82 | Herbaceous Tundra |
| 83 | Bare Ground Tundra |
| 84 | Wet Tundra |
| 85 | Mixed Tundra |
| 9 | Perennial Snow or Ice |
| 91 | Perennial Snowfields |
| 92 | Glaciers |

**USGS Land Cover Characteristics (LCC)**

The USGS North America Land Cover Characteristics (LCC) database is part of an on-going global vegetation database development, These data are on a 1-km by 1-km grid for the entire North American continent and are presented in four different classification systems and two coordinate system projections. The most detailed classification scheme includes 205 categories for the entire continent of North America. The data are available in monthly composites spanning from April 1992 to March 1993 and 10-day composites for a slightly larger time frame. Each classification system is available in both Lambert Equal Area and Interrupted Goode Homolosine coordinate projections. These data were derived from Advanced Very High Resolution Radiometer (AVHRR) data with a Normalized Difference Vegetation Index (NDVI). AVHRR data are high resolution data produced from orbiting satellites. The NDVI composites depict the relative density or vigor of different vegetation types. The NDVI is calculated by taking the difference of near-infrared and visible reflectance values divided by total reflectance. These values are then scaled from 0 to 200 where values less than 100 are usually clouds, snow or water, The NDVI is then composited with the AVHRR data which involves creating a multi-band image with five AVHRR channels, the NDVI value, four bands of computed satellite/solar geometry, and a band which identifies the specific daily overpass from which each pixel was extracted. The data can be obtained from the ftp site at edcftp.cr.usgs.gov. Quality assurance of the database is in varying stages and lacks accompanying ground-truthing.

In addition to the 205 detailed classification scheme, the data are available in a number of simpler composite classification schemes which may be more appropriate for use in developing ammonia emission source category surrogate indicators. Table 2-11 presents the USGS Land Use/Land Cover Modified Level 2 classification scheme consisting of 24 land cover categories. While the USGS LULC classification scheme presented distinguishes the basic land cover categories for surrogate development, certain relevant categories are not represented. For example, although various types of cropland and pasture are represented, the desired detail in terms of crop types (row crops, grains and hay, orchards and vineyards) relevant to certain source categories (fertilizer application, soil systems) are not distinguishable.

**Table 2-11.** USGS Land Use/Land Cover Category Codes (Modified Level 2).

| Value | Code | Description |
|---|---|---|
| 1 | 100 | Urban and Built-up Land |
| 2 | 211 | Dryland Cropland and Pasture |
| 3 | 212 | Irrigated Cropland and Pasture |
| 4 | 213 | Mixed Dryland/Irrigated Cropland and Pasture |
| 5 | 280 | Cropland/Grassland Mosaic |
| 6 | 290 | Cropland/Woodland Mosaic |
| 7 | 311 | Grassland |
| 8 | 321 | Shrubland |
| 9 | 330 | Mixed Shrubland/Grassland |
| 10 | 332 | Savanna |
| 11 | 411 | Deciduous Broadleaf Forest |
| 12 | 412 | Deciduous Needleleaf Forest |
| 13 | 421 | Evergreen Broadleaf Forest |
| 14 | 422 | Evergreen Needleleaf Forest |
| 15 | 430 | Mixed Forest |
| 16 | 500 | Water Bodies |
| 17 | 620 | Herbaceous Wetland |

| Value | Code | Description |
|---|---|---|
| 18 | 610 | Wooded Wetland |
| 19 | 770 | Barren or Sparsely Vegetated |
| 20 | 820 | Herbaceous Tundra |
| 21 | 810 | Wooded Tundra |
| 22 | 850 | Mixed Tundra |
| 23 | 830 | Bare Ground Tundra |
| 24 | 900 | Snow or Ice |

**USGS National Land Cover Data (NLCD)**

The National Land Cover Data (NLCD) was developed as part of a cooperative project between the U.S. Geological Survey and the U.S. Environmental Protection Agency to produce a consistent land cover data layer for the entire conterminous U.S. based on 30-meter Landsat thematic mapper (TM) data. The NLCD was developed from TM data acquired from the Multi-Resolution Land Characterization (MRLC) Consortium, a partnership of federal agencies that produce or use land cover data. The partners include USGS (National Mapping, Biological Resources, and Water Resources Divisions), the USEPA, the U.S. Forest Service and the National Oceanic and Atmospheric Administration.

Two seasonally distinct TM mosaics are produced, a leaves-on (summer) and a leaves-off (spring/fall) version. The TM bands 3,4,5 and 7 are mosaiced for both the leaves-on and leaves-off versions, and a base scene is selected for each mosaic. Other scenes are adjusted to mimic the spectral properties of the base scene using histogram matching in regions of spatial overlap. Following the selection of a base scene, the 4 TM bands of the base mosaic are clustered to produce a single 100-class image, with each of the spectrally distinct clusters/classes subsequently assigned to one or more Anderson level 1 or 2 land cover classes using National High Altitude Photography program (NHAP) and National Aerial Photography program (NAPP) aerial photographs as a reference. Invariably, some individual clusters/classes will be confused between two or more land cover classes. The separation of confused clusters/classes into appropriate NLCD classes is accomplished with the use of ancillary data sets. These ancillary data sets include the non-base mosaic TM bands and 100-class cluster image; derived TM Normalized Difference Vegetation Index (NDVI); various TM band ratios; TM date bands; 3-arc second DTED, population and housing density data; USGS Land Use/Land Cover; and National Wetland Inventory data. Additional source of ancillary data include soils data, unique state and/or regional land cover datasets, and data from other federal programs including the National Gap Analysis Program (GAP) of the USGS Biological Resources Division (BRD). Quality assurance of the data is on-going on a Federal Region basis following a revision cycle which incorporates feedback from MRLC Consortium partners and affiliated users and is being conducted by private sector vendors under contract to the USEPA according to a defined QA protocol established by the USGS and the USEPA.

The base data set for the project was leaves-off Landsat TM data, nominal-1992 acquisitions. Ancillary data layers include leaves-on TM, USGS 3-arc second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief, Bureau of the Census population and housing density data, USGS Land Use/Land Cover (LULC), and National Wetland Inventory data. The general development procedures for the NLCD is to: (1) mosaic subregional scenes and classify them using an unsupervised clustering algorithm, (2) interpret and label the cluster/classes using aerial photographs as reference data, (3) resolve the labeling of confused cluster/classes using appropriate ancillary data sources, and (4) incorporate land cover information from other data sets and perform manual edits to augment and refine the basic classification.

The NLCD datasets are available as flat generic raster image files which are easily imported into a GIS (e.g., ARC/Info) and are provided in an Albers Conic Equal Area projection at a spatial resolution of 30-meters. The data can be obtained from the following URL http://edcwww.cr.usgs.gov/pub/edcuser/vogel/states/, and for California is available as two separate data files for the northern and southern portions of the state. The land cover characteristics are defined in terms of the 21 separate categories presented in Table 2-12.

**Table 2-12.** NLCD Land Cover Classification Codes.

| Code | Description |
|---|---|
| 11 | Open Water |
| 12 | Perennial Ice/Snow |
| 21 | Low Intensity Residential |
| 22 | High Intensity Residential |
| 23 | Commercial/Industrial/Transportation |
| 31 | Bare Rock/Sand/Clay |
| 32 | Quarries/Strip Mines/Gravel Pits |
| 33 | Transitional |
| 41 | Deciduous Forest |
| 42 | Evergreen Forest |
| 43 | Mixed Forest |
| 51 | Shrubland |
| 61 | Orchards/Vineyards/Other |
| 71 | Grasslands/Herbaceous |
| 81 | Pasture/Hay |
| 82 | Row Crops |
| 83 | Small Grains |
| 84 | Fallow |
| 85 | Urban/Recreational Grasses |
| 91 | Woody Wetlands |
| 92 | Emergent Herbaceous Wetlands |

### California Gap Analysis Program Land Cover/Vegetation Data

The purpose of the Gap Analysis Program (GAP) is to provide regional assessments of the conservation status of native vertebrate species and natural land cover types and to facilitate the application of this information to land management activities. The National GAP URL is http://www.gap.uidaho.edu/gap/. The GAP is conducted as state-level projects and is

coordinated by the USGS Biological Resources Division. Currently the program is developing land cover mappings for all U.S. States. Although each state is being developed separately, detailed vegetation species covers are being developed based on predetermined classifications. The status of the land cover mappings is at varying levels of completion depending on the individual state. For California, the GAP land cover mappings were completed in 2000. The California GAP URL is http://www.biogeog.ucsb.edu/projects/gap/ and provides more detailed information specific to the state of California as well access to the GAP datasets in the form of ARC/Info coverages. The data is available in an Albers Conical Equal Area projection coordinate system at a nominal spatial resolution of approximately 50 meters. The land cover classifications are based on the National Vegetation Classification system and are derived primarily from Thematic Mapper imagery from 1990 with ancillary input data from aerial photography and other maps mostly from the 1980's through 1995, with accuracy assessment of the data pending. The classification system provides for several hundred species designations and are group into broad categories and stratified according to primary, secondary and tertiary coverages based on percent of land cover in each of several broad regions. Although the spatial resolution is approximately 50 meters, due to the structure of the data is not always possible to spatially distinguish different species at the required resolution of 1 km. Figure 2-1 displays the primary land cover classifications for the state of California. The lack of distinguishable land cover features at a fine scale resolution and due to the early dates of source data, it was determined that the GAP database would not be the most appropriate source of data for development of gridding surrogates for ammonia inventories.

