Construction/Mining Equipment Inventory Data

In order to estimate the emissions benefit and costs of the off-road equipment rule, ARB staff must estimate the total population of affected equipment, its ages and characteristics, and how much it is used. ARB staff plan to use the ARB OFFROAD model as the primary tool to estimate off-road equipment population and emissions. However, we will update the model's assumptions where appropriate to more accurately reflect the fleet affected by the off-road equipment rule. ARB staff have evaluated other sources of off-road equipment inventory data including the following:

- 2003 MacKay and Company Construction Equipment Universe of Construction Equipment and Machinery study (MacKay, 2003) - a study of construction equipment populations and characteristics by the market research firm, MacKay and Company, prepared for Construction Equipment magazine.
- Yengst and Associates equipment analysis reports (Yengst, October 2003, June 2004, August 2004, October 2004, April 2005, June 2005, July 2005, November 2005, December 2005, February 2006a, and February 2006b) - a series of Equipment Analysis Reports published by Yengst Associates, a machinery market research firm, for many of the most important types of construction equipment.
- United States Environmental Protection Agency (USEPA) NONROAD model – the USEPA's model of population and emissions from off-road equipment.
- 2003 TIAX public fleet survey and 2005 ARB off-road equipment survey – The TIAX survey was conducted for ARB and included on- and off-road diesel equipment owned by public fleets in California. The 2005 off-road equipment survey was conducted by ARB staff and included off-road equipment owned by both public and private entities.

This discussion paper describes the equipment use, lifetime and population assumptions in the OFFROAD model for construction/mining equipment and compares them to comparable data from MacKay, Yengst, EPA NONROAD, and the 2003 TIAX and 2005 off-road equipment surveys. ARB staff have prepared similar discussion papers for industrial equipment and airport ground support equipment. We would like to solicit any additional data or comments regarding the values presented in this paper.

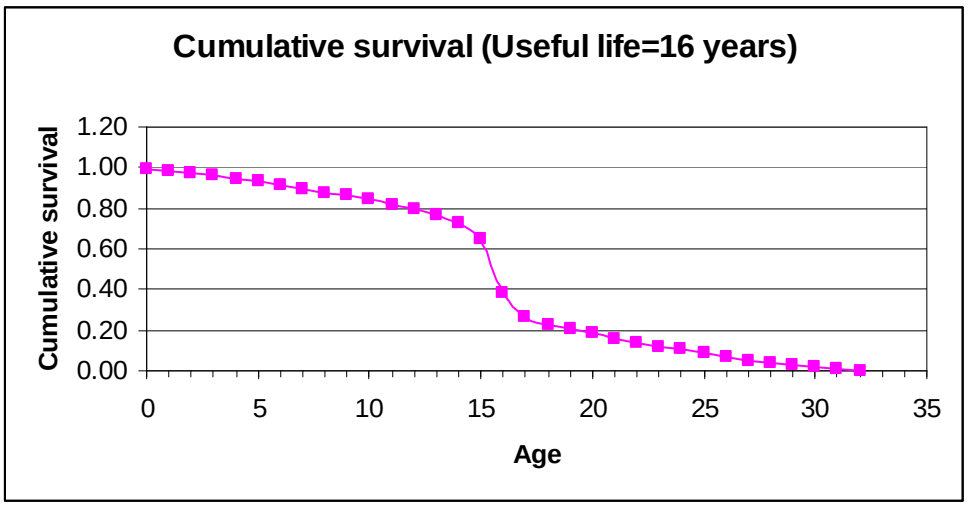
Equipment Use and Lifetime

Understanding how equipment naturally ages and is replaced will be important for predicting the costs and benefits of the off-road rule. One way to comply with the rule will be to turn equipment over to cleaner equipment, so understanding the natural turnover that would occur in the absence of the rule will be critical.

