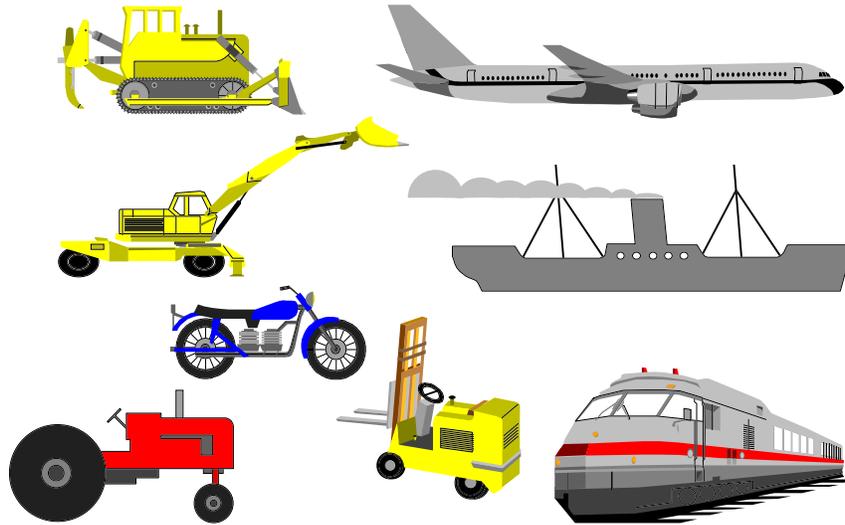# Nonroad Modeling

EPA National Nonroad
Emissions Inventory Model
(NONROAD)

Workshop
June 25, 1998
Chicago

7/8/ 98

Today's Topic

- EPA NONROAD Emissions Model
  - » SIP Tool Principal Focus
  - » EPA Regulatory Development
  - » EPA Strategic Planning

Today's Focus

- Ensure User Needs Met
- Explain Draft Nonroad Model
- Feedback
  - » Model features, function, and inputs

7/8/98

Agenda

- Part I
  - » Introduction
  - » Model Overview
  - » Development Schedule
  - » Draft NONROAD Release
  - » Stakeholder/EPA Communications

Agenda (con't)

- Part II
  - » Model Description
  - » Preliminary Results
  - » Specific Default Inputs
  - » Computational Sequence and Methodology
  - » Open Discussion/Audience Presentations
  - » Commercial Marine

7/8/ 98

3

Agenda (con't)

- Part III
  - » Workshop Summary
  - » Next Steps
  - » Ajourn Workshop
  - » Hands-On Demonstration

Introductions
NONROAD Team

- EPA's Office of Mobile Sources
  - » Assessment and Modeling Divison
    - – Gary Dolce
    - – Craig Harvey
    - – Greg Janssen
    - – Chris Lindhjem
    - – Mike Sklar
    - – Rich Wilcox

7/8/ 98

Introductions
NONROAD Contract Support

- ENVIRON International Corporation
  - » Gary Wilson
  - » Alison Pollack
- Dyntel

Model Overview (cont'd)

- Stand Alone *(No User Data Necessary)*

- All Nonroad Sources
  (*except locomotives and aircraft*)

- Differentiated by Equipment Type and
  Other Characteristics

- HC, CO, NO_x, PM, SO_x, CO_2

7/8/ 98

Model Overview (cont'd)

- Past, Present and Future Year Inventories

- Temporal Allocation

- Geographic Allocation

Development Schedule

● Milestone	● Date
» Draft Release	» June 18
» Workshop	» June 25
» Close Comments	» August 18
» Draft Final Release*	» November
» Close Comments	» December
» Final Release	» February '99

    * w/ Draft Com. Marine

7/8/ 98

Draft NONROAD Release

- Availability
  - » Web Site
  - » CD ROM

- Contents
  - » Installation Program
  - » Source Code
  - » User's Guide
  - » Tech Support Documents
  - » Read.me Document
  - » Release Notes

Stakeholder/EPA Communications

- Electronic Information Sources
  - » Listserver
    – subscriber instructions on nonroad web page
  - » Web Site: http://www.epa.gov/omswww/nonrdmdl.htm
  - » Email: nonroad@epa.gov

- Personal Assistance
  - » EPA Contact Person

7/8/ 98

Equipment Types

- Airport service
- Agricultural
- Commercial
- Construction
- Industrial
- Lawn & garden
- Logging

- Railroad (not locomotives)
- Recreational equip.
- Recreational marine

  (*more than 80 basic and 260 specific categories*)

Pollutants Reported

- HC
  (THC, TOG, NMOG, NMHC, VOC)

- Non-exhaust HC by Mode
  (diurnal, refueling, crankcase)

- HC not reported:
  (hot soak, running loss, resting loss)

- NO_x
- CO
- CO_2
- SO_x
- PM
  (PM_{tot}, PM_{10}, $PM_{2.5}$)
- Fuel Consumption

7/8/98

8

Geographic Coverage

- US Total

- 50-State

- State

- County

- Option to add sub-county data for nonattainment area analysis.

Temporal Coverage

- Estimates of past, present and future year emissions

- Annual, seasonal, monthly, or daily emissions.

- Daily emissions distinguished by season and weekday/weekend.

7/8/98

Model Structure

- Graphical User Interface (Visual Basic)
  - » Scenario definition

- Core Model (Fortran)
  - » Calculations

- Reporting Utility (Microsoft Access)
  - » Output content selection

Hardware/Software

- Minimum: 486 with 16MB RAM
  (core model will run separately with 8MB)

- DOS, Win 3.1 or Win 95

- MS ACCESS not required

7/8/ 98

Input Options

- User Selected:
  - » Year
  - » Temporal Period
  - » Geographic Area
  - » Equipment Types

  - » Fuel Characteristics
  - » (altitude unused)

Default Input Data

User Change OK if <u>Better Data</u>	User Change Not <u>Recommended</u>
» Equipment Population *(*.pop)*	» Useful Life & Scrappage *(*.pop)*
» Growth Rate *(*.grw)*	» Load Factors & Usage *(activity.dat)*
» Geographic Allocation *(*.alo)*	» Emission Deterioration Factors *(*.det)*
» Temporal Allocation *(season.dat)*	
» Emission Factors *(*.emf)*	

7/8/ 98

Output Options

- ASCII File
- Pre-formatted ACCESS Reports
  - » Access not required
- ACCESS database
- Excel Spreadsheet

Report Options

- By County
- By Source Category
- By Equipment type/code
- By Horsepower

7/8/98

12

Know Limitations

- Error Checking via Interface
- State and County Populations
  - » Certain categories only
- Seasonal or Daily U.S. Totals
- Refueling Method
- Aircraft Ground Equipment Method

Inventory News

- Nat'l Nonroad Inventories Changing
  - » NONROAD vs. NEVES
    - VOC +25%
    - NOx +25%
    - PM Down -5%

7/8/ 98

Inventory News

- Why?