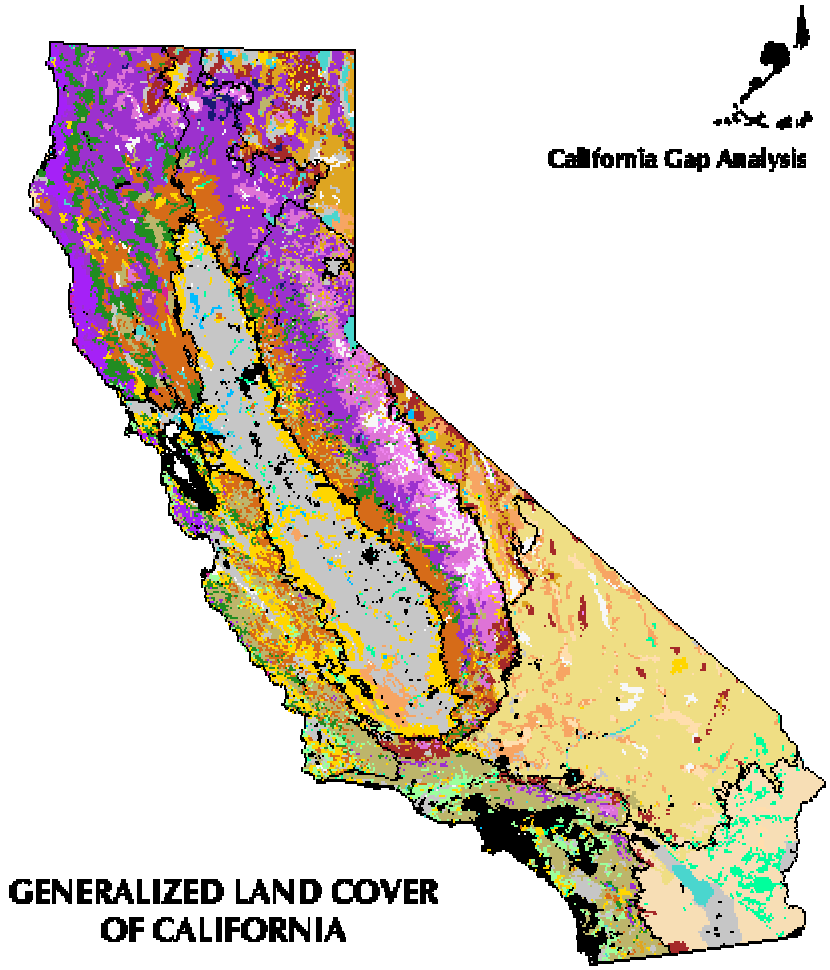


**Figure 2-1.** Generalized landcover of California from the Gap Analysis Program.

**California Department of Conservation Farmland Mapping and Monitoring Program**

The Farmland Mapping and Monitoring Program (FMMP) of the California Department of Conservation develops land use maps and statistical data for use in analyzing impacts on California's agricultural resources. The program was established in 1982 in response to a need for assessing the location, quality, and quantity of agricultural lands and the conversion of these lands over time. The program provides a consistent and impartial analysis of agricultural land use and land use changes throughout California. The database is compiled on a county level and is based on soil survey information, aerial photographs at various resolution and field reconnaissance with a minimum mapping unit of 10 acres. The land use data is classified according to several subcategories based on the primary land use categories of important farmland and interim farmland map categories. Important farmland map classification include several mapping categories including prime farmland, farmland of

statewide and local importance, grazing land, urban and built-up land, water, and other land. The

interim farmland classification include two subcategories, irrigated and non-irrigated farmland.

The FMMP databases are updated biennially with the latest update available from 1998. As the data is compiled from soil surveys, the extent of the farmland coverage corresponds to the availability of what the National Resources Conservation Service (NRCS) considers "modern soil surveys", and therefore the current coverage is limited to 48 of the state's 58 counties. In addition, of the 48 counties included in the database some have only been partially mapped since the NRCS has limited its efforts to areas which are considered agriculturally important. Figure 2-2 displays the extent of the data coverage in terms of the important and interim farmland map categories as well as unmapped regions. The data can be obtained in vector format from the World Wide Web at http://www.consrv.ca.gov/dlrp/FMMP/ and is available in an Alberts Equal Area projection coordinate system. Because the data coverage is limited and, in several cases, incomplete for the study area, it was determined that the FMMP database would not be appropriate for development of gridding surrogates for ammonia inventories. In addition, the lack of the high resolution, detailed land use classifications necessary for ammonia emissions surrogate indicators preclude their use for this study.

**Figure 2-2.** Farmland mapping and monitoring survey area.

**Department of Water Resources Land Use Survey**

The California Department of Water Resources (DWR) Land Use Survey databases are developed by the department's Division of Planning and Local Assistance in order to aid in DWR's efforts to continually monitor land use for the purpose of determining the amount of and changes in the use of water. The data are available at the county level and include detailed agricultural land use classifications, as well as lesser detailed urban and native vegetation land uses. The data was compiled from aerial photography with subsequent extensive field verification and are updated on a rotating basis by county approximately every seven years. Thus the data are based on varying years, depending on the county, ranging from the late 1980's through the late 1990's. Databases for each county are available in AUTOCAD DWG format, as

well as ARC/Info shape file format employing a Transverse Mercator coordinate projection and can be obtained from the DWR's developing web site at http://dplasp.water.ca.gov/landwateruse/. The classification scheme used allows for up to three land use attribute per polygon (land parcel) and is considered very accurate due to the field survey verification of the aerial photograph imagery. Figure 2-3 displays a typical land use map for Kern county based on 1998 data.

While this database was not determined to be appropriate for the development of statewide gridding surrogates, due to the varying dates of data acquisition and less resolved non-agricultural land use classifications, it will be used for verification purposes and for use in augmentation of statewide datasets with the detailed agricultural land use categories.

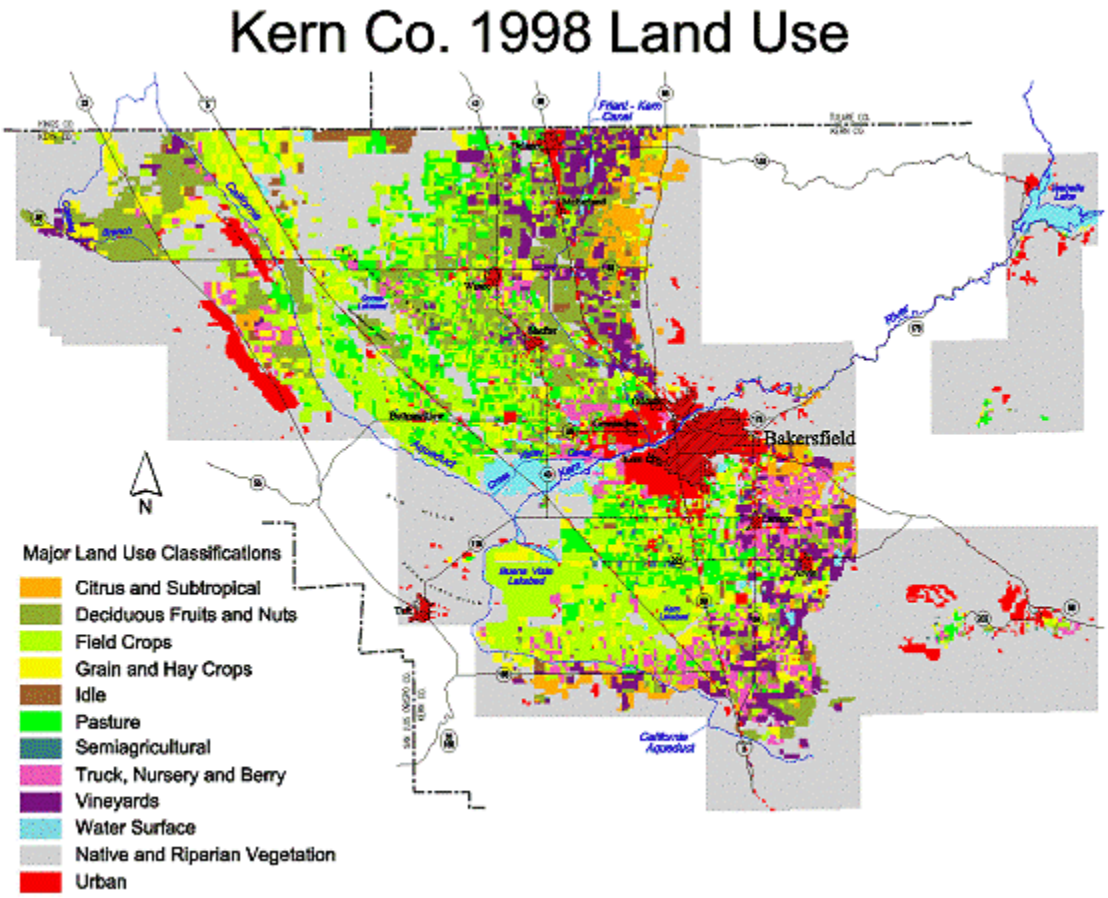


**Figure 2-3.** 1998 DWR Landuse survey coverage for Kern county.

Given the resource restraints of the project, the following approach will be taken to develop gridded surrogates for the spatial allocation of county-level ammonia emission estimates. The NLCD will be used as the primary data source, as this database provides the relevant land cover characteristics at the best resolution for the entire state of California, is based on fairly recent year data and is freely available and periodically updated. A preliminary evaluation of the data reveals that the various land use categories are well represented at a resolution of approximately 1-km. While currently under-going final quality assurance, the data is periodically updated to reflect the status of the QA process, and since the data covers the entire state of California available from a single source, the underlying data used for surrogate development can be easily updated with minimal processing effort. The final gridded surrogate datasets derived from the NLCD will be supplemented with the more current DWR database where deemed necessary or appropriate. Likewise, for those land cover categories which are not explicitly represented by the NLCD (e.g., confined feed lots, detailed crop types), the gridding surrogate data will be augmented and verified with the LULC database which best represents these categories.