ARB's OFFROAD model and USEPA's NONROAD model assume that equipment enters the fleet, ages and is eventually scrapped. As equipment of a certain model year ages, each year some fraction of it is scrapped and some fraction of it

survives. The cumulative survival at age x, S(x), is the fraction of equipment that survives to age x. By plotting survival versus age, the turnover of equipment can be represented by a survival curve. In the OFFROAD and NONROAD models, the survival curve is assumed to have a normal distribution of cumulative scrappage versus age. An example survival curve from the OFFROAD model is shown below in Figure C-1:

Figure C-1 – OFFROAD Model Cumulative Survival for Equipment of Useful Life 16 years



Eventually, all equipment of a certain model year will have been scrapped. When this occurs, cumulative survival equals 0. The survival curve for any given equipment type can be represented by one number, the useful life. The useful life, akin to a half-life, is the age at which the survival curve shows a point of inflection and is equivalent to when half of the units of a certain model year will have been scrapped. At the age of twice the useful life, all equipment will have been scrapped. The useful life for the survival curve shown in Figure C-1 is 16 years.

Both ARB's OFFROAD model and USEPA's NONROAD model estimate useful life based on the following equation:

Useful life (years) = Engine life at rated horsepower (hrs) / (Load factor x Annual Use (hours/year))

NONROAD caps maximum useful life at 25 years. Thus the maximum age of equipment in NONROAD is 50 years.

Both OFFROAD and NONROAD use engine life at rated horsepower (hp) primarily from an analysis by Energy and Environmental Analysis, Inc. of Power Systems Research (PSR) on-highway engine life data, supplemented by interviews of engine manufacturers (EEA, September 2001). However, EPA did a recent review of the EEA work that resulted in USEPA using longer engine lives at rated hp than are used in the OFFROAD model (USEPA, April 2004). For example, NONROAD now

assumes that diesel engines over 300 hp last 7000 hours at full load versus OFFROAD's 6,000 hours.

Load factor indicates the average proportion of rated horsepower used. OFFROAD uses load factors estimated by Power Systems Research (PSR) based on surveys of equipment owners regarding how they use their equipment (ARB, 1999). USEPA has done some recent work to refine these estimates, and NONROAD uses load factors obtained from engine testing over several transient cycles (USEPA, April 2004).

OFFROAD uses estimates of annual use from a 1999 MacKay and Company Construction Equipment Universe of Construction Equipment and Machinery study (MacKay, 1999), supplemented by the 1996 PSR database. NONROAD uses estimates of annual use from a 1998 database developed by PSR. Neither NONROAD nor OFFROAD take into account changes in annual use as equipment ages. As shown in Table C-1 below, the annual use estimates in OFFROAD and NONROAD are very similar and differ more than 10% only for scrapers, bore/drill rigs, cranes, rough terrain forklifts, and rubber tired loaders, for which OFFROAD's annual use estimates are somewhat higher.

Table C-1 also shows annual use from the 2003 MacKay and Company Construction Equipment Universe of Construction Equipment and Machinery study, which is an update to the 1999 MacKay study (MacKay, 2003). Finally, Table C-1 shows the reported average annual use from ARB's 2005 off-road equipment survey and the 2003 TIAX public fleets survey. For each equipment type, the reported annual use from each survey response was weighted by the number of equipment of a certain type for which annual use was reported.

ARB staff proposes using the 2005 off-road equipment survey annual uses in most cases. When the survey only had limited data reported for annual use, staff proposes using the 2003 MacKay annual use. Before making a final determination, however, we would like to solicit any additional data on annual use of construction/mining equipment.

Table C-1 – OFFROAD vs. NONROAD Annual Use (hrs/yr) for Construction/Mining Equipment

Construction/ Mining Equipment Types	ARB OFFROAD Annual Use	USEPA NONROAD Annual Use	MacKay Average Annual Use[1]	2005 Off-road Equipment & 2003 TIAX Survey Average Annual Use[2]	2005 Off-road Equip-ment & 2003 TIAX Survey Number of Equipment with Reported Annual Use[2]
Bore/Drill Rigs	726	466	811	2,548	*312*
Cranes	1464	990	1,252	428	*187*
Crawler Tractors[3]	936	936	1,110	1,013	*626*
Excavators	1162	1092	1,172	1,396	*577*
Graders	965	962	929	713	*765*
Off-Highway Tractors	855	855	NA	1,091	*736*
Off-Highway Trucks	1641	1641	1,958	1,286	*248*
Other Construction Equipment	606	606	NA	690	*466*
Pavers	828	821	821	598	*136*
Paving Equipment	622	622	829	450	*93*
Rollers	748	760	695	462	*545*
Rough Terrain Forklifts	1198	662	1,123	672	*541*
Rubber Tired Dozers	899	899	NA	1,589	*67*
Rubber Tired Loaders	1346	761	1295	957	*1,943*
Scrapers	1090	914	1,068	1,092	*665*
Skid Steer Loaders	811	818	834	1,032	*321*
Surfacing Equipment	561	561	NA	446	*15*
Tractors/Loaders/ Backhoes[4]	1135	1135	919	942	*3,625*
Trenchers	620	593	618	316	*98*

