STATE OF COLORADO

J. DAVID BARBA, CPA
State Auditor

OFFICE OF THE STATE AUDITOR
(303) 866-2051
FAX (303) 866-2060

Legislative Services Building
200 East 14th Avenue
Denver, Colorado 80203-2211

OFFICE OF THE STATE AUDITOR
FINAL REPORT

1999 Audit of the Colorado AIR Program

November 22, 1999

for:

State of Colorado
Office of the State Auditor
Legislative Services Building
200 East 14th Avenue
Denver, Colorado
80203-2211

by:

Air Improvement Resource, Inc.
47298 Sunnybrook Lane
Novi, Michigan
48374

Table of Contents

List of Tables

List of Figures

Glossary of Abbreviations and Acronyms

Acronyms, Abbreviations, and Other Terms Used in This Report

AIR Program	Automobile Inspection and Readjustment Program
CDPHE	Colorado Department of Public Health and Environment
CO	Carbon monoxide
EPA	U. S. Environmental Protection Agency
FTP	Federal test procedure
GVW	Gross vehicle weight
HC	Hydrocarbons
HEV	High emitting vehicle
I/M	Inspection and Maintenance
IM240	A specific I/M test procedure lasting 240 seconds
LDT	Light duty truck
LEV	Low Emission Vehicle
NAAQS	National ambient Air quality standards
NLEV	National Low Emission Vehicle
NOx	Nitrogen oxides
OBD	Onboard diagnostics
PM	Particulate matter
ppm	Parts per million
RAQC	Regional Air Quality Council
RPM	Revolutions per minute
RSD	Remote sensing device
SIP	State Implementation Plan
SUVs	Sport utility vehicles

Acknowledgements

The authors wish to acknowledge the Office of the State Auditor, and the following persons serving on the Technical Advisory Committee, who provided valuable assistance in identifying data sources and analyses as well as provided feedback on the scope of work, the preliminary results and the draft report.

Mr. Rick Barrett, Air Pollution Control Division, Department of Public Health and Environment

Mr. Patrick Cummins, Deputy Director, Regional Air Quality Council

Mr. Jerry Gallagher, Ph.D., Director of Mobile Sources Unit, Air Pollution Control Division, Department of Public Health and Environment

Mr. Larry Gupton, Deputy State Auditor, Office of the State Auditor

Mr. Carleton Howard, Ph.D., Senior Research Chemist, National Oceanic and Atmospheric Administration

Mr. Doug Lawson, Ph.D., Principal Scientist, National Renewable Energy Laboratory

Mr. John Schoen, Emission Compliance Inspector, Motor Vehicle Department, Department of Revenue

Mr. Lou Skull, Office of the State Auditor

The contribution provided by individual members of the Technical Advisory Committee does not signify an endorsement of the material contained in this report. The statements contained herein represent the opinion of the audit contractor, Air Improvement Resource, Inc. and the Office of the State Auditor.

[This page is intentionally blank.]

1. Executive Summary

Introduction

In June 1999, the State Auditor's Office contracted with Air Improvement Resource, Inc. of Novi, Michigan to conduct a performance audit of the Colorado Automobile Inspection and Readjustment (AIR) Program. This audit is required by state statute (Section 42-4-316, C.R.S.) to be completed by January 1, 2000. The statute requires the audit to consider several factors, including the effect of the AIR Program on ambient air quality, the cost-effectiveness of the Program, and the need to reduce air pollution to comply with federal air quality standards.

This report provides an evaluation of the costs and benefits of the current AIR Program and an analysis of options for modifying the Program in the future. The following is a summary prepared jointly by Air Improvement Resource, Inc. and the State Auditor's Office, which highlights the major findings and conclusions of the audit. Following the summary are three other sections:

- the response of the Colorado Department of Public Health and Environment (CDPHE) to the audit,
- Auditor's Addendum presenting the response to the Colorado Department of Public Health and Environment, and
- Appendix to the Executive Summary presenting a summary of modifications and alternatives to the AIR Program.

Overview of the AIR Program

The Colorado General Assembly enacted legislation in 1980 to create the AIR Program to meet national ambient air quality standards. The AIR Program inspects automobiles to measure exhaust emissions and cause vehicles with excessive emissions to be repaired. The AIR Program is operated in the six county Denver Metro area and three other Front Range counties which include Colorado Springs, Ft. Collins, and Greeley. Approximately 1.2 million vehicles were inspected by the AIR Program during calendar year 1998. Of these, 10 percent (121,000 vehicles) failed the initial test. Approximately 78 percent (95,000) of the failed vehicles returned and subsequently passed the test or received a waiver, and the remaining 22 percent (26,000) of the failed vehicles did not return for a retest. Most of the failed vehicles were pre-1990 model years.

The cost of the AIR Program in 1998 was about $42 million. Of the total cost, $24 million was spent on inspections, $13 million on repairs, and $5 million on administration. There was also an estimated $3 million of fuel economy cost savings realized by motorists after vehicles were repaired. With this savings included, the net cost of the AIR Program in 1998 was about $39 million.

Colorado's AIR Program consists of two types of inspection test procedures, one called the two-speed idle, and the other called the IM240. The IM240 is operated in the

Denver Metro area for 1982 and newer vehicles. The two-speed idle test is used in the other three counties as well as to test 1981 and older vehicles in the Denver Metro area. The term "Enhanced Program" refers to the combined IM240 and idle testing performed in the six-county Denver Metro area and the term "Basic Program" refers to the idle testing performed in the remaining three Front Range counties.

Air Quality in Colorado

The levels of carbon monoxide in the air have dropped significantly over the past 10 years. The levels have decreased so much that the Denver Metro area has not exceeded the federal standard for carbon monoxide since 1995 and the other Front Range counties since 1991. The following table displays the second maximum 8-hour carbon monoxide concentrations for 1997 and 1998 in the counties covered by the AIR Program. This table shows that the levels of carbon monoxide in all counties were 30 to 65 percent lower than federal standard of 9 ppm in both years.

Table 1-1. Second Maximum 8-Hour Carbon Monoxide Values (ppm) for 1997 and 1998*

County	1997	1998
Adams	4.3	3.5
Arapahoe	2.8	N/A
Boulder	5.4	4.8
Denver	6.4	5.2
Jefferson	4.9	3.6
El Paso	4.9	6.1
Larimer	5.2	4.1
Weld	4.8	4.4
Mesa	5.4	5.3

* The carbon monoxide standard is 9 ppm; an exceedance takes place when the level is above 9.5 ppm (ppm = parts per million). Arapahoe is shown as N/A for 1998 because the site was discontinued due to low readings.

Similar to carbon monoxide, the levels of particulate matter have also been declining over the last five to 10 years and the federal particulate standard has not been violated since 1993. Over the last 10 years, ozone levels in terms of the 1-hour average have declined slightly, and ozone levels in terms of the 8-hour average have been fairly constant. There has not been a violation of the federal ozone standard for over 10 years.

The primary reasons for the improvement in carbon monoxide air quality are cleaner cars which have improved technologies to meet stricter federal emissions standards, and fleet turnover resulting from the replacement of older vehicles with newer vehicles that have lower emission levels. Air quality benefits have also been realized from other pollution control programs such as the AIR and Oxygenated Fuels Programs.

Benefits of the AIR Program

The best way to evaluate the effectiveness of the AIR Program is to compare air quality with the Program to air quality without the Program. However, it is very difficult to determine what the air quality would be if the Program did not exist, because many factors besides the AIR Program affect air quality (e.g., changes in the weather, effects of pollutants from sources other than motor vehicles, changes in the vehicle fleet technology, effects of other pollution control programs). The existence of these other factors makes it very difficult to isolate the effect of the AIR Program on air quality.

The benefits of the AIR Program were estimated through several methods. One method was to analyze the changes in emissions before and after vehicles are repaired during calendar year 1998 and the first five months of 1999. We then projected the emissions benefit to the entire vehicle fleet to estimate an annual percentage reduction in fleet emissions. This method showed an emissions benefit for carbon monoxide of about 6 percent for 1998 and about 8 percent for 1999 for all on-road gasoline vehicles. It is important to note that this annual benefit may not adequately reflect the benefit of vehicles that were repaired the previous year, and still may have a benefit in the current year (so called “cumulative” benefits of the program).

We also projected emission reductions by means of a mathematical model used by the U.S. Environmental Protection Agency (EPA) for emission projections. An updated version of an EPA model (“Serious CO Area Model”) was used which reflects more recent trends in vehicle technologies and inspection/maintenance (I/M) benefits. The model does incorporate the cumulative benefits of I/M. The application of this model to the Denver area estimated a carbon monoxide reduction of about 17 percent in calendar year 1999. Lastly, we compared the emission reductions from these methods to those found in three Colorado remote sensing studies. The reduction in carbon monoxide in these studies ranged from 4 to 19 percent.

Each of the methods had a different estimate of the emissions reduction for carbon monoxide. Consequently, we believe a range provides the best estimate of the emissions benefit of the AIR Program. We estimate the emissions benefit range for carbon monoxide to be between 8 and 17 percent in 1999 for all on-road gasoline vehicles. This range is considerably lower than the carbon monoxide benefit range of 7 to 34 percent estimated by the Air Quality Control Commission, a 31 percent benefit predicted in the State Implementation Plan (i.e., Colorado’s plan to achieve compliance with federal standards), and a 30 to 34 percent benefit range estimated in the 1998 audit of the AIR Program.

Based on our analysis of the changes in emissions before and after vehicle repairs, we estimate the emission reductions for hydrocarbons to be about 6 percent, with nitrogen oxide emissions increasing by less than one percent.

Future Need of the AIR Program

In addition to the significant improvements that have already taken place in air quality, there is an influx of new technology and stricter federal emission standards that will lower carbon monoxide emissions even further in years to come. For example, there are various new federal requirements affecting carbon monoxide emissions that are either currently being implemented, or will be implemented in the near future. We estimate that over 50 percent of Colorado's passenger vehicles will be equipped with the technologies to meet federal emission standards by about 2005, and over 90 percent by about 2012. Also, onboard diagnostic systems began to be installed in automobiles for 1996 and later model years. Onboard diagnostic systems notify drivers of problems with emission control technologies in their vehicles, so that drivers can get the problems fixed. It is possible that onboard diagnostics can help reduce or eliminate the future need for state emission inspection programs because monitoring of emission control technologies will be performed by the vehicle. However, this does require drivers to respond to system problems by getting their vehicles repaired, and it is currently not known how well drivers will respond as vehicles age.

We attempted to determine whether the improved air quality trends will continue in the future. We did so by projecting carbon monoxide, hydrocarbon, and nitrogen oxide emission from 1995 to 2010. We used emissions projection models that take into account as many of the new technologies as possible. The results of our projections for carbon monoxide in the Denver Metro area are shown in Figure 1-1.[1] The results indicate the following.

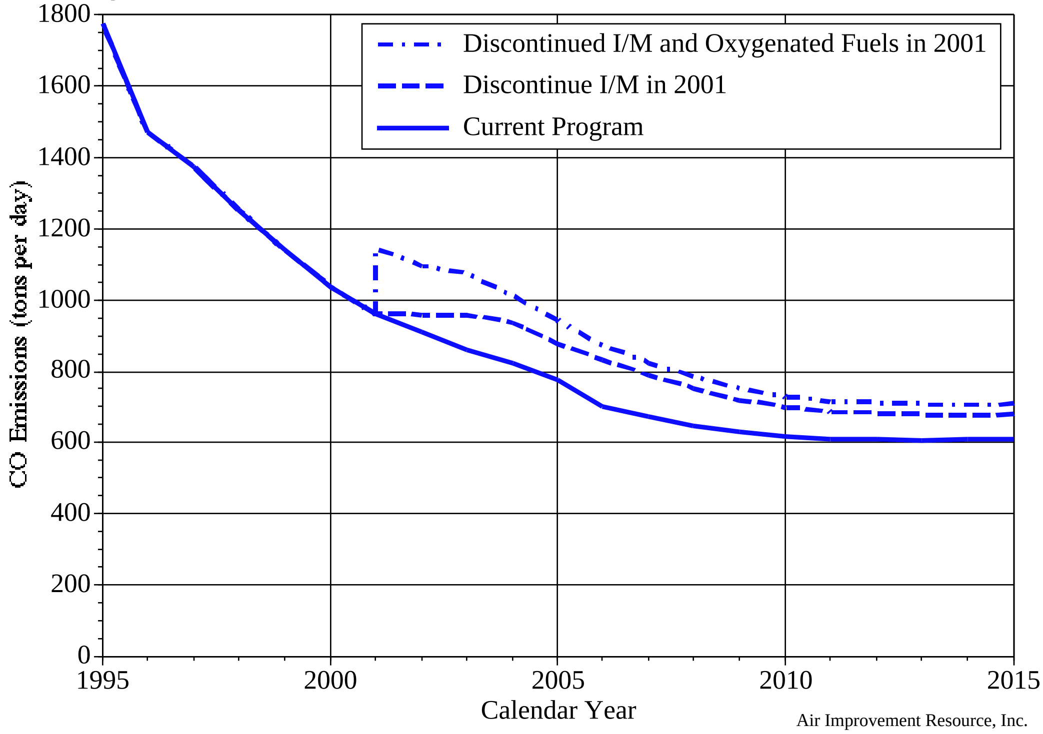
- Under the current AIR Program, carbon monoxide emissions will be reduced by 65 percent between 1995 and 2010, in spite of the growth anticipated in the region.

- Even if the AIR Program is discontinued in 2001, carbon monoxide emissions appear to level out for 2 years and continue to decline thereafter. The percent reduction between 1995 and 2010 is 61 percent.

- If the AIR *and* Oxygenated Fuels Programs are discontinued in 2001, carbon monoxide emissions increase by 14 percent and then start to decline again. The carbon monoxide reduction from 1995 to 2010 is 59 percent. The temporary increase would not be expected to cause a violation of the carbon monoxide standard because ambient carbon monoxide levels are already 35 to 60 percent below the standard. However, to avoid the increase in carbon monoxide emissions due to the discontinuation of the Oxygenated Fuels Program, one option would be to phase down the Program similarly to what is proposed in the Redesignation Request and Maintenance Plan recently prepared by the Regional Air Quality Council (described further below).

[1] We have used the upper bound estimate for the AIR Program benefit in the analysis summarized in Figure 1-1. In this manner, the impacts of discontinuing the Program represent a worst-case estimate.

Figure 1-1. Carbon Monoxide Projections for Denver Metro Area



The trends are similar for hydrocarbon and nitrogen oxide emissions which are precursors for ozone (i.e., these compounds lead to the formation of ozone). The sum of hydrocarbon and nitrogen oxide emissions will decline by 50 percent from 1995 to 2010 under the current Program. If the AIR Program is discontinued in 2001, ozone precursor emissions increase slightly over the short-term (by about 6 percent) and continue to decline thereafter. Under the discontinuation scenario, ozone precursor emissions will decline by 42 percent from 1995 and 2010.

The implications of these projections are profound. They suggest that even if the AIR and Oxygenated Fuels Programs are discontinued in 2001, there will be little short or long-term impact on carbon monoxide, hydrocarbon, and nitrogen oxide emissions in the Denver Metro area. This is because new technology and fleet turnover will continue to reduce motor vehicle emissions, even with existing growth.

EPA Requirements for Redesignation to Attainment Status

The Denver Metro area is currently designated by the EPA as a serious non-attainment area for carbon monoxide. Because the Denver Metro area has not had any violations of the carbon monoxide standard since 1995, it is eligible for redesignation to attainment status.

The Regional Air Quality Council, with the help of the Colorado Air Pollution Control Division, is in the process of preparing a Redesignation Request and

Maintenance Plan. Among other requirements, the Plan must demonstrate that the Denver Metro area will maintain the carbon monoxide standard for at least 10 years following redesignation by the EPA. The Plan must also contain contingency measures that could be implemented if a violation of the standard is monitored at any time during the maintenance period.

Before being submitted to the EPA, the Plan must be approved by the Air Quality Control Commission, the General Assembly, and the Governor. The EPA has up to two years to review and approve the redesignation request.

The Maintenance Plan includes some proposed changes to the two primary control strategies currently used for carbon monoxide (vehicle inspections and oxygenated fuels). One is to gradually decrease the use of oxygenated gasoline. This would involve a gradual reduction of the minimum oxygen content requirement from the current level of 3.5 percent to 1.5 percent by November 2005.

The other significant change is to implement a remote sensing, clean screening program. The remote sensing program is intended to reduce the number of vehicles subjected to routine inspection. The remote sensing program is planned to be phased-in starting January 1, 2002 and cover 80 percent of the on-road vehicles by 2006. The Maintenance Plan projects that nine percent of the Denver Metro vehicles will be exempted by remote sensing in 2003 and 36 percent by 2006.

The basis used in the Redesignation Request and Maintenance Plan to project future emissions is EPA currently approved emissions model (MOBILE5b). The Plan acknowledges that this model is outdated. It underestimates the recent decline in carbon monoxide emissions over time and over-predicts the benefits of I/M and oxygenated fuel programs. The Regional Air Quality Council plans to revise the Maintenance Plan once the EPA approves an updated emissions projection model.