Finally, we recognize that given the current in-progress status of various other data collection and development projects sponsored by the ARB in support of the CRPAQS, there may be more appropriate and/or more current data available for use in spatial allocation of ammonia emission sources. However, due to project scheduling issues, we cannot rely exclusively on the use of these special study data. In addition, as the specific episodes (annual, seasonal, episodic) for the final inventory has not yet been determined, it is unknown which of these special study databases would be most appropriate. Therefore it will be more appropriate to use a single consistent data source for the entire study area with possible augmentation from regional and/or seasonally specific data sources applicable to a particular episode, resulting in a more generally applicable gridding surrogate database. In addition, the ENVIRON team anticipates continued collaboration with these projects and will attempt to incorporate additional land cover data as allowed by the project schedule and resource constraints.

The spatial allocation of domestic ammonia emission sources will be based on gridded surrogate indicators developed from population data. The 1990 US Census data in FoxPro format will be processed into the appropriate file formats for use in the ammonia emission model. If available, data from the 2000 US Census, as well as local data sources, will be incorporated into the database for development of gridding surrogates for domestic sources.

The spatial allocation of the on-road mobile source emissions will rely on the underlying gridded VMT data used for developing the ammonia emission estimates. The final gridded mobile source emissions will be gridded to the required 1-km by 1-km resolution of the modeling domain.

As discussed above, the spatial allocation of industrial sources will be based on ZIP code in order to protect the confidentiality of the underlying activity data. A similar treatment was used in the recent updated gridded ammonia inventory developed for the SCAQMD (ATC, 2000). ZIP code coverages, in ARC/Info format, were obtained from Geographic Data Technology, Inc. and processed in the ARC/Info GIS system in a manner similar to LULC data. The ZIP code coverages are based on recent year 2000 information.

Quality Assurance/Quality Control

Quality assurance (QA) will be conducted on all data collected during the development of the ammonia emission inventory. Emission calculation will be checked to ensure that the methodology calculations were performed correctly. Emission estimates will also be examined to ensure that the developed inventory is reasonable. Various archiving procedures will be developed and documented to ensure that the integrity of all emissions data is maintained, included emission factor data and sources, spatial and temporal allocation data, and final gridded inventories. Appropriate file naming conventions will be established to facilitate efficient revision control of all input data and future updates and revision to the ammonia inventories.

For point sources, the Team will use in-house programs for QA/QC of point source emissions files. These programs have been developed to identify out of range release parameters (e.g., stack heights, temperatures) and source locations (UTM coordinates). In addition, the Team will use emission density plots to evaluate whether emissions are being properly located and temporally allocated.

For area sources, the Team will rely on the review of emission density plots to verify proper spatial and temporal allocation. Daily emission density plots for each season will be made for each of the source categories described above. Team members will verify that the plots show the proper spatial allocation and that the emissions shown can be scaled up to match the annual totals for each category.

**Task 3: Develop Ammonia Emission Model**

The objective of this task will be to develop an emissions model that will accurately and efficiently prepare gridded emissions inventories for the SJV based on the data assembled through this study. The model will address all sources of ammonia for which emissions are related to land area – area sources. Point sources will be treated separately by geo-coding each source location and emissions characteristics. Mobile sources will also be treated separately to take advantage of the link-based emissions modeling systems (e.g., DTIM) developed specifically for mobile sources. As noted in the RFP for the project, this completion and level of effort for this task is subordinate to Task 4, producing a draft ammonia inventory.

Review of Existing and On-going Development of GIS-based Emissions Models

The ARB has several ongoing projects where the contractors are using bottom-up GIS models to estimate ammonia emissions from specific source categories. UC-Berkeley is estimating emissions of pollutants (including ammonia) from wildfires. The UC-Berkeley project coordinator is James Scarborough and some information on the project is available at http://www.gisc.berkeley.edu/~jscar/emissions/. There is no information on ammonia emissions estimates at this source. Ammonia emissions from wildfires are not considered a high priority at this time.

The ARB also has a contract on fertilizer ammonia emissions with CSU-Fresno that includes development of a GIS-based soil emissions model called CAL-CASA. The CAL-CASA model is being developed by Dr. Chris Potter at NASA-Ames Research Center. This contract is almost completed but the final report is not yet available. Some information is available from a NASA web page at http://geo.arc.nasa.gov/sge/casa/. Ammonia emissions from fertilizer emissions are

considered important, but at this time it is unclear what results will be available from the CSU-Fresno study and how they can be incorporated into this work.

Overview of Approach

The need for a separate area source emissions model depends upon the amount of detail to be included in the emission relationships. In the simple case where ammonia emissions are estimated from land area multiplied by an emission factor, there is no need for a separate model because (1) the calculation is simple to accomplish within the GIS (e.g., ARC/Info) and (2) since there are no day specific effects on emissions the calculation need only be performed once. A schematic of the calculation is shown in Figure 2-4.

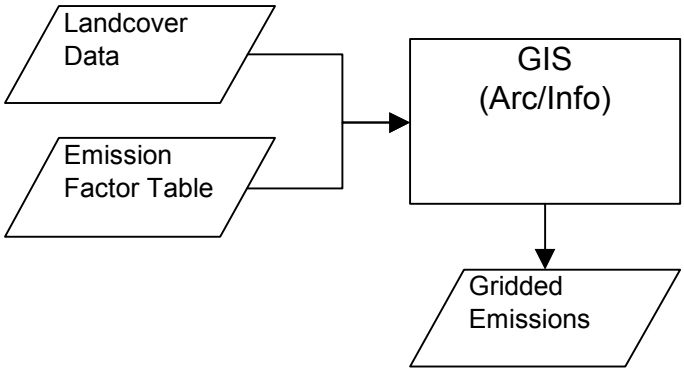


**Figure 2-4**. Simple approach to estimating ammonia emissions within the GIS.

The simple approach shown in Figure 2-4 neglects environmental impacts (e.g., temperature dependence, seasonal dependence) on ammonia emissions. Incorporating environmental effects is a superior approach provided that information on environmental effects is available. One result is likely to be a need to prepare day specific inventories (similar to biogenic emissions modeling) which means that the emissions calculation must be repeated several times and efficiency becomes important. This suggests a different calculation approach, similar to that used in biogenic emissions preparation, as shown schematically in Figure 2-5. Under this approach, the landcover data are pre-processed using GIS into a gridded landcover database. This operation need only be performed once. An emissions model then combines the gridded landcover data with the emission factors and makes adjustments to account for environmental effects.

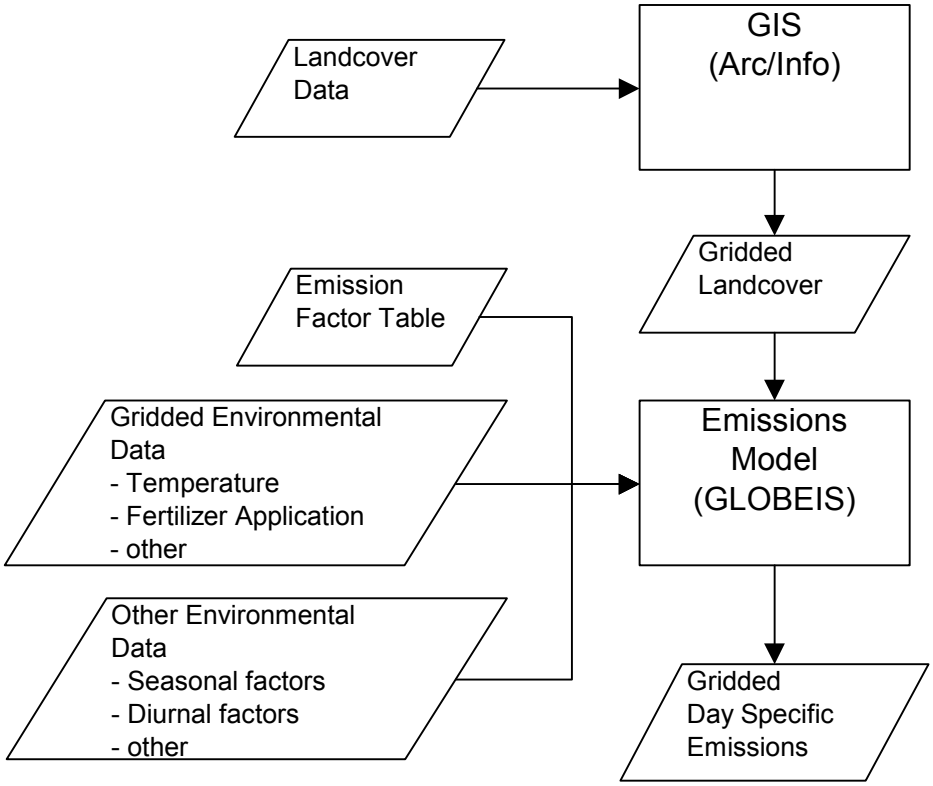


**Figure 2-5**. Estimating ammonia emissions using a model to account for environmental effects.

There are several advantages to this approach:

- Improved efficiency because the landcover data are gridded only once.
- Improved efficiency because emissions calculations are performed at the resolution of the modeling grid which is generally lower than the resolution of the raw landcover data.
- Improved usability because the emissions modeling step is separated from the GIS processing, therefore expensive GIS software is not required to prepare new emission inventories.