[1] - Equipment types from MacKay (2003) were matched as closely as possible to those used in the OFFROAD model. MacKay often had more detailed equipment types than OFFROAD. For example, MacKay includes data for three types of excavators and four types of pavers. The annual use shown in Table C-1 is an average of the MacKay data for the more detailed equipment types, weighted by the reported equipment population.

[2] – The survey data reported is combined data from both the 2003 TIAX (TIAX, 2003) survey of public fleets and the 2005 off-road equipment survey.

[3] – The survey annual use shown here is a weighted average of the reported data for crawler tractors and crawler dozers.

[4] – The 2005 off-road equipment survey and the 2003 TIAX survey included a number of equipment types that correspond to tractors/loaders/backhoes – crawler loader or backhoe, crawler tractor, wheel loader or backhoe, and wheel tractor, skip loaders, backhoe loaders, etc. The annual use shown here is a weighted average of the values reported for those categories.

Table C-2 below shows the useful lives for construction and mining equipment in the OFFROAD and NONROAD models and the average age when retired or sold reported in the 2005 off-road equipment survey. To determine the average age when retired for each equipment type, the reported age when retired from each survey response was weighted by the number of equipment of a certain type for which age when retired was reported. Useful lives range from 3 years to a maximum of 16 years in the OFFROAD model. NONROAD's lifetimes range from 4 to 25 years for construction equipment.

The estimates of useful life vary widely between OFFROAD and NONROAD, but NONROAD's are generally longer. Table C-2 also shows estimates of average age and average age when scrapped from 2003 Construction Equipment Universe of Construction Equipment and Machinery (MacKay, 2003). MacKay's estimates of average age are similar to OFFROAD's useful life. Average age when scrapped is generally longer than both the OFFROAD and NONROAD estimates of useful life. Before making a determination as to whether to update the useful life estimates in OFFROAD, ARB staff would like to solicit any additional data on the useful life of construction/mining equipment.

Table C-2 – Useful Life and Average Age When Scrapped Estimates for Construction/Mining Equipment (years)

Construction/Mining Equipment Type	ARB OFFROAD Useful Life	USEPA NONROAD Useful Life	MacKay (2003) Average Age When Scrapped[1]	MacKay (2003) Average Age	2005 Off-road Equipment Survey Average Age When Retired (years)	2005 Off-road Equipment Survey: # of Equipment with Age Retired Data
Pavers – 25-50 hp	8	5	17	8	19	86
Pavers – 50-300 hp	8	10	17	8	19	86
Pavers – >300 hp	8	14	17	8	19	86
Rollers – 25-50 hp	8	6	20	8	14	370
Rollers – 50-300 hp	8	10	20	8	14	370
Rollers – >300 hp	8	16	20	8	14	370
Scrapers – 50-300 hp	12	9	26	12	21	474
Scrapers – >300 hp	12	13	26	12	21	474
Paving Equipment – 25-50 hp	16	7	12	6	18	72
Paving Equipment– 50-300 hp	16	13	12	6	18	72
Paving Equipment– >300 hp	16	19	12	6	18	72
Surfacing Equipment– 25-50 hp	16	8	NA	NA	21	11
Surfacing Equipment– 50-300 hp	16	14	NA	NA	21	11
Surfacing Equipment– >300 hp	16	21	NA	NA	21	11
Trenchers– 25-50 hp	7	7	13	8	16	11
Trenchers– 50-300 hp	7	13	13	8	16	11
Trenchers– >300 hp	7	20	13	8	16	11
Bore/Drill Rigs– 25-50 hp	3	12	10	4	10	292
Bore/Drill Rigs– 50-300 hp	3	23	10	4	10	292
Bore/Drill Rigs– >300 hp	3	25	10	4	10	292
Excavators– 25-50 hp	7	4	17	6	15	287
Excavators– 50-300 hp	7	7	17	6	15	287
Excavators– >300 hp	7	11	17	6	15	287
Cement and Mortar Mixers– 25-50 hp	7	21	NA	NA	NA	NA
Cement and Mortar Mixers– 50-300 hp	7	25	NA	NA	NA	NA
Cement and Mortar Mixers– >300	7		NA	NA	NA	NA