It is not clear whether or not the Regional Air Quality Council will also update the Maintenance Plan analysis with a more recent carbon monoxide design value, which would be substantially lower than the 16.2 ppm currently used. Updating the analysis to a more recent design value should be considered as equally as important to updating the emissions model.

Considerations for Future Program Changes

The State is currently facing some major decisions about the future of the AIR Program. There are several reasons for this. One is the need to decide what type of vehicle inspection program or other pollution control strategies are necessary in the future to show continued maintenance of federal air quality standards. Another reason is to decide what to do after the State's contract with Envirotest to perform the IM240 test expires on December 31, 2001.

We believe there are several factors that the General Assembly and the Governor should consider in making these decisions.

Carbon Monoxide Air Quality Should Continue to Improve in the Future, in Spite of Growth in the Region

Carbon monoxide air quality has greatly improved over the last 10 years. All program areas were 35 to 65 percent below the federal standard for carbon monoxide in 1998. Our projections show that carbon monoxide emission will continue to decline even if the AIR Program is discontinued beginning in 2001. Continued reduction of carbon monoxide and other pollutants will occur because of new automobile technology and fleet turnover. Therefore, it is questionable whether any type of vehicle inspection program is needed to meet federal carbon monoxide standards in the future.

Addressing ozone air quality is somewhat more complex due to the chemistry involved in ozone formation and due to contributions from sources other than motor vehicles. In the Denver area, trends in 1-hour ozone concentrations have declined slightly and trends in 8-hour ozone concentrations have remained fairly flat or have increased slightly. The region continues to be below the federal 1-hour standard, and currently there is no federal standard for 8-hour ozone concentrations.[2] If additional reductions in ozone precursors from motor vehicles were found to be needed in the future, a vehicle inspection and maintenance program is one of several control options that could be implemented to reduce hydrocarbons and nitrogen oxides. However, with or without the current AIR Program, we estimate that ozone precursor emissions from motor vehicles will continue to decline.

Current Proposal to Modify the AIR Program May Not Be Warranted

The Redesignation Request and Maintenance Plan currently proposes that the enhanced program area be modified to include a remote sensing, clean screening program with 80 percent fleet coverage. Based on our estimates, this program will exempt about one-third of the automobiles that would otherwise be required to have a vehicle inspection and will still require two-thirds (about 600,000) of the vehicles to be periodically tested. We estimate that the clean screen with 80 percent coverage will cost an additional $5.8 million to implement in order to save $9.7 million in I/M costs and will result in a net program savings of about $3.9 million. Based on the current air quality in the Denver Metro area and our projections of air quality when this program will be fully implemented (2006), it is questionable whether a program of this magnitude and additional cost is warranted. This program is similar to the current Enhanced Program from the standpoint that it requires most vehicles be tested to prove they are clean. Since only about 7 percent of the automobiles will fail the IM240 test during 1999, most motorists will have their vehicles inspected unnecessarily. Alternatively, there are much

[2] The EPA recently published new federal air quality standards for ozone (8-hour) and fine particulate matter (24-hour and annual). These standards have since been remanded by the courts back to the EPA for further justification. The timetable for the establishing an 8-hour ozone standard, if at all, is uncertain.

lower cost methods of exempting vehicles from inspection, as explained in the Appendix to the Executive Summary.

Obtaining EPA Approval for Possible Elimination of the AIR Program

As discussed above, the State must show it can maintain compliance with the federal standard for carbon monoxide for at least 10 years following redesignation to attainment status. The scientific evidence suggests that the State may be able to comply with the carbon monoxide federal standards without a vehicle inspection program. However, we understand that it is currently very difficult to obtain EPA approval to eliminate the AIR Program. The primary reason is that current EPA models and processes are structured in ways that almost require the State to have some type of vehicle inspection program. We believe the State should take an assertive position when working with the EPA to overcome obstacles to redesignation, using scientific evidence to demonstrate future compliance with federal standards without a vehicle inspection program. If the General Assembly and Governor want to continue some inspection and maintenance program to address gross polluting vehicles or to reduce hydrocarbons and nitrogen oxides emissions, then we recommend the following points be considered.

- The program should address only the high-risk portion of the vehicle fleet (typically older vehicles that do not have adequate emission control technology).

- The program chosen should be the least costly and least intrusive to Colorado vehicle owners.

- Any model used for projecting program design and program effectiveness should incorporate assumptions based on the most recent technology, and actual program experience.

Department of Public Health and Environment Response to the Colorado AIR Program, 1999 Audit

The Colorado Department of Public Health and Environment (the Department) appreciates the opportunity to respond to the findings and conclusions of the 1999 Audit of the Colorado AIR Program. We believe the audit process is valuable, constructive and can lead to meaningful improvements in our air quality programs. The Department looks forward to continuing the collaborative approach to develop future strategies for the protection of Colorado's air quality. The Department is currently working closely with interested stakeholders to develop a carbon monoxide redesignation plan. It is anticipated that this plan will be submitted to the EPA early in the year 2000. We are including many of the issues in this report in our stakeholder evaluation process of the plan.

Overall, the Department agrees with the auditors' conclusion that general trends show the air quality in Colorado is improving. However, we have concerns regarding the report's projections related to air improvement because the projections cannot be verified. For example, the audit report concludes that elimination of the current motor vehicle Inspection and Maintenance and Oxygenated Fuel programs will not result in a violation of the ambient air quality standard. We believe that this conclusion cannot be supported because of problems with the model the auditors used to project future air quality.

The conclusions in the report are based upon the application of the Serious CO Area Model, rather than the EPA's approved model (MOBILE5). We agree that the MOBILE5 Model has several shortcomings, but we have been unable to determine whether the Serious CO Area Model is any better. The Department has conducted a cursory review of the Serious CO Area Model to determine if it is indeed more viable than the MOBILE5 model for use in Colorado. (A cursory review was done because the model was not available in final form until August of 1999 and substantial effort would be required to conduct a detailed review.) We found that the Serious CO Area Model considers some factors that the approved MOBILE5 does not (i.e., lower deterioration rates, off cycle and aggressive driving effects, and updated oxygenated gasoline benefit estimates). However, we believe the following shortcomings offset the benefits of these additional factors:

- *The Serious CO Area Model has no complete documentation and user guide, reducing the likelihood that analyses are conducted consistently and properly and that results are appropriate.*

- *The Serious CO Area Model does not consider high altitude driving conditions—a critical factor in Colorado's air quality. It also fails to consider factors such as national low emitting vehicle credits or on-board-diagnostic features.*

- *The Serious CO Area Model does not include a method to evaluate or project volatile organic compounds or oxides of nitrogen which lead to the production of* *ozone.*

- *The Serious CO Area Model has not withstood the rigors of a peer review or the EPA approval process.*

Based on our review of the Serious CO Area Model, we question whether it can adequately consider Colorado's situation and meet the rigorous process requirements set forth by EPA. Although we support the development of new (and more accurate) models, relying on the future projections produced with this unapproved model puts the State of Colorado at risk both financially and with regard to air quality. For example, relying on these projections and discontinuing the Inspection and Maintenance and Oxygenated Fuel programs would jeopardize compliance with the requirements for the State Implementation Plan and would leave Colorado unable to demonstrate compliance with federal transportation air quality requirements. Failure to comply with these standards would pose an immediate threat of Federal sanctions on transportation funding that flows to the State.

AUDITOR'S ADDENDUM: Response to the Department of Public Health and Environment

This addendum clarifies the use of the Serious CO Area Model for the analyses completed as part of this study and for general regulatory planning purposes. It is provided in response to the comments provided by the Department of Public Health and Environment in which the model is not properly characterized.

The Serious CO Area Model was prepared by the EPA to facilitate regulatory air quality planning activities in serious carbon monoxide non-attainment areas such as Denver. It will officially be released shortly, and unofficial versions have already been made available to serious carbon monoxide non-attainment areas including Denver. The model was provided as an updated alternative to the model's predecessor (MOBILE5), which is considered outdated in many key aspects important to modeling carbon monoxide emission inventories. For carbon monoxide plans currently under preparation, EPA is permitting the use of either model, MOBILE5 or the Serious Area CO Model. EPA expects that the Serious CO Area Model will be used in carbon monoxide plans for Fairbanks and Anchorage, Alaska and Spokane, Washington. The model is also being considered for use in Las Vegas, Nevada.

The improvements incorporated into the Serious CO Area Model are described in this report and are not repeated here. Additional specific comments on the issues raised by the Department of Public Health and Environment are as follows.

- The model *does* include the effects of onboard diagnostics; MOBILE5 does not.

- The effects of high-altitude driving conditions are the same as MOBILE5.

- Neither MOBILE5 nor the Serious CO Area Model properly accounts for the impact of National Low Emission Vehicle (NLEV) standards on carbon monoxide. The NLEV program will serve to further reduce future-year carbon monoxide emissions from those levels currently predicted by the models.

- The operation of the model is not significantly different from MOBILE5b thus the existing User's Guide is suitable for use with the Serious CO Area Model.

- Emissions of volatile organic compounds and oxides of nitrogen are not a consideration for carbon monoxide planning. For example, the recent Redesignation Request and Maintenance Plan prepared by the Regional Air Quality Council does not include inventories for volatile organic compounds and oxides of nitrogen.

[This page is intentionally blank.]

APPENDIX TO EXECUTIVE SUMMARY: AIR Program Modifications and Alternatives

Even though our future projections suggest that the AIR Program may not be needed because the Program will have little impact on emissions, we evaluated potential modifications to the Enhanced Program. We did so to provide an assessment of alternatives to the Enhanced Program that could be considered by the State if deemed appropriate.

Modifications of the AIR Program

We evaluated the cost-effectiveness of three modifications that could be made to augment the current Enhanced Program. These supplemental modifications include:

(1) additional model year exemptions (i.e., exempting more newer vehicles from emissions tests),

(2) vehicle profiling (i.e., testing only vehicles with a higher probability of failure), and

(3) a remote sensing, clean screen program (i.e., using remote sensing devices to exempt some vehicles from a vehicle inspection).

There was little change in the carbon monoxide benefit for the three options compared to the benefit of the current Enhanced Program (less than 10 percent change in benefit). Of the three options, exempting additional model years costs is essentially free to implement, there are minimal costs associated with vehicle profiling, and the costs of remote sensing clean screening are fairly high since a new inspection infrastructure must be put into place. We estimate that the remote sensing clean screen infrastructure costs range from $3.7 million for 50 percent fleet coverage to $5.8 million for 80 percent fleet coverage. These are additional costs incurred by the Program. If the State were to continue the current Enhanced Program structure with some modifications, it would be better to maximize the minimal cost screening alternatives (i.e., additional model year exemptions and vehicle profiling) before adding a remote sensing clean screen program that is much more costly.

Alternatives to the AIR Program

We also analyzed the cost-effectiveness of three alternatives that could replace the current Enhanced Program. These are:

(1) conversion from centralized (single contractor) to decentralized (multiple contractors) transient testing,

(2) conversion to an idle test for all vehicles, and

(3) using remote sensing for two levels of fleet coverage (50 percent and 80 percent) to detect high emitting vehicles only (i.e., this process would not screen for low emitting vehicles).

Our analysis of AIR Program alternatives is summarized in Table 1-1 below. Converting to decentralized testing indicates that costs and benefits would stay essentially the same as centralized testing but there may be significant transition issues for this alternative. Of the other alternatives, each achieves a reduction in Program cost and also loses a portion of the current program's carbon monoxide benefit. The idle program would fail a significantly greater number of vehicles, yet produce less benefit. The remote sensing program with IM240 confirmatory testing achieves the greatest cost savings ($16.0 to $22.2 million saved) while retaining 42 to 65 percent of the current carbon monoxide benefit. However, there is higher level of risk and uncertainty with the remote sensing options because a program of this size has not been implemented elsewhere.

Table 1-2. Replacement Alternatives for Existing Enhanced Program 1999 Calendar Year

Program	Program Cost (Million $)	Vehicles I/M Tested (Annual)	Vehicles Repaired (Annual)	% of Program Carbon Monoxide Benefit Retained
Existing Enhanced Program	$33.4	894,659	61,236	100%
Decentralized Transient	$33.4	894,659	61,236	100%
Idle Program	$28.7	894,659	138,404	74%
80% Remote Sensing with IM240 Confirmatory Testing	$17.4	151,462	26,178	65%
50% Remote Sensing with IM240 Confirmatory Testing	$11.2	94,664	16,361	42%
80% Remote Sensing with Idle Confirmatory Testing	$18.0	151,462	50,277	48%
50% Remote Sensing with Idle Confirmatory Testing	$11.6	94,664	31,423	30%

2. Introduction

The AIR Program has been in existence in Colorado since the latter half of 1980. During that time, it has changed and improved many times, to adapt to the needs of the state, the requirements of EPA, and to the on-road vehicle fleet. In the 1980s, there were many exceedances of the carbon monoxide (CO) air quality standard, providing ample justification for the program. However, there have been no exceedances of the CO air quality standard in Denver metro since 1995, and earlier for the remainder of the state. The lack of a clear CO air quality need has led to questions about whether or not it is time to change the AIR Program again, or discontinue it altogether. Several organizations in the State are grappling with these issues at this time.

In June of 1999, the Colorado State Auditor's Office contracted with Air Improvement Resource, Inc., of Novi, Michigan to perform the 1999 Audit of the Colorado AIR Program. In June and July, Air Improvement Resource met with the Auditor's Office and the Technical Advisory Committee to refine the tasks that we would perform in addressing these questions. We settled on three primary tasks, as follows:

Task 1 – Estimate the benefits of the current AIR Program
Task 2 – Evaluate alternatives to the current AIR Program
Task 3 – Project emissions into the future for the current AIR Program and the various alternatives

After finalizing the tasks, Air Improvement Resource obtained much I/M and other data from the State relative to the project, and other references from other sources. The Technical Advisory Committee was especially helpful in identifying sources of data and analyses that assisted in this analysis. In mid-September Air Improvement Resource met with the Technical Advisory Committee a second time, to present preliminary results and seek the Committee's input on various items. The Committee provided valuable feedback on the focus for the remainder of the project. Air Improvement Resource produced a draft report in early October, which was reviewed by the Technical Advisory Committee. Air Improvement Resource incorporated most of the comments provided by the Committee. The Auditor's department also assisted in writing the Executive Summary.

The 1999 I/M audit is organized in the following manner.

- Chapter 3 – Background – discusses the history of the I/M program, the organizations that have responsibility for the Program, our summary of last year's audit and the status of implementation of those recommendations, recent reports and documents such as the Redesignation Request and Maintenance Plan, and Report to the Legislature on I/M, and finally, the trends in air quality in Colorado.

- Chapter 4 – Benefits of The Current Colorado AIR Program – uses data obtained from the State and other sources to estimate the benefits of the current AIR

Program, and compares these estimates with last year's audit, and benefits as estimated by other techniques and sources.

- Chapter 5 – Impacts of Current and Future Technology – explains which vehicle technologies are being implemented now and in the near future as they will have an impact on reducing CO, hydrocarbons (HC), and nitrogen oxides (NO_x) in Colorado.

- Chapter 6 – Projections of Emissions – discusses the tools that could be used to project emissions in the future, and makes estimates of these emissions in the future using the latest available tools at this time. This chapter includes an estimate of the current program in the future, and also an assessment of the result if the AIR Program and the oxygenated fuels programs were discontinued, or phased-down.

- Chapter 7 – Analysis of AIR Program Modifications – discusses a number of options to the current program, some of which could decrease the costs of the Program significantly without a large impact on benefits.

- Chapter 8 – Methods of Evaluating the Effectiveness of Program Changes – discusses ways in which Colorado could monitor the effects of program changes.

Chapters 1, 2, and 3 follow a traditional organization style. To facilitate the readability of the report, the remaining chapters present summary information first, followed by a brief description of methods used, and then a review of other sources. Our recommendation is that the summaries of all chapters be read first and then the detailed material in each chapter, as needed. Additional information from each chapter is also included in appendices.

3. Background

This chapter contains a history of I/M in Colorado, describes the organizations in Colorado that have responsibility for planning, implementing, and operating the I/M program, reviews recent reports related to the AIR Program, and reviews recent trends in air quality.

A. History of I/M in Colorado

The AIR Program started inspecting government fleets and a change of ownership vehicles in the latter half of 1980. The Program was expanded for the general public in the eight Front Range counties, including the Denver metro area, Fort Collins, and Colorado Springs in 1981. A single speed idle test was used to inspect all cars and the lightest of the light duty trucks on an annual basis. Facilities licensed to perform the test could also perform repairs. The initial program was a sticker-based program, where complying vehicles displayed a sticker on the vehicle.