A prototype emissions modeling system of the type shown in Figure 2-5 already exists in the GLOBEIS model. GLOBEIS was developed for modeling biogenic VOC and NOx emissions, but also includes ammonia. The ammonia emission algorithms in the current version of GLOBEIS are very simple and so improvements will be required for this study. Depending on the availability of information concerning specific algorithms used in the CAL-CASA model, these will also be incorporated as part of the enhancements.

Current GLOBEIS Capabilities

GLOBEIS, short for the Global Biosphere Emissions and Interactions System, was developed by Dr. Alex Guenther at the National Center for Atmospheric Research (NCAR) and Stella Shepard, Gary Wilson and Dr. Greg Yarwood at ENVIRON. The idea behind GLOBEIS is to provide a biogenic emissions modeling system that embodies up-to-date scientific information in a

package that is easy to use, easy to update, and compatible with a wide range of input data (hence "Global"). The development of GLOBEIS is described in Yarwood et al. (1999). GLOBEIS model runs under Microsoft Access on Windows based personal computers. The following computer resources are needed to run GLOBEIS effectively:

- Recent CPU such as Pentium II or AMD K6 family
- Minimum 64 Mb RAM
- 300 Mb hard disk space
- Microsoft Access 97 or Access 2000

A regional scale, day specific biogenic emission inventory for photochemical modeling can be prepared in minutes using GLOBEIS.

GLOBEIS is designed to provide interactive control of the emissions modeling process through menu screens to select which modules to run (Figure 2-6) and to specify input data and options (Figure 2-7).

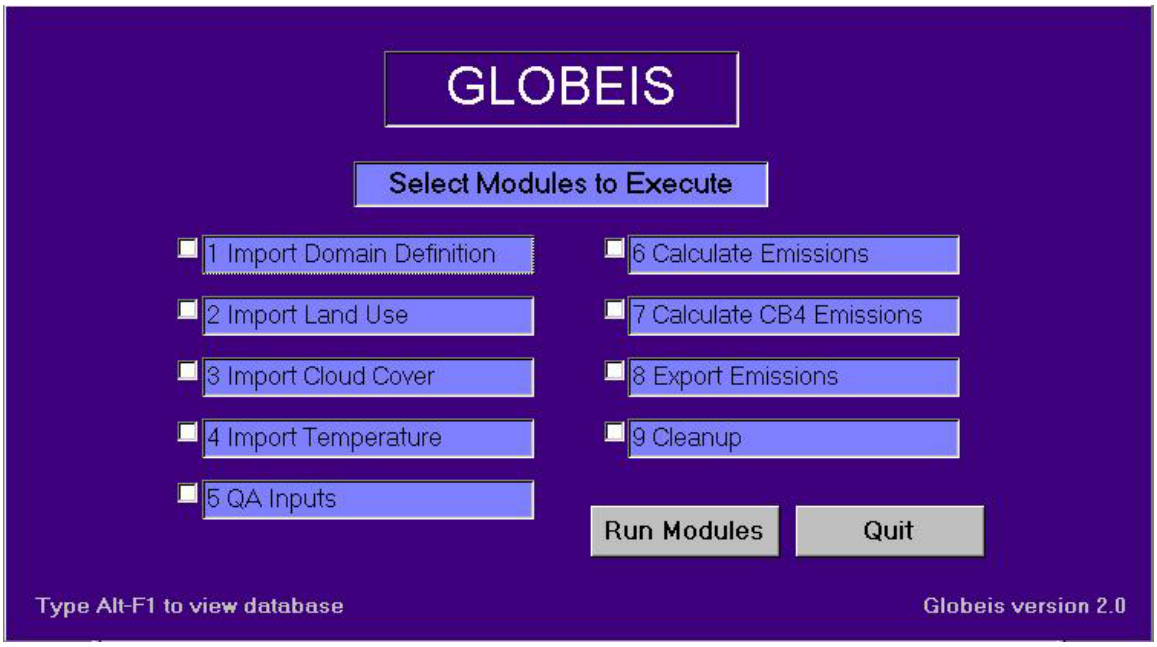


**Figure 2-6**. The main GLOBEIS control interface.

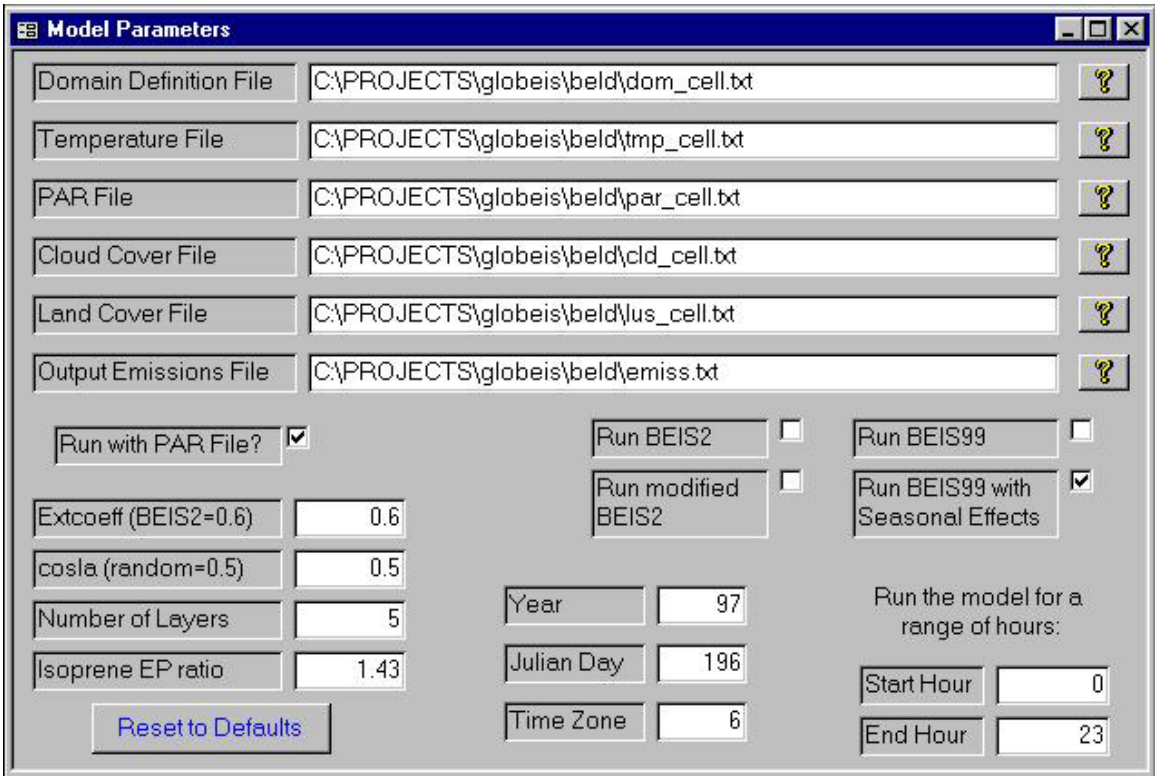


**Figure 2-7**. Selection of input data and model options in GLOBEIS.

The main input data for GLOBEIS are:

- GIS data on gridded LULC distributions
- Plant species distributions for each LULC category (internal data table)
- Emission factors by plant species (internal data table)
- Gridded environmental data (temperature, solar radiation or cloud cover)
- Seasonal biomass adjustments (satellite data based)

Data processing tasks for GLOBEIS have been divided to make best use of the capabilities of GIS and database software tools. The LULC data for GLOBEIS are prepared using GIS tools such as ARC/Info or ARCView. This data preparation step is a straightforward application for the GIS software. The emission calculations are performed in GLOBEIS, which is based on the Microsoft ACCESS database, because this step is essentially a data synthesis and cross-referencing application and is well suited to a modern database program like ACCESS. The reporting capabilities available within ACCESS also allow strong QA/QC capabilities to be built into GLOBEIS. The system is easy to maintain and upgrade because it is based on widely used software tools.

A significant advantage of GLOBEIS is the ease with which an emission inventory can be regenerated with alternate assumptions. For example, all of the emission factor data are readily accessible in data tables within the model, so an alternate emission factor can be used and the inventory regenerated in a single step.

The output from GLOBEIS includes a gridded, temporally allocated, speciated emissions file ready for use in a photochemical modeling. An example emission inventory for the Houston area is shown in Figure 2-8. This figure demonstrates the ability of a GIS based system (like GLOBEIS) to accurately resolve areas of high and low emissions density without introducing artifacts related to geopolitical boundaries.

