2006 Ozone Season Weekday Quarry Equipment Emissions Inventory for the Capital Area Council of Governments Air Quality Program Area

FINAL REPORT, Task 3.4f, Rider 8 Phase II Work Plan

Prepared by the Capital Area Council of Governments

July 2013

Prepared in Cooperation with the Texas Commission on Environmental Quality

The preparation of this report was financed through grants from the State of Texas through the Texas Commission on Environmental Quality

Executive Summary

CAPCOG has updated the typical 2006 ozone season weekday emissions from quarry equipment for the 11-county Rider 8 CAPCOG air quality program area, which consists of Bastrop, Blanco, Burnet, Caldwell, Fayette, Hays, Lee, Llano, Milam, Travis, and Williamson Counties. The inventory includes updated daily emission estimates of nitrogen oxides (NO_X), volatile organic compounds (VOC), and carbon monoxide (CO). CAPCOG used data developed by the Alamo Area Council of Governments (AACOG) in conjunction with local quarry production figures from the U.S. Mine Health and Safety Administration (MHSA) (AACOG, 2012) (U.S. Mine Safety and Health Administration, 2012). CAPCOG compared AACOG's survey results to the survey conducted by Eastern Research Group, Inc. (ERG) in 2008, which formed the basis for the existing estimate of emissions from this source category. The analysis year – 2006 – was chosen because CAPCOG uses a June 2006 photochemical modeling episode to perform ozone modeling for the region. This emissions inventory does not include updated emissions estimates for the one lignite coal mine in the region – the Three Oaks Coal mine in Lee County. AACOG's survey did not include the coal mine in their region, and ERG's study showed that coal mines have significantly different equipment profiles than quarries.

The table below summarizes CAPCOG's emissions estimates from quarry equipment in each county in CAPCOG's program area for a typical ozone season day in 2006 using the updated equipment populations, activity levels, and horsepower ratings in conjunction with the Texas NONROAD (TexN) model. The table also presents the estimated NO_X reduction benefit of Texas Low-Emissions Diesel (TxLED) if all of the subject equipment in the region was using lower-emission diesel during 2006.

Table 1: 2006 Typical Ozone Season Day Quarry Equipment Emissions by County (tons per day)

County	VOC	CO	NO_X	TxLED NO_X Adjustment
Bastrop	0.0084	0.0610	0.1548	-0.0096
Blanco	0.0000	0.0000	0.0000	0.0000
Burnet	0.0430	0.3098	0.7436	0.0000
Caldwell	0.0000	0.0000	0.0000	0.0000
Fayette	0.0205	0.1494	0.3690	-0.0229
Hays	0.0131	0.0935	0.2398	-0.0149
Lee	0.0000	0.0000	0.0000	0.0000
Llano	0.0030	0.0204	0.0505	0.0000
Milam	0.0248	0.1814	0.4477	-0.0278
Travis	0.0485	0.3512	0.8940	-0.0554
Williamson	0.1658	1.2015	3.0574	-0.1896
Total	0.3270	2.3682	5.9568	-0.3201

Contents

Executive Summary 2

Introduction 5

Equipment Populations and Horsepower Ratings 8

Activity 11

Annual Hours of Use 11

Weekday/Weekend Allocation 12

Seasonal Allocation 12

Emissions Rates & Estimates 13

Conclusions and Recommendations .... 15~~16~~

Works Cited .... 16~~17~~

List of Tables

Table 1: 2006 Typical Ozone Season Day Quarry Equipment Emissions by County (tons per day) 2
Table 2: Pieces of Equipment Surveyed, AACOG & ERG 6
Table 3: Equipment Ratios (per 10,000 hours) and Average Horsepower Ratings 8
Table 4: 2006 Quarry Production Hours by County 9
Table 5: Annual Hours of Use 11
Table 6: Quarterly Activity Allocations for Mine and Quarry Equipment, 2006 13
Table 7: Fuel/Meteorology County Groupings 13
Table 8: Default Meteorological Parameters by Met Station .... 14~~15~~
Table 9: Emission Adjustment Factors .... 14~~15~~
Table 10: NO_X Emissions by Equipment Type .... 15~~16~~
Table 11: Soil Type Adjustment Factors for Earthmoving Equipment .... 16~~17~~

List of Figures

Figure 1: Relative Share of Quarry Production in AACOG and CAPCOG Program Areas and in ERG Survey 5
Figure 2: Comparison of Annual Hours of Activity Estimates for Selected Equipment 7
Figure 3: Comparison of Average Horsepower Rating for Selected Equipment 7
Figure 4: Rock Processing Equipment Counts in CAPCOG Program Area 9
Figure 5: Default v. Updated Equipment Populations 10
Figure 6: Comparison of ERG and AACOG Average Horsepower Ratings 11
Figure 7: Comparison of ERG and AACOG Annual Activity Estimates (hours/year) 12

