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Evaluation of Methodologies to Estimate Nonroad Mobile Source Usage

prepared for:

Office of Mobile Sources
U.S. Environmental Protection Agency

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prepared by:

Sierra Research, Inc.
1521 I Street
Sacramento, California 95814
(916) 444-6666

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EVALUATION OF METHODOLOGIES TO ESTIMATE NONROAD MOBILE SOURCE USAGE

Contract No. 68-C1-0079
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prepared for:

Kevin Green, Work Assignment Manager
Certification Division
U.S. Environmental Protection Agency

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Principal authors:

Philip Heirigs
Robert G. Dulla

Sierra Research, Inc.
1521 I Street
Sacramento, CA 95814
(916) 444-6666

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1. EXECUTIVE SUMMARY

The Clean Air Act Amendments of 1990 directed EPA to evaluate the contribution of nonroad engines and vehicles to air pollution in nonattainment communities. The result of that directive was the "Nonroad Engine and Vehicle Emission Study" (NEVES) which was published by EPA in November 1991. That study quantified emissions of nonroad vehicles in 24 ozone and/or carbon monoxide nonattainment areas. Although the methodologies evolving from that work have significantly improved the state-of-the-art in developing nonroad emission inventory estimates, there may be different methodologies that could more accurately reflect the distribution and usage of equipment that actually occurs within those communities.

A total of 10 nonroad equipment categories were considered in NEVES, which constitute over 80 individual equipment types. For the current study, eight of those equipment categories were investigated:

- Lawn and Garden Equipment,
- Airport Service Equipment,
- Recreational Equipment,
- Construction Equipment,
- Light Commercial Equipment,
- Industrial Equipment,
- Agricultural Equipment, and
- Logging Equipment.

Overview

Sierra Research (Sierra) provides support to the Certification Division of EPA's Office of Mobile Sources under a contract entitled "Analytical and Testing Support for the Certification Division at EPA's Motor Vehicle Emissions Laboratory." Work Assignment 1-08 of that contract directed Sierra to investigate a variety of issues related to nonroad mobile source usage. The scope of that effort identified three main tasks:

- Review of recent nonroad emission inventory studies and investigation of alternative data sources;
- Development of alternative methodologies for estimating nonroad activity and emissions; and
- Evaluation of methodologies.

Although each of the topics outlined above was presented as a separate task in the Scope of Work, the evaluation of each task was not performed independently. As individual equipment categories were analyzed, all three issues were considered. Thus, the discussion below expands upon elements of all three tasks as the evaluation of alternative methodologies for each equipment category is presented.

Review of Nonroad Studies

The review of previous nonroad inventory studies focused on NEVES and recent work performed by and for the California Air Resources Board (CARB). In NEVES, two sets of inventories were prepared ("Inventory A" and "Inventory B"). The first was based on information and data compiled by an EPA contractor, while the second was based on information submitted by industry. In this study, the activity estimates (in annual bhp-hr) for both inventories were compiled and compared, and the methodologies utilized to develop local-level equipment population and usage estimates were assessed.

Because of recent and pending efforts by CARB to regulate nonroad equipment, new efforts have been undertaken to more accurately assess the nonroad inventory in California. Several studies to support regulatory development have included emission estimates for nonroad vehicles and equipment, while others have focussed exclusively on inventory development. Among the equipment categories that have been investigated are heavy-duty construction equipment, lawn and garden equipment, and agricultural equipment. Although prepared for California, some of the techniques employed in those studies were utilized in developing new methodologies for this work (e.g., categorization of lawn and garden equipment by residential versus commercial usage; development of "bottom-up" methodologies for agricultural equipment activity estimates).

Development of Alternative Methodologies

The studies outlined above have primarily relied on "top-down" methodologies to determine local-level equipment population and usage. These methodologies typically scale national or state-level equipment populations to the local level (e.g., county or air basin) using local statistics that are related to equipment usage (e.g., the number of households in a community may be used to allocate lawnmowers). The rationale behind this approach is that national-level equipment populations and usage are generally available for most equipment types, and these should be proportional to certain data indicative of equipment usage (provided the so-called "activity indicators" are chosen with care). However, a problem with this approach is that local nuances in equipment usage patterns are often lost when relying on this methodology. For example, NEVES Inventory A allocated 450 off-road motorcycles to California's San Joaquin Valley, whereas California Department of Motor Vehicles (DMV) records indicate that approximately 15,000 are registered in that area. Given the rural nature of the San Joaquin Valley, motorcycle population and usage would be expected to be more closely approximated by the DMV records than the estimate prepared for NEVES.

An alternative to the "top-down" procedure is the "bottom-up" method whereby local information forms the basis of the calculation. For example, Sierra has developed a methodology to estimate agricultural field emissions that relies upon farm cooperative estimates of equipment activity (i.e., hours/acre per operation and average equipment horsepower) for producing individual crop types. This information is coupled with the number of acres under cultivation (by crop type) to arrive at an estimate of equipment activity for the area of interest. The farm cooperative data show that there are enormous differences among crop equipment operations. Some crops, such as pasture, may require only one or two equipment operations, whereas others, such as cotton or tobacco, may require 20 separate equipment operations. The differences in crop activity lead to significant temporal and spatial variations in county emission estimates, particularly when contrasted with those that assume the same level of activity for all crops. Clearly, the same argument can be applied to other equipment categories, and the evaluation of bottom-up approaches for all equipment categories is an important step in assessing potential improvements to local-level nonroad equipment activity estimates.

Considering that the NEVES report exclusively employed a top-down approach for estimating local-level equipment activity, the main focus of this task was to evaluate the potential of developing bottom-up methodologies for determining nonroad equipment usage. A primary component of this evaluation was to assess the availability of data required to develop such procedures. Thus, considerable effort was expended in contacting industry associations and government agencies (federal, state, and local) for data related to equipment usage patterns. For cases in which a bottom-up approach was not considered feasible, effort was directed at identifying data sources that would improve upon current top-down procedures.

The above evaluation was carried out for the eight equipment categories considered in this study; a brief summary of the results follows.

<u>Lawn and Garden Equipment</u> - Considerable effort was expended in attempts to locate information that could be used to develop a bottom-up methodology for lawn and garden equipment. This consisted of extensive contact with industry associations (e.g., Professional Grounds Management Society), local and state Parks Departments, the National Park Service, state Agricultural Extension services, and state highway maintenance agencies. Although information was identified that would allow for the development of a bottom-up procedure for certain

specialized cases (e.g., golf courses), the information was not comprehensive enough to form the basis of a bottom-up approach encompassing the entire lawn and garden equipment usage regime. Thus, a top-down procedure was developed in which equipment was stratified according to commercial and residential use. The commercial equipment was allocated according to employment in the horticultural service industries, while residential equipment was allocated according to lot size or single family housing units, depending upon equipment type. (Lot size was considered a good indicator since equipment such as lawn and garden tractors would not be expected to be found on small lots.) Although Inventory A for NEVES utilized two activity indicators (single family housing units and horticultural service employment), these activity indicators were applied equally to residential and commercial equipment. This may not provide reliable estimates when allocating an equipment type that is used primarily in commercial or primarily in residential applications.

Airport Service Equipment - A bottom-up procedure was developed that expanded on previous airport inventory methodologies in which total equipment requirements (e.g., minutes of belt loader operation) by aircraft type were estimated. Because the Federal Aviation Administration publishes data on the number of flights by aircraft type for each commercial airport in the country, data on flights by aircraft type are readily available. This approach has the added advantage of being compatible with current inventory procedures for aircraft. Before implementing this approach, however, additional information on equipment requirements for cargo operations needs to be collected (e.g., minutes per ton of cargo loaded/unloaded by equipment type). Finally, an alternative top-down procedure was proposed in which total passengers and cargo tonnage served as the activity indicators. Because equipment requirements are much greater for aircraft with a high passenger capacity (although not confirmed, it is also anticipated that equipment usage is a strong function of cargo tonnage), these indicators are likely to provide a better indication of equipment usage than total air carrier operations, which was the activity indicator used in NEVES.

Recreational Equipment - Again, some information was located that could potentially be used in the development of a bottom-up methodology (i.e., visitor-hours in Bureau of Land Management areas), but its coverage was not complete (e.g., ridership on other public and private lands could not be determined). An alternative top-down approach was proposed, however, that allocated recreational equipment according to rural population. This is felt to provide a much better estimate of equipment activity than the number of motorcycle dealerships as used in NEVES. (In evaluating methodologies for allocating recreational equipment, it was determined that motorcycle dealerships are typically located in urban areas, whereas ridership generally occurs in more rural environments.)

Construction Equipment - Although effort was directed at developing a bottom-up approach for construction equipment, data necessary to perform such a calculation were not located. However, an alternative top-down method was proposed that utilized metropolitan area statistics on construction valuation as the activity indicator. Because of the mobile nature of the construction industry, there were concerns about retaining

NEVES's use of construction employment as the activity indicator since employment data are gathered according to where the business is located, not where the work is actually performed.

Light Commercial Equipment - This category consists of equipment types such as generator sets, pumps, air compressors, and welders. Because of the variety of applications for which these can be used, development of a bottom-up approach was not considered feasible. However, a top-down methodology was proposed which relied on construction valuation as the activity indicator because many of these equipment types are used in the construction industry. This is considered an improvement over the NEVES methodology which relied upon wholesale establishments to allocate this equipment category to the local level.

Industrial Equipment - This category consists of equipment such as forklifts, sweepers, and material handling equipment, and because of the variable nature of the equipment, a bottom-up approach is not feasible. Also, the activity indicator utilized in NEVES (i.e., manufacturing employment) is considered an appropriate choice. The only potential improvement offered is to also include a construction indicator when allocating forklifts and aerial lifts, because these equipment types are also used in the construction industry.

Agricultural Equipment - Considerable effort was spent in determining if the bottom-up methodology developed by Sierra for the San Joaquin Valley could also be applied to other areas of the country. In conversations with various state cooperatives, it was discovered that equipment usage by crop type is available for most parts of the U.S. Further, information was located on horsepower-time requirements for field operations (e.g., plowing, chiseling, etc.) that could form the basis for crop-specific equipment usage estimates in areas where the information does not currently exist. Thus, a bottom-up method for agricultural equipment is considered a very viable option. The top-down procedure utilized in NEVES relied on county-level tractor population data contained in the 1987 Census of Agriculture to scale national equipment populations to the local level. Several improvements to that approach were suggested in this study, also based on information contained in the agricultural census (e.g., allocating local-level combine population based on census data on combine population rather than tractor population).

Logging Equipment - A bottom-up methodology was also proposed for estimating equipment usage in logging operations. Contacts with logging interests revealed that a few standard methods are used to harvest timber, and the equipment requirements were obtained as a function of board footage harvested. Since board footage appears to be readily available (by county) from state tax agencies, this approach is considered viable, subject to review of the equipment usage information by the U.S. Forest Service and the logging industry. (NEVES made use of county-specific logging employment data to allocate national equipment populations to the local level. However, as with the construction category, employment data by county are based on where the business is located, not necessarily where the logging activity takes place.)

Evaluation of Methodologies

Each of the methodologies developed above was evaluated by performing sample calculations for two representative nonattainment areas: the Washington, D.C. metropolitan area (DC/MD/VA) and the San Joaquin Valley (SJV) of California. This provided not only numerical comparisons with previous estimates, but also a reasonable assessment of the difficulties associated with gathering the necessary data (and the availability of data). Although complete numerical comparisons are provided in the category-specific sections of this report, Table 1-1 outlines in general terms the differences between the equipment activity estimates prepared for NEVES Inventory A and the results of this study. As seen, the differences are not consistent, with the results of this work showing increases in activity for some equipment categories, decreases for others, and very similar estimates for others.

Table 1-1

Comparison of Equipment Activity Estimates
This Study Versus NEVES Inventory A
(Increase [+] or Decrease [-] Relative to NEVES)

Equipment Category	DC/MD/VA	SJV
Lawn and Garden		
Residential Equipment	-	+
Commercial Equipment	+	-
Airport Service	-	-
Recreational	NA*	+
Construction	-**	+
Light Commercial	+	+
Industrial (Forklifts Only)	-	-
Agricultural	-	-
Logging		
Heavy-Duty Diesel	NA	-
Chainsaws	NA	-

* NA: Not analyzed.
** -: Insignificant change in activity estimate.

Recommendations

For many of the equipment categories outlined above, alternative methodologies to estimate equipment usage have been proposed. Some of them can be easily implemented, while a full evaluation of others would require additional data or resources. Some areas in which additional effort should be considered include:

- Evaluation of lawn and garden equipment usage to determine the difference between commercial and residential ownership and usage characteristics;
- Evaluation of the equipment requirements for aircraft cargo operations;
- Evaluation of the use of multiple activity indicators for equipment in the construction category that is used in several applications; and
- Coordination with the U.S. Forest Service to formally review the alternative logging equipment methodology proposed in this work.

Finally, this study identified some of the difficulties associated with developing very detailed, county-level nonroad equipment activity estimates. However, air quality planners are more frequently utilizing models that require emissions estimates on an even finer level of geographical (and temporal) detail. Thus, in the long term, additional effort should be devoted to the investigation of spatially allocating equipment usage at the sub-county level, particularly with respect to how this might be applied to current grid-cell level air quality modeling approaches.

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2. INTRODUCTION

Background

In response to a mandate from the 1990 Clean Air Act Amendments, EPA completed a detailed study of emissions from nonroad engines and vehicles[1,2*]. That study employed a "top-down" approach to quantify the emissions of nonroad vehicles in a wide range of ozone and carbon monoxide (CO) nonattainment communities. While the methodologies evolving from that work have significantly improved the state of the art in developing nonroad emission inventory estimates, there is concern that the activity levels estimated for specific nonattainment communities may not correctly represent either the distribution or usage of equipment that actually occurs within those communities.

Due to the magnitude of nonroad engine/vehicle emissions estimated in the EPA study, it is imperative that the contribution of this source category be directly related to accurate estimates of local activity. The need for accurate inventory estimates will rise steadily in coming years as nonattainment communities struggle to identify cost-effective control strategies to ensure that they reach and maintain the National Ambient Air Quality Standards.

Technical Approach

The purpose of this study was to determine whether the current "top-down" methodologies that have been employed to develop emission inventories for nonattainment communities accurately reflect local activity levels. To accomplish this objective, the effort was divided into three main tasks:

1. Review of recent nonroad emission inventory studies and investigation of alternative data sources;

2. Development of alternative methodologies for estimating nonroad activity and emissions; and

3. Evaluation of methodologies.

A key element of this work was concentrating data collection and evaluation efforts on two representative nonattainment communities. Because methodologies developed as part of this work could eventually

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[*] Superscripts denote references provided at the end of each section.

form the basis of a generic nonroad model, it was important to evaluate data availability and the effort required to compile the information needed for suggested alternative methodologies. Any approach requiring excessive data collection and compilation would likely meet with resistance from local air quality planners who would ultimately have to employ these methods.

The following communities were selected to evaluate alternative methodologies:

- Washington, DC Metropolitan Area (DC/MD/VA) - This community represents a large urban nonattainment area with a multi-state geographical boundary. The problems of collecting data from different state and local agencies (i.e., Virginia, Maryland and the District of Columbia) were well represented by this community.

- San Joaquin Valley (SJV) - This area is the focus of an ongoing study to accurately represent 1990 emissions by source category. Sierra is in the process of completing a detailed "bottom-up" estimate of agricultural field emissions for the SJV. Thus, by focusing on the SJV, it was possible to compare "top-down" and "bottom-up" methodologies for agricultural equipment. Further, the SJV represented a more rural area, and differences in the availability of information between urban and rural areas could be evaluated.

Although it was not possible to evaluate data availability for all portions of the U.S., the communities above provided a reasonable basis for such an assessment. Further, as data sources were identified and evaluated, the geographic coverage of those sources was considered.

Methodologies to Determine Nonroad Equipment Activity

As alluded to above, methodologies to estimate nonroad equipment usage can broadly be categorized as "top-down" or "bottom-up." Historically, nonroad equipment activity and emissions estimates have been prepared utilizing top-down techniques in which national or state-level equipment populations are scaled to the local level (e.g., county or air basin) using local statistics (e.g., number of households, employment in particular industries, etc.). The rationale behind this approach is that national-level equipment populations and usage are generally available for most equipment types, and these should be proportional to certain statistics indicative of equipment usage (provided the so-called "activity indicators" are chosen with care). However, reliance on national-level equipment population estimates and usage levels is akin to assuming that all communities in the U.S. experience the same annual growth rate in highway travel. The fact is that growth rates in highway travel vary dramatically by community; it is believed that nonroad activity levels exhibit significant variations as well.

Bottom-up methodologies for estimating equipment activity rely on local information to form the basis of the calculations. For example, Sierra developed a methodology to estimate agricultural field emissions in the SJV that relied upon farm cooperative estimates of equipment activity (i.e., hours/acre per operation per crop and average horsepower by operation per crop) and county statistics on the number of acres under cultivation by crop. The farm cooperative data show that there are enormous differences among crop equipment operations. Some crops, such as pasture, may only require one or two equipment operations, whereas others, such as cotton, may require 20 separate equipment operations. The differences in crop activity lead to significant temporal and spatial variations in county emission estimates, particularly when contrasted with those that assume the same level of activity for all crops.

There are advantages and disadvantages in utilizing either the top-down or bottom-up methodology to estimate nonroad equipment usage. The data requirements for top-down methodologies are generally much less severe compared to bottom-up approaches; however, local nuances in usage patterns are often lost when relying on national data that have been scaled to the local level. On the other hand, while bottom-up approaches can be tailored to include very detailed information on local conditions, the data needed to perform the estimates are often time-consuming to obtain and compile or are entirely unavailable. The focus of this work, then, was to evaluate the feasibility of developing bottom-up procedures that rely upon information that could be readily compiled by local air quality planners. For cases in which bottom-up methodologies were not considered feasible, means to make the current top-down procedures more area-specific were investigated.

An additional issue that must be considered when implementing a bottom-up methodology is the "coverage" of vehicle usage represented by the approach. For example, agricultural tractors can be used for purposes not directly related to crop operations (e.g., powering grain elevators, hauling animal feed), and a methodology that only accounts for crop operations may result in an under-estimation of equipment activity *if it is determined that other activities significantly contribute to the overall equipment usage.*[*] There are two ways to treat these cases: (1) ensure that the proposed bottom-up methodology accounts for the vast majority of equipment usage, or (2) determine the percentage of equipment usage that is not represented by the approach and apply a different methodology (either bottom-up or top-down) to the remaining equipment. (In this work, it is felt that the proposed bottom-up methodologies account for the majority of usage experienced by the subject equipment types.)

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[*] For agricultural tractors, it is felt that "miscellaneous" activities account for a small portion of the overall usage, particularly since the load experienced by the engine is much greater for activities related to land cultivation compared to miscellaneous hauling.

Nonroad Equipment Categories

Because of the large number of individual equipment types used in the nonroad environment, EPA has categorized equipment types according to general function. In its 1991 nonroad study, EPA listed ten separate equipment categories, eight of which are discussed in this report. These include lawn and garden equipment, airport service equipment, recreational equipment, light commercial equipment, industrial equipment, construction equipment, agricultural equipment, and logging equipment. Although categorization of equipment types made allocation of nonroad equipment populations to the local level more tractable, EPA assumed the same equipment mix for all nonattainment communities, which led to a lack of specificity at the local level. For example, the same relative percentage of lawn and garden tractors would not be expected when comparing lawn and garden equipment populations in Atlanta and New York City. This is one example of where the current top-down methods could be improved.

Organization of the Report

Immediately following the Introduction, Section 3 provides the reader with a review of recently completed nonroad inventory studies. Emphasis was placed on EPA's 1991 "Nonroad Engine and Vehicle Emission Study" and on several studies performed under contract to CARB. The remaining sections discuss each of the nonroad equipment categories separately. Section 4 covers lawn and garden equipment, while airport service equipment is discussed in Section 5. Section 6 details recreational equipment. The construction equipment category is treated in Section 7, light commercial equipment in Section 8, and industrial equipment in Section 9. Finally, agricultural equipment is discussed in Section 10, and Section 11 contains information on logging equipment. Several appendices then provide more detailed information and data, as referenced throughout the report.

References for Section 2

1. "Nonroad Engine and Vehicle Emission Study - Report," U.S. Environmental Protection Agency, Office of Air and Radiation, November 1991.

2. "Nonroad Engine and Vehicle Emission Study - Appendixes," U.S. Environmental Protection Agency, Office of Air and Radiation, November 1991.

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3. REVIEW OF NONROAD INVENTORY STUDIES

As outlined in the previous section, the methodologies used to determine nonroad vehicle and engine activity (e.g., bhp-hr/yr) can be broadly categorized as top-down or bottom-up. By far, the great majority of previous emission estimates have relied on a top-down approach in which national-level data on equipment population are scaled by a local statistic such as employment. EPA and CARB have recently generated emission estimates for nonroad equipment and have generally relied on this methodology. It is worthwhile to review these studies to assess if the data sources utilized in allocating activity could also be useful in a bottom-up approach, and to assess how top-down methodologies might be improved. Further, an understanding of existing methodologies is important in estimating uncertainties associated with developing local inventories.

EPA Nonroad Engine and Vehicle Study

The 1990 Clean Air Act Amendments directed EPA to determine the emissions impact of nonroad vehicles and equipment on nonattainment areas and recommend emission standards if these sources were found to be significant contributors to nonattainment. The result of the first part of that directive was the "Nonroad Engine and Vehicle Emission Study" (NEVES) published by EPA in November 1991.[1,2] Because of the limited timeframe in which emission inventories were to be developed, EPA contracted some of this effort to outside firms. Energy and Environmental Analysis, Inc. (EEA) was responsible for developing population and activity estimates for nonroad equipment and engines.[3] In addition to the estimates developed by EEA, industry provided activity and usage estimates for several categories of nonroad equipment. EPA used these data sets to calculate two separate emission inventories (i.e., "Inventory A," which relied primarily upon data developed by EEA; and "Inventory B," which incorporated industry-supplied data for many equipment types). EEA's analysis and the industry-supplied data are briefly described below.

<u>Equipment Population and Usage Estimates Developed by EEA</u> – Because of the large number of equipment types used in the nonroad environment, equipment was categorized according to general use patterns. For example, lawn mowers, leaf blowers, and string trimmers can be broadly categorized as lawn and garden equipment, while pavers, graders, and cranes can be grouped as construction equipment. The equipment categories chosen for this work are given in Table 3-1, with examples of specific equipment types included in each category. A complete breakdown of the 78 equipment types included in the nonroad emission

Table 3-1

Equipment Categories Used in EPA's 1991 Nonroad Inventory

Equipment Category	Equipment Types
Lawn and Garden	Lawn Mowers, Leaf Blowers, Trimmers
Airport Service	Airport Service Equipment
Recreational	ATVs, Off-Road Motorcycles, Golf Carts
Marine/Recreational	Inboard, Outboard, Sailboats
Light Commercial	Generators, Pumps, Compressors, Welders
Industrial	Aerial Lifts, Fork Lifts
Construction	Pavers, Graders, Cranes
Agricultural	Agricultural Tractors, Combines, Balers
Logging	Chainsaws (>4 HP), Skidders
Marine/Commercial	Ocean-Going Marine, Harbor and Fishing Vessels

study is given in Appendix A. (Population and activity estimates were developed for each of these equipment types.)

The first step in estimating activity was to determine equipment population. To accomplish this, EEA utilized data supplied by Power Systems Research (PSR). PSR develops national-level population counts by first determining the total number of engines placed into service each year. These data are gathered from engine sales reported by original equipment manufacturers (OEMs), and product literature is used to determine specific engine/equipment application. PSR then applies an attrition rate to each model year according to expected engine life (which is developed from surveys of end users). By summing the remaining equipment for each model year, the total population in the field at any given time is obtained.

Since PSR supplied equipment population on only national and state levels, EEA developed a methodology to distribute the statewide PSR data to the county level. This involved establishing a statistical relationship between the statewide equipment population and specific activity indicators for each equipment category. In most cases, a linear relationship was established between equipment population and the activity indicator. For example, the light commercial equipment population was plotted against the number of wholesale trade establishments for each state included in the study. A regression analysis was performed which resulted in coefficients (i.e., slope and intercept in the case of a linear model) that represented the best fit of the data. The coefficients determined from the state data were then used in conjunction with the county-level activity indicator (the number of wholesale trade establishments in the above example) to estimate county-level equipment populations. The activity indicators used by EEA for each equipment category are summarized in Table 3-2.

Although a regression technique results in improved local-level equipment populations and activity estimates for most equipment categories, imbedded in this methodology is the assumption that the state-level equipment populations used in the regressions are valid. Because PSR employs its own activity indicators to allocate equipment populations to the state level, there could be instances in which the state-level data are in error. Thus, EEA established a set of statistical criteria to be met in its regression analyses. For cases in which these criteria were not met, the regression technique was not employed and a more traditional scaling of national population data by the local-to-national activity indicator ratio was used.

Annual hourly usage, horsepower, and load factors also were obtained to complete the activity calculation (in bhp-hr/yr); this information was supplied by PSR. Based on survey results from over 40,000 respondents, PSR estimated these parameters for each equipment type. Further, PSR determined geographical differences in equipment usage for six regions of the country: northeast, southeast, southwest, northwest, northcentral, and southcentral. This information included an accounting of seasonal variations in activity.

Table 3-2

Activity Indicators used by EEA[3] to Distribute
PSR's State Equipment Population Estimates to County Level

Equipment Category*	Activity Indicator(s)
Lawn and Garden	Single Family Housing Units Landscape and Horticultural Service Employees
Airport Service	Air Carrier Operations
Recreational	Motorcycle Dealerships
Light Commercial	Wholesale Establishments
Industrial	Total Manufacturing Employees
Construction	Total Construction Employees
Agricultural	Agricultural Services Employees
Logging	County-Level Logging Activity (Employees)

* Since recreational and commercial marine vessels are not included in the work assignment, they have not been included in this table.

Equipment Population and Usage Data Supplied by Industry - Manufacturers and manufacturer associations also provided population and usage data which was used by EPA to construct an alternative inventory (i.e., Inventory B). The information supplied is summarized as follows.

- The Equipment Manufacturers Institute (EMI) provided population data, average horsepower, annual use, and load factors on various types of construction and agricultural equipment. Construction equipment population data were based on work performed by MacKay & Company for the Associates Commercial Corporation and Construction Equipment magazine. The national construction equipment population determined by MacKay was scaled to the county level based on industry sales data from 1983 to 1987. Agricultural equipment populations were based on the 1987 agricultural census. Usage, horsepower, and load factor data developed by EMI were based on a survey of principal manufacturers of construction and agricultural equipment.

- The Outdoor Power Equipment Institute (OPEI) submitted population data, average horsepower, annual use, and load factors for various types of lawn and garden equipment. Population estimates appeared to have been developed by summing historical sales records over an assumed life span of the product.

- The Portable Power Equipment Manufacturers Association (PPEMA) provided population, usage, horsepower, and load factor information on portable 2-stroke gasoline equipment (e.g., chainsaws). This information was compiled by Heiden Associates, Inc. The population data were developed from historical shipment data to which an assumed average life was applied (for both commercial and residential applications). Annual hourly usage estimates were provided for commercial and residential equipment. Finally, county-level populations were developed with regression techniques similar to those used by EEA in the 1991 NEVES. However, Heiden's activity indicators accounted for the differences in the urban and rural population in nonattainment areas, arguing that some equipment (e.g., chainsaws) is more likely to be found in a rural setting.

- The Industrial Truck Association (ITA) supplied data on population, annual use, and load factors for industrial forklifts. The national and local population data were based on 1983 to 1990 shipment information from ITA member companies.

- The International Snowmobile Industry Association (ISIA) provided information on population and annual usage for snowmobiles.

- The Motorcycle Industry Council (MIC) provided population estimates and survey data on the annual mileage of ATVs and off-road motorcycles. This information was compiled from MIC's "Motorcycle Statistical Annual."

Recent CARB Nonroad Inventory Studies

Because of recent and pending efforts by CARB to regulate nonroad equipment, new efforts have been undertaken to more accurately assess the nonroad inventory in California. Several studies to support regulatory development have included emission estimates for nonroad vehicles and equipment, while others have focussed exclusively on inventory development. These include:

1. "Feasibility of Controlling Emissions from Off-Road, Heavy-Duty Construction Equipment", prepared by EEA;[4]

2. "Technical Support Document for California Exhaust Emission Standards and Test Procedures for 1994 and Subsequent Model Year Utility and Lawn and Garden Equipment Engines", prepared by Booz, Allen, & Hamilton (BAH);[5]

3. "Development of an Off-Highway Mobile Source Emissions Model" which has been contracted to EEA;[6] and

4. "SJVAQS/AUSPEX Agricultural Emissions Inventory," prepared by Sierra Research.[7]

Below is a summary of these studies, with particular emphasis on the methodologies used to develop activity estimates.

Off-Road, Heavy-Duty Construction Equipment - This report was prepared for CARB by EEA in 1988. The primary focus was on technology and potential emission standards; however, baseline and future-year inventories were developed to assess the emissions impact of regulating this equipment category. As with other inventories of this kind, PSR data on equipment population, horsepower, annual usage, and load factor were used to calculate emissions. The data were stratified by northern and southern sections of the state; thus, emission estimates could be more area-specific than is normally the case. In addition to construction equipment, material handling (e.g., forklifts) and agricultural equipment were included in the population estimates.

Although EEA did not report emissions for each county in California, CARB has used these statewide equipment data to develop county-specific inventories for some categories of nonroad equipment.[8] CARB includes construction, mining, and logging equipment in a generalized "Heavy-Duty Non-Farm" category, and it used the construction equipment population and usage data to determine emissions from this category. The statewide data were scaled by each county's construction valuation, mining production, and logging production to determine emissions from each of the subcategories. Agricultural equipment data were apportioned to each county on the basis of harvested acreage. Data on material handling equipment were not used in inventory development.

Utility and Lawn and Garden Equipment - The technical support document for this rulemaking was prepared by Booz, Allen, & Hamilton (BAH), and it contains a fairly detailed emission estimate for this equipment category. As with the EPA inventory work, BAH utilized strictly a top-down approach in estimating localized emissions. However, rather than relying on population, usage, horsepower, and load factor data from PSR, BAH instead used primarily California-specific information that was supplied by manufacturers and trade associations. Data on yearly sales were adjusted to account for attrition using scrappage rates that were developed by CARB in 1982,[9] and county-level emission estimates were determined by scaling the statewide inventory based on the number of single family housing units.

Because there is a vast difference in activity patterns between equipment used commercially and that used in consumer (or household) use, BAH estimated equipment populations according to intended use. BAH relied on manufacturer estimates, the 1982 CARB study, and a report on emissions from two-stroke equipment performed by Heiden Associates for the Portable Power Equipment Manufacturers Association (PPEMA)[10] to determine this split.

Nonroad Inventory Computer Model - EEA and its subcontractor, Systems Applications, International (SAI), were recently retained by CARB to develop an off-highway mobile source inventory model. Although this effort is in the initial phases, a review of the proposed work scope is worthwhile. The project is to be divided into three main tasks: (1) review of current off-highway methodologies, (2) compilation of off-highway emission parameters, and (3) development of emission algorithms. In Task 1, EEA plans to review various nonroad reports and analyses that have been performed by and for CARB and EPA over the last several years. These include many of the studies summarized here, as well as additional new data and methodologies that are anticipated to be submitted by industry groups in response to potential regulatory action by EPA. Task 2 is devoted to compiling engine emission parameters to be used in the computer model. This would include choosing the more important emission-related parameters by which engine types would be stratified, e.g., Diesel versus spark ignition, 2-stroke versus 4-stroke, valve train design, etc. Additionally, EEA will investigate duty cycles, in-use adjustments, temperature corrections, and scrappage rates. Finally, emission algorithms and computer code (FORTRAN) will be developed in Task 3.

San Joaquin Valley Agricultural Emissions Study - As part of a detailed assessment of emissions in California's San Joaquin Valley, Sierra was contracted by CARB to estimate emissions from agricultural field operations in the eight-county San Joaquin Valley Air Basin (SJVAB) and in 33 additional counties that could impact air quality in the SJVAB. In that work, Sierra deviated considerably in methodology from previous agricultural emission estimates. Rather than utilize a top-down approach in which state-level equipment population and usage data are scaled by harvested acreage, a bottom-up methodology was developed in which local farming practices and equipment types served as the basis for the calculations. Annual and temporal emissions were estimated as a function of crop type, acreage, operation, and equipment type. Crucial to the emission calculations, however, were sample production cost estimates for each crop and area of interest; these are described below.

In California, sample production cost estimates are prepared by county Farm Advisors in conjunction with the University of California Cooperative Extension. These reports are used by farmers to estimate operating costs and provide a basis for farm loans. Hence, they contain a detailed summary of the operations required to produce a given crop, along with the month in which the operation is performed and the required equipment (including horsepower) and time (hours/acre). This information, coupled with load factor estimates, makes it possible to calculate the power requirements per acre (i.e., bhp-hr/acre) associated with cultivating a particular crop. Thus, emission estimates specific to crop type can be made. This is important in cases where a county has a large proportion of machine-intensive crops that would otherwise be misrepresented when using a top-down approach with total harvested acreage as the scaling factor. For example, cotton has over 20 operations associated with its production, whereas certain tree crops such as walnuts may have only five or six.

Additional CARB Studies - In addition to the studies described above, two other studies related to nonroad equipment are being performed for CARB. First, BAH has been contracted to develop a nonroad emissions inventory for California, and second, EEA has been contracted to investigate regulatory strategies for lower horsepower nonroad equipment. Neither study has been released for public review, so a review was not possible.

Summary

The vast majority of recent emission inventory studies have relied exclusively on a top-down methodology to allocate state or national equipment populations to the county level. Although EPA's NEVES advanced the state of the art in developing local inventories from national and state data, the fact remains that local specificity is often lost when top-down methodologies are utilized. As an example, Section 6 compares California off-road motorcycle registrations and the population generated in NEVES for the SJV air basin. California Department of Motor Vehicles records indicate that approximately 15,000 off-road motorcycles are registered in the eight-county SJV. On the other hand, the methodology developed by EEA[3] for NEVES results in a total of 450 off-road motorcycles being allocated to the SJV. Clearly, the accuracy of methodologies used to develop nonroad equipment emissions inventories must be improved if local air quality districts are to efficiently implement control strategies necessary to attain ambient air quality standards.

References for Section 3

1. "Nonroad Engine and Vehicle Emission Study - Report," U.S. Environmental Protection Agency, Office of Air and Radiation, November 1991.

2. "Nonroad Engine and Vehicle Emission Study - Appendixes," U.S. Environmental Protection Agency, Office of Air and Radiation, November 1991.

3. "Methodology to Estimate Nonroad Equipment Populations by Nonattainment Areas," Energy and Environmental Analysis, September 1990.

4. "Feasibility of Controlling Emissions from Off-Road, Heavy-Duty Construction Equipment," Energy and Environmental Analysis, December 1988.

5. "Technical Support Document for California Exhaust Emission Standards and Test Procedures for 1994 and Subsequent Model Year Utility and Lawn and Garden Equipment Engines," Booz, Allen, and Hamilton, October 1990.

6. "Response to RFP 91-19: Development of an Off-Highway Mobile Source Emissions Model," Energy and Environmental Analysis, February 1992.

7. "SJVAQS/AUSPEX Agricultural Emissions Inventory (DRAFT)," Sierra Research, November 1992.

8. "Methods for Assessing Area Source Emissions in California," California Air Resources Board, Technical Support Division, September 1991.

9. "Status Report: Emissions Inventory on Non-Farm (MS-1), Farm (MS-2), and Lawn and Garden (Utility) (MS-3) Equipment," California Air Resources Board, Mobile Source Control Division, July 1983.

10. "A 1989 California Baseline Emissions Inventory for Total Hydrocarbon & Carbon Monoxide Emissions from Portable Two-Stroke Power Equipment," Heiden Associates, July 1990.

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4. LAWN AND GARDEN EQUIPMENT

The lawn and garden equipment category encompasses a wide range of equipment types, and because of its diversity, not all equipment types are likely to be evenly distributed across the country. Although this is true for most of the equipment categories included in NEVES, it seems to be especially valid for lawn and garden equipment. For example, snowblowers would not be found in Baton Rouge, and the relative percentage of lawn and garden tractors is likely to be quite different between Atlanta and the South Coast Air Basin. Thus, procedures to adequately represent the local mix of equipment types are needed to provide reliable estimates of lawn and garden equipment activity. Specific equipment types included in the lawn and garden category are trimmers/edgers/brush cutters, lawn mowers, leaf blowers/vacuums, rear engine riding mowers, front mowers, chainsaws (< 4 HP), shredders (< 5 HP), tillers (< 5 HP), lawn and garden tractors, wood splitters, snowblowers, chippers/stump grinders, commercial turf equipment, and "other" lawn and garden equipment.

NEVES Methodology

NEVES Inventory A relied primarily upon PSR population data to develop activity estimates for lawn and garden equipment. In allocating equipment to the local level, two variables were used in EEA's[1] regression analysis to establish a relationship between local indicators and equipment population. First, the number of single family housing units (SFHU) was chosen because there is a logical link between lawn and garden equipment usage and the number of SFHUs in an area, and this indicator has been used successfully in the past to allocate lawn and garden equipment. The second indicator utilized in the modeling analysis was the number of employees in Standard Industrial Classification (SIC) code 078 - Landscape and Horticultural Services. This indicator was included to account for an increasing number of landscaping firms that care for both commercial and residential properties.

A summary of lawn and garden equipment activity estimates based on data developed for NEVES Inventory A is given in Table 4-1 on a national basis, for the DC/MD/VA area, and for the SJV. On a bhp-hr/yr basis, the largest contributors to overall lawn and garden equipment activity are lawn mowers, lawn and garden tractors, chippers/stump grinders, and commercial turf equipment. The sheer number of lawn mowers makes their contribution significant, while higher horsepower and annual hourly usage result in a large influence from commercial turf equipment and chippers/stump grinders. Although trimmers/edgers/brush cutters and

Table 4-1

NEVES Inventory A Lawn and Garden Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Trmrs/Edgrs/Brsh Ctrs	0	18,172,282	0	98,130	98,130	1.1
Lawn Mowers	0	35,764,096	0	2,523,515	2,523,515	29.2
Leaf Blowers/Vacuums	0	2,025,786	0	28,361	28,361	0.3
Rear Eng. Riding Mowers	8,713	1,575,407	2,026	193,964	195,990	2.3
Front Mowers	0	257,880	0	55,702	55,702	0.6
Chainsaws < 4 HP	0	16,124,970	0	258,000	258,000	3.0
Shredders < 5 HP	0	107,322	0	618	618	0.0
Tillers < 5 HP	0	3,812,000	0	128,083	128,083	1.5
Lawn & Garden Tractors	211,631	5,903,369	441,886	1,771,011	2,212,896	25.6
Wood Splitters	79	502,181	186	28,875	29,061	0.3
Snowblowers	0	4,782,000	0	130,549	130,549	1.5
Chippers/Stump Grinders	17,087	16,791	273,517	186,357	459,874	5.3
Commercial Turf Eqpmt	0	568,732	0	2,521,189	2,521,189	29.1
Other L&G Equipment	180	396,454	24	8,920	8,945	0.1
Total	237,690	90,009,270	717,639	7,933,274	8,650,912	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Trmrs/Edgrs/Brsh Ctrs	0	275,497	0	1,488	1,488	1.2
Lawn Mowers	0	542,246	0	38,261	38,261	29.8
Leaf Blowers/Vacuums	0	30,711	0	430	430	0.3
Rear Eng. Riding Mowers	132	23,921	31	2,945	2,976	2.3
Front Mowers	0	3,905	0	843	843	0.7
Chainsaws < 4 HP	0	199,579	0	3,193	3,193	2.5
Shredders < 5 HP	0	1,627	0	9	9	0.0
Tillers < 5 HP	0	58,048	0	1,950	1,950	1.5
Lawn & Garden Tractors	3,191	89,026	6,663	26,708	33,371	26.0
Wood Splitters	1	7,614	2	438	440	0.3
Snowblowers	0	18,191	0	497	497	0.4
Chippers/Stump Grinders	229	255	3,666	2,830	6,496	5.1
Commercial Turf Eqpmt	0	8,622	0	38,221	38,221	29.8
Other L&G Equipment	3	6,011	3	135	138	0.1
Total	3,556	1,265,253	10,364	117,949	128,313	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Trmrs/Edgrs/Brsh Ctrs	0	134,924	0	874	874	1.1
Lawn Mowers	0	265,563	0	27,534	27,534	33.1
Leaf Blowers/Vacuums	0	15,041	0	286	286	0.3
Rear Eng. Riding Mowers	65	11,715	20	1,923	1,943	2.3
Front Mowers	0	1,912	0	505	505	0.6
Chainsaws < 4 HP	0	175,627	0	3,337	3,337	4.0
Shredders < 5 HP	0	797	0	6	6	0.0
Tillers < 5 HP	0	28,429	0	1,137	1,137	1.4
Lawn & Garden Tractors	1,563	43,600	3,964	15,958	19,921	23.9
Wood Splitters	1	3,729	2	186	189	0.2
Snowblowers	0	0	0	0	0	0.0
Chippers/Stump Grinders	127	125	2,400	1,638	4,039	4.9
Commercial Turf Eqpmt	0	4,223	0	23,332	23,332	28.0
Other L&G Equipment	1	2,944	2	124	125	0.2
Total	1,757	688,629	6,388	76,839	83,228	100.0

chainsaws are responsible for a relatively small percentage of the bhp-hr/yr activity, their impact on inventory calculations can be significant due to the relatively higher emissions of their gasoline 2-stroke engines.

Because the regression technique employed for Inventory A utilized total equipment <u>category</u> population as the dependent variable (i.e., regressions were not performed for each equipment type individually), the national equipment distribution was uniformly applied to the calculated county (or nonattainment area) category population when developing population estimates for each individual equipment type. This approach was taken since it was not possible within the timeframe of NEVES to develop regressions for each separate type of equipment (78 different equipment types were considered in NEVES). Although there was some attempt to account for local conditions in lawn and garden equipment populations (e.g., snowblowers were not allocated to Baton Rouge; PPEMA's local-level chainsaw distribution, based on an alternative regression model described below, was used in conjunction with the PSR national population to establish the Inventory A local-level chainsaw populations), the national equipment mix was generally applied to all areas. As alluded to above, this approach is cause for concern, especially for some equipment types (e.g., lawn and garden tractors) that would obviously be more prevalent in areas with a higher percentage of larger lot sizes.

As discussed in Section 3 of this report, industry associations provided EPA with alternative population and usage estimates for some categories of nonroad equipment. For lawn and garden equipment, both OPEI and PPEMA submitted data for some equipment types included in the lawn and garden category. OPEI provided information on population (by metropolitan area), annual usage, horsepower, and load factor for lawn mowers, rear engine riding mowers, lawn and garden tractors, and tillers. (Additionally, OPEI submitted horsepower data for commercial turf equipment.) PPEMA submitted population, usage, horsepower, and load factor data for 2-stroke equipment, including trimmers/edgers/brush cutters, leaf blowers, and chainsaws. (PPEMA's data were taken from two reports prepared by Heiden Associates under contract to PPEMA.[2,3])

To determine local equipment populations, OPEI relied on historical sales information coupled with assumptions on equipment life. The PPEMA population data were also developed from shipment data (state-level) to which an assumed average life was applied (for both commercial and residential applications). County-level populations were then determined with a regression technique similar to the approach used in the development of NEVES Inventory A. This regression approach utilized activity indicators that accounted for differences in rural and urban population in nonattainment areas (e.g., one of the models proposed by PPEMA/Heiden included urban SFHU, rural SFHU, and SIC 078 employment as the activity indicators), with the thought that some equipment types are more likely to be found in a rural environment.

The equipment activity (in bhp-hr/yr) estimated for Inventory B is summarized in Table 4-2 on a national basis, for the DC/MD/VA area, and for the SJV. In comparing Tables 4-1 and 4-2, a net decrease of roughly

Table 4-2

NEVES Inventory B Lawn and Garden Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Trmrs/Edgrs/Brsh Ctrs	0	13,583,335	0	167,754	167,754	2.6
Lawn Mowers	0	32,000,000	0	1,532,160	1,532,160	23.9
Leaf Blowers/Vacuums	0	2,871,164	0	71,779	71,779	1.1
Rear Eng. Riding Mowers	9,460	1,710,540	1,283	232,052	233,335	3.6
Front Mowers	0	280,000	0	65,170	65,170	1.0
Chainsaws < 4 HP	0	7,895,502	0	290,554	290,554	4.5
Shredders < 5 HP	0	107,322	0	9,582	9,582	0.1
Tillers < 5 HP	0	2,737,564	0	145,967	145,967	2.3
Lawn & Garden Tractors	184,567	5,148,433	37,312	1,040,807	1,078,119	16.8
Wood Splitters	79	502,181	186	28,875	29,061	0.5
Snowblowers	0	4,782,000	0	110,966	110,966	1.7
Chippers/Stump Grinders	17,087	16,791	273,517	186,357	459,874	7.2
Commercial Turf Eqpmt	0	568,732	0	2,210,889	2,210,889	34.5
Other L&G Equipment	180	396,454	168	8,920	9,089	0.1
Total	211,373	72,600,018	312,466	6,101,833	6,414,299	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Trmrs/Edgrs/Brsh Ctrs	0	114,061	0	1,409	1,409	1.3
Lawn Mowers	0	608,000	0	29,111	29,111	27.6
Leaf Blowers/Vacuums	0	50,512	0	1,263	1,263	1.2
Rear Eng. Riding Mowers	66	11,979	9	1,625	1,634	1.6
Front Mowers	0	1,955	0	455	455	0.4
Chainsaws < 4 HP	0	97,410	0	3,585	3,585	3.4
Shredders < 5 HP	0	1,627	0	145	145	0.1
Tillers < 5 HP	0	41,482	0	2,212	2,212	2.1
Lawn & Garden Tractors*	4,107	114,555	830	23,158	23,989	22.8
Wood Splitters	1	7,614	2	438	440	0.4
Snowblowers	0	18,191	0	422	422	0.4
Chippers/Stump Grinders	259	255	4,146	2,830	6,976	6.6
Commercial Turf Eqpmt	0	8,622	0	33,517	33,517	31.8
Other L&G Equipment	3	6,011	3	135	138	0.1
Total	4,436	1,082,274	4,990	100,305	105,296	100.0

* The lawn and garden tractor population reported here differs from the value used in developing the NEVES inventory because of a data entry error.

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Trmrs/Edgrs/Brsh Ctrs	0	97,092	0	1,199	1,199	2.0
Lawn Mowers	0	265,563	0	10,596	10,596	17.7
Leaf Blowers/Vacuums	0	26,386	0	660	660	1.1
Rear Eng. Riding Mowers	65	11,715	10	1,725	1,735	2.9
Front Mowers	0	1,912	0	483	483	0.8
Chainsaws < 4 HP	0	85,720	0	3,154	3,154	5.3
Shredders < 5 HP	0	797	0	71	71	0.1
Tillers < 5 HP	0	28,429	0	1,320	1,320	2.2
Lawn & Garden Tractors	1,563	43,600	2,504	13,442	15,946	26.6
Wood Splitters	1	3,729	2	186	189	0.3
Snowblowers	0	0	0	0	0	0.0
Chippers/Stump Grinders	127	125	2,400	1,638	4,039	6.7
Commercial Turf Eqpmt	0	4,223	0	20,460	20,460	34.1
Other L&G Equipment	1	2,944	2	124	125	0.2
Total	1,757	572,235	4,918	55,060	59,978	100.0

25 percent in activity is observed for the national estimates. (The decrease is 18 percent for DC/MD/VA and 28 percent for the SJV.) This is the result of decreased equipment population predicted in the industry submittals used for Inventory B, as well as lower annual usage for some equipment types.

Approach

Considerable effort was expended in attempting to identify alternative data sources of population and usage patterns for lawn and garden equipment. However, since this category is comprised of large numbers of small, relatively inexpensive equipment types, detailed records are generally unavailable. Nonetheless, an attempt was made to locate information that might be useful in improving top-down methodologies and in developing a bottom-up approach to estimate lawn and garden equipment activity. Presented below is a discussion of potential methodologies that might be employed to accomplish that task.

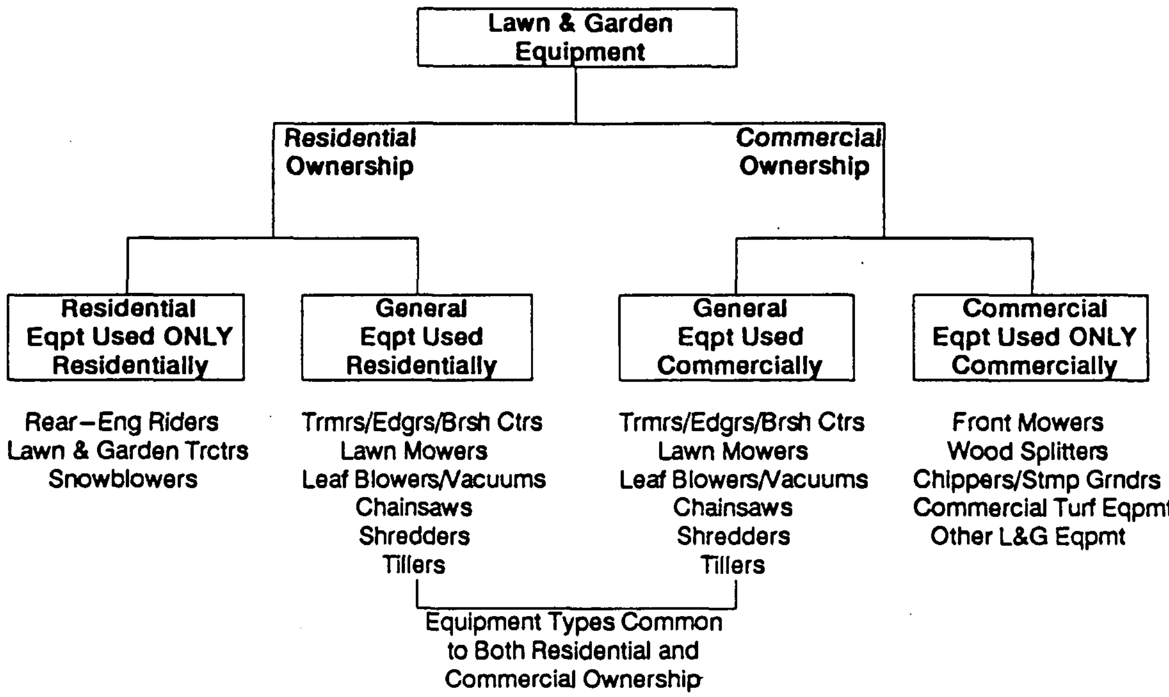
Top-Down - As noted above, the methodology developed for NEVES Inventory A utilized the national-level equipment distribution to calculate populations of individual equipment types in each nonattainment community, which results in a lack of specificity at the local level. One means of making a top-down methodology more area-specific would be to run regressions on each type of equipment separately, carefully choosing activity indicators to be closely matched with particular equipment types. For example, utilization of SFHU multiplied by yearly snowfall would likely provide a better indicator of localized snowblower population than current estimates. The drawback in doing this, of course, is the increased effort that would have to be devoted to nonroad equipment inventory development. (Although end-users would obviously not be expected to develop locality-specific models, there would be increased data gathering requirements if the number of activity indicators was expanded.)