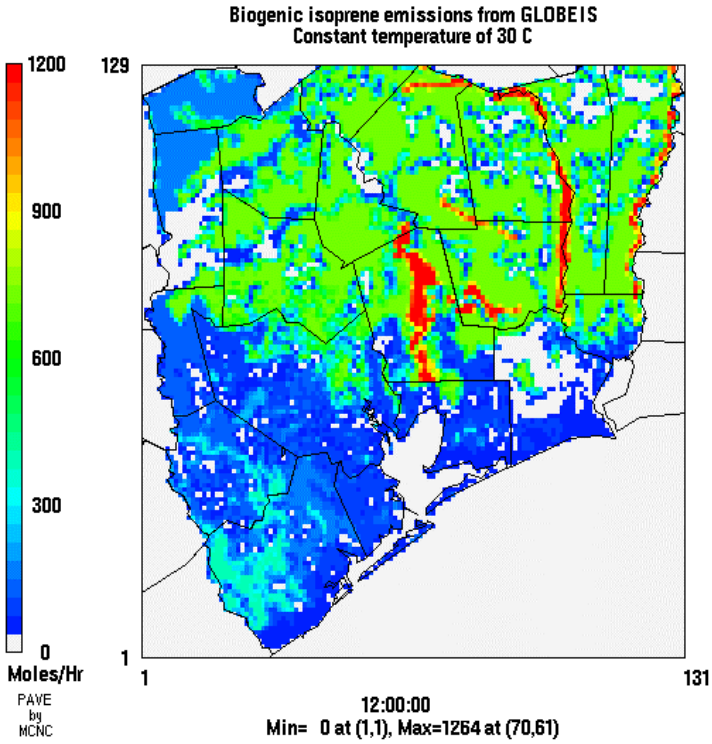


**Figure 2-8**. Isoprene emission inventory for the Houston area prepared with GLOBEIS.

Enhancements to GLOBEIS for this Study

As discussed above, GLOBEIS was designed as a biogenic emissions processing system but support for ammonia was built into the model. Several simple improvements to GLOBEIS are proposed to allow maximum use of available ammonia emissions information and improve the efficiency of the system for processing ammonia emissions.

- Switch to turn off the biogenic emissions calculations if they are not being used (or possibly adapt GLOBEIS into a new system for ammonia only). This would reduce unnecessary computational and data requirements.

- Add the ability to specify seasonal and temporal profiles by source category.

- Add environmental relationships between ammonia emission factor and environmental factors (e.g., dependence on temperature) to provide day specific emissions. This would be analogous to the current built-in emission relationships between isoprene emission factors and sunlight/temperature. GLOBEIS already reads gridded hourly temperature and radiation data, and other environmental data inputs can be added if needed. Specific additional environmental data which will be included, primarily for the treatment of natural soils emissions, would be relative humidity, soil pH and soil moisture. These data are available from, and will be provided by, the ARB.
- Add the ability to treat point source emission data.

- Update look-up tables for source specific and landuse specific emissions factors.

The objective is to build an emissions modeling system that makes the maximum use of currently available information and also can accommodate more detailed information as it becomes available from future studies.

**Task 4: Produce Draft Ammonia Modeling Inventory**

The purpose of this task is develop the draft gridded ammonia emissions modeling inventory based on the best available data and processing methodologies.

Modeling Episodes and Domain

The CRPAQS is currently conducting a field measurement program consisting of fourteen months (annual program) of monitoring throughout the San Joaquin Valley and surrounding areas. The field program includes a number of episodic field programs within the annual monitoring period. The winter episodic field study will focus on collection of $PM_{2.5}$ data and is being conducted from mid-November through January, 2001. The summer and fall episodic studies were to have taken place during July 1, 2000 through August 31, 2000 and from September 15, 2000 through November 15, 2000, respectively. Ideally, the draft gridded ammonia emission inventories will be developed for time periods corresponding to these field measurement studies. However, at this time, the precise episodes for particulate modeling have not yet been finalized.

As specified in the Statement of Work for the project, the modeling domain will cover the entire San Joaquin Valley study area. However, as the exact specification of the modeling domains and grid structure has not been finalized, data collection efforts will focus on the SJV study area, but will also include the entire state of California for those cases were the data collection efforts would not jeopardize the project in terms of resource constraints. Figure 2-9 displays the proposed modeling domains for the CCOS and CRPAQS studies in a Lambert Conformal Projection (LCP) coordinate system at a grid resolution of 4-km. For the 4-km Statewide grid, the domain consists of 273 x 273 grid cells, while the CCOS and CRPAQS 4-km domain is centered over the San Joaquin Valley study area and consists of 190 x 190 grid cells.

The draft gridded ammonia emission inventories this project will be developed at a horizontal resolution of 1-km by 1-km and 1-hour temporal resolution. The modeling domain will correspond to the CRPAQS grid shown in Figure 2-9 and will consist of 760 x 760 grid cells. The draft inventories will be developed for two time periods coinciding with the 1999-2001 CRPAQS field measurement study. These two periods will be determined by the Technical Committee.

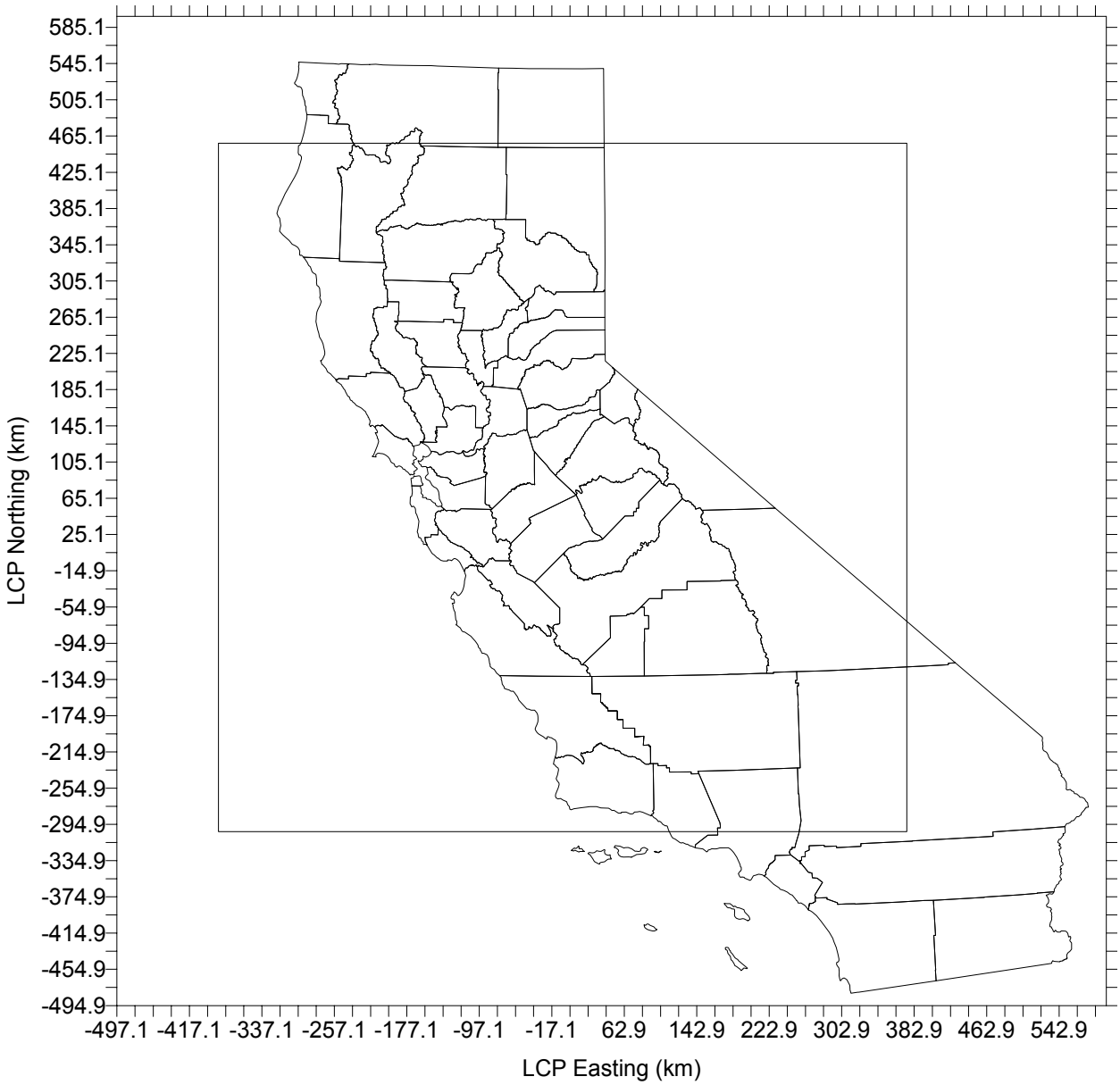


**Figure 2-9.** Proposed CCOS and CRPAQS Modeling Domains.

Treatment of Emission Source Categories

The recommended treatment for each ammonia emission source category is summarized with respect to spatial and temporal allocation in the following subsections.

Spatial Allocation

Point sources will be spatially allocated using the appropriate coordinate projection system for the CRPAQS modeling domain. This includes sources within certain categories previously modeled as area sources (e.g., livestock) where the Team has identified information (e.g., dairy locations) to model the sources as point sources. For area and mobile sources, the Team will spatially allocate the emissions with the sources of data shown in Table 2-13 below.