Construction/Mining Equipment Type	ARB OFFROAD Useful Life	USEPA NONROAD Useful Life	MacKay (2003) Average Age When Scrapped[1]	MacKay (2003) Average Age	2005 Off-road Equipment Survey Average Age When Retired (years)	2005 Off-road Equipment Survey: # of Equipment with Age Retired Data
hp		25				
Cranes – 25-50 hp	9	6	19	8	16	330
Cranes – 50-300 hp	9	11	19	8	16	330
Cranes – 300-750 hp	9	16	19	8	16	330
Cranes > 750 hp	16	16	19	8	16	330
Graders– 25-50 hp	10	4	23	10	18	359
Graders– 50-300 hp	10	8	23	10	18	359
Graders– >300 hp	10	12	23	10	18	359
Off-Highway Trucks– 25-300 hp	10	5	17	8	17	142
Off-Highway Trucks– >300 hp	10	7	17	8	17	142
Rough Terrain Forklifts– 25-50 hp	8	6	16	7	15	329
Rough Terrain Forklifts – 50-300 hp	8	12	16	7	15	329
Rough Terrain Forklifts – >300 hp	8	18	16	7	15	329
Rubber Tired Loaders– 25-50 hp	8	6	21	9	18	466
Rubber Tired Loaders – 50-300 hp	8	10	21	9	18	466
Rubber Tired Loaders – >300 hp	8	16	21	9	18	466
Rubber Tired Dozers <= 175 hp	6	NA	NA	NA	17	3
Rubber Tired Dozers > 175 hp	16	NA	NA	NA	17	3
Tractors/Loaders/Backhoes– 25-50 hp[2]	16	10	18	7	17	773
Tractors/Loaders/Backhoes– >50 hp[2]	16	20	18	7	17	773
Crawler Tractors– 25-50 hp	16	5	19	9	21	17
Crawler Tractors – 50-300 hp	16	8	19	9	21	17
Crawler Tractors – >300 hp	16	13	19	9	21	17
Skid Steer Loaders– 25-50 hp	5	15	13	5	17	65
Skid Steer Loaders – >50 hp	5	25	13	5	17	65
Off-Highway Tractors– <=300 hp	16	9	NA	NA	15	115

Construction/Mining Equipment Type	ARB OFFROAD Useful Life	USEPA NONROAD Useful Life	MacKay (2003) Average Age When Scrapped[1]	MacKay (2003) Average Age	2005 Off-road Equipment Survey Average Age When Retired (years)	2005 Off-road Equipment Survey: # of Equipment with Age Retired Data
Off-Highway Tractors – >300 hp	16	14	NA	NA	15	115
Other Construction Equipment– 25-50 hp	16	7	NA	NA	17	278
Other Construction Equipment – 50-300 hp	16	13	NA	NA	17	278
Other Construction Equipment – >300 hp	16	20	NA	NA	17	278

[1] – Equipment types from MacKay (2003) were matched as closely as possible to those used in the OFFROAD model. MacKay often had more detailed equipment types than OFFROAD. For example, MacKay includes data for three types of excavators and four types of pavers. The data shown in Table C-2 is an average of the MacKay data for the more detailed equipment types, weighted by the reported equipment population.

[2] – The off-road equipment survey included four categories that correspond to tractors/loaders/backhoe – crawler loader or backhoe, crawler tractor, wheel loader or backhoe, and wheel tractor. The average age when retired shown here is a weighted average of the values reported for those four categories.

Tier Distribution

Table C-3 and Figure C-2 show the distribution of construction/mining equipment among the various emission standard tiers as modeled in ARB's OFFROAD model for the year 2005. The fleet in 2005 is split among Tier 0, 1, and 2 equipment, with the largest fraction being Tier 1. We would like to solicit input from fleet owners on whether this tier distribution appears reasonable and consistent with their fleets.