  » VOC and NOx -- Updated database has more equipment and new equipment categories added.

  » PM -- Same as above, but lower EFs.

Engine Population Estimates

- Recently revised Technical Report available on EPA Web Page (NR-006A)

- Changes in current Report

  » Request for comment on Mobile vs. Stationary engines

  » Modification of Residential/Commercial Lawn & Garden split

  » Modification of small engine classification scheme

7/8/ 98

Engine Population Estimates
Population Breakdown

- Engine populations rather than equipment populations (based on emissions regs)

- Engine populations are divided into:

  » Market segments (e.g., Agricultural, Construction, Lawn & Garden, etc.)

  » Applications (e.g. lawn mowers, leaf blowers, shredders, etc.)

  » 5 Fuel types: Diesel, Gasoline 2-stroke, Gasoline 4-Stroke, CNG, LPG

  » 19 Power levels (e.g., 0-1 hp, 1-3 hp, 3-6 hp, etc.)

Engine Population Estimates
Source Classification Codes (SCC)

- Each combination of application and fuel type has a unique SCC

- For most applications:

  » First 4 digits specify fuel type (2260xxxxxx = 2-stroke gasoline)

  » Next 3 digits specify market segment (2260004xxx = 2-stroke gasoline lawn & garden)

  » Last 3 digits specify application (226004010 = residential lawn mowers)

- Marine, rail, and aircraft are exceptions

7/8/ 98

Engine Population Estimates
PSR Database

- Base year (1996) engine populations come from estimates made by Power Systems Research (PSR)

  » PSR population estimates are based on manufacturer sales surveys, experimentally determined engine life, and surveys of engine usage

  » PSR application codes were matched to SCCs

Engine Population Estimates
Changes from NEVES Inventories

- Majority of changes in population between NEVES and NONROAD are the result of:

  » Updating inventory from 1989 to 1996

  » Adding several equipment classes no included in NEVES

7/8/ 98

Engine Population Estimates
Mobile vs. Stationary Nonroad

- An engine that moves from one place in a 12 month period is defined as a mobile source

  » This distinction is not immediately obvious (e.g., pallet mounted engines appear to be stationary but are moved)

  » Mobile/stationary allocation taken from Booz, Allen, and Hamilton report to California ARB

Engine Population Estimates
Mobile vs. Stationary Nonroad

- These fractions are applied to PSR populations for generator sets, pumps, compressors and welders.

- Should they also be applied to general industrial engines, hydro power units and irrigation sets?

Power Range (Hp)	Percent Mobile Equipment
0 to 25	90
25 to 40	90
40 to 100	70
100 to 175	20
175 to 300	15
300 to 500	10
500+	0

7/8/ 98

17

Engine Population Estimates
Commercial vs. Residential Lawn & Garden

- Many lawn and garden applications are operated by both commercial and residential users

    » Usage patterns are significantly different

        – Commercial has higher use in hr./year, shorter average life in years, different hr./weekday vs. weekend compared to residential

    » PSR populations don't distinguish between the two

Engine Population Estimates
Commercial vs. Residential Lawn & Garden

- Commercial/residential sales fractions by application were derived by California ARB

- Calculation of population fraction from sales fraction:

    » Commercial Population Fraction = (Commercial Sales Fraction * Commercial Average Life in Years) / (Commercial Sales Fraction * Commercial Average Life + Residential Sales Fraction * Residential Average Life)

7/8/ 98

Engine Population Estimates
Commercial vs. Residential Lawn & Garden

Application	Residential		Commercial	
	Sales	Population	Sales	Population
Lawn mowers	90.0%	96.3%	10.0%	3.7%
Trimmers/edgers/ cutters	81.9%	89.4%	18.2%	10.6%
Chainsaws	75.0%	93.5%	25.0%	6.5%
Leaf blowers/ vacuums	86.9%	92.5%	13.1%	7.5%
Tillers <6 hp	82.0%	85.7%	18.0%	14.3%
Snowblowers	90.0%	90.0%	10.0%	10.0%
Commercial turf equipment	0.0%	0.0%	100.0%	100.0%
Rear engine rider	95.0%	97.4%	5.0%	2.6%
Lawn and garden tractors	95.0%	97.4%	5.0%	2.6%
Other lawn and garden equipment	25.0%	45.7%	75.0%	54.3%
Front Mowers, Chippers/stump grinders, commercial turf, all other equipment	0.0%	0.0%	100.0%	100.0%

Engine Population Estimates
Small SI Lumping

- Proposed regs for small spark-ignition (SI) engines (<25hp) define engines based on use and displacement while NONROAD classifies by application and power level

- Proposed regs will likely result in shift from 2-stroke to 4-stroke engines

- NONROAD methodology cannot currently accommodate that shift if 2- and 4-stroke engines are in different SCCs

7/8/ 98

19

Engine Population Estimates
Small SI Lumping (Cont'd)

- Solution:
  - » All SI engines <25HP (2- and 4-stroke, CNG, and LPG) for a single application were lumped
  - » Distinctions between different types of engines for sales fraction and emission rates are maintained by using technology groups

Engine Population Estimates
Recreational Marine

- In Rec Marine Rulemaking, EPA determined that populations derived from sales data supplied directly by the manufacturers was more accurate than PSR for SI rec marine engines.
  - » NONROAD uses these rulemaking populations
- Same problem as for small SI engines:
  - » Because of inconsistencies between NONROAD and rec marine regs, engines are lumped into a single group with separate tech types

7/8/ 98

Engine Population Estimates
Summary of Remaining Issues

- Should mobile/stationary fractions also be applied to general industrial engines, hydro power units, and irrigation sets?