The Program was changed in 1982 when it was expanded to include 1968 and newer trucks less than 10,000 lbs. gross vehicle weight (GVW). A tampering inspection was also added for all newer vehicles. In the latter 1980s, the inspection equipment was upgraded, and the State went to a two-speed idle test, instead of the single idle test. In the latter 1980s, the newest 5 model year vehicles went to an inspection on a biennial basis, with the remainder of vehicles on an annual test. The two-speed idle test was dropped for certain vehicles experiencing a high probability of false failures. The Program also went to registration enforcement, instead of a sticker-based program. Also, inspections were expanded to heavy-duty gasoline vehicles. Finally, tampering inspections were expanded back to the 1975 model year, and a significant number of vehicles experienced catalyst replacements. I/M tests were also started in the Greeley area in 1988.

In 1990, the Clean Air Act was amended by Congress, and areas with CO "design values" above 12.7 ppm were required to implement enhanced I/M by January 1, 1995. The "design value" is the CO level that EPA uses to determine if a state or area is in nonattainment. Denver's design value is 16.2 ppm, which was the ambient concentration registered in the Denver/Boulder area on December 5, 1988. The remainder of the design values in the State were below 12.7 ppm, and thus the other areas were not required to have enhanced I/M.[3]

After the 1990 Clean Air Act amendments were finalized, preparations then began to implement enhanced I/M in the Denver area. In 1994, prior to the advent of enhanced I/M in Denver, every vehicle was required to be inspected. In 1995, the Denver area test changed to the IM240 transient test on a biennial basis for all 1982 and later vehicles (including change-of-ownership), and inspections were performed by a contractor

[3] The other Design Values were as follows (all 1988):
Colorado Springs: 11.8, Ft. Collins: 11.3, Longmont: 10.2, and Greeley: 9.2.

(Envirotest). The youngest four model years of vehicles were exempt from the program. Pre-1982 vehicles continued with annual two-speed idle tests at test-only facilities. The State signed a seven-year contract with Envirotest to perform IM240 testing in the Denver area; the current contract expires at the end of 2001. The IM240 test was implemented in 1995 and 1996 with fairly loose emission standards, or cutpoints, because of the concern on the part of the State of the effect of high altitude on the overall, initial failure rate. The cutpoints were lowered to an interim set for 1997 and 1998, and lowered once more to a final set of cutpoints on January 1, 1999. The idle test cutpoints have remained the same for several years.

The people of Colorado currently spend about $39 million per year on the AIR Program for inspections, repairs, and administrative costs minus the fuel economy savings (see Chapter 4, Table 4-7). For comparison, they spend about 12 million dollars per year on the oxygenated fuels program, which runs for 2_ months in the winter season. [1] [4]

B. Organizational Responsibilities

A number of organizations in Colorado have responsibilities for planning and implementing various aspects of the AIR Program, as follows:

- The Colorado Air Quality Commission is responsible for overseeing the AIR Program and reports to the Legislature. The most recent report was sent to the Legislature on September 1, 1999.

- The Regional Air Quality Council (RAQC) is designated by the Governor as the lead air quality planning agency in the metro Denver area. The RAQC and the Colorado Department of Public Health and the Environment (CDPHE) are responsible for evaluating all aspects of the AIR Program to ensure compliance with the State Implementation Plan (SIP).

- The RAQC and CDPHE are also responsible for preparation of all SIPs. These organizations recently prepared a "Proposed Carbon Monoxide Redesignation Request and Maintenance Plan for the Denver Metropolitan Area", which was forwarded to the Air Quality Commission for approval on September 27, 1999.

- The Department of Public Health also maintains and analyzes the emissions inspection data, and reports the results of the analyses to the RAQC.

- The Department of Revenue is responsible for all licensing requirements for mechanics and inspection stations. In addition, they provide program oversight to these facilities, and conduct various audits of the facilities to ensure compliance with regulations. The Department of Revenue also receives all fees related to the program, and supervises the contract with Envirotest. The Department of Revenue

[4] Numbers in brackets refer to references used in the report. The reference refers to the statement prior to the bracket.

also submits an Annual Report to the Legislature, which is contained in the Colorado Air Quality Control Commission's report to the Legislature.

· The various County Clerk's offices ensure that vehicles comply with the AIR Program requirements prior to issuing new registrations. These offices collect the fees for the Program, and forward these fees to the Department of Revenue.

· The Office of the State Auditor is responsible for performing periodic audits of the overall program. The most recent audit was conducted in 1998.

The following sections review in chronological order the 1998 Audit (March 1998), the recent Colorado Air Quality Control Commission report to the Legislature (September 1, 1999), and the Proposed CO Redesignation Request (September 27, 1999).

1. 1998 Audit

In the 1998 audit, the contractor examined the emission benefits, costs and cost-effectiveness of the AIR Program, CO air quality trends in Colorado, and made various recommendations for further study and development of the Program. [1] Overall, this audit found that the Program was providing significant CO benefits (even though these benefits could not be discreetly detected from the effects of other factors such as fleet turnover in the ambient air measurements), that the cost-effectiveness of the Program was comparable to the oxygenated fuels programs and other mobile source programs recently adopted by EPA, and that there was widespread improvement in CO levels in Colorado. This widespread improvement in CO levels was directly attributed to consistent reductions in the on-road CO emissions inventory.

The 1998 Audit formulated recommendations on improving emissions data quality, training data entry personnel, conducting an operational audit of the Program, and evaluating other program options such as remote sensing for use in the AIR Program. In this year's audit, we determined that all of these recommendations had been acted-upon by the various responsible agencies. For example, we found that AIR Program emissions data quality had improved considerably, and that very little processing of the data was necessary to obtain a very useable database for analysis. Other recommendations, like evaluating remote sensing and its potential role in the AIR Program, are ongoing efforts by the agencies, and are also part of this year's audit.

2. Air Quality Commission Report to Legislature

The most recent "Report to the Colorado General Assembly on the Automobile Inspection and Readjustment Program" was finalized on September 1, 1999. [2] The report summarizes the AIR Program CO benefit as between 7 and 34 percent, depending on the method used to estimate the benefit, and notes that there have been no CO exceedances in the Denver area since 1995. The report requests authority from the Legislature to establish a clean screen program to exempt clean vehicles from inspections, and to utilize other means such as model year exemptions and emissions profiling to exempt more vehicles from inspections. In addition, the report states that the AIR Program should identify and repair smoking vehicles, and goes on to request funding for the CDPHE to develop a baseline of motor vehicle emissions from which to compare changes in the AIR Program, and funding to establish positive incentives for motorists to maintain vehicle and reduce emissions.

3. Redesignation Request and Maintenance Plan

The "Proposed Carbon Monoxide Redesignation Request and Maintenance Plan for the Denver Metropolitan Area" was developed by the RAQC and submitted to the Air Quality Commission on September 27. [3] The Plan notes that based on the fact that there have been no exceedances of the CO NAAQS for the past few years, that Colorado is currently eligible for redesignation as an area that is attainment for CO. The Plan lists the five requirements for a redesignation request, one of which is that the State must have a Maintenance Plan which shows that the area can meet the CO standard for 10 years following redesignation by the EPA. The Maintenance Plan must also contain contingency measures that could be implemented if a violation of the standard is monitored at any time during the maintenance period.

The Maintenance Plan calls for a continuation of the AIR Program in the Denver area with a remote sensing clean-screen,[5] and a gradual phase-down of the oxygenated fuels program to a lower level of oxygen content. These changes are summarized in Table 3-1.

Table 3-1. Future Mobile Source Program in Denver

Year	Estimated CO Inventory (tons per winter day)	Oxygen Content	Estimated Percent of On-Road Fleet Evaluated with Remote Sensing
2002	851	2.7%	Program start
2003	850	2.6%	20%
2004	827	2.0%	40%
2005	850	1.9%	60%
2006	846	1.5%	80%

The Maintenance Plan demonstrates attainment through 2013, ten years after the redesignation request is expected to be approved by the EPA. The Plan used EPA modeling techniques available at the time of preparation; however, it recognized that EPA modeling practices were changing very quickly. Therefore, the Plan viewed the above I/M and oxygenated fuel programs as placeholders until EPA revised its emission models, at which time, a new Maintenance Plan would be prepared that was equivalent, but different than the Plan already submitted to the EPA. Finally, The Plan contemplates spending an additional 5 million dollars per year on Remote Sensing to save about 10 million dollars in inspection costs, for a net savings to the people of Colorado of about 5

[5] In this program, remote emissions sensing devices placed by the side of the road measure emissions from vehicles passing by. Vehicles with low emissions are exempt from their next scheduled AIR Program test, provided their next scheduled test is within a few months of the on-road emission measurement.

million dollars per year over the current 39 million dollar per year cost. In this study, we reviewed these costs. Our analysis is found in Chapter 7.

Due to the need to prepare the Maintenance Plan quickly and prepare a Plan with a high likelihood of being accepted by the EPA, the Plan relied as much as possible on past modeling efforts. Two key factors were carried-over from previous modeling efforts: the use of the 1988 CO design value, and the use of the EPA MOBILE5b model to predict emissions in the future. The 1988 design value is very high (16.2 ppm), and the MOBILE model is expected to over predicts CO emissions in the future (due to outdated technology assumptions), so these two factors contribute to the projected need for enhanced I/M and oxygenated fuels in the Maintenance Plan. Alternatively, the State could have used a more recent (and lower design value)[6], and also could have attempted to use an alternative model, the EPA Serious Area CO Model. In doing so, the anticipated control programs might have been very different. The State considered this seriously, however, this would have required much additional analyses and taken additional time that the parties did not have, and submission of a Plan using these inputs might have been less acceptable to the EPA. EPA's policy on the use of the Serious CO Area Model has not been released, but currently, EPA is allowing states to use the Serious CO Area Model that may be required to implement additional programs: EPA may not allow the use of the model to ramp-down on certain programs.[7] Also, the State was concerned that EPA was not fully supporting the Serious Area CO Model, and that if the Plan was not accepted by the EPA, that the State would have to re-do the entire Plan, thus delaying the Plan by a year or so. Thus, the Maintenance Plan was prepared using MOBILE5b and the 1988 design value, and the State currently plans to update all of this analysis (both the design value and the model) once the fully supported MOBILE6 model is available (scheduled for release in 2000).

Regarding how the State would proceed to amend the existing Maintenance Plan once accepted by the EPA, and once new modeling by the State is conducted, a discussion of the options available here and potential outcomes is beyond the scope of this audit.

C. Air Quality in Colorado

As a part of this audit, we asked CDHPE to provide a recent analysis of CO, ozone, particulate matter (PM) air quality levels and trends in Colorado. The purpose of this request was to examine the air quality context of potential changes in the AIR

---

[6] We are not suggesting the use of a later design value just because it is conveniently lower than the 1988 value, but because it is much more current. The Maintenance Plan is projecting emissions to 2013, or 25 years beyond 1988. We think it is appropriate to narrow the time period between the design value and the latest projection year by selecting a more recent design value from mid-1990s.

[7] It may take a state like Colorado submitting a Plan utilizing the Serious CO Area Model to test EPA's resolve. To us, it does not make sense to allow the use of a model for states having to implement programs, and not allow its use for states wanting to ramp-down on programs. This may become a moot point if EPA releases MOBILE6 this year, but if further delays in the release of MOBILE6 are encountered, the use of the Serious CO Area Model may become a viable option for Colorado.

Program. Their analysis is provided in Appendix A. The results are briefly summarized below.

CDHPE examined CO trends from 1989 through 1998. The trends in average and CO levels and 95th percentile CO levels over the past ten years are down. The analysis also provided 2nd maximum 8-hour CO values over the past two years. The 2nd maximum values are the most appropriate levels to compare to the CO ambient standard of 9 ppm. These are shown in Table 3-2 below. The data indicate that all of the 2nd highest CO values in the State are currently well below the 9 ppm level.

Table 3-2. 2nd Maximum 8-Hour CO Values (ppm) for 1997 and 1998*

County	1997	1998
Adams	4.3	3.5
Arapahoe	2.8	N/A
Boulder	5.4	4.8
Denver	6.4	5.2
Jefferson	4.9	3.6
El Paso	4.9	6.1
Larimer	5.2	4.1
Weld	4.8	4.4
Mesa	5.4	5.3

* The CO standard is 9 ppm, an exceedance takes place when the level is above 9.5 ppm

CDHPE also examined 2nd maximum, average, and 95th percentile 1-hour ozone trends from 1989-1996, and estimated 8-hour average ozone for 1998 to compare to EPA's new 8-hour ozone standard. The Denver area has been in compliance with the federal 1-hour ozone standard for the last decade. The trend in average ozone is downward to flat. Some locations saw significant increases in 2nd maximum ozone in 1998, but none of the locations appeared to exceed the 1-hour ozone standard of 0.12 ppm. The analysis also showed that, unlike the CO values being quite far below the CO standard, the 8-hour ozone values are very close to EPA's remanded ozone standard.[8]

The Denver metro area and Colorado Springs last exceeded the PM_{10} standards in 1993. Nearly all monitors have shown significant ambient reductions over the last 6-7 years. All Front Range monitors have been well under the annual PM_{10} standard of 500 ug/m3 for the last ten years. EPA recently adopted a new $PM_{2.5}$ standard (see footnote below). Colorado is currently implementing a monitoring network to measure $PM_{2.5}$.

Except for ozone, ambient levels of pollutants have been trending down for the last 9-10 years. Over this time period, CO, HC, and NOx emissions have declined considerably, and it is likely that the AIR Program contributed to some of the HC

[8] EPA's new PM2.5 and 8-hour standards were remanded by the courts back to the EPA for further consideration. Thus, EPA cannot currently require states to attain these standards. EPA is currently pursuing various means to get the standards reinstated.

reductions. The CO-focus of the AIR Program has resulted in a small NOx increase, but overall, the sum of HC+NOx is lower with the AIR Program (see Chapter 4).

[This page is intentionally blank.]

4. Benefits of the Colorado AIR Program

This chapter develops our estimate of the emission benefits and costs of the current AIR Program.

Section A summarizes the results of our analysis. Section B describes the method used. Section C provides additional results. Section D reviews other benefit estimates, and compares our estimate to them.

A. Summary

In our approach, we estimated the emission benefits of the repaired vehicles, for the year in which they were repaired. Our assumptions are that the repair benefit would last at least a year, that there is no deterioration in emissions for the repaired vehicles, and that vehicles that fail the test and are not tested again are assumed to be operating in the area at their failed emission levels. We did not estimate the benefit from vehicles that were repaired last year, and are still okay. These assumptions tend to cancel each other, but overall, we think our benefit estimate is conservative, or on the low side.

During 1998, approximately 1.2 million vehicles were inspected in the AIR Program in all of Colorado. Of these, 121 thousand vehicles failed their initial test, 94 thousand were repaired, and 420 were waived. The remaining 26 thousand vehicles that failed their initial test did not return for a retest. It is likely that those that did not return for a retest were retired, were sold out of the area, were subsequently registered out of the area and are still operating in the area, or are operating in the area without a current registration.

In 1998, failure rates for 1990 and later vehicles were very low, or 1 to 4 percent for the IM240 and 1 to 15 percent for the idle test. Failure rates for pre-1990 vehicles were 6 to 16 percent for the IM240, and 20 to 35 percent for the idle test. Thus, most of the AIR Program benefit came from pre-1990 vehicles.

For the vehicles that were repaired, we estimated a 50 to 60 percent CO and exhaust HC benefit for vehicles subject to the IM240 test, and a 20 percent CO benefit and a 13 percent exhaust HC benefit for vehicles subject to the idle test. For the fleet of on-road gasoline vehicles in the enhanced program area in 1998, we estimated a 6.1 percent CO benefit and a 5.1 percent HC benefit, with NOx increasing by less than one percent. For those vehicles in the basic program area in 1998, we estimated CO and HC benefits of 6.5 and 4.2 percent, respectively. The basic program area benefit was about the same as the enhanced area, owing to the higher observed failure rate of vehicles but smaller benefits per repair. In 1999, the cutpoints were lowered for 1982 and later vehicles receiving an IM240 test, and more vehicles were failed and repaired in the enhanced program area. This led to an increase in the enhanced area benefit from 6.1 and 5.1 percent for CO and HC, respectively, to 7.8 and 5.8 percent for CO and HC.

Repair costs in 1998 averaged $211 for IM240 vehicles, and about $100 for idle test vehicles. In 1999, average repair costs increase to $244 and $115. In 1998, the AIR Program net cost is about $39 million, not including inconvenience cost to motorists, which were not estimated. Of this net cost, $24 million was spent on inspection, $13 million on repairs, $5 million on administration, with a $3 million fuel economy improvement (cost benefit).

In comparison with other studies, last year's audit indicated that the CO benefit is in the range of 36 to 41 percent for the IM240 test and 15 to 18 percent for the idle test. Benefits of the enhanced program from remote sensing studies conducted in Colorado ranged from 4 to 19 percent (includes whole fleet). The new Serious CO Area Model, a forerunner of the MOBILE6 model being prepared by the EPA, predicts a CO on-road fleet benefit of 17 percent for the AIR Program in 1999. Our analysis shows the enhanced benefit (idle and IM240 combined) was 6.1 percent in 1998, and 7.8 percent in 1999 for the fleet subject to I/M. Our analysis is for only one year and does not include any potential cumulative benefits. The different studies represent a very wide range of benefits under differing assumptions and methods and represent the AIR Program at different points in time. We believe a reasonable estimate of the CO benefit of the current AIR Program ranges from 8 percent (our estimate from repairs occurring in 1999, which is conservative) to 17 percent (the Serious CO Area Model estimated benefit).