An alternative to treating each piece of equipment individually is to categorize lawn and garden equipment according to a limited number of usage regimes. It appears a logical way to do this is to first distinguish equipment according to residential or commercial ownership. (This distinction has been made in several previous analyses of lawn and garden equipment.[3-5]) This is important from a number of perspectives. First, some equipment types (e.g., commercial turf mowers) are not used for residential applications, and utilizing SFHUs as an activity indicator to distribute equipment that is used solely by commercial landscape firms likely results in inaccuracies at the local level. Second, the equipment age distributions and use patterns are substantially different when comparing commercially and residentially owned equipment. This difference would have to be accounted for in models used to forecast emissions, particularly models used to estimate the impact of proposed regulations.

Figure 4-1 illustrates equipment types included in the lawn and garden category according to their primary ownership patterns. Sierra has categorized equipment into four basic regimes: residential equipment

Figure 4-1

Categorization of Lawn and Garden Equipment
According to Anticipated Use



used only residentially, general equipment used residentially, general equipment used commercially, and commercial equipment used only commercially.* This categorization would allow more appropriate activity indicators to be applied in generating top-down methodologies, and it would aid in allocating equipment usage when considering potential bottom-up approaches.

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* The distribution of equipment types according to ownership regime was based on assumed usage patterns. Some equipment types included in the Residential Only regime (e.g., snowblowers) are also likely to be used commercially, whereas woodsplitters are likely to be owned also by private individuals. Survey data indicating the exact nature of lawn and garden equipment ownership and usage patterns would clearly improve any methodology developed according to ownership regime. Nonetheless, Figure 4-1 and the following discussion provides a basis for an alternative top-down methodology.

Sierra's efforts to develop improved methodologies for distributing equipment according to the top-down approach focused on identifying appropriate activity indicators for the four equipment subcategories listed in Figure 4-1. Lot size appears to be a good indicator for equipment distribution for residentially owned equipment; thus, considerable effort was expended in identifying sources of data for lot size and consumer buying habits as a function of lot size. Although SIC 078 is a logical indicator of commercial equipment usage, several other indicators were analyzed for potential use.

Categorization of lawn and garden equipment according to residential and commercial ownership may not adequately describe population and usage for all equipment types. For example, a significant fraction of chainsaw usage may be attributed to areas outside of nonattainment communities. This was recognized by EPA in the development of NEVES, which (through the use of PPEMA's equipment distribution) relied on rural population as one of the activity indicators to allocate equipment populations for this equipment type. The use of lot size, however, can be considered a surrogate for rural activity (i.e., larger lots are expected to be found in more rural settings). Thus, the use of rural population as an activity indicator was not investigated in this study. (See Reference 2 for details of the methodology recommended by PPEMA which utilizes a multivariate regression model that includes rural population, urban population, and SIC 078 employment as activity indicators.)

The above discussion has focused on equipment populations, but activity estimates are also directly proportional to annual hourly usage. Because annual equipment usage is significantly different between residential and commercial equipment, it is important to account for this difference in activity estimates. EPA recognized this and included a correction for commercially owned equipment when the annual hourly use figures were developed for NEVES. However, this correction was based on relatively limited data. Thus, some effort was expended in this work attempting to identify alternative data sources for usage estimates.

Bottom-Up - Developing a bottom-up methodology for estimating lawn and garden equipment activity at first appears to be a difficult, if not impossible, task. However, part of this study was devoted to evaluating the feasibility of alternative methodologies for calculating equipment usage at the local level. Thus, Sierra investigated the data (and availability of those data) that would be required to prepare a bottom-up estimate of lawn and garden equipment activity. In addition, it was felt that information obtained as part of this effort might also be useful in refining top-down approaches.

Similar to the aforementioned top-down approach, the first aspect of a bottom-up approach would be to distinguish between residential and commercial properties. The number and size of residential lots in a community appear to be a good indicator of residential activity, and if estimates of landscaped area by lot size can be obtained, the total residential maintained acreage in an area could be estimated. Estimating the total acreage of commercially maintained properties is likely to be a much more difficult task because of the large number of individual properties, as well as the different types of properties, that are maintained. As seen in Table 4-3, there are many different classifications of property types, and each one may have differing levels of maintenance requirements. For example, an acre of golf course would have much different equipment requirements than an acre of urban park. Although this list is not all-inclusive, it does give an indication of the level of effort that would be involved in compiling the commercially maintained acreage in an area.

If the total number of maintained acres in an area were to be compiled, the next step in a bottom-up approach would be to apply equipment-specific hour/acre estimates and maintenance intervals to obtain an estimate of lawn and garden equipment activity. Thus, some effort was devoted to identifying sources of information for equipment-time requirements (i.e., hours/acre or hours/1000 ft^2) and regional differences in maintenance practices.

Table 4-3

Types of Properties Maintained by Commercial Landscape Firms*

Residential Homes
Apartments, Condos, Planned Communities
Hotels and Resorts
Golf Courses
Urban Parks
Schools, Colleges, Universities
Athletic Fields
Industrial/Office Parks
Shopping Malls
Hospitals
Cemeteries
Amusement Parks
Roadways, Rest Areas

* Based in part on information received from the Professional Grounds Management Society.

Potential Data Sources

As outlined above, the primary information needed to develop alternative top-down methodologies consists of commercial versus residential equipment ownership distribution, activity indicators to allocate residential and commercial equipment, and equipment usage patterns. A bottom-up approach would require local statistics on the number and size of residential lots (to develop residential landscape acreage), commercial landscape acreage, and information on time-equipment requirements for maintaining different types of landscape designs.

A variety of different organizations were contacted to determine if information relating to the above subjects is available. Information on commercial equipment usage was solicited from professional and trade associations as listed in Table 4-4. Inquiries for lot size information were directed to federal, state, and local planning agencies, while commercial landscape acreage and maintenance requirements were sought from federal, state, and county maintenance agencies. The following discussion details the effort to obtain the above information and summarizes the type of information that is available.

Top-Down Information Sources

Commercial Versus Residential Equipment Ownership – The methodology developed for NEVES accounts for commercially owned equipment by including the number of employees in landscape and horticultural services as an activity indicator in the regression analysis. Additionally, a "commercial" correction was made to annual hourly usage estimates for equipment considered to be owned by both residences and commercial firms. Other lawn and garden equipment activity and emissions estimates have more explicitly differentiated between commercial and residential equipment populations and usage, choosing to treat commercial and residential equipment entirely separately in terms of annual sales, expected life, population, and annual hours of operation. These studies include a report prepared by BAH for CARB to

Table 4-4

Associations Solicited for Information on Lawn and Garden Equipment Populations and Usage Patterns

American Society of Agricultural Engineers
Lawn and Garden Dealers Association
National Gardening Association
National Lawn and Garden Distributors Association
American Sod Producers Association
Landscape Nursery Council
National Golf Foundation
Golf Course Superintendents Association of America
Associated Landscape Contractors of America
Professional Grounds Management Society
American Society of Agronomy
National Landscape Association
National Recreation and Parks Association
National Institute on Park and Grounds Management
Professional Lawn Care Association of America
University of Georgia – Agricultural Extension
Grounds Maintenance Magazine
Landscape Management Magazine

support CARB's rulemaking on lawn and garden equipment[4] and a report prepared by Heiden Associates for PPEMA in response to CARB's rulemaking on lawn and garden equipment.[3] Although these estimates exist, they generally have been developed at the state level. County-level activity and emissions estimates were based on applying the county-to-state ratio of SFHU to the state-level results. As part of this work, information was sought that could be used to develop estimates of commercial and residential equipment populations at the county level. Unfortunately, none of the organizations listed in Table 4-4 could provide additional information on populations, usage, or ownership patterns for lawn and garden equipment.

Potential Activity Indicators for Commercial Equipment - Several methodologies to distribute commercial lawn and garden equipment populations to the local level were considered. First, the associations listed in Table 4-4 were contacted to determine if information was available on equipment ownership or usage patterns. However, as it became apparent that little data existed on commercial equipment usage and local populations, other approaches to allocate commercial equipment to the local level were investigated. Some of these are discussed below.

Licensing requirements for landscape firms were investigated as a possible means of distributing national-level commercial equipment populations to the local level. Several calls were placed to state agencies to determine if there were any general licensing requirements for landscape maintenance firms. It was discovered that in California, landscape contractors must be licensed, but there are no state requirements for licensing of firms performing only maintenance services. Although many counties and cities require business licenses, it was felt that the effort to compile such information would exceed its usefulness.

Another potential indicator of commercial lawn and garden activity that was considered is the number of EPA-certified pesticide applicators in an area. Initially it was felt that this information might be available from EPA on a national and state basis. Unfortunately, discussions with Region IX staff revealed that although there is a federal requirement for states to keep records of certified applicators, there is no requirement that they submit this information to EPA. Thus, this approach would require a substantial effort to compile the needed information from individual states. In addition, the level of detail that could be provided by each state is likely to be highly variable.

Finally, land use information was sought on a national and local level. It was felt that if acreage data were available for various land use categories (e.g., residential, commercial/industrial, bare ground, agriculture, etc.) at national and local levels, this information could be used to allocate commercial lawn and garden equipment. Although this information has been compiled for Maryland based on detailed aerial photography, identification of other sources proved unsuccessful. It appears that digitized land use maps available from the U.S. Geological Survey might be used to develop this information, but such an effort is well beyond the scope of this project. In addition to the purchase price, the time required to compile the data into a usable form would be excessive.

Potential Activity Indicators for Residential Equipment - One approach to make top-down methodologies more area-specific that deserves consideration is to distribute national equipment populations by lot size. This makes intuitive sense because certain equipment types would not be expected to be found at residences with small lots. For example, it is doubtful that many lawn and garden tractors are located in highly urbanized areas where lot sizes are generally well below 1/4 acre in size. Conversely, although not considered in great detail in this report, the relative percentage of electric lawn and garden equipment is likely to be greater for smaller lots which generally have more accessible electrical outlets.*

Because lot size would appear to have a bearing on lawn and garden equipment distribution and usage in an area, Sierra investigated potential sources of this information. The search focused on federal agencies (e.g., Department of Housing and Urban Development (HUD), Department of Commerce/Census Bureau), state agencies, and local agencies to determine if lot size information is readily available. Contact with state and local planning agencies was limited to the DC/MD/VA and SJV areas, while a broader perspective was obtained in discussions with federal agencies.

The most complete data on lot size information identified in this work are published by HUD and the Census Bureau.[6] Every two years, the American Housing Survey is conducted in which information on housing statistics throughout the U.S. is compiled. Included in the survey results is information on lot size of detached SFHUs. In addition to the national survey, approximately 10 to 12 different metropolitan areas are surveyed each year, with the area-specific surveys conducted in a four-year cycle. Thus, lot size information is readily available for 40 to 50 metropolitan areas in the U.S. The metropolitan areas included in the survey are listed in Table 4-5.

Lot size distributions are shown in Figure 4-2 for the DC/MD/VA area,[7] Los Angeles/Long Beach area,[8] and for the U.S. as a whole.[6] It is apparent from this figure that lot size is a strong function of geographic area and the degree of urbanization. As seen, roughly 50 percent of the detached SFHU lots are between 1/4 and 1 acre in the DC/MD/VA area, whereas over 75 percent of the lots in the highly urban Los Angeles/Long Beach area are less than 1/4 acre.

Although lot size information is available from the American Housing Survey for many metropolitan areas of the U.S., not all nonattainment communities are represented. For example, the SJV contains no metropolitan areas that are individually treated in the survey. Thus, some effort was expended in determining other sources of lot size

* Several calls were, however, placed to electric utilities to determine if information was available on usage patterns or purchasing profiles for electric lawn and garden equipment. Unfortunately, no information was identified.

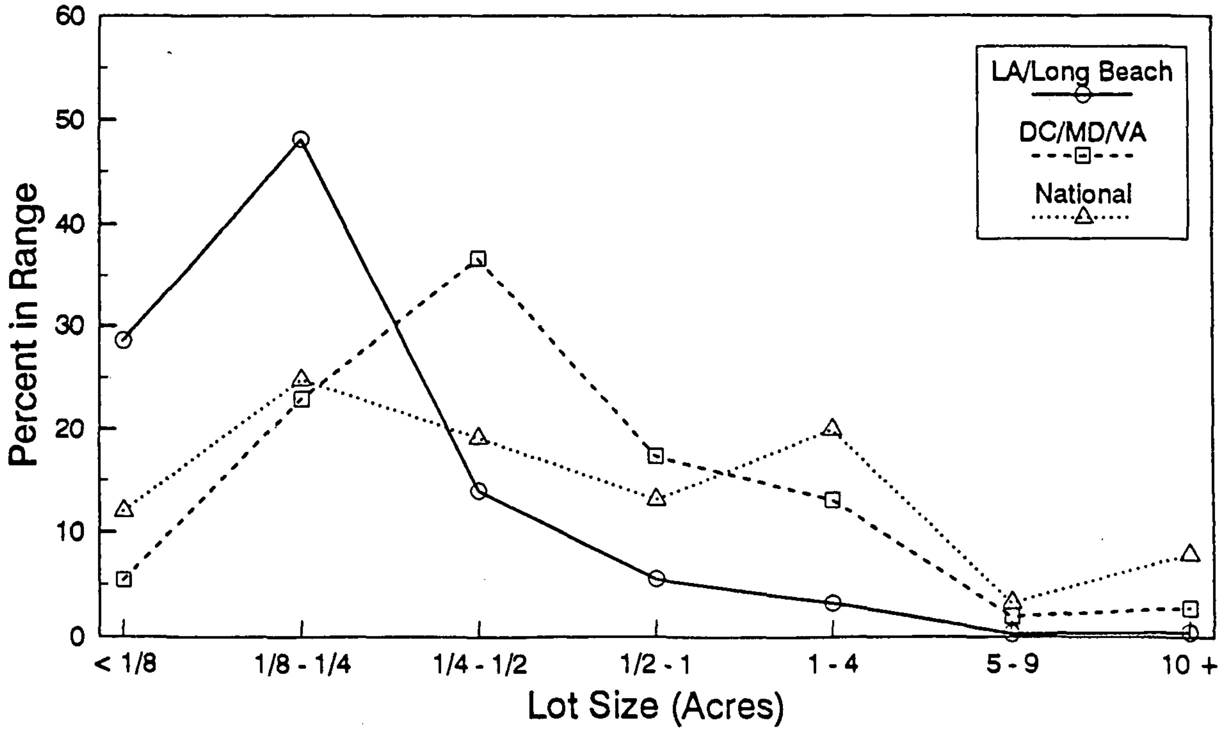
Table 4-5

Metropolitan Areas Included in the American Housing Survey[6]

Anaheim-Santa Ana, CA
Atlanta, GA
Baltimore, MD
Boston, MA
Birmingham, AL
Buffalo, NY
Chicago, IL
Cincinnati, OH
Cleveland, OH
Columbus, OH
Dallas, TX
Denver, CO
Detroit, MI
Fort Worth-Arlington, TX
Hartford, CT
Houston, TX
Indianapolis, IN
Kansas City, MO-KS
Los Angeles-Long Beach, CA
Memphis, TN
Miami-Fort Lauderdale, FL
Milwaukee, WI
Minneapolis-St. Paul, MN
New Orleans, LA
New York-Nassau-Suffolk, NY
Norfolk-Virginia Beach-Newport News, VA
Northern NJ
Oklahoma City, OK
Philadelphia, PA
Phoenix, AZ
Pittsburgh, PA
Portland, OR
Providence-Pawtucket-Warwick, RI-MA
Riverside-San Bernardino-Ontario, CA
Rochester, NY
St. Louis, MO
Salt Lake City, UT
San Antonio, TX
San Diego, CA
San Francisco-Oakland, CA
San Jose, CA
Seattle-Tacoma, WA
Tampa-St. Petersburg, FL
Washington, DC-MD-VA

Figure 4-2

Lot Size Distribution for Selected Areas
Single Family Housing Units



information. State and local planning agencies were contacted both in the SJV and in the DC/MD/VA areas to determine the availability of data and the level of effort required to compile the information. In general, reasonable success was achieved in the DC/MD/VA area, whereas this information was often unavailable or of limited detail in the smaller, more rural communities making up the SJV air basin.

Although it appears possible to compile enough information to establish a reasonable approximation of lot size distribution in areas not covered by the American Housing Survey, the cost and level of effort required to gather the data from local sources may exceed many air quality planners' resources. For example, 31 separate city and county planning agencies were contacted within the SJV to establish a lot size distribution for that area. Generally, the information was received in the form of total acreage, number of improved parcels, and minimum lot size by zoning category. Thus, a considerable amount of work was required to develop the lot size distribution for the entire area. In addition, lot size information from the SJV's largest county, Fresno, would require a computer sort at a cost of either $2,500 (through the Fresno County Planning Office) or $11,000 (through the Fresno County Assessor's Office). An alternative methodology for areas in which lot size information is not readily available may be to use a community included in the American Housing Survey that has similar characteristics in terms of population, urban versus rural split, etc. A complete summary of the organizations contacted to develop lot size statistics for this study is included as Appendix B.

Equipment Distribution as a Function of Lot Size - Once information on lot size is obtained, it is necessary to determine the distribution of equipment as a function of lot size. This information was provided for rear-engine riding mowers and lawn and garden tractors by OPEI in its comments on NEVES.[9] Further, it appears that this information is also available for several lawn and garden equipment types (e.g., string trimmers, riding mowers and tractors, walk-behind mowers, yard blowers, and chain saws) from Irwin Broh & Associates (IB&A). IB&A is a marketing research firm that specializes in the leisure time industry, including outdoor power equipment. Drawbacks to the IB&A data include its high cost ($9,500 for each equipment type) and the fact that the surveys are based on units purchased in the past year only.

If lot size were not chosen to allocate lawn and garden equipment types to the local level, there does appear to be some survey information that establishes regional differences in residential equipment distributions. Each year the National Gardening Association contracts the Gallup Organization to conduct a survey of U.S. consumer gardening practices.[10] Included in this survey is information on product purchases by region, size of community, type of community, and income. Also included in the survey results are 5-year trendlines for purchases of 12 different equipment types (e.g., walk-behind mowers, chainsaws, string trimmers, etc.). The cost of the survey is $350. (EPA could purchase it for the nonprofit/government rate of $125.) Although this information provides regional differences in equipment distributions, it is anticipated that this information would be best utilized as a cross-check of PSR and manufacturer-supplied data.

Bottom-Up Information Sources

Commercial Equipment Usage Patterns - As noted above, the primary contacts for information on commercial lawn and garden equipment populations and usage were the professional and trade associations listed in Table 4-4. For the most part, little information is available on the usage of equipment by commercial landscape firms. Although estimates of annual equipment usage are contained in NEVES (based on PSR survey data), it was hoped that alternative data could be obtained to compare with those figures.

One area in which fairly detailed information on commercial maintenance practices is available, however, is golf courses. The Golf Course Superintendents Association of America publishes the "Mower and Maintenance Equipment Report" which lists detailed usage patterns for equipment such as riding greensmowers, walking greensmowers, riding rotary mowers (under and over-72 inch deck), riding reel mowers (four categories), tractors, blowers, sweepers, boom sprayers, and powered sand trap rakes.[11] Information in the report includes the distribution of manufacturers and the mean hours used per week by season and type of golf course. Further, it appears that the National Golf Foundation could supply information on the number of golf courses in a region. Thus, detailed estimates of equipment activity and emissions could be generated for golf courses using a bottom-up approach. The obvious drawback, however, is that golf courses represent only a portion of the commercially maintained acreage in any given area, and the maintenance requirements of golf courses are generally much more severe than other commercial properties. Thus, information from these sources would not be generally applicable to all commercial lawn and garden equipment. Additionally, the cost of the maintenance report is $1500, while the National Golf Foundation also charges fees for computer sorts of its data base.

Other sources were queried for information relating to commercial landscape maintenance equipment and usage. Several highway departments were contacted in the DC/MD/VA region to determine if records were kept on roadside maintenance. It was initially felt that if the miles of maintained roadway and general maintenance requirements were available, a bottom-up methodology could be developed. In conversations with maintenance engineers, however, it became clear that maintenance practices are highly variable. For example, the frequency of mowing in the DC/MD/VA region can vary from two to five times per season, depending upon rainfall and budget constraints. In addition, the effort to compile the information on maintained roadways in an area can be considerable. Although it was a fairly straightforward process to obtain landscaped miles for state roads (at least for Maryland), gathering the same information for county and city roads requires numerous individual requests. Such an effort would likely be impractical for most local air quality districts.

Maintenance requirements for urban parks were also investigated. As with highways, the total maintained acreage for urban parks could probably be reasonably estimated, but the effort to do so would be overwhelming because of the large number of state, county, and city agencies that would have to be contacted. Nonetheless, some effort was expended in determining if any organizations keep records of park acreage or maintenance practices. Several associations listed in Table 4-4 were solicited for this information without success. Additionally, Parks Departments in the DC/MD/VA and SJV areas were contacted. In this effort, it was discovered that the National Park Service keeps records of maintained acreage for its parks. This information was received for the National Capital Region and for California. Again, however, this information is only for a small component of the total commercially maintained acreage.

If total acreage and mowing schedules could be compiled for an area, machine-hours per acre would be needed to complete an activity calculation. Some information was collected on hour/acre requirements by equipment type. In general, these estimates are based on the width of cut of the implement, an assumed average speed, and an assumed efficiency. OPEI submitted information from two published articles to EPA in conjunction with its review of NEVES.[9] These articles estimated hour/acre for walk-behind mowers, riding mowers, and lawn and garden tractors. A study funded by the National Park Service and the

Department of Energy[12] lists hour/acre requirements for a variety of mowers, ranging from walk-behind to large self-propelled or tractor-drawn units. Finally, a January 1992 issue of Landscape Management magazine lists the square feet per hour for deck sizes ranging from 21 to 60 inches.[13] As an example, Table 4-6 lists hour/acre estimates as a function of implement width and speed with an assumed efficiency of 80 percent.

Table 4-6

Acres Mowed Per Hour as a Function of Implement Width and Speed[12]
(80 Percent Efficiency Assumed)

Speed	Implement Width (Inches)				
(mph)	18	25	36	60	84
1.5	0.23	0.30	0.44	0.72	1.02
2.0	0.30	0.40	0.58	0.96	1.40
3.0	0.45	0.60	0.87	1.45	2.04
4.0	0.60	0.80	1.16	1.92	2.72
5.0	0.75	1.00	1.45	2.43	3.40

Sample Calculations

Although considerable effort was expended in determining the viability of a bottom-up approach for estimating lawn and garden equipment activity, it appears that developing such a methodology is not feasible because of the labor-intensive nature of compiling the needed information. Therefore, the discussion that follows is focused on improvements to the top-down approach that was developed for NEVES.

Commercial Equipment Used Only Commercially - One possible improvement to the lawn and garden equipment activity estimates developed for NEVES would be to distinguish between commercial and residential equipment. As illustrated previously in Figure 4-1, it is anticipated that certain equipment types are used primarily in either commercial or residential applications. Thus, a top-down model that uses both SFHUs and SIC 078 would not necessarily be appropriate for allocating commercial lawn and garden equipment to the local level. For example, Table 4-7 summarizes the results of rerunning the regression analysis performed for NEVES using only SFHU, SFHU and SIC 078, and only SIC 078. (The summary statistics and the data used for the regression analysis are contained in Appendix C.) As seen, the choice of indicators has a considerable impact on the results for the DC/MD/VA region. Using only SIC 078 as the activity indicator increases the lawn and garden equipment

Table 4-7

Relative Impact of Current Activity Indicators on Total Lawn and Garden Equipment Population in the DC/MD/VA and SJV Areas

Area	Activity Indicator(s) Used in Regression		
	SFHU	SFHU & SIC078*	SIC078
DC/MD/VA	1,278,500	1,578,500	1,965,000
SJV	792,000	765,000	744,600

* These indicators were used for NEVES. Note that the total equipment populations shown here do not match those reported in NEVES (i.e., Table 4-1) because of special treatment given to chainsaws and other adjustments made to the PSR lawn and garden equipment population estimates.

population over 50 percent compared to the results of just using SFHUs. Obviously, by accounting for commercial and residential equipment separately, the results obtained in a top-down approach would be improved. (PSR state-level population data on individual equipment types were not available for this study, therefore a regression analysis performed for equipment regimes outlined in Figure 4-1 could not be performed.)

Residential Equipment Used Only Residentially - For rear-engine riding mowers and lawn and garden tractors, an analysis can be performed to determine the population in the DC/MD/VA area using lot size to distribute the equipment. OPEI provided information on the lot size distribution of riding mowers, lawn tractors, and garden tractors, which is summarized in Table 4-8.[9] (Because PSR reports population data for lawn and garden tractors combined, the data from OPEI were combined by the sales split prior to developing population estimates.) This information was combined with the lot size data obtained from the American Housing Survey to calculate the population of rear-engine riding mowers and lawn and garden tractors in the DC/MD/VA area. The spreadsheets used to perform these calculations are included in Table 4-9. The national equipment populations used in the calculations were those provided by PSR for NEVES. (Note that the equipment distributions reported in Table 4-8 have been adjusted in Table 4-9 to be consistent with the lot size ranges reported in the American Housing Survey.)

When comparing these results with the NEVES populations reported in Table 4-1 for the DC/MD/VA region, an approximate 30 percent reduction in population is observed when using the lot size approach. One explanation for this difference is that it was assumed here that these equipment types are used primarily for residential purposes because of their bulk and limited maneuverability. (The same opinion was offered

Table 4-8

Lawn and Garden Equipment Distribution as a Function of Lot Size (From OPEI Retail Sales Data)*

Lot Size (Acres)**	Percent by Equipment Type		
	Rear-Eng Rider	Lawn Tractor	Garden Tractor
1/4	13	8	7
1/2	21	20	14
1	26	27	21
1-1/2	10	11	12
2	20	29	41

* Note that columns do not sum to 100. Remainder of equipment was assumed to be allocated to lots greater than 2 acres.
** Represents average lot size.

Table 4-9

Calculation of Rear-Engine Riding Mower and Lawn & Garden Tractor Populations Using Lot Size to Distribute National Population Data

Rear-Engine Riding Mowers							
	National Statistics				DC/MD/VA Statistics		
	Detached SFHUs*		Rear-Engine Riders		Detached SFHUs*		Rear-Eng
Lot Size	Percent	Total	Percent	Total	Percent	Total	Riders
0 – 1/8	12.0	7,638,600	0	0	5.4	39,026	0
1/8 – 1/4	24.8	15,786,440	6.5	102,968	22.9	165,498	1,079
1/4 – 1/2	19.1	12,158,105	17.0	269,300	36.7	265,231	5,875
1/2 – 1	13.1	8,338,805	23.5	372,268	17.3	125,027	5,582
1 – 4	19.9	12,667,345	53.0	839,584	13.1	94,674	5,443
5 – 9	3.2	2,036,960			1.9	13,731	
10+	7.9	5,028,745			2.7	19,513	
Totals		63,655,000		1,584,120		722,700	17,978

* Includes mobile homes.

Lawn and Garden Tractors							
	National Statistics				DC/MD/VA Statistics		
	Detached SFHUs*		Rear-Engine Riders		Detached SFHUs*		Rear-Eng
Lot Size	Percent	Total	Percent	Total	Percent	Total	Riders
0 – 1/8	12.0	7,638,600	0	0	5.4	39,026	0
1/8 – 1/4	24.8	15,786,440	4.0	244,600	22.9	165,498	2,564
1/4 – 1/2	19.1	12,158,105	13.5	825,525	36.7	265,231	18,009
1/2 – 1	13.1	8,338,805	22.5	1,375,875	17.3	125,027	20,629
1 – 4	19.9	12,667,345	60.0	3,669,000	13.1	94,674	23,784
5 – 9	3.2	2,036,960			1.9	13,731	
10+	7.9	5,028,745			2.7	19,513	
Totals		63,655,000		6,115,000		722,700	64,986

* Includes mobile homes.

by BAH in its study of lawn and garden equipment prepared for CARB.[4]) As seen in Table 4-7, including SIC 078 as an indicator to allocate lawn and garden equipment in the DC/MD/VA area significantly increases the population counts. If these equipment types were allocated according only to SFHUs using the NEVES methodology, the agreement between the two estimates would be closer. (Also note, however, that both estimates for DC/MD/VA are below the population figures submitted to EPA by OPEI [see Table 4-2]. This reinforces the point that lawn and garden equipment population and usage estimates are subject to considerable uncertainty because of limited availability of field data.)

Recommendations

It is obvious that the limiting factor in improving the accuracy of lawn and garden equipment activity and emissions estimates is the limited availability of data. This is apparent for both top-down and bottom-up approaches. Because the data requirements for bottom-up methodologies are far more extensive, the possibility of developing a generalized bottom-up approach to estimate lawn and garden activity at the local level is bleak. However, with some additional effort to develop data on lawn and garden equipment usage, top-down approaches can be improved.

It is recommended that a survey of manufacturers and end users be conducted to determine the distribution and usage patterns of commercial and residential equipment. Although such estimates exist to a limited extent, there has not been a comprehensive survey conducted in a consistent manner to establish the validity of existing data. Among the data needs are:

- Equipment population and sales by residential and commercial ownership;
- Annual hourly usage by residential ownership, commercial ownership, and region; and
- Equipment distributions as a function of lot size.

References for Section 4

1. "Methodology to Estimate Nonroad Equipment Populations by Nonattainment Areas," Energy and Environmental Analysis, September 1991.

2. "Estimates of 24 Nonattainment Area Portable Two-Stroke Power Equipment Populations Based on Actual Industry Shipments Data and Four Alternative Activity Models," Heiden Associates, October 1991.

3. "A 1989 California Baseline Emissions Inventory for Total Hydrocarbon & Carbon Monoxide Emissions from Portable Two-Stroke Power Equipment," Heiden Associates, July 1990.

4. "Technical Support Document for California Exhaust Emissions Standards and Test Procedures for 1994 and Subsequent Model Year Utility and Lawn and Garden Equipment Engines," Booz, Allen, and Hamilton, October 1990.

5. "Status Report: Emissions Inventory on Non-Farm (MS-1), Farm (MS-2), and Lawn and Garden (Utility) (MS-3) Equipment," California Air Resources Board, July 1983.

6. "American Housing Survey for the United States in 1989," U.S. Department of Commerce and U.S. Department of Housing and Urban Development, July 1991.

7. "American Housing Survey for the Washington Metropolitan Area in 1989," U.S. Department of Commerce and U.S. Department of Housing and Urban Development, July 1991.

8. "American Housing Survey for the Los Angeles-Long Beach Metropolitan Area in 1985," U.S. Department of Commerce and U.S. Department of Housing and Urban Development, August 1989.

9. Letter of August 6, 1991. John Liskey (Outdoor Power Equipment Institute) to Clare Ryan (U.S. Environmental Protection Agency).

10. "National Gardening Survey 1991-1992," National Gardening Association, 1992.

11. "1991 Mower and Maintenance Equipment Report," The Center for Golf Course Management, Golf Course Superintendents Association of America, 1991.

12. "Energy Conservation Concepts in Managing Urban Parks," National Park Service and U.S. Department of Energy (No Date).

13. "Calculating Mowing Costs," in <u>Landscape Management</u>, January 1992.

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5. AIRPORT SERVICE EQUIPMENT

Airport service equipment has been stratified into just two equipment types: aircraft support equipment and terminal tractors. Aircraft support equipment includes aircraft load lifters, de-icing equipment, start units, ground power units, utility service equipment, baggage conveyors, and airport service vehicles. Terminal tractors include push-back tractors, tow tractors (i.e., baggage tugs), and yard spotters. Although it would be desirable to consider each equipment type individually, national and state-level population, horsepower, and usage data are not available to this level of detail. Unfortunately, this reduces confidence in local activity estimates developed according to top-down and, to a lesser extent, bottom-up methodologies. (Military installations could account for a significant fraction of the airport service equipment activity in some communities, and contact with U.S. Air Force personnel was initiated. However, resource constraints did not allow for a thorough investigation of this source. See Appendix D for correspondence.)

NEVES Methodology

In the top-down methodology developed for NEVES, EEA utilized air carrier operations as the activity indicator in its regression analysis performed on the PSR state-level equipment populations.[1] This makes intuitive sense in that the number of take-offs and landings would be expected to correlate with equipment populations at individual airports, and this indicator met EEA's statistical criteria for an acceptable model. Airport service equipment population and activity derived from this approach are summarized in Table 5-1 for the U.S., the DC/MD/VA area, and the SJV. (Note that Inventory A and Inventory B are equivalent for this equipment category.) As seen, the bulk of the activity is attributed to terminal tractors used to pull baggage carts and tow planes. This is somewhat surprising given the variety of equipment types included by PSR under the heading of "aircraft support equipment." (This apparent anomaly is discussed in further detail below.)

As a cross-check of the EEA/PSR methodology and data, it is interesting to calculate the number of equipment-hours required to service each air carrier operation. For example, using the data from NEVES for the DC/MD/VA region, the total annual equipment-hours sum to 2,273,250. Dividing this figure by the total air carrier operations at Dulles and National Airports (318,302 in 1989) results in an average of 7.1 equipment-hours per operation (or 14.2 equipment-hours per landing and take-off (LTO) cycle). The same calculation results in an average of 9.4 equipment-hours for each air carrier operation in the SJV

Table 5-1

NEVES Airport Service Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aircraft Support	9,529	2,767	487,359	50,651	538,010	7.7
Terminal Tractors	64,598	6,516	6,102,185	329,243	6,431,429	92.3
Total	74,127	9,283	6,589,545	379,894	6,969,438	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aircraft Support	237	69	12,121	1,263	13,384	7.7
Terminal Tractors	1,604	162	151,520	8,186	159,706	92.3
Total	1,841	231	163,642	9,449	173,090	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aircraft Support	13	4	765	84	849	7.8
Terminal Tractors	86	9	9,532	533	10,065	92.2
Total	99	13	10,297	617	10,914	100.0

(18.8 equipment-hours per LTO). Clearly, these values appear to be unreasonably high, particularly for the SJV in which the bulk of the flights are performed by smaller aircraft which generally have lower servicing requirements.

The equipment-hours calculated above are the result of compiling a number of variables, and errors in any one directly impact the overall calculation. It is very difficult to assess potential problem areas such as overestimates of annual usage or state equipment populations, and the statistical validity of any top-down model based on inaccurate data is meaningless. Nonetheless, the discussion that follows outlines potential improvements to the top-down approach and builds upon previous efforts to develop a bottom-up methodology for estimating activity from airport service equipment.

Approach

Sierra contacted a number of airport and air cargo industry representatives to determine the type of information that is readily available and might be used in estimating activity from airport service equipment. Among those contacted included the Federal Aviation Administration (FAA), selected airports (e.g., Sacramento, Dulles, Washington National, Los Angeles, and several in the San Joaquin Valley), United Parcel Service (UPS), the U.S. Postal Service, Emery Worldwide Air, United Airlines, and several industry associations. This effort led to the conclusion that very good records are available on the number and type of flights from airports in the U.S., while equipment and fuel usage data are generally not available. However, three documents were identified that contained support equipment usage data by type of aircraft; thus, these data formed the foundation of a bottom-up methodology as described below. Additionally, effort was expended to examine alternative activity indicators that might be used in a top-down approach to allocate PSR equipment data to the local level.

Methodology and Data Sources

Top-Down - Because the methodology developed for NEVES appeared to overestimate airport service equipment activity, additional indicators were investigated that might provide a more representative allocation of equipment using the top-down approach. The number of air carrier operations was used in NEVES to allocate equipment to the local level, and this initially appears to be a good choice. However, there are dramatically different service equipment requirements depending upon the type of aircraft. For example, a 400-passenger Boeing 747 has greater equipment requirements than a 150-passenger Boeing 727. Additionally, cargo planes have different equipment requirements than passenger planes. Thus, two activity indicators that may provide a better basis for a top-down model are total passengers and tons of cargo. This information is readily available and is published yearly by the FAA in its "Airport Activity Statistics of Certified Route Air Carriers."[2] Use of these data to develop a model patterned after that proposed in NEVES resulted in quite different equipment populations for the two study areas included in this work.

Bottom-Up - In investigating potential bottom-up methodologies for airport service equipment, Sierra took two approaches: one based on fuel usage, and another based on servicing requirements. First, fuel usage information was considered. Since most airports have a limited number of fueling locations, it was initially felt that fuel records would be readily available. From this information, it would be possible to estimate service equipment activity. After placing calls to a number of airports and fuel suppliers, however, it became apparent that the fuel supply systems at airports are highly variable. For example, Sacramento Metro has a single fueling location (managed by the county), and it was possible to obtain data on fuel usage by month and air carrier. On the other hand, other airports had a number of private firms supplying fuel, and those firms generally declined requests for fuel sales records. In addition, even if fuel records are available, it is often impossible to determine how much fuel is used in nonroad support equipment versus other uses without contacting individual air carriers directly. A methodology based on extensive polling of air carriers at each individual airport was not considered viable and would likely meet with resistance from local air quality planners responsible for preparing inventories.

The second approach to developing a bottom-up methodology was based on the servicing requirements of different types of aircraft. Since the FAA publishes the number of flights by each type of aircraft at all airports supporting commercial operations, a bottom-up approach is possible if information can be compiled on the equipment needs of each aircraft type. This approach has been utilized in the past, and three documents were identified that contain this information. The first, published in 1973, was based on ground support equipment activity at Chicago's O'Hare airport.[3] Subsequent analyses used a similar methodology to estimate support equipment activity. Sacramento Metro published aircraft support equipment activity estimates in its "Air Quality Program Report,"[4] and an Environmental Impact Report prepared to support an expansion at Ontario International Airport also contains information on service equipment requirements by aircraft type.[5] This information is summarized in Table 5-2 for Ontario International and Sacramento Metropolitan airports. As can be seen, the time required for individual aircraft types is a strong function of passenger capacity.

Table 5-2

Equipment Requirements by Aircraft Type
Ontario International and Sacramento Metro Airports

		Equipment Type and Time (Min.)														
Aircraft Type	Approx. Capacity	Tractor	Belt Loader	Container Loader	Cabin Service	Lvtry Truck	Water Truck	Food Truck	Fuel Truck	Tow Tractor	Cond-itioner	Air Start	Ground Power Unit	Trans-porter	Auxiliary Power Unit	Total Eqpmt-hrs
Ontario																
B-747	400-420	77.5	96	92	24	24	12	55	50	10	0	3	60	19	20	9.0
B-767	290	74	80	80	25	18	10	20	45	10	0	0	40	0	20	7.0
L-1011	290	74	80	80	25	18	10	20	45	10	0	0	40	0	20	7.0
DC-10	270	74	80	80	25	18	10	20	45	10	0	0	40	0	20	7.0
B-757	224	33	56	6	12	15	0	17	20	10	0	0	15	3	25	3.5
DC-8	166	49	60	0	15	18	0	30	40	5	30	5	30	0	20	5.0
B-727	120-150	33	56	6	12	15	0	17	20	10	0	0	15	3	25	3.5
B-737	110-150	42.5	60	0	15	15	0	20	15	5	0	0	0	0	40	3.5
DC-9	100	24	30	0	0	15	10	17	15	5	0	0	0	0	40	2.6
BAE-146	75	24	30	0	0	15	10	17	15	5	0	0	0	0	40	2.6
CNA500	50	20	0	0	0	10	10	0	10	0	0	0	0	0	30	1.3
DHC7	50	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0.2
Sacramento																
B-727	120-150	40	30	0	16	10	0	17	15	2.5	0	0	18	0	20	2.8
MD-80	150	40	30	0	16	10	0	17	15	2.5	0	0	18	0	20	2.8
B-737	110-150	40	30	0	16	10	0	17	15	2.5	0	0	18	0	20	2.8
BAE-146	75	40	30	0	16	10	0	17	15	2.5	0	0	18	0	20	2.8
JETSTREAM	20	0	0	0	16	10	0	0	15	0	0	0	18	0	0	1.0
SHORTS 360	36	0	0	0	16	10	0	0	15	0	0	0	18	0	0	1.0
EMBRAER	30	0	0	0	16	10	0	0	15	0	0	0	18	0	0	1.0

Because the above-referenced reports supply information only on passenger planes, several cargo carriers were contacted to determine the availability of data on equipment usage per ton of cargo. The U.S. Postal Service at first appeared to be a likely source of information, but it was discovered that all of their air operations are contracted to private firms. Thus, Emery Worldwide Air (a Postal Service contractor) and UPS were contacted, and written requests for information were submitted to them. Unfortunately, neither company responded to these requests.

Sample Calculations

Top-Down - The top-down regression model developed by EEA for NEVES was rerun utilizing total passengers and tons of cargo as the activity indicators (independent variables), with the state-level PSR equipment populations serving as the dependent variable. The regression results are presented in Table 5-3, while Table 5-4 lists the results for the case in which a zero intercept is assumed. (Data and regression results are also contained in Appendix C.)

Sierra's regression analysis results in an R-square of 0.82 (Table 5-3); thus, this model meets the R-square criterion established by EEA.[1] Further, the summary statistics in Table 5-3 indicate that collinearity is not a problem with this multivariate model. However, the statistics also indicate that the passenger variable is only valid at the 90 percent confidence interval, and the criterion for the intercept not to be significantly different from zero at the 95 percent confidence level is not met (although this latter criterion is only marginally exceeded). Nonetheless, this model was used to determine airport service equipment populations for the DC/MD/VA and the SJV areas, which provided a comparison to the current NEVES approach.

The results of the above regression model (assuming a zero intercept, i.e., Table 5-4) were used in conjunction with data on enplaned passengers and enplaned cargo for the two study areas to arrive at a total equipment population for each area. This calculation is summarized in Table 5-5. The total population determined above was then used with PSR's assumed mix of equipment and fuel types, horsepower, and annual hourly usage to arrive at the activity (in Bhp-hr/year) for the DC/MD/VA and SJV regions. This calculation is summarized in Table 5-6.

As indicated in Table 5-6, the equipment population estimated for DC/MD/VA and the SJV is significantly lower using total passenger and cargo enplanement as activity indicators. For the SJV, this was anticipated because of the lower average passenger carrying capacity of the planes serving the area. However, for the DC/MD/VA region, the result was somewhat surprising.

Bottom-Up - Using the data summarized in Table 5-2 in conjunction with information from FAA's "Airport Activity Statistics of Certified Route Carriers" on the type of flight, it was possible to develop bottom-up activity estimates for passenger aircraft. This was done for the SJV, and the results are given in Table 5-7. The total equipment-hrs (47,654) was multiplied by an average of 76 bhp-hr per equipment-hour (based on PSR data) to obtain the results in bhp-hr/year. (The same analysis could also be performed for the DC/MD/VA metropolitan area, but the SJV analysis adequately demonstrates the methodology.) Because airports in the SJV are similar in structure to Sacramento Metro, equipment-time data from Sacramento were used in the calculations to arrive at a total equipment-hour value for airport service equipment in the SJV.

A comparison of results from the three different estimates (i.e., NEVES, the alternative top-down approach outlined above, and the bottom-up estimate) is shown in Table 5-8. The different methodologies give vastly different results. The alternative top-down method resulted in a 42 percent decrease in annual bhp-hr compared to NEVES, while the bottom-up method resulted in a 67 percent decrease from NEVES. It

Table 5-3

Regression Model Using Airport Service Equipment as the Dependent Variable and Total Passengers and Cargo Tonnage as the Independent Variables

DEP VARIABLE: AP_POP
ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	93621472.78	46810736.39	45.281	0.0001
ERROR	20	20675541.66	1033777.08		
C TOTAL	22	114297014.43			

ROOT MSE	1016.748	R-SQUARE	0.8191
DEP MEAN	2669.739	ADJ R-SQ	0.8010
C.V.	38.08418		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	622.28967864	306.59441114	2.030	0.0559
PASS	1	.00006553352	.00003816396	1.717	0.1014
CARGO	1	0.005678711	0.002716053	2.091	0.0495

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP INTERCEP	VAR PROP PASS	VAR PROP CARGO
1	2.587314	1.000000	0.0524	0.0103	0.0110
2	0.372742	2.634633	0.9155	0.0221	0.0376
3	0.039943	8.048298	0.0321	0.9676	0.9514

MODEL: AP_POP = a*(PASS) + b*(CARGO) + c
AP_POP = AIRPORT SERVICE EQUIPMENT POPULATION
PASS = ENPLANED PASSENGERS
CARGO = ENPLANED CARGO (TONS)
a = 0.00006553
b = 0.005679
c = 622

Table 5-4

Regression Model Using Airport Service Equipment as the Dependent Variable and Total Passengers and Cargo Tonnage as the Independent Variables (Forced Zero Intercept)

DEP VARIABLE: AP_POP
ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	253295369.81	126647684.91	106.664	0.0001
ERROR	21	24934306.19	1187347.91		
U TOTAL	23	278229676.00			

ROOT MSE	1089.655	R-SQUARE	0.9104
DEP MEAN	2669.739	ADJ R-SQ	0.9018
C.V.	40.81503		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
PASS	1	.00008840719	.00003907664	2.262	0.0344
CARGO	1	0.005606375	0.002910559	1.926	0.0677

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP PASS	VAR PROP CARGO
1	1.958873	1.000000	0.0206	0.0206
2	0.0411265	6.901477	0.9794	0.9794

ZERO INTERCEPT MODEL

MODEL: AP_POP = a*(PASS) + b*(CARGO)
AP_POP = AIRPORT SERVICE EQUIPMENT POPULATION
PASS = ENPLANED PASSENGERS
CARGO = ENPLANED CARGO (TONS)
a = 0.00008841
b = 0.005606

Table 5-5

Summary of Airport Service Equipment Population Calculation

Nonattainment Community	Enplaned Passengers	Enplaned Cargo (Tons)	Estimated Eqpmt. Pop.	PSR/Est. Ratio*	Final Eqpmt. Pop.
DC/MD/VA	11,477,384	116,771	1,669	0.79	1,319
SJVAB	558,272	2,300	62	1.03	64

* This represents the ratio of the PSR state-level equipment population to the estimated state-level population based on the regression coefficients. EEA recommends multiplying the estimated local-area population (i.e., that estimated with the regression results) by this ratio to ensure PSR's total state-level populations are maintained. See reference 1 for a more thorough discussion of this approach.

Table 5-6

Airport Service Equipment Activity Utilizing Enplaned Passengers and Cargo (Tons) as Activity Indicators

DC/MD/VA Estimates												
	Population		Horsepower		Load Factor		Annual Hours		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Total	Activity
Aircraft Support	152	36	137	48	0.51	0.56	791	735	8,401	711	9,112	7.7
Terminal Tractors	1,028	103	96	82	0.82	0.78	1282	844	103,745	5,560	109,305	92.3
Total	1,180	139							112,145	6,271	118,417	100.0

San Joaquin Valley Air Basin Estimates												
	Population		Horsepower		Load Factor		Annual Hours		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Diesel	Gas	Total	Activity
Aircraft Support	7	2	137	48	0.51	0.56	842	783	412	42	454	7.2
Terminal Tractors	50	5	96	82	0.82	0.78	1408	926	5,542	296	5,838	92.8
Total	57	7							5,954	338	6,292	100.0

Table 5-7

Bottom-Up Estimate of Airport Service Equipment Activity
San Joaquin Valley Air Basin*

Aircraft Type	Approx. Capacity	Approx. Eqpmt-hrs	Departures Performed							Total Eqpmt-hrs
			Bakersfield	Fresno	Merced	Modesto	Stockton	Visalia	Total	
Passenger										
DC-9-80	150	2.8	722	3	0	0	1	0	726	2,033
B-727-100	112	2.8	0	460	0	0	0	0	460	1,288
B-727-200	158	2.8	0	1,244	0	0	0	0	1,244	3,483
B-737-300	136	2.8	0	1,006	0	0	2	0	1,008	2,822
B-737-100/200	120	2.8	0	1,794	0	0	0	0	1,794	5,023
EMBRAER	30	1	1,669	4,424	1,788	1,190	1,106	0	10,177	10,177
EMBRAER 120	30	1	1,626	1,623	70	0	1,083	0	4,402	4,402
JETSTREAM 31	19	1	395	5,965	300	509	526	0	7,695	7,695
B-747	400	9	0	1	0	0	0	0	1	9
B-737-400	146	2.8	0	0	0	0	1	0	1	3
SHORTS 360	36	1	0	753	0	0	2	0	755	755
BAE-146-200/300	75	2.8	0	1,932	0	0	880	0	2,812	7,874
DCH-8	37	1	1,024	1,066	0	0	0	0	2,090	2,090
Total Passenger:			5,436	20,271	2,158	1,699	3,601	0	33,165	47,654
Cargo										
BEECH 18			3	2	0	0	0	0	5	
C-208			259	606	0	0	0	192	1,057	
B-727-200			3	0	0	0	0	0	3	
Total Cargo:			265	608	0	0	0	192	1,065	
Total Departures:			5,701	20,879	2,158	1,699	3,601	192	34,230	

* Activity = (47,654 Equipment-hr) * (76 Bhp-hr/Equipment-hr) = 3,621,700 Bhp-hr/yr

Table 5-8

Comparison of Airport Service Equipment
Activity Estimates for the SJV

Method	Equipment-Hours	1000 bhp-hr/Year
NEVES	143,500	10,914
Alternative Top-Down	82,700	6,292
Bottom-Up	47,654	3,622

should be noted, however, that the 1067 cargo flights (accounting for 2,300 tons of enplaned cargo) would increase the overall bottom-up activity estimate for the SJV.

Additional Considerations

Although the data compiled on airport service equipment are useful in making rough estimates of equipment activity using a bottom-up approach, there are a number of problems in using this information to develop a generalized bottom-up methodology. First, no information on cargo operations was obtained, and this could be an important contribution to service equipment activity in some areas because cargo, unlike passengers, does not unload itself. Second, the time estimates for some pieces of equipment are highly airport specific, and would vary according to an airport's physical layout. Third, it is not clear that the data compiled on equipment usage by aircraft type include all of the applications for which the equipment is used. Finally, fuel type, horsepower, and load factor data were not obtained on an equipment-specific basis, which necessitated the use of an average bhp-hr/equipment-hr value based on PSR data. All of these factors reduce the confidence of any estimates developed with this methodology.