- Mistake in Airport Support Equipment populations
  - » Conflicting information as to whether PSR application "Terminal Tractors" falls into the Airport Support Equipment category
  - » Currently they are not included in that category, but at least some of the population should be

Growth Factors

- Technical Report available on EPA Web Page (NR-008)

- Approach described in Technical Report and used in Draft NONROAD is a new one
  - » Comments with suggestions for improvement are encouraged

7/8/ 98

Growth Factors
Option 1: Economic Indicators

- Use Bureau of Economic Analysis growth forecasts for major sectors of the economy

- Match those sectors to the nonroad equipment that would be used in each sector

Growth Factors
Economic Indicators - Limitations

- BEA may tend to under-predict growth
  » Total growth, 1990-1996
    – BEA projected: 9.3%
    – PSR growth in nonroad population: 18.1%
- BEA can't be used to project market shifts
  » Shift from gasoline to diesel engines
  » Shift from lower to higher hp
  » Increased mechanization

7/8/ 98

Growth Factors
Option 2: Historical Population Growth

- Project future growth by extrapolating from historical growth in nonroad equipment populations

- Population growth estimated from Power Systems Research (PSR) PartsLink database

  » Includes historical engine population estimates for 1989-1996

  » Allows for segregation by market sector, application type, fuel type, and horsepower

- Provides a more direct measure of change than economic forecasts

Growth Factors
Historical Population Growth - Limitations

- PSR database may contain errors

  » Errors have bigger impact as one goes to finer grained breakdown of population

  » Can limit impact by not going to extremely fine detail

- 1989-1996 may not be representative

  » Includes periods of low and high economic growth

7/8/ 98

23

Growth Factors
Historical Population Growth - Limitations

● 7 years of historical projections is not a long enough period of time on which to base 20-30 year projections

 » Could modify method to use historical growth for near-term and BEA for long-term or cap long-term growth in some other way

Growth Factors
Projected Annual Growth Rate Comparison

Market Segment	BEA	PSR				
		Total	Diesel	Gasoline	LPG	CNG
Airport Service	5.5%	8.2%	9.4%	1.4%		
Construction	1.0%	2.6%	3.6%	0.3%		
Farm	2.4%	2.8%	3.2%	2.0%		-7.7%
Industrial	1.9%	3.1%	4.4%	-3.5%	4.1%	
Lawn & Garden	1.0%	2.7%	9.6%	2.6%		
Light Commercial	1.9%	4.9%	5.5%	4.7%	14.2%	5.1%
Logging	7.4%	5.2%	-0.8%	5.9%		
Railway	-0.9%	2.7%	5.1%	1.3%		
Recreational	1.0%	0.9%	3.9%	0.9%		

7/8/ 98

24

Growth Factors
Market Shifts

● Problem with fuel-specific growth rates

» Fuel-specific growth rates must be capped by the overall market segment growth rate

» For Draft NONROAD, we have scaled the fuel specific populations to the total market segment population to avoid this problem

» In the future, we might want a single market segment growth rate with a separate input to project % market share

Growth Factors
Market Shifts - Scaled Results

Market Segment	Total	Diesel	Scaled Diesel	Gasoline	Scaled Gasoline	LPG	Scaled LPG	CNG	Scaled CNG
					PSR				
Airport Service	8.2%	9.4%	8.3%	1.4%	0.8%				
Construction	2.6%	3.6%	3.3%	0.3%	0.0%				
Farm	2.8%	3.2%	3.1%	2.0%	1.9%			-7.7%	-8.1%
Industrial	3.1%	4.4%	3.6%	-3.5%	-4.3%	4.1%	3.3%		
Lawn & Garden	2.7%	9.6%	9.1%	2.6%	2.5%				
Light Commercial	4.9%	5.5%	5.3%	4.7%	4.6%	14.2%	13.2%	5.1%	5.0%
Logging	5.2%	-0.8%	-1.2%	5.9%	5.4%				
Railway	2.7%	5.1%	4.5%	1.3%	0.8%				
Recreational	0.9%	3.9%	3.8%	0.9%	0.8%				

7/8/ 98

25

Growth Factors
State and Local Factors

● Draft NONROAD only contains national growth factors

● We have state by state historical populations from PSR, but haven't analyzed them yet

● We plan to include the state growth factors in the final NONROAD

● States that have their own estimates of state or local growth could substitute them subject to EPA SIP Guidance

Growth Factors
Summary of Remaining Issues

● Should we do something to cap growth rates in the long term? Proposals?

● How fine should we cut the database?

  » Currently only market segment and fuel

  » Plan to segment the database by state

  » Should we include horsepower or applications?

7/8/ 98

Growth Factors
Summary of Remaining Issues (Cont'd)

- Should we switch to a % market share approach or stick with scaled growth factors?
    - » Change may not be feasible for Final NONROAD
- Growth rate for Airport Service equipment will change
    - » Incorrect populations taken from PSR database
    - » Other sources of information may be better for this category
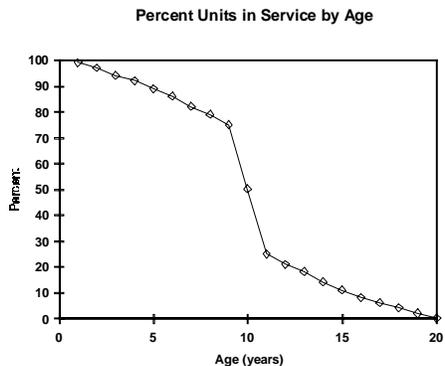   - – FAA projections of take-offs and landings?

Age Distribution & Scrappage

Chris Lindhjem

NONROAD NR-007

7/8/ 98

Scrappage Function

Based on a normal distribution

Percent Units in Service by Age
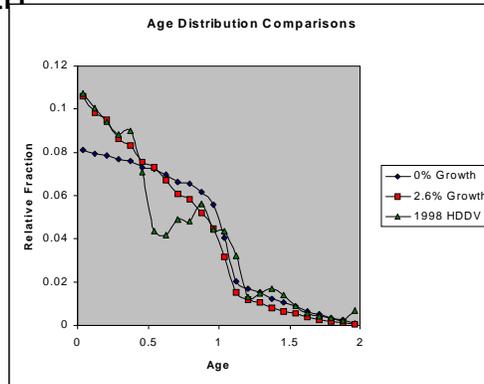
Scrappage in NONROAD

- Included in the Growth File (nation.grw)

- Alternate Scrappage functions can be used

- Will affect fleet turnover and phase-in rates of new engine emission standards

- Currently not using a use-by-age function, so the scrappage distribution estimates both age and use-by-age together