Table C-3: 2005 OFFROAD Construction/Mining Equipment Population by Emission Standard Tier

Tier	Model Years[1]	Age of Equipment in Tier in 2005 (years)[1]	OFFROAD Population	OFFROAD Percent
0	Up to 1999	>=6	35468	22
1	1996-2005	0-9	80813	50
2	2001+	0-4	45302	28

[1] – The effective dates of each emission standard tier vary by maximum horsepower. The off-road compression ignition engine standards are in Title 13, California Code of Regulations, Section 2423.

Figure C-2: Percent Population in Each Emission Standard Tier: 2005 OFFROAD Model

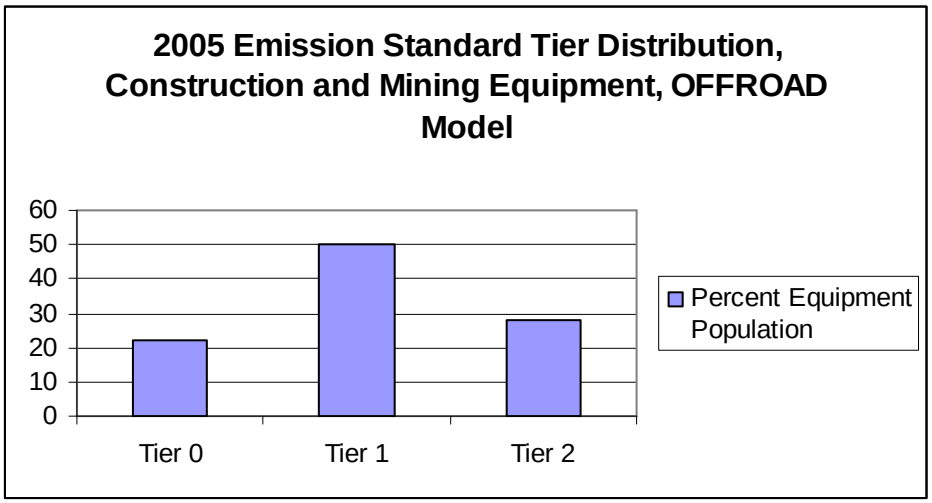


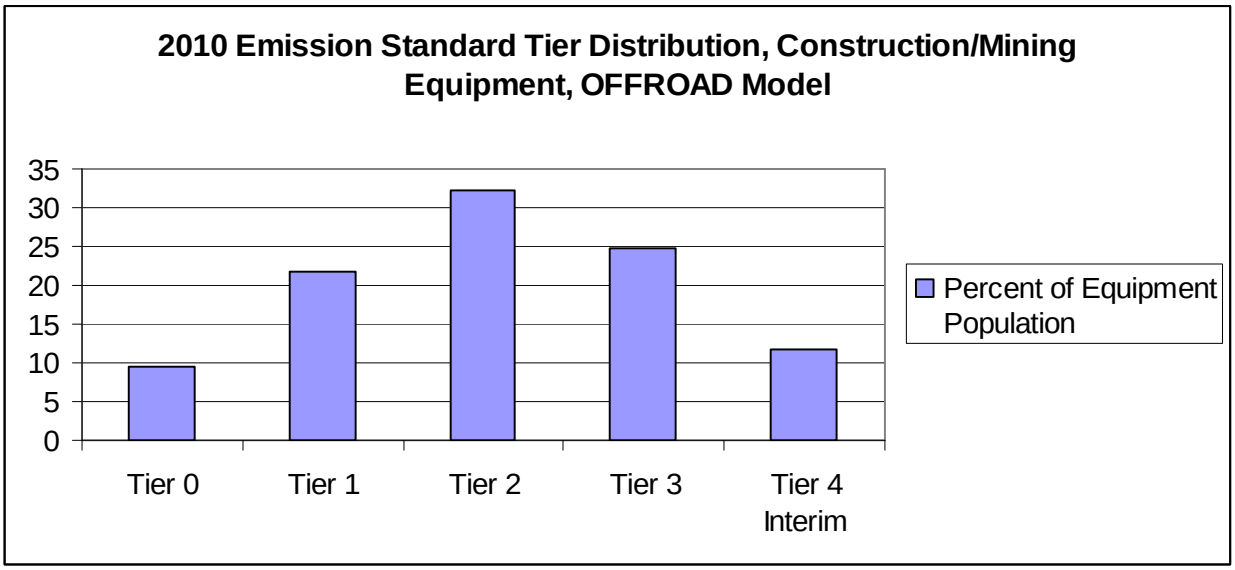
Table C-4 and Figure C-3 show the distribution of construction/mining equipment among the various emission standard tiers as projected in ARB's OFFROAD model for the year 2010. In 2010, the fleet is projected to be divided among Tier 0, 1, 2, 3, and interim 4 emission standard tiers. The largest portion of the fleet is projected to be Tier 2 in 2010, and Tier 0 is projected to make up less than 10% of the construction/mining fleet.