On the other hand, another point to be considered is that the bottom-up approach outlined above is consistent with the current recommended procedures for developing emissions inventories for aircraft.[6] Because information on number of flights by aircraft type must be compiled to prepare aircraft inventories, much of the data needed in a bottom-up approach for estimating airport service equipment activity would already be available to local authorities responsible for inventory preparation.

Although there are deficiencies in the bottom-up method outlined above, there appear also to be problems with the estimates performed for NEVES. When considering the total equipment-hours per LTO, the NEVES estimates seem unreasonably high. This could be the result of an overestimate of population, annual usage, or both. In addition, inspection of Table 5-2 indicates that terminal tractor usage generally accounts for less than 25 percent of the equipment time to service an aircraft. However, NEVES data suggest that 90 percent of the overall airport service equipment activity is attributable to terminal tractors. Given the large number of equipment types included in "aircraft support equipment," their contributing only 10 percent of the total equipment hours might be questioned.

Recommendations

It appears that additional effort is needed to make either top-down or bottom-up methodologies adequate for estimating airport service equipment activity. There is a data gap that must be filled before estimates can be made with any confidence. For top-down estimates, serious consideration should be given to alternative activity indicators, while population and usage estimates provided by PSR need careful review. For bottom-up estimates, details on cargo operations are needed, and more information on equipment fuel and horsepower ratings would be helpful. Nonetheless, an adequate bottom-up method could be developed with little additional effort, provided industry was willing to share data related to equipment usage by type of flight (e.g., passenger versus cargo). Finally, the bottom-up methodology discussed above would mesh well with the approach that is recommended by EPA for developing emission estimates from aircraft.[6]

References for Section 5

1. "Methodology to Estimate Nonroad Equipment Populations by Nonattainment Areas," Energy and Environmental Analysis, September 1990.

2. "Airport Activity Statistics of Certified Route Air Carriers," U.S. Department of Transportation, 1990.

3. "An Air Pollution Impact Methodology for Airports," Argonne National Laboratory, 1973.

4. "Sacramento Metropolitan Airport Air Quality Program Report," County of Sacramento, Department of Airports, 1992.

5. "Ontario International Airport Final Environmental Impact Report for Terminals, Other Facilities and Operations to Support 12 Million Annual Passengers," City of Los Angeles, Department of Airports, November 1991.

6. "Procedures for Emission Inventory Preparation. Volume IV: Mobile Sources," U.S. Environmental Protection Agency, July 1989.

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6. RECREATIONAL EQUIPMENT

The recreational equipment category consists of all-terrain vehicles (ATVs), minibikes, off-road motorcycles, snowmobiles, golf carts, and specialty vehicles/carts (e.g., snow-grooming equipment, ice maintenance equipment, go-carts, personnel carriers, and industrial ATVs). On a national basis, recreational equipment accounts for the smallest percentage of bhp-hr/yr activity of all the nonroad equipment categories. Furthermore, it is likely that much of this activity occurs outside of nonattainment areas. Thus, any alternative methodology developed to improve local estimates of recreational equipment activity must be easy to apply to justify its use.

NEVES Methodology

The local population estimates developed for Inventory A in NEVES were based on a regression analysis of state-level PSR data using SIC 557 (Motorcycle Dealers - Establishments) as the activity indicator. In a few areas, however, data for SIC 557 were unavailable. Thus, SIC 55 (Automotive Dealers and Service Stations - Employees) was used as an alternative indicator for the Baton Rouge, El Paso, Provo-Orem, and Spokane metropolitan areas. The statistical criteria established by EEA[1] were satisfied for both models.

The population and usage estimates for ATVs, minibikes, and off-road motorcycles were modified in Inventory B based on information submitted to EPA by the Motorcycle Industry Council (MIC). MIC's national population estimates (which were much higher than those developed by EEA for Inventory A) were allocated to the local level using the same local-to-national equipment population ratio established in Inventory A. MIC also provided estimates for the average number of miles ridden annually for ATVs and off-road motorcycles (263 and 313 miles, respectively). These estimates were divided by an assumed average speed to arrive at an annual hourly usage. Similarly, the International Snowmobile Industry Association (ISIA) provided EPA with an independent estimate of the national snowmobile population and average annual usage. This national population estimate was also scaled to the local level by using the Inventory A local-to-national population ratios.

Tables 6-1 and 6-2 show the results of the above analyses for the nation, the DC/MD/VA metropolitan area, and the SJVAB for Inventories A and B, respectively. Note that only annual hourly usage is compiled in these tables because EPA chose to use emission factors in units of grams/hour when generating the emissions inventories for this equipment category (except snowmobiles, for which the use of bhp-hr/yr to represent activity was retained).

Table 6-1

NEVES Inventory A Recreational Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
All Terrain Vehicles	0	1,312,981	0	152,306	152,306	36.9
Minibikes	0	48,990	0	2,156	2,156	0.5
Off-Road Motorcycles	0	201,125	0	20,314	20,314	4.9
Golf Carts	0	122,670	0	116,537	116,537	28.2
Snowmobiles	0	776,559	0	103,282	103,282	25.0
Specialty Vehicles & Carts	3,334	266,096	1,400	16,764	18,164	4.4
Total	3,334	2,728,421	1,400	411,358	412,758	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
All Terrain Vehicles	0	7,219	0	837	837	45.4
Minibikes	0	269	0	12	12	0.6
Off-Road Motorcycles	0	1,106	0	112	112	6.1
Golf Carts	0	674	0	640	640	34.7
Snowmobiles	0	1,067	0	142	142	7.7
Specialty Vehicles & Carts	19	1,464	8	92	100	5.4
Total	19	11,799	8	1,835	1,843	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
All Terrain Vehicles	0	2,941	0	397	397	48.0
Minibikes	0	110	0	7	7	0.9
Off-Road Motorcycles	0	451	0	62	62	7.5
Golf Carts	0	275	0	315	315	38.0
Snowmobiles	0	0	0	0	0	0.0
Specialty Vehicles & Carts	7	596	3	44	47	5.7
Total	7	4,373	3	824	828	100.0

A potential deficiency in the NEVES methodology to estimate emissions from nonroad recreational equipment is the choice of activity indicators used to distribute the national equipment population to the local level. Because these equipment types are generally used outside of urban areas, activity indicators that are expected to be based within urban areas (such as motorcycle dealerships) will not provide the best estimate of equipment distribution and activity, regardless of the favorable statistics resulting from such a choice. For example, according to EEA's estimates (which were based on the Department of Commerce's "County Business Patterns"), there are 11 motorcycle dealerships in the entire SJVAB, while Los Angeles County alone has 112. Given the rural nature of the SJVAB and the highly urban characteristics of Los Angeles County, nonroad recreational vehicle usage in Los Angeles County would not be expected to be 10 times than that in the SJVAB. Furthermore,

Table 6-2

NEVES Inventory B Recreational Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
All Terrain Vehicles	0	2,240,000	0	33,600	33,600	11.7
Minibikes	0	48,990	0	735	735	0.3
Off-Road Motorcycles	0	750,000	0	11,250	11,250	3.9
Golf Carts	0	122,670	0	116,537	116,537	40.4
Snowmobiles	0	1,200,000	0	108,000	108,000	37.5
Specialty Vehicles & Carts	3,334	266,096	1,400	16,764	18,164	6.3
Total	3,334	4,627,756	1,400	286,885	288,286	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
All Terrain Vehicles	0	12,317	0	185	185	16.2
Minibikes	0	269	0	4	4	0.4
Off-Road Motorcycles	0	4,124	0	62	62	5.4
Golf Carts	0	674	0	640	640	56.2
Snowmobiles	0	1,650	0	149	149	13.0
Specialty Vehicles & Carts	19	1,463	8	92	100	8.8
Total	19	20,497	8	1,132	1,140	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
All Terrain Vehicles	0	5,017	0	75	75	18.6
Minibikes	0	110	0	2	2	0.4
Off-Road Motorcycles	0	1,680	0	25	25	6.2
Golf Carts	0	275	0	261	261	64.7
Snowmobiles	0	0	0	0	0	0.0
Specialty Vehicles & Carts	7	596	3	38	40	10.0
Total	7	7,678	3	401	404	100.0

California Department of Motor Vehicles (DMV) records indicate that there are roughly 14,000 off-road motorcycles registered in the eight-county SJVAB[2], whereas Inventories A and B in NEVES estimated 450 and 1680, respectively. Finally, using motorcycle dealerships to allocate golf carts and specialty vehicles/carts makes little intuitive sense.

Approach

The challenge in allocating nonroad recreational vehicle usage to individual counties is to develop a methodology that distributes activity to the areas where that activity actually occurs. Identifying a consistently published and all-encompassing data source that provides such information, however, proved difficult. A number of agencies were contacted to determine the availability of information on nonroad recreational vehicle usage. At a national level, the Bureau of Land Management and the National Forest Service were contacted. State DMVs were contacted in California, Maryland, and Virginia to determine the registration requirements for off-highway recreational vehicles. The California Department of Parks and Recreation and several off-highway vehicle recreation areas in California were solicited for information on vehicle usage. Finally, manufacturer associations (i.e., MIC, ISIA) were also asked for data concerning nonroad recreational equipment populations and usage.

Methodology and Data Sources

Equipment Population - The most obvious source of equipment population information at first appeared to be state DMVs. It was felt that if registration records were kept at the county level, distributing equipment according to registrations would be an improvement over using motorcycle dealerships (although it was recognized that the equipment is not necessarily used in the county in which it is registered). After contacting several states, however, it became clear that the registration requirements for nonroad recreational equipment are highly variable, as is the level of detail available from each state. For example, California requires registration of off-highway recreational vehicles and keeps independent records of these vehicles. Maryland also requires registration of off-road motorcycles, but combines both off-road and on-road in its registration records. On the other hand, Virginia and North Carolina require no registration of off-highway recreational equipment. (Because detailed data were not available for DC/MD/VA, North Carolina was contacted because it could potentially serve as a surrogate for this area.)

Besides those from state DMVs and PSR, the only other estimates of off-highway recreational equipment populations that were identified came from industry associations. MIC annually publishes population estimates for motorcycles and ATVs in its "Motorcycle Statistical Annual."[3] In that document, national and state-level population estimates are provided for on-highway motorcycles (motorcycles certified by the manufacturer to be in compliance with Federal Motor Vehicle Safety Standards (FMVSS)), off-highway motorcycles (motorcycles not certified to be in compliance with FMVSS, including ATVs), and dual-purpose motorcycles (motorcycles complying with FMVSS and designed for use on public roads or off-highway recreational use). Because of their different use characteristics, however, a means to separate the total off-highway motorcycle population into motorcycles and ATVs is necessary. Additionally, methodologies to allocate the state-level populations to the county level (i.e., to the county in which the equipment is used) are also needed.

To determine the number of off-road motorcycles and ATVs from the state-level total off-highway populations, results of a 1990 survey conducted for MIC by Burke Marketing Research[4] can be used. That survey compiled information on motorcycle type for 2,595 motorcycles throughout the United States. The motorcycle types of interest included scooters, on-highway motorcycles, dual-purpose motorcycles, off-highway motorcycles, competition motorcycles, and ATVs. These survey results, summarized in Table 6-3, can be used in conjunction with the state population figures reported by MIC to arrive at ATV and off-road motorcycle populations. The results for "off-highway" and "competition" motorcycles were combined to determine the appropriate fraction of off-road motorcycles for this work.

Table 6-3

Distribution of Off-Highway Motorcycles
Based on MIC's Definition and the Burke Survey[4]

Location	Off-Road Motorcycle Distribution		
	Off-Highway MC	Competition MC	ATV
Total U.S.	143 (15.1%)	198 (20.8%)	609 (64.1%)
Western U.S.	49 (18.3%)	80 (29.9%)	139 (51.9%)
California	16 (15.8%)	39 (38.6%)	46 (45.6%)

Table 6-4 compares California DMV estimates and MIC estimates of off-road motorcycle (including dual-purpose motorcycles) and ATV population for the eight SJVAB counties and the entire state of California. The DMV estimates include only "active" off-road registrations, and the county-specific industry estimates are based on the same ratio of county to state off-highway populations reported by the DMV. It is recognized that such a procedure could not be applied on a national basis, but the analysis is included here to provide a cross-check of the MIC data.

As seen in Table 6-4, the off-road motorcycle population appears to be under-represented by the California DMV compared to the MIC estimates, while the ATV populations are reasonably similar. A report prepared by Tyler and Associates for the California Departments of Transportation and Parks and Recreation indicated that a significant number of off-highway vehicles used in California are not registered with the State DMV.[5] That study, which was based on surveys conducted in California, determined that almost 5 times more *unregistered* off-road motorcycles were ridden off-highway compared to the number of *registered* off-road motorcycles. Applying this factor to the California DMV off-highway motorcycle registrations results in an estimated California population of roughly 950,000 vehicles. Similarly, Tyler determined that the "true" population of ATVs in California should be 2.5 times the number of registered ATVs. Although these numbers appear to be unreasonably

Table 6-4

Comparison of Off-Road Motorcycle and ATV Populations
California DMV and MIC Estimates

County	California DMV		MIC*	
	Off-Rd MC**	ATV	Off-Rd MC**	ATV
Fresno	2,289	4,326	4,058	3,964
Kern	3,808	3,788	6,750	3,471
Kings	437	948	775	869
Madera	506	870	897	797
Merced	746	1,124	1,322	1,030
San Joaquin	2,156	2,474	3,822	2,267
Stanislaus	2,435	3,079	4,317	2,821
Tulare	1,467	2,737	2,601	2,508
SJVAB	13,844	19,346	24,541	17,727
California	159,849	161,335	283,365	147,835

* MIC only reports state-level populations; thus, the county-level estimates shown here are based on scaling the MIC state-level data by the same county-to-state ratios provided by the California DMV.
** Includes dual-purpose motorcycles. The California DMV requires dual-registration for motorcycles that are used both on- and off-highway.

high, they do explain the higher population reported by MIC for motorcycles.

In addition to off-highway motorcycles and ATVs, alternative sources of equipment population data for the remaining equipment types included in the recreational equipment category were also sought; however, the only equipment type for which additional information was obtained was snowmobiles, and this had previously been supplied to EPA by ISIA. In response to Sierra's requests for information, ISIA provided comments it had prepared on CARB's proposed regulations for off-highway vehicles.[6] In this submittal, ISIA estimated the California snowmobile population based on California DMV registration records. In support of NEVES, ISIA also provided an estimate for the national snowmobile population.

Annual Usage - A number of organizations were contacted to determine usage patterns for off-highway recreational equipment. On a national level, the U.S. Forest Service was contacted to determine if studies are available on off-highway vehicle usage in the National Forest System. Although the number of trail-miles on the National Forest System are available for each state,[7] county-level numbers do not appear to be available. (This was at first considered a potential activity indicator for a modified top-down approach.) Furthermore, in speaking with Forest Service personnel, it appears that information related to off-highway vehicle usage is generally compiled on a case-by-case basis. For example, off-highway vehicle usage was being investigated in California's Mojave Desert and Imperial Sand Dunes, but the focus of that research was on the impacts these vehicles have on the desert tortoise.[8] Thus, standardized, regularly updated information on off-highway vehicle usage is not available from the U.S. Forest Service.

The Department of Interior's Bureau of Land Management (BLM) was also contacted for information related to off-highway vehicle usage. BLM keeps good records of trail-miles and visitor hours by type of activity for each area and state in which BLM has jurisdiction, and Sierra was able to obtain a computerized printout of the above information for fiscal year 1991.[9,10] The states for which information was obtained included Alaska, Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, and Wyoming. Although the information received provides a good assessment of vehicle usage on BLM lands, it does not allow for the quantitative estimate of vehicle usage for an entire state or county because vehicle usage is obviously not confined to BLM lands. It is interesting, however, to look at the reported usage in California BLM areas, which is summarized in Table 6-5. This table indicates that the California Desert region, which is a vast tract of essentially uninhabited land southeast of Los Angeles, receives the majority of off-highway vehicle usage in California's BLM areas. Again, this points out the importance of choosing an activity indicator that represents the area in which the equipment is used.

Two reports cited earlier, the Burke[4] and Tyler[5] studies, contain information related to annual off-highway recreational vehicle usage. Both studies were based on surveys; however, the Burke study contains results for the entire U.S., while the Tyler study is specific to

Table 6-5

Off-Highway Vehicle Travel on BLM Lands in California
Fiscal Year 1991

BLM District	Number of Participants	Total Visitor-hrs	Percent of Visitor-hrs
Bakersfield	297,000	1,858,500	5.3
Susanville	333,700	991,000	2.8
Ukiah	255,800	1,214,600	3.5
California Desert	5,075,804	31,021,325	88.4
Total Calif. BLM	5,962,304	35,085,425	100

California. Burke compiled the average number of miles ridden annually for off-road motorcycles and ATVs by region of the country. On average, off-highway motorcycles are ridden 313 miles and ATVs are ridden 263 miles annually. In addition, the average number of days ridden each year was determined in the Burke survey. On the other hand, Tyler estimated the annual fuel consumption for off-road motorcycles (in California) to be 43 gallons and the annual fuel consumption for ATVs to be 28 gallons. (The purpose of the Tyler report was to develop a methodology to estimate the monthly fuel usage by recreational off-highway vehicles. This information was then used to determine how much fuel tax refund monies were to be placed into an off-highway vehicle account.)

Unfortunately, a direct comparison between the results presented by Burke and Tyler is not possible because of the different units in which the activities were reported. However, dividing the average 313 miles per year reported by Burke by the average 43 gallons per year reported by Tyler, the fuel economy for off-highway motorcycles is calculated as 7.3 miles/gallon. This value *appears* rather low, but detailed fuel economy data for off-highway motorcycles could not be obtained in order to validate the above estimate. (Based on conversations with various experts, Tyler reported a range of 10 to 65 miles/gallon, depending on engine size, type of riding, and 2- or 4-stroke.) Assuming a value of 7.3 miles/gallon is low, this indicates that the Burke annual mileage estimates are low, the Tyler annual fuel usage estimates are high, or both.

<u>Temporal Usage</u> - Burke[4] and Tyler[5] also reported information that can be used to determine seasonal and weekend use for off-highway recreational equipment. This information is available directly from Burke's summary statistics (e.g., percent of riding by season, percent of riding done on weekends), while monthly vehicle usage can be inferred from the monthly fuel usage data reported by Tyler.

In addition to the above studies, off-road vehicle parks in California were contacted to determine if information on vehicle usage was available. Although the yearly attendance for each park is not particularly useful, the distribution of attendance by month and by day of week can be important from an emissions modeling perspective. Figure 6-1 shows the monthly distribution of attendance for the Hollister Hills State Vehicle Recreation Area (SVRA). As seen, attendance peaks in the November to April period. (An exception is a spike in attendance for June 1989. This apparent anomaly may have been the result of competition events.) This pattern confirms discussions held with a number of park officials who indicated that summer ridership is low because of higher temperatures and low soil moisture content, which results in poor traction and dusty conditions.

Information from the Burke survey indicated that roughly two-thirds of off-road motorcycle and ATV usage occurs on weekends. Attendance data from the Carnegie SVRA (which is located in the SJVAB) confirmed this assessment. Figure 6-2 shows the daily motorcycle attendance for a number of months in 1991. This figure indicates that weekend usage for this park averages 70 to 80 percent of the total usage. (Also note the increased attendance for the fall months compared to the summer months.)

Figure 6-1

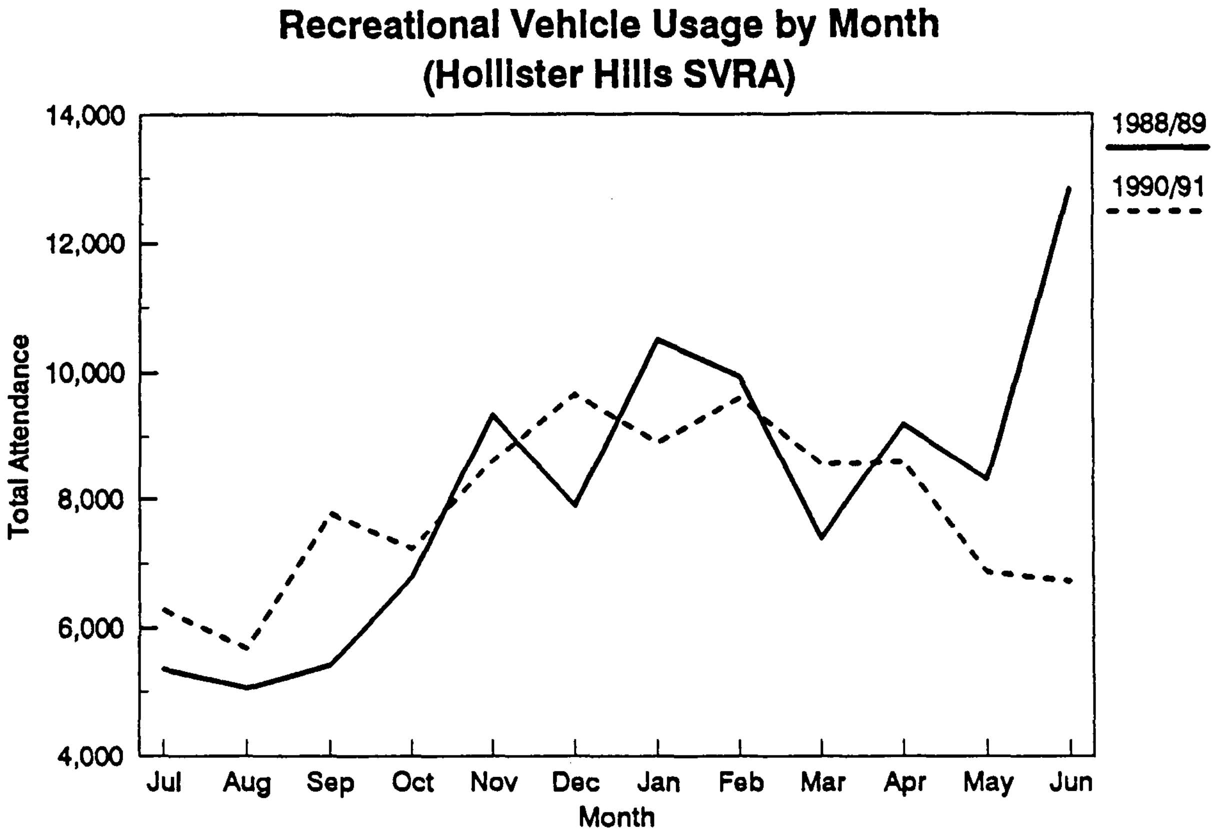
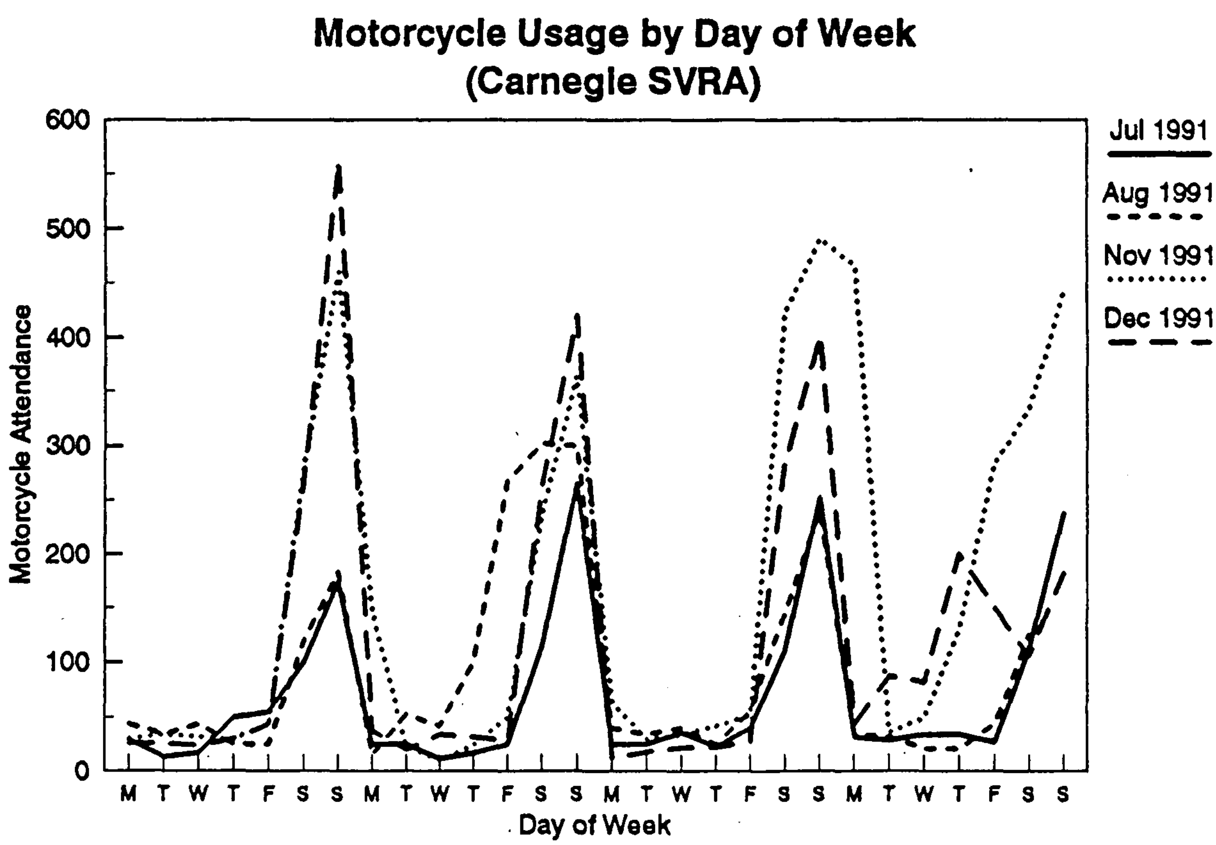


Figure 6-2



Sample Calculations

After reviewing all available data, it became clear that developing a bottom-up approach to estimating nonroad recreational vehicle usage is nearly impossible. Although Sierra was able to compile information on vehicle usage for certain areas (e.g., BLM land, California SRVAs), there are no data available from which a comprehensive bottom-up methodology can be developed. Therefore, the focus of the area-specific calculations was on an improved top-down approach. Furthermore, the estimates that follow are specific to the SJVAB, although the methodology could obviously be extended to other areas.

As discussed above, when investigating activity indicators for off-highway recreational vehicle usage, it is important to choose an indicator that is representative of <u>where</u> the vehicles are operated. This proved difficult, especially since these vehicles are often operated in remote areas where commonly used statistics (e.g., employment by SIC code) are not applicable.

One of the more obvious activity indicators, which was evaluated in a regression model, is the number of acres of public land in each state.[*] The statistical validity of this model, however, was highly questionable (e.g., R-square of 0.28), and no further attempts to base equipment distribution on land ownership characteristics were made. It appears that this indicator provided poor results because a large percentage of the public land is in the western U.S., while a significant fraction of off-road motorcycles and ATVs are located in eastern states.

Because off-highway recreational equipment is used primarily in rural areas (MIC reports that roughly 80 percent of the off-highway motorcycle and ATV usage occurs in rural areas[11]), another activity indicator that was investigated is rural population. A regression model was developed in which the state-level off-highway motorcycle populations reported by MIC[3] served as the dependent variable, while the state-level rural population was used as the independent variable. (The population statistics were obtained from the 1990 Census of Population and Housing.[12]) The 23 states used in the NEVES analysis were included in this analysis as well.

The results of the above model are summarized in Table 6-6, which shows a very poor correlation between rural population and off-highway motorcycle population (R-square of 0.42). In investigating the reason for the poor correlation, however, it became clear that California had a profound effect on the overall regression results. By taking California out of the model, the statistical significance of the regression improved substantially, as seen in Table 6-7 (R-square of 0.84), and removing Utah from the model resulted in still further improvement (R-square of 0.87).

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[*] Data and regression statistics are summarized in Appendix C for the models developed in this section.

Table 6-6

Regression Model Using MIC Off-Highway Motorcycle Population as the Dependent Variable and Rural Population as the Independent Variable

DEP VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	40208213665	40208213665	15.298	0.0008
ERROR	21	55193745465	2628273594		
C TOTAL	22	95401959130			

ROOT MSE	51266.69	R-SQUARE	0.4215
DEP MEAN	81021.74	ADJ R-SQ	0.3939
C.V.	63.27523		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	10442.78781	20973.53352	0.498	0.6237
R_POP	1	0.04436638	0.0113431	3.911	0.0008

MODEL: MC_POP = a*(R_POP) +b
MC_POP = MOTORCYCLE POPULATION
R_POP = RURAL POPULATION
a = 0.0444
b = 10,443

Table 6-7

Regression Model Using MIC Off-Highway Motorcycle Population as the Dependent Variable and Rural Population as the Independent Variable (Excluding California)

DEP VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	28370921916	28370921916	108.964	0.0001
ERROR	20	5207385811	260369290.56		
C TOTAL	21	33578307727			

ROOT MSE	16135.96	R-SQUARE	0.8449
DEP MEAN	69968.18	ADJ R-SQ	0.8372
C.V.	23.06186		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	11154.18142	6601.52593	1.690	0.1066
R_POP	1	0.03761341	0.003603304	10.439	0.0001

MODEL: MC_POP = a*(R_POP) +b
MC_POP = MOTORCYCLE POPULATION
R_POP = RURAL POPULATION
a = 0.0376
b = 11,154

The above results can be explained by considering _where_ off-highway recreational vehicles are ridden. In the southwestern U.S., there is considerable access to open areas that have _no_ significant human population, and these are areas in which off-highway vehicles are often used by individuals living in urban areas. For example, Table 6-5 indicates a considerable amount of off-highway vehicle ridership in the California Desert region, although there is no discernable human population inhabiting this area. It is likely that many off-road enthusiasts making use of this area are from the Los Angeles metropolitan area, which is only a couple of hours drive from the desert. On the other hand, the eastern U.S. has much less public land available for off-road recreational purposes. (Only 2 percent of the land in the Northeast is federally owned, whereas 47 percent of the land in the West is federally owned.[13]) Therefore, vehicle usage in the eastern U.S. is likely to be concentrated in areas where the rural population is significant.

Because the assessment of nonroad equipment usage and emissions is focused on nonattainment communities (which are not likely to contain significant areas of uninhabited land), the following approach was taken in estimating local equipment populations for the SJVAB:

1. A regression model was developed that correlated state off-highway motorcycle populations (from MIC[3]) with rural population (from the 1990 Census[12]). However, California and Utah were not included in the analysis. Summary statistics for this regression are given in Table 6-8.

Table 6-8

Regression Model Using MIC Off-Highway Motorcycle Population as the Dependent Variable and Rural Population as the Independent Variable (Excluding California and Utah)

DEP VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	28498709451	28498709451	121.896	0.0001
ERROR	19	4442101977	233794840.91		
C TOTAL	20	32940811429			

ROOT MSE	15290.35	R-SQUARE	0.8651
DEP MEAN	71142.86	ADJ R-SQ	0.8581
C.V.	21.49246		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	6694.67763	6723.66782	0.996	0.3319
R_POP	1	0.03960076	0.00358681	11.041	0.0001

MODEL: MC_POP = a*(R_POP) +b
MC_POP = MOTORCYCLE POPULATION
R_POP = RURAL POPULATION
a = 0.0396
b = 6,695

2. Because the value of the t-statistic in Table 6-8 indicates the intercept for this model is not significantly different from zero, the regression was re-evaluated such that the intercept was forced through the origin. The new value of the slope resulting from this calculation is 0.0427.

3. The total rural population for the SJVAB was used with the slope determined above to arrive at a local equipment population.

4. The local equipment population derived above was not adjusted by the actual-to-predicted MIC state population ratio. Doing this for California would raise the equipment population by 3.5 times. By not making this adjustment (which was recommended by EEA in its analysis of local-level equipment populations[1]), a portion of the California off-highway population is inherently being allocated to areas with no human population (e.g., the desert).

5. The off-road population determined above (which, because MIC state data were used, includes both off-highway motorcycles and ATVs) was stratified according to off-highway motorcycles and ATVs based on the information contained in Table 6-3.

The results of the above analysis are summarized in Table 6-9.

Table 6-9

Comparison of Nonroad Recreational Equipment Populations for the SJVAB

Equipment Type	NEVES Inventory A	NEVES Inventory B	This Study
ATVs	2,941	5,017	10,330
Minibikes	110	110	371
Off-Road MC	450	1,680	12,320
Golf Carts	275	275	686
Specialty Vehicles	596	596	2,016

In addition to off-highway motorcycles and ATVs, other equipment types are included in the nonroad recreational vehicle category. For snowmobiles, a similar approach as taken above would likely result in reasonably accurate estimates of equipment usage. Although Sierra was not able to obtain state-level snowmobile population estimates for this study, a recent report by JFA[14] indicates that such information may be available from ISIA. The only change to the methodology would be to account for the rural population located in areas that receive sufficient snowfall to allow snowmobile operation. As an alternative, the state equipment population could simply be scaled by the local-to-state rural population. Since snowmobiles would not be operated in the non-mountainous portions of the counties comprising the SJVAB, their usage was assumed to be zero and is therefore not included in Table 6-9.

To determine the local golf cart population, the most obvious activity indicator is golf courses. Because state-level golf course statistics were not available, a regression analysis was not performed. A simple scaling of the national equipment population (from the PSR data base) by the local-to-national golf course population ratio served as the basis of the calculation. Although this admittedly is not a rigorous approach to determine golf cart populations, it likely provides a more accurate assessment of local-level equipment populations than the activity indicator used in NEVES (i.e., motorcycle dealerships). The National Golf Foundation provided information on the total number of golf courses in the U.S. (14,136),[15] while county road maps were utilized to determine the number of golf courses in the SJVAB (79).[16-20] Applying this ratio to the national golf cart population resulted in a total of 686 golf carts in the SJVAB. This is also shown in Table 6-9. (Clearly, this does not account for golf carts used for utility purposes. However, it may be impossible to identify an appropriate activity indicator that would properly apportion golf carts used for utility purposes.)

Because minibikes are likely to be used in the same areas as off-highway motorcycles, the local minibike population was determined by simply scaling the PSR national population by the local-to-national ratio of off-highway motorcycle population. The derivation of the SJVAB population is described above, and the MIC national population (from the "Motorcycle Statistical Annual"[3]) served as the denominator of the scaling factor. For utility vehicles/carts, it is difficult to determine an appropriate activity indicator to distribute equipment to the local level; however, because many of the equipment types included in this "catch-all" category are used in a more rural environment (e.g., snow-grooming equipment, go-carts), this equipment was also allocated using the local-to-national ratio of off-highway motorcycle population.

Not included in Table 6-9 are the overall annual hourly usage estimates. For ATVs, motorcycles, and minibikes, information from the Burke survey should be used to arrive at annual usage figures, while ISIA estimates of usage should be used for snowmobiles. (Although PSR reports usage information for recreational equipment, the quality and quantity of data used to develop those estimates is unclear.) For the remaining equipment types in this category, PSR usage estimates appear to be the only ones available.

Additional Considerations

For ATVs and off-highway motorcycles, the state-level population figures reported by MIC are the best available, but a means of incorporating dual-purpose motorcycles into the analysis would improve its accuracy.

This could be accomplished by simply summing the off-highway and dual-purpose state populations before performing the regression analysis. Annual usage estimates, however, are likely to differ between off-highway and dual-purpose motorcycles, and care would have to be exercised to ensure that the dual-purpose usage was not included in both on-highway and off-highway inventory estimates.

The remaining equipment types are relatively minor contributors to an area's overall inventory, but improvements in methodologies could be made. For golf carts, the number of golf courses in each state is available from the National Golf Foundation (which could be used in conjunction with PSR state-level population data in a regression analysis), but data from this organization typically is purchased. Similarly, state snowmobile populations, coupled with rural population *in areas with sufficient snowfall*, would provide a better distribution of snowmobile population.

Recommendations

In investigating alternative methodologies, Sierra found that a bottom-up approach for this equipment category would be nearly impossible to develop. Alternative top-down methodologies, however, were considered that appear to offer a significant improvement over the current methodology. Although additional variables could be factored into the regression analysis, rural population is a reasonably easy parameter for local air quality planners to obtain, and it is more likely to place the vehicles in the areas where they are used. Furthermore, the use of MIC state population data is recommended,[3] as are the usage estimates developed by Burke.[4]

References for Section 6

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15. National Golf Foundation, Personal Communication, November 1992.

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17. "Kern County," Automobile Club of Southern California, August 1991.

18. "Madera, Mariposa, and Merced Counties," California State Automobile Association, May 1991.

19. "San Joaquin and Stanislaus Counties," California State Automobile Association, May 1991.

20. "Tulare County," Automobile Club of Southern California, June 1991.

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7. CONSTRUCTION EQUIPMENT

Construction equipment comprises the largest single category of nonroad equipment investigated in NEVES, both in terms of number of individual equipment types and overall energy output (i.e., bhp-hr/year). Twenty-seven specific equipment types are included in this category, ranging from lower horsepower machines, such as compactors, signal boards, and cement mixers, to large, high-horsepower equipment such as scrapers, crawler tractors, and off-highway trucks.

NEVES Methodology

NEVES Inventory A estimates relied on state-level PSR data to develop local-level construction equipment populations, and the activity indicator used by EEA in its regression analysis was total construction employment.[1] Initially, EEA attempted to develop separate estimates for road construction equipment and general construction equipment; however, the models developed for these subcategories showed the best statistical fits using total construction employment as the indicator. In addition, the Equipment Manufacturers Institute (EMI) objected to disaggregating equipment according to application because many specific equipment types are used in a number of different industries. Thus, EEA's final analysis grouped the entire construction equipment category together when developing the regression coefficients.

The Inventory B estimates prepared for NEVES were based primarily on recommendations from EMI. For equipment populations, EMI relied on national population estimates that were developed by MacKay & Company under contract to Construction Equipment magazine and the Associates Commercial Corporation.[2] These data were published in a series of articles that appeared in Construction Equipment in 1987, which included information on 16 specific equipment types. EMI's county-level equipment populations were determined by scaling the national populations by known county-to-national sales for each equipment type over a five-year period (1983-1987). EMI developed usage, horsepower, and load factor information from a survey of its member companies that was conducted specifically in support of NEVES. (A total of 33 companies responded to EMI's survey.)

A summary of the Inventory A construction equipment population and activity for the U.S., DC/MD/VA, and the SJVAB is shown in Tables 7-1, 7-2 and 7-3, respectively (Inventory B estimates are listed in Appendix E.) Because of their large numbers and relatively high horsepower, crawler tractors, rubber-tired loaders, and tractors/loaders/backhoes are responsible for roughly one-half of the total activity from the construction equipment category. Other

Table 7-1

NEVES Inventory A Construction Equipment Activity Estimates for the United States

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Asphalt Pavers	15,536	16,824	597,301	111,995	709,297	0.8
Tampers/Rammers	0	29,419	0	9,216	9,216	0.0
Plate Compactors	2,322	145,233	3,383	58,012	61,394	0.1
Concrete Pavers	5,511	0	323,975	0	323,975	0.3
Rollers	36,300	21,999	1,259,405	120,952	1,380,357	1.5
Scrapers	26,700	0	4,918,049	0	4,918,049	5.3
Paving Equipment	43,615	230,810	1,160,099	135,957	1,296,055	1.4
Surfacing Equipment	0	30,833	0	44,827	44,827	0.0
Signal Boards	20,384	1,559	71,110	1,987	73,098	0.1
Trenchers	50,510	27,170	1,186,116	171,280	1,357,396	1.5
Bore/Drill Rigs	7,761	8,501	473,367	32,401	505,768	0.5
Excavators	61,336	18	4,781,386	251	4,781,637	5.2
Concrete/Industrial Saws	135	36,900	2,689	191,723	194,411	0.2
Cement & Mortar Mixers	4,016	232,152	5,476	64,833	70,310	0.1
Cranes	98,357	2,541	5,753,469	23,716	5,777,184	6.2
Graders	70,045	0	5,038,080	0	5,038,080	5.4
Off-Highway Trucks	16,529	0	6,917,672	0	6,917,672	7.5
Crushing/Proc Eqpt	7,207	1,007	599,983	10,892	610,875	0.7
Rough Terrain Forklifts	53,853	2,217	1,710,805	43,655	1,754,460	1.9
Rubber Tired Loaders	209,454	3,433	12,919,561	60,414	12,979,975	14.0
Rubber Tired Dozers	7,757	0	1,332,898	0	1,332,898	1.4
Trctrs/Ldrs/Backhoes	299,265	1,365	12,730,588	31,782	12,762,370	13.8
Crawler Tractors	285,923	0	22,054,701	0	22,054,701	23.8
Skid Steer Loaders	150,054	27,805	2,069,835	120,434	2,190,269	2.4
Off-Highway Tractors	38,921	16,023	4,652,038	0	4,652,038	5.0
Dumpers/Tenders	194	26,136	797	10,166	10,962	0.0
Other Construction Eqpt	11,867	7,506	592,223	165,413	757,635	0.8
Total	1,523,552	869,451	91,155,005	1,409,905	92,564,910	100.0

equipment types that are large contributors to overall construction equipment activity include large earthmoving equipment (e.g., scrapers, excavators) and multi-purpose equipment that is used in many different industries, such as skid steer loaders.

Approach

When investigating activity indicators for a top-down methodology, data on county-level employment or the number of establishments by SIC code have generally been the most obvious choices. Detailed employment data (by SIC code) are readily available from the Department of Commerce, and this information is updated yearly in "County Business Patterns." For industries in which nonroad equipment is likely to be used in the same county that establishments (and employees) are based, this approach will likely result in a reasonably good distribution of national or state equipment populations to the local level. For industries that are very

Table 7-2

NEVES Inventory A Construction Equipment Activity Estimates for the DC/MD/VA Area

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Asphalt Pavers	271	53	10,404	350	10,754	0.7
Tampers/Rammers	0	411	0	129	129	0.0
Plate Compactors	40	2,530	59	1,010	1,069	0.1
Concrete Pavers	96	0	5,643	0	5,643	0.4
Rollers	635	383	22,035	2,107	24,142	1.5
Scrapers	464	0	85,549	0	85,549	5.3
Paving Equipment	760	4,020	20,207	2,368	22,575	1.4
Surfacing Equipment	0	537	0	781	781	0.0
Signal Boards	355	27	1,239	35	1,273	0.1
Trenchers	880	473	20,660	2,983	23,643	1.5
Bore/Drill Rigs	135	148	8,245	564	8,810	0.5
Excavators	1,068	0	83,283	4	83,288	5.2
Concrete/Industrial Saws	2	643	47	3,339	3,386	0.2
Cement & Mortar Mixers	70	4,044	95	1,129	1,225	0.1
Cranes	1,713	44	100,215	413	100,629	6.3
Graders	1,220	0	87,755	0	87,755	5.5
Off-Highway Trucks	288	0	120,494	0	120,494	7.5
Crushing/Proc Eqpt	126	18	10,451	190	10,640	0.7
Rough Terrain Forklifts	938	39	29,799	760	30,560	1.9
Rubber Tired Loaders	3,648	60	225,036	1,052	226,089	14.1
Rubber Tired Dozers	135	0	23,217	0	23,217	1.4
Trctrs/Ldrs/Backhoes	5,213	24	221,745	554	222,298	13.8
Crawler Tractors	4,980	0	384,155	0	384,155	23.9
Skid Steer Loaders	2,614	484	36,053	2,098	38,151	2.4
Off-Highway Tractors	678	0	81,030	0	81,030	5.0
Dumpers/Tenders	3	423	14	165	179	0.0
Other Construction Eqpt	207	19	10,315	423	10,739	0.7
Total	26,540	14,380	1,587,747	20,456	1,608,203	100.0

mobile (such as construction), however, reliance on county employment statistics will not necessarily distribute the equipment to the area where it is actually used. Thus, a shortcoming of the NEVES methodology to allocate equipment to the local level is its reliance on an activity indicator that may not represent the area where the equipment is used.

In investigating alternative methodologies for estimating construction equipment usage at the local level, both top-down and bottom-up approaches were considered. A primary concern in this effort was developing a methodology that would provide a better representation of <u>where</u> construction equipment is actually used. Thus, considerable effort was expended in attempts to identify sources of information that might offer a means of improving local estimates of equipment usage. This search primarily focused on fuel usage and equipment usage. For fuel usage information, a number of federal and state agencies were contacted. As discussed below, these included the Department of Energy (DOE), the Department of Transportation (DOT), the Department of Commerce (DOC), the California Energy Commission, and the California Department of Transportation (CalTrans). It was felt that if detailed

Table 7-3

NEVES Inventory A Construction Equipment Activity Estimates for the San Joaquin Valley Air Basin

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Asphalt Pavers	141	27	6,610	223	6,833	0.7
Tampers/Rammers	0	215	0	86	86	0.0
Plate Compactors	21	1,321	44	748	791	0.1
Concrete Pavers	50	0	3,710	0	3,710	0.4
Rollers	332	200	13,697	1,310	15,006	1.5
Scrapers	243	0	54,594	0	54,594	5.4
Paving Equipment	397	2,099	14,758	1,730	16,487	1.6
Surfacing Equipment	0	280	0	553	553	0.1
Signal Boards	185	14	877	25	902	0.1
Trenchers	459	247	13,239	1,912	15,151	1.5
Bore/Drill Rigs	71	77	5,981	409	6,390	0.6
Excavators	558	0	51,982	3	51,984	5.1
Concrete/Industrial Saws	1	336	30	2,117	2,147	0.2
Cement & Mortar Mixers	37	2,111	67	798	866	0.1
Cranes	895	23	59,543	245	59,788	5.9
Graders	637	0	54,873	0	54,873	5.4
Off-Highway Trucks	150	0	77,009	0	77,009	7.6
Crushing/Proc Eqpt	66	9	7,441	135	7,576	0.7
Rough Terrain Forklifts	490	20	20,806	531	21,337	2.1
Rubber Tired Loaders	1,905	31	142,234	665	142,900	14.0
Rubber Tired Dozers	71	0	15,053	0	15,053	1.5
Trctrs/Ldrs/Backhoes	2,722	12	132,132	330	132,462	13.0
Crawler Tractors	2,600	0	248,230	0	248,230	24.4
Skid Steer Loaders	1,365	253	26,560	1,545	28,106	2.8
Off-Highway Tractors	354	0	47,992	0	47,992	4.7
Dumpers/Tenders	2	221	10	121	131	0.0
Other Construction Eqpt	108	10	6,594	271	6,864	0.7
Total	13,857	7,508	1,004,065	13,756	1,017,821	100.0

construction industry fuel records were available on a county basis, local-level equipment usage and emissions could be estimated.

In addition to fuel usage information, a number of construction industry representatives were also asked about data related to equipment usage by type of activity or dollar value of construction work. Because a comprehensive listing of construction project valuation is published by McGraw-Hill for every urban area in the U.S.,[3] it was felt that a bottom-up methodology could be developed if information on equipment usage as a function of construction valuation could also be obtained. Among those contacted were a variety of professional associations (e.g., American Institute of Constructors, Associated General Contractors, International Union of Operating Engineers), private contractors, Data Resources Institute, and firms specializing in construction-estimating software.

The above contacts were made with the intention of developing a bottom-up methodology. Information found in this search, however, could also be used in developing alternative top-down procedures. The most obvious example of this is McGraw-Hill's "Dodge Construction Potentials Bulletin" (DCPB) cited above.[3] As detailed below, this information provided an alternative to construction employment in allocating national and state equipment populations to the local level.

Methodology and Data Sources

Sources of Fuel Use Information - Fuel usage was initially considered a parameter that should be available in reasonably detailed form. The most likely source of fuel usage information, at least at the national level, appeared to be DOE. Numerous calls were placed to various divisions of DOE, including the Energy Information Administration. Although state-level statistics on fuel consumption are available in several DOE publications,[4-6] none of these documents contain information in sufficient detail to develop equipment usage estimates from the data. Furthermore, conversations with DOE staff did not reveal any unpublished information that might be used in such estimates.

In addition to DOE, DOT was contacted to determine the availability of fuel consumption data. Although state-level statistics on gasoline consumption in the construction industry are published in DOT's "Highway Statistics" series,[7] there are no sources of these data at the county level. Furthermore, conversations with DOT staff indicated that these data are compiled from state tax refund information, which is likely not to include all of the fuel used off-highway (e.g., if applications for refunds are not submitted for all qualifying fuel purchases, the state tax refund records would underestimate the quantity of fuel sold for off-highway purposes).

In conversations with the above agencies, it was discovered that the Commerce Department may have developed fuel use estimates through its various census activities; thus, DOC was also contacted. This led to two documents published by the Census Bureau: "Census of Mineral Industries"[8] and "Census of Construction Industries"[9], both of which were based on 1987 surveys of these industries. Although the mineral industries census contains gasoline and fuel oil purchases by state and by two-digit SIC code, it is impossible to distinguish between on-highway and off-highway use. Additionally, the fuel oil purchases do not distinguish between Diesel fuel that could be used to power nonroad equipment and other grades of distillate fuel oil. Thus, this information cannot be used in estimating equipment usage in the mining industries (where some equipment types in the "Construction" category are used).

The "Census of Construction Industries" provides a considerable amount of information about the construction industry. There are two basic components of this census: a geographic area series that lists information for each state (and selected metropolitan areas within each state), and an industry series that compiles information for specific industries (by 4-digit SIC code). Included in the geographic area series is a category entitled "Cost of materials, components, supplies, and fuels." For each state (and for selected metropolitan areas within each state), data for this category are compiled by 4-digit SIC code. If a means of separating nonroad equipment fuel usage from this more generic materials category could be developed, it would be possible to arrive at an estimate of fuel cost (and fuel usage) for certain metropolitan areas, at least for the year in which the census was conducted (which is every five years for the Census of Construction Industries).

Within each SIC code, the industry series contains a detailed breakdown of the materials, components, supplies, and fuels category, including an estimate of gasoline and Diesel fuel used on- and off-highway. This information, however, is not area-specific; it is compiled for the nation as a whole. Nonetheless, it is interesting to look at a summary of the off-highway fuel component for some selected SIC codes as shown in Table 7-4. (A more complete compilation of materials, components, supplies, and fuels for all 27 SIC codes included in the construction census is contained in Appendix F.) The trends shown in the table indicate that for the more equipment-intensive activities, fuel costs comprise a larger share of the overall cost of construction. This makes intuitive sense, and was not unexpected.