7/8/ 98

Initial Year (1996) Age Distribution

● Initial year assumes 0% historical growth

Age Distribution Comparisons

- 0% Growth
- 2.6% Growth
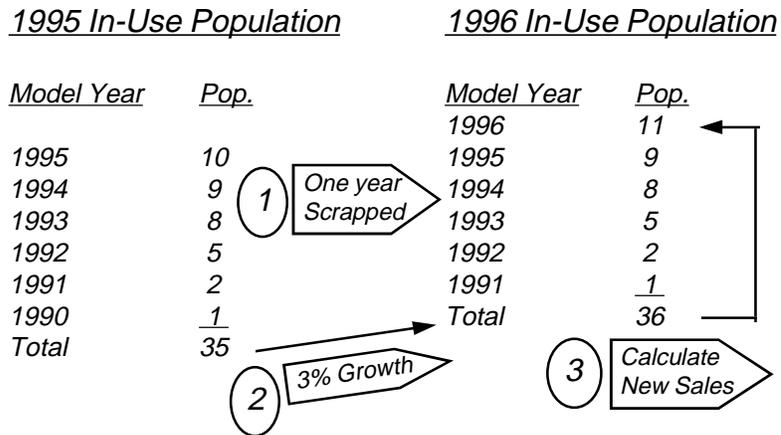- 1998 HDDV

4
NONROAD 6/25/98

Age Distribution Calculations

• Future year sales is calculated by adding one year of scrappage and the growth in the overall population (inlcuding some scrappage in the first year)

– Previous year's engines are scrapped by one additional year

– Next year's sales is the sum of that year's scrapped engines plus that needed to bring the engine population

5
NONROAD 6/25/98

7/8/ 98

29

Growth Methodology (sample)

1995 In-Use Population

1996 In-Use Population

Model Year	Pop.
1995	10
1994	9
1993	8
1992	5
1991	2
1990	1
Total	35

① One year Scrapped

② 3% Growth

Model Year	Pop.
1996	11
1995	9
1994	8
1993	5
1992	2
1991	1
Total	36

③ Calculate New Sales
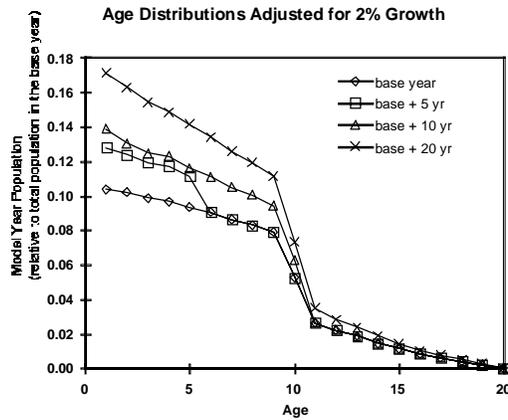
6
NONROAD 6/25/98

Sales Perturbation

- In the previous example 3% population growth results in 10% sales growth

- Initial year age distribution is responsible for this

7
NONROAD 6/25/98

7/8/98

30

Effect on Age Distribution

Age Distributions Adjusted for 2% Growth

MOBILE Comparison

- Age distributions predetermined (using a similar methodology)

- Sales growth estimates fixed for the purpose of age distribution

- Travel fractions include both age distribution and use-by-age function
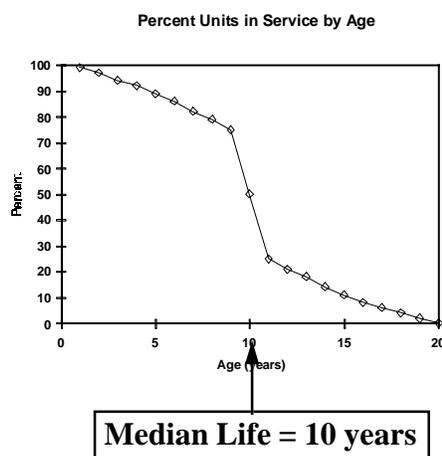
7/8/ 98

Median Life Estimations

Chris Lindhjem

NONROAD Report NR-005A

Definition

- Median Life; 50% of new engines scrapped

- NONROAD input; Hours at Full Load

- Calculation

$$Median\ Lifetime\ (years) = \frac{Median\ Life\ (hrs)}{Activity\ (hrs/yr) * Load\ Factor}$$

7/8/ 98

Use of Median Life

Percent Units in Service by Age

Median Life = 10 years

Information Source

- Energy and Environmental Analysis Inc. analysis of the Power Systems Inc. database for the Air Resources Board of California

- Lawn & Garden - Estimation from EPA\Manufacturers Regulatory Negotiation Committee work - generally lower than EEA estimates

- The median life is found in the *.pop files

7/8/ 98

Activity and Load Factors

Chris Lindhjem

NONROAD Report NR-005A

General

- Emissions = (Population * Power * Load Factor * Activity * Emission Factor)

- Load Factor - Average Fraction of Available Power

- Activity - Engine Hours Use per Year

7/8/ 98

34

Source Information

- Power Systems Research - Conducts User Surveys to Estimate Load and Hours Use *(PSR estimates used for most applications)*

- Other Survey Information for Lawn & Garden and Spark-Ignition Recreation Marine

How to Determine

- Hours is determined by use of meters on engines (often called Hobbs meters); analogous to an odometer

- Load Factor is determined from the Hours and Fuel Consumption

7/8/ 98

Load Factor Estimations

- Load Factor = EP/(FC/(BSFC * Hours Used))

  » EP - Engine Power

  » FC - Fuel Consumption (actual)

  » BSFC - Brake Specific Fuel Consumption (lb/hp-hr or g/kW-hr); derived from test data

  » Hours Used - Engine On and Fuel Consumption Information

5
NONROAD 6/25/98

Collecting New Data

- Important to collect data from professionally designed surveys (apocryphal information abounds)

- Determine engine related parameters (such as power level and age of engine) in addition to hours of use and fuel consumption

6
NONROAD 6/25/98

7/8/ 98

Emission Factors

Chris Lindhjem

Reports NR-009A & NR-010A

plus deterioration

Emission Factor

- Emission Factors are zero hour (new engine)

- Deterioration applied for in-use engines

- Emission Factors; gram/hp-hr or g/gallon or g/gallon

- Draft release only uses g/hp-hr factors

7/8/ 98

CI Emission Factors

Chris Lindhjem

NR-009A

CI Emission Factors

- Pre-1988 model years from NEVES emission rates

- >1988 Precontrolled engine emissions from new (1998) EPA\SwRI study

- New engine standards are included (rulemaking not yet finalized)

- Adjustment from steady-state certification test results to in-use emission rates

4

NONROAD 6/25/98

7/8/ 98

Emission Factors in NONROAD

- Pre-Calculation Method
  - » EF = Steady-state EF * Adjustment for In-Use
  - » $EF_{(THC\ for\ Backhoes)}$ = 0.68 (g/hp-hr) * 2.19

- Emission factors calculated outside of the model and included in the data files

- Emission factors are included in *.emf files and new standards are phased-in through technical types in the tech dat

[5]
NONROAD 6/25/98

Pre1988; NEVES Factors

- Older Equipment (Early 1980's and older engines)

- NEVES adjusted steady emission rates with the use of highway certification test cycle

- Recast emission factors with new in-use adjustments

- Sparse data delineated by equipment type

[6]
NONROAD 6/25/98

7/8/ 98

39

>1988 Precontrolled Engines

- New and more test data than NEVES

- Emission factors generally lower (highway diesel engine technology improvements transferred to nonroad engines)

- >100 hp and <100 hp engines treated separately due to emission results (different engine technology; fuel injection systems)

7
NONROAD 6/25/98

New Standards

- Includes Tier I, II, and III emission standards

- *Tier II and III rulemaking is not finalized so may change from draft version of NONROAD*

8
NONROAD 6/25/98

7/8/ 98

Adjustment for In-Use Activity

- ● Test data on three representative in-use test cycles (backhoe\loader; crawler dozer; and agricultural tractor)

- ● Transient nature and average load of cycles

- ● Mapping of the three test cycle adjustments or no adjustment to equipment applications (given in the Report)

9
NONROAD 6/25/98

Adjustment (cont.)