Table C-4 - 2010 OFFROAD Construction/Mining Population by Emission Standard Tier

Tier[1]	Model Years[1]	OFFROAD Population	OFFROAD Percent
0	Up to 1999	15829	9
1	1996-2005	36533	22
2	2001-2007	54377	32
3	2006-2011	41559	25
4i	2008+	19827	12

[1] – The effective dates of each emission standard tier vary by maximum horsepower. The off-road compression ignition engine standards are in Title 13, California Code of Regulations, Section 2423.

Figure C-3 - 2010 OFFROAD Construction/Mining Equipment Population by Emission Standard Tier



Equipment Population

OFFROAD uses a base year of 2000 and then forecasts or backcasts populations from that year. OFFROAD equipment populations are based on MacKay and Company estimates from 1999, supplemented by PSR's 1996 database (ARB, 1999). OFFROAD allocated 10% of the national construction equipment population to California.

NONROAD uses a base year of 2000 and then forecasts or backcasts equipment populations from that year. NONROAD equipment populations are based on estimates of sales of off-road equipment from PSR through the year 2000. The PSR sales data were combined with NONROAD estimates of load factor, activity, median life, scrappage, and growth, to obtain national equipment population estimates for each year (USEPA, December 2005a). National construction equipment populations were allocated to states based on the dollar value of construction in each area, adjusted to

account for the different cost of construction in various areas of the country. California has about 11% of the national total (Harvey, 2006, and USEPA, December 2005b).

Table C-5 shows equipment population by equipment type from the OFFROAD and NONROAD models for calendar year 2005. NONROAD's total equipment population is overall about 20% higher than OFFROAD's, but the equipment populations vary widely. For example, NONROAD estimates many more bore/drill rigs than OFFROAD, whereas OFFROAD estimates many more off-highway tractors than NONROAD.

Table C-5 also includes estimates of population from the MacKay and Company 2003 Construction Equipment Universe of Construction Equipment & Machinery study. The 2003 MacKay report is an updated version of the 1999 MacKay study, which was largely used as the source of equipment populations and lifetimes in ARB's OFFROAD model. The MacKay 2003 estimates vary somewhat from the OFFROAD and NONROAD estimates and often lie between the two estimates. The MacKay estimates are generally within 40% of the OFFROAD estimates, except for bore/drill rigs and paving equipment.

Table C-5 contains estimates from Yengst and Associates equipment analysis reports. Yengst Associates, a machinery market research firm, publishes Equipment Analysis Reports for many of the most important types of construction equipment that include field population estimates. Yengst population estimates are based on contacts with equipment manufacturers, component suppliers and dealers, as well as a scrappage model. The Yengst population estimates are generally within 30% of OFFROAD estimates, except for cranes, off-highway trucks, rough terrain forklifts, and skid steer loaders, for which Yengst populations are significantly higher. Except for graders, Yengst populations generally vary in the same direction as the MacKay estimates. That is, if the MacKay (2003) estimate is higher than OFFROAD, the Yengst estimate is also higher.

Finally, Table C-5 includes the total reported population from the 2003 TIAX public fleets and 2005 off-road equipment surveys for each equipment type. The total count of equipment reported on these surveys for construction/mining equipment was 13,129, which is only about 8% of the total construction/mining equipment population estimated in OFROAD for 2005. Thus, the response on the surveys was not adequate to allow use of these populations to update overall equipment populations.