Table 7-4

Off-Highway Fuel Cost Per Million Dollars Valuation by SIC Code
Based on the 1987 Census of Construction

SIC Code	Off-Hwy Fuel Cost/ $Million Valuation	Off-Hwy Fuel Cost Normalized to SFH
1521 - Single Family Housing (SFH)	$1,200	1.0
1522 - Residential, Non-SFH	$880	0.7
1541 - Industrial Bldgs, Warehouses	$2,030	1.7
1542 - Nonresidential Buildings	$1,690	1.4
1611 - Highway & Street Construction	$17,450	14.5
1622 - Bridges, Tunnels, Elevated Hwys	$8,030	6.7
1629 - Hvy Construction, Other	$14,110	11.7
1794 - Excavation Work	$25,210	20.9
Average Over All Construction SIC Codes	$4,370	3.6

The information contained in Appendix F (from which Table 7-4 was derived) could be used in conjunction with data from the geographic area series to estimate total off-highway fuel costs for a state or metropolitan area. Making assumptions about fuel costs and the Diesel/gasoline sales split would then allow an estimate of the overall fuel usage related to construction activity for 1987. Because this approach would not be valid for the years between censuses, however, and because DOC staff indicated that less confidence is placed in the fuel usage data than many of the other figures compiled in the census,[10] such an approach is not recommended for developing a general methodology to estimate construction equipment activity.

In addition to federal agencies, several California state agencies were contacted to determine the availability of fuel consumption information for construction equipment by activity or at a county level. Because CalTrans is responsible for maintaining state highways in California, it was felt that it might keep information on fuel usage for highway and bridge construction; however, conversations with several staff members did not reveal any information of this kind. The California Board of Equalization and the State Controller's Office were contacted to determine the availability of fuel tax refund records. Although records are available on nonroad gasoline refunds, the same concerns expressed by DOT that are discussed above would apply in this case as well. Finally, the California Energy Commission was contacted, but it also had no information on construction equipment fuel usage.

Finally, several industry associations and private firms were solicited for fuel consumption information. In several cases[11-13], the representatives contacted were of the opinion that developing a generalized methodology to estimate fuel usage (or equipment usage) based on permit valuation (or other suitable parameter, such as lane-miles or square footage) would be impossible due to the variability associated with different construction projects. Furthermore, even within a particular type of construction, fuel usage can vary widely depending upon the site preparation requirements. Another potential source for fuel use information that was considered was construction project estimation software packages. Two firms were consulted for details on their products,[13,14] and fuel usage is estimated in one software package. Inputs to this model, however, are very specific in terms of type of equipment and number of hours required. Obviously, this type of information would be impossible to compile for an entire urban area.*

<u>Sources of Equipment Use Information</u> - Many of the industry associations contacted for fuel consumption information were also asked about guidelines for equipment usage. In general, the response was the same as that received above (i.e., because of the highly variable nature of

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* In a study performed for CARB,[15] KVB developed a methodology that related cubic yards of earth moved to fuel usage. (The data on earth moved came from construction permits.) However, there appear to be significant data gaps (i.e., not all areas have data on earth moved) when applying this methodology and extrapolations are necessary. Thus, no effort was directed at refining this approach.

construction projects, it is not possible to predict equipment usage based on a general parameter of construction activity). A listing of the associations contacted is contained in Table 7-5.

Table 7-5

Industry Associations Solicited for Information Related to Construction Equipment Activity

American Society of Professional Estimators
Building Research Board
Construction Industry Research Board
American Institute of Constructors
International Union of Operating Engineers
Associated General Contractors
National Joint Heavy and Highway Construction Committee/ Construction Industry Information Network

Alternative Activity Indicators - As outlined above, because construction work is often performed outside the county in which a firm is based for a top-down approach, it is important to choose an activity indicator that places the equipment in the area where it is used. Therefore, rather than using county-level construction employment, the DCPB cited above appears to be a more appropriate choice. This document is published monthly and contains various statistics on contracts for new, addition, and major alteration projects. Each state (and all urban areas within each state) is represented.* The statistics reported in this document include (1) the number of projects, the square footage, and the value of non-residential and residential building; and (2) the number of projects and the value of non-building construction projects (e.g., streets and highways, dams and reservoirs, bridges, water supply systems, etc.), although the non-building projects are not reported by urban area. The data are compiled for the current month, the current year, and the previous year, and two-year trends on a regional basis are included.

Although the DCPB is copyrighted, Sierra obtained permission to include a sample copy in this report, which is contained in Appendix G. The cost of the DCPB is variable, and depends upon the following:

- Whether each community purchases data individually or EPA purchases the data and disseminates the information to local areas. Volume discounts are available for purchases on a

* Although every county of every state is not represented in DCPB, the coverage is reasonably complete. For example, summing the non-residential building valuation for the individual metropolitan areas in California resulted in 97 percent of the total California non-residential valuation listed in the DCPB.

national level, and these discounts would likely apply if EPA served as a central data base manager for this information.

- Many federal, state, and local agencies already purchase this information. The extent to which this information is currently available to EPA and/or local communities (including licensing limits under existing contracts) would also influence the cost of the data.

- The media upon which the data are supplied (i.e., paper or electronic form) also impacts the cost of the data. If EPA purchased this data, the electronic data base form is highly recommended.

Once the above parameters are defined, EPA can request the preparation of a formal price quotation.

Temporal Usage Patterns - Appendix L of NEVES[16] included a discussion of seasonal adjustments to the annual emissions inventories calculated in that work. For construction equipment, the seasonal adjustments were based on assumptions reported by Hare and Springer[17] in their 1973 study of nonroad vehicle emissions. As an alternative to the information cited above, the 1987 Census of Construction[9] contains data on the hours worked by construction workers by quarter. This information is summarized in Table 7-6 for the U.S. as a whole and for several selected states. As seen, there is a slight decrease in activity in the colder months for the more northern states, but the decrease is not as significant as might be expected. The same information was also compiled for heavy construction only (i.e., SIC 16), which showed a more substantial decrease in wintertime activity.

Table 7-6

Hours Worked by Construction Workers by Quarter for Selected States[9]

Area	Hours Worked by Construction Workers (Percent)			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
U.S.	22	25	27	25
Maryland	22	25	27	26
Virginia	22	25	27	25
California	23	25	27	25
Florida	23	25	26	26
Alaska	20	26	31	23

Sample Calculations

Bottom-Up - Although considerable effort was expended in attempting to identify sources of information that could be used to develop a bottom-up methodology, no suitable data were obtained. Nonetheless, the data reported in Table 7-4 were used in conjunction with local-level statistics on total construction valuation to arrive at an average expenditure for off-highway gasoline and Diesel fuel for the SJVAB. From the DCPB,[3] the total construction valuation for the SJVAB (for the year ending August 1992) is $1,921.8 million. From Table 7-4, the average off-highway fuel expenditures for all SIC codes included in the construction census[9] is $4370 per $1 million valuation. Multiplying these figures results in a total expenditure of $8.4 million, or roughly 15 million gallons of fuel (assuming an average 1987 pre-tax price (refiner to end user) of $0.55 per gallon for No. 2 Diesel fuel, as reported by DOE[4]).

For comparison purposes, the Inventory A estimates of bhp-hr/yr summarized in Table 7-3 can be converted to gallons per year using conversion factors recommended by Southwest Research Institute in a recent report prepared for EPA.[18] (Using the values of 7.1 lb/gal and 0.4 lb/bhp-hr results in a conversion factor of 0.056 gal/bhp-hr for Diesel-fueled engines.) This analysis resulted in a total of 57 million gallons of fuel being used for nonroad construction equipment in the SJVAB, which represents a four-fold increase over the estimate prepared with fuel expenditure data from the construction census. Although some of the equipment types included in the NEVES definition of construction equipment are used in other applications (e.g., mining, agriculture), clearly such a large difference in estimates cannot be explained by equipment usage not included in construction activities. Because DOC staff indicated that less confidence is placed in the off-highway fuel expenditure data than other data reported in the census, and because there is no way to separate gasoline and Diesel usage, no further attempts were made to use these data to estimate construction equipment activity.

Top-Down - As discussed previously, it is important for activity indicators used in allocating equipment populations to the local level to be representative of where the equipment is used. For construction equipment, the best source of such information identified in this work is the DCPB.[3] Thus, the sample calculations presented below have made use of this information.

Another consideration to be made in constructing a top-down methodology is whether to use a regression technique or the more simple scaling of national-level equipment population data (accomplished by applying the following ratio to the national equipment population: local-level value of the chosen activity indicator/national value of the activity indicator). As discussed previously, for cases in which little confidence is placed in the state-level population data (which form the basis of the regression analysis), it is more appropriate to use the scaling approach. For equipment that is inherently mobile and can move freely from state to state (such as construction equipment), it can also be argued that a scaling approach is more appropriate. Thus, both approaches are presented below.

A regression model was formulated in which state-level total construction valuation data reported in DCPB (sum of non-residential, residential, and non-building construction) for the 23 states included in NEVES served as the independent variable, and PSR state-level equipment populations served as the dependent variable. The results of this regression analysis are summarized in Table 7-7. (Although regressions were attempted with non-residential, residential, and non-building construction valuation independently, the best statistical results were obtained when using total construction valuation.)

As seen in Table 7-7, the statistics resulting from the use of construction valuation as the independent variable indicate a good correlation with equipment population, with an R-square value of 0.89. These results were used with the local-level construction valuation data to calculate local-level equipment populations for the DC/MD/VA nonattainment area and the SJVAB. (Because the t-statistic indicates that the intercept term is not significantly different from zero, the model was rerun with no intercept prior to calculating populations. This resulted in a change in slope to 15.525 which was used in the

Table 7-7

Regression Model Using Construction Equipment Population as the Dependent Variable and Total Construction Valuation as the Independent Variable

DEP VARIABLE: CON_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	101237642787	101237642787	167.603	0.0001
ERROR	21	12684715174	604034055.90		
C TOTAL	22	113922357961			

ROOT MSE	24577.1	R-SQUARE	0.8887
DEP MEAN	76879.83	ADJ R-SQ	0.8834
C.V.	31.96821		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-10514.5	8475.44193	-1.241	0.2284
TOT_CON	1	16.80812764	1.29831190	12.946	0.0001

MODEL: CON_POP = a*(TOT_CON) + b
CON_POP = CONSTRUCTION EQUIPMENT POPULATION
TOT_CON = CONSTRUCTION VALUATION (MILLION $)
a = 16.808
b = -10,515

ensuing calculations; the summary statistics are contained in Appendix C.) Since the DCPB does not report the non-building valuation (e.g., highways, bridges, etc.) for each metropolitan area, it was first necessary to estimate the local-level non-building valuation from the state-level statistics. This was accomplished by assuming the same relative percentage of non-building valuation (compared to the sum of non-residential and residential construction) for the metropolitan area and the state. Data used in this calculation for the SJVAB are summarized in Table 7-8.

Table 7-8

Construction Valuation Reported in DCPB[3] for Communities in the San Joaquin Valley Air Basin*

Metropolitan Area	Construction Valuation (Million $)		
	Non-Residential	Residential	Non-Building
Bakersfield	178.8	256.2	NR**
Fresno	135.0	274.9	NR
Merced	10.7	78.0	NR
Modesto	59.3	141.8	NR
Stockton	75.9	168.7	NR
Visalia-Tulare	40.9	111.1	NR
SJVAB	500.6	1,030.7	390.5
California	6,691.8	8,120.7	3,777.2

* Shaded cell represents estimated parameter.
** NR: Not reported.

After the total construction valuation was determined for the DC/MD/VA area and the SJVAB, construction equipment populations were estimated utilizing the regression model results. Table 7-9 shows the resulting estimates, and Table 7-10 compares these results with the equipment populations estimated for Inventories A and B from NEVES.* As seen, the results from Inventory A and this study are very similar for the

* Note that a simple scaling approach utilizing the DCPB data and Inventory A equipment populations results in an equipment population of 46,760 for DC/MD/VA and 27,800 for the SJV. These estimates are both higher than Inventory A and Inventory B equipment populations, which are shown in Table 7-10.

Table 7-9

Construction Equipment Population Estimates Utilizing DCPB Construction Valuation (in Million $) as the Activity Indicator

Nonattainment Community	Const. Valuation	Estimated Eqp. Pop.	PSR/Est. Pop.*	Final Eqp. Pop.
DC/MD/VA	3231.8	50,174	0.815	40,892
SJVAB	1921.8	29,836	1.07	31,924

* See footnote on Table 5-5.

Table 7-10

Comparison of Equipment Population Estimates for DC/MD/VA and the SJVAB NEVES Inventory A and Inventory B vs. This Study

Nonattainment Area	Total Construction Equipment Populations		
	NEVES Inventory A	NEVES Inventory B	This Study
DC/MD/VA	40,920	31,800	40,892
SJVAB	21,365	16,272	31,924

DC/MD/VA area, while there is considerable deviation for the SJVAB. (Significantly lower populations are observed in the Inventory B estimates for both communities.) The increase in equipment population estimates for the SJVAB determined in this work is probably due to the fact that the activity indicator used for Inventory A is based on county construction industry employment, whereas the DCPB lists construction valuation in the metropolitan area where the work is being performed. In the case of the SJVAB, its southern section borders Los Angeles County and its northern section is in reasonable proximity to the San Francisco area, both economic hubs for California. It is quite likely that much of the construction work performed in the SJVAB is actually performed by firms that are located outside of the basin. Thus, the "County Business Patterns" employment data would tend to over-predict construction equipment activity in areas that "export" construction labor and equipment, while areas that "import" these services (such as the SJVAB) would be under-represented if county employment figures were used as the activity indicator.

Another factor that would be useful to include in a top-down methodology is the use of some equipment types classified in the construction category in other fields. For example, off-highway heavy-duty trucks are also used in the mining industries and skid steer loaders are used for numerous different applications (e.g., agriculture, material handling). Although data are not available that indicate the applications for which all equipment types included in the construction category are used, the MacKay study cited earlier[2] contains its estimates of usage by vocation for 16 individual equipment types. These data are summarized in Table 7-11.

Table 7-11

Distribution of Construction Equipment by Vocation as Reported in Construction Equipment Magazine

		Distribution by Vocation (Percent)							
Equipment Type	National Population	Building Contractors	Highway Contractors	Heavy Const.	Materials Producers	Utilities	Mining	Govt.	Other
Crawler Loaders	64,000	24	14	47	3	3	2	4	2
Wheel Loaders	130,000	14	14	28	14	10	9	6	6
Crawler Dozers	115,000	21	13	28	11	10	7	4	6
Crawler Excavators	46,000	21	17	43	5	7	3	2	2
Telescoping Excavators	8,000	24	26	22	0	2	4	15	7
Motor Graders									
Rigid	47,000	19	31	17	7	6	7	9	4
Articulated	27,000	15	37	22	5	4	3	13	1
Wheel Excavators	8,800	17	15	32	0	4	3	24	5
Off-Hwy Haulers									
Rigid Frame	16,600	4	11	6	14	2	60	2	1
Articulated	1,100	9	32	10	12	0	34	3	0
Tractor-Trailer	2,300	10	4	15	24	0	46	1	0
Scrapers									
Conventional	10,100	12	22	39	7	4	7	7	2
Elevated	6,300	19	24	38	5	5	3	4	2
Skid-Steer Loaders*	57,000	10	10	18	**	**	**	**	**
Trenchers									
Chain	38,000	14	10	19	7	37	4	2	7
Wheel	12,500	15	13	26	8	26	2	5	5
Backhoe Loaders	189,000	29	29	10	7	4	7	7	7
Asphalt Pavers	12,000	16	48	17	**	**	**	12	**
Rollers/Compactors									
Drum	37,000	22	33	23	7	2	3	4	6
Rubber	58,000	15	30	24	8	8	2	11	2
Planers/Profilers	1,800	2	59	16	6	5	1	9	2
Concrete Pavers									
Slab	4,800	1	49	44	**	**	**	4	**
Slipform	3,600	2	52	41	**	**	**	4	**
Combination	1,100	5	31	63	**	**	**	1	**

* MacKay estimates that 59 percent of the skid-steer loader population is owned by non-construction industries. The total U.S. machine population was reported as 140,000.

** The remaining equipment population is distributed among these vocations.

There are two approaches that could be taken to account for multi-use characteristics of certain equipment types. First, additional indicators could be included in the regression analysis (i.e., multiple independent variables). This approach, however, is most valid when all equipment types included in the category populations are related to the activity indicators. This could be accomplished for the construction category by using individual equipment type state-level populations (or smaller groups of construction equipment) in the regression analysis. Unfortunately, Sierra did not have access to the PSR data base from which the NEVES category populations were derived, so regressions by individual equipment type could not be attempted.

Although using multiple independent variables in a regression analysis offers a refinement for cases in which an equipment type is used in more than one application, inaccuracies could result if the equipment type is not used to a similar extent in the applications represented by the activity indicators. In those cases, a more traditional scaling of the national-level equipment populations could be performed based on expected usage in various industries. An example of this approach follows.

Table 7-11 lists the distribution by vocation of off-highway haulers as roughly 57 percent mining, 28 percent construction, and 15 percent materials producers (the small percentages in the remaining vocations were combined with construction). Therefore, if statistics on national and county-level mining activity, construction activity, and materials production activity are available, then county-level equipment populations can be estimated. This was done for the SJVAB in which employment data for SIC codes 10 (metal mining), 12 (coal mining), and 14 (nonmetallic minerals) were used to represent equipment engaged in mining;[19] construction valuation from DCPB[3] was used to represent construction; and employment data from SIC code 32 (stone, clay, glass products) were used to represent materials production.[20] The analysis resulted in a total of 93 off-highway trucks being allocated to the SJVAB when the PSR national equipment population was used, which represents a 40 percent reduction compared to the NEVES Inventory A estimates. (This decrease in population is primarily related to the small number of employees engaged in the mining industries represented by SICs 10, 12, and 14. Total mining employment was not used in this analysis because most of California's mining employment is related to oil and gas extraction (SIC 13) which would not be expected to have a significant population of heavy-duty off-highway trucks.)

Additional Considerations

Because the DCPB data used for allocating construction equipment to the local level do not contain local statistics on non-building construction, this parameter had to be estimated from the state-level data. Although some level of uncertainty was introduced into the calculation by taking this approach, it was felt that this method was superior to simply ignoring the non-building construction. Furthermore, basing the local-level non-building estimate on the sum of residential and non-residential construction valuation has merit since the non-building sector (particularly highways and bridges) is likely to be related to other types of construction in an area.

Although little attention was given to annual hourly usage in this section, it is obviously an important parameter in estimating total equipment activity. There appear to be three sources for this information: PSR, a recent update to MacKay's 1987 study of construction equipment populations[20] (although the level of detail of the annual use estimates is unclear*), and EMI. It is difficult to determine which data source is most reliable without considerable background on how the estimates were derived. It appears, however, that the PSR and MacKay data were developed based on surveys of end users, while the EMI data came from a survey of its members (i.e., equipment manufacturers).

Recommendations

Although development of a generalized bottom-up methodology to estimate local-level construction equipment activity appears to be infeasible, various improvements to the NEVES top-down approach can be easily implemented. The primary change that would result in improved local-level population estimates is the use of construction valuation data in McGraw-Hill's "Dodge Construction Potentials Bulletin" for the activity indicator. This information is more accurate in assigning equipment to the area in which it is used than are the county employment statistics, and it is updated monthly.

In the long term, consideration should be given to using multiple activity indicators for equipment that is used for several applications. A missing element of this approach, however, is data indicating the fields in which many of the equipment types are used. Although MacKay has compiled some information of this kind, their data are by no means complete. Any future proposed survey work related to nonroad equipment usage should include questions related to the industry in which the equipment is used.

References for Section 7

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3. "Dodge Construction Potentials Bulletin," McGraw-Hill, August 1992.

* The update of MacKay's 1987 study was not purchased for this work (its cost is $6,000). Thus, details of the study's exact contents were not obtained.

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8. LIGHT COMMERCIAL EQUIPMENT

The light commercial equipment category consists of equipment powered by engines less than 50 horsepower. Specific equipment types in this category include generator sets, pumps, air compressors, gas compressors, welders, and pressure washers. Although this category consists of equipment powered by smaller engines, the methodologies discussed below can also be utilized to develop local-level equipment usage estimates for similar, higher-horsepower machines.

NEVES Methodology

NEVES Inventory A estimates relied on state-level PSR data to develop local-level construction equipment populations. The activity indicator employed by EEA in its regression analysis was wholesale activity (number of establishments).[1] This indicator was chosen by EEA because of the many different applications for which these equipment types are used. Although this model did not initially meet the statistical criteria established by EEA for an acceptable model (i.e., the R-square was below 0.8), removal of two outliers (New York and Texas) resulted in an R-square of 0.9. Thus, the number of wholesale establishments was retained as the activity indicator. (For this equipment category, Inventory B was the same as Inventory A because industry associations did not provide EPA with alternative population and usage estimates.)

The Inventory A population and usage estimates for light commercial equipment are given in Table 8-1 for the U.S., DC/MD/VA, and the SJVAB. As seen, generator sets make up the majority of this equipment category, followed by welders and pumps. Although the equipment population is substantial, second only to lawn and garden equipment in total numbers, the lower horsepower of this equipment category results in it accounting for only 3.4 percent of the total (gas plus Diesel) bhp-hr/yr attributed to the entire nonroad equipment category.

As with construction equipment, it is unclear if the activity indicator used in NEVES to allocate equipment population to the local level adequately reflects the area in which the equipment is ultimately used. For example, Sierra has recently investigated the light commercial equipment populations for Anchorage, Alaska.[2] In that work, it was discovered that although Anchorage had a fair number of wholesale establishments, much of the light commercial equipment (notably, generator sets) purchased through these businesses ultimately was transported to the North Slope or the "bush." Thus, such equipment would be improperly allocated to the Anchorage area if wholesale establishments were to serve as the activity indicator for distributing the state-level equipment populations to the local level.

Table 8-1

NEVES Inventory A Light Commercial Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Generator Sets	198,391	2,943,286	1,359,748	3,148,256	4,508,005	57.0
Pumps	61,810	651,687	415,542	683,040	1,098,582	13.9
Air Compressors	15,713	176,124	208,181	393,236	601,416	7.6
Gas Compressors	0	436	0	66,708	66,708	0.8
Welders	100,490	350,545	845,171	587,643	1,432,814	18.1
Pressure Washers	3,943	290,959	3,478	192,164	195,642	2.5
Total	380,347	4,413,037	2,832,120	5,071,047	7,903,167	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Generator Sets	1,502	22,279	10,295	23,831	34,125	57.1
Pumps	468	4,933	3,146	5,170	8,317	13.9
Air Compressors	119	1,333	1,577	2,976	4,553	7.6
Gas Compressors	0	3	0	459	459	0.8
Welders	761	2,653	6,400	4,447	10,848	18.1
Pressure Washers	30	2,202	26	1,454	1,481	2.5
Total	2,880	33,403	21,444	38,338	59,782	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Generator Sets	1,253	18,586	7,650	17,795	25,445	47.8
Pumps	390	4,115	3,186	5,227	8,413	15.8
Air Compressors	99	1,112	1,647	3,122	4,769	9.0
Gas Compressors	0	3	0	459	459	0.9
Welders	635	2,214	7,461	5,170	12,631	23.7
Pressure Washers	25	1,837	26	1,454	1,480	2.8
Total	2,402	27,867	19,971	33,227	53,198	100.0

Approach

Based on contacts with Departments of Motor Vehicles and local air pollution control agencies, it was quickly determined that this equipment is generally not registered or permitted in any way. In addition, these equipment types have highly variable use patterns. For example, generator sets may range from emergency back-up to primary power sources. Thus, developing a bottom-up strategy to determine local-level populations and usage was not considered possible. Therefore, efforts were directed at improving the current top-down methodologies for equipment allocation.

Data Sources and Sample Calculations

As discussed in previous sections, NEVES Inventory A relied on regressions by equipment category rather than by individual equipment type when determining local-level equipment populations. Not only does this approach apply the same national-level equipment mix to each nonattainment area, it also assumes that the same activity indicators are applicable to each equipment type in a given category. Although the equipment categories defined by EEA[1] were chosen so that equipment with similar engines, uses, and operating characteristics were grouped together, there are cases in which the same activity indicator(s) are not equally relevant to each equipment type included in a category. This is apparent for several of the equipment types included in the light commercial equipment category (e.g., pressure washers are likely to be used primarily in construction activities, whereas generator sets are used in many different applications), and it will likely result in a less-than-perfect regression analysis, regardless of the activity indicator chosen to distribute the equipment populations to the local level.

Only one equipment type in the light commercial category appears to be used in just a single application: gas compressors. Although the equipment definitions provided in NEVES are not explicit, it is assumed that this equipment type is used in oil and gas field operations to compress natural gas for storage. The most obvious indicator to allocate this equipment type to the local level is oil and gas production. This information can be obtained at the state level from the Energy Information Administration[3]; however, the availability of county-level data for all states is uncertain.[4] (County-level production figures are available for California and the SJVAB from the California Department of Conservation.[5]) Because the population of this equipment type is relatively insignificant (only 436 in the entire U.S., according to PSR[1]), the effort to allocate this equipment type should be minimal. A simple scaling of the national population by the ratio of local to national oil production is adequate.

For the remaining equipment types, there does not appear to be a single activity indicator that entirely describes equipment usage. Furthermore, as discussed above, data on wholesale trade establishments do not necessarily indicate the location in which light commercial equipment is likely to be used. Because most of these equipment types are used at least partially in the construction industry, an alternative activity indicator that appeared logical was total construction valuation. Thus, statistics from the Dodge Construction Potentials Bulletin (DCPB)[6] (described in Section 7) were used in conjunction with PSR state-level equipment population data to develop an alternative regression model. These results are summarized in Table 8-2.

In reviewing the regression results presented in Table 8-2, it is apparent that the R-square statistic is below the 0.8 value recommended by EEA.[1] The poor correlation is being driven, however, primarily by two outliers: Louisiana and Texas. By removing these states from the model and retaining total construction valuation as the independent

Table 8-2

Regression Analysis for Light Commercial Equipment Utilizing
Total Construction Valuation as the Independent Variable

DEP VARIABLE: COMM_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	256621047782	256621047782	40.741	0.0001
ERROR	21	132274749379	6298797589		
C TOTAL	22	388895797162			

ROOT MSE	79364.96	R-SQUARE	0.6599
DEP MEAN	126128.5	ADJ R-SQ	0.6437
C.V.	62.92391		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-13013.6	27369.09684	-0.475	0.6393
TOT_CON	1	26.76051470	4.19253939	6.383	0.0001

MODEL: COMM_POP = a*(TOT_CON) + b
COMM_POP = COMMERCIAL EQUIPMENT POPULATION
TOT_CON = CONSTRUCTION VALUATION (MILLION $)
a = 26.761
b = -13,013

variable, the R-square value improves to 0.89. Based on the statistical criteria followed for NEVES Inventory A, this model is acceptable for determining the local equipment populations.

The above regression model was used to estimate equipment populations for the DC/MD/VA nonattainment area and the SJVAB; however, the slope was first recalculated with the assumption of a zero intercept, which resulted in a slope of 25.173. (The data and regression statistics for this model are in Appendix C.) The resulting equipment populations are summarized in Table 8-3. (The gas/Diesel split and the annual hourly usage are the same as reported in NEVES because there are no other known sources of data for these parameters; thus, only total equipment populations are reported in Table 8-3.) As seen in the table, the estimates for the DC/MD/VA area are reasonably similar when comparing the NEVES estimates to those calculated in this study. On the other hand, the equipment populations generated with construction valuation as the activity indicator resulted in a 50 percent increase over the NEVES estimates which relied on wholesale establishments. This can be explained by considering that the northern and southern portions of the SJVAB are fairly close to the San Francisco and Los Angeles metropolitan areas, respectively. It is likely that a certain percentage of the equipment used in the SJVAB is actually purchased from wholesale establishments in the larger metropolitan areas. Again, this points out the need to choose activity indicators carefully so that equipment is allocated to the area where it is actually used.

Table 8-3

Comparison of Light Commercial Equipment Populations for the DC/MD/VA Nonattainment Area and the SJVAB

Equipment Type	DC/MD/VA		SJVAB	
	NEVES	This Study	NEVES	This Study
Generator Sets	23,781	28,260	19,839	30,122
Pumps	5,401	6,420	4,505	6,843
Air Compressors	1,452	1,725	1,211	1,838
Gas Compressors	3	0	3	39
Welders	3,414	4,057	2,849	4,325
Pressure Washers	2,232	2,652	1,862	2,826
Total	36,283	43,114	30,269	45,993

Additional Considerations

Although a model based solely on total construction valuation makes intuitive sense and meets the aforementioned statistical criteria for acceptability, there was concern about the underprediction of equipment populations for Louisiana and Texas (88,000 and 303,000 units, respectively). It was initially felt that some of the unaccounted equipment population for these states might be related to the oil industry. Therefore, an additional activity indicator that was attempted in a regression model was oil production. (Oil production by state is available from the Energy Information Administration.[3]) The results, summarized in Table 8-4, indicate that the model exhibits very good statistical validity. A subsequent review of oil field operations, however, indicated that small generator sets are not likely to be used, and this regression model is not recommended for allocating light commercial equipment. This analysis reinforces the need to consider how applicable an activity indicator is to equipment usage rather than relying too heavily on favorable regression statistics.

In exploring other potential explanations for the apparent underprediction of state-level equipment populations for Louisiana and Texas, product literature for generator sets and water pumps was consulted to determine the end users that are targeted by manufacturers.[7,8] For smaller generator sets with engines about five horsepower and below (at least for Honda products), the primary focus of the product literature is on recreational uses (e.g., fishing, hunting, camping). On the other hand, construction was cited as a primary application for Honda's larger, heavy-duty models (8 to 20 horsepower).

Table 8-4

Regression Analysis for Light Commercial Equipment Utilizing
Total Construction Valuation and Oil Production as the Independent Variables

DEP VARIABLE: COMM_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	370534210391	185267105195	201.799	0.0001
ERROR	20	18361586771	918079338.54		
C TOTAL	22	388895797162			

ROOT MSE	30299.82	R-SQUARE	0.9528
DEP MEAN	126128.5	ADJ R-SQ	0.9481
C.V.	24.02298		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	16335.76794	10776.01149	1.516	0.1452
TOT_CON	1	15.31559258	1.90201628	8.052	0.0001
OIL_PROD	1	0.55632647	0.04994395	11.139	0.0001

MODEL: COMM_POP = a*(TOT_CON) + b*(OIL_PROD) + c
COMM_POP = COMMERCIAL EQUIPMENT POPULATION
TOT_CON = CONSTRUCTION VALUATION (MILLION $)
OIL_PROD = OIL PRODICTION (1000 BARRELS)
a = 15.316
b = 0.556
c = 16,336

Water pump applications cited by Honda include agriculture (i.e., irrigation), construction, emergency flood situations, boating, and personal home use.

Because all of the equipment types included in this equipment category are used at least partially in the construction industry (with the exception of gas compressors, which have a negligible population and should be allocated using natural gas or oil production), it is important to use construction valuation as an activity indicator to distribute state or national populations to the local level. However, for multi-purpose equipment types, more accurate local-level population estimates could be obtained by determining the fraction of the equipment population that is used in various other activities. Ideally, this would be accomplished through a survey of end users; however, a rough estimate for generator sets is possible by assuming usage by horsepower range. An example of this follows.

Based on the product literature cited above, generator sets could be stratified into two groups: above and below 5 horsepower. Although such an analysis was not performed in this work (because Sierra did not have access to the PSR data base purchased for NEVES), it is possible to obtain population by horsepower rating through PSR's data base. Generator sets below 5 horsepower would be allocated to the local level using an appropriate activity indicator that represents recreational usage, while those above 5 horsepower would be allocated to the local level using construction activity. Although this approach is not as accurate as using survey results to determine typical usage, it would be an improvement over a method that relies only on construction activity for all sizes of generator sets.

Recommendations

Because it is unlikely that a reliable bottom-up methodology could be developed for this equipment category, recommendations for improvements to inventory techniques are limited to top-down methodologies. In the short term, Sierra recommends that construction valuation (based on DCPB[6]) be used as the activity indicator in a regression model rather than wholesale establishments as utilized in NEVES. Construction valuation will allow a better representation of where the equipment is used, although some of the equipment types in the light commercial category are used in more than just the construction industry.

In the long term, several additional improvements can be made in allocating light commercial equipment to the local level. First, equipment types should be considered independently when performing regression analyses with state-level data. If EPA plans future purchases of PSR data bases, state-level equipment populations can be compiled for each equipment type. With these data, a mix of activity indicators can be used for each equipment type. For example, generator sets should be allocated using a construction indicator and a recreation indicator, while pumps should be allocated using construction and agriculture activity indicators.

Data related to the mix of industries (or activities) in which individual equipment types are used could also be utilized to improve local-level equipment populations, provided activity indicators linking equipment population to the industry or activity can be acquired. Because information on equipment usage patterns is not currently available, the compilation of such data would likely require a survey of end users.

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5. "77th Annual Report of the State Oil and Gas Supervisor. 1991," California Department of Conservation, 1992.

6. "Dodge Construction Potentials Bulletin," McGraw-Hill, August 1992.

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8. "Honda Water Pumps," American Honda Motor Co., Inc., 1991.

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9. INDUSTRIAL EQUIPMENT

The industrial equipment category includes primarily material handling equipment used in manufacturing and construction activities. Specific equipment types included in this category are aerial lifts, forklifts, sweepers/scrubbers, "other" general industrial equipment (e.g., abrasive blasting equipment, industrial blowers/vacuums), and "other" material handling equipment (e.g., conveyors).

NEVES Methodology

NEVES Inventory A estimates utilized state-level PSR data in a regression analysis to develop local-level industrial equipment populations, and the activity indicator used by EEA in the model was the number of employees engaged in manufacturing.[1] The regression statistics were very favorable, with an R-square value of 0.93, and the use of manufacturing employment as the activity indicator makes intuitive sense.

Data from only two of the five equipment types in this category were revised for Inventory B as a result of input from industry associations. First, the annual usage, the horsepower, and the load factor for aerial lifts were modified based on data received from the Equipment Manufacturers Institute (EMI), although EMI did not provide alternative population estimates. Second, the forklift population was significantly revised, particularly the Diesel/gasoline split (LPG and CNG equipment are included in the gasoline population), based on input from the Industrial Truck Association (ITA). ITA also provided alternative estimates for forklift annual hourly usage, while the horsepower and load factor remained unchanged from Inventory A.

The activity estimates (in bhp-hr/yr) developed in Inventories A and B are summarized in Tables 9-1 and 9-2, respectively, for the U.S., the DC/MD/VA metropolitan area, and the SJVAB. As seen in the tables, including industry estimates in the calculations caused a net decrease in total activity for this category by roughly 30 percent. This decrease is attributed to the substantial decrease in forklift activity that resulted from a lower annual usage (about one-half the Inventory A estimate) and a higher percentage of gasoline machines (which have a corresponding lower horsepower rating). Also of interest in the tables is the net increase in relative activity for aerial lifts when using industry data. This change is caused by a much higher annual hourly usage reported by EMI compared to PSR's estimate (a seven-fold increase), while the equipment population remained the same between the two inventories.

Table 9-1

NEVES Inventory A Industrial Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aerial Lifts	12,310	28,388	81,326	147,613	228,939	1.3
Forklifts	160,583	182,482	6,425,616	5,773,475	12,199,091	71.9
Sweepers/Scrubbers	36,977	25,892	3,034,120	377,115	3,411,235	20.1
Other General Industrial	18,366	23,724	813,813	160,649	974,462	5.7
Other Material Handling	5,258	2,036	139,805	20,472	160,277	0.9
Total	233,494	262,522	10,494,680	6,479,325	16,974,005	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aerial Lifts	60	138	396	718	1,114	1.3
Forklifts	782	887	31,291	28,063	59,355	71.8
Sweepers/Scrubbers	180	126	14,770	1,835	16,605	20.1
Other General Industrial	90	116	3,988	786	4,773	5.8
Other Material Handling	26	10	691	101	792	1.0
Total	1,138	1,277	51,137	31,502	82,639	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aerial Lifts	67	154	529	956	1,485	1.5
Forklifts	868	986	37,110	33,341	70,451	71.2
Sweepers/Scrubbers	200	140	17,057	2,121	19,178	19.4
Other General Industrial	99	128	5,786	1,143	6,929	7.0
Other Material Handling	28	11	834	124	958	1.0
Total	1,262	1,419	61,316	37,685	99,001	100.0

Approach

As with the light commercial equipment category, developing a bottom-up methodology to estimate local-level activity from industrial equipment appears to be an impossible task. The equipment types included in this category are not registered or permitted in any way, and because they are used in a multitude of industries, it is difficult to develop generalized usage guidelines upon which to base a bottom-up approach. Therefore, the bulk of the effort for this section was devoted to investigating potential improvements to the top-down methodology developed for NEVES.

Data Sources and Sample Calculations

Several of the equipment types included in this category at first appeared to be associated with warehouse activity. Conversations with

Table 9-2

NEVES Inventory B Industrial Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aerial Lifts	12,310	28,388	535,784	1,062,908	1,598,692	13.2
Forklifts	47,068	311,884	996,194	4,930,886	5,927,080	49.1
Sweepers/Scrubbers	36,977	25,892	3,034,120	377,115	3,411,235	28.3
Other General Industrial	18,366	23,724	813,813	160,649	974,462	8.1
Other Material Handling	5,258	2,036	139,805	20,472	160,277	1.3
Total	119,979	391,924	5,519,715	6,552,031	12,071,746	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aerial Lifts	60	138	2,611	5,167	7,778	10.5
Forklifts	338	2,342	7,154	37,027	44,181	59.6
Sweepers/Scrubbers	180	126	14,770	1,835	16,605	22.4
Other General Industrial	90	116	3,988	786	4,773	6.4
Other Material Handling	26	10	691	101	792	1.1
Total	694	2,732	29,214	44,915	74,130	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Aerial Lifts	67	154	2,658	5,256	7,914	11.5
Forklifts	886	948	18,752	14,988	33,740	49.1
Sweepers/Scrubbers	200	140	17,057	2,121	19,178	27.9
Other General Industrial	99	128	5,786	1,143	6,929	10.1
Other Material Handling	28	11	834	124	958	1.4
Total	1,280	1,381	45,088	23,631	68,719	100.0

warehouse managers, however, indicated that most facilities are enclosed and therefore do not use equipment with internal combustion engines <u>inside</u> because of problems with potential OSHA violations.[2] Many of these facilities rely on electrically driven equipment with internal combustion equipment backups when necessary. Thus, it is reasonable to assume that most of this equipment is used in construction activity (e.g., large job sites, delivery of materials to jobsites, etc.), manufacturing, and open warehouses.

The activity indicator chosen by EEA in its regression analysis (i.e., manufacturing employment) resulted in very favorable statistics and makes intuitive sense when allocating this equipment to the local level. As alluded to above, however, not all of the equipment in this category would be expected to be operated solely in the manufacturing industries. Additionally, as discussed in Section 8, inaccuracies in allocating equipment can be introduced if some of the equipment types within a category are used in industries that are not associated with the activity indicator. For example, aerial lifts and forklifts are used in construction as well as manufacturing. Thus, a model that includes both manufacturing and construction indicators would likely provide more accurate local-level estimates for these two equipment types.

The above discussion points out the desirability of allocating equipment types individually (or in smaller groups) to local areas rather than relying on larger equipment groupings. However, local air quality planners would have to balance a more detailed approach with the available resources needed to perform the analysis. In the case of industrial equipment, the inclusion of a construction indicator for some of the equipment types would not result in much additional effort, particularly since construction statistics are necessary for the construction equipment category. With this in mind, the regression analysis performed for NEVES was reevaluated using both manufacturing employment and construction valuation as activity indicators.

Table 9-3 summarizes the regression results utilizing PSR state-level equipment populations as the dependent variable, with manufacturing employment (from the Department of Commerce's "County Business Patterns"[3]) and construction valuation (from McGraw-Hill's "Dodge Construction Potentials Bulletin"[4]) serving as independent variables. As seen in the table, the R-square value is favorable at 0.94 and the condition numbers indicate that collinearity is not a problem; however, the t-statistic for construction valuation indicates that the coefficient is significant at only about an 80 percent confidence level. It is possible that the use of total industrial equipment populations, which include a portion of equipment not related to construction (i.e., sweepers/scrubbers, "other" general industrial equipment, and "other" material handling equipment), may be influencing the poor t-statistic for the construction coefficient.

Although poor statistics resulted from the use of both construction valuation and manufacturing employment in the regression analysis, the aerial lift and forklift populations for the DC/MD/VA nonattainment area and the SJVAB were estimated using the results of this model. These populations are shown in Table 9-4. As seen, the results for the DC/MD/VA area are essentially the same for both models (i.e., manufacturing employment alone versus manufacturing employment and construction valuation), while the SJVAB equipment population estimates decrease by about 10 percent when construction valuation is included in the regression model. Also shown in the table are results for NEVES Inventory B, which indicate a substantially higher forklift population for the DC/MD/VA region and an estimate similar to Inventory A for the SJVAB.

Additional Considerations

As discussed above, combining equipment types into a single category prior to performing regressions and allocating equipment to the local level introduces uncertainty when a portion of the equipment is also used for applications that are not associated with the chosen indicator.

Table 9-3

Industrial Equipment Regression Results with Total Construction Valuation and Manufacturing Employment as Independent Variables

DEP VARIABLE: IND_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	2223666886	1111833443	156.074	0.0001
ERROR	20	142474751.15	7123737.56		
C TOTAL	22	2366141637			

ROOT MSE	2669.033	R-SQUARE	0.9398
DEP MEAN	12189.17	ADJ R-SQ	0.9338
C.V.	21.89675		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-687.942	930.38319149	-0.739	0.4682
TOT_CON	1	0.44009757	0.30738663	1.432	0.1677
MFR_EMP	1	0.01754764	0.002578607	6.805	0.0001

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP INTERCEP	VAR PROP TOT_CON	VAR PROP MFR_EMP
1	2.698238	1.000000	0.0402	0.0100	0.0102
2	0.260361	3.219233	0.9568	0.0414	0.0500
3	0.0414013	8.072964	0.0029	0.9486	0.9398

MODEL: IND_POP = a*(TOT_CON) + b*(MFR_EMP) + c
IND_POP = INDUSTRIAL EQUIPMENT POPULATION
TOT_CON = CONSTRUCTION VALUATION (MILLION $)
MFR_EMP = MANUFACTURING EMPLOYMENT
a = 0.440
b = 0.0175
c = -688

Table 9-4

Comparison of Aerial Lift and Forklift Population Estimates Using Manufacturing Employment Only vs. Manufacturing Employment and Construction Valuation as Activity Indicators

	Manufacturing Employment*		Mfr. Emp. & Const. Valuation		Inventory B	
Equipment	DC/MD/VA	SJVAB	DC/MD/VA	SJVAB	DC/MD/VA	SJVAB
Aerial Lifts	198	221	201	197	198	221
Forklifts	1,669	1,854	1,690	1,659	2,680	1,834

* Represents Inventory A population.

Although an attempt was made to account for aerial lifts and forklifts used in construction as well as the manufacturing industries, the state-level data upon which the analysis was based included equipment that is not used in construction. It is unclear if this contributed to the unfavorable statistics resulting from this model, and it was not possible to develop state-level populations only for aerial lifts and forklifts because Sierra does not have access to the PSR data base used in the development of NEVES Inventory A.

Although the regression technique developed by EEA for NEVES results in improved local-level equipment activity estimates for most equipment categories (provided the activity indicator(s) are chosen with care), imbedded in this methodology is the assumption that the state-level equipment populations used in the regressions are valid. Because PSR employs its own chosen activity indicators to allocate national equipment populations to the state level for each equipment type, there are likely to be instances in which the state-level populations are in error. Such an occurrence could result in a statistically insignificant relationship between the state population and the activity indicator. EEA recognized that this could occur, and in such cases recommended an alternative methodology to allocate national populations to the county level based on a simple scaling of the national equipment population (i.e., the national population is multiplied by the ratio of the county to national activity indicator). This alternative methodology was used in the allocation of logging equipment for NEVES Inventory A.

Because inaccuracies in the state-level industrial equipment populations could also be driving the poor statistical validity of the regression model utilizing manufacturing employment <u>and</u> construction valuation, utilization of the above alternative allocation methodology should be considered. To apply this approach, however, the fraction of this equipment used in manufacturing versus construction would have to be known. Unfortunately, no sources of such information were identified in this work. Alternatively, consideration should be given to the use of industry-supplied data to apportion forklifts in the communities for which data are available.

Recommendations

Although the regression analysis including both manufacturing employment and construction valuation resulted in statistics that indicated the construction valuation coefficient to be significant only at an 80 percent level, some means to account for construction usage of aerial lifts and forklifts should be considered. Such an approach adds a moderate amount of complexity, but would result in improved equipment population estimates. In the short-term, EPA should consider either: (1) ignoring the poor statistics and proceeding with use of the model for developing local-level population estimates for aerial lifts and forklifts, or (2) utilizing industry information in the communities where data are available.

In the long-term, the above model should be rerun with only the state-level aerial lift and forklift populations, while the remaining equipment types in this category should retain the use of manufacturing employment as the activity indicator. Additionally, survey data to quantify the fractional usage of these equipment types in various applications and industries should be collected. This would allow for a more accurate allocation of equipment to the local level.

References for Section 9

1. "Methodology to Estimate Nonroad Equipment Populations by Nonattainment Areas," Energy and Environmental Analysis, September 1991.

2. Robert Davis, Warehouse Manager, Lionel Toys, Personal Communication, July 1992.

3. "County Business Patterns," U.S. Department of Commerce.

4. "Dodge Construction Potentials Bulletin," McGraw-Hill, August 1992.

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10. AGRICULTURAL EQUIPMENT

Specific nonroad equipment types included in the agricultural equipment category include 2-wheel tractors, agricultural tractors, agricultural mowers, combines, sprayers, balers, larger walk-behind tillers (> 5 HP), swathers, hydro power units, and "other agricultural equipment." Among those items in the "other" category are harvesters, detasslers, and cotton pickers. By far, the great majority of the work performed on a farm is by agricultural tractors. Because they can be equipped with a variety of attachments, agricultural tractors often negate the need for some of the single-purpose, self-propelled equipment listed above such as mowers, sprayers, and swathers.

NEVES Methodology

NEVES Inventory A utilized national PSR data on population and annual hourly usage to develop activity estimates for agricultural equipment. However, EPA chose to deviate from the regression technique suggested by EEA in allocating national equipment populations to the local level. Instead, national equipment populations were scaled by the county to national equipment population ratios contained in the 1987 Census of Agriculture.[1] This approach was taken by EPA because the equipment populations developed from the EEA regression methodology resulted in questionable local-level equipment populations.

The Inventory B estimates developed by EPA are very similar to the Inventory A estimates. The primary difference between the two inventories is that the number of tillers was reduced in Inventory B by about 30 percent because industry felt that many of the higher horsepower tillers are used for lawn and garden applications. In addition to tillers, a slight difference in swather population is observed in the local area inventories.

The results of the analysis are summarized in Tables 10-1 and 10-2 for Inventory A and Inventory B, respectively, on a national basis, for DC/MD/VA, and for the SJV. As mentioned above, agricultural tractors are responsible for a great majority of the activity on farms, accounting for 90 percent of the total bhp-hr. Thus, in any methodology used to develop agricultural activity estimates, it is important to focus on agricultural tractors.

Approach

Because of Sierra's previous experience in developing agricultural emission inventories, it was felt at the outset that a bottom-up

Table 10-1

NEVES Inventory A Agricultural Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
2-Wheel Tractors	0	13,802	0	15,874	15,874	0.0
Agricultural Tractors	2,519,295	5,808	71,030,515	149,123	71,179,638	93.7
Agricultural Mowers	0	16,023	0	14,213	14,213	0.0
Combines	284,854	1,835	3,758,250	18,322	3,776,572	5.0
Sprayers	9,691	72,721	39,229	68,067	107,296	0.1
Balers	4,260	0	17,004	0	17,004	0.0
Tillers > 5 HP	78	783,102	103	233,521	233,624	0.3
Swathers	50,032	32,857	193,476	137,642	331,118	0.4
Hydro Power Units	2,366	15,042	27,625	46,700	74,325	0.1
Other Ag Equipment	18,042	6,403	173,079	20,725	193,804	0.3
Total	2,888,618	947,593	75,239,281	704,187	75,943,467	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
2-Wheel Tractors	0	35	0	40	40	0.0
Agricultural Tractors	6,385	15	180,023	385	180,408	93.7
Agricultural Mowers	0	41	0	36	36	0.0
Combines	722	5	9,526	50	9,576	5.0
Sprayers	25	184	117	224	341	0.2
Balers	11	0	44	0	44	0.0
Tillers > 5 HP	0	1,985	0	592	592	0.3
Swathers	127	83	491	348	839	0.4
Hydro Power Units	6	38	70	118	188	0.1
Other Ag Equipment	46	16	441	52	493	0.3
Total	7,322	2,402	190,712	1,845	192,557	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
2-Wheel Tractors	0	189	0	272	272	0.0
Agricultural Tractors	34,454	79	1,257,406	2,625	1,260,031	93.0
Agricultural Mowers	0	219	0	208	208	0.0
Combines	3,896	25	75,860	371	76,231	5.6
Sprayers	133	995	781	1,521	2,302	0.2
Balers	58	0	346	0	346	0.0
Tillers > 5 HP	1	10,710	2	3,779	3,781	0.3
Swathers	684	449	4,042	2,920	6,962	0.5
Hydro Power Units	32	206	438	749	1,187	0.1
Other Ag Equipment	247	88	3,202	386	3,588	0.3
Total	39,505	12,960	1,342,076	12,832	1,354,908	100.0

--- See Disclaimer on Cover ---

Table 10-2

NEVES Inventory B Agricultural Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
2-Wheel Tractors	0	13,802	0	15,847	15,847	0.0
Agricultural Tractors	2,519,295	5,808	71,008,919	149,038	71,157,957	93.8
Agricultural Mowers	0	16,023	0	14,213	14,213	0.0
Combines	284,854	1,835	3,750,675	18,342	3,769,018	5.0
Sprayers	9,692	72,721	39,321	68,416	107,738	0.1
Balers	4,260	0	74,579	0	74,579	0.1
Tillers > 5 HP	29	562,407	5	38,383	38,389	0.1
Swathers	50,032	32,857	254,362	181,109	435,471	0.6
Hydro Power Units	2,366	15,042	27,630	46,701	74,331	0.1
Other Ag Equipment	18,042	6,405	172,849	20,782	193,632	0.3
Total	2,888,569	726,900	75,328,341	552,831	75,881,173	100.0

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
2-Wheel Tractors	0	35	0	40	40	0.0
Agricultural Tractors	6,385	15	180,023	385	180,408	91.5
Agricultural Mowers	0	41	0	36	36	0.0
Combines	722	5	9,526	50	9,576	4.9
Sprayers	25	184	101	172	273	0.1
Balers	11	0	193	0	193	0.1
Tillers > 5 HP	0	1,418	0	98	98	0.0
Swathers	678	445	3,447	2,453	5,900	3.0
Hydro Power Units	6	38	70	118	188	0.1
Other Ag Equipment	46	16	441	52	493	0.3
Total	7,873	2,197	193,800	3,405	197,205	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
2-Wheel Tractors	0	189	0	272	272	0.0
Agricultural Tractors	34,454	79	1,257,406	2,625	1,260,031	86.4
Agricultural Mowers	0	219	0	208	208	0.0
Combines	3,896	25	75,860	371	76,231	5.2
Sprayers	133	995	673	1,170	1,843	0.1
Balers	58	0	1,015	0	1,015	0.1
Tillers > 5 HP	1	10,710	0	647	647	0.0
Swathers	2,166	1,422	59,354	9,249	68,603	4.7
Hydro Power Units	32	206	438	749	1,187	0.1
Other Ag Equipment	4,155	88	48,556	386	48,942	3.4
Total	44,895	13,933	1,443,302	15,677	1,458,979	100.0

approach is clearly superior to current top-down methodologies. Top-down methodologies do not account for regional differences in farming practices or crop types, and thus do not account for local nuances. This is particularly troublesome from the standpoint of crop type. The type of crop grown has a significant impact on the amount of activity that a farmer must provide. For example, if an area has most of its acreage devoted to pasture, its activity would be quite different from an area with a large fraction of machine-intensive crops such as cotton or tobacco. The bulk of this effort, therefore, was devoted to developing a bottom-up procedure that could be used by local air quality planning agencies to estimate emissions from agricultural operations. Nonetheless, some effort was devoted to assessing current top-down methodologies and providing recommendations for potential improvements, as detailed below.