Introduction

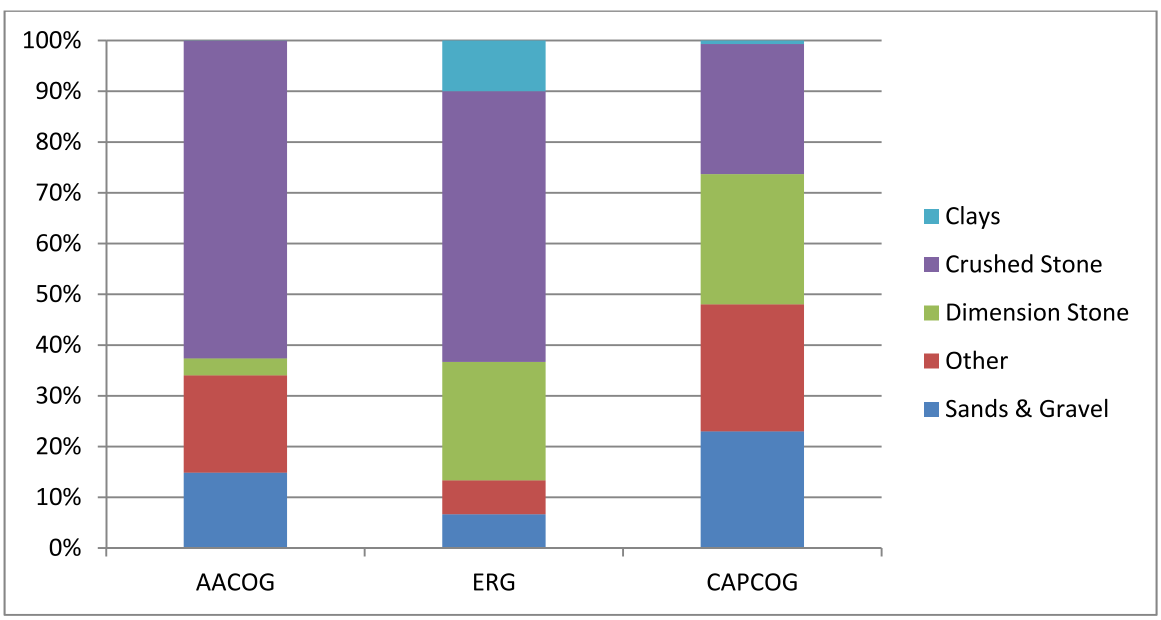
The default emissions inventory for quarry equipment is based on surveys conducted by ERG in 2008 (ERG, 2009). In order to evaluate whether using AACOG's survey as the basis for estimating quarry equipment emissions in the CAPCOG program area, CAPCOG performed a series of analyses comparing ERG's data to AACOG's.

One point of comparison between the two surveys is to see how closely the mix of commodities produced at quarries surveyed match the production in CAPCOG's program area. CAPCOG calculated the total number of production hours by commodity type for the AACOG region in 2011 and the CAPCOG program area for 2006, and also used the number of survey responses ERG received in its 2009 study to compare these data sources. CAPCOG grouped the commodities into the following commodity categories:

- Clays,
- Crushed Stone,
- Dimension Stone (whole stones cut to specific dimensions),
- Sand and Gravel, and
- Other.

As the chart below shows, there are significant differences in the relative importance of these product categories. In particular, crushed stone production makes up a much smaller portion of CAPCOG's total production compared to the AACOG region and ERG's survey respondents. ERG's survey included a proportion of responses from dimension stone production similar to the proportion of CAPCOG's production, but AACOG's survey included production of sand and gravel and other commodity types that were closer to CAPCOG's program area. Based on these differences, CAPCOG concluded that neither the ERG nor AACOG surveys were clearly more representative of CAPCOG's production than the other.

Figure 1: Relative Share of Quarry Production in AACOG and CAPCOG Program Areas and in ERG Survey



Another point of comparison is the number of responses each survey was able to complete. AACOG's equipment populations were based on surveys of 22 quarries and aerial imagery of another 22 quarries, while ERG's equipment populations were based on survey responses at 30 quarries. Both AACOG and ERG used pit production hours from MSHA's data retrieval system as a scaling factor for equipment populations. ERG's activity and horsepower ratings, however, were based on a total of 30 surveys, whereas AACOG's is only based on 22.

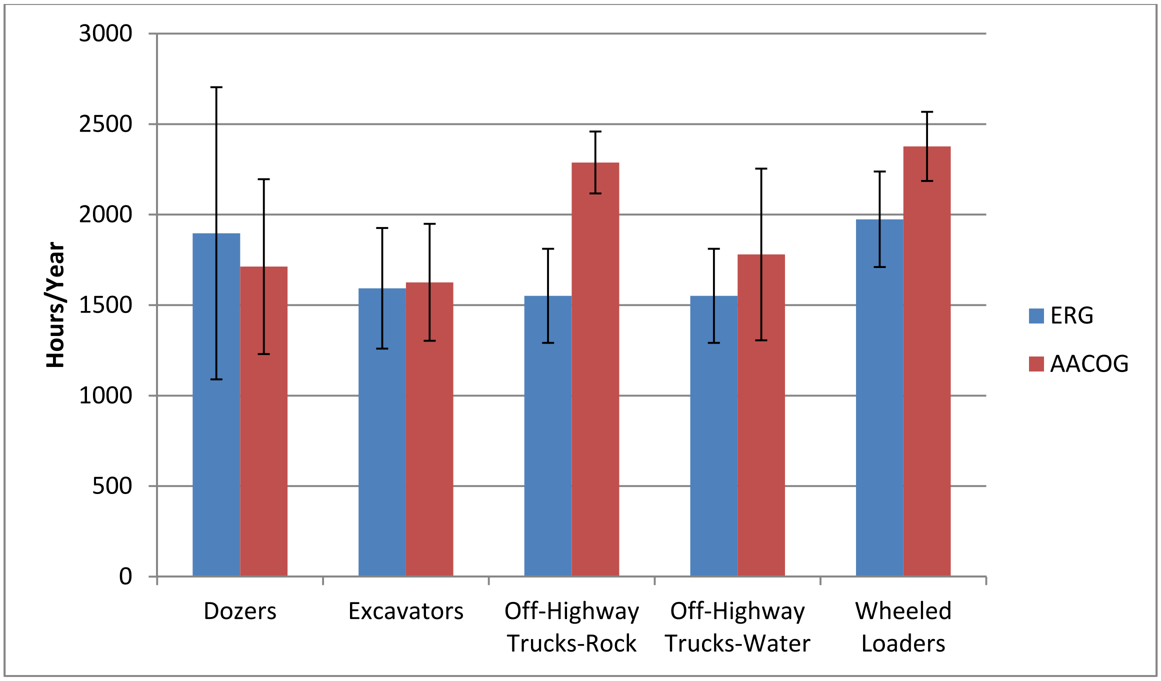
AACOG's survey did, however, include more surveyed pieces of equipment than ERG for almost every equipment category, and especially the most prevalent types – off-highway trucks and wheeled loaders.