B. Method

At the most fundamental level, I/M causes vehicles which fail the I/M test to be repaired to pass the emission test, and this results in some quantifiable emission reduction on the various test cycles, that in most cases should result in in-use emission benefits as well. For example, if an I/M test identifies a vehicle with a faulty oxygen sensor, and the oxygen sensor is replaced, there *will* be in-use emission reductions over the full range of vehicle operation, and I/M will have caused the emissions benefit. Every year in Colorado, there are vehicles that fail the test, are serviced, and then pass the test. In this approach, we estimate the annual emission benefits of the repaired vehicles during the year, and estimate the percent reduction in fleetwide emissions for those vehicles covered by the AIR Program.

Like all of the other approaches, this approach requires the use of certain simplifying assumptions. The assumptions made are as follows.

1. The difference in the initial and final I/M test can be used to measure reductions in in-use emissions. This means that vehicles are not just being adjusted to "pass the test" nor is vehicle variability or conditioning causing a significant number of false failures, which would result in no real-world benefit at all. If this assumption is not valid, then we are overestimating the I/M benefits with this technique.

2. Repaired vehicles also remain repaired on average for the whole year. There is some evidence that vehicles that are repaired also experience a greater failure rate at the next inspection than vehicles that passed. [4]

3. Repaired vehicles not only stay repaired so that they would not fail in that year, but that they also do not deteriorate through the year.

4. Closely related assumption to assumption number 2, we have not estimated any *cumulative* benefit to I/M. In the technique employed, we examine only the repairs made this year, not those that have been made in previous years and carryover to this year.

5. Testing covers all of the vehicles subject to I/M. This means that there are no scofflaw vehicles that refuse to submit to an initial I/M test and are driving around the areas with either expired registrations, or they have been registered in another part of the State and are still being used in the I/M area.

6. It is possible that vehicle owners fix vehicles in anticipation of failing the I/M test. We assume that this does not occur. This program benefit, if significant, has not been accounted for in our analysis.

7. A final assumption is that "unresolved failures," which are vehicles failing the initial I/M test and never receive a passing test, continue to operate in the I/M area anyway. In evaluating the I/M program data, we find that 1 in 5 vehicles failing the initial I/M test are unresolved failures.[9] In the primary analysis, we assumed that all unresolved failures continue to operate in the area without complying, which is the most conservative assumption. As a sensitivity analysis, we removed the unresolved failures from the analysis and estimated the increase in I/M program benefit.

Summarizing the above, we have four factors which may lead to an overestimate of the I/M benefit, and three factors that may lead to an underestimate. In our view, the cumulative benefit factor causing an underestimate is probably larger than the other factors leading to overestimating the benefit.

In our method, emission reductions are estimated based on the I/M test procedure. These are translated to in-use reductions, which are somewhat different than the I/M test results. The in-use reductions were then adjusted to arrive at the percent reduction in on-road fleet emissions. The process is described in further detail in Appendix B.

We evaluated the AIR Program data for the 1998 calendar year, as this is the most recent complete year of data available. In addition, we wanted to include an examination of the 1999 calendar year, since the IM240 test cutpoints were revised January 1, 1999,

[9] There are a number of outcomes for the unresolved failures. First, they may have been scrapped. Second, they could have moved out of the area if their owners moved. Third, they could have been sold out the area. Fourth, they could be operating in the area without complying with the I/M requirement.

and it was important to be able to include the latest test cutpoints. In 1999, IM240 HC and CO cutpoints for light duty trucks were tightened significantly. For light duty vehicles, the 1999 HC and CO cutpoints reductions were much more modest. The changes in IM240 cutpoints were implemented as very few light duty trucks were failing the IM240 test in 1997 and 1998.[10]

To evaluate the 1999 calendar year, we relied on the portion of the AIR Program data available at the commencement of this study (January through May). Information provided by the Colorado Department of Public Health and the Regional Air Quality Council indicated that seasonal variation in I/M performance exists, and therefore, it is inappropriate to assume that the I/M benefit estimated for January through May is representative of the full-year 1999.[11] To estimate the full-year 1999 benefit, we examined the relative benefits of the full-year 1998 benefit to that of January through May 1998. We then assumed that the same relative changes observed in 1998 (January through May relative to January through December) are applicable to the 1999 data.

C. Results

1. Emission Benefits

Tables 4-1 and 4-2 present the failure rate results for 1998 and 1999, respectively. Table 4-1 shows that failure rates for the idle test (in both the basic or enhanced areas) are much higher than for the IM240 test in 1998. In the basic areas, the idle test is performed on all vehicles, whereas in the enhanced area, the idle test is performed on pre-1982 light duty vehicles and all model year heavy-duty vehicles. The percent of initial test failures that are repaired, waived, and unresolved are about the same in the two program areas. In 1999, IM240 test failure rate increased from 5.1 to 6.7 percent, whereas, the idle test failure rates remained are about the same in 1999 as in 1998.

Table 4-1. Initial Test Failure Rate Results 1998

Item	Enhanced		Basic Idle
	IM240	Idle	
Vehicles Inspected	678,483	163,721	320,629
I/M Failures (vehicles)	34,607	32,448	53,502
I/M Repairs (vehicles)	26,762	25,224	42,185
I/M Waivers (vehicles)	178	43	199
Failure Rate (%)	5.1%	19.8%	16.7%
Failures Repaired (%)	77.3%	77.7%	78.8%
Failures Waived (%)	0.5%	0.1%	0.4%
Unresolved Failures (%)	22.2%	22.1%	20.8%

[10] AIR Program I/M cutpoints are provided in Appendix C.
[11] The seasonal oxygenated fuels program appears to cause lower CO failure rates when oxygenated fuels are in-use.

Table 4-2. Initial Test Failure Rate Results 1999 (Projected Full-Year)			
Item	Enhanced		Basic
	IM240	Idle	Idle
Vehicles Inspected	732,267	162,384	342,994
I/M Failures (vehicles)	49,274	30,187	53,061
I/M Repairs (vehicles)	37,813	23,421	41,614
I/M Waivers (vehicles)	302	47	230
Failure Rate (%)	6.7%	18.6%	15.5%
Failures Repaired (%)	76.7%	77.6%	78.4%
Failures Waived (%)	0.6%	0.2%	0.4%
Unresolved Failures (%)	22.6%	22.3%	21.1%

Of the vehicles failing I/M, approximately 80 percent receive repairs and less than 1 percent are waived from the Program requirements. About 1 in 5 failures are unresolved. As stated earlier, we will handle these vehicles one of two ways: (1) they are assumed to continue operating in the region at the failure level of emissions, and (2) they are removed from the analysis.

The emissions benefit for repaired vehicles where emissions are expressed in terms of the I/M test is shown in Table 4-3. Both 1998 and 1999 results are reported in Table 4-3, and the emission reductions due to repairs are similar for the two years. The emissions benefit for repairs for both idle and IM240 tests generally produced a 60 to 70 percent reduction in I/M CO and HC emissions. For NOx, the negative benefit reported in Table 4-3 indicates that IM240 emissions are higher after repair, by about 23 percent in both 1998 and 1999. NOx emissions are not measured in the idle test.

Table 4-3. I/M Benefit Per Repaired Vehicle				
Calendar Year	Pollutant	Enhanced		Basic
		IM240	Idle	Idle
1998	CO	63.4%	63.0%	68.6%
	HC	58.1%	64.5%	61.9%
	NOx	-23.8%	N/D	N/D
1999	CO	69.4%	63.5%	73.4%
	HC	58.6%	64.7%	62.6%
	NOx	-22.5%	N/D	N/D

N/D = not determined

The benefits of repair as measured by the I/M test are not used directly, but are first converted to an in-use emissions basis using the data and methods documented in Appendix B. We are using the Federal Test Procedure (FTP) as the basis for representing in-use emissions. The idle test only measures steady-state engine emissions at two speeds (idle and 2500 RPM), whereas the IM240 is a transient test encompassing a wider range of operating conditions. Both I/M tests are performed on warmed-up vehicles. The FTP contains transient operation as well as vehicle start-up and cold operating conditions and thus represents more aspects of in-use driving.[12]

The estimated FTP benefit for the above idle test benefits are shown in Table 4-4. The IM240 produces a similar reduction in FTP emissions due to repair. On the other hand, repairs based on the idle test produce much less of a reduction in FTP relative to the reduction observed in the idle test score. Overall, the results show that the CO and HC emissions benefit per repair (on an FTP basis) is greater for IM240 than for the idle test. In addition, vehicles undergoing an IM240-based repair observe, on average, a 14 to 15 percent increase in exhaust FTP NOx. This is expected. Anytime HC and CO emissions are lowered; the engine and emission control system is leaner, thereby producing more NOx.

Table 4-4. FTP Benefit Per Repaired Vehicle

Calendar Year	Pollutant	Enhanced		Basic
		IM240	Idle	Idle
1998	CO	57.7%	20.8%	22.9%
	HC	57.1%	13.4%	17.4%
	NOx	-14.6%	N/D	N/D
1999	CO	57.6%	21.2%	24.5%
	HC	62.6%	13.6%	19.0%
	NOx	-14.1%	N/D	N/D

N/D = not determined

Estimated benefits for the gasoline fleet subject to I/M are shown in Table 4-5. The fleet subject to I/M is the light duty gasoline fleet in both areas plus heavy-duty gasoline vehicles in the enhanced area. Whereas Table 4-4 includes the benefits of repaired vehicles only, the benefits in Table 4-5 include all vehicles (vehicles passing inspection, unresolved failures, repaired vehicles, waived vehicles and vehicles not tested in the inspection cycle).

Table 4-5. Gasoline Vehicle Benefits of the AIR Program for the Fleet Subject to I/M (FTP Basis)

Year	Enhanced I/M			Basic I/M		
	CO	HC	NOx	CO	HC	NOx
1998	6.1%	5.1%	-0.2%	6.5%	4.2%	N/D
1999	7.8%	5.8%	-0.5%	5.6%	4.1%	N/D

N/D = not determined

[12] In addition, there are "off-cycle" emissions such as those from hard accelerations, which are not measured by the FTP. The impacts of I/M on off-cycle emissions have not been measured. In our analysis, we assumed that the FTP represents in-use emissions and thereby we assume that off-cycle emissions effect will be proportionally the same as that estimated for the FTP.

As shown in Table 4-5, the estimated CO benefit of the enhanced I/M program in Colorado was 6.1 percent in 1998, which increased to 7.8 percent in 1999 when the cutpoints were reduced. HC benefits increased from 5.1 to 5.8 percent and the NOx disbenefit increased slightly. The basic I/M program benefits appear to be about the same as the enhanced benefits in 1998, at 6.5 percent in 1998 but decreasing to 5.6 percent in 1999. There is about a 4 percent HC benefit, while the NOx impacts cannot be determined. However, based on the similarity of the HC and CO data, the NOx disbenefit is expected to be between 0 and 1 percent.

Comparing the enhanced program to the basic program, both achieve about the same overall CO benefit in 1998. However, the basic program fails far more vehicles and the benefits of each repair are less. Therefore, while the total benefits are about the same, the enhanced program is a more efficient program.

The results reported in Table 4-5 assume that unresolved failures continue to operate in the area. We also examined the impact if the unresolved failures are removed from the analysis as a sensitivity analysis. Under the sensitivity case, CO and HC benefits in 1998 increased from 6.1 and 5.1 percent, respectively, to 6.5 and 5.5 percent, respectively for the enhanced I/M program. This change represents a 6 and 8 percent increase in the CO and HC benefits. As a result of this sensitivity analysis, increases in benefits of similar magnitude were noted for the basic I/M program and for the 1999 analysis for both program areas as well.

The impact of the AIR Program on the total on-road fleet emissions (including diesel vehicles and motorcycles) can be determined by factoring out the emissions from the remaining vehicle classes not affected by the I/M program. For example in 1999 for the enhanced area, we estimated that 95, 88 and 60 percent of the exhaust emissions of CO, HC and NOx, respectively, are from the vehicle classes subject to I/M.[13] Thus the CO benefit of 7.8 percent for vehicle classes subject to I/M reported in Table 4-5 becomes a 7.4 percent benefit when expressed on a total on-road fleet basis.

Additionally, to estimate the impact of I/M on total ambient emissions, other non-mobile sources must be factored out. From the Denver CO Maintenance Plan, between 73 and 77 percent of the CO emissions are from on-road engines. [3] For HC and NOx, estimating the emissions from other sources was beyond the scope of this study, but national estimates can be found in the EPA's emission inventory trends publication [24] which estimated that 27 and 30 percent of the HC and NOx, respectively, were emitted from on-road engines in 1997.

2. Program Costs

The cost elements of the AIR Program are inspection costs, repair costs, fuel economy improvement costs, and administrative costs. The costs of motorist fuel and time spent complying with I/M were not estimated. The data and assumptions used to

[13] The percent of exhaust emissions from other vehicles not subject to I/M by year and by program area is included in Appendix B.

estimate the costs for the 1998 calendar year and projected costs for the 1999 calendar year are provided followed by a summary of the total cost for the AIR Program.

The fees for inspection are $24.25 for the IM240 test and $15 for the idle test (enhanced and basic program areas). Costs are incurred for the initial inspection only, so total costs of inspection are the multiplication of the unique number of vehicles tested and the inspection fees.

For repair costs, the cost data recorded as part of the AIR Program database were used. Costs in excess of $1000 were omitted in this calculation as these were assumed to be entered incorrectly in the database. Overall, the cost data were sparse in the database (only 8 percent of vehicles receiving repairs had cost information recorded), as recording this information is not required.[14] The costs for vehicles receiving a program waiver are tabulated separately as these costs are generally higher, as expected. The costs per repair were multiplied by the number of repaired and waived vehicles to estimate the cost of repairs for the AIR Program.

The cost-per-repair data are presented in Table 4-6. Between 1998 and 1999, costs per repair increased by 16, 8, and 21 percent for enhanced IM240, enhanced idle and basic idle, respectively. Note that the IM240 cutpoints were tightened between 1998 and 1999, whereas, the idle cutpoints remained the same. The 1999 modification to the IM240 cutpoints does not appear to have had a large impact on the costs per repair. Overall, the IM240 repair costs are about double that of the idle test on a per vehicle basis in both 1998 and 1999.

Table 4-6. Cost Per Repair

Calendar Year	Final Status of Vehicle	Enhanced		Basic
		IM240	Idle	Idle
1998	Repaired	$211	$107	$95
	Waived	$334	$468	$257
1999	Repaired	$244	$116	$115
	Waived	$347	$504	$264

Administrative costs were provided by the CDPHE, and are $0.25 per inspected vehicles (which is already included in the inspection fee) and $2.20 per registered vehicle. These fees fund the administrative activities at the Department of Revenue, CDPHE, and the various County Clerks offices.

There is also an estimated cost savings due to fuel economy improvements for vehicles receiving I/M repairs. For this analysis, we used the same per vehicle fuel economy improvement as in the Environ analysis (6.6 percent for IM240, 5.5 percent for enhanced idle and 1.4 percent for basic idle). [1] For fuel consumption, we used 598

[14] There is a greater uncertainty in the estimated repair costs for the program due to the inconsistent recording of vehicle repair costs and the unknown representativeness of those data recorded.

gallons per year, which represents 1996 in Colorado. [5] Finally, we assumed a retail price of gasoline with taxes at $1.13 per gallon, which represents Colorado in 1997. [6]

A summary of the total program costs is shown in Tables 4-7 and 4-8 for 1998 and 1999, respectively.

Table 4-7. Summary of Estimated 1998 AIR Program Costs (Million $/Year)

Cost Item	Enhanced			Basic Idle	Total Program
	IM240	Idle	Total		
Inspection	16.5	2.5	18.9	4.8	23.7
Administrative	3.0	0.7	3.7	1.4	5.1
Repair	5.7	2.7	8.4	4.0	12.5
Fuel Economy	-1.2	-0.9	-2.1	-0.4	-2.5
Total	23.9	5.0	28.9	9.9	38.7

Table 4-8. Summary of Estimated 1999 Total Program Costs (Million $/Year)

Cost Item	Enhanced			Basic Idle	Total Program
	IM240	Idle	Total		
Inspection	17.8	2.4	20.2	5.1	25.3
Administrative	3.1	0.7	3.7	1.4	5.2
Repair	9.3	2.7	12.1	4.8	16.9
Fuel Economy	-1.7	-0.9	-2.6	-0.4	-2.9
Total	28.5	5.0	33.4	11.0	44.4

In summary, the consumers spent a net $39 million on I/M in 1998, not including inconvenience costs. About $29 million of this was on the enhanced program in Denver, and $10 million was on the programs outside of Denver. The largest component of cost is for the inspection, and the IM240 test has a higher inspection cost than the idle test. Cost per failed vehicle was much lower for vehicles subject to the idle test, but the repair benefits for these vehicles were less than for the IM240; as shown earlier, what the basic test lacked in repair benefits, it made up for in failing more vehicles, whether this was appropriate or not.