Top-Down - In EEA's development of local-level agricultural equipment populations for NEVES, many of the more obvious activity indicators (e.g., number of farms, total farmed acreage, average farm revenue, etc.) were attempted but failed to meet EEA's criteria for an "acceptable" model. The model ultimately developed by EEA utilized the number of employees in agricultural services (excluding Landscaping and Horticultural Services) as the activity indicator. However, because it appeared that this model allocated too much equipment to nonattainment communities, EPA chose to use a simplified approach that scaled the national equipment population (from PSR) by the county to national tractor population ratio reported in the 1987 Census of Agriculture.[1] (The equipment populations reported in the census were not used directly because it was felt that a large proportion of inoperable machines are included in these data.)

The above approach has merit, in that the distribution of tractors (and other equipment, e.g., combines, cotton pickers, mower conditioners, and pickup balers) among counties is very well represented by the census data. Potential improvements that could be considered, however, include the following:

- The Agricultural Census contains data on total equipment population as well as data on equipment manufactured in the 1983 to 1987 timeframe. Thus, utilization of data on equipment manufactured from 1983 to 1987 to develop the equipment distribution might be considered.

- Because the census contains population data specifically for combines, a separate county-level distribution for combines could be prepared.

The first of these potential changes to the EPA methodology is being presented because newer equipment is generally used more, and it is unlikely that never- and seldom-used equipment form a substantial percentage of this group. However, if economic conditions in certain regions of the country influenced purchasing decisions in the 1983 to 1987 timeframe, it would be more appropriate to maintain the current methodology and utilize the total tractor population to establish the distribution. As seen in Table 10-3, shifting the basis for developing the equipment distribution has a profound effect on the percentage of

Table 10-3

Tractor Population by County for the San Joaquin Valley Air Basin
1987 Census of Agriculture

County	Tractors: Total Population Number	Tractors: Total Population Percent	Tractors: 1983-1987 Number	Tractors: 1983-1987 Percent	Combines: Total Population Number	Combines: Total Population Percent	Combines: 1983-1987 Number	Combines: 1983-1987 Percent
Fresno	18,738	0.41%	2,726	0.64%	158	0.02%	25	0.04%
Kern	7,123	0.15%	1,319	0.31%	103	0.02%	14	0.02%
Kings	3,465	0.08%	433	0.10%	181	0.03%	32	0.05%
Madera	4,467	0.10%	640	0.15%	89	0.01%	14	0.02%
Merced	7,204	0.16%	818	0.19%	89	0.01%	19	0.03%
San Joaquin	8,995	0.20%	1,113	0.26%	270	0.04%	37	0.06%
Stanislaus	8,538	0.19%	1,087	0.25%	199	0.03%	21	0.03%
Tulare	12,335	0.27%	1,061	0.25%	165	0.02%	31	0.05%
Total Air Basin	70,865	1.54%	9,197	2.15%	1,254	0.19%	193	0.29%
National	4,609,388		426,837		667,128		67,192	

tractors in the SJVAB. This obviously would also translate into a change in the overall inventory when utilizing a top-down approach.

Because combines are second only to tractors in activity (see Tables 10-1 and 10-2), it is important to consider developing a separate distribution for this equipment type. As seen in Table 10-3, the combine population distribution for the SJVAB does not match its tractor distribution; the SJVAB accounts for 1.5 percent of the national tractor population but only 0.2 percent of the combine population. Clearly, the inventory estimates could be improved by assigning combine population according to the combine data contained in the Agricultural Census.

Bottom-Up - The remaining discussion in this section focuses on a bottom-up approach for estimating emissions from agricultural operations. As discussed above, it is believed that this methodology results in much better local estimates of agricultural equipment activity.

To implement a bottom-up strategy, it was necessary to identify specific operations performed in the production of crops grown in a particular area. In an analysis performed for CARB[2], it was discovered that very detailed estimates of farming operations by crop type are available through the University of California Cooperative Extension. These so-called "Production Budgets" or "Sample Production Cost Estimates" list the operations performed, equipment used (including horsepower) and time per acre, and often indicate the month in which the operation is performed. Production budgets are generally used by farmers to estimate operating costs and provide a basis for farm loans. However, it is also possible to use this information, coupled with data on the number of acres under cultivation by crop type, to develop activity estimates for agricultural equipment. A typical production cost estimate for irrigated wheat in California is shown in Table 10-4.

To cross-check the data contained in the production budgets, the hour/acre values listed in the sample production cost estimates were analyzed to determine the corresponding equipment speed. If speeds

Table 10–4

Summary of Production Cost Estimate for Wheat

Wheat: Glenn County, California															
		Horse-	Hours/	Relative Activity by Month											
Operation	Equipment	Power	Acre	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Disc	Tractor Crawler	125	0.25											1	
Chisel	Ag Tractor	200	0.13											1	
Disk Offset	Ag Tractor	200	0.13											1	
Triplane	Tractor Crawler	125	0.2											1	
Fertilize	Ag Tractor	135	0.1												1
Spiketooth	Ag Tractor	135	0.1												1
Drill & Fert	Ag Tractor	135	0.2												1
Border	Ag Tractor	100	0.1												1
Ditch	Tractor Crawler	125	0.1				1								
Harvest	SP Combine 24'	65	0.33							1					

Table 10–5

Equipment Speed as a Function of Implement Width (mph)*

Wheat: Glenn County, California															
		Horse-	Hours/	Implement Width (feet)											
Operation	Equipment	Power	Acre	6	8	10	12	14	16	18	20	22	24	26	28
Disc	Tractor Crawler	125	0.25	5.5	4.1	3.3	2.8	2.4	2.1	1.8	1.7	1.5	1.4	1.3	1.2
Chisel	Ag Tractor	200	0.13	10.6	7.9	6.3	5.3	4.5	4.0	3.5	3.2	2.9	2.6	2.4	2.3
Disk Offset	Ag Tractor	200	0.13	10.6	7.9	6.3	5.3	4.5	4.0	3.5	3.2	2.9	2.6	2.4	2.3
Triplane	Tractor Crawler	125	0.2	6.9	5.2	4.1	3.4	2.9	2.6	2.3	2.1	1.9	1.7	1.6	1.5
Fertilize	Ag Tractor	135	0.1	13.8	10.3	8.3	6.9	5.9	5.2	4.6	4.1	3.8	3.4	3.2	2.9
Spiketooth	Ag Tractor	135	0.1	13.8	10.3	8.3	6.9	5.9	5.2	4.6	4.1	3.8	3.4	3.2	2.9
Drill & Fert	Ag Tractor	135	0.2	6.9	5.2	4.1	3.4	2.9	2.6	2.3	2.1	1.9	1.7	1.6	1.5
Border	Ag Tractor	100	0.1	13.8	10.3	8.3	6.9	5.9	5.2	4.6	4.1	3.8	3.4	3.2	2.9
Ditch	Tractor Crawler	125	0.1	13.8	10.3	8.3	6.9	5.9	5.2	4.6	4.1	3.8	3.4	3.2	2.9
Harvest	SP Combine 24'	65	0.33	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.0	1.0	0.9

* These mph estimates assume 100 percent efficiency. The steady–state speeds would be slighty higher than shown here when accounting for turns and overlap.

outside a reasonable range were obtained, the utility of using these data might be questioned. Using wheat as an example, the equipment speeds have been calculated as a function of implement width. This calculation is summarized in Table 10–5. As seen, the speeds range from 2 to 8 mph for tractors pulling implements between 10 and 20 feet in width (assuming 100 percent efficiency). The steady–state speeds would be slightly higher than shown in the table when accounting for turns and overlap. These speeds are within values expected for farm operations and correspond to speeds listed by Caterpillar for its line of general-purpose agricultural tractors.[3]

Although detailed production budgets are available from the Cooperative Extension in California, it was unclear if similar information existed in other states. Availability of this information from states (or areas) throughout the U.S. is crucial to the development of a generalized bottom-up methodology to estimate agricultural equipment activity. Thus, considerable effort was expended to determine the extent to which information on crop operations exists on a national basis. Fortunately, the information appears to be readily available, and production budgets specific to the mid-atlantic region were obtained and used to develop estimates of agricultural activity in the DC/MD/VA area, in addition to the estimates developed for the SJV. A discussion of those estimates follows.

Methodology and Data Sources

Estimation of agricultural activity (in Bhp-hr) can be represented by the following equation:

$$\text{Activity}_{i,j,k} = \text{Acreage}_{i,j} \times \text{Hours/Acre}_{j,k} \times \text{HP}_{k,l} \times \text{Load Factor}_l$$

where:

i = County
j = Crop
k = Operation
l = Equipment Type.

Thus, information on acreage by county and crop, hours/acre by crop and operation, horsepower by operation and equipment type, and load factor by equipment type is needed to complete the calculation. This equation can be further disaggregated to include fuel type and temporal activity for a more detailed estimate of activity.

Acreage by Crop Type – The number of acres under cultivation by county and crop type is generally available from a state's Cooperative Extension or Department of Agriculture. For the DC/MD/VA area, acreage data were obtained from "Maryland Agricultural Statistics, Summary for 1990"[4] and "Virginia Agricultural Statistics 1990."[5] For the SJV, acreage data were compiled from the "1990 Agricultural Commissioners' Data."[6] These documents are published annually and contain acreage data by county for major crop types. (The California document was more detailed than those published by Maryland and Virginia; however, anticipated funding cuts may result in reporting of only major crops in the future.) Additionally, the Virginia document contained information on planting and harvesting times, which proved valuable in estimating temporal activity. It is believed that this information is reasonably reliable because of the close contact and cooperation between local farmers and farm advisors.

Crop Operations – As discussed above, the availability of production budgets was critical in developing a bottom-up methodology for agricultural operations. For the DC/MD/VA region, several state

Cooperative Extension services were contacted for this information. Although Maryland did not publish production budgets, it was their opinion that any information obtained from Virginia, North Carolina, Pennsylvania, and New Jersey would be generally applicable to the entire mid-atlantic region.[7] Thus, Cooperative Extensions and Departments of Agriculture were contacted in those states with some success. For example, the Virginia Cooperative Extension publishes the "Virginia Farm Management Crop and Livestock Budgets,"[8] and the Pennsylvania State University College of Agriculture publishes the "Farm Management Handbook."[9] Both documents contain production budgets for the major crops grown in these states. Although not in a single document, the North Carolina Cooperative Extension Service was able to provide production budgets for selected crops. Overall, the production budgets for the various states were reasonably similar, as shown in Table 10-6 for corn. However, production budgets from Virginia were the primary source of information in developing activity estimates for the DC/MD/VA area. The budgets used in this analysis were compiled into spreadsheets for 12 separate crops and are contained in Appendix H.

For the SJV, production budgets for individual crops (or several similar crops) were obtained through the University of California Cooperative Extension and by contacting individual county Farm Advisors. For California as a whole, over 100 production budgets were identified. These were compiled into spreadsheets for 34 crop types. Because of the agricultural diversity in the SJV, it was impossible to develop (or obtain) production budgets for each individual crop. Thus, several specific crops were consolidated into crop types for the purpose of calculation. The production budgets and a summary of crops included in each crop type for the SJV are included as Appendix I.

Although it appears that production budgets are available for most areas of the U.S., there could be cases in which not all crops are covered, or the information is incomplete. Thus, some effort was devoted to identifying a generic source of information related to machinery usage for various field operations. For areas in which detailed production budgets are not readily available, Doane's Agricultural Report[10] lists data on agricultural machinery usage, including tractor horsepower requirements, acres per hour, and fuel usage per hour for a variety of field operations. The operations included in this report are: plowing, chiseling, discing, planting, cultivating, and harvesting. Thus, if a local air pollution control agency can obtain information on the operations required for each crop (e.g., through a survey of local cooperatives), an estimate can be made regarding equipment usage.

<u>Temporal Activity</u> - For the SJV, the temporal patterns outlined in the production budgets were used to establish monthly activity patterns. However, temporal activity patterns were not presented in the crop budgets prepared by Virginia. Because utilization of the Virginia budgets was desired, Virginia's temporal patterns had to be estimated. This was achieved as follows. "Virginia Agricultural Statistics 1990"[5] contained detailed information on planting and harvesting times for specific crops. These data were coupled with the production budgets from North Carolina and Pennsylvania which contain temporal activity information for each operation. By overlaying the planting and harvesting operations outlined in the North Carolina and Pennsylvania

Table 10-6

Corn Production Budgets for DC/MD/VA Area
Conventional Tillage

Corn Production – Virginia						
Operation/ Implement	Equipment	Horse–Power	Hours/ Acre	Load Factor	Bhp–hr/ Acre	Diesel Gal/Acre
Bush Hog	AG Tractor	110	0.17	0.7	13.1	0.73
Plow	AG Tractor	110	0.44	0.7	33.9	1.90
Disc	AG Tractor	110	0.15	0.7	11.6	0.65
Harrow	AG Tractor	50	0.20	0.7	7.0	0.39
Plant	AG Tractor	70	0.31	0.7	15.2	0.85
Sprayer	AG Tractor	50	0.11	0.7	3.9	0.22
Harvest	Combine	152	0.53	0.7	56.4	3.16
Total			1.91		141.0	7.89

Corn Production – Pennsylvania						
Operation/ Implement	Equipment	Horse–Power	Hours/ Acre	Load Factor	Bhp–hr/ Acre	Diesel Gal/Acre
Plow	AG Tractor	150	0.25	0.7	26.3	1.47
Cultivate	AG Tractor	120	0.52	0.7	43.7	2.45
Herbicide	AG Tractor	95	0.13	0.7	8.6	0.48
Plant	AG Tractor	150	0.18	0.7	18.9	1.06
Fertilize	AG Tractor	95	0.13	0.7	8.6	0.48
Harvest	Combine	152	0.33	0.7	35.1	1.97
Haul	AG Tractor	120	0.12	0.7	10.1	0.56
Total			1.66		151.3	8.47

Corn Production – North Carolina						
Operation/ Implement	Equipment	Horse–Power	Hours/ Acre	Load Factor	Bhp–hr/ Acre	Diesel Gal/Acre
Bush Hog	AG Tractor	45	0.33	0.7	10.4	0.58
Tandom Disc	AG Tractor	130	0.18	0.7	16.4	0.92
Ripper–Bedder	AG Tractor	130	0.22	0.7	20.0	1.12
Plant	AG Tractor	70	0.37	0.7	18.1	1.02
Sprayer	AG Tractor	45	0.44	0.7	13.9	0.78
Roll Cultivator	AG Tractor	70	0.28	0.7	13.7	0.77
Harvest	Combine	152	0.40	0.7	42.6	2.38
Total			2.22		135.1	7.56

production budgets on the established planting and harvesting times for Virginia, the timing of the remaining Virginia operations was estimated. For example, 25 percent of Virginia's corn is planted in April. Because information from Pennsylvania suggests that ground preparation (e.g., plowing, discing) is performed one month prior to planting, 25 percent of the ground preparation related to corn production in Virginia was assumed to occur in March.

Load Factors - Load factors are an important part of the activity calculation and have a direct bearing on the ultimate outcome of any estimates. In actual operation, load factors likely vary as a function of the type of operation the tractor is performing (e.g., plowing versus spraying), horsepower rating for a particular operation, soil conditions, etc. Unfortunately, however, there are little data relating load factor to these types of variables. Thus, an average load factor is generally applied in activity estimates. This approach was followed here, and the load factors from NEVES were used throughout.

Fuel Usage - Although not required for the calculational methodology outlined above, fuel usage is another parameter that can be used as the basis of an equipment activity or emissions estimate, and several means to estimate fuel usage (by crop type) were identified. First, Table 10-6 contains an estimate which was determined by simply assuming all equipment was Diesel-fueled, and applying a conversion factor of 0.056 gal/bhp-hr[11] to the bhp-hr/acre activity estimates. Second, information related to fuel use is typically contained in the crop production budgets (although it is generally listed in terms of $/acre rather than gallons/acre). Finally, Doane's Agricultural Report[10] is a source of fuel use by operation.

A comparison of the three approaches outlined above, based on corn production in Virginia, is contained in Table 10-7. As seen in the table, the estimates are highly variable, particularly the value determined from the cost data in the production budget. However, comparing the values from this work (i.e., Table 10-6) and those calculated from the Doane's data gives reasonable agreement. Further, the Doane's information would be expected to give somewhat optimistic values because the data are based on new machinery.

Table 10-7

Comparison of Diesel Fuel Usage Estimates for Corn Production

Corn Production -- Virginia						
Operation/ Implement	Equipment	Horse-Power	Table 10-6 (Gal/Acre)	VA Production Budget* ($/Acre)	VA Production Budget* (Gal/Acre)	Doane's** (Gal/Acre)
Bush Hog	AG Tractor	110	0.73	$1.20	1.41	0.70
Plow	AG Tractor	110	1.90	$3.04	3.58	1.82
Disc	AG Tractor	110	0.65	$1.05	1.24	0.55
Harrow	AG Tractor	50	0.39	$0.53	0.62	0.40
Plant	AG Tractor	70	0.85	$1.34	1.58	0.60
Sprayer	AG Tractor	50	0.22	$0.29	0.34	0.15
Harvest	Combine	152	3.16	$3.43	4.04	2.00
Total			7.89		12.80	6.22

* Cost of Diesel fuel was assumed to be $0.85 per gallon based on 1992 Doane's Report.
** "Bush Hog" fuel use was not reported in Doane's. The value listed was calculated as 40 percent of the "Plow" value (based on the difference reported in the Virginia crop budget for corn).

Gasoline Versus Diesel Fraction - Although the focus of this study is on equipment usage, another parameter that enters into an emissions calculation is the type of fuel used in the equipment. Estimates of the gasoline versus Diesel fraction for agricultural equipment exist, but the numbers cited in various studies often do not agree. For example, NEVES estimates the U.S. agricultural tractor population to consist of over 2.5 million Diesel machines and only 5,800 gasoline machines. On the other hand, a 1988 EEA report for CARB[12] contains estimates of 29,193 Diesel and 14,617 gasoline agricultural tractors for northern California in 1990.

In speaking with county Farm Advisors, industry representatives, and other experts, it became clear that a large number of gasoline tractors are still being used on farms even though the vast majority of new tractors sold since the late-1960s and early-1970s have been Diesel-fueled. It is also our understanding, however, that while there is a significant population of gasoline tractors, the annual hourly usage is much lower when compared to Diesel-fueled machines. This view has been substantiated through an analysis of data from a survey of tractor use on California farms, which is described below.

The Department of Agricultural Engineering at the University of California, Davis recently conducted a survey of California farms for the 1990 crop year to determine tractor usage patterns[13]. Although the primary focus of the survey was on safety issues, data collected can be used to estimate the fraction of gasoline- versus Diesel-fueled tractors in California. As part of the survey, participants were asked to list tractor age and annual hourly field use. The results are summarized in Table 10-8. From this information, it was possible to estimate the annual hours for each age group by combining the midpoint of the annual hourly usage category with the number of tractors in each bin. This calculation indicates that older tractors are, in fact, used far less than newer tractors, with the annual hourly usage of machines 30 years old being one-third that of machines under five years of age. The usage versus age distribution is also shown graphically in Figure 10-1.

Although the survey did not differentiate between gasoline and Diesel tractors, an estimate can be made by combining information contained in the survey with data published in the 1973 SwRI emissions study[14]. In that work, the market penetration of Diesel farm tractors was given for the 1950 to 1971 timeframe. The Diesel fraction remained below 20 percent until 1958, grew to 40 percent in 1960, 60 percent in 1965, and approached 80 percent in 1970. Based on this information, the following Diesel fractions were applied to the age groupings given in Table 10-8.

- 0-19 Years - 100 percent Diesel penetration was assumed. Although SwRI estimated the Diesel fraction at 75 percent for 1971, there are no data beyond that point. According to industry organizations, however, the majority of agricultural tractors were Diesel-fueled beyond 1970[15].

- 20-24 Years - 70 percent Diesel penetration was assumed based on interpolating the 1965 and 1970 Diesel penetration rates.

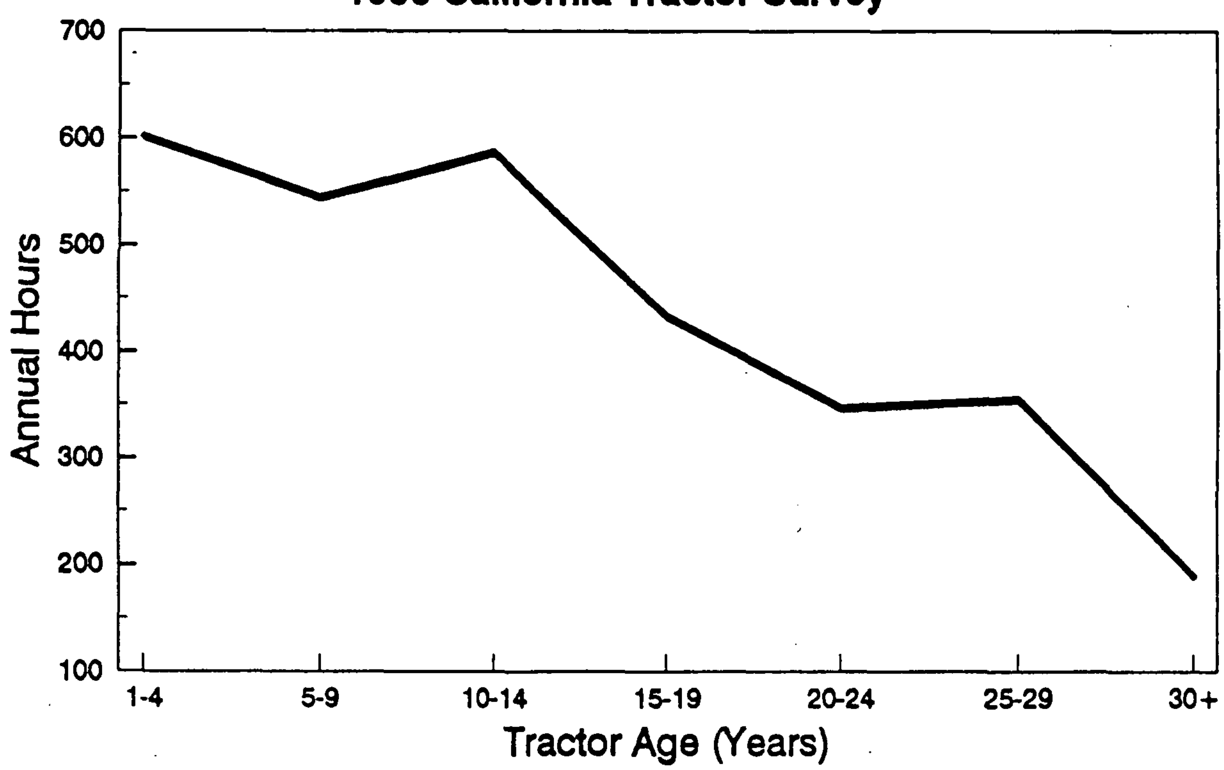
Table 10-8

Tractor Age Versus Annual Hourly Usage for California Farms

Tractor Age	Number of Tractors in Usage Category				Total Tractors	Annual Hours
	<104 hrs	104-519 hrs	520-1999 hrs	≥2000 hrs		
<1	0	0	0	0	0	n/a
1-4	34	89	61	3	187	601
5-9	41	114	59	3	217	544
10-14	61	172	72	22	327	586
15-19	62	104	40	2	208	433
20-24	86	82	29	1	198	346
25-29	32	47	11	1	91	354
≥30	230	114	13	2	359	189
Total	546	722	285	34	1587	429

Figure 10-1

Annual Hourly Usage vs. Tractor Age
1990 California Tractor Survey



25-29 Years – 50 percent Diesel penetration was assumed based on interpolating the 1960 and 1965 Diesel penetration rates.

30+ Years – 10 percent Diesel penetration was assumed. This figure was arrived at by distributing the 30+ tractor population equally among four age groups: 1940-1945, 1945-1950, 1950-1955, and 1955-1960. Based on the SwRI data, 25 percent Diesel penetration was assumed for the 1955-1960 group, and 10 percent for the 1950-1955 group; the remaining groups were assumed to be entirely gasoline-fueled.

These percentages were applied to the data in Table 10-8 to arrive at an hourly weighted gasoline/Diesel split in the field. This calculation is summarized in Table 10-9. As seen in the table, the above methodology results in a Diesel usage fraction of 86 percent for California tractors.

Although the above analysis is specific to California, it points out that gasoline tractor use is not insignificant. Thus, a similar calculation should be carried out on a national basis, provided information on tractor age distribution can be obtained.

Table 10-9

Gasoline Versus Diesel Fraction for California Tractors

Tractor Age	Number of Tractors		Annual Hours*	Percent Usage	
	Diesel	Gasoline		Diesel	Gasoline
<1	0	0	n/a	0	0
1-4	187	0	601	16.5	0
5-9	217	0	544	17.3	0
10-14	327	0	586	28.2	0
15-19	208	0	433	13.2	0
20-24	139	59	346	7.1	3.0
25-29	46	45	354	2.4	2.3
≥30	36	323	189	1.0	9.0
Total	1159	427	n/a	85.7	14.3

* Annual hours were assumed to be the same for gasoline and Diesel within each age group; however, the overall average would be higher for Diesel because of the greater percentage of newer tractors.

Sample Calculations

The bottom-up methodology discussed above was applied to the DC/MD/VA and SJV areas, and a summary of the results is given in Tables 10-10 and 10-11, respectively. These tables list the number of acres by crop type in each area, the relative monthly activity (on a Bhp-hr/acre basis and 1000 Bhp-hr), total Bhp-hr for each crop (per acre and total for crop), and Diesel fuel usage (per acre and total for crop). The Diesel estimates were arrived at by assuming all equipment was Diesel-fueled* and applying the conversion of 0.056 gal/Bhp-hr.[11] Totals (and totals by month) are also included in the tables for each area.

It is interesting to compare the temporal activity patterns for the two areas under study, which are shown in Figures 10-2 and 10-3 for DC/MD/VA and the SJV, respectively. As expected, the most activity is observed from late-spring to early fall, with relatively more activity in the winter months in the SJV. The DC/MD/VA area experiences its highest activity in September, primarily the result of corn harvesting and continued hay production. The large spike in activity for the SJV in November can be attributed to harvest and post-harvest operations associated with cotton production.

It is also of interest to compare the results of this bottom-up methodology to those obtained in NEVES as shown in Table 10-12. NEVES has predicted almost four times higher activity for the DC/MD/VA area, while the results for the SJV are surprisingly close. One possible explanation for this large difference in area-specific estimates relates back to the issue of crop-specific differences in equipment requirements. In Sierra's previous effort to develop agricultural emissions estimates for the SJV,[2] it was noted that farming practices in the eight-county SJV were much more machine-intensive than the remaining counties in California. It is probably also true that farming in the SJV is more machine-intensive than most other areas of the United States. Thus, close agreement between NEVES and a bottom-up methodology for the SJV may be indicative of overestimates of equipment population and usage for the remainder of the U.S. Certainly the results for the DC/MD/VA area indicate that local conditions play an important factor in determining local activity.

Additional Considerations

Although the analysis above is fairly complete, a number of additional variables could be included to improve its accuracy. For example, Extension specialists in the DC/MD/VA area indicated that no-till practices are popular among local farmers for corn and soybean

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* Although an estimate of gasoline versus Diesel equipment usage is presented above, the sample calculation prepared here assumed 100 percent Diesel. This was done to be on the same basis as NEVES, which allowed for a more consistent comparison between methodologies.

Table 10–10

Summary of Bottom–Up Agricultural Activity Estimate
DC/MD/VA

DC/MD/VA Crop Summary																
			Relative Monthly Activity												Bhp–hr	Diesel
Crop	Acres		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total	Total*
Corn (Grain)	92,000	Bhp–hr/acre:	0.0	0.0	0.0	14.6	37.7	24.9	6.6	0.8	0.0	22.6	19.7	14.1	141.0	7.89
		1000 Bhp–hr:	0	0	0	1,346	3,471	2,288	603	71	0	2,075	1,816	1,297	12,968	726
Corn (Silage)	34,300	Bhp–hr/acre:	0.0	0.0	0.0	11.4	30.5	22.3	6.6	0.8	19.1	66.9	9.6	0.0	167.0	9.35
		1000 Bhp–hr:	0	0	0	390	1,047	763	225	26	655	2,294	328	0	5,729	321
Wheat	36,500	Bhp–hr/acre:	0.0	0.0	1.9	1.9	0.0	0.0	13.8	13.8	0.0	0.0	25.1	25.1	81.7	4.58
		1000 Bhp–hr:	0	0	70	70	0	0	505	505	0	0	916	916	2,982	167
Soybean	55,000	Bhp–hr/acre:	16.9	0.0	0.0	0.0	13.6	27.1	22.5	7.3	1.0	0.0	11.3	28.2	127.9	7.16
		1000 Bhp–hr:	930	0	0	0	750	1,491	1,237	400	53	0	620	1,551	7,032	394
Barley	11,000	Bhp–hr/acre:	0.0	0.0	1.9	1.9	0.0	0.0	24.9	2.8	0.0	12.5	25.1	12.5	81.7	4.58
		1000 Bhp–hr:	0	0	21	21	0	0	274	30	0	138	276	138	899	50
Tobacco	4,000	Bhp–hr/acre:	0.0	0.0	19.8	19.8	10.7	55.2	57.4	24.6	22.2	28.8	26.8	8.5	273.9	15.34
		1000 Bhp–hr:	0	0	79	79	43	221	230	98	89	115	107	34	1,096	61
Oats	2,800	Bhp–hr/acre:	0.0	0.0	1.9	1.9	0.0	0.0	24.9	21.1	18.4	12.5	25.1	12.5	118.5	6.63
		1000 Bhp–hr:	0	0	5	5	0	0	70	59	51	35	70	35	332	19
Alfalfa Establishment	2,750	Bhp–hr/acre:	0.0	0.0	28.2	44.3	16.1	1.0	42.2	42.2	42.2	41.2	0.0	0.0	257.3	14.41
		1000 Bhp–hr:	0	0	77	122	44	3	116	116	116	113	0	0	707	40
Alfalfa Production	11,010	Bhp–hr/acre:	0.0	0.0	0.0	1.3	1.3	57.7	59.0	59.0	59.0	59.0	41.2	0.0	337.3	18.89
		1000 Bhp–hr:	0	0	0	14	14	635	649	649	649	649	454	0	3,713	208
Hay Establishment	16,730	Bhp–hr/acre:	0.0	0.0	28.2	41.0	12.8	0.0	0.0	24.3	24.3	24.3	0.0	0.0	154.8	8.67
		1000 Bhp–hr:	0	0	471	686	214	0	0	406	406	406	0	0	2,589	145
Hay Production	100,410	Bhp–hr/acre:	0.0	0.0	0.0	0.0	0.0	0.0	35.2	35.2	35.2	35.2	0.0	0.0	140.7	7.88
		1000 Bhp–hr:	0	0	0	0	0	0	3,532	3,532	3,532	3,532	0	0	14,128	791
Fresh Vegetables	2,777	Bhp–hr/acre:	0.0	11.4	11.4	16.9	18.4	7.1	7.1	1.5	1.5	0.0	0.0	0.0	75.3	4.22
		1000 Bhp–hr:	0	32	32	47	51	20	20	4	4	0	0	0	209	12
Total DC/VA/MD	369,277	1000 Bhp–hr:	930	32	757	2,780	5,635	5,420	7,460	5,898	5,556	9,358	4,587	3,971	52,384	2,933

* Units: Gallons/Acre and 1000 Gallons, respectively.

Table 10-11

Summary of Bottom-Up Agricultural Activity Estimate
San Joaquin Valley

San Joaquin Valley Crop Summary																
			Relative Monthly Activity												Bhp-hr	Diesel
Crop	Acres		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total	Total*
Alfalfa	603,477	Bhp-hr/Acre:	0.0	0.0	0.0	0.0	27.0	27.0	27.0	27.0	45.2	41.0	35.6	0.0	229.7	12.86
		1000 Bhp-hr:	0	0	0	0	16,288	16,288	16,288	16,288	27,257	24,737	21,470	0	138,615	7,762
Almonds	327,975	Bhp-hr/Acre:	0.0	63.4	13.0	15.9	4.2	15.9	8.4	24.7	49.0	2.1	8.4	0.0	204.9	11.5
		1000 Bhp-hr:	0	20,777	4,247	5,223	1,377	5,223	2,755	8,093	16,063	689	2,755	0	67,202	3,763
Apricots/Cherries	21,805	Bhp-hr/Acre:	54.4	54.4	20.3	54.8	36.6	54.8	98.3	80.1	35.9	7.7	7.7	7.7	512.7	28.7
		1000 Bhp-hr:	1,187	1,187	443	1,194	798	1,194	2,144	1,747	782	168	168	168	11,179	626
Asparagus	20,161	Bhp-hr/Acre:	62.7	0.0	0.0	9.5	9.5	14.8	5.3	0.0	0.0	4.9	67.6	67.6	241.9	8.47
		1000 Bhp-hr:	1,263	0	0	192	192	299	107	0	0	99	1,363	1,363	4,878	171
Beans	129,981	Bhp-hr/Acre:	0.0	59.5	59.5	85.8	31.5	19.3	14.0	14.0	3.5	3.5	3.5	0.0	294.0	16.46
		1000 Bhp-hr:	0	7,734	7,734	11,146	4,094	2,502	1,820	1,820	455	455	455	0	38,214	2,140
Citrus	163,294	Bhp-hr/Acre:	0.0	0.0	0.0	30.8	15.2	6.0	16.9	27.0	20.4	23.8	0.0	0.0	140.0	7.84
		1000 Bhp-hr:	0	0	0	5,029	2,477	972	2,762	4,401	3,334	3,886	0	0	22,861	1,280
Clover Seed	22,874	Bhp-hr/Acre:	3.8	2.0	8.8	2.8	2.0	2.0	2.9	2.9	1.0	13.8	16.0	15.7	73.6	4.12
		1000 Bhp-hr:	88	45	202	63	45	45	67	67	22	315	366	360	1,684	94
Field Corn	269,247	Bhp-hr/Acre:	29.4	0.0	0.0	112.1	39.2	7.3	0.0	0.0	0.0	0.0	0.0	13.7	201.6	11.29
		1000 Bhp-hr:	7,916	0	0	30,175	10,554	1,960	0	0	0	0	0	3,675	54,280	3,040
Cotton	1,217,135	Bhp-hr/Acre:	0.0	38.1	24.5	0.0	49.9	38.7	43.6	39.2	0.0	1.4	0.0	134.9	370.3	20.74
		1000 Bhp-hr:	0	46,349	29,820	0	60,776	47,144	53,108	47,712	0	1,704	0	164,143	450,754	25,242
Grape	507,736	Bhp-hr/Acre:	0.0	0.0	0.0	21.0	126.0	126.0	126.0	126.0	15.8	26.3	10.5	0.0	577.5	32.34
		1000 Bhp-hr:	0	0	0	10,662	63,975	63,975	63,975	63,975	7,997	13,328	5,331	0	293,218	16,420
Kiwi	3,628	Bhp-hr/Acre:	0.0	38.5	74.7	17.5	36.2	24.5	24.5	24.5	0.0	0.0	0.0	11.7	252.0	14.11
		1000 Bhp-hr:	0	140	271	63	131	89	89	89	0	0	0	42	914	51
Lettuce	25,236	Bhp-hr/Acre:	4.7	25.0	26.6	95.0	92.2	127.2	25.0	26.6	95.0	144.7	74.7	4.7	741.2	41.50
		1000 Bhp-hr:	118	630	672	2,397	2,326	3,209	630	672	2,397	3,651	1,884	118	18,704	1,047
Melon	73,035	Bhp-hr/Acre:	97.1	112.9	42.0	89.0	73.3	62.9	0.0	0.0	0.0	0.0	0.0	0.0	477.2	26.72
		1000 Bhp-hr:	7,094	8,244	3,067	6,503	5,353	4,594	0	0	0	0	0	0	34,854	1,952
Oat Hay	126,975	Bhp-hr/Acre:	28.2	0.0	2.0	0.9	0.0	0.0	15.9	0.0	0.0	0.0	0.0	77.0	124.1	6.95
		1000 Bhp-hr:	3,582	0	258	116	0	0	2,022	0	0	0	0	9,777	15,754	882
Olive	19,996	Bhp-hr/Acre:	0.0	0.0	0.0	0.0	7.7	0.0	0.0	7.7	0.0	0.0	259.7	0.0	275.1	15.41
		1000 Bhp-hr:	0	0	0	0	154	0	0	154	0	0	5,193	0	5,501	308
Onion	29,394	Bhp-hr/Acre:	0.0	0.0	0.0	171.1	171.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	342.2	19.16
		1000 Bhp-hr:	0	0	0	5,029	5,029	0	0	0	0	0	0	0	10,057	563
Irrigated Pasture	211,600	Bhp-hr/Acre:	0.0	12.9	12.9	0.0	0.0	0.0	0.0	25.7	0.0	0.0	0.0	0.0	51.5	2.88
		1000 Bhp-hr:	0	2,722	2,722	0	0	0	0	5,443	0	0	0	0	10,887	610
Peach	81,077	Bhp-hr/Acre:	0.0	41.0	38.7	18.0	11.4	42.3	44.7	17.4	15.9	52.3	21.0	20.0	322.7	18.07
		1000 Bhp-hr:	0	3,320	3,136	1,461	922	3,429	3,628	1,414	1,291	4,242	1,703	1,617	26,164	1,465
Pear/Apple	12,250	Bhp-hr/Acre:	12.6	12.6	9.0	38.0	25.5	25.5	38.1	46.9	27.3	0.0	24.1	0.0	259.7	14.54
		1000 Bhp-hr:	154	154	110	466	313	313	467	575	334	0	295	0	3,181	178
Pistachio	48,722	Bhp-hr/Acre:	0.0	22.8	0.0	22.8	0.0	45.5	0.0	0.0	113.8	183.6	0.0	68.3	456.6	25.57
		1000 Bhp-hr:	0	1,108	0	1,108	0	2,217	0	0	5,542	8,945	0	3,325	22,246	1,246

* Units: Gallons/Acre and 1000 Gallons, respectively.

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Table 10-11, Continued

San Joaquin Valley Crop Summary																
			Relative Monthly Activity												Bhp-hr	Diesel
Crop	Acres		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total	Total*
Plum	40,641	Bhp-hr/Acre:	0.0	146.1	4.1	29.9	4.1	58.7	187.7	87.4	4.1	32.8	33.0	4.1	592.2	33.16
		1000 Bhp-hr:	0	5,938	168	1,216	168	2,387	7,630	3,552	168	1,333	1,339	168	24,067	1,348
Potato	34,371	Bhp-hr/Acre:	13.5	13.5	13.5	13.5	174.9	174.9	174.9	0.0	0.0	13.5	13.5	13.5	619.3	34.68
		1000 Bhp-hr:	464	464	464	464	6,013	6,013	6,013	0	0	464	464	464	21,286	1,192
Prune	8,023	Bhp-hr/Acre:	11.6	46.2	37.2	85.6	12.8	36.9	35.6	6.4	220.5	0.0	0.0	0.0	492.8	27.59
		1000 Bhp-hr:	93	371	298	687	103	296	286	51	1,769	0	0	0	3,953	221
Rice	19,464	Bhp-hr/Acre:	0.0	0.0	0.0	15.4	44.8	60.2	7.5	0.0	0.0	39.2	39.2	0.0	206.2	11.55
		1000 Bhp-hr:	0	0	0	300	872	1,172	145	0	0	762	762	0	4,013	225
Safflower	57,503	Bhp-hr/Acre:	15.0	41.6	50.2	8.6	8.6	0.0	0.0	0.0	19.7	37.3	17.6	17.6	216.3	12.11
		1000 Bhp-hr:	860	2,394	2,889	495	495	0	0	0	1,132	2,146	1,014	1,014	12,438	697
Silage (Corn)	150,346	Bhp-hr/Acre:	0.0	0.0	0.0	0.0	0.0	0.0	110.7	31.2	0.0	0.0	3.6	0.0	145.5	8.15
		1000 Bhp-hr:	0	0	0	0	0	0	16,639	4,683	0	0	547	0	21,869	1,225
Squash	4,280	Bhp-hr/Acre:	0.0	0.0	52.5	166.3	245.0	192.5	131.3	52.5	52.5	0.0	0.0	0.0	892.5	49.98
		1000 Bhp-hr:	0	0	225	712	1,049	824	562	225	225	0	0	0	3,820	214
Sugarbeet	82,634	Bhp-hr/Acre:	44.0	65.3	70.5	31.8	33.0	33.0	23.0	22.5	0.0	0.0	0.0	0.0	323.2	18.10
		1000 Bhp-hr:	3,636	5,398	5,827	2,629	2,729	2,729	1,900	1,861	0	0	0	0	26,709	1,496
Sunflower Seed Total	2,020	Bhp-hr/Acre:	0.0	0.0	0.0	33.6	27.7	17.6	0.0	0.0	13.9	13.9	109.9	16.8	233.4	13.07
		1000 Bhp-hr:	0	0	0	68	56	36	0	0	28	28	222	34	471	26
Tomato Total	189,269	Bhp-hr/Acre:	0.0	0.0	15.5	45.3	45.3	45.3	88.6	88.6	105.3	105.3	46.4	46.4	632.1	35.40
		1000 Bhp-hr:	0	0	2,938	8,566	8,566	8,566	16,777	16,777	19,936	19,936	8,787	8,787	119,637	6,700
Vegetables (Seasonal)	166,232	Bhp-hr/Acre:	0.0	44.2	44.2	44.2	44.2	44.2	44.2	0.0	0.0	0.0	0.0	0.0	265.3	14.86
		1000 Bhp-hr:	0	7,350	7,350	7,350	7,350	7,350	7,350	0	0	0	0	0	44,101	2,470
Vegetables (Year-Long)	12,084	Bhp-hr/Acre:	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	265.3	14.86
		1000 Bhp-hr:	267	267	267	267	267	267	267	267	267	267	267	267	3,206	180
Walnut	95,013	Bhp-hr/Acre:	0.0	46.2	30.8	3.9	53.9	42.4	42.4	15.4	42.4	11.6	11.6	0.0	300.3	16.82
		1000 Bhp-hr:	0	4,390	2,926	366	5,121	4,024	4,024	1,463	4,024	1,097	1,097	0	28,532	1,598
Wheat	427,795	Bhp-hr/Acre:	0.0	0.0	0.0	8.8	0.0	0.0	15.0	0.0	0.0	0.0	75.8	44.8	144.3	8.08
		1000 Bhp-hr:	0	0	0	3,743	0	0	6,423	0	0	0	32,416	19,165	61,748	3,458
Total	5,205,273	1000 Bhp-hr:	26,721	118,980	76,034	107,690	207,592	187,114	217,877	181,330	93,023	88,253	87,899	214,487	1,607,000	89,890

* Units: Gallons/Acre and 1000 Gallons, respectively.

Figure 10-2

Agricultural Temporal Activity Distribution
DC/MD/VA

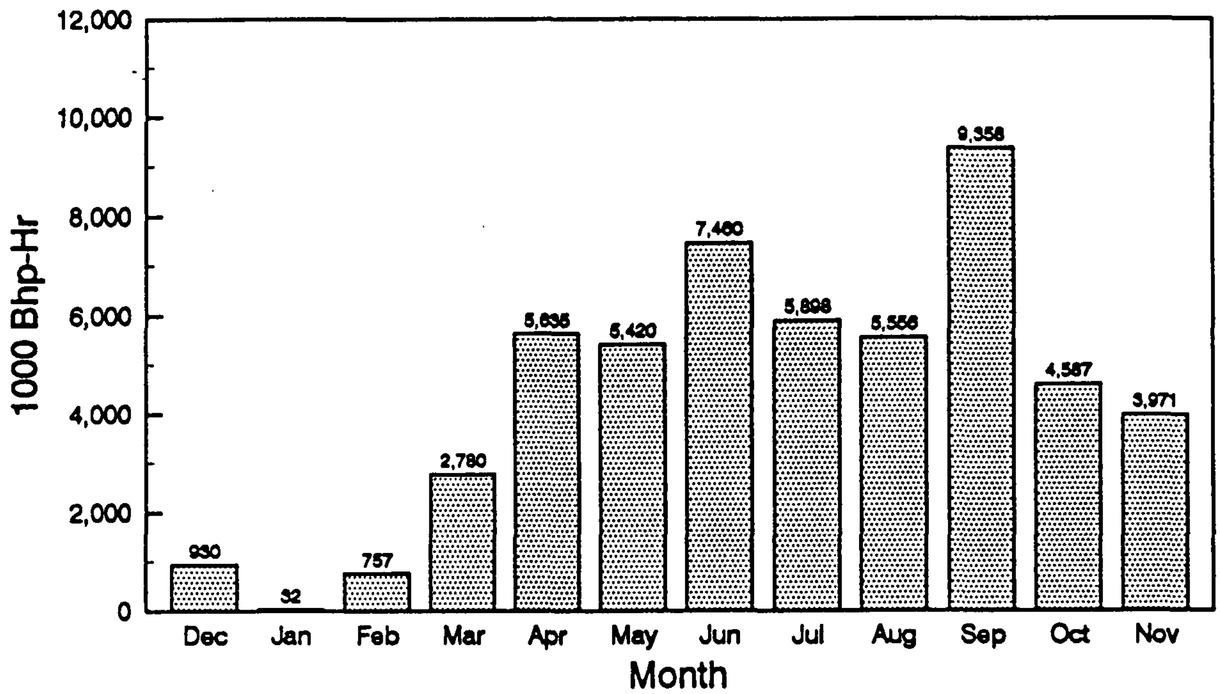

Figure 10-3

Agricultural Temporal Activity Distribution
San Joaquin Valley

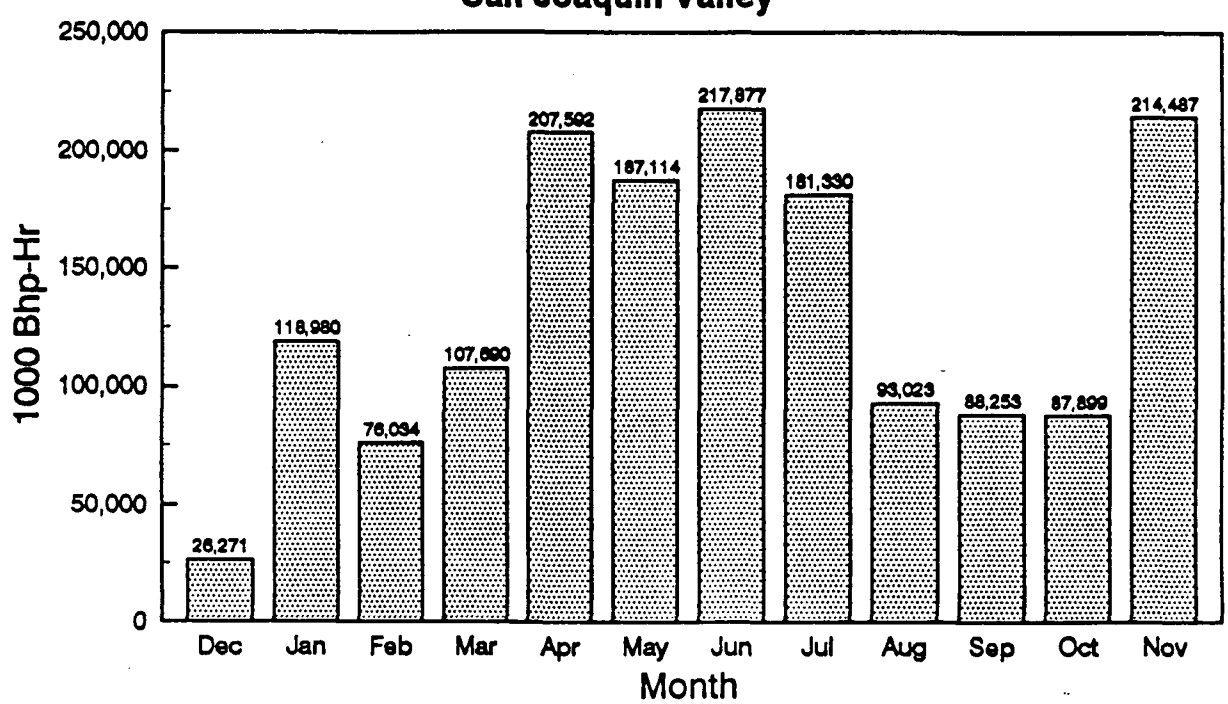

Table 10-12

Comparison of Top-Down (NEVES Inventory A) and Bottom-Up (This Study) Agricultural Activity Estimates for the DC/MD/VA and SJV Areas (1000 Bhp-hr)

Area	NEVES	This Study
DC/MD/VA	200,700	52,400
SJV	1,606,000	1,607,000

production (i.e., seed is planted directly into the stubble from the previous year). Developing an estimate of the percentage of no-till operations and including this in the analysis would reduce the overall activity in the area.

The analysis above focused on activity associated with field crops because that accounts for the majority of equipment usage. However, there is some nonroad equipment used in livestock operations (e.g., moving hay bales, transporting animal wastes), and accounting for this would also increase the accuracy of the activity estimates. However, detailed data on fuel or equipment usage for livestock operations were not identified. General information is contained in the livestock production budgets prepared by Pennsylvania State University[9] which list gasoline, fuel, and oil costs (combined) for livestock operations (e.g., dairy cows). However, these cost estimates are not detailed enough to develop equipment usage estimates, and since the fuel costs comprise only 0.5 percent of the overall dairy cow budget, the accuracy of these estimates is uncertain.