Table 2: Pieces of Equipment Surveyed, AACOG & ERG

Equipment Type	AACOG	AACOG Activity/HP	ERG
Backhoe	14	18/12	4
Crawler Tractor/Dozer	31	26/23	24
Crushing/Proc. Equipment	3	3/3	11
Excavator	34	17/16	25
Grader	14	11/10	7
Off-Highway Truck (Rock)	125	81/73	39
Roller/Compactor	2	2/2	1
Scraper	7	7/7	7
Wheeled Loader	148	90/77	74
Bore/Drill Rigs	16	7/7	0
Cranes	19	8/8	0
Aerial Lifts	12	7/7	0
Pumps	3	0/0	0

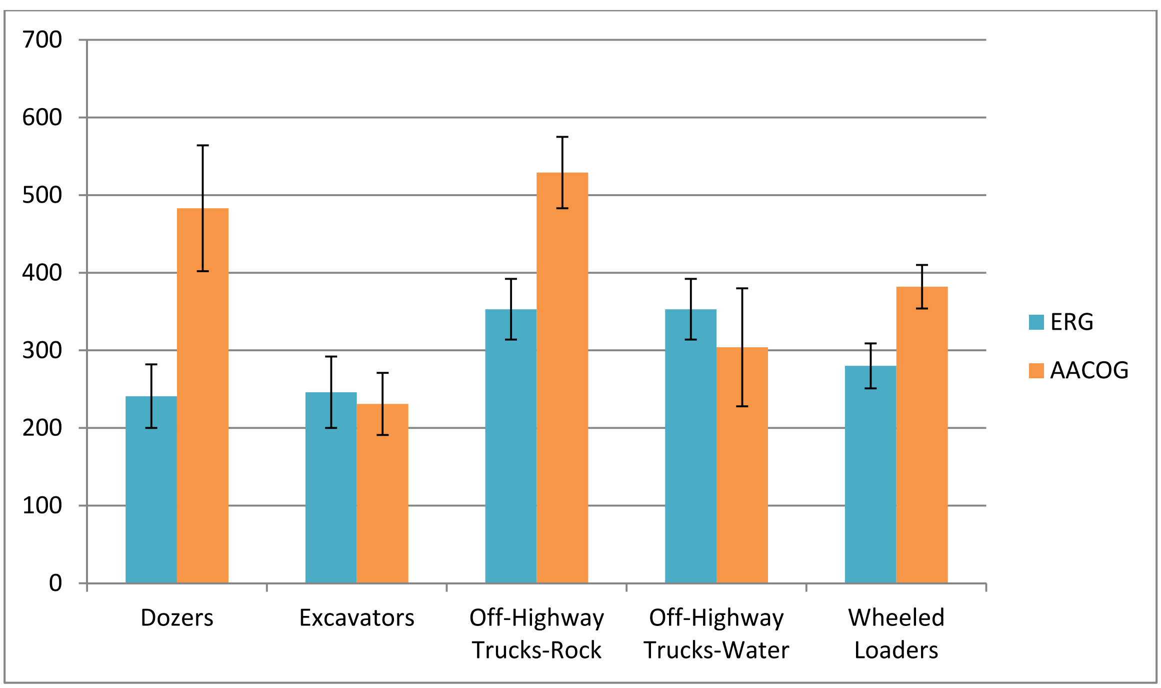
CAPCOG also compared the confidence intervals for activity and horsepower ratings from the two surveys. With the exception of water trucks – which is a sub-category of off-highway trucks that AACOG split out – AACOG's confidence intervals for annual activity are smaller than ERG's, both in absolute and relative terms. For rock trucks and wheeled loaders, AACOG's survey results showed statistically significantly higher usage.

Figure 2: Comparison of Annual Hours of Activity Estimates for Selected Equipment



AACOG's confidence intervals for the average horsepower ratings for these equipment types were also smaller as a percentage of the mean than ERG's were for these equipment types (other than water trucks). AACOG's average horsepower ratings for dozers, rock trucks, and wheeled loaders were also significantly higher than ERG's.