In 1999, the estimated cost of the Program has increased from $39 to $44 million – about a 14 percent increase in program cost. The increase in cost is primarily due to increased repair costs in terms of higher cost per repair (enhanced and basic program areas) and a greater number of repaired vehicles in the enhanced area due to tighter emission limits.

D. Review of I/M Program Benefit Methods

We reviewed four approaches that can be used to estimate I/M benefits and summarize our findings in the following. We also present the results for those cases in which estimates of the AIR Program have been made using alternative methods and compare those results to those made in this study.

1. EPA/Sierra Research Approach

Section 182c(e)C of the Clean Air Act requires that all states subject to enhanced I/M "biennially prepare a report to the Administrator which assesses the emission reductions achieved by the program required under this paragraph based on data collected during the inspection and repair of vehicles. The methods used to assess the emission reductions shall be those established by the Administrator." [7]

The original methods were quite prescriptive, but as I/M programs evolved, EPA substantially changed its guidance on how to estimate the effectiveness of I/M programs. In 1997 and 1998, EPA opened a stakeholder process, in which candidate methods of evaluating I/M program effectiveness were evaluated. Four methods were identified by the EPA. Two are not appropriate for Colorado; the other two are the Sierra Research method, and the RSD fleet characterization method. In October 1998 EPA approved three of the methods, withholding judgement on the RSD fleet characterization method until it could be evaluated further. [8]

The Sierra Research method is only useful for comparing other I/M programs to Arizona's program, which EPA considers the "benchmark" program. It does not develop a percent reduction in fleet emissions that can be used to make decisions concerning the Colorado I/M program and thus was not used in this study.

We discuss the RSD method, which EPA did not yet approve, in Section 3 below.

2. Ambient Air Quality Analysis

Ambient air quality data offer the potential to measure the impact of the AIR Program on ambient CO concentrations. There are quite a few CO monitoring sites in the basic and enhanced I/M areas, which collect hourly CO concentration measurements along with wind speed, wind direction and temperature. These hourly measurement data theoretically can be used to evaluate a change in an air quality program by examining the record of data for the periods before and after the change to identify any significant impact. In theory, air quality data could be used to estimate the benefits of I/M, changes in an I/M program, or benefits of other air quality control programs such as oxygenated fuels.

The previous audit of the AIR Program completed March 1998 included an evaluation of ambient air quality data as estimated by the audit contractor (Environ). [1] Environ examined the 12-year period of ambient CO data from 1986 through 1997 and used a simple linear model to examine CO concentration versus total winter emissions. The study found a good statistical agreement between CO concentrations and emissions. However, in using these linear models, Environ was not able to find a significant impact on CO air quality due to the switchover to enhanced I/M in 1995. In effect, this means that the impact of I/M could not be separated out from the many other factors affecting ambient air quality.[15]

Perhaps using air monitoring data to perform this kind of impact would be useful if we were evaluating a very significant change that occurred in a single year, for example, a very stringent change in fuel specifications, that affects every vehicle on the road. However, to use this technique to find smaller order effects is much more difficult. Because of the difficulty involved in separating out other factors, we consider this a secondary method, rather than a primary method, for estimating I/M program benefits.

3. Use of Remote Sensing Data

A remote sensing device (RSD) is an on-road measurement device that measures the exhaust plume of passing vehicles for a fraction of a second. HC, CO and NOx pollutant concentrations are measured and current devices also record speed, acceleration, and the license plate of the passing vehicles.

The effects of an I/M program can be estimated from RSD measurements in two ways. In one approach, a RSD can be placed at one location over a period of time during which a change in I/M program has occurred. The RSD measurements before and after the change in the program can be used to evaluate the change in fleet emissions. The approach assumes the fleet that passes by the RSD device stays approximately the same over the time period of the measurements, which is a valid assumption if the RSD device remains in one place. In a second approach, two or more locations can be measured by RSDs where there are different I/M requirements for each location or group of vehicles. The I/M benefit is computed by comparing the RSD measurements for one site or group of vehicles against the other. In this approach, the assumption of equivalent fleets is more tenuous; it is necessary to also obtain license plate information at both sites, so that vehicle ages can be matched between the two sites.

The primary advantage to evaluating I/M with RSD measurements is that RSDs are a relatively inexpensive means to measure a large quantity of vehicles while they operate on the road at ambient conditions. Vehicles can also be examined throughout the year (as opposed to a single day's measurement with an I/M test), and vehicles not complying with I/M requirements can be identified from the data collected.

A key limitation to using RSD measurements to evaluate the effectiveness of an I/M program is that a number of circumstances result in elevated or highly variable emissions as measured by an RSD. These elevated readings are valid measurements; however, they may not be indicative of a malperforming vehicle. To avoid a significant number of high readings on properly operating vehicles, RSD sites are generally selected

[15] One technical limitation to successfully examining ambient data is the number of confounding factors, which result in considerable noise in the ambient data record. The confounding factors include daily, seasonal, and annual meteorological variation; variation in off-highway mobile and non-mobile sources; changes in other mobile source emission and fuels programs; fleet turnover; and variation in total activity and congestion levels.

so as to observe vehicles under warmed-up and loaded operation when their tailpipe concentrations are more stable. For this reason, though, RSD measurement data do not represent a typical mix of on-road operating conditions, but they do represent emissions under warm-running, partially loaded conditions.

The lack of respresentativeness of the operating conditions may impact the effectiveness of I/M as measured through a RSD for individual vehicles. This means that a reduction in emissions observed by a RSD may not correspond to the same reduction when measured by IM240, which contains a wider range of on-road operating conditions. However, combining RSD data across vehicles into a fleet average has been shown to improve the accuracy of RSD predictions.

Three previous studies have compared emission levels from vehicles subject to the Colorado AIR Program.

a. Stedman Study

In the first study, Dr. Don Stedman was the principal investigator of an effort that examined RSD and I/M data records at the end of 1995 – the end of the first year of enhanced IM240 testing. [10] The researchers estimated the benefits of the AIR Program from comparing vehicles that had been inspected in the first year of the new biennial program versus those that had yet to be tested. This study found that the new enhanced testing program reduced fleet CO between 4 and 7 percent and had a negligible effect on HC.

The original Stedman analysis was updated to analyze the significant number of even model year vehicles had been tested in 1995 as a result of the change of ownership inspection requirement and as a result of including the 1994 model year in the first year of testing. The revised results, reported at the 1998 Coordinating Research Council's On-Road Emissions Workshop, indicated that the RSD-measured benefit of the AIR Program increased from 4 - 7 percent (noted above) to 8 - 11 percent. [11]

This study estimated the benefits for the 1995 (first) inspection cycle of the Enhanced Program, and thus these estimates do not include cumulative benefits of the Program, if significant, and do not include the latest cutpoints, which have been tightened twice since 1995. However, the benefit may also be overstated due to not accounting for vehicles reregistering outside the I/M area to avoid testing, which the authors note can be observed in the vehicle registration patterns.

b. Colorado 0.5 % Audit

A second study compared RSD measurements of vehicles in Denver to the RSD measurements of vehicles in Greeley. [12] The measurements in both areas were collected sequentially in time using the same RSD unit.

Two key figures from the Colorado 0.5% Sample report are duplicated in Figures 4-1 and 4-2 of this report. These figures show the average CO concentration, as measured by RSD, for each model year for passenger vehicles and light trucks. The figures are based on 58,000 measurements in Denver and 236,000 measurements in Greeley. For 1982 and later model year vehicles, the Denver data represent the IM240 test and the Greeley data represent the idle test. For 1981 and earlier model years, both basic and enhanced areas rely on the idle test; however, the enhanced area uses test-only facilities (primarily centralized) and the basic area uses test-and-repair facilities (decentralized).

Figure 4-1. On-Road Passenger Vehicle CO
(Same as Figure IV-1 from Colorado 0.5% Sample Study)

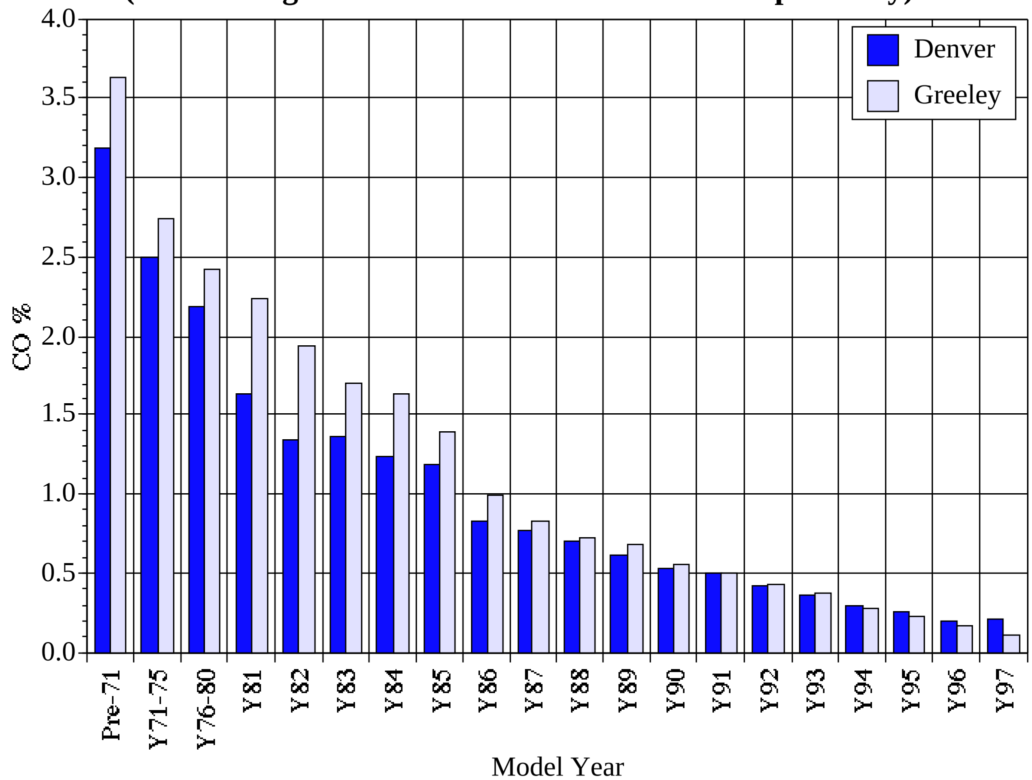


Figure 4-2. On-Road Light Duty Truck CO
(Same as Figure IV-2 from Colorado 0.5% Sample Study)

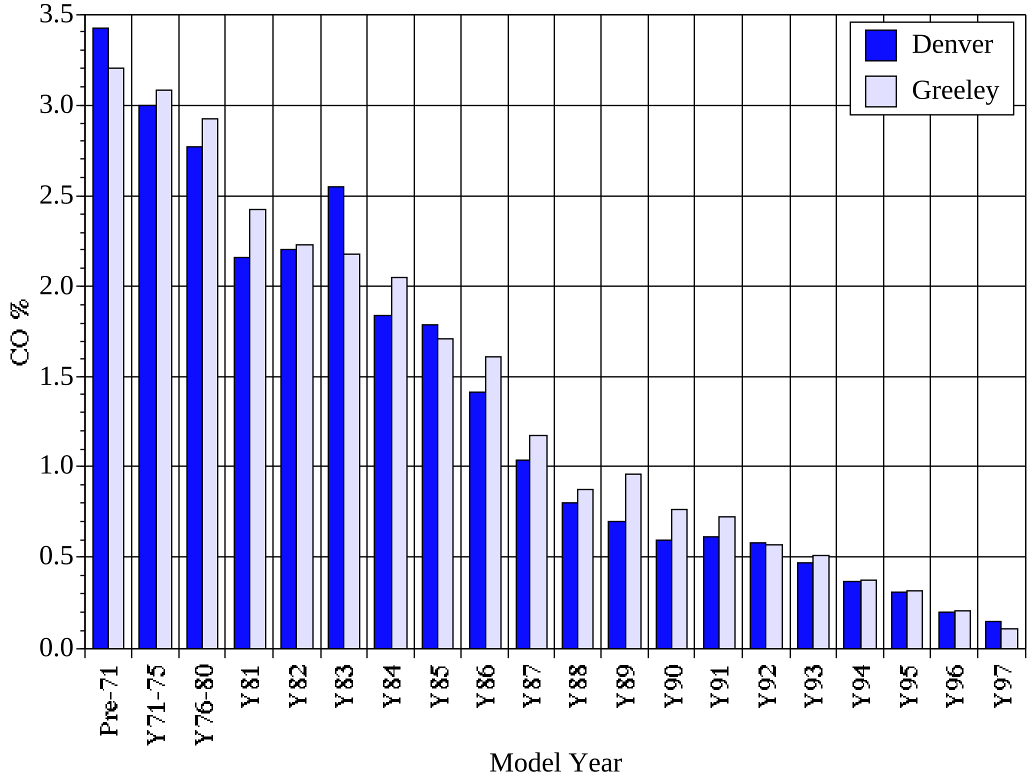


Figure 4-1 shows that for 1990 and later model year cars, there appear to be no difference in RSD readings for the IM240 on a biennial basis and the idle test on an annual basis. This is probably because the failure rates of 1990 and later cars are quite low compared to the older vehicles, and so the average emissions are dominated by relatively clean cars. For 1982-1990 vehicles, the average RSD readings in Denver appear to be 15 to 20 percent lower than in Greeley. This may indicate that the IM240 is more effective than the idle test for these cars. However, for pre-1982 cars, Denver results are lower even though both areas use the idle test on an annual basis. So, we are left wondering whether the difference in 1982-1990 RSD readings may not be due to the test type. Other factors that may have a significant impact on these results are the difference in facility types (test-only in Denver and test-and-repair in Greeley), differences in RSD siting characteristics, and/or differences in general maintenance habits in the two areas.

Figure 4-2 for light duty trucks shows a similar patter for 1992 and later trucks as for 1990 and later cars. For the 1982-1992 trucks, there is less of an apparent advantage to the IM240 test, but then the IM240 cutpoints up until 1999 were much less stringent for trucks than for cars. The results for pre-1982 trucks are about the same for both areas.

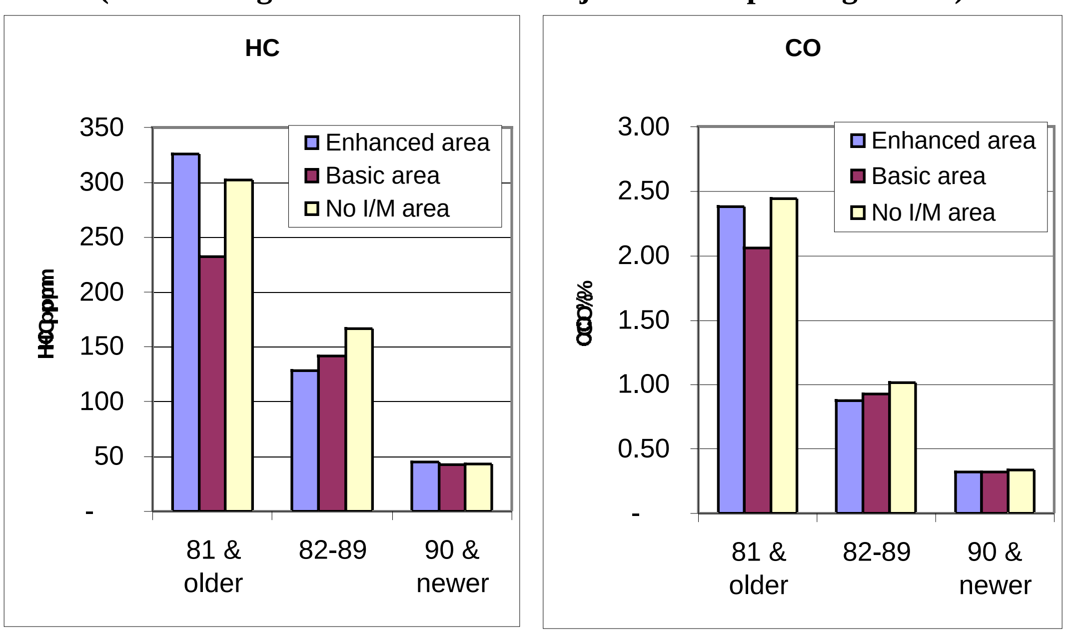
Overall, even though 1982 –1990 cars in Denver have RSD readings that are about 14 percent cleaner than they are in Greeley; however, it is difficult to attribute all of this difference to IM240 relative to basic I/M, because of the potential factors noted above.

c. CRC Study

The third RSD study is the on-going Coordinating Research Council (CRC) Project E-23. [13] This study is evaluating the capability of RSD to identify high emitting vehicles, and a draft interim report from this study is currently available. This interim draft report describes the results of 50,000 measurements made at five locations in Denver in 1997. After these data were matched with registration data records, 93 percent of the in-state vehicles were registered in the enhanced I/M area, 4 percent in basic I/M areas and 3 percent in non-I/M areas. A comparison between emission rates by the three levels of I/M requirement (enhanced, basic and no-I/M) was included in the report.