Recommendations

The results of this analysis indicate that developing a bottom-up methodology for estimating agricultural equipment usage deserves serious consideration. It appears that information relating to cropping practices exists and is available through state Cooperative Extension services and Departments of Agriculture. If Bhp-hr/acre estimates were developed by crop and region, it would be reasonably easy for local air quality planners to determine the corresponding acreage and crop distributions for the counties of interest.

References for Section 10

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4. "Maryland Agricultural Statistics, Summary for 1990," Maryland Department of Agriculture, 1991.

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6. "1990 Agricultural Commissioners' Data," California Agricultural Statistics Service and California Department of Agriculture, 1991.

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11. LOGGING EQUIPMENT

Specific nonroad equipment types included in the logging equipment category are larger chainsaws and shredders (>4 and >5 HP, respectively), skidders, and fellers/bunchers. This category represents a very minor portion of the nonroad equipment inventory in nonattainment areas, primarily because logging activities are generally not conducted within metropolitan areas. In fact, only 5 of the 24 nonattainment areas considered in NEVES had any logging activity attributed to them. Thus, an alternative methodology developed for this equipment category must be easily applied to justify its use.

NEVES Methodology

NEVES again utilized PSR data on population and annual hourly usage to develop activity estimates for logging equipment. However, the state-level PSR data upon which a regression analysis would be based appeared flawed, according to EEA. This conclusion was arrived at after the most obvious indicators of logging activity (e.g., SIC 241 - Logging Establishments) failed to meet the statistical criteria established by EEA for an acceptable model. Thus, national-level equipment populations were scaled to the local level by simply applying the county to national ratio of SIC 241 Employees. Number of employees was used as the indicator because it was felt that this was a better representation of activity than number of establishments. (Note that data on logging equipment were not supplied by industry for NEVES; thus, an alternative inventory was not developed.)

Data generated with the above methodology were used to calculate the activity (bhp-hr) attributable to logging equipment on a national basis and for the SJV as shown in Table 11-1. As seen, the bulk of the activity (on a bhp-hr basis) is from the heavy-duty Diesel equipment; however, the high emission rates of 2-stroke chainsaw engines warrant their inclusion in this category.

A fundamental flaw in the top-down methodology (in particular, the choice of activity indicators for this equipment category), becomes apparent when examining the SIC 241 data. As with the construction industry, the logging industry is relatively mobile. Although a company (or companies) may be based in a specific county, there are no assurances that it does the majority of its work in that county. For example, all of the SIC 241 employees in the SJV are located in Fresno County, which contains the largest metropolitan area in the air basin. However, Fresno County accounts for only 40 percent of the timber harvested in the eight-county area.[1] It is likely that these firms do business in counties within the SJV that are not represented by any

Table 11-1

NEVES Logging Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Chainsaws > 4 HP	0	51,775	0	52,015	52,015	0.8
Shredders > 5 HP	0	100,271	0	133,481	133,481	2.1
Skidders	30,911	0	3,973,238	0	3,973,238	62.0
Fellers/Bunchers	15,581	0	2,247,128	0	2,247,128	35.1
Total	46,492	152,046	6,220,366	185,496	6,405,862	100.0

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Chainsaws > 4 HP	0	562	0	639	639	5.1
Shredders > 5 HP	0	151	0	234	234	1.9
Skidders	47	0	7,231	0	7,231	58.3
Fellers/Bunchers	23	0	4,309	0	4,309	34.7
Total	70	713	11,540	873	12,413	100.0

employees in SIC 241, and it is just as likely that they harvest timber outside the SJV. Conversely, firms located outside the SJV also are likely to harvest timber inside the SJV. This problem is even more apparent when investigating data for the South Coast Air Basin (SCAB). Although there are half the number of SIC 241 employees in the SCAB compared to the SJV, the timber harvest is 0.2 percent of that recorded in the SJV (223,600,000 board feet compared to 400,000 board feet).[1] Obviously, the firms located in the SCAB perform the majority of their work outside the SCAB.

Approach

Because the choice of activity indicators appeared questionable in the distribution of logging equipment performed for NEVES, some effort was devoted to investigating alternative indicators. The most obvious indicator of logging activity is board feet of timber harvested. This information is available on a national and regional basis from the U.S. Forest Service[2] (for National Forest lands), but it does not include timber harvested on private lands. (However, it does appear that detailed, local-level timber harvest data are available from state agencies as described below.)

As discussions with logging interests continued, it became apparent that there are relatively few logging systems (or methods) employed by timber harvesters in the U.S. Generally, these can be categorized as cable, mechanized, tractor, and helicopter methods. As outlined below, equipment requirements and production from each system were obtained from industry experts, and a bottom-up method was developed using thousand board feet (MBF) as the activity variable.

Methodology and Data Sources

Representatives of private firms, logging industry associations, and the U.S. Forest Service were contacted for information relating to equipment usage for timber harvesting operations. This information was compiled and formed the basis of a bottom-up methodology for determining logging equipment activity. Details on each of the timber harvesting methods outlined by the logging industry are contained in Table 11-2, and a brief description of each follows.

Cable Systems - Also known as a "high lead side," this methodology utilizes a Diesel engine to power a cable that is strung between two points in the harvest area. Trees in the harvest area are felled, attached to the cable, and dragged to a loading area. A tractor is used to move the felled logs into position for attachment to the cable, and a hydraulic log loader is used to load the logging trucks. Chainsaws are used to fell the trees and trim branches prior to loading. Generally, this method is used in rough terrain.

Mechanical Systems - Mechanical systems rely on feller/bunchers to fell trees rather than chainsaws. Thus, only one saw is listed in Table 11-2 which would be used for general cutting purposes. Also shown in Table 11-2 for this system is a Harvester/Processor. These are used to trim the logs prior to transport. Mechanical systems are generally limited to smooth terrain.

Tractor Systems - Tractor systems remain the most common method of timber harvesting.[3] This approach relies on manual felling of timber with chainsaws and a tractor or skidder to drag the tree to the loading area.

Helicopter Systems - Helicopter systems are not used to a great extent, but they allow for high production rates when they are utilized. The helicopter essentially takes the place of the cable or skidders in moving the log from the harvest area to the loading zone.

Horsepower and Load Factor Estimates - In addition to equipment and daily usage patterns for each system, industry provided horsepower estimates for the corresponding equipment types. These estimates were used as received for equipment not included in NEVES (e.g., harvester/processor, log loader). However, it was felt that horsepower estimates provided by PSR were more representative of the industry as a whole and were used for chainsaws, feller/bunchers, and skidders. Load factor data were applied in the same fashion. Although actual load factor estimates were not provided by industry, percent of time at idle, part throttle, and full throttle was submitted. Composite load factors were developed from these data by assuming 10 percent load at idle, 50 percent load at part throttle, and 90 percent load at full throttle. Horsepower and load factor information was combined with the daily equipment usage and production rates to develop bhp-hr/MBF estimates for each logging system. Results of this analysis are given in Table 11-2.

Table 11-2

Summary of Production and Equipment Requirements for Standard Logging Systems

Cable (High Lead) Side – 45 MBF/Day Average Production				
Equipment Type	HP	Load Factor	Daily Hours	Bhp–hr
1 – Skagit Tower	275	0.6	6	990
1 – Log Loader	250	0.8	9	1800
1 – Cat Tractor	230	0.7	1	161
Total Diesel	66 Bhp–hr/MBF			2951
2.5 – Feller Saws	6	0.92	5	69
1 – Chaser Saw	6	0.92	4	22
Total 2–Stroke Gasoline	2.02 Bhp–hr/MBF			91

Mechanical Side – 80 MBF/Day Average Production				
Equipment Type	HP	Load Factor	Daily Hours	Bhp–hr
1 – Feller/Buncher	183	0.71	9	1169
2 – Skidders	150	0.74	6	1332
1 – Harvester/Processor	200	0.8	9	1440
1 – Log Loader	250	0.7	10	1750
Total Diesel	71 Bhp–hr/MBF			5691
1 – Chaser Saw	6	0.92	8	44
Total 2–Stroke Gasoline	0.55 Bhp–hr/MBF			44

Tractor Side – 80 MBF/Day Average Production				
Equipment Type	HP	Load Factor	Daily Hours	Bhp–hr
2 – Tractors/Skidders	150	0.74	6	1332
1 – Log Loader	250	0.7	10	1750
Total Diesel	39 Bhp–hr/MBF			3082
4 – Feller Saws	6	0.92	8	177
1 – Chaser Saw	6	0.92	8	44
Total 2–Stroke Gasoline	2.76 Bhp–hr/MBF			221

Helicopter Side – 250 MBF/Day Average Production				
Equipment Type	HP	Load Factor	Daily Hours	Bhp–hr
1 – Front–End Loader	216	0.7	10	3024
1 – Log Loader	250	0.7	10	1750
Total Diesel	19 Bhp–hr/MBF			4774
8 – Feller Saws	6	0.92	8	353
4 – Chaser Saw	6	0.92	8	177
Total 2–Stroke Gasoline	2.12 Bhp–hr/MBF			530

Regional Distribution of Logging Systems - In order to apply the information above to develop activity estimates for specific areas, it was necessary to determine the type of system(s) used in various regions of the U.S. This information is summarized in Table 11-3,[3] and Figure 11-1 illustrates the boundaries for each region.

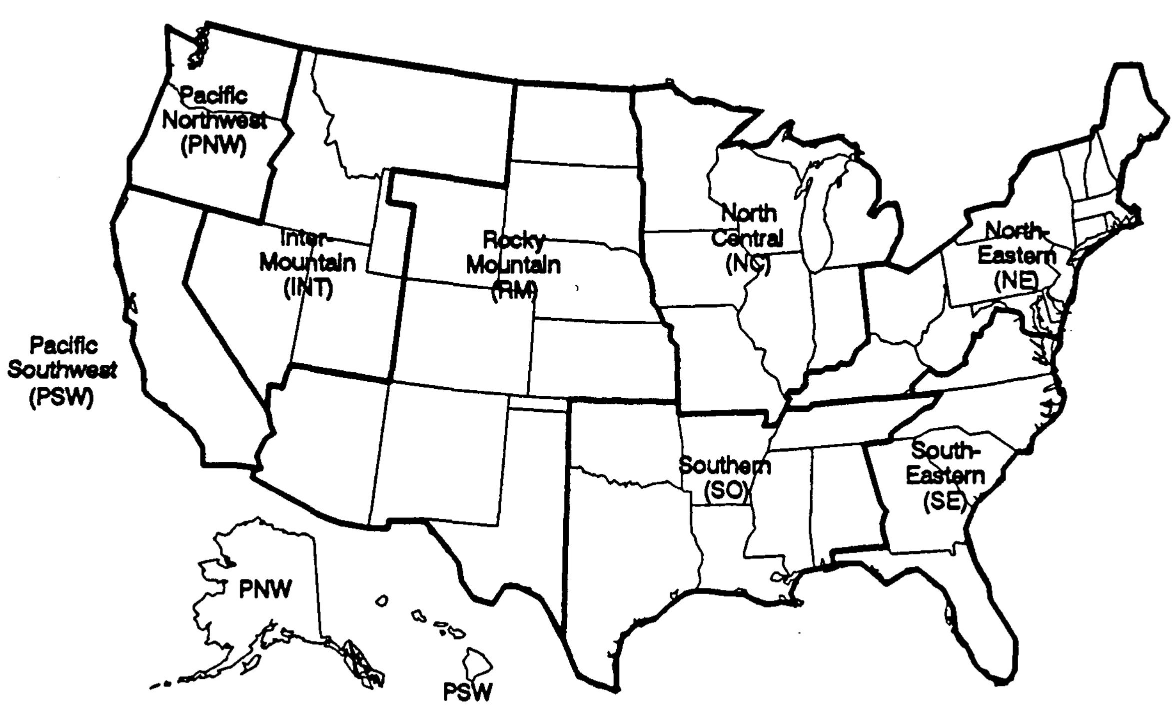
Table 11-3

Regional Distribution of Logging Systems

Region	Logging System			
	Cable	Mechanical	Tractor	Helicopter
Alaska	100%			
Northwest	35%	10%	50%	5%
Northeast		10%	90%	
Intermountain	20%	10%	70%	
South	5%	25%	70%	

Figure 11-1

Logging Regions in the U.S.



Timber Harvested - The final variable needed to complete the activity calculation for logging equipment is MBF of timber harvested by county. This information appears to be readily available from state Departments of Forestry, Natural Resources, or Tax Agencies. This was confirmed for Washington,[4] Oregon,[5] and California[3]. In addition to total MBF, Oregon and Washington report MBF according to land ownership (i.e., federal versus private) for each county, while California reports MBF by land ownership for the whole state. (This distinction could be important if it was found that harvesting methods differ by land ownership.)

Sample Calculations

The above methodology was applied to the SJV air basin using the "Northwest" logging system distribution given in Table 11-3. This resulted in an average Diesel equipment activity of 51 bhp-hr/MBF and a 2-stroke gasoline (i.e., chainsaw) activity of 2.2 bhp-hr/MBF. Applying an annual timber harvest total of 223,6000 MBF for the SJV[32] gives a total logging activity of 11,404,000 bhp-hr for heavy-duty Diesel equipment and 492,200 bhp-hr for chainsaws. (These results are summarized in Table 11-4.) Both the heavy-duty Diesel and the 2-stroke gasoline figures compare reasonably well with the PSR estimates. The close agreement between estimates is somewhat curious, however, particularly since the methodology used in NEVES appears only to account for mechanical systems. (Note the 2 to 1 ratio of skidders to feller/bunchers - consistent with the mechanical system outlined in Table 11-2.)

Table 11-4

Comparison of Logging Equipment Activity Estimates for the SJVAB (1000 bhp-hr)

Methodology	Heavy-Duty Diesel	Chainsaws
NEVES	11,540	639
This Work	11,404	492

Additional Considerations

Shredders over 5 HP were categorized as logging equipment in NEVES. When discussing the use of shredders with U.S. Forest Service personnel,[37] however, it was discovered that they are only used in limited applications, such as clearing brush along road sides. There are generally no requirements for loggers to shred slash after timber harvesting. Slash treatment normally consists of "lopping and scattering", which is simply spreading out limbs to a maximum depth of 18 inches.

On the other hand, chippers are used in the field in some instances, and the chips produced in this fashion are sent to pulp mills. An example of this type of operation is found in lodge pole stands in eastern Oregon where chippers may process whole trees at one time.[37] Detailed equipment requirements for chip production in the field were not obtained, but including this method of timber harvesting/processing would improve the overall accuracy of the activity estimates. However, given the small contribution of logging equipment to the nonroad inventory in most metropolitan areas, the benefits of doing so may be questionable.

The above points out an inherent problem in classifying equipment types in specific categories. Although chippers are included under lawn and garden equipment, a portion of them should be allocated to logging operations. Conversely, even the larger shredders (which average 8 HP, according to PSR) would more appropriately be placed in the lawn and garden category because they are likely used primarily in commercial landscape maintenance operations.

Although the above information on equipment usage by logging system is based on the opinions and expertise of a limited number of industry representatives, the bottom-up approach developed in this work likely provides a better estimate of logging equipment activity than the current top-down methodology. However, a number of issues would need to be considered prior to utilizing the bottom-up approach for official inventory purposes. These include:

- a more thorough review of the logging systems outlined above by the timber industry,
- a more thorough assessment of the types of systems used by logging region, and
- an evaluation of how often logging systems and equipment requirements are modified.

These issues would be best resolved through close contact with the U.S. Forest Service.

Recommendations

The methodology developed above provides a sound basis for estimating logging equipment activity. Additionally, the data requirements are minimal, easing the burden on local air quality planners. Therefore, use of this method is recommended contingent upon additional industry review of the equipment requirements and daily production estimates outlined in Table 11-2.

References for Section 11

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APPENDIX A

Equipment Types Included in EPA's 1991
"Nonroad Engine and Vehicle Emission Study"

APPENDIX A

Equipment Types Included in EPA's 1991 "Nonroad Engine and Vehicle Emission Study"

Equipment Category	Equipment Types
Lawn and Garden	Trimmers/Edgers/Brush Cutters Lawn Mowers Leaf Blowers/Vacuums Rear Engine Riding Mowers Front Mowers Chainsaws <4 HP Shredders <5 HP Tillers <5 HP Lawn and Garden Tractors Wood Splitters Snowblowers Chippers/Stump Grinders Commercial Turf Equipment Other Lawn and Garden
Airport Service	Aircraft Support Equipment Terminal Tractors
Recreational	All Terrain Vehicles (ATVs) Minibikes Off-Road Motorcycles Golf Carts Snowmobiles Specialty Vehicles/Carts
Light Commercial	Generator Sets <50 HP Pumps <50 HP Air Compressors <50 HP Gas Compressors <50 HP Welders <50 HP Pressure Washers <50 HP
Industrial	Aerial Lifts Forklifts Sweepers/Scrubbers Other General Industrial Equipment Other Material Handling Equipment

Equipment Category	Equipment Types
Construction	Asphalt Pavers
	Tampers/Rammers
	Plate Compactors
	Concrete Pavers
	Rollers
	Scrapers
	Paving Equipment
	Surfacing Equipment
	Signal Boards
	Trenchers
	Bore/Drill Rigs
	Excavators
	Concrete/Industrial Saws
	Cement and Mortar Mixers
	Cranes
	Graders
	Off-Highway Trucks
	Crushing/Processing Equipment
	Rough Terrain Forklifts
	Rubber Tired Loaders
	Rubber Tired Dozers
	Tractors/Loaders/Backhoes
	Crawler Tractors
	Skid Steer Loaders
	Off-Highway Tractors
	Dumpers/Tenders
	Other Construction Equipment
Agricultural	2-Wheel Tractors
	Agricultural Tractors
	Agricultural Mowers
	Combines
	Sprayers
	Balers
	Irrigation Sets
	Tillers >5 HP
	Swathers
	Hydro Power Units
	Other Agricultural Equipment
Logging	Chainsaws >4 HP
	Shredders >5 HP
	Skidders
	Fellers/Bunchers

APPENDIX B

Summary of Organizations Contacted to Develop Lot Size Statistics

APPENDIX B

Summary of Organizations Contacted to Develop Lot Size Statistics

Significant efforts were made to collect information relating to lot size distributions. The following is a summary of the organizations contacted to acquire this information.

Federal Agencies:

Department of Housing and Urban Development - Duane McGough (202) 708-1060.
Mr. McGough provided further information on the methodology involved in compiling HUD's American Housing Survey which we had previously obtained from the State Library. The survey includes a distribution of lot sizes within selected metropolitan areas.

Bureau of Land Management - (916) 322-7777
Requested any regional land use information or maps that they might have. We were informed that they have data for BLM land only.

U.S. Geological Survey - Todd (703) 648-6045
Digital land use and land cover data are available at a cost of well over $100.00 for the San Joaquin Valley alone. It is also questionable whether our software is compatible with their format. USGS referred us to the California Division of Mines and Geology.

State of California:

California Division of Mines and Geology - (916) 324-7380
We were informed that they have mining reclamation and geology information only.

California Department of Finance - (916) 445-3878
Obtained population and housing estimates for each of the eight counties in the San Joaquin Valley. These reports list the number of single family, multi family, and mobile housing units, updated annually.

San Joaquin Valley:

Sacramento County Planning - Melinda Grosh (916) 440-5917
Sent 1988 acreage/zone and minimum lot size/zone information for unincorporated county.

Sacramento City Planning - Gary Ziggenfootz (916) 264-5381

Was supposed to send acreage/zone information. Still waiting.

Fresno County Planning - Rick Hoover (209) 453-5010
Wanted $2,500 to do a data sort. Referred us to County Assessor (Barry Kondo) who wanted $11,000 to do a data sort.

Fresno City Planning - Cathy Chung (209) 498-2715
Verbally gave estimates based on "looking at the lot size distributions in a few key areas of the city," and applying the percentages to data from the 1992 Population and Housing Estimates report.

Kern County Planning Commission - Dave Mitchell (805) 861-2615
Sent the 1988 Land Use Inventory report that lists the number of DU's by zone and average lot size/zone.

Bakersfield City Planning - Jim Eggert (805) 326-3733
Sent total acreage/zone and minimum lot size/zone information. Calculated number of DU's differed from Population and Housing Estimates report data by several orders of magnitude. Follow-up phone call to Jim Eggert revealed that the acreage/zone information included a lot of undeveloped land, but he didn't know exactly how much.

Taft City Planning - Marilyn Beardslee (805) 763-3144
Never called back.

Delano City Planning Commission - Jeremy Tobias (805) 721-3303
Verbally gave us total acreage/zone and DU density/zone data. Poor distribution.

McFarland City Planning - Mike O'Haver (805) 792-3091
Sent total acreage/zone and minimum lot size/zone information. Poor distribution.

Shafter City Planning - Lawrence Tomasello (805) 746-6361
Verbally gave us total acreage/zone and DU density/zone information. Poor distribution.

Arvin City Planning - Howard Phillips (805) 854-3134
Never called back.

Tehachappi City Planning - Christopher Grimes (805) 822-2200
Had nothing but Population and Housing Estimates data that we had already obtained from the California Department of Finance.

Kings County Planning - Bill Zumwald (209) 582-3211
Sent fairly good acreage/zone data for unincorporated county.

Corcoran City Planning - No information available.

Hanford City Planning - Greg Shindler (209) 585-2578
Sent total developed acreage/zone and minimum lot size/zone information.

Merced County Planning - No information available.
Referred us to Robert Beckler at the Merced County Area Government who wanted $500.00 to do a data search.

Merced City Planning - No information available.

Madera County Planning - No information available.

Stanislaus County Planning - Julie Larson (209) 525-6330
Sent acreage/zone and minimum lot size/zone information. Poor distribution.

Stanislaus County Assessors Office - Jan Perroti (209) 525-6461
No information available.

Ceres City Planning - Bill Carlson (209) 538-5774
Verbally gave us acreage/zone and minimum lot size/zone information. Poor distribution.

Hughson City Planning - (209) 883-4054
Never called back.

Modesto City Planning - Steve Mitchell (209) 577-5267
Sent acreage/zone and minimum lot size/zone data. Very poor distribution.

Newman City Planning - (209) 862-3725
Never called back.

Oakdale City Planning - John Thayer (209) 847-4245
Sent acreage/zone and minimum lot size/zone information. Poor distribution.

Patterson City Planning - Jenny (209) 892-2041
No information available.

Riverbank City Planning - Glory (209) 869-6193
Never called back.

Turlock City Planning - Ernie Rubi (209) 668-5565
Verbally gave us lot size/zone information. Poor distribution.

Waterford City Planning - Harder Bruch (209) 874-2328
Never called back.

San Joaquin County Planning - Bill Factor (209) 468-2200
No information available. Referred us to Ron Sugimoto at County Assessors Office who wanted $450 to do a data search.

Tulare County Planning - Andrew Pacheco (209) 733-6254
No information available.

Tulare City Planning - Mark Kelty (209) 685-2300
No acreage/zone information available.

Washington D.C. Area:

Washington D.C. Planning - Anita Royster (202) 727-6492
Sent acreage/zone and minimum lot size/zone information.

State of Virginia:

Northern Virginia Planning District and Commission -
Mr. Billingsly (703) 642-0700.
No lot size information available.

Arlington County Planning - Margaret Simkovsky (703) 358-3525
Sent acreage/zone and lot size/zone information.

Fairfax City Planning - Sue Cotellessa (703) 385-7930
Only very general lot size data were available. 2600 out of 4000 total city acres are zoned for single family and duplex lots. Single family lots are all between 9,500 and 20,000 square feet.

Fairfax County Planning - Fatima Khaja (703) 324-3820
Sent detailed breakdown of acreage/zone and minimum lot size/zone information for both incorporated and unincorporated areas of county.

Falls Church City Planning - Gary Fuller (703) 241-5040
Verbally gave acreage/zone and minimum lot size/zone information. Poor distribution, but the city is comprised of only two square miles so we wouldn't expect a wide lot size distribution.

Loudoun County Planning - Cynthia Richmond (703) 777-0296
Verbally gave us very good estimates of DU's across a distribution of lot sizes. This information was from a report compiled by the Economic Development and Demographics Department using 1990 census and county assessment records. Both incorporated and unincorporated Loudoun County is included in this report.

Manassas City Planning - Liz Weiler (703) 257-8200
Sent developed and undeveloped acres/zone information.

Manassas Park City Planning - Troy Taylor (703) 335-8800
Verbally gave us acreage/zone and minimum lot size/zone information. Poor distribution.

Prince William County Planning - Dan Eurich (703) 792-6830
Sent some zoning data which was not very helpful. We sent the required letter of request for additional lot size data. Received detailed acreage/lot size and minimum lot size information.

Stafford County Planning - Jeff Harvey (703) 659-8668
No information available.

State of Maryland:

Calvert County Planning - Randi Vott (410) 535-2348
Had nothing except estimated of SFU's in Calvert County. Referred us to Maryland Office of Planning.

Maryland Office of Planning - John Kozarski (410) 225-4500
Sent a publication that contains land use/acre by county information as well as census data for each of the five counties in the nonattainment area.

APPENDIX C

Data and Summary Statistics for Regression Analyses

Data Used in Regression Analyses for
Lawn and Garden Equipment

STATE	SFHU	SIC 078 Employment	PSR Population
Nation	57,130,570	230,059	
California	5,753,543	43,819	14,565,558
Colorado	766,655	3,326	1,898,121
Connecticut	700,160	4,552	1,512,989
Delaware	160,615	802	279,525
Florida	2,498,179	18,897	5,590,445
Georgia	1,412,873	7,179	2,286,651
Illinois	2,542,992	8,452	4,153,123
Indiana	1,549,401	4,597	1,855,420
Louisiana	1,105,431	1,470	1,677,623
Maryland	1,055,018	6,913	2,035,273
Massachusetts	1,117,154	5,949	2,351,447
Minnesota	1,073,613	2,362	1,582,153
Missouri	1,429,688	3,604	1,899,011
New Hampshire	218,958	954	455,364
New Jersey	1,564,273	8,695	3,290,457
New York	2,786,819	10,790	5,872,506
Ohio	2,866,325	10,702	4,310,529
Pennsylvania	2,898,363	10,716	4,099,958
Texas	3,863,693	14,172	7,994,691
Utah	342,290	663	557,840
Virginia	1,437,060	6,728	2,292,295
Washington	1,145,385	4,179	2,177,032
Wisconsin	1,213,055	2,435	1,677,327

DEP VARIABLE: LG_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	1.95099E+14	1.95099E+14	256.507	0.0001
ERROR	21	1.59726E+13	760601122205		
C TOTAL	22	2.11072E+14			

ROOT MSE	872124.5	R-SQUARE	0.9243
DEP MEAN	3235449	ADJ R-SQ	0.9207
C.V.	26.95528		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-707243	306058.26742	-2.311	0.0311
SFU	1	2.29565527	0.14333671	16.016	0.0001

EP VARIABLE: LG_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	4.31805E+14	4.31805E+14	474.176	0.0001
ERROR	22	2.00341E+13	910641766303		
U TOTAL	23	4.51839E+14			

ROOT MSE	954275.5	R-SQUARE	0.9557
DEP MEAN	3235449	ADJ R-SQ	0.9536
C.V.	29.49437		

OTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
SFU	1	2.02923856	0.09318868	21.776	0.0001

DEP VARIABLE: LG_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	1.95227E+14	1.95227E+14	258.753	0.0001
ERROR	21	1.58444E+13	754494758144		
C TOTAL	22	2.11072E+14			

ROOT MSE	868616.6	R-SQUARE	0.9249
DEP MEAN	3235449	ADJ R-SQ	0.9214
C.V.	26.84686		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	637563.09721	242666.46080	2.627	0.0157
SIC078	1	328.38371235	20.41452694	16.086	0.0001

DEP VARIABLE: LG_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	4.30786E+14	4.30786E+14	450.174	0.0001
ERROR	22	2.10525E+13	956933400614		
U TOTAL	23	4.51839E+14			

ROOT MSE	978229.7	R-SQUARE	0.9534
DEP MEAN	3235449	ADJ R-SQ	0.9513
C.V.	30.23474		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
SIC078	1	364.07981859	17.15957404	21.217	0.0001

DEP VARIABLE: LG_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	2.05558E+14	1.02779E+14	372.790	0.0001
ERROR	20	5.51403E+12	275701693591		
C TOTAL	22	2.11072E+14			

ROOT MSE	525073	R-SQUARE	0.9739
DEP MEAN	3235449	ADJ R-SQ	0.9713
C.V.	16.22875		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-206946	201375.61924	-1.028	0.3164
SFU	1	1.20543012	0.19692648	6.121	0.0001
SIC078	1	173.44157757	28.16024114	6.159	0.0001

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP INTERCEP	VAR PROP SFU	VAR PROP SIC078
1	2.607524	1.000000	0.0335	0.0096	0.0137
2	0.351239	2.724665	0.5431	0.0061	0.0984
3	0.0412371	7.951884	0.4234	0.9843	0.8878

EP VARIABLE: LG_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	4.31805E+14	4.31805E+14	474.176	0.0001
ERROR	22	2.00341E+13	910641766303		
U TOTAL	23	4.51839E+14			

ROOT MSE	954275.5	R-SQUARE	0.9557
DEP MEAN	3235449	ADJ R-SQ	0.9536
C.V.	29.49437		

OTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
SFU	1	2.02923856	0.09318868	21.776	0.0001

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP SFU
1	1.000000	1.000000	1.0000

Data Used in Regression Analyses for
Airport Service Equipment

State	PSR Population	Enplaned Passengers	Enplaned Cargo (Tons)		
			Total	Freight	Mail
California	9950	53,556,596	881,441.17	713,222.60	168,218.57
Colorado	1473	12,896,777	107,754.34	68,740.08	39,014.26
Connecticut	1547	2,312,455	28,758.02	14,432.08	14,325.94
Delaware	219	0	3,449.54	3,449.54	0.00
Florida	3355	34,081,249	373,889.13	290,246.86	83,642.27
Georgia	1646	23,385,836	261,276.15	167,448.17	93,827.98
Illinois	4636	29,593,824	452,863.48	307,692.38	145,171.10
Indiana	1745	3,160,635	124,392.59	113,379.40	11,013.19
Louisiana	1406	4,164,618	31,997.17	22,504.93	9,492.24
Maryland	1571	4,420,547	38,113.76	18,390.83	19,722.93
Massachusetts	2201	9,654,220	158,505.94	128,002.89	30,503.05
Minnesota	1685	9,090,931	111,425.60	68,429.16	42,996.44
Missouri	1826	12,775,950	122,828.80	68,139.79	54,689.01
New Hampshire	326	267,963	7,724.80	7,092.79	632.01
New Jersey	2726	9,979,900	198,040.31	163,974.49	34,065.82
New York	4938	26,263,054	456,300.91	334,645.80	121,655.11
Ohio	4525	11,719,192	116,144.31	72,389.78	43,754.53
Pennsylvania	4003	15,960,382	150,203.32	81,550.94	68,652.38
Texas	6739	46,435,641	372,104.12	247,401.15	124,702.97
Utah	469	5,388,178	54,094.25	35,305.65	18,788.60
Virginia/DC	1570	13,991,121	134,609.08	75,287.58	59,321.50
Washington	1230	8,457,229	151,155.94	113,697.71	37,458.23
Wisconsin	1618	2,779,015	27,996.24	18,616.36	9,379.88

EP VARIABLE: AP_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	93621472.78	46810736.39	45.281	0.0001
ERROR	20	20675541.66	1033777.08		
C TOTAL	22	114297014.43			

ROOT MSE	1016.748	R-SQUARE	0.8191
DEP MEAN	2669.739	ADJ R-SQ	0.8010
C.V.	38.08418		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	622.28967864	306.59441114	2.030	0.0559
PASS	1	.00006553352	.00003816396	1.717	0.1014
CARGO	1	0.005678711	0.002716053	2.091	0.0495

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP INTERCEP	VAR PROP PASS	VAR PROP CARGO
1	2.587314	1.000000	0.0524	0.0103	0.0110
2	0.372742	2.634633	0.9155	0.0221	0.0376
3	0.039943	8.048298	0.0321	0.9676	0.9514

DEP VARIABLE: AP_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	89102394.43	89102394.43	74.268	0.0001
ERROR	21	25194620.01	1199743.81		
C TOTAL	22	114297014.43			

ROOT MSE	1095.328	R-SQUARE	0.7796
DEP MEAN	2669.739	ADJ R-SQ	0.7691
C.V.	41.02754		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	613.87832009	330.26127347	1.859	0.0771
PASS	1	0.0001389359	.00001612182	8.618	0.0001

:P VARIABLE: AP_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	90573247.67	90573247.67	80.174	0.0001
ERROR	21	23723766.76	1129703.18		
C TOTAL	22	114297014.43			

ROOT MSE	1062.875	R-SQUARE	0.7924
DEP MEAN	2669.739	ADJ R-SQ	0.7826
C.V.	39.81194		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	777.75309211	306.21128357	2.540	0.0191
CARGO	1	0.00996907	0.001113363	8.954	0.0001

DEP[illegible]ABLE: AP_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	253295369.81	126647684.91	106.664	0.0001
ERROR	21	24934306.19	1187347.91		
U TOTAL	23	278229676.00			

ROOT MSE	1089.655	R-SQUARE	0.9104
DEP MEAN	2669.739	ADJ R-SQ	0.9018
C.V.	40.81503		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
PASS	1	.00008840719	.00003907664	2.262	0.0344
CARGO	1	0.005606375	0.002910559	1.926	0.0677

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP PASS	VAR PROP CARGO
1	1.958873	1.000000	0.0206	0.0206
2	0.0411265	6.901477	0.9794	0.9794

Data Used in Regression Analyses for Recreational Equipment

State	Rural Population	U.S. Acreage (1000s)				MIC
		Total	Fed. Owned	State Owned	Total Public	Population
Nation		2,271,342	724,068	10,817	734,885	
California	2,188,700	100,207	46,465	1,277	47,742	324,200
Colorado	578,887	66,486	24,045	287	24,332	39,100
Connecticut	685,568	3,135	14	181	195	23,900
Delaware	178,830	1,266	30	12	42	6,800
Florida	1,771,304	34,721	4,261	341	4,602	102,300
Georgia	2,380,887	37,295	2,030	62	2,092	104,500
Illinois	1,762,050	35,795	500	372	872	65,700
Indiana	1,946,060	23,158	437	57	494	65,200
Louisiana	1,348,214	28,868	1,142	38	1,180	80,300
Maryland	893,039	6,319	198	283	481	33,700
Massachusetts	946,822	5,035	83	267	350	39,700
Minnesota	1,318,625	51,206	3,460	3,441	6,901	68,000
Missouri	1,601,064	44,248	2,069	109	2,178	77,700
New Hampshire	543,582	5,769	740	31	771	21,800
New Jersey	819,547	4,813	160	298	458	52,100
New York	2,826,408	30,681	1,555	258	1,813	113,900
Ohio	2,807,706	26,222	318	208	526	110,200
Pennsylvania	3,693,348	28,804	641	276	917	136,800
Texas	3,351,993	168,218	3,270	225	3,495	171,300
Utah	223,769	52,697	33,535	116	33,651	45,300
Virginia	1,893,915	25,496	2,465	54	2,519	59,600
Washington	1,148,744	42,694	12,480	234	12,714	64,000
Wisconsin	1,679,813	35,011	1,830	120	1,950	57,400

DEP VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	40208213665	40208213665	15.298	0.0008
ERROR	21	55193745465	2628273594		
C TOTAL	22	95401959130			

ROOT MSE	51266.69	R-SQUARE	0.4215
DEP MEAN	81021.74	ADJ R-SQ	0.3939
C.V.	63.27523		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	10442.78781	20973.53352	0.498	0.6237
R_POP	1	0.04436638	0.0113431	3.911	0.0008

EP VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	28370921916	28370921916	108.964	0.0001
ERROR	20	5207385811	260369290.56		
C TOTAL	21	33578307727			

ROOT MSE	16135.96	R-SQUARE	0.8449
DEP MEAN	69968.18	ADJ R-SQ	0.8372
C.V.	23.06186		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	11154.18142	6601.52593	1.690	0.1066
R_POP	1	0.03761341	0.003603304	10.439	0.0001

DEP VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	28498709451	28498709451	121.896	0.0001
ERROR	19	4442101977	233794840.91		
C TOTAL	20	32940811429			

ROOT MSE	15290.35	R-SQUARE	0.8651
DEP MEAN	71142.86	ADJ R-SQ	0.8581
C.V.	21.49246		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	6694.67763	6723.66782	0.996	0.3319
R_POP	1	0.03960076	0.00358681	11.041	0.0001

)EP VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	190540655751	190540655751	75.063	0.0001
ERROR	22	55845314249	2538423375		
U TOTAL	23	246385970000			

ROOT MSE	50382.77	R-SQUARE	0.7733
DEP MEAN	81021.74	ADJ R-SQ	0.7630
C.V.	62.18426		

IOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
R_POP	1	0.04922551	0.005681701	8.664	0.0001

DEP VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	135329623022	135329623022	477.577	0.0001
ERROR	21	5950706978	283366998.93		
U TOTAL	22	141280330000			

ROOT MSE	16833.51	R-SQUARE	0.9579
DEP MEAN	69968.18	ADJ R-SQ	0.9559
C.V.	24.0588		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
R_POP	1	0.04280965	0.001958934	21.854	0.0001

:P VARIABLE: MC_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	134554354925	134554354925	575.771	0.0001
ERROR	20	4673885075	233694253.75		
U TOTAL	21	139228240000			

ROOT MSE	15287.06	R-SQUARE	0.9664
DEP MEAN	71142.86	ADJ R-SQ	0.9648
C.V.	21.48784		

)TE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
R_POP	1	0.04270133	0.001779576	23.995	0.0001

Data Used in Regression Analyses for Construction Equipment

State	Dodge Statistics (Value, $Millions) Non-Residential	Residential	Non-Building	Total Construction	PSR Population
Nation	55,753.0	74,368.0	35,279.0	165,400.0	
CA	6,691.8	8,120.7	3,777.2	18,589.7	309,940
CO	1,169.2	1,516.5	1,259.9	3,945.6	53,587
CT	823.0	647.7	342.3	1,813.0	34,536
DE	162.5	198.3	135.3	496.1	7,664
FL	2,634.9	5,843.4	1,418.8	9,897.1	115,151
GA	1,528.0	3,055.1	538.7	5,121.8	51,304
IL	2,331.5	2,985.9	1,718.2	7,035.6	107,700
IN	1,480.5	2,086.3	623.9	4,190.7	40,068
LA	586.9	677.2	759.8	2,023.9	53,258
MD	1,042.6	2,036.2	548.3	3,627.1	51,648
MA	1,184.8	1,261.9	1,122.9	3,569.6	53,500
MN	1,062.8	1,815.3	748.1	3,626.2	42,174
MO	892.3	1,385.7	644.4	2,922.4	45,658
NH	184.5	313.8	108.3	606.6	9,546
NJ	1,283.1	1,071.2	1,258.8	3,613.1	71,940
NY	3,676.8	2,613.3	2,936.9	9,227.0	140,785
OH	2,686.6	3,098.5	1,482.9	7,268.0	89,420
PN	2,948.8	2,570.4	1,331.8	6,851.0	103,140
TX	3,613.3	4,817.3	2,081.0	10,511.6	242,129
UT	425.4	660.4	186.7	1,272.5	15,650
VA	1,109.9	2,427.1	1,265.1	4,802.1	52,952
WA	1,889.8	2,529.5	932.3	5,351.6	42,185
WI	1,045.5	1,555.8	625.6	3,226.9	34,301

DEP VARIABLE: CON_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	101237642787	101237642787	167.603	0.0001
ERROR	21	12684715174	604034055.90		
C TOTAL	22	113922357961			

ROOT MSE	24577.1	R-SQUARE	0.8887
DEP MEAN	76879.83	ADJ R-SQ	0.8834
C.V.	31.96821		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-10514.5	8475.44193	-1.241	0.2284
TOT_CON	1	16.80812764	1.29831190	12.946	0.0001

DEP VARIABLE: CON_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	236249672745	236249672745	381.765	0.0001
ERROR	22	13614361377	618834608.02		
U TOTAL	23	249864034122			

ROOT MSE	24876.39	R-SQUARE	0.9455
DEP MEAN	76879.83	ADJ R-SQ	0.9430
C.V.	32.3575		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
TOT_CON	1	15.52524188	0.79458445	19.539	0.0001

Data Used in Regression Analyses for
Light Commercial Equipment

State	Dodge Statistics (Value, $Millions)				Oil	PSR
	Non–Residential	Residential	Non–Building	Total Construction	Production (1000 BBL)	Population
Nation	55,753.0	74,368.0	35,279.0	165,400.0	2,684,687	
CA	6,691.8	8,120.7	3,777.2	18,589.7	320,868	444,051
CO	1,169.2	1,516.5	1,259.9	3,945.6	30,454	94,743
CT	823.0	647.7	342.3	1,813.0	0	51,276
DE	162.5	198.3	135.3	496.1	0	8,511
FL	2,634.9	5,843.4	1,418.8	9,897.1	5,674	124,741
GA	1,528.0	3,055.1	538.7	5,121.8	0	69,850
IL	2,331.5	2,985.9	1,718.2	7,035.6	19,954	186,748
IN	1,480.5	2,086.3	623.9	4,190.7	3,000	62,894
LA	586.9	677.2	759.8	2,023.9	147,583	128,868
MD	1,042.6	2,036.2	548.3	3,627.1	0	55,539
MA	1,184.8	1,261.9	1,122.9	3,569.6	0	95,626
MN	1,062.8	1,815.3	748.1	3,626.2	0	69,189
MO	892.3	1,385.7	644.4	2,922.4	146	64,153
NH	184.5	313.8	108.3	606.6	0	14,390
NJ	1,283.1	1,071.2	1,258.8	3,613.1	0	109,978
NY	3,676.8	2,613.3	2,936.9	9,227.0	416	217,406
OH	2,686.6	3,098.5	1,482.9	7,268.0	10,008	158,436
PN	2,948.8	2,570.4	1,331.8	6,851.0	2,643	161,093
TX	3,613.3	4,817.3	2,081.0	10,511.6	678,480	571,015
UT	425.4	660.4	186.7	1,272.5	27,604	27,465
VA	1,109.9	2,427.1	1,265.1	4,802.1	15	68,948
WA	1,889.8	2,529.5	932.3	5,351.6	0	59,106
WI	1,045.5	1,555.8	625.6	3,226.9	0	56,929

COMMERCIAL EQUIPMENT - REGRESSION WITH TOTAL CONSTRUCTION VALUATION 1
10:50 TUESDAY, MARCH 9, 1993

DEP VARIABLE: COMM_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	256621047782	256621047782	40.741	0.0001
ERROR	21	132274749379	6298797589		
C TOTAL	22	388895797162			

ROOT MSE	79364.96	R-SQUARE	0.6599
DEP MEAN	126128.5	ADJ R-SQ	0.6437
C.V.	62.92391		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-13013.6	27369.09684	-0.475	0.6393
TOT_CON	1	26.76051470	4.19253939	6.383	0.0001

DEP VARIABLE: COMM_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	621090009404	621090009404	102.200	0.0001
ERROR	22	133698827411	6077219428		
U TOTAL	23	754788836815			

ROOT MSE	77956.52	R-SQUARE	0.8229
DEP MEAN	126128.5	ADJ R-SQ	0.8148
C.V.	61.80723		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
TOT_CON	1	25.17271385	2.49003371	10.109	0.0001

DE[illegible]IABLE: COMM_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	161612415752	161612415752	155.001	0.0001
ERROR	19	19810474691	1042656563		
C TOTAL	20	181422890443			

ROOT MSE	32290.19	R-SQUARE	0.8908
DEP MEAN	104813	ADJ R-SQ	0.8851
C.V.	30.80745		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-9781.2	11591.86758	-0.844	0.4093
TOT_CON	1	22.47916001	1.80556596	12.450	0.0001

DEP VARIABLE: COMM_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	391570902966	391570902966	381.038	0.0001
ERROR	20	20552842200	1027642110		
U TOTAL	21	412123745166			

ROOT MSE	32056.86	R-SQUARE	0.9501
DEP MEAN	104813	ADJ R-SQ	0.9476
C.V.	30.58482		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
TOT_CON	1	21.26941308	1.08961041	19.520	0.0001

DEP VARIABLE: COMM_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	370534210391	185267105195	201.799	0.0001
ERROR	20	18361586771	918079338.54		
C TOTAL	22	388895797162			

ROOT MSE	30299.82	R-SQUARE	0.9528
DEP MEAN	126128.5	ADJ R-SQ	0.9481
C.V.	24.02298		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	16335.76794	10776.01149	1.516	0.1452
TOT_CON	1	15.31559258	1.90201628	8.052	0.0001
OIL_PROD	1	0.55632647	0.04994395	11.139	0.0001

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP INTERCEP	VAR PROP TOT_CON	VAR PROP OIL_PROD
1	2.162498	1.000000	0.0545	0.0498	0.0699
2	0.682194	1.780427	0.1502	0.0069	0.6282
3	0.155308	3.731479	0.7954	0.9433	0.3018

DEP VARIABLE: COMM_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	734317440595	367158720298	376.639	0.0001
ERROR	21	20471396220	974828391.42		
U TOTAL	23	754788836815			

ROOT MSE	31222.24	R-SQUARE	0.9729
DEP MEAN	126128.5	ADJ R-SQ	0.9703
C.V.	24.75432		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
TOT_CON	1	17.57040980	1.22153628	14.384	0.0001
OIL_PROD	1	0.53781424	0.0499023	10.777	0.0001

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP TOT_CON	VAR PROP OIL_PROD
1	1.577467	1.000000	0.2113	0.2113
2	0.422533	1.932190	0.7887	0.7887

Data Used in Regression Analyses for Industrial Equipment

State	Dodge Statistics (Value, $Millions)				CBP	PSR
	Non-Residential	Residential	Non-Building	Total Construction	Mfr Emp	Population
Nation	55,753.0	74,368.0	35,279.0	165,400.0		
CA	6,691.8	8,120.7	3,777.2	18,589.7	2,140,959	43,110
CO	1,169.2	1,516.5	1,259.9	3,945.6	184,893	5,372
CT	823.0	647.7	342.3	1,813.0	383,455	7,993
DE	162.5	198.3	135.3	496.1	67,621	799
FL	2,634.9	5,843.4	1,418.8	9,897.1	517,930	11,866
GA	1,528.0	3,055.1	538.7	5,121.8	580,809	7,049
IL	2,331.5	2,985.9	1,718.2	7,035.6	1,033,272	24,322
IN	1,480.5	2,086.3	623.9	4,190.7	620,193	8,871
LA	586.9	677.2	759.8	2,023.9	163,435	5,204
MD	1,042.6	2,036.2	548.3	3,627.1	231,375	5,468
MA	1,184.8	1,261.9	1,122.9	3,569.6	600,730	11,464
MN	1,062.8	1,815.3	748.1	3,626.2	387,642	8,437
MO	892.3	1,385.7	644.4	2,922.4	432,073	8,634
NH	184.5	313.8	108.3	606.6	110,611	1,588
NJ	1,283.1	1,071.2	1,258.8	3,613.1	684,408	13,573
NY	3,676.8	2,613.3	2,936.9	9,227.0	1,249,626	23,924
OH	2,686.6	3,098.5	1,482.9	7,268.0	1,119,170	25,036
PN	2,948.8	2,570.4	1,331.8	6,851.0	1,051,180	18,910
TX	3,613.3	4,817.3	2,081.0	10,511.6	938,491	27,475
UT	425.4	660.4	186.7	1,272.5	94,934	1,883
VA	1,109.9	2,427.1	1,265.1	4,802.1	429,930	5,614
WA	1,889.8	2,529.5	932.3	5,351.6	326,080	4,810
WI	1,045.5	1,555.8	625.6	3,226.9	530,128	8,949

DEP VARIABLE: IND_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	2209064094	2209064094	295.334	0.0001
ERROR	21	157077543.01	7479883.00		
C TOTAL	22	2366141637			

ROOT MSE	2734.937	R-SQUARE	0.9336
DEP MEAN	12189.17	ADJ R-SQ	0.9305
C.V.	22.43743		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-379.266	927.40687683	-0.409	0.6867
MFR_EMP	1	0.02082825	0.001211982	17.185	0.0001

DEP VARIABLE: IND_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	1893772515	1893772515	84.191	0.0001
ERROR	21	472369122.77	22493767.75		
C TOTAL	22	2366141637			

ROOT MSE	4742.76	R-SQUARE	0.8004
DEP MEAN	12189.17	ADJ R-SQ	0.7909
C.V.	38.90961		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	236.18946674	1635.54592	0.144	0.8866
TOT_CON	1	2.29885844	0.25054136	9.176	0.0001

DEP VARIABLE: IND_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	2223666886	1111833443	156.074	0.0001
ERROR	20	142474751.15	7123737.56		
C TOTAL	22	2366141637			

ROOT MSE	2669.033	R-SQUARE	0.9398
DEP MEAN	12189.17	ADJ R-SQ	0.9338
C.V.	21.89675		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-687.942	930.38319149	-0.739	0.4682
TOT_CON	1	0.44009757	0.30738663	1.432	0.1677
MFR_EMP	1	0.01754764	0.002578607	6.805	0.0001

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP INTERCEP	VAR PROP TOT_CON	VAR PROP MFR_EMP
1	2.698238	1.000000	0.0402	0.0100	0.0102
2	0.260361	3.219233	0.9568	0.0414	0.0500
3	0.0414013	8.072964	0.0029	0.9486	0.9398

DEP VARIABLE: IND_POP

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	2	5637019162	2818509581	404.378	0.0001
ERROR	21	146369571.26	6969979.58		
U TOTAL	23	5783388733			

ROOT MSE	2640.072	R-SQUARE	0.9747
DEP MEAN	12189.17	ADJ R-SQ	0.9723
C.V.	21.65915		

NOTE: NO INTERCEPT TERM IS USED. R-SQUARE IS REDEFINED.