ARB staff proposes updating the OFFROAD populations to match those of MacKay (2003) for equipment types for which MacKay provides an estimate, except for graders. For graders, the Yengst and NONROAD estimates are lower than the OFFROAD estimate but the MacKay estimate is higher. For graders, ARB staff proposes maintaining the OFFROAD estimate of population. Before making a final determination, however, ARB staff would like to solicit any additional data on construction/mining equipment populations.

Table C-5 – Estimates of 2005 California Populations of Construction/Mining Equipment by Equipment Type -- ARB OFFROAD model, USEPA NONROAD model, MacKay and Co (MacKay, 2003), Yengst Associates Equipment Reports, and 2005 Off-road Equipment/2003 TIAX Surveys

Construction/ Mining Equipment Type	**ARB OFF-ROAD**	**USEPA NON-ROAD**	***% diff = (NONROAD - OFFROAD)/ OFFROAD***	**MacKay[1]**	**% diff = (MacKay - OFFROAD)/ OFFROAD**	**Yengst[2]**	**% diff = (Yengst - OFFROAD) / OFFROAD**	**2005 Off-road Equipment & 2003 TIAX Surveys[3]**
Bore/ Drill Rigs	321	4,868	*1417%*	1,267	295%	NA	*NA*	345
Cranes	2,241	4,033	*80%*	2,688	20%	3,808	*70%*	484
Crawler Tractors	26,052	11,906	*-54%*	15,833	-39%	19,774	*-24%*	NA[4]
Excavators	14,005	14,930	*7%*	19,057	36%	16,864	*20%*	712
Graders	6,558	3,694	*-44%*	6,654	1%	5,114	*-22%*	1261
Off-Highway Tractors	2,667	505	*-81%*	NA	NA	NA	*NA*	NA[4]
Off-Highway Trucks	1,637	1,946	*19%*	1,805	10%	2,992	*83%*	302
Other Construction Equipment	606	1485	*145%*	NA	NA	NA	*NA*	626
Pavers	2,491	2,739	*10%*	2,919	17%	NA	*NA*	175
Paving Equipment	3,445	599	*-83%*	323	-91%	NA	*NA*	101
Rollers	7,231	8368	*16%*	7,866	9%	NA	*NA*	683
Rough Terrain Forklifts	5,873	13,741	*134%*	6,645	13%	13,790	*135%*	767
Rubber Tired Dozers	541	NA	*NA*	NA	NA	NA	*NA*	220
Rubber Tired Loaders	18,214	17137	*-6%*	19,230	6%	22,717	*25%*	NA[4]
Scrapers	1,608	2,096	*30%*	1,829	14%	NA	*NA*	859

Construction/ Mining Equipment Type	ARB OFF-ROAD	USEPA NON-ROAD	*% diff = (NONROAD - OFFROAD)/ OFFROAD*	MacKay[1]	% diff = (MacKay - OFFROAD)/ OFFROAD	Yengst[2]	% diff = (Yengst - OFFROAD) / OFFROAD	2005 Off-road Equipment & 2003 TIAX Surveys[3]
Skid Steer Loaders	25,371	56,042	*121%*	30,652	21%	61,907	*144%*	416
Surfacing Equipment	11	293	*2564%*	NA	NA	NA	*NA*	19
Tractors/ Loaders/ Backhoes	35,113	41,039	*17%*	30,370	-14%	25,786	*-27%*	NA[4]
Trenchers	7,240	7,045	*-3%*	8,376	16%	9,052	*25%*	137

[1] – The equipment populations shown are the MacKay (2003) national populations multiplied by 10.88% to get a California population. Sometimes the equipment types from MacKay were summed to match OFFROAD equipment types. For example, the population of graders shown is the total of the MacKay populations of articulated motor grader and rigid frame motor grader. Tractors/loaders/backhoes is the sum of backhoe loaders and crawler loaders.