Figure 3: Comparison of Average Horsepower Rating for Selected Equipment



One possible reason that AACOG's survey provides annual activity and average horsepower ratings that are statistically significantly different from ERG's is the mix of production, mentioned before. If crushed stone and limestone quarries require heavier equipment or more operating hours per year, their importance in the AACOG region would help explain these differences. Since neither ERG nor AACOG presented their data broken out by commodity type, however, it is not possible to know whether that accounts for the differences.

Ultimately, CAPCOG's assessment is that AACOG's 2012 estimates provide a more robust basis for estimating mine and quarry equipment in CAPCOG's program area than ERG's 2008 survey. AACOG's equipment population scaling factors are based on a larger number of quarries than ERG's are, and AACOG's activity data and horsepower ratings vary less as a percentage of their means than ERG's estimates do.

Equipment Populations and Horsepower Ratings

CAPCOG used local quarry and mine production figures from the MSHA data retrieval system and equipment ratios developed by AACOG in order to calculate the equipment counts for each county in CAPCOG's program area. AACOG's 2012 report also included survey-derived horsepower averages for each equipment type. CAPCOG assumes that these horsepower averages are also representative of equipment used in CAPCOG's program area. The table below shows the parameters developed by AACOG. The equipment ratio is the number of pieces of equipment per 10,000 labor-hours of production:

Table 3: Equipment Ratios (per 10,000 hours) and Average Horsepower Ratings

Equipment Type	SCC	Equipment Ratio	Avg. Horsepower
Rollers	2270002015	0.01	110
Scrapers	2270002018	0.05	315
Bore/Drill Rigs	2270002033	0.12	269
Excavators	2270002036	0.25	231
Cranes	2270002045	0.14	200
Graders	2270002048	0.10	142
Rock Trucks	2270002051	0.85	529
Water Trucks	2270002051	0.08	304
Vacuum Trucks	2270002051	0.01	355
Rock. Proc. Eq.	2270002054	n/a	369
Loaders	2270002060	1.10	382
Backhoes	2270002066	0.10	97
Bulldozers	2270002069	0.23	483
Aerial Lifts	2270003010	0.09	59
Pumps	2270006010	0.02	288

Rock processing equipment was not included among these ratios since AACOG used TCEQ permit data to find the engine-powered rock crushers within their region. For all of the other equipment types, CAPCOG calculated the equipment populations by multiplying the ratios listed above by the 2006 production totals listed below and dividing by 10,000. The actual equipment populations for each SCC and county are provided in an accompanying spreadsheet.

Table 4: 2006 Quarry Production Hours by County

County	2006 Labor Hours
Bastrop	51,591
Blanco	0
Burnet	409,693
Caldwell	0
Fayette	290,734
Hays	100,149
Lee	168,270
Llano	20,862
Milam	351,082
Travis	327,132
Williamson	1,205,212
TOTAL	2,622,349

For rock processing equipment, CAPCOG performed a search in TCEQ's permit database for rock crusher permits issued between January 1, 1990, and January 1, 2007. This search yielded 58 permits in the region during the period. Upon reviewing the actual permit documents, CAPCOG was able to affirmatively identify 24 rock crushers that were engine-powered. CAPCOG is not completely confident of these numbers – just because a permit was issued at one point, it doesn't mean that the permit was being used in 2006. There were also some problems viewing the actual permits.

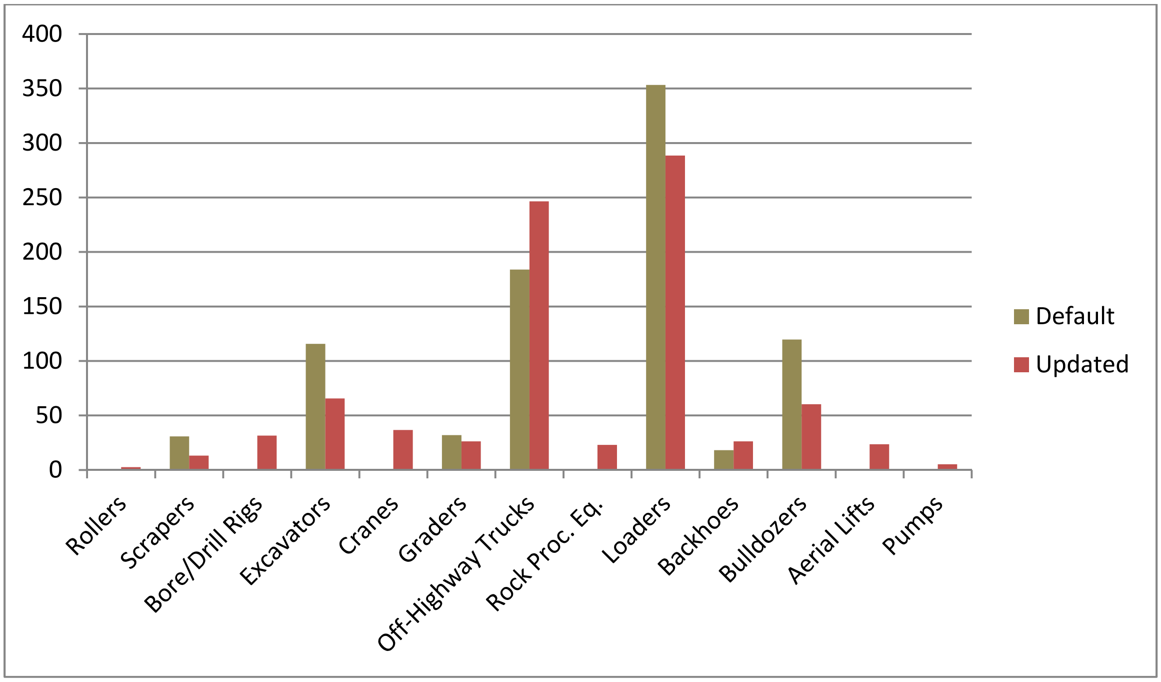
The table below shows the rock processing equipment counts for each county:

Figure 4: Rock Processing Equipment Counts in CAPCOG Program Area

County	Count
Burnet	5
Hays	3
Llano	2
Milam	4
Travis	3
Williamson	10

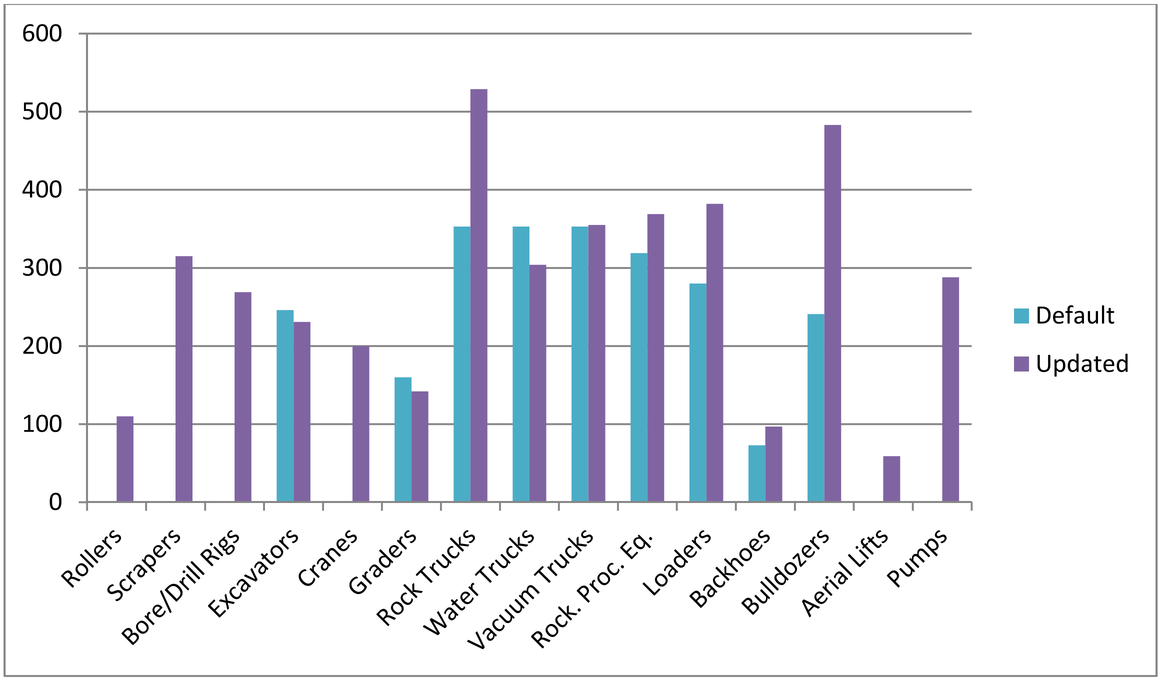
The updated quarry equipment populations for the region are presented in the chart below, along with the default TexN equipment populations for comparison. There are a total of 849 pieces of equipment estimated in the updated equipment population, and 854 pieces of equipment in the default equipment population. While there are variations within the specific source categories, these largely offset one another in aggregate – there are 59 fewer bulldozers but 63 more off-highway trucks, for instance.

Figure 5: Default v. Updated Equipment Populations



The updated average horsepower data, on the other hand, are more clearly higher in AACOG's survey compared to ERG's. There are a few equipment types with very close estimates, such as excavators, water trucks, vacuum trucks, and rock processing equipment. But the more prevalent equipment types – rock trucks, loaders, and bulldozers – have significantly higher horsepower ratings.

Figure 6: Comparison of ERG and AACOG Average Horsepower Ratings



Activity

Annual Hours of Use

CAPCOG's estimates for annual activity were based on AACOG's 2012 report. These activity estimates were based on survey data collected from local quarries in the AACOG region. The table below summarizes these activity estimates:

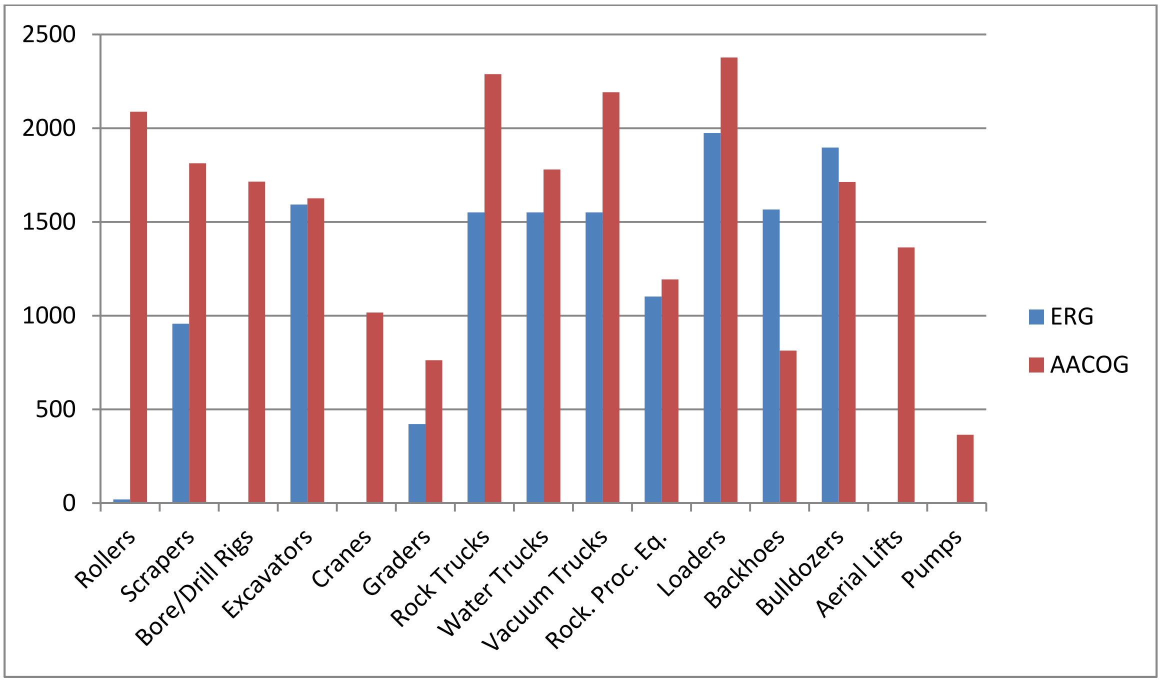
Table 5: Annual Hours of Use

Equipment Type	SCC	Annual Hours
Rollers	2270002015	2,088
Scrapers	2270002018	1,813
Bore/Drill Rigs	2270002033	1,715
Excavators	2270002036	1,626
Cranes	2270002045	1,017
Graders	2270002048	762
Rock Trucks	2270002051	2,288
Water Trucks	2270002051	1,780
Vacuum Trucks	2270002051	2,192
Rock. Proc. Eq.	2270002054	1,193
Loaders	2270002060	2,377
Backhoes	2270002066	814
Bulldozers	2270002069	1,713
Aerial Lifts	2270003010	1,364

Equipment Type	SCC	Annual Hours
Pumps	2270006010	365

Similar to the data on engine horsepower rating, AACOG's annual activity estimates are higher almost across the board (except for bulldozers). This is consistent with CAPCOG's findings in its agricultural tractor emissions inventory – higher horsepower equipment tends to get used more than lower horsepower equipment (CAPCOG, 2013).

Figure 7: Comparison of ERG and AACOG Annual Activity Estimates (hours/year)



Weekday/Weekend Allocation

AACOG's survey found that weekend use of mine and quarry equipment was 29.6% of weekday use. This translates into each weekday receiving a 17.9% allocation of a week's worth of activity, compared to the 18% default in the NONROAD model for construction equipment. Since the survey data was so close to the NONROAD default, CAPCOG did not update the weekday/weekend allocation in the model.

Seasonal Allocation

The MHSA production totals used to calculate the equipment populations for each quarry have production both at the quarterly and the annual level. Since the TexN model would otherwise use the NONROAD default monthly/seasonal allocations for the "Southwest" region of the country for construction equipment, light commercial equipment, and industrial equipment, CAPCOG decided to update the SEASON.DAT file to reflect the actual variation in production throughout 2006. Since the TexN model calculates average summer weekday emissions, it would include June, July, and August. The production periods for MHSA are based on calendar year quarters, so the typical "ozone season day" emissions would weight the 2nd quarter production at 1/3 and the 3rd quarter production at 2/3.

The default allocation for the three summer months is 27.3% for construction and mining equipment, 25% for industrial equipment, and 25% for light commercial equipment. For the entire region, there is very little variation quarter to quarter (23.4% for Quarter 1 up to 26.7% for Quarter 3), which suggests there is no systematic variation in production over time. However, for individual counties, there were significant fluctuations throughout 2006. For example, production in the 2nd quarter, when the June 2006 ozone episode occurred, was as little as 14.8% of annual production in Fayette County but as high as 42.7% of annual production in Lee County. Accounting for these monthly variations appears to be important for modeling a specific historical year, but CAPCOG recommends that for any projections from this sector, each month receive an equal allocation of activity.

CAPCOG used the following allocation factors for each quarter for each county:

Table 6: Quarterly Activity Allocations for Mine and Quarry Equipment, 2006

County	Q1 %	Q2 %	Q3%	Q4%
Bastrop	22.30%	21.60%	30.96%	25.13%
Burnet	24.36%	23.49%	26.32%	25.83%
Fayette	23.85%	24.20%	25.66%	26.28%
Hays	26.32%	26.78%	23.28%	23.62%
Llano	24.24%	25.93%	29.46%	20.37%
Milam	24.15%	24.54%	26.75%	24.56%
Travis	19.70%	27.38%	28.00%	24.92%
Williamson	23.14%	25.84%	26.91%	24.10%
TOTAL	**23.07%**	**25.47%**	**26.86%**	**24.61%**

For the table above, the quarters correspond to calendar quarters, so that Q1 represents January – March, Q2 represents May – June, Q3 represents July – September, and Q4 represents October – November. There did not appear to be any systematic variation by season across the whole region. Nevertheless, CAPCOG updated the SEASON.dat file to reflect the quarterly production figures for the region as a whole.