Table C1 NEVES Test Cycle Adjustment from ISO-C1 Emission Factors

	HC	CO	NOx	PM
NEVES Adjustment	1.4	2.0	1	1.6

Table C2 In-use Adjustment Factor (Ratio of Application Test Cycle to Steady-State ISO-C1 Emissions)

Test Cycle	HC	CO	NOx	PM	BSFC
Agricultural Tractor	0.89	0.42	0.99	0.64	0.98
Backhoe\Loader	2.19	2.31	1.03	2.04	1.18
Crawler Dozer	0.93	1.27	0.99	1.21	0.98

10
NONROAD 6/25/98

7/8/ 98

New Standards Phase-In

- New emission factors are phased-in through the use of a tech type description

- New technology or new mix of technologies by model year

11

Tech. Types (example)

Tech types use for standards phase-in for Base (pre-1988), T0 (>1988), T1 (Tier 1 Standards), T2 (Tier 2), T3 (Tier3)

Model Year	SCC	Low & High Hp		Technical Types--------------------------				
	2270005000	175	300	Base	T0	T1	T2	T3
1900				1	0	0	0	0
1988				0	1	0	0	0
1996				0	0	1	0	0
2003				0	0	0.3	0.7	0
2004				0	0	0.15	0.85	0
2006				0	0	0.15	0	0.85
2011				0	0	0	0	1

7/8/98

Fuel Sulfur PM Adjustment

- Diesel PM is a combination of unburnt fuel, engine oil, carbon core, and hydrated sulfate

- Fuel sulfur adjustments affects only the sulfate related PM, not total PM

Fuel Sulfur PM Adjustment

- PM sulfur adjustment for PM

$$PM = PMBase - BSFC * A * (0.0033 - Fuel\ Sulfur)$$

where

> PMBase = PM emissions with default fuel, in g/hp-hr
> PM = PM emissions with test fuel, in g/hp-hr
> BSFC = Brake Specific Fuel Consumption in g/hp-hr
> A = 0.157 g PM/hp-hr/Weight Fraction sulfur/BSFC
> 0.0033= the default weight fraction of fuel sulfur for nonroad diesel
> Fuel Sulfur = Weight Fraction of sulfur in test fuel

7/8/ 98

SI Emission Factors

Chris Lindhjem

NR-010A

General Emission Factors

- NEVES baseline for >25 hp SI engines

- Engines unique because of rulemakings

  » <25 hp general-use engines (except recreational vehicles and underground mining)

  » Recreational SI marine

- LPG and CNG engines

- Zero-hour (new) engine emission

16
NONROAD 6/25/98

7/8/ 98

44

>25 hp SI Engines

- NEVES
  - » construction
  - » agricultural
  - » all other applications use NEVES industrial

17
NONROAD 6/25/98

Recreational, LPG, and CNG

- Recreational (motorcycles, all-terrain vehicle, snowmobiles, and other specialty)
  - » Use new data on snowmobile engines
- LPG & CNG
  - » Two types; industrial and all other applications
  - » Emission rates used for <25 hp engines also

18
NONROAD 6/25/98

7/8/ 98

US EPA ARCHIVE DOCUMENT

<25 SI Emission Factors

- Engines considered under a rulemaking

- 5 engine classifications (Class I-V)

  » Class I and II; nonhandheld small and large

  » Class III-V; handheld small to large

  » Class definition described in Report NR-006A

- Rule definition is by use and engine size - NONROAD defines by use and engine power

19
NONROAD 6/25/98

Small Engine Rulemaking

- Averaging Standard (some low emitters and some high; averaging lower overall)

- Rulemaking results in lower THC emissions due to lower emission factors for new model years and a shift in technology type from 2-stroke to 4-stroke

20
NONROAD 6/25/98

7/8/ 98

Recreational SI Marine

- Averaging standard also

- Outboard (2-stroke) & Personal Watercraft (2-stroke) are the focus of rulemaking

- Inboard (4-stroke) is assumed not to change

21
NONROAD 6/25/98

Outboards

- Generally two types currently (2 and 4-stroke)

- New engine standards are expected to result in more 4-stroke engines and lower emitting 2-stroke engines

- Emission rates vary by engine power

22
NONROAD 6/25/98

7/8/ 98

Personal Watercraft

- Generic name instead of JetSki® brand name

- A move from 2-stroke to 4-stroke is expected here as well

Tech. Type Phase-In (example)

- M2 (standard 2-stroke), M14 (lower emitting 2-stroke) M13 (current 4-stroke)

Table 20 Estimate Phase-in of New Personal Water Craft Engines >50 hp

Year	M2	M13	M14
1900	1.000	0.000	0.000
1999	0.177	0.092	0.731
2000	0.177	0.259	0.564
2001	0.177	0.533	0.291
2002	0.177	0.823	0.000
2004	0.038	0.962	0.000

7/8/ 98

Deterioration

Chris Lindhjem\Greg Janssen

Report Due Soon

Summary

- Deterioration Report Imminent
- Application
  - » Emission Rate = Emission Factor (zero hour) * Deterioration
    - – Deterioration = $1 + A \, (age)^{b}$
      - A, b constants
      - Age = Cumulative hours * Load Factor / Median Life
    - – Deterioration caps allowed and used
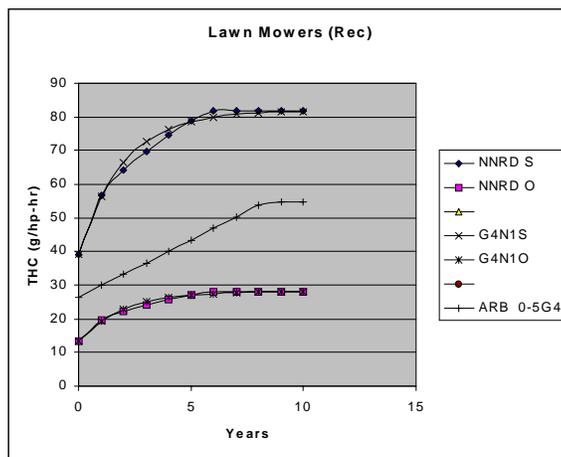- Input in NONROAD in *.det files