Figure 4-3, reproduced from the data of the CRC report, shows the average CO emission rates by I/M program requirement and model year group. For the 1990-and-newer model years, there appears to be little impact of I/M on the observed emission rates. For 1982 to 1989 model years, the RSD data suggest an improvement in fleet average CO of 5 percent for basic I/M and 13 percent for enhanced I/M over the no-I/M data. For the pre-1982 model years, the data do not show a consistent benefit for CO due to I/M; however, as noted below, limited sample sizes may have impacted this comparison of the pre-1982 model year fleet. Overall, CO and HC emissions are both 19 percent lower for the enhanced versus no I/M, and CO and HC emissions are 14 and 17 percent lower, respectively, for Basic I/M than no I/M.

Figure 4-3. RSD HC & CO Emissions by I/M Area and Model Year Range (Same as Figure 5-7 from CRC Project E-23 Report Figure 5-7).



There are some uncertainties and data limitations to the comparisons of Figure 4-3 that also need to be considered when reviewing these results. First, the sample size of the basic and non-I/M areas is much smaller than that of the enhanced area. This is particularly the case of the pre-1982 model year vehicles (total number of vehicles measured was 83 for CO and 59 for HC) and is likely an important factor in the inconsistent results observed for the oldest model year group. Second, since the observations were made only in Denver, it is possible that vehicles used to drive into Denver from outlying basic and non-I/M areas are not typical of the vehicles generally in-use in the basic and non-I/M areas. Third, commuter vehicles in Denver are supposed to participate in the enhanced program, so it is possible that some of the basic and non-I/M vehicles (even though registered outside Denver) may have complied with the enhanced I/M requirement. Lastly, since the drivers of these vehicles are known to travel to Denver, there could be a component of these vehicles that were purchased as used vehicles from dealers in Denver and which met the enhanced I/M requirement at some time in their maintenance history.

Overall, the first study indicated a 4 to 11 percent benefit in RSD results of enhanced I/M versus basic I/M in 1995 (the first year of the Program). The second study failed to show a consistent benefit to enhanced I/M over basic I/M in 1997, but it also did not disprove that there was a benefit either. The third study indicated a 19 percent CO benefit for enhanced I/M, and a 15 percent benefit for the basic program over no program at all; however, the sample sizes of the no I/M and basic I/M cases were quite small relative to the enhanced I/M sample.

4. I/M Program Benefits from EPA's Computer Model

I/M program benefits can be predicted using the MOBILE computer model, a regulatory tool developed by the U.S. Environmental Protection Agency (EPA). The current official version is MOBILE5a released in 1993; however, local and state agencies may also use MOBILE5b (released in 1996), which includes added flexibility for modeling regulations passed since the release of MOBILE5a. Although EPA has not released it, there is also the Serious Area CO Model, which EPA has made available to states completing CO planning activities. The next official model, MOBILE6, was originally due to be released in 1998. Presently, its release is expected sometime in 2000.

With respect to I/M, both MOBILE5a and MOBILE5b rely on the same underlying databases to estimate program benefits. Thus, there is no difference in estimated I/M benefits; however, MOBILE5b does include added modeling flexibility, such as remote sensing clean screens not available in MOBILE5a. Since the deterioration rates in the Serious Area CO Model are much lower than in previous models, EPA derived a special set of I/M credits that are consistent with this model. As shown in the previous chapter, the I/M benefits from this model are much lower than from the previous models.

In MOBILE, I/M program benefits are derived from input data consisting of a series of program-derived statistics (such as failure rates, I/M test type, and inspection frequency). MOBILE has the capability to model emission rates with and without an I/M program from which the benefits of the program can be assessed, and is simple and easy to use. A major limitation is that local emissions data cannot be used to calibrate the benefits of the model. This is the reason that EPA does not suggest its use in the biennial report to the EPA Administrator for areas requiring IM240 programs. Other disadvantages are the underlying data used to develop I/M credits are becoming very out-of-date, and the model is not capable of estimating benefits of change-of-ownership I/M, and varying cutpoint strategies employed for different model years and vehicle classes.

The previous audit of the AIR Program included an evaluation of the I/M benefits using MOBILE5a. [1] The benefits, representing the exhaust FTP benefits of the current program relative to the complete absence of an I/M in Colorado. The estimated benefits are a 20 to 34 percent reduction in exhaust CO and 22 to 43 percent reduction in exhaust HC, depending on test type (greater benefit for the IM240 test).

In this study, we estimated the benefits of enhanced I/M with the EPA Serious CO Area Model, relative to no I/M. The results indicated that the CO benefit for 1999 is around 17 percent using the CO Maintenance Plan modeling conditions provided by the CDPHE. This is much lower than MOBILE5a or MOBILE5b, and we attribute this lower benefit to the reflection of more recent trends in vehicle technology affecting CO emissions being included in the emission model.

5. Summary of Methods

We have presented varying estimates of the CO benefits of the Colorado program, as shown below.

- The most recent RSD measurement analysis (CRC Project E-23) indicates the benefit of the enhanced and basic programs relative to no I/M program is about 19 and 15 percent, respectively.

- Other RSD measurement analyses indicate that the benefit of the enhanced program relative to the basic program is between 4 and 11 percent, and that the benefit appears to be greater for automobiles than for light duty trucks.

- The previous audit indicated that the benefit based on MOBILE5a modeling for the enhanced program relative to no I/M is 34 percent.

- The new Serious Area CO Model indicates that the benefit of enhanced I/M relative to no I/M is about 17 percent in 1999.

- This study estimates the 1999 benefit at about 8 and 6 percent for the enhanced and basic program areas, respectively.

The different studies represent a very wide range of benefits under varying conditions and points in time. Of those cited, the estimates from the previous audit are unrealistically high due to the known over prediction of deterioration in the MOBILE5a model. Our estimates from this study are likely conservative due to not estimating a cumulative benefit and the treatment of unresolved failures.[16]   We feel the estimates from this study, therefore, are a reasonable lower bound estimate of the I/M program benefit. Our expectation of reasonable upper bound estimates are those from the most recent emission factor model (the Serious CO Area Model), which includes any cumulative benefit, if significant. Thus for the enhanced area, our expectation is that the CO benefit of the AIR Program is between 8 to 17 percent.

[16] Estimating the cumulative benefit due to I/M is difficult to complete with certainty and was considered beyond the scope of this project.

5. Impacts of New Motor Vehicle Technologies on Emissions in Colorado

The 1998 Audit of the AIR Program showed a downward trend in CO emissions from gasoline vehicles though about 2005 for most areas in Colorado. This downward trend in CO emissions in the MOBILE model has been due primarily to fleet turnover of newer, much cleaner vehicles for older, higher-polluting vehicles, but I/M has also contributed mainly by preventing many older vehicles from operating continually as high-emitting vehicles. Also, oxygenated fuels have also contributed by reducing the emissions of the older vehicles.

Although the new vehicle CO standard in g/mi at 75^{o} F has been unchanged since 1981, new technologies and standards for hydrocarbons, coupled with the All-Altitude standards in 1984 and the Serious Area CO standards introduced in 1994 have kept reducing CO emissions as well. In addition, new technologies being introduced currently, and others that will be introduced in Colorado in the near future, are expected to bring about further reductions in CO emissions.

In this chapter, we will identify new technologies and emissions standards that are reducing CO. Because of the changing ozone standards, we will also identify technologies that are, and will be reducing the ozone precursors, HC and NOx.

Section A summarizes the chapter. Sections B-G discuss current and future regulations that affect CO emissions, at cold and warm temperatures. Section H addresses additional controls that will affect primarily HC in the summer, and NOx year-round.

A. Summary

There are many emission standards and requirements that are currently be phased-into the vehicle fleet, which should reduce CO, HC, and NOx emissions from cars, light duty trucks, and SUVs, for years to come. In addition, these technologies are being continually monitored by an onboard diagnostic (OBD) system, which notifies the driver of a system malfunction.

A good measure of how these technologies are being phased-into the fleet is to estimate the year at which 90% of the on-road vehicle miles traveled is from vehicles with the new technologies. We have estimated that for passenger cars, the 90% point is about 2012, and the 90% point for light duty trucks is a little later, or from 2014-2019, depending on the vehicle class.

The second generation of onboard diagnostic systems, which started phasing in for the 1994 model year, is currently impacting the fleet and the AIR Program in four ways. First, vehicle manufacturers have probably built these vehicles to be more durable than vehicles without OBD systems, so they are likely stay cleaner for a longer time than non-OBD-equipped vehicles. Second, the systems notify the driver of an emission control problem, so that the drivers can get the problem fixed long before their emission inspection, assuming they respond to the warning light. Third, on average it appears that the OBD self-inspection is more stringent than the current AIR Program. And fourth, it is possible that the OBD inspection could be used in place of the current emissions inspection for all OBD-equipped vehicles.

B. Cold CO Standards

The 1990 Clean Air Act Amendments required the implementation of Phase 1 of the Cold CO standards in 1994. The CO standard is 10.0 g/mi at 20^{o} F for cars and 12.0 g/mi for all LDTs. The standards were phased-in with the Tier 1 vehicle standards, or 40% in 1994, 80% in 1995, and 100% in 1996. Thus, only a portion of the on-road fleet currently meets these standards, and the fraction of the fleet equipped is increasing steadily each year.

An examination of EPA's data on new vehicles indicates that both cars and light trucks have average Cold CO emissions of about 5 g/mi or 60% below the standards. To meet the Cold CO standards, manufacturers have employed close-coupled catalysts, and have improved calibrations resulting in tighter air/fuel ratio control, especially during cold-starts.

The 1990 Clean Air Act Amendments also required to EPA to conduct a study of the need for a second phase of Cold CO standards. The requirement was that if 6 or more areas in the U.S. were still in CO nonattainment as of 1997, then EPA should implement Phase 2 of the Cold CO standards. These standards are 3.4 g/mi at 20^{o} F for cars and 4.2 g/mi for trucks, which represent about a 65% reduction from the Phase 1 standards. EPA has not determined definitively how many areas were in nonattainment in 1997, and is studying the need for the Phase 2 Cold CO standards. The effects of the Phase 2 Cold CO standards were not included nor assumed to be implemented in this analysis.

C. Off-Cycle Controls

Off-cycle emissions are emissions that are emitted during real world vehicle operation that goes beyond the historical test cycles. The traditional test procedure for certifying gasoline vehicles is called the Federal Test Procedure, or FTP, so off-cycle emissions are emissions that occur outside of the FTP. A good example of these is "aggressive driving." The historical FTP was limited to an acceleration of 3.3 mph/sec because of dynamometer limitations. Driving surveys conducted in the early 1990s, however, showed that there are frequent acceleration events faster than 3.3 mph/sec. During these acceleration events, CO emissions from uncontrolled vehicles can be very high, or on the order of 50-100 g/mi for a brief period of time. These high emissions were the result of a emissions calibration strategy called "acceleration enrichment", in which extra fuel was supplied to the engine during high acceleration, so that vehicles would have adequate acceleration performance, for example, during passing situations, and during merging on a freeway. This acceleration enrichment would also occur during the FTP test, but not to the degree sometimes experienced in-use.

To curb these off-cycle emissions, EPA implemented the Supplemental Federal Test Procedure standards, or SFTP requirements, in 1996. These applied to passenger cars and LDTs starting in model year 2000.

In the Final Regulatory Impact Analysis (RIA), EPA estimated that its Supplemental FTP rules would reduce overall (on-cycle plus off-cycle) HC emissions from cars and light trucks by about 2.5%, CO by about 11%, and NOx by 9%, when fully phased in. The percent reductions in off-cycle emissions alone are much greater (on the order of 80-90%). This analysis assumed reformulated gasoline and an enhanced I/M program, and estimated the reduction in CO under summer, rather than winter conditions. We expect that the reductions would about the same in Colorado in the winter as estimated under summer conditions. Also, the percent reduction that EPA calculated was for properly operating vehicles (i.e., non-high emitters); EPA further speculated that the emission reductions for normal in-use vehicles could be a factor of two higher.

Manufacturers will be using tighter air/fuel ratio control over a wider range of operating conditions, electronically controlled exhaust gas recirculation (EGR), and increased precious metal loading on catalytic converters to reduce emissions during off-cycle events.

There are important implications of off-cycle emissions on RSD which may have an impact on the effectiveness of remote sensing readings at identifying broken vehicles, and which have an impact on siting remote sensing equipment. Since RSD measures instantaneous emissions, there is the possibility that a high remote sensing reading on a vehicle is not the result of the vehicle being a broken vehicle (i.e., high emitter); it could just be experiencing a very temporary heavy acceleration. For this reason, remote sensing operators typically site the equipment were traffic is flowing by under steady-state conditions, to attempt to eliminate this possibility.

Implementation of the SFTP requirement starting in 2000 should significantly reduce the frequency and severity of emissions from transient enriched operation. However, vehicles that do not meet the SFTP standards will continue to be in the fleet for the next 20 years. Therefore, these factors need to be carefully considered in the design of any remote sensing program, especially as a stand-alone program such as a roadside pullover program. This concern is much less important for a clean screening program, because vehicles which are confirmed clean with remote sensing with 2 or more measurements are either not broken, or are not experiencing high emissions due to acceleration at the time of measurement.

D. Onboard Diagnostics

In a traditional I/M program, vehicles receive an emissions inspection (either idle, 2-speed idle, ASM, or IM240) only once every year or two. Although not a typical scenario, a vehicle’s emission control system can fail immediately after its inspection, and it can operate at high emissions mode for a year or two before being detected and repaired. If there is no I/M program at all, the vehicle can continue to operated as a high emitter for a long time, unless the vehicle is repaired for other reasons.

Remote sensing can be used as a more frequent and less expensive inspection to detect emission control system failures between I/M inspections. However, a fairly large infrastructure of remote sensing stations is required to cover most of the vehicle fleet, and provide several readings per vehicle per year. Also, ensuring that repairs are made and that the repairs provide the necessary emission reductions is problematic.

Onboard diagnostics systems that are installed on vehicles to detect failures solve the inspection frequency problem, since they are continually checking the performance of the emission control system components while the vehicle is being operated. If there is an emission control system failure, the driver of the vehicle is notified through a malfunction indicator light (MIL). The effectiveness of the system requires the driver to respond to the MIL.

First generation onboard diagnostics systems (i.e., OBDI) have been on cars and light trucks since 1988, however the second generation onboard diagnostic requirements (OBDII) were phased-in starting in 1994. By 1996, 100% of cars and light duty trucks up to 8500 lbs GVW are required to be equipped with these systems. In 1999 in Colorado, 15% of the vehicles on-road are equipped with second generation OBD systems (as shown in Section G, these vehicles drive about 30% of the vehicle miles traveled). These systems perform nearly continuous checks of the following emission control systems:

- Catalyst(s)
- Oxygen sensor(s)
- Evaporative canister purge system
- Fuel tank leak check
- Misfire detection
- Air pump (if equipped)
- Onboard computer
- Sensors used in engine and emissions management

If these systems detect an emission control system problem that would cause emissions to exceed 1.5 times the emission standards they are certified to, then a malfunction indicator light (i.e., MIL) is illuminated. It is then up to the driver of the vehicle to take the vehicle in for service. It is hoped that most drivers will have their vehicles repaired if and when these lights come on. Some may not, however, and may wait until the next I/M inspection to have their vehicles repaired. However, the delay in doing so could cause damage to the emissions control systems.

To compare the stringency of the OBD tests to the current Denver IM240 program, we have multiplied the emission standards for 1996-2000 vehicles, and 2001 and later vehicles by 1.5, and compared these emission levels to the IM240 cutpoints. The results are shown in Table 5-1.

Table 5-1. Comparison of OBD Standards and IM240 Cutpoints (g/mi)					
		OBDII			IM240
Vehicle Type	Model Year Group	HC	CO	NOx	CO
Passenger Cars	1996-2000	0.375	5.1	0.6	20
	2001+	0.11	5.1	0.3	20
LDTs	1996-2000	0.48	6.2	0.6-1.5	20
	2001+	0.13	6.2	0.45-0.9	20

The comparison shows that for CO, the emissions level at which the MIL is designed to come on is much lower (5.1 g/mi) than the level vehicles are currently failed for in the current Denver I/M program (20 g/mi). Thus, the OBD check appears to be more stringent than the Denver I/M program. Another factor making it more stringent is that the OBD level includes cold start emissions, where the IM240 is conducted in the warmed-up configuration. Note that the MIL is also illuminated for HC and NOx failures. At this time, HC and NOx are not a focus of the Denver I/M program. However, vehicles equipped with OBD whose lights are coming on and whose vehicle owners are taking them in for repair, are probably experiencing HC and NOx reductions, as well as CO reductions. Additionally, when EPA's requirement to incorporate OBD light checks in I/M programs in 2001 takes effect, these vehicles will experience HC and NOx reductions as well. There is no feasible method to make OBD a CO-only program.