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
TOT_CON	1	0.38742900	0.29577522	1.310	0.2044
MFR_EMP	1	0.01726934	0.002523311	6.844	0.0001

COLLINEARITY DIAGNOSTICS

NUMBER	EIGENVALUE	CONDITION NUMBER	VAR PROP TOT_CON	VAR PROP MFR_EMP
1	1.958496	1.000000	0.0208	0.0208
2	0.0415041	6.869355	0.9792	0.9792

APPENDIX D

Correspondence With U.S. Air Force Regarding Nonroad Vehicle Usage on Military Installations

September 17, 1992

sierra
research

1521 I Street
Sacramento, CA 95814
(916) 444-6666
Fax: (916) 444-8373

Mr. David Carillo
Compliance Program Manager
Directorate of Environmental Quality
HQ USAF CEVC
Bolling Air Force Base
Washington, D.C. 20332

Dear Mr. Carillo:

As we have previously discussed, Sierra Research, Inc. has been contracted by the U.S. Environmental Protection Agency (EPA) to develop methodologies to estimate nonroad vehicle and equipment usage. Because military installations could contribute a significant fraction of the nonroad inventory in some nonattainment areas, it is important for local air quality planners to have a proper assessment of that contribution. Thus, Sierra is interested in obtaining recommendations for the most efficient means of developing estimates of nonroad vehicle and equipment usage at military installations.

Attached is a brief description of the project as it relates to military installations. It would be most helpful if you could distribute this to the Air Programs Technical Committee at, or prior to, its meeting scheduled for September 23, 1992. Any information you can provide relating to nonroad equipment usage and recommendations for retrieval of this information from individual bases would be very helpful in developing guidance for estimating nonroad equipment usage at military installations.

Thank you for your assistance in this matter. If you have any questions about the study, I can be reached at (916) 444-6666. The EPA project manager is Kevin Green. Questions can also be directed to him at (313) 668-4510.

Sincerely,

Philip Heirigs

Philip Heirigs

Attachment

cc: Kevin Green, EPA

ATTACHMENT

Nonroad Equipment Usage on Military Installations

Background

The 1990 Clean Air Act Amendments required the U.S. Environmental Protection Agency (EPA) to determine the emissions impact of nonroad vehicles and equipment on certain metropolitan areas that do not meet the National Ambient Air Quality Standards (NAAQS) for ozone and/or carbon monoxide. The result of this mandate was the "Nonroad Engine and Vehicle Emissions Study" (NEVES) published by EPA in November 1991. Although this study improved the state-of-the-art in developing nonroad emissions estimates, there is concern that the activity levels developed for specific nonattainment areas may not accurately reflect the distribution or usage of equipment that actually occurs within those communities. Hence, Sierra Research has been contracted by the EPA to investigate alternative data sources and methodologies that may be used to develop estimates of nonroad equipment activity at the local level.

The approach utilized in NEVES to determine county-level equipment populations and usage can be categorized as a "top-down" methodology in which national estimates of equipment population were scaled to the local level using activity indicators specific to different equipment categories (e.g., the number of employees in the construction industry was used to allocate construction equipment). This approach, however, neglected to account for nonroad equipment that is used on military installations. Because military installations could potentially represent a significant portion of the nonroad equipment usage in certain nonattainment areas, it is important to account for them in developing local inventories.

Nonroad Equipment and Vehicle Types

Eight different equipment categories are being considered in Sierra's analysis of nonroad vehicle usage. These include lawn and garden equipment, aircraft support equipment, recreational equipment, light commercial equipment, industrial equipment, construction equipment, agricultural equipment, and logging equipment. The specific equipment types falling within these categories are listed in Table 1. Obviously, not all of these categories are applicable to military installations, however, some may be used to a fair degree. Thus, Sierra is interested in obtaining recommendations on how local air quality planners could obtain the necessary information from military installations to develop an accurate estimate of nonroad equipment usage.

Data Requirements

Because of the large number of nonroad equipment types (and potentially large number of individual pieces of equipment), an assessment of equipment usage may, at first glance, appear to be infeasible. However, surrogates for equipment usage may provide reliable estimates of actual equipment activity without having to track each piece of equipment separately. One such surrogate that has been used with some success in the past is fuel usage. For example, if the total amount of fuel used for landscape maintenance is available and a rough approximation of the mix of lawn and garden equipment can be made, then this information can be used to obtain a reasonably accurate estimate of emissions from lawn and garden equipment.

The biggest challenge in developing methodologies to estimate nonroad equipment usage on military installations appears to be identifying the kind of information that could be easily compiled by individual bases for use by local air quality planners. This is an area in which the Technical Committee might be able to provide considerable input. Thus, Sierra is soliciting recommendations for potential indicators of nonroad equipment activity and the most efficient means of obtaining the information needed to develop nonroad equipment usage estimates on military installations.

Table 1

Equipment Categories Used by EPA in the 1991
"Nonroad Engine and Vehicle Emissions Study"

Equipment Category	Equipment Types
Lawn and Garden	Trimmers/Edgers/Brush Cutters Lawn Mowers Leaf Blowers/Vacuums Rear Engine Riding Mowers Front Mowers Chainsaws <4 HP Shredders <5 HP Tillers <5 HP Lawn and Garden Tractors Wood Splitters Snowblowers Chippers/Stump Grinders Commercial Turf Equipment Other Lawn and Garden
Airport Service	Aircraft Support Equipment Terminal Tractors
Recreational	All Terrain Vehicles (ATVs) Minibikes Off-Road Motorcycles Golf Carts Snowmobiles Specialty Vehicles/Carts
Light Commercial	Generator Sets Pumps Air Compressors Gas Compressors Welders Pressure Washers
Industrial	Aerial Lifts Forklifts Sweepers/Scrubbers Other General Industrial Equipment Other Material Handling Equipment

Equipment Category	Equipment Types
Construction	Asphalt Pavers
	Tampers/Rammers
	Plate Compactors
	Concrete Pavers
	Rollers
	Scrapers
	Paving Equipment
	Surfacing Equipment
	Signal Boards
	Trenchers
	Bore/Drill Rigs
	Excavators
	Concrete/Industrial Saws
	Cement and Mortar Mixers
	Cranes
	Graders
	Off-Highway Trucks
	Crushing/Processing Equipment
	Rough Terrain Forklifts
	Rubber Tired Loaders
	Rubber Tired Dozers
	Tractors/Loaders/Backhoes
	Crawler Tractors
	Skid Steer Loaders
	Off-Highway Tractors
	Dumpers/Tenders
	Other Construction Equipment
Agricultural	2-Wheel Tractors
	Agricultural Tractors
	Agricultural Mowers
	Combines
	Sprayers
	Balers
	Irrigation Sets
	Tillers >5 HP
	Swathers
	Hydro Power Units
	Other Agricultural Equipment
Logging	Chainsaws >4 HP
	Shredders >5 HP
	Skidders
	Fellers/Bunchers

APPENDIX E

NEVES Inventory B Construction Equipment Activity Estimates
for the U.S., DC/MC/VA, and the San Joaquin Valley Air Basin

NEVES Inventory B Construction Equipment Activity Estimates

National Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Asphalt Pavers	12,000	0	421,196	0	421,196	0.5
Tampers/Rammers	0	23,611	0	7,397	7,397	0.0
Plate Compactors	2,322	145,233	3,383	58,012	61,394	0.1
Concrete Pavers	8,400	0	294,837	0	294,837	0.4
Rollers	42,800	0	1,704,965	0	1,704,965	2.2
Scrapers	16,400	0	3,952,236	0	3,952,236	5.0
Paving Equipment	43,615	230,810	1,160,099	135,957	1,296,055	1.6
Surfacing Equipment	0	30,833	0	44,827	44,827	0.1
Signal Boards	20,384	1,559	71,110	1,987	73,098	0.1
Trenchers	53,390	27,170	270,316	0	270,316	0.3
Bore/Drill Rigs	7,761	8,501	473,367	32,401	505,768	0.6
Excavators	52,295	0	5,250,434	0	5,250,434	6.6
Concrete/Industrial Saws	61,336	36,900	1,221,613	191,723	1,413,336	1.8
Cement & Mortar Mixers	4,016	232,152	5,476	64,833	70,310	0.1
Cranes	98,357	2,541	5,753,469	23,716	5,777,184	7.3
Graders	64,000	0	4,694,216	0	4,694,216	5.9
Off-Highway Trucks	19,400	0	10,508,951	0	10,508,951	13.3
Crushing/Proc Eqpt	7,207	1,007	599,983	10,892	610,875	0.8
Rough Terrain Forklifts	25,132	2,217	645,043	0	645,043	0.8
Rubber Tired Loaders	130,000	0	17,174,430	0	17,174,430	21.7
Rubber Tired Dozers	7,757	0	1,332,898	0	1,332,898	1.7
Trctrs/Ldrs/Backhoes	189,000	0	3,569,454	0	3,569,454	4.5
Crawler Tractors	159,050	0	12,403,352	0	12,403,352	15.7
Skid Steer Loaders	140,000	0	1,850,957	0	1,850,957	2.3
Off-Highway Tractors	38,921	0	4,652,038	0	4,652,038	5.9
Dumpers/Tenders	194	24,301	797	9,452	10,249	0.0
Other Construction Eqpt	11,867	1,103	592,223	24,307	616,530	0.8
Total	1,215,604	767,938	78,606,841	605,503	79,212,344	100.0

NEVES Inventory B Construction Equipment Activity Estimates

DC/MD/VA Estimates						
	Population		Activity (1000 Bhp-hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Asphalt Pavers	28	0	994	0	994	0.1
Tampers/Rammers	0	411	0	129	129	0.0
Plate Compactors	40	2,530	59	1,010	1,069	0.1
Concrete Pavers	20	0	691	0	691	0.1
Rollers	171	0	6,812	0	6,812	0.6
Scrapers	234	0	56,392	0	56,392	5.2
Paving Equipment	760	4,020	20,207	2,368	22,575	2.1
Surfacing Equipment	0	537	0	781	781	0.1
Signal Boards	355	27	1,239	35	1,273	0.1
Trenchers	880	473	4,454	0	4,454	0.4
Bore/Drill Rigs	135	148	8,245	564	8,810	0.8
Excavators	678	0	68,071	0	68,071	6.3
Concrete/Industrial Saws	2	643	47	3,339	3,386	0.3
Cement & Mortar Mixers	70	4,044	95	1,129	1,225	0.1
Cranes	1,713	44	100,215	413	100,629	9.3
Graders	278	0	20,390	0	20,390	1.9
Off-Highway Trucks	201	0	108,881	0	108,881	10.1
Crushing/Proc Eqpt	126	18	10,451	190	10,640	1.0
Rough Terrain Forklifts	938	39	24,076	0	24,076	2.2
Rubber Tired Loaders	910	0	120,221	0	120,221	11.2
Rubber Tired Dozers	135	0	23,217	0	23,217	2.2
Trctrs/Ldrs/Backhoes	3,024	0	57,111	0	57,111	5.3
Crawler Tractors	3,898	0	303,982	0	303,982	28.2
Skid Steer Loaders	2,940	0	38,870	0	38,870	3.6
Off-Highway Tractors	678	0	81,030	0	81,030	7.5
Dumpers/Tenders	3	423	14	165	179	0.0
Other Construction Eqpt	207	19	10,315	423	10,739	1.0
Total	18,424	13,376	1,066,080	10,547	1,076,627	100.0

NEVES Inventory B Construction Equipment Activity Estimates

San Joaquin Valley Air Basin Estimates						
	Population		Activity (1000 Bhp–hr/yr)			% Total
Equipment Type	Diesel	Gas	Diesel	Gas	Total	Activity
Asphalt Pavers	57	0	2,450	0	2,450	0.4
Tampers/Rammers	0	215	0	86	86	0.0
Plate Compactors	21	1,321	44	748	791	0.1
Concrete Pavers	39	0	1,702	0	1,702	0.3
Rollers	342	0	13,963	0	13,963	2.4
Scrapers	94	0	24,812	0	24,812	4.2
Paving Equipment	397	2,099	14,758	1,730	16,487	2.8
Surfacing Equipment	0	280	0	553	553	0.1
Signal Boards	185	14	877	25	902	0.2
Trenchers	459	247	2,437	0	2,437	0.4
Bore/Drill Rigs	71	77	5,981	409	6,390	1.1
Excavators	144	0	15,563	0	15,563	2.6
Concrete/Industrial Saws	1	336	30	2,117	2,147	0.4
Cement & Mortar Mixers	37	2,111	67	798	866	0.1
Cranes	895	23	59,543	245	59,788	10.1
Graders	442	0	36,349	0	36,349	6.2
Off–Highway Trucks	51	0	30,387	0	30,387	5.2
Crushing/Proc Eqpt	66	9	7,441	135	7,576	1.3
Rough Terrain Forklifts	490	20	13,852	0	13,852	2.3
Rubber Tired Loaders	1,040	0	144,275	0	144,275	24.5
Rubber Tired Dozers	71	0	15,053	0	15,053	2.6
Trctrs/Ldrs/Backhoes	1,701	0	36,164	0	36,164	6.1
Crawler Tractors	900	0	83,728	0	83,728	14.2
Skid Steer Loaders	1,323	0	18,581	0	18,581	3.1
Off–Highway Tractors	354	0	47,992	0	47,992	8.1
Dumpers/Tenders	2	221	10	121	131	0.0
Other Construction Eqpt	108	10	6,594	271	6,864	1.2
Total	9,288	6,984	582,652	7,238	589,889	100.0

APPENDIX F

Summary of 1987 Construction Census Data by SIC Code

Item	SIC 152 – Gnl Cntrs, Res: SIC 1521 Single Family Housing	SIC 152 – Gnl Cntrs, Res: SIC 1522 Residential, Non–SFH	SIC 1531 Operative Builders	SIC 154 – Gnl Cntrs, Nonres: SIC 1541 Ind Bldgs & Warehouses	SIC 154 – Gnl Cntrs, Nonres: SIC 1542 Nonresidential Buildings	SIC 1611 Highway & Street Const.	SIC 162 – Heavy Const, Except Highway: SIC 1622 Bridge, Tunnel Elev Hwy	SIC 162 – Heavy Const, Except Highway: SIC 1623 Water, Sewer Utility Lines	SIC 162 – Heavy Const, Except Highway: SIC 1629 Hvy Const, Other
Net Value of Construction Work	27,319,239	6,257,443	26,837,792	11,094,502	39,510,241	27,983,839	4,186,846	15,055,297	21,209,274
Work Subbed IN from Others	3,035,374	707,613	559,465	1,143,085	3,024,631	7,065,089	745,097	3,419,333	3,294,752
Work Subbed OUT to Others	11,778,907	7,058,100	22,122,017	10,367,065	50,283,190	6,177,587	1,294,090	1,954,721	4,423,695
Materials, Components, Supplies	12,863,522	2,796,294	12,773,237	4,897,508	15,984,990	11,067,102	1,767,054	4,734,144	6,949,590
Power, Fuels, Lubes	493,123	80,036	379,023	170,543	600,125	1,163,712	87,835	476,371	636,206
Electicity	89,445	19,832	143,007	29,785	123,906	103,582	12,623	32,128	65,774
Natural Gas	16,792	2,867	30,464	9,366	34,593	76,196	2,711	7,666	5,350
Gasoline and Diesel Fuel	356,584	52,123	187,447	119,340	404,289	886,197	65,599	400,312	512,577
On–Highway	323,666	46,602	168,907	96,819	337,666	397,964	31,998	209,814	213,346
Off–Highway	32,917	5,521	18,539	22,520	66,622	488,233	33,600	190,498	299,231
Other, Incl. Oil and Grease	30,300	5,213	18,104	12,051	37,337	97,736	6,901	36,264	52,503
Matls, Cmpnts, Spls, Fuels (MCSF)	13,356,645	2,876,330	13,152,260	5,068,051	16,585,115	12,230,814	1,854,889	5,210,515	7,585,796
Fraction Off–Hwy Fuel Use	0.0025	0.0019	0.0014	0.0044	0.0040	0.0399	0.0181	0.0366	0.0394
Fraction Off–Hwy Fuel Use Normalized to SFH MCSF	1.00	0.78	0.57	1.80	1.63	16.20	7.35	14.83	16.01
Net Value of Construction Work	27,319,239	6,257,443	26,837,792	11,094,502	39,510,241	27,983,839	4,186,846	15,055,297	21,209,274
Fraction Off–Hwy Fuel Use	0.00120	0.00088	0.00069	0.00203	0.00169	0.01745	0.00803	0.01265	0.01411
Fraction Off–Hwy Fuel Use Normalized to SFH Net Value	1.00	0.73	0.57	1.68	1.40	14.48	6.66	10.50	11.71

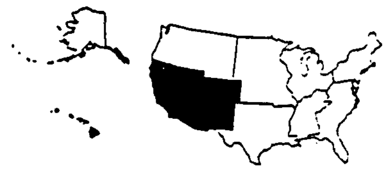
Item	SIC 1711 Plumbing, HVAC	SIC 1721 Painting, Paper Hanging	SIC 1731 Electrical Work	SIC 1741 Masonry & Oth Stone Work	SIC 1742 Plastering, Drywall, Insl	SIC 1743 Tile, Marble, Mosaic	SIC 1751 Carpentry	SIC 1752 Floor Laying & Other Flr	SIC 1761 Roofing, Sdg Sheet Metal
Net Value of Construction Work	44,517,739	7,445,552	34,657,764	8,269,188	15,137,323	2,181,972	10,038,947	3,371,200	14,182,802
Work Subbed IN from Others	21,987,082	3,405,709	16,067,963	5,477,793	11,653,461	1,317,188	4,964,753	1,626,503	5,685,007
Work Subbed OUT to Others	4,985,584	507,770	1,180,462	444,973	1,289,527	89,620	1,204,915	280,234	845,003
Materials, Components, Supplies	18,556,072	1,641,607	12,788,495	2,715,354	5,521,016	871,938	3,997,519	1,548,341	5,637,184
Power, Fuels, Lubes	766,206	162,121	489,713	142,508	192,618	36,522	172,121	63,085	252,272
Electicity	119,454	19,761	81,132	13,033	23,317	5,156	26,963	11,249	39,938
Natural Gas	32,481	4,543	16,935	3,173	6,686	1,129	5,481	2,204	12,525
Gasoline and Diesel Fuel	567,556	129,315	362,957	116,154	151,494	27,720	129,077	46,453	184,020
On–Highway	519,004	114,005	337,671	100,806	139,341	25,953	118,997	43,785	170,647
Off–Highway	48,551	15,309	25,286	15,348	12,153	1,766	10,080	2,667	13,373
Other, Incl. Oil and Grease	46,713	8,501	28,688	10,147	11,120	2,516	10,599	3,178	15,786
Matls, Cmpnts, Spls, Fuels (MCSF)	19,322,278	1,803,728	13,278,208	2,857,862	5,713,634	908,460	4,169,640	1,611,426	5,889,456
Fraction Off–Hwy Fuel Use	0.0025	0.0085	0.0019	0.0054	0.0021	0.0019	0.0024	0.0017	0.0023
Fraction Off–Hwy Fuel Use Normalized to SFH MCSF	1.02	3.44	0.77	2.18	0.86	0.79	0.98	0.67	0.92
Net Value of Construction Work	44,517,739	7,445,552	34,657,764	8,269,188	15,137,323	2,181,972	10,038,947	3,371,200	14,182,802
Fraction Off–Hwy Fuel Use	0.00109	0.00206	0.00073	0.00186	0.00080	0.00081	0.00100	0.00079	0.00094
Fraction Off–Hwy Fuel Use Normalized to SFH Net Value	0.91	1.71	0.61	1.54	0.67	0.67	0.83	0.66	0.78

	SIC 1771 Concrete Work	SIC 1781 Water Well Drilling	SIC 1791 Structural Steel	SIC 1793 Glass & Glazing	SIC 1794 Excavation Work	SIC 1795 Wrecking & Demolition	SIC 1796 Install Bldg Equipment	SIC 1799 Special Trade Contractors	SIC 6552 Land Subdvdr & Developers
Net Value of Construction Work	13,853,510	1,299,288	4,510,231	3,142,354	7,490,988	844,714	5,009,764	9,832,759	2,505,153
Work Subbed IN from Others	9,045,744	213,779	2,854,127	1,767,757	4,281,940	364,834	1,489,221	3,523,255	84,450
Work Subbed OUT to Others	1,202,160	30,768	352,424	80,118	753,409	67,769	350,061	981,554	2,130,768
Materials, Components, Supplies	5,242,978	495,741	1,318,112	1,599,680	1,582,800	79,210	1,363,562	3,439,643	606,656
Power, Fuels, Lubes	323,906	62,217	80,001	52,933	408,444	30,000	66,236	250,775	67,440
Electicity	28,072	5,169	12,184	12,799	23,079	2,285	11,696	33,931	23,497
Natural Gas	10,223	883	3,260	3,600	3,696	501	3,388	6,745	2,665
Gasoline and Diesel Fuel	263,008	51,794	60,043	34,614	348,871	24,766	47,437	196,900	34,952
On-Highway	215,662	37,230	50,011	32,604	160,059	15,431	42,714	174,695	31,028
Off-Highway	47,345	14,564	10,031	2,210	188,812	9,334	4,722	22,205	3,924
Other, Incl. Oil and Grease	22,602	4,369	4,513	1,917	32,796	2,446	3,714	13,198	6,325
Matls, Cmpnts, Spls, Fuels (MCSF)	5,566,884	557,958	1,398,113	1,652,613	1,991,244	109,210	1,429,798	3,690,418	674,096
Fraction Off-Hwy Fuel Use	0.0085	0.0261	0.0072	0.0013	0.0948	0.0855	0.0033	0.0060	0.0058
Fraction Off-Hwy Fuel Use Normalized to SFH MCSF	3.45	10.59	2.91	0.54	38.48	34.68	1.34	2.44	2.36
Net Value of Construction Work	13,853,510	1,299,288	4,510,231	3,142,354	7,490,988	844,714	5,009,764	9,832,759	2,505,153
Fraction Off-Hwy Fuel Use	0.00342	0.01121	0.00222	0.00070	0.02521	0.01105	0.00094	0.00226	0.00157
Fraction Off-Hwy Fuel Use Normalized to SFH Net Value	2.84	9.30	1.85	0.58	20.92	9.17	0.78	1.87	1.30

APPENDIX G

Sample Copy of Dodge Construction Potentials Bulletin
for the Pacific Southwest (August 1992)

Dodge Construction Potentials Bulletin



Pacific Southwest

Region 9 — Arizona, California, Colorado, Nevada, New Mexico, Hawaii, Utah

August 1992

F. W. Dodge Division
McGraw-Hill, Inc.
1221 Avenue of the Americ[illegible]
New York, N.Y. 10020

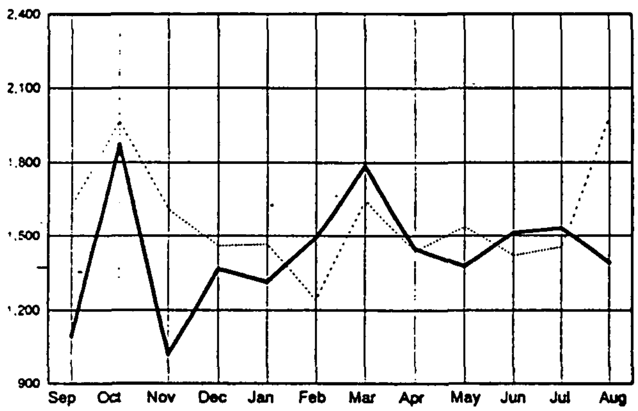
Contracts for New, Addition and Major Alteration Projects

Square Feet in Thousands
Value in $Millions

	Current Month				Cumulative to Date*						
	Number of Projects	Square Feet	Value	Last Year Value	Number of Projects This Year	Number of Projects Last Year	Square Feet This Year	Square Feet Last Year	Value This Year	Value Last Year	% Ch.
Total Construction	15,905	42,261	4,331.2	4,538.0	137,348	122,863	336,730	371,460	33,154.6	32,671.7	-1
Total Building	14,727	42,261	2,980.8	3,651.0	126,340	115,914	336,730	371,460	25,972.4	26,454.1	-2
Non-Residential	2,185	17,646	1,388.0	1,986.2	18,038	14,704	124,067	139,818	11,853.0	12,182.5	-3
Residential	12,542	24,615	1,592.8	1,664.8	108,302	101,210	212,663	231,642	14,119.5	14,271.6	-1
Non-Building	1,178	---	1,350.3	887.0	11,008	6,949	---	---	7,182.2	6,217.6	+16
Non-Residential											
Commercial	1,431	11,457	706.4	778.1	11,796	9,772	76,275	83,205	5,948.8	5,716.8	+4
Stores & Food Service	432	2,966	214.6	212.3	3,374	3,052	26,225	29,191	1,806.6	1,825.9	-1
Warehouses (Ex. Mfr. Own.)	145	3,490	133.0	116.3	973	1,267	16,145	23,983	683.2	917.8	-25
Office & Bank Buildings	753	2,061	270.4	231.0	6,404	4,633	12,224	15,253	1,853.0	2,050.1	-10
Hotels & Motels	28	72	11.2	131.3	256	182	8,346	4,196	1,080.1	461.3	★
Garages & Service Stations	73	2,868	77.2	87.2	789	638	13,334	10,583	525.8	461.7	+14
Manufacturing	98	445	37.1	154.2	751	669	5,360	11,196	481.5	731.6	-34
Manufacturing Plants	78	194	18.3	91.1	610	557	4,444	7,628	388.3	502.6	-23
Warehouses (Mfr. Owned)	20	251	18.8	3.7	134	93	913	2,307	86.9	85.1	+2
Laboratories (Mfr. Owned)	0	0	0.0	59.5	7	19	3	1,260	6.3	143.9	-96
Education & Science	235	2,084	273.9	275.1	1,868	1,568	15,628	16,970	2,130.7	2,120.8	[illegible]
Schools & Colleges	179	1,540	184.7	193.2	1,499	1,266	11,462	12,838	1,522.1	1,573.9	[illegible]
Laboratories (Ex. Mfr. Own.)	18	334	51.7	68.0	165	178	1,849	3,083	264.7	375.2	[illegible]
Libraries, Museums, etc.	38	211	37.5	14.0	204	124	2,317	1,049	344.0	171.7	[illegible]
Dormitories	9	56	4.7	9.7	80	71	974	1,097	96.4	103.3	-7
Hospital & Health Treatment	115	584	86.2	171.4	1,059	762	5,415	6,130	866.4	970.8	-11
Public Buildings	46	499	70.2	149.4	355	340	4,872	7,224	653.3	1,038.9	-37
Government Administration	17	26	10.8	13.4	110	86	1,087	735	201.7	121.4	+66
Other Government Service	29	473	59.4	135.9	245	254	3,784	6,489	451.6	917.5	-51
Religious	62	230	23.1	39.4	544	377	3,094	2,498	282.7	260.4	+9
Amusement	132	549	76.5	96.2	1,137	853	6,132	4,714	950.7	640.5	+48
Miscellaneous Non-Res.	57	1,743	109.9	312.8	448	292	6,317	6,785	442.5	599.5	-26
Residential											
One-Family Houses	12,198	21,917	1,440.1	1,423.3	105,353	95,009	193,040	189,384	12,876.6	11,735.2	+10
Two-Family Houses	44	153	8.2	69.6	884	3,483	2,634	11,805	149.0	592.6	-75
Apartment Buildings	300	2,545	144.6	171.9	2,065	2,718	16,990	30,453	1,093.9	1,943.8	-44
Non-Building											
Streets & Highways	329	---	289.2	272.1	2,688	2,316	---	---	1,994.0	2,121.9	-6
Bridges	31	---	65.7	51.4	235	243	---	---	517.3	274.8	+88
Dams & Reservoirs	5	---	1.8	4.2	68	62	---	---	81.2	59.8	+36
River & Harbor Development	87	---	72.7	71.0	606	603	---	---	492.3	441.1	+12
Sewerage & Waste Disposal	107	---	46.8	58.0	682	518	---	---	826.0	854.9	-3
Water Supply Systems	138	---	72.3	109.3	949	868	---	---	799.2	797.5	+0
Elec. Power & Heating Sys.	26	---	413.0	44.2	166	176	---	---	569.6	466.7	+22
Gas Systems	0	---	0.0	1.6	2	20	---	---	0.7	25.0	-97
Communication Systems	11	---	1.6	0.7	58	52	---	---	21.9	20.1	+9
Airport & Space Facilities	11	---	55.1	33.5	103	134	---	---	268.0	151.1	+77
Miscellaneous Non-Bldg.	433	---	332.0	241.1	5,451	1,957	---	---	1,612.1	1,004.7	+60

*"Cumulative to Date" figures include delayed entries and adjustments affecting projects entered in previously reported months. In the % Change column, increases of 100% or more are indicated by ★.

$Millions Non-Residential Construction Value



Last 12 Months: Sep. 91 - Aug. 92 ———
Previous Year: Sep. 90 - Aug. 91 ....

Metropolitan Areas/Counties

Square Feet in Thousands, Value in $Millions

	Current Month			Cumulative to Date						
	Number of Projects	Square Feet	Value	Number of Projects This Year	Number of Projects Last Year	Square Feet This Year	Square Feet Last Year	Value This Year	Value Last Year	% Ch.
Albuquerque, NM	31	240	22.5	218	109	947	1,049	99.3	92.7	+7
Anaheim-Santa Ana, CA	113	426	51.9	1,017	961	4,084	8,875	486.6	677.9	-28
Bakersfield, CA	25	107	5.4	223	247	2,892	1,818	178.8	132.1	+35
Boulder-Longmont, CO	10	26	2.4	107	94	1,209	1,284	81.6	76.7	+6
Chico, CA	8	34	2.0	67	22	248	139	22.6	10.3	★
Colorado Springs, CO	26	500	38.8	149	143	1,485	931	134.4	81.9	+64
Denver, CO	81	2,845	121.0	1,653	409	7,929	6,326	618.5	590.8	+5
Adams, CO	2	13	1.4	60	46	246	182	36.7	25.0	+47
Arapahoe, CO	18	106	8.5	181	77	597	706	61.0	70.4	-13
Denver, CO	46	2,563	101.1	1,226	200	5,819	4,716	433.7	436.7	-1
Douglas, CO	2	9	0.5	19	16	230	253	9.2	16.1	-43
Jefferson, CO	13	155	9.5	167	70	1,038	469	77.8	42.6	+83
Fort Collins-Loveland, CO	9	65	4.8	64	47	498	587	41.7	52.0	-20
Fresno, CA	10	51	3.2	77	213	1,629	1,880	135.0	139.5	-3
Greeley, CO	3	26	1.6	20	20	272	90	18.5	8.0	★
Honolulu, HI	164	1,128	103.7	777	739	4,880	6,785	553.6	731.4	-24
Las Cruces, NM	7	14	5.7	44	31	172	265	19.1	26.1	-27
Las Vegas, NV	65	268	22.3	503	386	11,106	6,427	1,214.3	456.4	★
Los Angeles-Long Beach, CA	391	1,683	183.2	2,694	2,529	13,433	21,705	1,493.7	2,155.4	-31
Merced, CA	1	5	0.6	24	36	222	391	10.7	23.1	-54
Modesto, CA	20	138	7.9	120	135	752	768	59.3	65.1	-9
Oakland, CA	111	540	78.0	974	800	4,685	5,093	612.3	496.8	+23
Alameda, CA	68	289	51.2	627	488	2,800	3,307	375.7	306.9	+22
Contra Costa, CA	43	250	26.8	347	312	1,885	1,786	236.6	189.8	+25
Oxnard-Ventura, CA	31	55	8.9	216	223	1,240	1,707	147.0	116.0	+27
Phoenix, AZ	116	1,893	87.2	865	791	10,145	5,984	681.5	523.7	+30

Metropolitan Areas/Counties

Square Feet in Thousands, Value in $Millions

	Current Month			Cumulative to Date						
	Number of Projects	Square Feet	Value	Number of Projects This Year	Number of Projects Last Year	Square Feet This Year	Square Feet Last Year	Value This Year	Value Last Year	% Ch.
Provo-Orem, UT	9	4	0.9	138	61	539	830	44.7	51.0	-12
Pueblo, CO	0	0	0.0	22	29	63	309	7.2	19.4	-63
Redding, CA	24	77	5.6	76	50	261	415	22.5	23.4	-4
Reno, NV	12	23	1.4	105	145	1,208	735	62.7	60.5	+4
Riverside-San Bernardino, CA	69	778	64.6	1,026	959	10,300	16,803	743.3	989.7	-25
Riverside, CA	37	713	57.4	555	483	5,643	7,984	401.1	503.8	-20
San Bernardino, CA	32	65	7.2	471	476	4,657	8,820	342.2	485.9	-30
Sacramento, CA	65	212	24.2	524	427	4,580	5,710	464.7	492.7	-6
El Dorado, CA	8	51	4.0	48	11	192	149	16.1	18.0	-11
Placer, CA	11	70	6.4	66	75	945	823	78.7	56.3	+40
Sacramento, CA	43	84	12.9	376	296	3,121	4,281	353.4	356.2	-1
Yolo, CA	3	6	0.8	34	45	322	458	16.5	62.3	-73
Salinas-Seaside-Monterey, CA	15	62	7.3	101	105	718	1,457	56.5	82.0	-31
Salt Lake City-Ogden, UT	69	1,034	43.0	673	322	3,772	3,113	316.8	202.7	+56
Davis, UT	8	40	2.3	56	29	641	299	95.8	20.8	★
Salt Lake, UT	47	373	18.5	539	251	2,150	2,437	181.0	154.5	+17
Weber, UT	14	622	22.2	78	42	980	377	40.0	27.4	+46
San Diego, CA	99	616	64.2	1,112	986	5,036	9,022	530.2	840.0	[illegible]
San Francisco, CA	126	1,057	114.2	1,214	1,150	3,753	2,828	650.5	575.5	[illegible]
Marin, CA	4	568	58.3	64	40	821	391	95.5	32.8	[illegible]
San Francisco, CA	90	287	43.2	906	956	1,712	937	445.6	352.5	+26
San Mateo, CA	32	202	12.7	244	154	1,220	1,501	109.4	190.2	-43
San Jose, CA	100	199	40.7	624	495	2,593	4,749	352.0	538.0	-35
Santa Barbara-Santa Maria-Lompoc, CA	17	11	2.0	138	121	527	570	50.0	53.3	-6
Santa Cruz, CA	3	2	0.6	38	58	628	798	89.9	69.8	+29
Santa Fe, NM	8	89	5.4	46	37	248	291	19.7	34.9	-44
Los Alamos, NM	0	0	0.0	6	11	45	74	4.8	15.9	-70
Santa Fe, NM	8	89	5.4	40	26	202	217	14.9	19.1	-22
Santa Rosa-Petaluma, CA	16	78	7.0	125	136	750	1,072	49.9	76.2	-34
Stockton, CA	13	140	4.6	111	110	1,046	1,835	75.9	108.8	-30
Tucson, AZ	35	135	13.1	316	149	1,670	1,165	166.1	139.2	+19
Vallejo-Fairfield-Napa, CA	18	409	48.4	131	89	2,063	1,868	151.3	129.5	+17
Napa, CA	3	15	1.0	36	25	220	236	15.9	20.3	-22
Solano, CA	15	394	47.4	95	64	1,843	1,632	135.4	109.1	+24
Visalia-Tulare-Porterville, CA	9	115	4.5	80	88	630	2,247	40.9	105.4	-61
Yuba City, CA	4	192	8.2	38	31	674	536	37.2	30.4	+23
Sutter, CA	4	192	8.2	31	19	648	77	26.6	7.5	★
Yuba, CA	0	0	0.0	7	12	26	459	10.6	22.9	-54
Yuma, AZ	5	25	4.0	29	23	160	101	17.4	11.6	+50

D[ODGE] Construction P[illegible]tials B[illegible]tin

Pacific Southwest

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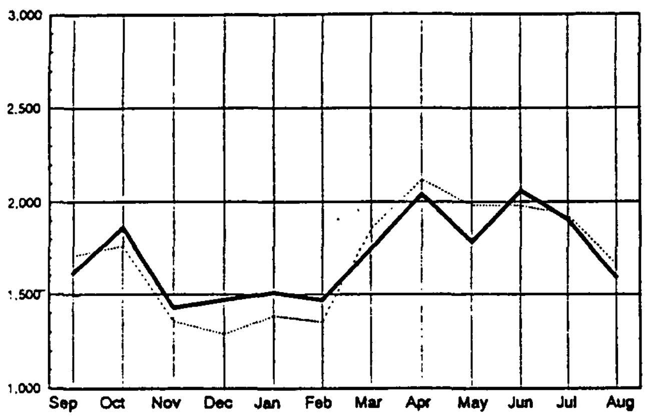
Residential Building

$Millions **Residential Construction Value**



Last 12 Months: Sep. 91 - Aug. 92
Previous Year: Sep. 90 - Aug. 91

Dwelling Units

	Current Month		Cumulative to Date		
	This Year	Last Year	This Year	Last Year	% Ch.
Total Dwelling Units	14,966	15,441	124,590	130,012	-4
One-Family Houses	12,188	12,007	105,260	94,986	+11
Two-Family Houses	88	744	1,758	6,958	-75
Apartment Buildings	2,690	2,690	17,572	28,068	-37

Metropolitan Areas/Counties

Square Feet in Thousands, Value in $Millions

	Current Month			Cumulative to Date						
	Dwelling Units	Square Feet	Value	Dwelling Units This Year	Dwelling Units Last Year	Square Feet This Year	Square Feet Last Year	Value This Year	Value Last Year	% Ch.
Alb[illegible]ue, NM	168	310	16.8	1,642	1,007	2,981	1,871	161.6	100.6	+61
Anaheim-Santa Ana, CA	446	718	64.3	4,336	5,671	7,493	9,569	658.8	769.3	-14
Bakersfield, CA	301	528	29.0	2,725	2,337	4,646	4,222	256.2	225.6	+14
Boulder-Longmont, CO	152	243	18.5	1,303	852	2,281	1,579	176.8	111.1	+59
Chico, CA	88	169	9.5	677	904	1,321	1,465	73.8	79.8	-8
Colorado Springs, CO	110	235	16.9	1,551	816	2,280	1,720	161.1	98.9	+63
Denver, CO	713	984	75.0	6,632	4,279	10,246	8,005	761.3	553.7	+37
Adams, CO	77	138	7.4	665	420	1,161	837	64.5	37.8	+70
Arapahoe, CO	236	251	23.0	1,597	760	2,172	1,436	178.4	108.3	+65
Denver, CO	79	77	5.2	271	366	409	408	36.1	26.3	+37
Douglas, CO	154	243	21.7	1,591	1,344	2,845	2,927	253.5	236.4	+7
Jefferson, CO	167	274	17.8	2,508	1,389	3,659	2,397	228.8	144.8	+58
Fort Collins-Loveland, CO	131	233	12.2	1,218	987	1,909	1,617	98.7	77.2	+28
Fresno, CA	404	727	38.4	2,910	3,051	5,209	5,307	274.9	274.4	0
Greeley, CO	36	49	2.7	296	239	463	395	24.9	19.2	+30
Honolulu, HI	268	331	23.5	2,847	3,681	3,599	5,451	360.6	491.7	-27
Las Cruces, NM	74	109	4.9	611	445	957	614	42.8	26.5	+62
Las Vegas, NV	1,181	1,660	69.8	9,554	11,235	14,335	15,916	603.0	652.5	-8
Los Angeles-Long Beach, CA	1,161	1,726	139.5	7,266	11,105	11,945	18,849	1,058.7	1,401.3	-24
Merced, CA	105	186	10.4	783	618	1,430	1,080	78.0	58.5	+33
Modesto, CA	225	371	19.0	1,486	1,486	2,771	2,326	141.8	115.5	+23
Oakland, CA	511	875	63.8	4,154	4,479	8,082	7,155	616.7	503.7	+22
Alameda, CA	159	329	28.4	1,739	1,598	3,099	2,900	277.4	224.9	+23
Contra Costa, CA	352	545	35.3	2,415	2,881	4,983	4,256	339.2	278.8	+22
Oxn[illegible]Ventura, CA	62	120	11.8	799	1,336	1,503	2,158	137.7	175.9	-22
Ph[illegible]Z	1,522	2,588	159.3	12,306	9,453	22,077	18,268	1,392.9	1,045.3	+33

Metropolitan Areas/Counties

Square Feet in Thousands, Value in $Millions

	Current Month			Cumulative to Date						
	Dwelling Units	Square Feet	Value	Dwelling Units This Year	Dwelling Units Last Year	Square Feet This Year	Square Feet Last Year	Value This Year	Value Last Year	% Ch.
Provo-Orem, UT	170	284	17.0	1,579	937	2,224	1,686	126.7	92.2	+37
Pueblo, CO	16	23	0.9	149	116	332	181	12.4	8.7	+43
Redding, CA	81	141	8.4	766	912	1,404	1,772	83.7	98.5	-15
Reno, NV	187	334	20.6	1,333	1,233	2,406	2,559	147.9	145.3	+2
Riverside-San Bernardino, CA	1,496	2,316	157.8	10,813	11,140	18,303	20,222	1,262.0	1,289.6	-2
Riverside, CA	882	1,278	90.5	5,990	6,584	9,610	10,922	685.0	746.0	-8
San Bernardino, CA	614	1,038	67.4	4,823	4,556	8,693	9,300	577.0	543.7	+6
Sacramento, CA	610	1,137	80.5	6,305	6,196	11,317	10,812	816.1	757.9	+8
El Dorado, CA	127	229	15.8	760	1,134	1,384	2,012	95.8	136.5	-30
Placer, CA	103	210	17.0	1,338	1,177	2,369	2,159	184.8	170.1	+9
Sacramento, CA	342	630	43.2	3,988	3,494	7,085	5,744	504.4	400.4	+26
Yolo, CA	38	69	4.4	219	391	479	897	31.0	50.9	-39
Salinas-Seaside-Monterey, CA	48	85	6.5	546	522	947	1,006	69.4	72.1	-4
Salt Lake City-Ogden, UT	420	680	38.0	3,707	3,142	6,474	6,216	360.7	299.4	+20
Davis, UT	106	177	11.3	884	744	1,515	1,339	96.1	80.3	+20
Salt Lake, UT	271	432	23.1	2,420	2,072	4,237	4,214	228.2	186.1	+23
Weber, UT	43	71	3.5	403	326	723	664	36.4	33.1	+[illegible]
San Diego, CA	371	703	64.7	4,412	6,678	7,601	12,709	697.3	1,032.3	[illegible]
San Francisco, CA	173	310	28.5	1,059	1,892	1,964	2,908	191.1	272.9	-30
Marin, CA	28	58	5.5	150	288	324	462	31.7	40.1	-21
San Francisco, CA	78	141	10.7	533	1,071	939	1,473	90.7	146.2	-38
San Mateo, CA	67	111	12.3	376	533	702	974	68.7	86.7	-21
San Jose, CA	253	344	27.7	1,680	2,990	2,613	4,304	215.8	333.1	-35
Santa Barbara-Santa Maria-Lompoc, CA	75	139	13.8	463	660	898	5,522	88.9	123.2	-28
Santa Cruz, CA	31	54	4.8	296	392	525	611	46.0	48.2	-5
Santa Fe, NM	32	67	5.2	282	276	527	533	40.5	34.3	+18
Los Alamos, NM	4	8	0.7	49	14	83	32	6.3	2.5	★
Santa Fe, NM	28	59	4.5	233	262	444	502	34.2	31.8	+8
Santa Rosa-Petaluma, CA	118	259	18.4	1,329	1,554	2,420	2,783	170.3	189.1	-10
Stockton, CA	85	175	11.7	1,482	1,628	2,519	2,539	168.7	170.1	-1
Tucson, AZ	213	383	20.0	2,422	1,928	4,899	3,904	246.3	185.5	+33
Vallejo-Fairfield-Napa, CA	127	233	19.0	1,467	1,181	2,835	2,543	233.7	199.3	+17
Napa, CA	20	35	3.3	278	300	550	692	53.3	62.4	-15
Solano, CA	107	198	15.7	1,189	881	2,285	1,852	180.4	137.0	+32
Visalia-Tulare-Porterville, CA	208	344	18.4	1,252	1,259	2,077	2,323	111.1	113.4	-2
Yuba City, CA	86	149	9.6	633	601	1,085	1,002	68.0	61.4	+11
Sutter, CA	76	132	8.7	475	473	826	764	54.2	48.6	+12
Yuba, CA	10	17	0.9	158	128	259	238	13.7	12.8	+8
Yuma, AZ	39	66	3.4	434	336	700	549	35.2	25.9	+36

Dodge Construction Potentials Bulletin

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Construction by State

Square Feet in Thousands, Value in $Millions

	Current Month				Cumulative to Date								
	Number of Projects	Dwelling Units	Square Feet	Value	Number of Projects This Year	Number of Projects Last Year	Dwelling Units This Year	Dwelling Units Last Year	Square Feet This Year	Square Feet Last Year	Value This Year	Value Last Year	% Ch.
Non-Residential	**2,185**	**---**	**17,646**	**1,388.0**	**18,038**	**14,704**	**---**	**---**	**124,067**	**139,818**	**11,853.0**	**12,182.5**	**-3**
Arizona	201	---	2,610	145.2	1,491	1,175	---	---	15,610	9,891	1,105.3	890.5	+24
California	1,334	---	7,182	750.7	11,084	10,211	---	---	65,589	94,023	6,691.8	8,105.4	-17
Colorado	156	---	4,304	200.6	2,215	909	---	---	14,580	11,483	1,169.2	1,119.4	+4
Hawaii	232	---	1,661	169.7	1,077	1,001	---	---	7,203	8,135	849.4	879.4	-3
Nevada	88	---	334	28.7	698	574	---	---	13,513	7,686	1,387.1	568.0	★
New Mexico	73	---	434	42.9	511	350	---	---	2,304	3,520	224.8	287.5	-22
Utah	101	---	1,122	50.2	962	484	---	---	5,268	5,080	425.4	332.3	+28
Residential	**12,542**	**14,966**	**24,615**	**1,592.8**	**108,302**	**101,210**	**124,590**	**130,012**	**212,663**	**231,642**	**14,119.5**	**14,271.6**	**-1**
Arizona	2,055	2,252	3,899	223.8	18,303	15,056	19,251	15,945	34,742	31,173	2,010.6	1,636.6	+23
California	6,301	7,704	12,982	923.9	55,102	56,362	63,195	75,081	111,155	134,622	8,120.7	9,007.6	-10
Colorado	1,239	1,472	2,313	157.6	12,428	8,898	14,064	9,760	22,453	17,877	1,516.5	1,094.1	+39
Hawaii	370	575	859	54.4	3,302	3,228	5,058	7,238	7,434	12,244	589.6	857.4	-31
Nevada	1,245	1,511	2,239	104.1	9,093	9,881	12,028	13,578	18,717	20,398	866.5	901.7	-4
New Mexico	518	543	899	47.7	3,660	2,584	3,781	2,779	6,462	4,599	355.1	236.5	+50
Utah	814	909	1,424	81.3	6,414	5,201	7,213	5,631	11,702	10,728	660.4	537.5	+23
Non-Building	**1,178**	**---**	**---**	**1,350.3**	**11,008**	**6,949**	**---**	**---**	**---**	**---**	**7,182.2**	**6,217.6**	**+16**
Arizona	90	---	---	65.6	1,640	609	---	---	---	---	517.9	556.7	-7
California	712	---	---	595.5	6,484	4,185	---	---	---	---	3,777.2	3,510.4	+8
Colorado	127	---	---	491.8	938	779	---	---	---	---	1,259.9	943.0	+34
Hawaii	46	---	---	86.3	488	470	---	---	---	---	614.5	381.2	+61
Nevada	67	---	---	55.7	568	212	---	---	---	---	559.0	285.6	+96
New Mexico	49	---	---	33.5	366	350	---	---	---	---	267.0	276.1	-3
Utah	87	---	---	21.8	524	344	---	---	---	---	186.7	264.7	-29

DODGE Construction Potentials Bulletin — Pacific Southwest — August 1992

Largest Entries

Square Feet in Thousands, Value in $Millions

State	County	Project Type	Dwelling Units	Square Feet	Value
CO	Weld	A Elec. Power & Heating Sys.	---	---	350.0
CA	Los Angeles	* Miscellaneous Non-Bldg.	---	---	172.1
HI	Honolulu	* Streets & Highways	---	---	58.0
AZ	Maricopa	Warehouses (Ex. Mfr. Own.)	---	1,500	50.0
CO	Denver	* Miscellaneous Non-Res.	---	500	44.4
CA	Marin	Office & Bank Buildings	---	455	40.0
CO	Denver	* Airport & Space Facilities	---	---	32.6
CO	Denver	*A Garages & Service Stations	---	1,820	32.6
CA	Solano	A Hospital & Health Treatment	---	152	28.0
CO	Morgan	Miscellaneous Non-Res.	---	785	25.5
CO	Morgan	Elec. Power & Heating Sys.	---	---	21.0
UT	Weber	Warehouses (Ex. Mfr. Own.)	---	610	21.0
CA	Los Angeles	A Stores & Food Service	---	323	20.0
CA	Los Angeles	* Water Supply Systems	---	---	18.7
CA	Riverside	* Amusement, Social & Rec.	---	119	18.3
CA	Orange	*A Streets & Highways	---	---	18.1
CA	Marin	* Other Government Service	---	109	17.9
CA	Alameda	River & Harbor Development	---	---	17.8
CA	Fresno	*A Streets & Highways	---	---	17.6
CA	Fresno	*A Bridges	---	---	17.6
CA	San Diego	* Laboratories (Ex. Mfr. Own.)	---	134	17.5
CA	Alameda	* Schools & Colleges	---	100	17.2
HI	Honolulu	* Garages & Service Stations	---	485	17.0
NM	San Juan	*A Elec. Power & Heating Sys.	---	---	16.2
CA	San Francisco	* Schools & Colleges	---	200	15.3
CO	El Paso	Office & Bank Buildings	---	200	15.0
CA	San Diego	* Schools & Colleges	---	107	14.2
CA	Los Angeles	* Libraries, Museums, etc.	---	90	13.9
NM	Bernalillo	* Laboratories (Ex. Mfr. Own.)	---	94	13.7
CA	Alameda	* Miscellaneous Non-Bldg.	---	---	13.5
AZ	Mohave	* Schools & Colleges	---	135	12.7
CO	Adams	*A Airport & Space Facilities	---	---	11.6
NV	Clark	*A Streets & Highways	---	---	11.5
CO	Mesa	* River & Harbor Development	---	---	11.4
HI	Honolulu	Miscellaneous Non-Bldg.	---	---	11.2
HI	Maui	*A Other Government Service	---	90	10.4
CA	Santa Clara	* Streets & Highways	---	---	10.4
CA	Santa Clara	* Bridges	---	---	10.4
CA	Los Angeles	* Miscellaneous Non-Bldg.	---	---	10.2
CA	Alameda	Hospital & Health Treatment	---	80	9.3
NV	Clark	Apartment Buildings	296	187	9.2
HI	Honolulu	Office & Bank Buildings	---	76	9.1
CA	Los Angeles	Apartment Buildings	153	187	8.5
CO	El Paso	Amusement, Social & Rec.	---	99	8.1
CA	Orange	* Schools & Colleges	---	60	8.0
CA	Sutter	Stores & Food Service	---	190	8.0