26
NONROAD 6/25/98

7/8/ 98

Deterioration Values

- < 25 hp SI engine emissions deterioration taken from EPA rulemaking

  » 2-stroke linear deterioration = 1 + A * Age

  » 4-stroke deterioration = $1 + A * (Age)^{0.5}$

  » All deterioration capped at 1 median life

  » Magnitude taken from Phase I rulemaking RIA

- >25 hp SI deterioration from NEVES

Sample Deterioration Effect

Lawn Mowers (Rec)

Legend:
- NNRD S
- NNRD O
- G4N1S
- G4N1O
- ARB 0-5G4

Axes: THC (g/hp-hr) vs Years

7/8/98

Other Deterioration

- Draft version of NONROAD has no deterioration for diesel for any pollutant

- Initial testing indicates concern

  » 4 of 9 engines recruited had maintenance problems with manifold leaks

    – Manifold leaks required repair to measure emissions

    – Manifold leaks will affect the turbocharger efficiency potentially raising emissions

29
NONROAD 6/25/98

Non-Exhaust Emissions

Modeled	Not Currently Modeled
Diurnal	Hot Soak
Crankcase	Running Losses
Refueling	Resting Losses

7/8/98

Non-Exhaust Emissions: Diurnal

Based on NEVES

3.0 g/gallon/day* (>25hp)

Modified for <25hp Engines per ARB Model

1.0 g/gallon/day* (<25hp)

* Grams per Day per Gallon fuel tank capacity

Non-Exhaust Emissions: Diurnal

**Would consider using method in EPA small
engine regulatory model (NSEEM)**

Gram per day values for specific applications

Data based on 72-96F tests

Ignores potentially large range of tank sizes
within an application (e.g., generator sets)

*7/8/
98*

Non-Exhaust Emissions: Diurnal

- **Fuel Tank Size is calculated by model based on engine application and horsepower**

- **See Refueling Loss presentation**

Non-Exhaust Emissions: Crankcase

Based on NEVES

Zero for 2-Stroke and Rec Marine

HC Only

   Would consider CO & NOx (much smaller)

7/8/ 98

53

Non-Exhaust Emissions: Crankcase

4-Stroke	Diesel
33.0 % of exhaust HC	2.0% of exhaust HC

Refueling Emissions

- Technical Report not yet available

- All refueling calculations are based on NEVES methodology described in Appendix I of the NEVES Report

- Planned changes from Draft NONROAD to Final

  » Draft NONROAD uses simplified method

  » Final NONROAD will revise this

7/8/ 98

Refueling Emissions

- Two components

  » Spillage

  » Vapor Displacement

- These are calculated separately and then combined for output

Refueling Emissions

- Refueling method assumptions

  » Container filled - all lawn and garden, recreational equipment, outboards and personal watercraft

  » Pump filled - all others

7/8/98

Refueling Emissions

- Refueling method - Alternative assumptions

  » NEVES - lawn and garden, recreational, light commercial, and all equipment with tank volumes less than 6 gallons are container filled

  » ARB - all gas 2-stroke and all equipment less than 15 hp are container filled

Refueling Emissions

- Spillage - Assumptions

  » All refuelings are fill-ups

  » 17.0 g per refueling event from containers

  » 3.6 g per refueling event from gas pump

7/8/ 98

Refueling Emissions

- ● Spillage - Calculation
  - » Container:
    - – Spillage (g/gal) = 17.0 / Tank Volume
  - » Pump:
    - – Spillage (g/gal.) = 3.6 / Tank Volume
  - » NONROAD uses fuel consumption to convert g/gal to total emissions in Tons

Refueling Emissions

- ● Spillage - Tank Volumes
  - » NEVES gave average tank volumes for each application
  - » Within an application, tank volumes vary by engine size
  - » Based on equipment specifications available on the World Wide Web, we developed application-specific tank volumes in gallons/hp

7/8/ 98

Refueling Emissions

- Spillage - Tank Volumes
  - » Analysis needs more work - could still go back to NEVES approach
  - » Interim values are in ACTIVITY.DAT file
  - » In draft model, ACTIVITY.DAT is only accessed for diurnal emissions calculations
  - » SPILLAGE.EMF contains emission factors for each application based on NEVES tank volumes

Refueling Emissions

- Vapor Displacement - NEVES approach
  - » Disp. = -5.909 - 0.0949 x dT + 0.0884 x Td + 0.485 x RVP
  - » Disp. = Displacement (g/gal)
  - » dT = Temp of Tank (Ambient Temp) - Temp of Dispensed Fuel (^{o}F)
  - » Td = Temp of Dispensed Fuel (^{o}F)
  - » RVP = Reid Vapor Pressure of Fuel

7/8/ 98

Refueling Emissions

- Vapor Displacement - NEVES approach
  - » NEVES used this formula to create a look-up table for summer and winter temperatures and container and pump refueling
  - » DISPLACE.EMF contains g/gal emission factors based on summer temperatures from the NEVES look-up table and 9.0 RVP
  - » NONROAD uses fuel consumption to convert g/gal to total emissions in Tons

Refueling Emissions

- Vapor Displacement - Final model approach
  - » NONROAD will calculate g/gal emission factors based on the NEVES formula and temperatures and RVP entered under Scenario: Options
  - » Temp. of dispensed fuel will be calculated by the following equation (derived from the NEVES table):
    - $T_d = 62 + 0.6 \times$ (Ambient Temp. - 62)

7/8/ 98

Refueling Emissions

- Summary of remaining issues
  - » Container vs. pump refueling allocation
  - » Tank volumes - use NEVES or collect more data for gal/hp method?
  - » Alternatives to "all refuelings are fill-ups" assumption?

Refueling Emissions

- Summary of remaining issues (cont'd.)
  - » Effect of Stage II controls
    - – Geographical allocation is a problem
    - – Most likely solution is a Stage II switch for county runs
    - – User would have to set the switch
    - – Stage II effectiveness for nonroad refueling?