Onboard diagnostic systems should reduce in-use emissions from vehicles equipped with the systems in two ways. First, it is expected that vehicle manufacturers have improved emission control systems, so that they are less likely to fail in the first place. Second, early detection of emission control system problems, as discussed above, should also reduce emissions, as long as drivers respond to the MILs.

The EPA has established requirements for all I/M programs to fail vehicles that have illuminated malfunction indicator lights (MILs), starting in 2001. [14] Colorado has already implemented OBD checks in its I/M program, and already fails vehicle for illuminated MILs, or for stored trouble codes. The vehicle must have no stored trouble codes and have the MIL off to pass. We analyzed Colorado's data on OBD checks; the results are presented in Chapter 7.

If OBD systems are very effective at identifying emission control system failures, and most owners also respond to the MILs, then there is a question as to whether any external I/M test (for example, and idle test or an IM240 test) is needed on vehicles equipped with the systems. The EPA, states and manufacturers are sponsoring testing that should answer this question within the next year. It is important to mention that Colorado, along with Arizona and Wisconsin, are currently providing valuable data and test vehicles to EPA in this research on the effectiveness of OBD. Additional details on integrating OBD and I/M are covered in Chapter 7.

E. National Low Emission Vehicle Standards

The National Low Emission Vehicle standards take effect in Colorado starting in the 2001 model year. These standards affect passenger cars and 0-6,000 lb light duty trucks, which includes all minivans and most sport utility vehicles (SUVs). The emission standards are shown in Table 5-2.

Table 5-2. National Low Emission Vehicle Standards (NLEVs)

Vehicles	HC (g/mi)	CO (g/mi)	NOx (g/mi)
50,000 Mile Standards			
Passenger Cars and 0-3750 lb. LDTs	0.075	3.4	0.2
3750-6000 lb. LDTs	0.09	4.2	0.3
100,000 Mile Standards			
Passenger Cars and 0-3750 lb. LDTs	0.09	4.2	0.3
3750-6000 lb. LDTs	0.13	5.5	0.5

The CO standards for these vehicles have not changed from earlier vehicles; however, the reduction of the HC standard has resulted in lower CO emissions at 75^o F and 20^o F. An examination of EPA new vehicle data shows that CO emissions from NLEV cars and light trucks are reduced by 20-40% over Tier 1 vehicles.

F. Proposed Tier 2/Gasoline Sulfur Standards

In May of 1999, EPA proposed more stringent Tier 2 exhaust and evaporative standards for cars and light trucks up to 8500 lbs GVW, and also proposed a national gasoline sulfur controls. [15] The comment period for the NPRM ended August 2^{nd}, 1999, and EPA is preparing a final rule for release later this year or early next year. The vehicle exhaust standards and lower gasoline fuel sulfur level would start taking effect in 2004.

In its Tier II proposal, EPA is proposing to reduce the HC standards for 6-8500 lb light trucks from Tier 1 levels to the corresponding California LEV levels. This should reduce CO emissions from the heavier light trucks, including full-size pickups, heavier SUVs such as the Chevrolet Suburban and Lincoln Navigator, and the larger vans.

EPA’s sulfur proposal is to reduce nationwide sulfur levels to 30 ppm average, with a cap of 80 ppm. AIR has examined the auto industry’s survey of gasoline samples in the Denver area for the summer of 1999, and has determined that gasoline sulfur is about 228 ppm in Denver. [16] The national average, according to the MOBILE5 model is about 330 ppm. [17]

The Western Regional Air Partnership (WRAP) has an alternative sulfur proposal, which it has forwarded to the EPA as a part of its comments on the proposed sulfur controls. [18] This proposal calls for the creation of a new small refinery category that allows the small refinery category to meet somewhat less stringent sulfur specifications of 150 ppm average and 300 ppm maximum in the 2004-2006 timeframe. After 2006, these refineries would conform to the EPA proposal.

Air Improvement Resource, Inc. has estimated the reductions in emissions from low sulfur fuel for both Tier 1 and NLEV vehicles. The reduction in HC, CO, and NOx were estimated going from the current level of 228 ppm to 30 ppm. The results for normal emitters[17] are shown in Table 5-3.

Table 5-3. Reduction in Tier 1 and NLEV Emissions for Normal Emitters Due to Reducing Gasoline Sulfur From 228 ppm to 30 ppm

Technology	CO	Exhaust HC	NOx
Tier 1	16%	18%	8%
NLEV	26%	24%	51%

As shown in Table 5-3, there are substantial emission reductions for all three pollutants from both Tier 1 vehicles and NLEVs if sulfur is reduced to 30 ppm. The table also shows that NLEVs (2001 and later) will experience generally greater percentage reductions than Tier 1 vehicles. This is why EPA has proposed lowering the sulfur level in gasoline.

G. Fraction of Fleet Equipped with Controls Affecting CO

Many Federal requirements affecting CO emissions are being implemented at this time. It is instructive to pose the question of when will these requirements be nearly fully-phased-into the fleet of vehicles on-road in Colorado? To answer this question, AIR used the registration distributions provided by CDPHE Staff to estimate the fraction of vehicle miles traveled by cars and two classes of light duty trucks that are quipped with these controls. The results are shown in Figures 5-1 through 5-3. Figure 5-1 for cars, for example, shows that fleet vehicle miles traveled equipped with controls affecting CO will keep increasing until about 2012 or 2013, at which point greater than 90% of the vehicle miles traveled by the passenger car fleet will be vehicles subject to the regulations discussed in previous sections. The technology implementations are a little later for trucks, so the time period of nearly complete implementation is a little later. The estimated fraction of passenger car vehicle miles traveled from vehicles equipped with these controls for 2000, 2005, and 2010, are shown in Table 5-4.

[17] Normal emitters as defined here are those with emissions less than twice their applicable standards.

Figure 5-1. Fraction of Automobile Vehicle Miles Traveled Affected by Regulation

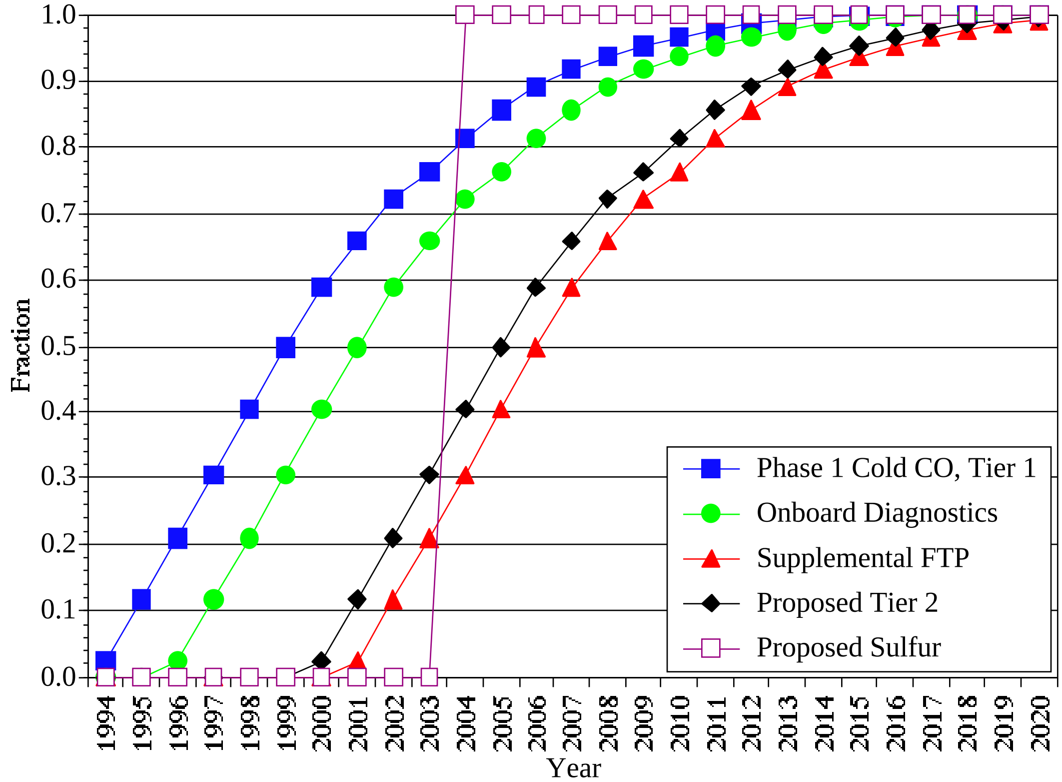


Figure 5-2. Fraction of LDT1 and LDT2 Vehicle Miles Traveled Affected by Regulation

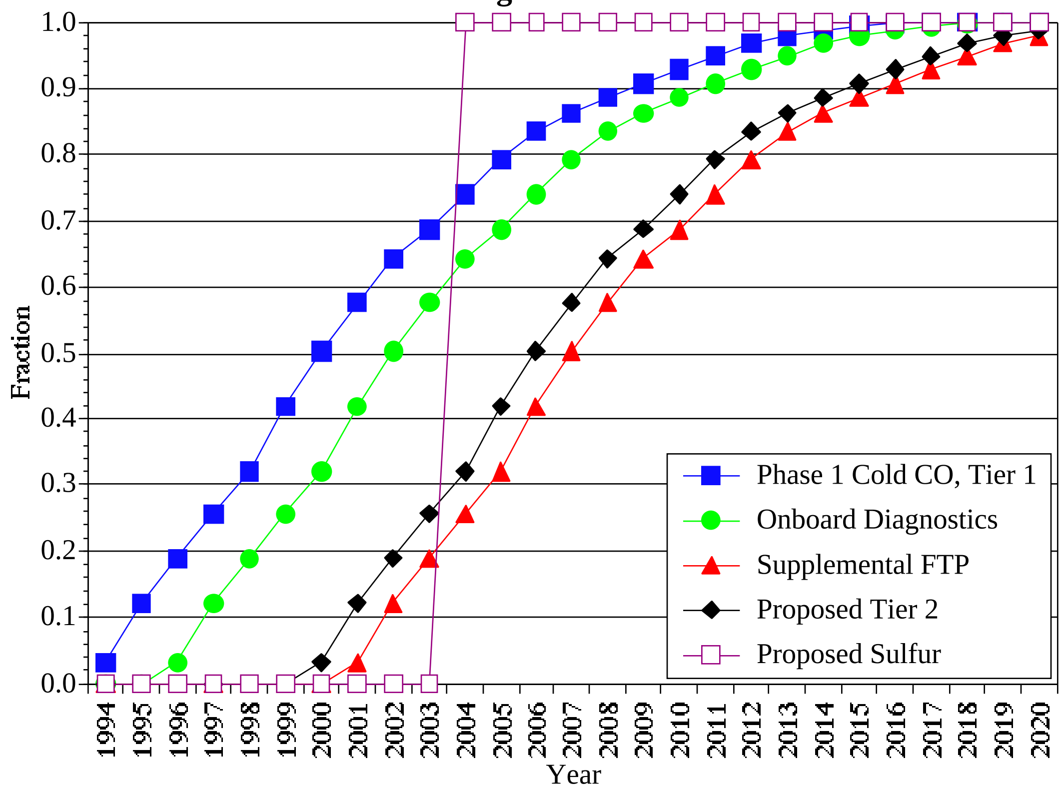


Figure 5-3. Fraction of LDT3 and LDT4 Vehicle Miles Traveled Affected by Regulation

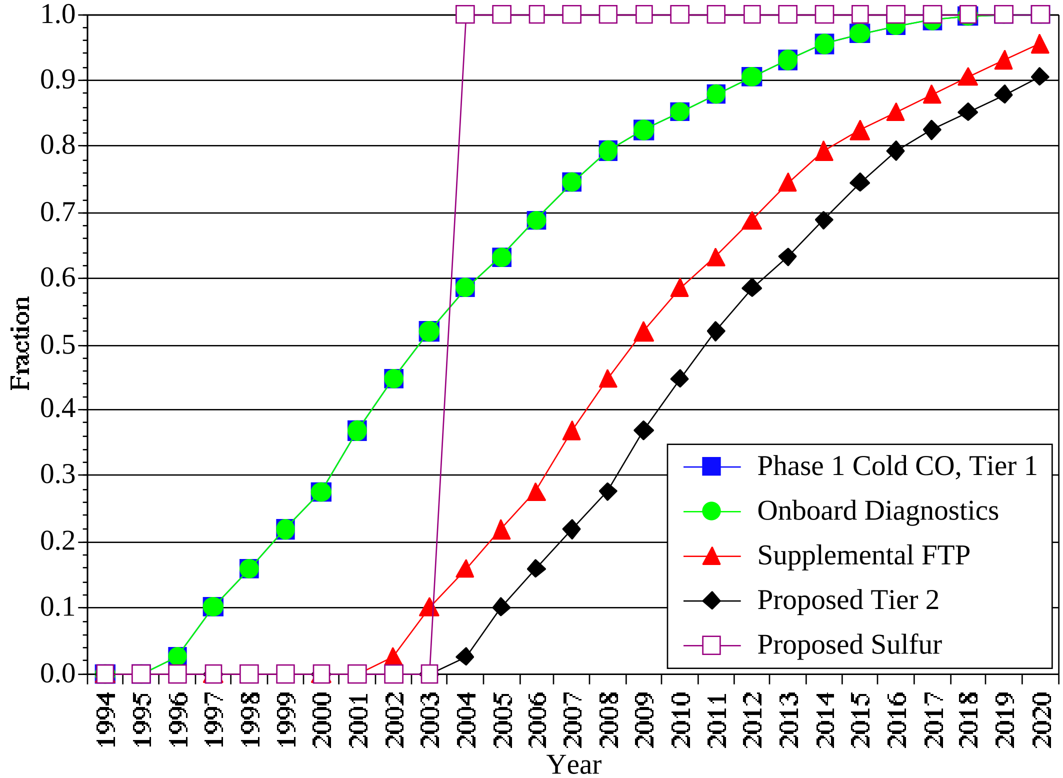


Table 5-4. Percent of Passenger Car Vehicle Miles Traveled that are Equipped with Controls Affecting CO Emissions (all values approximate)			
Regulation	2000	2005	2010
Phase 1 Cold CO	60%	85%	95%
Onboard Diagnostics	40%	75%	93%
NLEV Standards	0%	40%	75%
Revised FTP	0%	50%	82%
Proposed Sulfur	*0%*	*100%*	*100%*

H. Controls Affecting HC and NOx

Enhanced evaporative controls, implemented starting in 1994, will significantly reduce evaporative hydrocarbon emissions in the summertime. There are four sources of evaporative hydrocarbon emissions – hot soak emissions, diurnal emissions, resting losses and running losses. The enhanced evaporative requirements established a 3-day diurnal and hot soak standard of 2 g/test, which dramatically reduced hot soak, diurnal and resting losses. The standards also include a 0.05 g/mi running loss standard. EPA has estimated that the enhanced evaporative tests will reduce summertime HC emissions by about 80% from previously controlled levels. Enhanced evaporative requirements were phased in over 1996-1999.

EPA also implemented onboard vapor recovery systems. These systems reduce hydrocarbon vapor during vehicle refueling at service stations by 90%. Onboard vapor recovery requirements are phased in from 1998 through 2006.

The NLEV program will be implemented at 100% in 2001, and the proposed Tier 2, and proposed sulfur standards, if adopted, will be implemented starting in 2004.

In model year 1999, the heavy-duty NOx standard for diesel and gasoline engines was reduced by 20% from 5.0 g/hp-hr to 4.0 g/hp-hr. In 1997, EPA adopted more stringent standards for 2004 and later heavy-duty gasoline and diesel vehicles. The combined NMHC + NOx standard is reduced for 2004 and later engines to 2.5 g/hp-hr. With HC at about 0.5 g/hp-hr, this makes the effective NOx standard about 2 g/hp-hr or a further 50% reduction from the 1999-2003 model year levels.

In 1998, EPA determined that heavy-duty engine manufacturers were inappropriately increasing fuel economy and thus NOx emissions under steady-state operating conditions. As a result, EPA has moved to implement a steady-state test for heavy-duty engine manufacturers that will result in steady-state emissions being the same as transient emissions. In addition, many manufacturers will be reducing steady-state NOx emissions on engines brought in for rebuilding. Thus, heavy-duty NOx emissions should continue to decline over the next 10-15 years.

6. Projection of CO Emissions in the Future

Studies have shown that the trend in ambient CO levels in Colorado has declined considerably, and that this has almost certainly been caused by a reduction in on-road CO emissions from motor vehicles. [1] The strong implications from the work that has been done so far is that if emissions from motor vehicles continue lower, then, ambient CO levels should continue to improve.

In this chapter, we project CO, HC, and NOx emissions into the future, using emission models that take into account as many of the new technology items as possible. We have focused on CO, but have also included HC and NOx due to concerns about the effects of possible program changes on future ozone levels in Colorado.

The first section summarizes the results of our emission modeling. The second section discusses the methods and emission models used, and the last section discusses previous projections of CO in Colorado.