**Table 2-13.** Spatial surrogates for area and mobile sources.

| Source Category | Spatial Surrogate |
|---|---|
| On-Road Mobile Sources | Allocated based on existing gridded VMT. See discussion on on-road mobile source above. |
| Fertilizer Application | Crop coverages developed by Potter et al (2000) |
| Soils and Plant Canopy Systems | Coverages developed by Potter et al (2000) |
| Agriculture Burning | Crop coverages developed by Potter et al (2000) |
| Prescribed Burns/Wildfires | Coverages developed from CDFFP and NIFC data. |
| Residential Wood Burning | NLCD residential LULC and census data |
| Livestock: Beef Cattle | NLCD LULC coverages |
| Livestock: Hogs, Rabbits, Sheep, Goats | NLCD LULC coverages |
| Livestock: Horses, Mules, Donkeys, Burros | NLCD LULC coverages |
| Native Animals | NLCD LULC coverages |
| Industrial | ZIP code coverages |
| Domestic Sources Human | NLCD LULC coverages and census data |

The following emission source categories will treated as stationary point sources: dairy cattle, poultry operations, POTWs, composting and landfills.

Temporal Allocation

Table 2-14 provides a list of the suggested temporal allocation by source category. Details on the sources of temporal allocation methods and data sources are given under the descriptions for each source category under Task 2 above.

**Table 2-14**. Temporal allocation by source category.

| Source Category | Primary Temporal Allocation |
|---|---|
| On-Road Mobile Sources | Existing CCOS temporal allocation |
| Fertilizer Application | Monthly (minimum) – based on data from Potter |

| | |
|---|---|
| | et al. Depending on available data, weekly allocation may be possible. |
| Soils and Plant Canopy Systems | Seasonal (minimum) - based on data from Potter et al. Depending on available data, monthly allocation may be possible. |
| Agriculture Burning | Monthly – based on data from Fife, discussions with county agricultural offices. |
| Prescribed Burns/Wildfires | Seasonal (minimum) – based on activity data gathered from government agencies. Monthly allocation may be possible. |
| Residential Wood Burning | Monthly (minimum) – based on calculations of degree-heating days. Weekly may be possible. |
| Livestock: Dairy Cattle | Diurnal (to be determined) based on Wilkinson et al. and James et al. |
| Livestock: Beef Cattle | Diurnal (to be determined) based on Wilkinson et al. and James et al. |
| Livestock: Poultry | Diurnal (to be determined) based on Wilkinson et al. and James et al. |
| Livestock: Horses, Mules, Donkeys, Burros | Diurnal (to be determined) based on Wilkinson et al. and James et al. |
| Livestock: Hogs, Rabbits, Sheep, Goats | Diurnal (to be determined) based on Wilkinson et al. and James et al. |
| Native Animals | None |
| Industrial Point | None |
| Composting | None |
| Landfills | None |
| Sewage Treatment Plants | None |
| Domestic Sources | None |

In addition to the primary allocation schemes shown in Table 2-14 above, the Team will also be investigating methods and data sources for diurnal allocation of emissions (daily cycles) for certain source categories (e.g., livestock, fertilizer application, soil/plant canopy systems). For all source categories, the Team will provide recommendations for daily and weekly cycles.

Application of Ammonia Emission Model

Area source emissions will be processed using the enhanced GIS-based GLOBEIS model developed for this study. In addition, if feasible, point source emission data will also be treated within the GIS model. As the development of the model is currently in the conceptual planning stages, it is too early to specify precisely the details concerning the application of the model. The general processing techniques are presented above in the discussion of the development of the ammonia emission model. As part of the model development, a detailed Users' Guide will be produced specifying the required input data file formats, processing procedures, and output data formats.

EPS2.0 Processing

As noted in the RFP, the project requirements specify the need for a contingency plan in the unlikely event that the development of the GIS emission model is delayed or if it is determined that it would not be feasible to treat certain source categories within the GIS-based model. In addition, given the limited resources available for the development of the GIS model, it may not be possible to fully implement all of the desired processing elements within the budget and scheduling constraints of the project. Therefore, the EPA's Emission Processing System, EPS2.0 (EPA, 1992) will be configured for use as a fallback to the development of gridded, hourly ammonia emissions, as well as for use in the gridding of stationary point sources. Those emission categories to be treated as point sources include some portion of livestock emission, dairy and poultry farms, composting and landfill operations, POTW, sewage treatment facilities and industrial sources. The EPS2.0 has been used recently to develop an updated ammonia emission inventory for the South Coast Air Basin. (ATC, 2000).

The EPS2.0 is a publicly available FORTRAN based software program that is included with EPA UAM modeling system. The EPS2.0 is a complete integrated package that has been applied to many urban and regional areas and operated by many different groups. Like many emission models, it includes separate modules for the treatment of surrogate distributions, area sources, mobile sources and stationary point sources and provides the necessary tools for the chemical speciation and temporal allocation of county-level emission estimates. In addition, it includes several levels of quality assurance/quality control in the form of message files containing summaries of input and output emission mass totals by county and source category. While the standard output format of the gridded emission inventories processed with EPS2.0 are in a form compatible with several grid-based air quality models (CAMx, UAM-V, UAM-IV), the model can be easily modified to provide the required EMS-95 compatible output formats for this project.

The EPS2.0 modules used for developing gridded emission inventories are summarized as follows:

- Spatial Distributions: The EPS2.0 includes FORTRAN-based program that can generate surrogate distributions from landuse and census data for gridding county-level emission data. However, the software can also use surrogate distribution data generated from external program, including GIS. EPS2.0 application for this project will make use of gridding surrogate data developed with a GIS, as discussed above.
- Area Source Module: The EPS2.0 uses FORTRAN based software to spatially allocate the county-level area source emissions to the gridded surrogate distributions imposing user-provided temporal and chemical speciation profile data. For ammonia emission, no chemical speciation is required.
- Mobile Source Module: The EPS2.0 integrates county-level VMT by roadway class with county- and temperature-specific MOBILE5/6 simulations to estimate county-level mobile source emission that are spatially allocated according to surrogate distributions. Provisions for separating the mobile source emission by emissions mode (e.g., exhaust and evaporative) are also accounted for. As the ammonia emissions from mobile sources will be leveraged off of existing or in-progress mobile inventory development, as discussed previously, it will not be necessary to utilize this module of the processing system.
- Point Source Module: The EPS2.0 point source modules performs the same functions of other similar emissions models. These functions include the mapping of point source locations to the grid projection system of the modeling domain, application of seasonal and day-of-week adjustments, and the chemical speciation and temporal

allocation of emission based on the point source SCC code and user-provided speciation and diurnal emissions profiles. The EPS2.0 point source module also estimates plume rise for each point source. For ammonia emission point sources, no chemical speciation is required and the stack parameters (stack height, exit velocity and exit gas temperatures) will be set to default values to ensure that their emission are allocated to the lowest, or surface layer, of the gridded emission data files.

While the EPS2.0 does not include an explicit Quality Assurance/Quality Control module, it does provide for several levels of QA/QC in the form of emission summaries by source category and county/region. These reports will used as an additional layer of QA/QC in the overall development of the gridded ammonia emission inventory.

As both the GIS-based ammonia emissions model and the EPS2.0 processing system produce gridded output data in a format compatible with the UAM-IV modeling system, a straight forward re-formatting of the data will be required to produce the required EMS95 compatible data formats for the final draft gridded inventory. Processing software will be developed in the most appropriate programming language (FORTRAN, Perl, etc.) to perform this function and will be documented and included as a project deliverable submitted to the Technical Committee.

Quality Assurance/Quality Control

Final quality assurance of the draft gridded ammonia emission inventory will be performed based on the various message file generated by the emission model processing. These include numerous range checks on stack parameters (for point sources) and emission mass summaries by source category and county/region. Graphical summaries in the form of bar and/or pie charts will be used to provide an overall representation of the draft inventory and to identify any possible problems. Finally, plots of the spatial distribution of the emission density for each source category will be prepared and used for evaluating the reasonableness of the overall inventory with respect to the spatial and temporal allocation of emission estimates.

**Task 5: Documentation**

The ENVIRON team will prepare and submit a cumulative Draft Final Report documenting all aspects of the work performed for each task during the course of the project. After review by the Technical Committee, the ENVIRON team will modify the Draft Final Report in accordance with TC comments and submit a Final Report. In fulfilling the requirements of the project, the Final Report will include (at minimum):

- Executive Summary;
- Summary of the critical review of existing ammonia literature, ammonia inventories and processing techniques (performed under Task 1 and 2);
- Summary of gridded ammonia emissions inventory improvement issues addressed in the project;
- Identification and recommendation of most promising processing techniques and input data for development of accurate gridded ammonia emissions estimates for the study domain;
- Documentation of the development/adaptation of ammonia emissions model;
- Detailed description of gridded inventory development (performed under Task 4);

- Ammonia emission inventory summary (by source category); and
- Recommendations and Conclusions.

Documentation describing the QA/QC procedures used, as well as detailed descriptions of the standardized input data libraries developed under Task 2 will be provided as part of this task. All computer codes developed or used to perform work during the project will be internally documented and submitted in electronic form. A variety of software applications and operating system platforms may be required for completion of the project. These include spreadsheet and database applications (Excel and Access running under Windows) and GIS applications (ARC/Info running under Windows NT and AML).