7/8/ 98

Refueling Emissions

- ● Summary of remaining issues (cont'd.)
  - » Diesel emissions
    - – None in Draft NONROAD
    - – NEVES used 0.041 g/gal at 80 $^{\circ}$F for displacement
    - – Spillage is unknown
  - » Accounting for spillage and displacement when filling portable containers
    - – Unlikely to be addressed in Final NONROAD

Temperature & RVP Effects

Only affects calculated Diurnal loss

Based on MOBILE5
(Uncontrolled Diurnal Index, Wade equation)

- ● Start with base rate for 60-84F
- ● Adjust Vapor Pressure to desired Temperature & RVP

7/8/ 98

61

Fuel Sulfur & Oxygen Effects
Spark-Ignition

- **Oxygen Effects**

  Exhaust CO, NOx, and VOC

- **Sulfur Effects**

  Exhaust SOx and PM

Fuel Sulfur & Oxygen Effects
Spark-Ignition

- Assume no Feedback (closed-loop) controls

- Assume no Catalysts
  - » No reduction of catalyst efficiency
  - » Will need to revisit in future

- Effects of Aromatics, Olefins or Distillation curve are ignored

- Default gasoline sulfur content = 339 ppm

7/8/ 98

Fuel Sulfur & Oxygen Effects
Spark-Ignition

- 97% of fuel Sulfur converted to SO_2

- 3% of fuel Sulfur emitted as PM

Fuel Sulfur & Oxygen Effects
Oxygen

- Oxygen Effects based on older highway vehicle and some small engine testing

- CO & VOC decrease proportional to fuel oxygen

- NOx increases proportional to fuel oxygen

7/8/ 98

63

Fuel Sulfur & Oxygen Effects*
Oxygen

4-Stroke		**2-Stroke**	
VOC	-4.5%	VOC	-0.6%
CO	-6.5%	CO	-6.5%
NOx	+11.5%	NOx	+18.6%

* Per Percent Fuel Oxygen

Hydrocarbon Report Types

Chris Lindhjem

NONROAD Report NR-002

7/8/98

64

Definition of THC

- THC is total hydrocarbons

- Measured with a flame ionization detector (FID) calibrated with propane; the FID measures carbon content of sample.

- Hydrogen is added to the carbon emission rate to represent hydrocarbon emissions

THC (grams) = (FID Response) * (12 (Carbon) + ~1.8 (Hydrogen))
    12 - Molecular weight Carbon
    1.8 - Number of Hydrogen atoms associated with Carbon

Definition of TOG

- TOG - total organic gas

- FID doesn't measure carbon atoms associated with oxygen such as aldehydes and alcohols

- Aldehydes and alcohols are measured separately and added to the THC by weight as formaldehyde and methanol

TOG = THC + (total aldehydes) + (total alcohols)

7/8/ 98

Definition of NMHC, NMOG, and VOC

- NMHC - nonmethane hydrocarbons

- **NMHC = (THC - methane)**

- NMOG - nomethane organic gas

- **NMOG = (TOG - methane)**

- VOC - volatile organic compounds

- **VOC = (NMOG - ethane)**

Results

Engine Type	TOG/THC	NMOG/THC	NMHC/THC	VOC/THC
2-Stroke Gasoline [2]	1.044	1.035	0.991	1.034
4-Stroke Gasoline [2, 3]	1.043	0.943	0.900	0.933
Diesel [4]	1.070	1.054	0.984	1.053
LPG [5]	1.036	0.740	0.704	0.647
CNG [5]	1.002	0.049	0.048	0.004

7/8/ 98

Use in NONROAD

- Applied in the Reporting Utility not in the Core Model

- Lumped equipment (<25 hp SI) treated as either 2-stroke or 4-stroke gasoline whichever predominates

6
NONROAD 6/25/98

Geographic Allocation
Basic Approach

- Technical report available by mid-July

- Geographic allocation of engine populations accounts for how many and what types of equipment are being used in a certain location

  » Default data allocates to the county level

  » NONROAD can allocate equipment populations to the subcounty level, but <u>user</u> must provide fractions to allocate from the county to subcounty level

7/8/ 98

Geographic Allocation
Basic Approach

- National engine/equipment populations from Power Systems Research (PSR)
  - » PSR has state and county level numbers but methodology used to derive them is proprietary
  - » Publicly available data used as much as possible to allocate populations

- PSR national populations allocated outside NONROAD to county level using county-specific surrogate indicators

- County populations are then aggregated to produce default state population input files

Geographic Allocation
Basic Approach

- NONROAD allocates state level default population input data down to the county level for each equipment type using the county-specific surrogate indicators
  - » Equip. Pop_{county} = Equip. Pop_{state} X $\dfrac{\text{Surrogate}_{county}}{\text{Surrogate}_{state}}$

- Allocating equipment populations is surrogate for allocating activity
  - » NONROAD only has one activity level (hours/year) for each equipment type for all of U.S.

- Option for user to specify own state/county surrogate indicators
  - » Equipment category or by individual equipment types

7/8/ 98

Geographic Allocation
Application-Specific Surrogate Indicators

- Residential Lawn and Garden (except snowblowers) : 1 & 2 unit single family homes from 1990 Census (draft version)
  - » Final version adjusted by 1997 human population estimates
- Commercial Lawn and Garden (except snowblowers): number of employees in landscape and horticultural services (SIC 78)
  - » U.S. Census County Business Patterns 1995 (CBP)

Geographic Allocation
Application-Specific Surrogate Indicators

- Snowblowers
  - » Same as above, but plan to adjust by annual average snowfall data from NOAA for final version
  - » Set to zero for counties and states in draft version
- Construction: F.W. Dodge Database of total construction dollar value by county
  - » Census Bureau tracks value but only at MSA level
  - » CBP number employees does not address inter-county movement of equipment
- Agricultural: acreage of harvested cropland
  - » Source: Census Bureau: USA Counties Database 1996

7/8/98

Geographic Allocation
Application-Specific Surrogate Indicators

- Light Commercial Equipment
  - » Census CBP, number of wholesale establishments (SIC 50)
- Industrial
  - » Census CBP, number of employees in manufacturing (SIC 20)
- Oil Field Equipment
  - » Census CBP, number of employees in oil and gas extraction (SIC 1300)

Geographic Allocation
Application-Specific Surrogate Indicators

- Logging
  - » Draft version: number of employees in logging (SIC 2410) plus number of employees in saw and planning mills (SIC 2420)
    - – number of employees in saw and planing mills allocates to urban areas in some cases
  - » Final version will only use number of employees in logging

7/8/ 98

Geographic Allocation
Application-Specific Surrogate Indicators

- Recreational Marine
  - » Boats not necessarily used in county where purchased, registered, or stored
  - » Draft version uses water surface area
    - – Doesn't account for navigational limitations or max. number of boats that can fit on waterbodies
  - » Effort will be made to refine water surface area method or find a better method
  - » EPA open to ideas & suggestions for default surrogate allocation indicators
  - » Local data is probably best alternative