Emissions Rates & Estimates

CAPCOG used the TexN model to produce emission rates for each equipment type in four different groups of counties, based on their meteorological and fuel properties. The table below shows the sulfur percentage of diesel for each group of counties, whether the counties are subject to TxLED, and which weather station the county is assigned to in the TexN model.

Table 7: Fuel/Meteorology County Groupings

Counties	Sulfur Weight %	TxLED	Met
Bastrop, Caldwell, Hays, Lee, Travis, Williamson	0.0330	Yes	Austin
Blanco, Burnet, Llano	0.0330	No	Austin
Fayette	0.0371	Yes	Houston
Milam	0.0359	Yes	Houston

The table below shows the meteorological parameters relevant to diesel engines for typical meteorology at the Austin and Houston weather stations.

Table 8: Default Meteorological Parameters by Met Station

Metric	Austin	Houston
Relative Humidity (%)	65%	75%
Average Temperature (°F)	83.2	83.2
Atmospheric Pressure	992.55	1013.21

Using TexN to model a specific DCE subsector's emissions can be daunting due to the lengthy amount of time it takes to create scenarios for construction equipment categories. This is a result of having to update every single equipment population to zero for all but one DCE subsector, combined with the large amount of equipment types involved. Accordingly, CAPCOG decided to model each equipment type one at a time, setting the equipment populations to 1 in each of the four counties CAPCOG used to model the emissions (Bastrop, Burnet, Fayette, and Milam) in order to obtain emissions rates for each equipment type from the aggregate.out files.

CAPCOG then applied two sets of adjustments: a seasonal adjustment factor and an elevation adjustment factor. Since the SEASON.dat file only reflected region-wide seasonal fluctuations, it would not be able to reflect the seasonal variations within each county. Therefore, CAPCOG calculated the portion of annual production occurring within summer months (June – August) for each county, and then divided that percentage by the region-wide percentage to produce summer-time production adjustment factors for each county. According to the documentation for the TexN model, TexN also models the impact of elevation changes on emissions as part of its post-processing calculations (ERG, 2008). Specifically, emissions increase by 1% for every 1,000 feet of increased elevation. CAPCOG looked up the altitude for each county in the program area from the *postfactor_altitude* table in the SQL database used by TexN. CAPCOG then calculated the difference between each county's elevation and the reference county's elevation (Bastrop, Burnet, Fayette, or Milam Counties) and the corresponding emissions adjustment factor reflecting the difference in elevation. The soil and ground cover adjustments in the TexN model do not apply to this subsector. The table below shows both the summertime production and elevation adjustment factors.