Regular periodic (quarterly) system backups of all project data will be performed under this task. System backups will be delivered to the Program Manager in electronic form on appropriate media to be determined in consultation with the TC. As the ENVIRON team's facilities include networked Unix workstations with over 150 Gbytes of disk storage capacity with access to 4mm DAT, 8mm Exabyte, and DLT tape drives, data archival and system backups can be performed efficiently without the need for obtaining additional hardware resources. The recommended method and media for storage and transfer of data and system backups consists of using the Unix 'tar' archiving utility and 8mm Exabyte tape media.

In addition to the above, the ENVIRON team will produce and deliver a Users' Guide, as stipulated in the RFP. The Users' Guide will detail all processing procedures, and include a library of all utilized processing routines and input data. The Guide will be written to facilitate the generation of additional ammonia inventories by the program sponsors.

All documentation and reports developed and/or written for performance of the project will be submitted in electronic form, compatible with Microsoft Word.

# 3. PROJECT MANAGEMENT, RESOURCES AND SCHEDULE

In this section we describe the project management structure, resource allocation and schedule. Our project management structure (Figure 3-1) is designed to clearly delineate the staffing, responsibilities, and lines of authority for the project so as to maximize the use of available resources and ensure a high quality product.

Mr. Ralph Morris, an experienced Principal at ENVIRON, will serve as the project's Principal Investigator with Dr. Gerard Mansell, a Senior Consultant at ENVIRON, serving as Project Manager. Dr. Mansell's responsibilities as Project Manager will include:

- serving as primary contact with the CRPAQS project study officers;
- providing overall technical direction and oversight of all work performed;
- review of all project deliverables;
- preparation of monthly progress reports;
- management of project schedule and budget;
- management and coordination of the ENVIRON Team's subcontractors; and
- attending conference calls and meetings with the CRPAQS project officers.

In addition to overall project management, the ENVIRON staff will provide technical support for the review and recommendation of improved processing techniques and data inputs performed by ENVIRON's subcontractors under Tasks 1 and 2. ENVIRON staff will also lead the development and/or adaptation of an ammonia emissions modeling system as well as developing the procedures for the creation of standardized data libraries, quality assurance/quality control procedures and gridding of the draft ammonia modeling inventory. Additional ENVIRON staff assigned to this project include Dr. Greg Yarwood, Mr. Gary Wilson, Mr. Cuong Tran, Ms. Michele Jimenez, Ms. Rosa Chi and Shannon Coulter-Burke. Dr. Yarwood, a Senior Consultant, will take the lead role in investigation and development and/or adaptation of an ammonia emissions model. Dr. Yarwood will be assisted by Mr. Gary Wilson, also a Senior Consultant, who has extensive experience with the development and application of emissions inventory modeling systems. Mr. Cuong Tran, an Associate at ENVIRON, will assume responsibilities for GIS-related activities, including acquisition and processing of appropriate GIS (ARC/Info) databases and the processing and development of required gridded spatial surrogate data. Mr. Tran will be assisted by Ms. Coulter-Burke, also an Associate at ENVIRON. Ms. Jimenez, an Associate at ENVIRON, will provide technical assistance required for data collection, processing and gridding the ammonia emissions inventory. Ms. Chi , an Associate with ENVIRON, will provide technical assistance with data collection efforts as well as the processing and gridding of the ammonia emissions inventory.

The ENVIRON Team also includes Pechan-Avanti as a subcontractor. Pechan-Avanti will develop the ammonia inventory as well as leading the effort to review existing ammonia emissions, ammonia inventories, processing techniques and ammonia emission sources. In addition, Pechan-Avanti will provide recommendations regarding the most promising processing techniques and data inputs, including emissions factors, activity data, and temporal and spatial allocation data. Mr. Stephen Roe will provide day-to-day management functions for Pechan-Avanti staff. Mr. Roe will be assisted by Ms. Kirsten Thesing and Ms. Melissa Dagan.
Table 3-1 provides an estimated break down of resource allocation by task. Corresponding to the technical approach detailed in Section 2 above, five tasks are presented. Table 3-2 presents a

proposed project schedule by month for the 2-1/2 year study program. Also included are anticipated dates of delivery for those deliverables required of the project. As certain deliverables are due one or two months after receipt of TC comments, the dates shown are approximate and will be finalized as work progresses. These include a Draft and Final Workplan, input data for draft inventories, the draft inventory and an ammonia emission model, progress reports, and a Draft and Final Report.

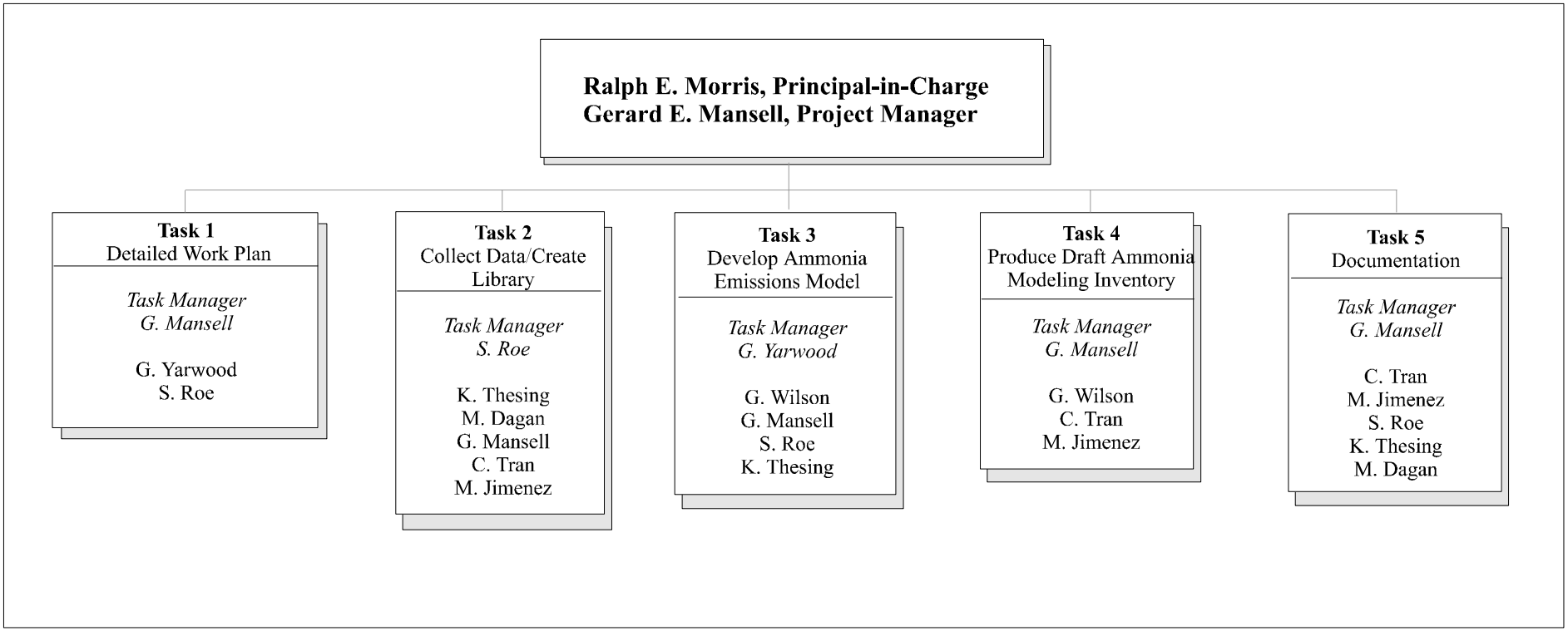


**Figure 3-1.** Project management structure.

**Table 3-1.** Estimated labor hours by task. (***Note: This table will be revised due to ATC default)***

| Staff | Task[1] | | | | | Total |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | |
| **ENVIRON** | | | | | | |
| R. Morris (Principal) | 4 | 0 | 0 | 0 | 4 | 8 |
| G. Mansell (Senior Consultant) | 32 | 32 | 32 | 20 | 40 | 156 |
| G. Yarwood (Senior Consultant) | 6 | 0 | 8 | 0 | 0 | 14 |
| G. Wilson (Senior Consultant) | 0 | 0 | 24 | 40 | 0 | 64 |
| M. Jimenez (Senior Associate) | 0 | 18 | 0 | 60 | 8 | 86 |
| C. Tran (Associate) | 0 | 40 | 0 | 100 | 8 | 148 |
| R. Chi (Associate) | 0 | 30 | 0 | 0 | 0 | 30 |
| S. Coulter-Burke (Associate) | 0 | 32 | 0 | 0 | 20 | 52 |
| Support | 4 | 4 | 4 | 4 | 4 | 20 |
| **Subtotal ENVIRON** | 46 | 156 | 68 | 224 | 84 | 578 |
| **Pechan** | | | | | | |
| S. Roe (Project Director) | 16 | 48 | 80 | 0 | 12 | 156 |
| K. Thesing (Environmental Scientist) | 0 | 100 | 40 | 0 | 8 | 148 |
| A. Bollman (Environmental Scientist) | 0 | 100 | 40 | 0 | 8 | 148 |
| K Aguilar (Contracts Mgr.) | 20 | 0 | 0 | 0 | 0 | 20 |
| M. Dagan (Staff Analyst) | 0 | 200 | 0 | 0 | 0 | 200 |
| Support | 2 | 16 | 0 | 0 | 8 | 26 |
| **Subtotal Pechan** | 38 | 464 | 160 | 0 | 36 | 698 |
| **Total** | **84** | **704** | **228** | **224** | **120** | **1276** |

[1] Task 1: Prepare a Detailed Work Plan; Task 2: Collect Data and Create Standard Input Library; Task 3: Develop Ammonia Emissions Model; Task 4: Produce Draft Ammonia Modeling Inventory; Task 5: Documentation.