Geographic Allocation
Application-Specific Surrogate Indicators

- Recreational Equipment (except snowmobiles and golf carts)
  - » Problem similar to recreational marine
  - » Have not been able to find reasonable surrogate indicator at county level
  - » Draft using number of RV park/camp establishments (SIC 7030) from Census CBP
    - – Only placeholder because these data appear to be incomplete
  - » EPA open to ideas and suggestions for defaults
  - » Local data is probably best alternative

7/8/ 98

Geographic Allocation
Application-Specific Surrogate Indicators

- Snowmobiles
  - » Allocation method not complete in draft version
  - » Could be allocated using same indicator as other recreational equipment or separately
  - » Draft version will report national population and emissions, but zero out state and county level information
  - » Final version will limit geographic allocation using annual average snowfall data from NOAA
  - » Local data may be best alternative

Geographic Allocation
Application-Specific Surrogate Indicators

- Golf carts
  - » Draft version uses number of employees at public golf courses (SIC 7992) from Census CBP
  - » These data have significant gaps
    - – No data available for many states
  - » Will be corrected for final version

7/8/ 98

Geographic Allocation
Application-Specific Surrogate Indicators

- Aircraft Ground Support Equipment
  - » Draft version uses number of employees in air transportation (SIC 4500) from Census CBP
  - » For final version, investigating the use of DOT landing/takeoff data at airports with commercial operations
- Railroad Maintenance Equipment
  - » Draft version uses 1990 human population
  - » Investigating better alternatives
    - – Track mileage by county?

Geographic Allocation
Application-Specific Surrogate Indicators

- Underground mining equipment
  - » Draft version uses number of employees in metal mining (SIC 1000) from Census CBP
  - » Final version will use indicator more appropriate to underground mining
    - – number of employees in coal mining (CBP 1200)?
- AC/refrigeration equipment
  - » Used on Truck Trailers
  - » Draft version uses 1990 human population
    - – Human population consistent with where this equipment operates

7/8/ 98

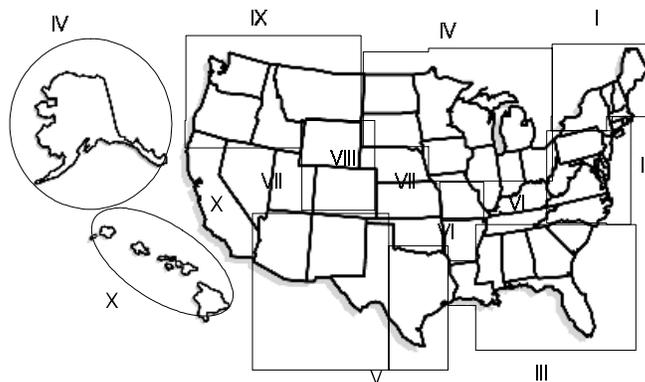## Seasonal Allocation
Background

- Technical report available on OMS web page

- Seasonal allocation fractions account for the effect of climatic variations on nonroad equipment usage patterns

- 1995 CA ARB TSD for OFFROAD model used for CA seasonal allocation

Seasonal Allocation
Background

- NEVES used for rest of country
  - Recreational equipment seasonal allocation data based on 1990 MIC survey
  - Recreational marine data based on 1991 NMMA survey of boaters
  - Other categories based on 1973 SwRI report by Hare and Springer, 1987 SIPs, 1991 CA ARB lawn & garden emission standards and testing procedures TSD

7/8/ 98

Seasonal Allocation
Regions

- Ten regions
  - » Composite of regions from the 3 sources in NEVES

Seasonal Allocation

- Seasons divided into 3 month periods

  - » 1 month = season/3

- NEVES only contained fractions for Summer and Winter

- Spring and Fall extrapolated by:
  1-(Summer + Winter)/2

7/8/
98

Seasonal Allocation

- States assigned to regions by geography and climate
  - » No data for HI and AK
    - – AK assigned to Great Lakes/Midwest region
    - – HI assigned to West Coast region along with CA (1995 CA ARB TSD)
  - » Best judgment used for large states spanning more than one region and having several climatic tendencies that could be categorized in more than one region.
    - – NY: Northeast/New England, Great Lakes/Midwest Middle Atlantic
    - – WY: Rocky Mountain, Central West, Northwest

Weekday/Weekend Allocation

- From CA ARB original draft MVOFF model
  - » Fractions allocate emissions for average week or weekend day
  - » Can be specific to the equipment type
    - – Currently specific to equipment category only
  - » EPA planning to study further and would like to hear ideas and suggestions

7/8/98

Commercial Marine Module
Default Input Data

- Covers top 150 U.S. ports
  - » number of trips and tonnage by vessel category
- 12 well-characterized ports
  - » Based on:
    - – representativeness of operations & geographic location
    - – data availability
  - » Ports matched up with 150 top ports

Commercial Marine Module
Detailed Port Data

- 5 large ocean ports
  - » NY/NJ, Philadelphia, Seattle, Corpus Christi, New Orleans
- 2 typical international ocean ports
  - » Baltimore, Coos Bay
- 1 typical domestic ocean port
  - » Tampa
- 2 river ports
  - » St. Louis, Cincinnati
- 2 Great Lake ports
  - » Burns Harbor, Cleveland

7/8/ 98

Commercial Marine Module
Detailed Port Data

- Detailed Port Activity by Vessel Category

  » Average Horsepower

  » Engine/Fuel Type

  » Range of dead weight tons

  » Number of Trips

  » Average Hours in Mode

    – Mode = Cruising, Maneuvering, and Hoteling

Commercial Marine Module
Methodology

- User specifies one of the top 150 ports

- Model matches a given port with a well-characterized port of a similar vessel mix and scales the emissions by activity per vessel category

7/8/ 98

Commercial Marine Module Methodology

- Module calculates emissions for one of the 12 detailed ports matched with the port chosen by user from the top 150
- For each vessel category and load by mode module will calculate emissions by mode

  » Emissions by Vessel Category and Mode =

  Emission Rate$_{\text{(ship \& engine type, mode)}}$ * Hours$_{\text{(mode)}}$ *

  Load$_{\text{(mode)}}$ * # Ship$_{\text{(Type)}}$ * # Trips

Commercial Marine Future Plans

- Work still underway on module and data

- Draft release expected Fall 1998

- Additional work

  » Acquiring data on interport emissions on the Great Lakes and rivers

  » To be included in future version of commercial marine module.

7/8/ 98