Adjustments and Delayed Entries

Square Feet in Thousands, Value in $Millions

State	County	Project Type	Date of Original Entry	Dwelling Units	Square Feet	Value
CA	Los Angeles	*A Amusement, Social & Rec.	July 1992	---	317	72.4
CA	Ventura	* Government Administration	July 1992	---	200	44.5
CA	Orange	Apartment Buildings	April 1992	382	400	20.0
CA	Alameda	Miscellaneous Non-Bldg.	July 1992	---	---	(17.9)
CA	Riverside	Sewerage & Waste Disposal	June 1992	---	---	(10.0)
CA	Sacramento	*A Sewerage & Waste Disposal	June 1992	---	---	8.9
NV	Clark	Stores & Food Service	February 1992	---	(200)	(8.0)
NM	McKinley	A Sewerage & Waste Disposal	February 1992	---	---	8.0

*Public Ownership A: Alterations or Additions

APPENDIX H

Crop-Specific Production Budgets for DC/MD/VA

Corn (Grain) Production Budget – Virginia

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Bush Hog	AG Tractor	110	0.17	0.7				0.25	0.55	0.2							13.1	0.73
Plow	AG Tractor	110	0.44	0.7				0.25	0.55	0.2							33.9	1.90
Disc	AG Tractor	110	0.15	0.7				0.25	0.55	0.2							11.6	0.65
Harrow	AG Tractor	50	0.2	0.7					0.25	0.55	0.2						7.0	0.39
Plant	AG Tractor	70	0.31	0.7					0.25	0.55	0.2						15.2	0.85
Spray/Fert	AG Tractor	50	0.11	0.7						0.25	0.55	0.2					3.9	0.22
Harvest	Combine	152	0.53	0.7										0.4	0.35	0.25	56.4	3.16
Corn (Grain) Total					0.0	0.0	0.0	14.6	37.7	24.9	6.6	0.8	0.0	22.6	19.7	14.1	141.0	7.89

Corn (Silage) Production Budget – Virginia

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Plow	AG Tractor	110	0.44	0.7				0.25	0.55	0.2							33.9	1.90
Disc	AG Tractor	110	0.15	0.7				0.25	0.55	0.2							11.6	0.65
Harrow	AG Tractor	50	0.20	0.7					0.25	0.55	0.2						7.0	0.39
Plant	AG Tractor	70	0.31	0.7					0.25	0.55	0.2						15.2	0.85
Spray/Fert	AG Tractor	50	0.11	0.7						0.25	0.55	0.2					3.9	0.22
Harvest	AG Tractor	110	0.70	0.7									0.2	0.7	0.1		53.9	3.02
Haul	AG Tractor	70	0.85	0.7									0.2	0.7	0.1		41.7	2.33
Corn (Silage) Total					0.0	0.0	0.0	11.4	30.5	22.3	6.6	0.8	19.1	66.9	9.6	0.0	167.0	9.35

Wheat Production – Virginia

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Offset	AG Tractor	110	0.26	0.7											0.5	0.5	20.0	1.12
Disc	AG Tractor	110	0.15	0.7											0.5	0.5	11.6	0.65
Plant	AG Tractor	70	0.38	0.7											0.5	0.5	18.6	1.04
Spray/Fert	AG Tractor	50	0.11	0.7			0.5	0.5									3.9	0.22
Harvest	Combine	152	0.26	0.7							0.5	0.5					27.7	1.55
Wheat Total					0.0	0.0	1.9	1.9	0.0	0.0	13.8	13.8	0.0	0.0	25.1	25.1	81.7	4.58

Soy Bean Production – Virginia
Conventional Tillage

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Plow	AG Tractor	110	0.44	0.7					0.3	0.45	0.25						33.9	1.90
Disc	AG Tractor	110	0.15	0.7					0.3	0.45	0.25						11.6	0.65
Harrow	AG Tractor	50	0.20	0.7						0.3	0.45	0.25					7.0	0.39
Plant	AG Tractor	70	0.31	0.7						0.3	0.45	0.25					15.2	0.85
Spray/Fert	AG Tractor	50	0.11	0.7							0.3	0.45	0.25				3.9	0.22
Harvest	Combine	152	0.53	0.7	0.3										0.2	0.5	56.4	3.16
Soybean Total					16.9	0.0	0.0	0.0	13.6	27.1	22.5	7.3	1.0	0.0	11.3	28.2	127.9	7.16

Barley Production – Virginia Conventional Tillage																		
Operation	Equipment	Horse–Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Offset	AG Tractor	110	0.26	0.7										0.25	0.5	0.25	20.0	1.12
Disc	AG Tractor	110	0.15	0.7										0.25	0.5	0.25	11.6	0.65
Plant	AG Tractor	70	0.38	0.7										0.25	0.5	0.25	18.6	1.04
Spray/Fert	AG Tractor	50	0.11	0.7			0.5	0.5									3.9	0.22
Harvest	Combine	152	0.26	0.7							0.9	0.1					27.7	1.55
Barley Total					0.0	0.0	1.9	1.9	0.0	0.0	24.9	2.8	0.0	12.5	25.1	12.5	81.7	4.58

Tobacco Production – North Carolina Operations/Virginia Temporal Pattern																		
Operation	Equipment	Horse–Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Tandem Disc	AG Tractor	110	0.13	0.7											0.5	0.5	10.0	0.56
Grain Drill	AG Tractor	45	0.22	0.7											0.5	0.5	6.9	0.39
Bottom Plow	AG Tractor	80	0.53	0.7			0.5	0.5									29.7	1.66
Tandom Disc	AG Tractor	110	0.13	0.7			0.5	0.5									10.0	0.56
Sprayer	AG Tractor	45	0.01	0.7					0.5	0.5							0.3	0.02
Tandem Disc	AG Tractor	110	0.18	0.7					0.5	0.5							13.9	0.78
Harrow	AG Tractor	80	0.13	0.7					0.5	0.5							7.3	0.41
Lime	AG Tractor	45	0.32	0.7						0.5	0.5						10.1	0.56
Disc–Hiller	AG Tractor	55	0.31	0.7						0.5	0.5						11.9	0.67
Transplant	AG Tractor	55	1.74	0.7						0.5	0.5						67.0	3.75
Cultivate	AG Tractor	45	0.35	0.7							0.5	0.5					11.0	0.62
Fertilize	AG Tractor	45	0.47	0.7							0.5	0.5					14.8	0.83
Cultivate	AG Tractor	45	0.35	0.7								0.5	0.5				11.0	0.62
Sprayer	AG Tractor	45	0.39	0.7								0.5	0.5				12.3	0.69
Tobacco Trailer	AG Tractor	25	1.20	0.7									0.5	0.5			21.0	1.18
Bottom Plow	AG Tractor	80	0.52	0.7										0.5	0.5		29.1	1.63
Bush Hog	AG Tractor	45	0.24	0.7										0.5	0.5		7.6	0.42
Tobacco Total					0.0	0.0	19.8	19.8	10.7	55.2	57.4	24.6	22.2	28.8	26.8	8.5	273.9	15.34

Oats Production – Virginia Conventional Tillage (Based on Barley with Added Hay Out and Haul)																		
Operation	Equipment	Horse–Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Offset	AG Tractor	110	0.26	0.7										0.25	0.5	0.25	20.0	1.12
Disc	AG Tractor	110	0.15	0.7										0.25	0.5	0.25	11.6	0.65
Plant	AG Tractor	70	0.38	0.7										0.25	0.5	0.25	18.6	1.04
Spray/Fert	AG Tractor	50	0.11	0.7			0.5	0.5									3.9	0.22
Harvest	Combine	152	0.26	0.7							0.9	0.1					27.7	1.55
Hay Harvest	AG Tractor	70	0.50	0.7								0.5	0.5				24.5	1.37
Hay Haul	AG Tractor	70	0.25	0.7								0.5	0.5				12.3	0.69
Oats Total					0.0	0.0	1.9	1.9	0.0	0.0	24.9	21.1	18.4	12.5	25.1	12.5	118.5	6.63

Alfalfa Establishment – Virginia
Conventional Tillage (Assume 2 Cuttings)

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom: Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
Establish:																		
Plow	AG Tractor	70	0.63	0.7			0.5	0.5									30.9	1.73
Disc	AG Tractor	70	0.52	0.7			0.5	0.5									25.5	1.43
Harrow	AG Tractor	50	0.20	0.7				0.5	0.5								7.0	0.39
Plant	AG Tractor	70	0.38	0.7				0.5	0.5								18.6	1.04
Cultipack	AG Tractor	50	0.19	0.7				0.5	0.5								6.7	0.37
Sprayer	AG Tractor	50	0.11	0.7						0.25	0.25	0.25	0.25				3.9	0.22
Production:																		
Cut Hay	AG Tractor	70	0.4	0.7							0.5		0.5				19.6	1.10
Rake Hay	AG Tractor	50	0.33	0.7							0.5		0.5				11.6	0.65
Bale Hay	AG Tractor	70	0.61	0.7							0.5		0.5				29.9	1.67
Haul	AG Tractor	50	0.61	0.7							0.5		0.5				21.4	1.20
Cut Hay	AG Tractor	70	0.4	0.7								0.5		0.5			19.6	1.10
Rake Hay	AG Tractor	50	0.33	0.7								0.5		0.5			11.6	0.65
Bale Hay	AG Tractor	70	0.61	0.7								0.5		0.5			29.9	1.67
Haul	AG Tractor	50	0.61	0.7								0.5		0.5			21.4	1.20
Alfalfa (Establishment) Total					0.0	0.0	28.2	44.3	16.1	1.0	42.2	42.2	42.2	41.2	0.0	0.0	257.3	14.41

Alfalfa Production
5 Tons/Acre (4 Cuttings)

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom: Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
Sprayer (2)	AG Tractor	50	0.22	0.7				0.33	0.33		0.33	0.33	0.33	0.33			7.7	0.43
Cut Hay (4)	AG Tractor	70	1.60	0.7						0.7	0.7	0.7	0.7	0.7	0.5		78.4	4.39
Rake Hay (4)	AG Tractor	50	1.32	0.7						0.7	0.7	0.7	0.7	0.7	0.5		46.2	2.59
Bale Hay (4)	AG Tractor	70	2.44	0.7						0.7	0.7	0.7	0.7	0.7	0.5		119.6	6.70
Haul (4)	AG Tractor	50	2.44	0.7						0.7	0.7	0.7	0.7	0.7	0.5		85.4	4.78
Alfalfa Production Total					0.0	0.0	0.0	1.3	1.3	57.7	59.0	59.0	59.0	59.0	41.2	0.0	337.3	18.89

Hay (Orchard Grass) Establishment – Virginia Conventional Tillage (Assume 1 Cutting)																		
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Establish:																		
Plow	AG Tractor	70	0.63	0.7			0.5	0.5									30.9	1.73
Disc	AG Tractor	70	0.52	0.7			0.5	0.5									25.5	1.43
Harrow	AG Tractor	50	0.20	0.7				0.5	0.5								7.0	0.39
Plant	AG Tractor	70	0.38	0.7				0.5	0.5								18.6	1.04
Production:																		
Cut Hay	AG Tractor	70	0.40	0.7								0.33	0.33	0.33			19.6	1.10
Rake Hay	AG Tractor	50	0.33	0.7								0.33	0.33	0.33			11.6	0.65
Bale Hay	AG Tractor	70	0.40	0.7								0.33	0.33	0.33			19.6	1.10
Haul	AG Tractor	70	0.45	0.7								0.33	0.33	0.33			22.1	1.23
Hay Establishment Total					0.0	0.0	28.2	41.0	12.8	0.0	0.0	24.3	24.3	24.3	0.0	0.0	154.8	8.67

Hay (Orchard Grass) Production – Virginia 2.5 Tons/Acre (2 Cuttings)																		
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Cut Hay (2)	AG Tractor	70	0.80	0.7							0.5	0.5	0.5	0.5			39.2	2.20
Rake Hay (2)	AG Tractor	50	0.66	0.7							0.5	0.5	0.5	0.5			23.1	1.29
Bale Hay (2)	AG Tractor	70	0.80	0.7							0.5	0.5	0.5	0.5			39.2	2.20
Haul (2)	AG Tractor	50	0.90	0.7							0.5	0.5	0.5	0.5			31.5	1.76
Spray/Fert (2)	AG Tractor	50	0.22	0.7							0.5	0.5	0.5	0.5			7.7	0.43
Hay Production Total					0.0	0.0	0.0	0.0	0.0	0.0	35.2	35.2	35.2	35.2	0.0	0.0	140.7	7.88

Fresh Vegetables – Pennsylvania Operations/Virginia Equipment (Based on Fresh Market Corn)																		
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Plow	AG Tractor	110	0.44	0.7		0.25	0.25	0.25	0.25								33.9	1.90
Disk	AG Tractor	110	0.15	0.7		0.25	0.25	0.25	0.25								11.6	0.65
Harrow	AG Tractor	50	0.20	0.7				0.25	0.25	0.25	0.25						7.0	0.39
Plant	AG Tractor	70	0.31	0.7				0.25	0.25	0.25	0.25						15.2	0.85
Spray/Insect	AG Tractor	50	0.11	0.7					0.2	0.2	0.2	0.2	0.2				3.9	0.22
Spray/Herb	AG Tractor	50	0.11	0.7					0.2	0.2	0.2	0.2	0.2				3.9	0.22
Fresh Vegetable Total					0.0	11.4	11.4	16.9	18.4	7.1	7.1	1.5	1.5	0.0	0.0	0.0	75.3	4.22

APPENDIX I

Crop-Specific Production Budgets for the San Joaquin Valley Air Basin

Asparagus Production Budget – SJV																		
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Year 1:*																		
Disc Stubble	Crawler	90	0.66	0.7				1	1	1							4.2	0.02
Make Levees	Ag Tractor 2wd	60	0.5	0.7				1	1	1							2.1	0.01
Remove Levees	Ag Tractor 2wd	60	0.33	0.7				1	1	1							1.4	0.01
Plow	Crawler	90	0.66	0.7				1	1	1							4.2	0.02
Disc	Crawler	90	0.33	0.7				1	1	1							2.1	0.01
Rip	Crawler	90	1	0.7				1	1	1							6.3	0.04
Landplane	Crawler	90	1	0.7				1	1	1							6.3	0.04
Disc	Crawler	90	0.33	0.7				1	1	1							2.1	0.01
Cult./cvr weeds	Ag Tractor 2wd	60	1.2	0.7						1	1						5.0	0.03
Cultivate	Ag Tractor 2wd	60	1.33	0.7						1	1						5.6	0.03
Year 2:*																		
Winter Disc	Crawler	90	0.66	0.7										1	1	1	4.2	0.02
Cultivate	Ag Tractor 2wd	60	1.33	0.7										1	1	1	5.6	0.03
Cult./cvr weeds	Ag Tractor 2wd	60	1.2	0.7										1	1	1	5.0	0.03
Chop Fern	Ag Tractor 2wd	60	0.4	0.7	1										1	1	1.7	0.01
Furrow	Ag Tractor 2wd	60	0.66	0.7	1										1	1	2.8	0.02
Chisel	Crawler	90	0.33	0.7	1										1	1	2.1	0.01
Years 3–10:*																		
Disc	Crawler	90	0.66	0.7	1										1	1	33.3	1.49
Ridge & Roll	Ag Tractor 2wd	60	0.25	0.7	1										1	1	8.4	0.38
Work Centers	Ag Tractor 2wd	60	1.6	0.7	1										1	1	53.8	2.41
Furrow	Ag Tractor 2wd	60	1	0.7	1										1	1	33.6	1.51
Cultivate	Ag Tractor 2wd	60	0.66	0.7	1										1	1	22.2	0.99
Split Ridge	Ag Tractor 2wd	60	0.5	0.7	1										1	1	16.8	0.75
Chop Fern	Ag Tractor 2wd	60	0.4	0.7	1										1	1	13.4	0.60
Asparagus Total					62.7	0.0	0.0	9.5	9.5	14.8	5.3	0.0	0.0	4.9	67.6	67.6	241.9	8.47

* Asparagus is grown on a 10–year cycle. Thus, hour/acre estimates were adjusted accordingly before calculating emissions.

Beans Production Budget – SJV																		
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Disc	Ag Tractor	90	1	0.7		1	1	1									63.0	3.53
Subsoil	Crawler	60	1	0.7		1	1	1									42.0	2.35
Landplane	Ag Tractor	90	0.5	0.7		1	1	1									31.5	1.76
Springtooth	Crawler	60	0.5	0.7		1	1	1									21.0	1.18
Listing	Crawler	60	0.5	0.7		1	1	1									21.0	1.18
Ditching	Crawler	60	0.25	0.7				1	1								10.5	0.59
Close Ditches	Ag Tractor	60	0.5	0.7				1	1								21.0	1.18
Harrow	Ag Tractor	60	0.5	0.7				1	1								21.0	1.18
Planting	Ag Tractor	60	0.25	0.7					1	1							10.5	0.59
Cultivate	Ag Tractor	60	1	0.7						1	1	1					42.0	2.35
Cut Beans	Ag Tractor	60	0.25	0.7									1	1	1		10.5	0.59
Beans Total					0.0	59.5	59.5	85.8	31.5	19.3	14.0	14.0	3.5	3.5	3.5	0.0	294.0	16.46

Citrus Production Budget – SJV																		
Operation	Equipment	Horse–Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Pest Control	Ag Tractor	50	0.7	0.7					1		1		1				24.5	1.37
Growth Regulator	Ag Tractor	50	0.7	0.7								1	1				24.5	1.37
Prune & Shred	Ag Tractor	50	0.2	0.7				1	1								7.0	0.39
Fertilize	Ag Tractor	50	0.5	0.7							1	1					17.5	0.98
Soil Amendments	Ag Tractor	50	0.2	0.7				1	1								7.0	0.39
Weed Control	Ag Tractor	50	1.7	0.7				1		0.25		0.25		1			59.5	3.33
Citrus Total					0.0	0.0	0.0	30.8	15.2	6.0	16.9	27.0	20.4	23.8	0.0	0.0	140.0	7.84

Clover Seed Production Budget – SJV																		
Operation	Equipment	Horse–Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Chisel *	Ag Tractor 4wd	200	0.16	0.7										1	1	1	7.5	0.42
Disc*	Ag Tractor 4wd	200	0.33	0.7										1	1	1	15.4	0.86
Land Plane*	Ag Tractor 4wd	200	0.3	0.7										1	1	1	14.0	0.78
Make Levees	Ag Tractor 2wd	70	0.05	0.7										1	1	1	2.5	0.14
Herbicide	Ag Tractor 2wd	70	0.04	0.7										1	1	1	2.0	0.11
Spot spray	Ag Tractor 2wd	70	0.2	0.7	1	1	1	1	1	1	1	1			1	1	9.8	0.55
Rodenticide	Ag Tractor 2wd	70	0.2	0.7	1	1	1	1	1	1	1	1			1	1	9.8	0.55
Herbicide	Ag Tractor 2wd	70	0.06	0.7	7			3							1		2.9	0.16
Roll Fields	Ag Tractor 2wd	70	0.14	0.7			1										6.9	0.38
Insecticide	Ag Tractor 2wd	70	0.04	0.7							1	1					2.0	0.11
Defoliate	Ag Tractor 2wd	70	0.02	0.7									1				1.0	0.05
Clover Seed Total					3.8	2.0	8.8	2.8	2.0	2.0	2.9	2.9	1.0	13.8	16.0	15.7	73.6	4.12

* Established every 3 years, thus, hour/acre estimates were divided by 3 before calculating monthly and yearly Bhp–hr values.

Field Corn Production Budget – SJV																		
Operation	Equipment	Horse–Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Chisel Deep	Ag Tractor	200	0.21	0.7	1												29.4	1.65
Disc Stubble	Ag Tractor	200	0.14	0.7				1									19.6	1.10
Chisel light	Ag Tractor	130	0.11	0.7				1									10.0	0.56
Disc light	Ag Tractor	130	0.12	0.7				1									10.9	0.61
Pre_plant Herb.	Ag Tractor	80	0.13	0.7				1									7.3	0.41
Triplane	Ag Tractor	130	0.14	0.7				1									12.7	0.71
List & Fert	Ag Tractor	130	0.15	0.7				1									13.7	0.76
Mulch beds	Ag Tractor	130	0.18	0.7				1									16.4	0.92
Roll beds	Ag Tractor	130	0.1	0.7				1									9.1	0.51
Open Ditch	Ag Tractor	130	0.02	0.7				1	1								1.8	0.10
Close Ditch	Ag Tractor	130	0.02	0.7				1									1.8	0.10
Disc over Ditch	Ag Tractor	130	0.02	0.7				1									1.8	0.10
Plant	Ag Tractor	80	0.14	0.7				1									7.8	0.44
Cultivate	Ag Tractor	80	0.31	0.7					1								17.4	0.97
Apply Manure	Ag Tractor	130	0.15	0.7												1	13.7	0.76
Fertilize	Ag Tractor	130	0.15	0.7					1								13.7	0.76
Apply Herbacide	Ag Tractor	80	0.13	0.7					1								7.3	0.41
Apply Miticide	Ag Tractor	80	0.13	0.7						1							7.3	0.41
Field Corn Total					29.4	0.0	0.0	112.1	39.2	7.3	0.0	0.0	0.0	0.0	0.0	13.7	201.6	11.29

Cotton Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Deep Rip	Crawler tractor	170	0.08	0.7		1											9.5	0.53
Primary Discing	Crawler tractor	170	0.14	0.7		1											16.7	0.93
Apply Herbacide	AG Tractor	100	0.12	0.7			1										8.4	0.47
Incrp Herb w/dsc	AG Tractor	100	0.1	0.7			1										7.0	0.39
Make Beds	AG Tractor	100	0.15	0.7			1				1	1					10.5	0.59
Make Ditch	AG Tractor	100	0.06	0.7			1				1			1			4.2	0.24
Close Ditch	AG Tractor	100	0.06	0.7			1										4.2	0.24
Plant	AG Tractor	100	0.18	0.7					1								12.6	0.71
Uncap Beds	AG Tractor	100	0.15	0.7					1								10.5	0.59
Cultivate	AG Tractor	100	1.15	0.7					1	1	1						80.5	4.51
Harvest	Harvester	170	0.65	0.51												1	56.4	3.16
Build Module	AG Tractor	55	0.33	0.7												1	12.7	0.71
Misc. Harvest	AG Tractor	100	0.65	0.7												1	45.5	2.55
Cut Stalks	AG Tractor	100	0.1	0.7												1	7.0	0.39
Cross Disc	AG Tractor	100	0.19	0.7												1	13.3	0.74
Preplant NH3	AG Tractor	100	0.17	0.7		1											11.9	0.67
Miticide	AG Tractor	100	0.17	0.7						1							11.9	0.67
Insect	AG Tractor	100	0.17	0.7								1					11.9	0.67
Herbicide	AG Tractor	100	0.17	0.7							1						11.9	0.67
Growth Regulator	AG Tractor	100	0.17	0.7								1					11.9	0.67
Sidedress Fert	AG Tractor	100	0.17	0.7								1					11.9	0.67
Cotton Total					0.0	38.1	24.5	0.0	49.9	38.7	43.6	39.2	0.0	1.4	0.0	134.9	370.3	20.74

Grape Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Raisin & Wine:																		
Chisel	AG Tractor	60	4	0.7					1	1	1	1					168.0	9.41
Disc	AG Tractor	60	4	0.7					1	1	1	1					168.0	9.41
Cultivation	AG Tractor	60	4	0.7					1	1	1	1					168.0	9.41
Trellis Rpr	AG Tractor	30	1	0.7				1									21.0	1.18
Raisin:																		
Terracing	AG Tractor	30	1.5	0.7									1	1			31.5	1.76
Box & Shake	AG Tractor	30	1	0.7										1	1		21.0	1.18
Grape Total					0.0	0.0	0.0	21.0	126.0	126.0	126.0	126.0	15.8	26.3	10.5	0.0	577.5	32.34

Kiwi Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Strip Weed Cntrl	Ag Tractor	50	1	0.7			1		1							1	35.0	1.96
Fertilize	Ag Tractor	50	1	0.7			1		1	1	1	1					35.0	1.96
Brush Rmvl	Ag Tractor	50	2.2	0.7		1	1										77.0	4.31
Mow	Ag Tractor	50	3	0.7			1	1	1	1	1	1					105.0	5.88
Kiwi Total					0.0	38.5	74.7	17.5	36.2	24.5	24.5	24.5	0.0	0.0	0.0	11.7	252.0	14.11

Lettuce Production Budget – SJV

Operation	Equipment	Horse– Power	Hours/ Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/ Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Land Prep	Ag Tractor	100	6	0.7				1	1	1			1	1	1		420.0	23.52
Plant	Ag Tractor	100	0.5	0.7		1					1						35.0	1.96
Cultivate	Ag Tractor	60	2.5	0.7			1	1	1			1	1	1			105.0	5.88
Misc.	Ag Tractor	40	2	0.7	1	1	1	1	1	1	1	1	1	1	1	1	56.0	3.14
Harvest/Haul	Ag Tractor	60	2.5	0.7						1				1			105.0	5.88
Herbacide	Ag Tractor	60	0.16	0.7		1	1				1	1					6.7	0.38
Fertilize	Ag Tractor	60	0.16	0.7			1	1				1	1				6.7	0.38
Pest Control	Ag Tractor	60	0.16	0.7		1	1	1			1	1	1				6.7	0.38
Lettuce Total					4.7	25.0	26.6	95.0	92.2	127.2	25.0	26.6	95.0	144.7	74.7	4.7	741.2	41.50

Melon Production Budget – SJV

Operation	Equipment	Horse– Power	Hours/ Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/ Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Land Prep	Crawler	135	1	0.7	1	1											94.5	5.29
Land Prep	Ag Tractor	90	0.5	0.7	1	1											31.5	1.76
Fumigation	Crawler	135	0.5	0.7	1	1											47.3	2.65
Fertilizer	Ag Tractor	90	0.5	0.7		1	1										31.5	1.76
Plant	Ag Tractor	90	0.5	0.7			1	1									31.5	1.76
Herbacide	Ag Tractor	90	0.33	0.7				1	1								20.8	1.16
Cultivate	Ag Tractor	90	2	0.7				1	1	1							126.0	7.06
Cut Ditch	Crawler	135	0.33	0.7				1	1	1							31.2	1.75
Misc	Ag Tractor	90	1	0.7	1	1	1	1	1	1							63.0	3.53
Melon Total					97.1	112.9	42.0	89.0	73.3	62.9	0.0	0.0	0.0	0.0	0.0	0.0	477.2	26.72

Oat Hay Production Budget – SJV

Operation	Equipment	Horse– Power	Hours/ Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/ Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Disc	Ag Tractor	200	0.14	0.7												1	19.6	1.10
Chisel	Ag Tractor	200	0.27	0.7												1	37.8	2.12
Triplane	Ag Tractor	200	0.14	0.7												1	19.6	1.10
Finish Disc	Ag Tractor	130	0.12	0.7	1												10.9	0.61
Border	Ag Tractor	130	0.02	0.7	1												1.8	0.10
Plant	Ag Tractor	80	0.26	0.7	1												14.6	0.82
Open Ditch	Ag Tractor	130	0.01	0.7				1									0.9	0.05
Close Ditch	Ag Tractor	130	0.01	0.7							1						0.9	0.05
Preplant Fert.	Ag Tractor	130	0.01	0.7	1												0.9	0.05
Fertilize	Ag Tractor	130	0.01	0.7			1										0.9	0.05
Herbacide	Ag Tractor	80	0.02	0.7			1										1.1	0.06
Harvest	Sp Combine	65	0.33	0.7							1						15.0	0.84
Oat Hay Total					28.2	0.0	2.0	0.9	0.0	0.0	15.9	0.0	0.0	0.0	0.0	77.0	124.1	6.95

Olive Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Pre emerg Herb.	Ag Tractor	55	0.2	0.7											1		7.7	0.43
Contact Herb.	Ag Tractor	55	0.4	0.7					1			1					15.4	0.86
Harvest shaker	Shaker Catcher	120	3	0.7											1		252.0	14.11
Olive Total					0.0	0.0	0.0	0.0	7.7	0.0	0.0	7.7	0.0	0.0	259.7	0.0	275.1	15.41

Onion Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Subsoil	Crawler	80	1.24	0.7				1	1								69.4	3.89
Disc & Roll	Crawler	80	0.69	0.7				1	1								38.6	2.16
Chisel	Crawler	80	0.66	0.7				1	1								37.0	2.07
Level	Crawler	80	0.52	0.7				1	1								29.1	1.63
Shape Beds &Roll	Ag Tractor	60	0.5	0.7				1	1								21.0	1.18
Plant	Ag Tractor	60	0.5	0.7				1	1								21.0	1.18
Cultivate	Ag Tractor	60	3	0.7				1	1								126.0	7.06
Onion Total					0.0	0.0	0.0	171.1	171.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	342.2	19.16

Irrigated Pasture Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Mow & Fertilize	AG Tractor	98	0.75	0.7		1	1					2					51.5	2.88
Irrigated Pasture Total					0.0	12.9	12.9	0.0	0.0	0.0	0.0	25.7	0.0	0.0	0.0	0.0	51.5	2.88

* Hour/acre estimate was halved to reflect assessment of county Farm Advisor.

Peach Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Shred Brush	Ag Tractor	65	1.8	0.7		1					1			1			81.9	4.59
Dormant Spray	Ag Tractor	65	0.3	0.7		1											13.7	0.76
Bloom Spray	Ag Tractor	65	0.7	0.7			1	1									31.9	1.78
OFM	Ag Tractor	65	1	0.7						1	1	1					45.5	2.55
Brown rot	Ag Tractor	65	0.3	0.7									1				13.7	0.76
Weed Cntrl	Ag Tractor	65	0.2	0.7					1								9.1	0.51
Fertilize	Ag Tractor	30	0.2	0.7				1		1							4.2	0.24
Potasium 1/4	Ag Tractor	30	0.1	0.7												0.25	2.1	0.12
Mow or Disc	Ag Tractor	65	1.5	0.7			1			1				1			68.3	3.82
Backhoe	Ag Tractor	65	0.3	0.7					1	1	1	1	1	1			13.7	0.76
Remove Tree	Ag Tractor	65	0.3	0.7												1	13.7	0.76
Replant Tree	Ag Tractor	30	0.2	0.7												1	4.2	0.24
Bin Handling	Ag Tractor	30	1	0.7											1		21.0	1.18
Peach Total					0.0	41.0	38.7	18.0	11.4	42.3	44.7	17.4	15.9	52.3	21.0	20.0	322.7	18.07

Pear/Apple Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom												Bhp-hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Brush Rmvl	Ag Tractor	30	0.6	0.7					1	1	1		1		1		12.6	0.71
Rodent Control	Ag Tractor	50	0.3	0.7								1					10.5	0.59
Fertilize	Ag Tractor	50	0.5	0.7				1				2					17.5	0.98
Chop Weeds	Ag Tractor	50	1.8	0.7			1		1	1	1	1	1		1		63.0	3.53
Herbacide &	Ag Tractor	50	0.36	0.7											1		12.6	0.71
Pest & Disease	Ag Tractor	50	0.36	0.7	1												12.6	0.71
	Ag Tractor	50	0.36	0.7		1											12.6	0.71
	Ag Tractor	50	0.12	0.7				1									4.2	0.24
	Ag Tractor	50	0.4	0.7				1									14.0	0.78
	Ag Tractor	50	0.4	0.7				1									14.0	0.78
	Ag Tractor	50	0.4	0.7					1								14.0	0.78
	Ag Tractor	50	0.4	0.7						1							14.0	0.78
	Ag Tractor	50	0.4	0.7							1						14.0	0.78
	Ag Tractor	50	0.36	0.7							1						12.6	0.71
Harvest	Ag Tractor	30	1.5	0.7								1	1				31.5	1.76
Pear/Apple Total					12.6	12.6	9.0	38.0	25.5	25.5	38.1	46.9	27.3	0.0	24.1	0.0	259.7	14.54

Pistachio Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom												Bhp-hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Brush Shredding	Ag Tractor	65	0.5	0.7		1											22.8	1.27
Disc	Ag Tractor	65	1.5	0.7									1				68.3	3.82
Weed Control	Ag Tractor	65	1.5	0.7												1	68.3	3.82
Weed Control	Ag Tractor	65	0.5	0.7						1							22.8	1.27
Fertilize	Ag Tractor	65	1	0.7						1			1				45.5	2.55
Pest Control	Ag Tractor	65	1	0.7				1					1				45.5	2.55
Harvest shaker	Shaker Catcher	120	3	0.51										1			183.6	10.28
Pistachio Total					0.0	22.8	0.0	22.8	0.0	45.5	0.0	0.0	113.8	183.6	0.0	68.3	456.6	25.57

Plum Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom												Bhp-hr/Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Brush Disposal	Ag Tractor	65	0.6	0.7		1											27.3	1.53
Furrowing	Ag Tractor	65	1.7	0.7				1		1		1					77.4	4.33
Disc	Ag Tractor	65	1.9	0.7						1		1			1		86.5	4.84
Misc.	Ag Tractor	65	1	0.7		1	1	1	1	1	1	1	1	1	1	1	45.5	2.55
Spray	Ag Tractor	65	3.15	0.7		4						1					143.3	8.03
Fertilize	Ag Tractor	65	0.63	0.7										1			28.7	1.61
Harvest shaker	Shaker Catcher	120	3	0.51							1						183.6	10.28
Plum Total					0.0	146.1	4.1	29.9	4.1	58.7	187.7	87.4	4.1	32.8	33.0	4.1	592.2	33.16

Potato Production Budget – SJV																		
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Chisel	Crawler	135	1	0.7					1	1	1						94.5	5.29
Disc	Crawler	135	1	0.7					1	1	1						94.5	5.29
Finish Level	Crawler	135	0.5	0.7					1	1	1						47.3	2.65
List	Crawler	135	0.5	0.7					1	1	1						47.3	2.65
Herbacide	Ag Tractor	90	0.33	0.7					1	1	1						20.8	1.16
Cultivate	Ag Tractor	90	1.5	0.7					1	1	1						94.5	5.29
Misc	Ag Tractor	90	2	0.7					1	1	1						126.0	7.06
Vine Rolling	Ag Tractor	90	1.5	0.7	1	1	1	1						1	1	1	94.5	5.29
Potato Total					13.5	13.5	13.5	13.5	174.9	174.9	174.9	0.0	0.0	13.5	13.5	13.5	619.3	34.68

Prune Production Budget – SJV																		
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Brush Disposal	Ag Tractor	55	1.2	0.7		1											46.2	2.59
Tillage	Ag Tractor	55	1.33	0.7			1	1									51.2	2.87
Fertilize	Ag Tractor	55	0.5	0.7					2			1					19.3	1.08
Spray: Weed Cntrl	Ag Tractor	55	0.6	0.7	1						1						23.1	1.29
Mow	Ag Tractor	55	2.5	0.7				1		1	1		1				96.3	5.39
Misc.	Ag Tractor	55	1	0.7				1		1			1				38.5	2.16
Dormant Spray	Ag Tractor	55	0.3	0.7			1										11.6	0.65
Bloom Spray	Ag Tractor	55	0.3	0.7				1									11.6	0.65
Zinc Spray	Ag Tractor	55	0.3	0.7				1									11.6	0.65
Harvest shaker	Shaker Catcher	120	3	0.51									1				183.6	10.28
Prune Total					11.6	46.2	37.2	85.6	12.8	36.9	35.6	6.4	220.5	0.0	0.0	0.0	492.8	27.59

Rice Production Budget – SJV																		
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Chisel	Crawler	125	0.16	0.7				1									14.0	0.78
Stubble Disc	Ag Tractor 4wd	200	0.16	0.7					1								22.4	1.25
Harrow Disc	Ag Tractor 4wd	200	0.3	0.7					1	1							42.0	2.35
3 Wheel Plane	Ag Tractor 4wd	200	0.16	0.7						1							22.4	1.25
Laser Level*	Ag Tractor 4wd	200	0.16	0.7							0.33						7.5	0.42
Roll	Ag Tractor	40	0.1	0.7						1							2.8	0.16
Mtn. Drains	Ag Tractor 4wd	200	0.1	0.7						1							14.0	0.78
Mtn. Roads	Ag Tractor	40	0.1	0.7				1	1								2.8	0.16
Harvest	SP Combine	120	0.75	0.7										1	1		63.0	3.53
Harvest	Bankout	60	0.5	0.51										1	1		15.3	0.86
Rice Total					0.0	0.0	0.0	15.4	44.8	60.2	7.5	0.0	0.0	39.2	39.2	0.0	206.2	11.55

Safflower Production Budget – SJV																		
Operation	Equipment	Horse–Power	Hours/ Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/ Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Stubble Disc	Crawler	190	0.11	0.7	1	1	1										14.6	0.82
Disc	Crawler	120	0.26	0.7	1	1	1										21.8	1.22
Fertilize	Crawler	120	0.1	0.7	1	1	1										8.4	0.47
List up Beds	Crawler	120	0.26	0.7		1	1										21.8	1.22
Incorp. Herbcd	Ag Tractor	135	0.2	0.7		1	1										18.9	1.06
Rolling Cultvtr	Ag Tractor	90	0.2	0.7		1	1										12.6	0.71
Plant	Ag Tractor	90	0.33	0.7			1	1	1								20.8	1.16
Ditch	Crawler	120	0.03	0.7			1	1	1								2.5	0.14
Misc.	Ag Tractor	90	0.04	0.7			1	1	1								2.5	0.14
Harvest	Combine	135	0.25	0.7									1	1			23.6	1.32
Bankout Wagon	Ag Tractor	90	0.25	0.7									1	1			15.8	0.88
Chop Stubble	Ag Tractor	135	0.25	0.7										1	1	1	23.6	1.32
Stubble disc	Crawler	190	0.22	0.7										1	1	1	29.3	1.64
Safflower Total					15.0	41.6	50.2	8.6	8.6	0.0	0.0	0.0	19.7	37.3	17.6	17.6	216.3	12.11

Silage (Corn) Production Budget – SJV																		
Operation	Equipment	Horse–Power	Hours/ Acre	Load Factor	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom												Bhp–hr/ Acre	Diesel Gal/Acre
					Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Disc Stubble	Ag Tractor	200	0.14	0.7							1						19.6	1.10
Disc finish	Ag Tractor	200	0.12	0.7							1						16.8	0.94
Land Plane Field	Ag Tractor	200	0.14	0.7							1						19.6	1.10
List & Fert	Ag Tractor	80	0.15	0.7							1						8.4	0.47
Mulch beds	Ag Tractor	130	0.18	0.7							1						16.4	0.92
Roll Beds	Ag Tractor	130	0.1	0.7							1						9.1	0.51
Open Ditch	Ag Tractor	130	0.02	0.7							1	1					1.8	0.10
Close Ditch	Ag Tractor	130	0.04	0.7							1				1		3.6	0.20
Disc over Ditch	Ag Tractor	130	0.04	0.7							1				1		3.6	0.20
Plant	Ag Tractor	80	0.14	0.7							1						7.8	0.44
Cultivate	Ag Tractor	80	0.31	0.7								1					17.4	0.97
Apply Manure	Ag Tractor	80	0.15	0.7							1						8.4	0.47
Fertilize	Ag Tractor	80	0.15	0.7								1					8.4	0.47
Apply Herbacide	Ag Tractor	80	0.04	0.7								1					2.2	0.13
Apply Miticide	Ag Tractor	80	0.04	0.7								1					2.2	0.13
Silage (Corn) Total					0.0	0.0	0.0	0.0	0.0	0.0	110.7	31.2	0.0	0.0	3.6	0.0	145.5	8.15

Squash Production Budget – SJV																			
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom													Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		Acre	Gal/Acre
Land Prep	Ag Tractor	75	3	0.7			1	1	1									157.5	8.82
Plastic Mulch	Ag Tractor	75	1.5	0.7				1	1	1								78.8	4.41
Fertilize	Ag Tractor	75	5	0.7				1	1	1								262.5	14.70
Planting	Ag Tractor	75	1.5	0.7					1	1	1							78.8	4.41
Tunnel Constrctn	Ag Tractor	75	3	0.7					1	1	1							157.5	8.82
Plastic Remvl	Ag Tractor	75	1	0.7							1	1	1					52.5	2.94
Plstc Mulch rmvl	Ag Tractor	75	2	0.7							1	1	1					105.0	5.88
Squash Total					0.0	0.0	52.5	166.3	245.0	192.5	131.3	52.5	52.5	0.0	0.0	0.0		892.5	49.98

Sugarbeet Production Budget – SJV																			
		Horse–	Hours/	Load	Relative Monthly Activity – Bhp–hr/Acre by Month Appears at Bottom													Bhp–hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		Acre	Gal/Acre
Stubble Disc	Crawler	190	0.22	0.7	1	1	1											29.3	1.64
Subsoil	Crawler	190	0.4	0.7	1	1	1											53.2	2.98
Triplane	Crawler	120	0.34	0.7	1	1	1											28.6	1.60
List	Crawler	120	0.25	0.7	1	1	1											21.0	1.18
Wntr Weed	Ag Tractor	90	0.2	0.7				1	1	1								12.6	0.71
lilliston	Ag Tractor	90	0.2	0.7		1	1	1										12.6	0.71
Herbacide	Ag Tractor	90	0.08	0.7		1	1	1										5.0	0.28
Incorporate	Ag Tractor	135	0.27	0.7		1	1	1										25.5	1.43
Plant	Ag Tractor	90	0.33	0.7			1	1	1	1								20.8	1.16
Recultivate	Ag Tractor	90	0.03	0.7				1	1	1								1.9	0.11
Replant	Ag Tractor	90	0.03	0.7				1	1	1	1							1.9	0.11
Cultivate	Ag Tractor	90	0.33	0.7					1	1	1	1						20.8	1.16
Flat Roll	Ag Tractor	90	0.12	0.7					1	1	1	1						7.6	0.42
Thin Elect.	Ag Tractor	90	0.33	0.7					1	1	1	1						20.8	1.16
Fertilize	Ag Tractor	90	0.33	0.7		1	1	1										20.8	1.16
Layby Herb	Ag Tractor	90	0.25	0.7					1	1	1	1						15.8	0.88
Rolling Cultvtr	Ag Tractor	90	0.2	0.7					1	1	1	1						12.6	0.71
V Ditch	Crawler	120	0.15	0.7					1	1	1	1						12.6	0.71
Sugarbeet Total					44.0	65.3	70.5	31.8	33.0	33.0	23.0	22.5	0.0	0.0	0.0	0.0		323.2	18.10

Sunflower Seed Production Budget - SJV																		
		Horse-	Hours/	Load	Relative Monthly Activity - Bhp-hr/Acre by Month Appears at Bottom												Bhp-hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Stubble Disc	Crawler	100	0.25	0.7											1		17.5	0.98
Disc	Crawler	100	0.2	0.7											1		14.0	0.78
Chisel	Ag Tractor 4wd	200	0.16	0.7											1		22.4	1.25
Land Plane	Ag Tractor 4wd	200	0.3	0.7											1		42.0	2.35
List Beds	Ag Tractor 2wd	120	0.2	0.7												1	16.8	0.94
Weed Control	Ag Tractor 2wd	120	0.2	0.7				1									16.8	0.94
Cult. & Fert	Ag Tractor 2wd	120	0.2	0.7				1									16.8	0.94
Plant & Herb.	Ag Tractor 2wd	120	0.33	0.7					1								27.7	1.55
Cultivate	Ag Tractor 2wd	120	0.01	0.7						1							0.8	0.05
Cult. & Apply N	Ag Tractor 2wd	120	0.2	0.7						1							16.8	0.94
Harvest	Combine	120	0.33	0.7									1	1			27.7	1.55
Stubble Disc	Crawler	100	0.2	0.7											1		14.0	0.78
Sunflower Seed Total					0.0	0.0	0.0	33.6	27.7	17.6	0.0	0.0	13.9	13.9	109.9	16.8	233.4	13.07

Tomato Production Budget - SJV																		
		Horse-	Hours/	Load	Relative Monthly Activity - Bhp-hr/Acre by Month Appears at Bottom												Bhp-hr/	Diesel
Operation	Equipment	Power	Acre	Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Acre	Gal/Acre
Plow	AG Tractor	165	0.4	0.7									1	1	1	1	46.2	2.59
Subsoil	Tracklayer	190	0.4	0.7									1	1	1	1	53.2	2.98
Disc Roller	Tracklayer	120	0.26	0.7									1	1	1	1	21.8	1.22
Triplane	Tracklayer	120	0.34	0.7									1	1	1	1	28.6	1.60
w/o Nemacide	AG Tractor	90	0.23	0.7									1	1	1	1	14.5	0.81
Nemacide	AG Tractor	90	0.04	0.7									1	1	1	1	2.5	0.14
Flat Roll	AG Tractor	90	0.12	0.7									1	1	1	1	7.6	0.42
Fall Appld Herb	AG Tractor	90	0.03	0.7									1	1	1	1	1.9	0.11
Herbacide	AG Tractor	90	0.15	0.7									1	1	1	1	9.5	0.53
Cultivate	AG Tractor	90	0.13	0.7			1	1	1	1							8.2	0.46
Herbacide	AG Tractor	90	0.24	0.7			1	1	1	1							15.1	0.85
Planting	Lght WT Trackl	65	0.07	0.7			1	1	1	1							3.2	0.18
Planting	AG Tractor	90	0.26	0.7			1	1	1	1							16.4	0.92
Remove Soil Cap	AG Tractor	90	0.07	0.7			1	1	1	1							4.4	0.25
Break Crust	Tracklayer	120	0.16	0.7			1	1	1	1							13.4	0.75
Replant	Lght WT Trackl	65	0.03	0.7			1	1	1	1							1.4	0.08
Cultivate	AG Tractor	90	0.4	0.7				1	1	1	1	1					25.2	1.41
Thin	AG Tractor	90	0.11	0.7				1	1	1	1	1					6.9	0.39
Fert	AG Tractor	90	0.33	0.7				1	1	1	1	1					20.8	1.16
V Ditch	Tracklayer	120	0.15	0.7				1	1	1	1	1					12.6	0.71
Layby Herbacide	AG Tractor	90	0.4	0.7				1	1	1	1	1					25.2	1.41
Cultivate	AG Tractor	90	0.29	0.7				1	1	1	1	1					18.3	1.02
Cult. Hi-Crop	AG Tractor	90	0.33	0.7				1	1	1	1	1					20.8	1.16
Vine Trainer	AG Tractor	135	0.2	0.7				1	1	1	1	1					18.9	1.06
Harvest 80% AC	AG Tractor	90	1	0.7							1	1	1	1			63.0	3.53
Harvest 20% AC	AG Tractor	90	0.32	0.7							1	1	1	1			20.2	1.13
Dollies 80% AC	AG Tractor	90	2	0.7							1	1	1	1			126.0	7.06
Dollies 20% AC	AG Tractor	90	0.32	0.7							1	1	1	1			20.2	1.13
Avenue Opener 7%	AG Tractor	90	0.1	0.7							1	1	1	1			6.3	0.35
Tomato Total					0.0	0.0	15.5	45.3	45.3	45.3	88.6	88.6	105.3	105.3	46.4	46.4	632.1	35.40

Vegetables (Seasonal) Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Subsoil	Crawler	80	1.24	0.7		1	1	1	1	1	1						69.4	3.89
Disc & Roll	Crawler	80	0.69	0.7		1	1	1	1	1	1						38.6	2.16
Chisel	Crawler	80	0.66	0.7		1	1	1	1	1	1						37.0	2.07
Level	Crawler	80	0.52	0.7		1	1	1	1	1	1						29.1	1.63
Shape Beds&Roll	Ag Tractor	60	0.25	0.7		1	1	1	1	1	1						10.5	0.59
Plant	Ag Tractor	60	0.42	0.7		1	1	1	1	1	1						17.6	0.99
Cultivate	Ag Tractor	60	1.5	0.7		1	1	1	1	1	1						63.0	3.53
Vegetables (Seasonal) Total					0.0	44.2	44.2	44.2	44.2	44.2	44.2	0.0	0.0	0.0	0.0	0.0	265.3	14.86

Vegetables (Year–Long) Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Subsoil	Crawler	80	1.24	0.7	1	1	1	1	1	1	1	1	1	1	1	1	69.4	3.89
Disc & Roll	Crawler	80	0.69	0.7	1	1	1	1	1	1	1	1	1	1	1	1	38.6	2.16
Chisel	Crawler	80	0.66	0.7	1	1	1	1	1	1	1	1	1	1	1	1	37.0	2.07
Level	Crawler	80	0.52	0.7	1	1	1	1	1	1	1	1	1	1	1	1	29.1	1.63
Shape Beds&Roll	Ag Tractor	60	0.25	0.7	1	1	1	1	1	1	1	1	1	1	1	1	10.5	0.59
Plant	Ag Tractor	60	0.42	0.7	1	1	1	1	1	1	1	1	1	1	1	1	17.6	0.99
Cultivate	Ag Tractor	60	1.5	0.7	1	1	1	1	1	1	1	1	1	1	1	1	63.0	3.53
Vegetables (Year–Long) Total					22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	265.3	14.86

Walnut Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Brush Dspsl	AG Tractor	55	1.2	0.7		1											46.2	2.59
Fertilize 200#	AG Tractor	55	0.2	0.7				1				1					7.7	0.43
Tillage	AG Tractor	55	1.8	0.7					1	1	1	1	1	1			69.3	3.88
Mow x 5	AG Tractor	55	4	0.7			1		1	1	1		1				154.0	8.62
Weed Spray	AG Tractor	55	0.6	0.7					1						1		23.1	1.29
Walnut Total					0.0	46.2	30.8	3.9	53.9	42.4	42.4	15.4	42.4	11.6	11.6	0.0	300.3	16.82

Wheat Production Budget – SJV

Operation	Equipment	Horse-Power	Hours/Acre	Load Factor	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Bhp-hr/Acre	Diesel Gal/Acre
					Relative Monthly Activity – Bhp-hr/Acre by Month Appears at Bottom													
Disc	Tractor Crawler	125	0.25	0.7											1		21.9	1.23
Chisel	Ag Tractor	200	0.13	0.7											1		18.2	1.02
Disk Offset	Ag Tractor	200	0.13	0.7											1		18.2	1.02
Triplane	Tractor Crawler	125	0.2	0.7											1		17.5	0.98
Fertilize	Ag Tractor	135	0.1	0.7												1	9.5	0.53
Spiketooth	Ag Tractor	135	0.1	0.7												1	9.5	0.53
Drill & Fert	Ag Tractor	135	0.2	0.7												1	18.9	1.06
Border	Ag Tractor	100	0.1	0.7												1	7.0	0.39
Ditch	Tractor Crawler	125	0.1	0.7				1									8.8	0.49
Harvest	SP Combine	65	0.33	0.7							1						15.0	0.84
Wheat Total					0.0	0.0	0.0	8.8	0.0	0.0	15.0	0.0	0.0	0.0	75.8	44.8	144.3	8.08