**Table 3-2.** Summary of initial schedule and costs for CRPAQS Draft Ammonia Inventory Development.

| | Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Task | Costs | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **1a** | $10,263 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **1b** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2a** | $35,441 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **2b** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **3** | $16,766 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **4** | $22,314 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **5a** | $13,568 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **5b** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p | p |
| | | | | | | dwp | | fwp | | | | | | | | | | | | | | | | | | | | d | | | f |

**Task 1a:** Prepare a Detailed Work Plan; Deliver Draft (1/01)
**Task 1b:** Prepare a Detailed Work Plan; Deliver Final (2/01)
**Task 2a:** Collect Data and Create Standard input Library (9/01)
**Task 2b:** Deliver Inputs to Draft Inventories (3/02)
**Task 3:** Develop Ammonia Emissions Model (3/02)
**ask 4:** Produce Draft Ammonia Modeling Inventory (3/02)
**Task 5a:** Documentation: Deliver Draft Final Report (11/01)
**Task 5b:** Documentation: Deliver Final Report (2/03)

p = Progress report
d = Deliver draft final report
f = Deliver final report
dwp = Deliver Draft Workplan
fwp = Deliver Final Workplan

# 4. REFERENCES

ARB, 1997. *Emission Inventory Procedural Manual, Volume III B Methods for Assessing Area Source Emissions,* California Environmental Protection Agency, Air Resources Board, October 1997.

ATC, 2000. 1997 *Gridded Ammonia Emission Inventory Update for the South Coast Air Basin*, prepared for the South Coast Air Quality Management District by ATC Associates, Arcadia CA. August

Battye, R., W. Battye, C. Overcash, and S. Fudge, 1994. *Development and Selection of Ammonia Emission Factors*. EPA/600/R-94/190. Final report prepared for U.S. Environmental Protection Agency, Office of Research and Development. EPA Contract No. 68-D3-0034, Work Assignment 0-3.

Bouwman, A.F., D.S. Lee, W.A.H. Asman, F.J Dentener, and. K.W. Van Der Hoek, 1997. A Global High Resolution Emission Inventory for Ammonia, *Global Biogeochemical Cycles*, Vol. II, No. 4, pp. 561-587.

DOE, 1993. U.S. Department of Energy, Energy Information Administration, *Household Energy Consumption and Expenditures, 1990,* DOE/EIA-0321(90), 1993.

DOF, 2000. *City/County Populations and Housing Estimates, 1991-2000, with 1990 Census Counts*, State of California, Department of Finance, Sacramento, California. May 2000.

EPA, 1997. *Volume III: Chapter 2, Residential Wood Combustion,* prepared by Radian Corporation for the Area Sources Committee, Emission Inventory Improvement Program, U.S. Environmental Protection Agency, September 1997.

EPA, 1992. "Users Guide for the Urban Airshed Model. Volume IV: User's Manual for the Emissions Preprocessor System 2.0". USEPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. June, 1992.

Fife, 2000. Les Fife, private consultant, personal communication with S. Roe, E.H. Pechan & Associates, Inc., December 2000.

Fraser and Cass, 1998. M.P. Fraser, and Cass, G.R., "Detection of Excess Ammonia Emissions from In-Use Vehicles and the Implications for Fine Particle Control", *Environmental Science & Technology*, 32, 1053-1057, 1998.

Gharib, S., and G.R. Cass, 1984. *Ammonia Emissions in the South Coast Air Basin*. Prepared by Environmental Quality Laboratory, California Institute of Technology, Pasadena, CA. Open file report 84-2, December.

Goode et al, 2000. Goode, J.G., R.J. Yokelson, R.A. Susott, and D.E. Ward, R.E. Babbitt, M.A. Davies, and W.M. Hao, "Measurements of excess O3, CO2, CO, CH4, C2H4, C2H2, HCN, NO, NH3, HCOOH, CH3COOH, HCHO, and CH3OH in 1997 Alaskan biomass burning plumes by airborne Fourier transform infrared spectroscopy (AFTR)", *Journal of Geophysical Research*, vol. 105, no. D17, pp. 22147-22166, Sep. 16, 2000.

Goode et al, 1999. Goode, J.G., R.J. Yokelson, R.A. Susott, and D.E. Ward, "Trace Gas emissions from laboratory biomass fires measured by open-path Fourier transform infrared spectroscopy: Fires in grass and surface fuels", *Journal of Geophysical Research*, vol. 104, no. D17, pp. 21237-21245, Sep. 20, 1999.

Griffith et al, 1991. Griffith, D.W.T, W. Mankin, M. Coffey, D. Ward, and A. Riebau, "FTIR Remote Sensing of Biomass Burning Emissions of $CO_2$, CO, $CH_4$, $CH_2O$, NO, $NO_2$, $NH_3$, and $N_2O$", *Global Biomass Burning: Atmospheric, Climatic, and Biospheric Implications,* MIT Press, Levine, J.S. (ed), 1991.

Houck, 1997. Houck, H., Omni Environmental Services, Inc., memorandum to J. Mangino, Eastern Research Group, November 19, 1997.

James, T, N. Fritas, L. Ashbaugh, and D. Meyer, 1997. Field Estimates of Volatilization from Cattle Production Facilities. *Proceedings from the Air And Waste Management Association Conference - Emission Inventory: Planning for the Future,* October 28-30, pp 259-267.

Lord et al, 2000. Lord III, H.C., M.M. Baum, E.S. Kiyomiya, S. Kumar, and A.M. Lappas, "Multi-Component Remote Sensing of Vehicle Exhaust by Dispersive Absorption Spectroscopy", *Environmental Science & Technology*, 34(13), 2851-2858, 2000.

Muck, R.E., and T.S. Steenhuis, 1982. *Nitrogen Losses from Manure Storages*. *Agricultural Wastes* 4, 41-54.

Potter et al, 2000. Potter, C., C. Krauter, and S. Klooster, *Statewide Inventory Estimates of Ammonia Emissions from Native Soils and Chemical Fertilizers in California, Draft*, prepared for the California Air Resources Board, December 31, 2000.

Radian, 1991. *Development of the Ammonia Emisson Inventory for the Southern California Air Quality Study Rep*ort prepared for the California Air Resources Board, Sacramento CA by Radian Corporation, Sacramento CA, Sept.

Scarborough, 2000. James Scarborough, U.C. Berkeley, personal communication with S. Roe, E.H. Pechan & Associates, Inc., December, 2000.

Schmidt, C.E., and E. Winegar, 1996. *Results of the Measurements of $PM_{10}$ Precursor Compounds from Dairy Industry Livestock Waste*. Technical report prepared for the South Coast Air Quality Management District.

STI., 1998. *Technical Support Study 15: Evaluation and Improvement of Methods for Determining Ammonia Emissions in the San Joaquin Valley*. Prepared for the California Air Resources Board by Sonoma Technology, Inc., January.

USDA, 1999a. *1997 Census of Agriculture*. USDA website

USDA, 1999b. *U.S. Equine Inventory*, National Statistics Service (NASS), Agricultural Statistics Board, U.S. Department of Agriculture, NASS wbsite

Warn, T.E., Zelmanowitz, S., and Saeger, M., 1990. Development and Selection of Ammonia Emission Factors for Office of Research and Development U.S. Environmental Protection Agency, Washington, D.C. by Alliance EPA-600/7-90-014, June. EPA Contract No. 68-02-4374, Work Assignment No. 43.

Wilkinson, James G., et al. *A Model to Estimate Temporally Resolved Ammonia Emissions at a Dairy,* for presentation at the Air & Waste Management Association's 91st Annual Meeting & Exhibition, June 14-18, 1998 San Diego, California, 98-WA45B.04 (A883).

Winegar E., 1999. *Review of Literature Sources for Emissions of Ammonia from Dairy Farms*, Applied Measurement Science.

Yarwood, G., G. Wilson, C. Emery, and A. Guenther. 1999. Development of GLOBEIS – A State of the Science Biogenic Emissions Modeling System. Final Report. Prepared for Texas Natural Resource Conservation Commission. December.

Yokelson, R.J., J.G. Goode, D.E. Ward, R.A. Susott, R.E. Babitt, D.D. Wade, I. Bertschi, D.W.T. Griffith, and W.M. Hao, "Emissions of formaldehyde, acetic acid, methanol, and other trace gases from biomass fires in North Carolina measured by airborne Fourier transform infrared spectroscopy", *Journal of Geophysical Research*, vol. 104, no. D23, pp. 30109-30125, Dec. 20, 1999.

Yokelson, R.J., D.W.T. Griffith, and D.E. Ward, "Open-path Fourier transform infrared studies of large-scale laboratory biomass fires", *Journal of Geophysical Research*, vol. 101, no. D15, pp. 21067-21080, Sep. 20, 1996.