[2] – Estimates are from Yengst Equipment Analysis Reports (Yengst, October 2003, June 2004, August 2004, October 2004, April 2005, June 2005, July 2005, November 2005, December 2005, February 2006a, and February 2006b). National populations were multiplied by 10.88% to get California population. Yengst equipment types were matched as closely as possible to OFFROAD types to get the estimates presented here; sometimes the equipment types from Yengst were summed to match OFFROAD equipment types. For example, tractors/loaders/backhoes includes the Yengst categories of backhoe loaders and compact track loaders. Mini-excavator populations were not included under excavators because most mini-excavators are under 25 hp. The most recent Yengst estimates are shown. Most Yengst estimates are for calendar year 2004, though some are for 2002 or 2003.

[3] – Survey populations are the sum of the populations reported in the 2003 TIAX (TIAX, 2003) survey of public fleets and the 2005 off-road equipment survey.

[4] – Survey populations cannot be used to compare to OFFROAD populations for crawler tractors, off-highway tractors, rubber tired loaders, or tractors/loaders/backhoes because these categories do not have a one-to-one correspondence to a survey equipment type. For example, the crawler tractor population in the surveys could correspond to either crawler tractor or tractor/loader/backhoe in OFFROAD. The reported survey populations (2005 off-road equipment survey plus 2003 TIAX survey) for these equipment types were: crawler tractor=103, crawler loader/backhoe=446, wheel loader or backhoe=3668, wheel tractor=965.

References

ARB, 1999. Mailout 99-32, Input Factors for Large CI Engine Emission Inventory.

MacKay, 2003. 2003 Construction Equipment Universe of Construction Equipment & Machinery. Prepared by MacKay and Company for Construction Equipment Magazine, 2003

EEA, September 2001. Documentation of Diesel Engine Life Values Used in the ARB Off-Highway Model, Prepared for Office of Mobile Sources, Environmental Protection Agency, EPA Purchase Order 1A-0462-NASX, by Energy and Environmental Analysis, Inc., September 2001.

Harvey, 2006. Email from Craig Harvey, Office of Transportation and Air Quality, USEPA, 2/27/06.

TIAX, 2003. California Public Fleet Heavy-Duty Vehicle and Equipment Inventory, Final Report, by TIAX LLC, Report to California Air Resources Board, March 17, 2003.

USEPA, April 2004. Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling, USEPA, EPA420-P-04-005, April 2004.

USEPA, December 2005a. Nonroad Engine Population Estimates, USEPA, EPA420-R-05-022, December 2005.

USEPA, December 2005b. Geographic Allocation of Nonroad Engine Population Data to the State and County level, EPA420-R-05-021, December 2005.

Yengst, October 2003. Equipment Analysis – North America Crawler Dozers/Crawler Loaders, Yengst Associates Machinery Market Research, Wilton, CT, October 2003.

Yengst, June 2004. Equipment Analysis – North America Backhoe Loaders, Yengst Associates Machinery Market Research, Wilton, CT, June 2004.

Yengst, August 2004. Equipment Analysis – North America Hydraulic Excavators, Yengst Associates Machinery Market Research, Wilton, CT, August 2004.

Yengst, October 2004. Equipment Analysis – North America Trenchers, Yengst Associates Machinery Market Research, Wilton, CT, October 2004.

Yengst, April 2005. Equipment Analysis – North America Mobile Cranes, Yengst Associates Machinery Market Research, Wilton, CT, April 2005.

Yengst, June 2005. Equipment Analysis – North America Motor Graders, Yengst Associates Machinery Market Research, Wilton, CT, June 2005.

Yengst, July 2005. Equipment Analysis – North America Articulated Haulers Rigid Haulers, Yengst Associates Machinery Market Research, Wilton, CT, July 2005.

Yengst, November 2005. Equipment Analysis – North America Rough Terrain Lift Trucks, Yengst Associates Machinery Market Research, Wilton, CT, November 2005.

Yengst, December 2005. Equipment Analysis – North America Wheel Loaders, Yengst Associates Machinery Market Research, Wilton, CT, December 2005.

Yengst, February 2006a. Equipment Analysis – North America Compact Track Loaders, Yengst Associates Machinery Market Research, Wilton, CT, February 2006.

Yengst, February 2006b. Equipment Analysis – North America Skid Steer Loaders, Yengst Associates Machinery Market Research, Wilton, CT, February 2006.

I:\OffRoadInventoryAssumptions.doc, 3/13/2006 2:47 PM