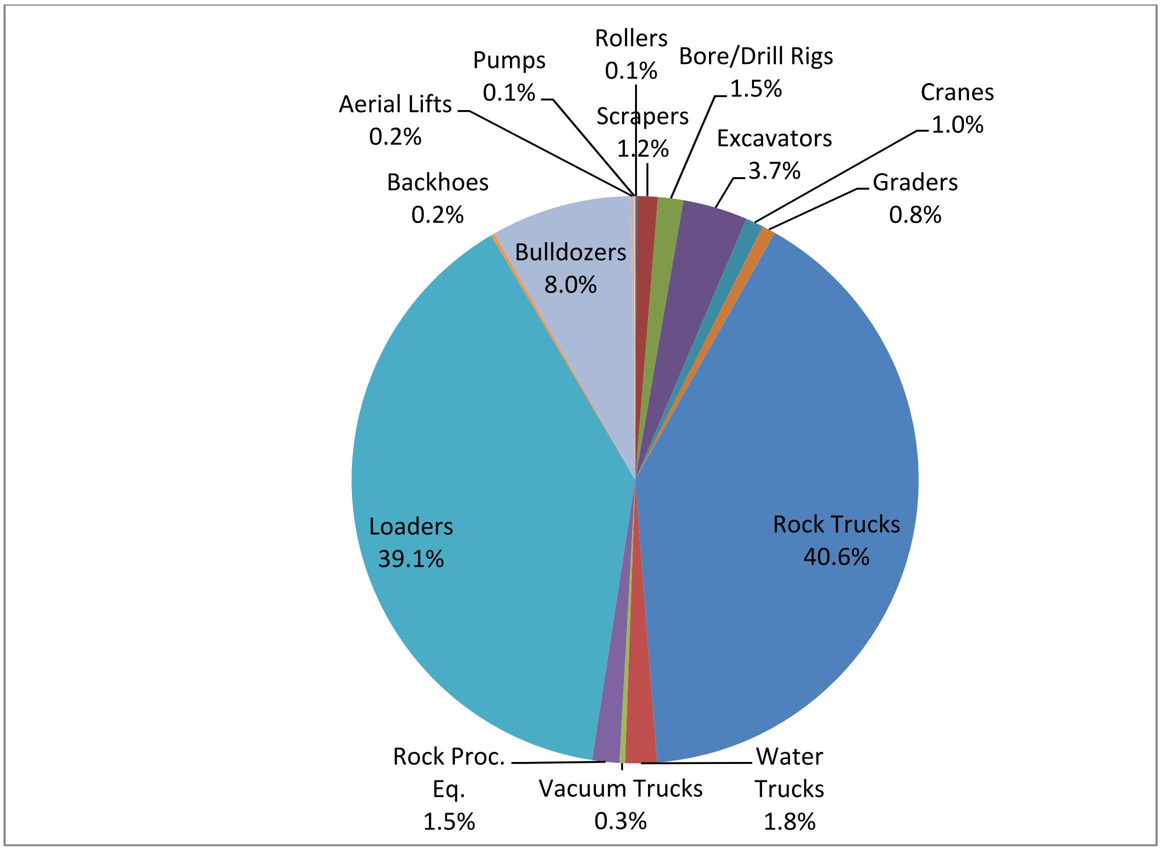
Table 9: Emission Adjustment Factors

County	Production Adjustment Factor	Elevation Adjustment Factor
Bastrop	1.054865	1.000000
Burnet	0.961516	0.996620
Fayette	0.953941	1.000000
Hays	0.926226	1.001470
Llano	1.071530	0.996070
Milam	0.985460	1.000000

Travis	1.052967	1.000760
Williamson	1.006179	1.002760

Table 1 of this report presents the overall emissions by county. The chart below presents the percentage of NO_X emissions by equipment type region-wide. Rock trucks and loaders dominate the emissions from quarries, making up 80% of all NO_X emissions from quarry equipment. Bulldozers and excavators make up the next-largest sources of NO_X emissions. The inclusion of rollers, bore/drill rigs, cranes, water trucks, vacuum trucks, aerial lifts, and pumps – which were not in the mine and quarry equipment diesel construction equipment subsector in the TexN model – did not have a significant impact on the inventory. They make up only 0.29 tons per day of NO_X emissions, or 5% of the total NO_X emissions for the region.

Table 10: NO_X Emissions by Equipment Type



Conclusions and Recommendations

CAPCOG used survey research by AACOG to update the estimate of emissions from quarry equipment in the CAPCOG region. While there are strengths and weaknesses in either leaving the inventory as-is or using AACOG's data, CAPCOG believes that on balance, AACOG's survey data likely provide a more solid basis for estimating the emissions from quarries in the CAPCOG region than ERG's study does. While CAPCOG could not determine whether ERG's survey or AACOG's survey was conclusively more representative of quarries in the region, one interesting point of comparison is to look at the soil type adjustment factors that ERG developed for the TexN model in relation to the types of commodities quarried in the AACOG and CAPCOG area (ERG, 2008). These factors apply to boring/drilling equipment, excavators, backhoes, graders, and crawler dozers. Table 4-15 of the TexN User's Guide provides adjustment factors depending on the type of soil that was being moved:

Table 11: Soil Type Adjustment Factors for Earthmoving Equipment

Soil Type	Adjustment Factor
Good common earth (loam)	1.0
Sand/Gravel	1.0
Easy digging (moist silt/clay)	1.0
Hard digging (dry clay)	1.1
Fragmented rock	1.2
Intact rock	1.7

If these adjustment factors were applied to quarry equipment too, presumably they could match up to the quarry type. Regardless, the main difference between quarry production in AACOG's region and CAPCOG's program area is the relative importance of crushed stone versus dimension stone. Clays and sand/gravel make up similar portions of the production. AACOG's 2012 report provides activity and horsepower estimates that are significantly different from ERG's findings – estimates which have tighter confidence intervals than the existing estimates did.

CAPCOG did not conduct its own survey for this project, but CAPCOG believes that future survey work on quarries in CAPCOG's region would likely be valuable. The significant differences between AACOG's findings and ERG's findings and the differences in the types of production in the CAPCOG and AACOG regions suggest that there might be some significant variations in equipment use region to region.

CAPCOG also believes that there are some opportunities for making modifications to the TexN model that would help reduce the labor required to produce emissions inventories for specific DCE subsectors. If the TexN model were configured to allow the user to select only a specific DCE subsector to model on the equipment page, it would greatly simplify this process. TCEQ may also wish to consider evaluating whether some of the equipment in the mining and quarrying DCE subsector should have soil adjustments applied to them to reflect the mix of quarry production within the county.

Works Cited

AACOG. (2012). *Non-Road Emissions Inventory Improvements.* Retrieved from http://www.aacog.com/DocumentCenter/View/6546

CAPCOG. (2013). *Agricultural Tractor 2006 Ozone Season Weekday Emission Inventory for the CAPCOG Program Area.*

ERG. (2008). *Texas NONROAD (TexN) Version 1.0 User's Guide.* Retrieved from ftp://amdaftp.tceq.texas.gov/pub/Nonroad_EI/TexN/TexN_Users_Guide.pdf

ERG. (2009). *Update of Diesel Construction Equipment Emissions Estimates for the State of Texas: Phases I and II.* Retrieved from http://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/20090731-ergi-DCE_EI_Update.pdf

U.S. Mine Safety and Health Administration. (2012). *U.S. Mine Safety and Health Administration*. Retrieved from Mine Data Retrieval System: http://www.msha.gov/drs/drshome.htm