A. Summary

The new EPA Serious CO Area Model was used to project CO emissions into the future, and our own modified MOBILE5 model was used to project HC and NOx emissions, since EPA does not have an HC and NOx model that adequately reflects the latest technologies and emission rates. Neither of these models is fully peer reviewed like the current EPA MOBILE5b model, but we believe they portray a more accurate picture of future emissions than the current peer-reviewed EPA model. Results are presented for four cases:

- Continuation of current AIR and Oxygenated Fuels Programs as outlined in the Maintenance Plan
- Impact of the EPA-proposed Tier 2 standards and the Western Governor's Association gasoline sulfur proposal
- Impact of discontinuing the AIR Program in 2001 (no Tier 2/sulfur)
- Impact of discontinuing the oxygenated fuels program in 2001 (no Tier 2/sulfur)

In estimating the impact of the discontinuing the AIR Program, we have used the Serious CO Area Model's estimate of I/M benefits. We initially considered using the annual CO benefit estimated in Chapter 4 but decided to use the Serious CO Area Model benefit to include potential cumulative effects. To estimate the benefits of oxygenated fuels, we have also relied on the Serious CO Area Model, since the oxygenated fuel benefits have been updated.

Results for Denver are shown in Figures 6-1 through 6-5. Emission projections start in 1995 (the date of the last exceedance in Denver) and extend to 2015. The figures show that:

1. Under the current program, CO will be reduced by 62 percent between 1995 and 2010, in spite of the growth anticipated in the region.

2. Even if the AIR Program is discontinued in 2001, CO levels out for 2-3 years, and then continues to decline. The percent reduction between 1995 and 2010 is 53 percent.

3. If EPA’s Tier 2 standards and the WGA sulfur proposal are adopted for Colorado, CO will decline over 70 percent between 1995 and 2010 under the current I/M program.

4. If the AIR and oxygenated fuel programs are discontinued in 2001, CO stays level from 2001 to 2002, and then starts to decline again. The CO reduction from 1995 to 2010 is 50 percent.

5. The sum of VOC and NOx emissions (ozone precursors) under the current program will decline by 50 percent from 1995 to 2010 under the current I/M program.

6. With the Tier 2 and WGA sulfur proposal, ozone precursors will decline by 56 percent between 1995 and 2010.

7. If the AIR Program is discontinued in 2001, ozone precursors increase by only a fraction in the short-term (about 6 percent). This is because the program only affects exhaust HC, and does not fail many vehicles for high NOx emissions. Under this scenario, ozone precursor emissions will decline by 42 percent between 1995 and 2010.

Figure 6-1. All Vehicle CO Trends with and without I/M, Denver Metro Region

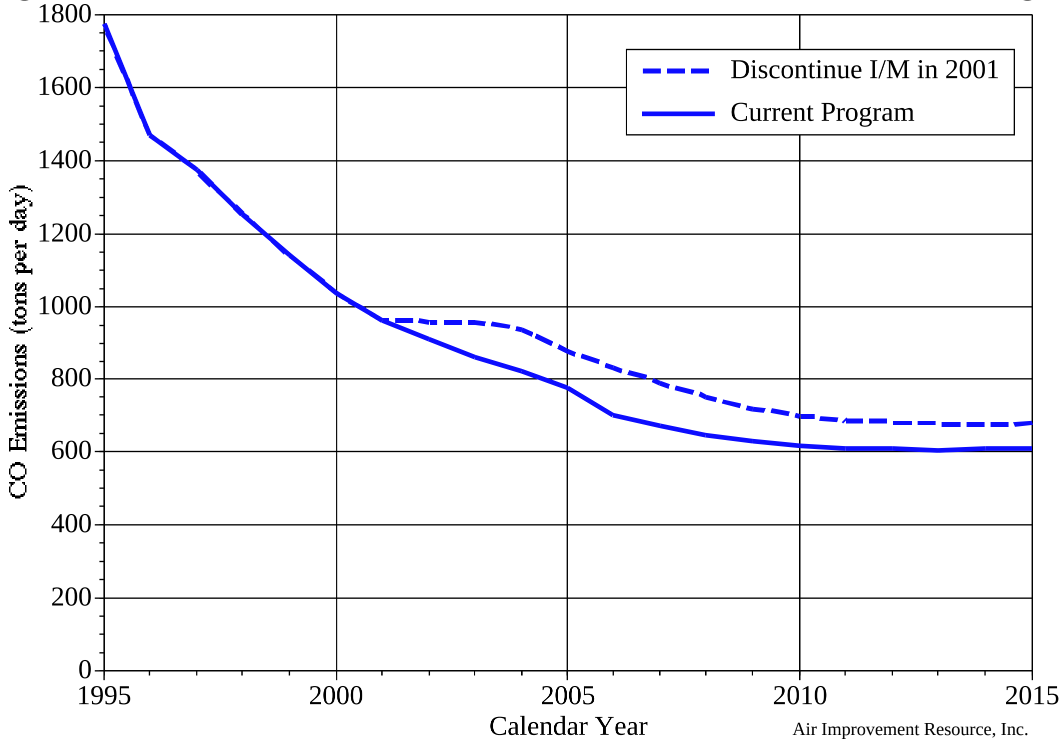


Figure 6-2. All Vehicle CO Trends with Proposed Tier 2 Standards and Fuels, Denver Metro Region

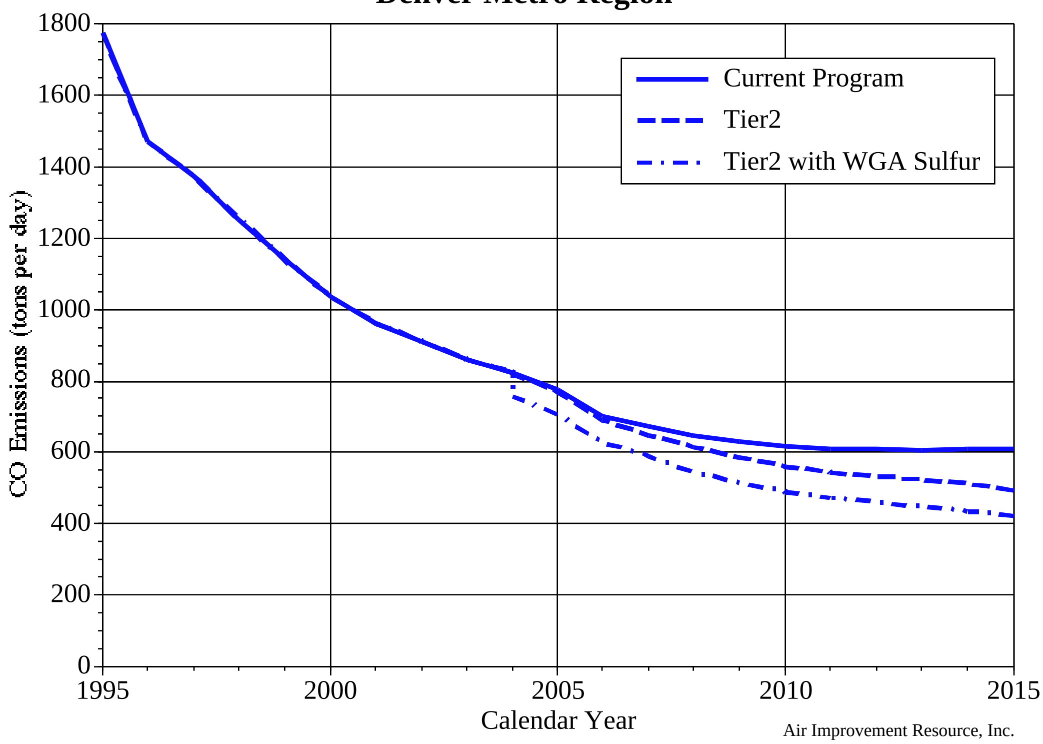


Figure 6-3. All Vehicle CO Trends with Discontinued I/M and Oxygenated Fuels, Denver Metro Region

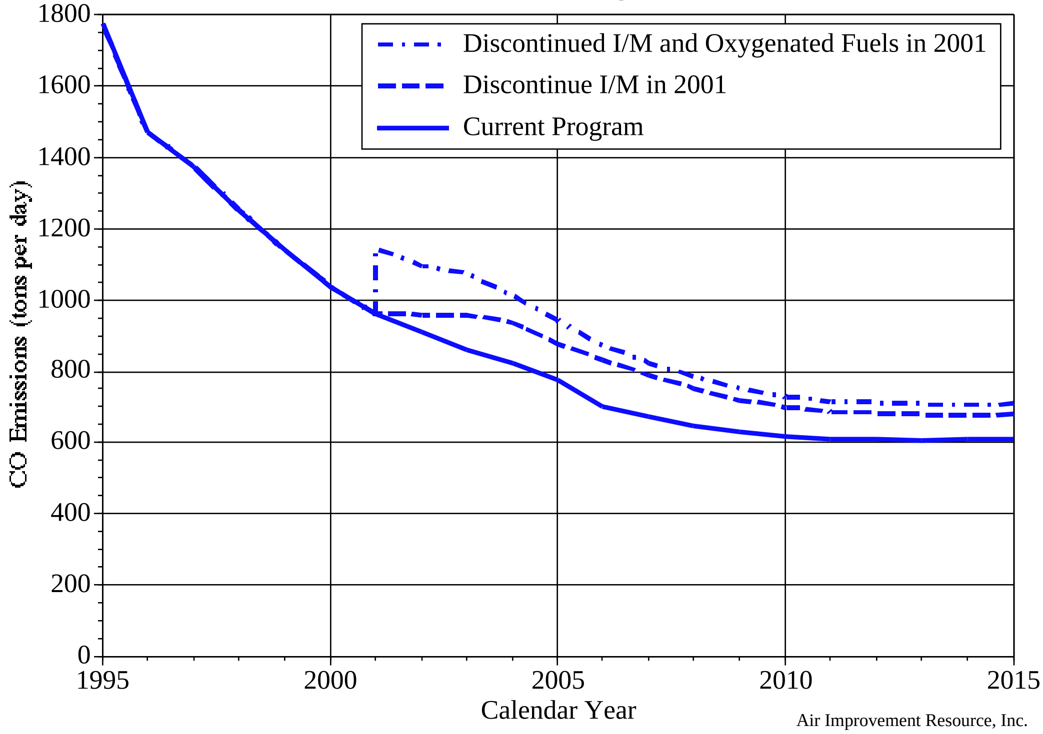


Figure 6-4. All Vehicle HC+NOx Trends with Proposed Tier 2 Standards and Fuels, Denver Metro Region

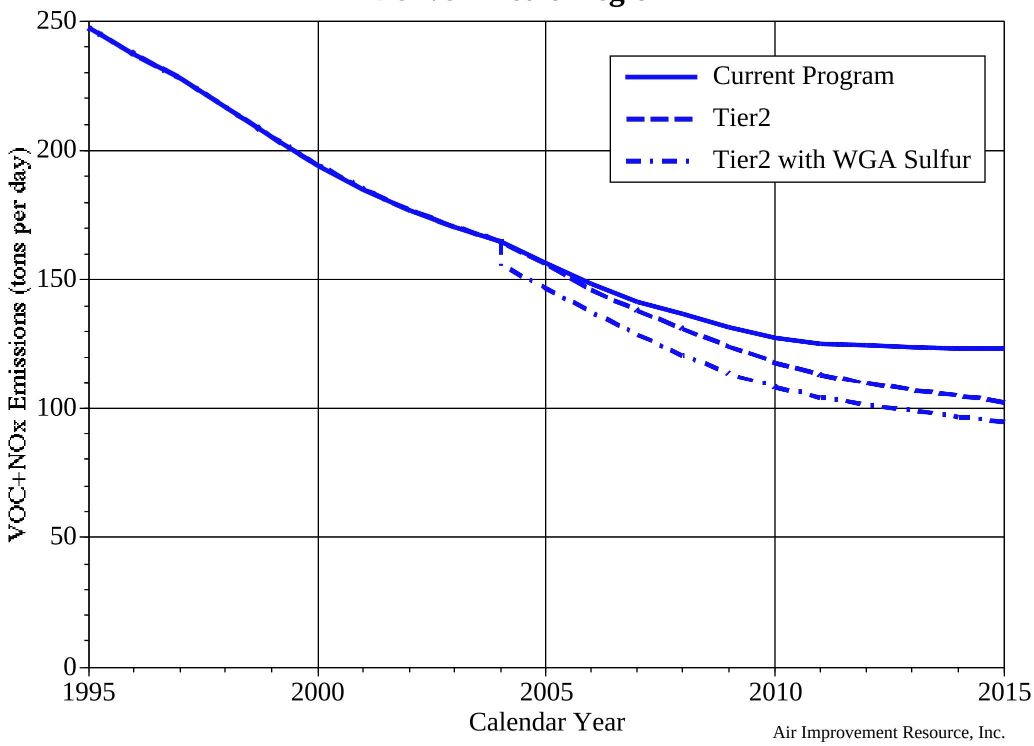
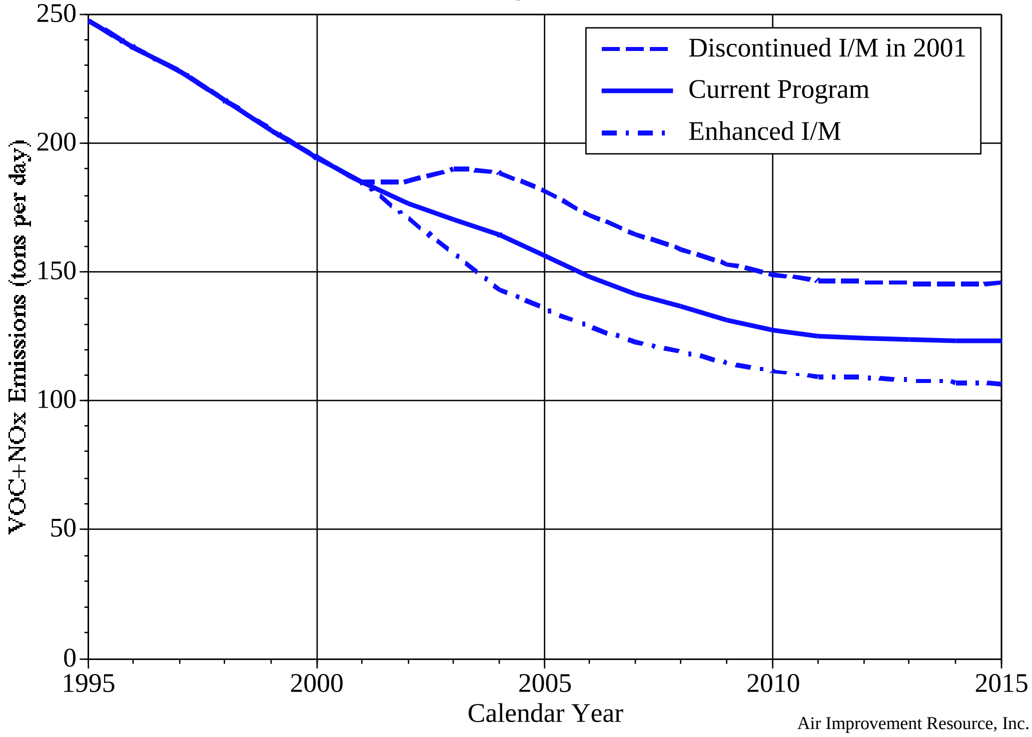


Figure 6-5. All Vehicle HC+NOx Trends under Various I/M Options, Denver Metro Region



In the CO analysis above, we still have not included lower CO due to NLEVs, so the reductions could be even greater (HC and NOx reductions due to NLEVs were included). For all other areas in the state, the relative reductions would look the same as for Denver, except, if the Basic I/M program were discontinued, the impact would be slightly less than for Denver.

The implications of these projections are profound: they imply that even if the State decided to discontinue I/M and oxygenated fuels, there would be only a small impact on CO, HC, and NOx emissions in the state in the long terms, since new technology and fleet turnover continue to reduce emissions from motor vehicles, even with existing growth.

B. Method

In this section, we discuss the models that are used in the analysis, the inputs, and the cases examined.

1. Models Used

a. MOBILE5a and MOBILE5b

EPA's current version of their model for projecting emission inventories is MOBILE5b, which was utilized extensively in the recent Maintenance Plan. MOBILE5a, a previous version of the MOBILE5 model, was used in last year's audit. There are a number of concerns with these two models, which cause concern over projections using the models.

- Cold CO effects are underestimated
- Oxygenated fuel effects are overestimated
- Emission deterioration is overestimated
- Off-cycle emissions and controls are not included
- Onboard diagnostics are not included
- I/M effects overestimated
- The effects of the NLEV standards on CO emissions are not included
- Fuel sulfur effects on advanced technology vehicles are not included

b. EPA Serious CO Area Model

In February 1998, under contract to the auto manufacturers, Air Improvement Resource created a Cold CO Model to address the known shortcomings of the MOBILE5a and MOBILE5b models. [19] The Cold CO model added off-cycle emissions, increased the fraction of vehicles equipped with port fuel injection to be more in line with actual production, increased the fractions of light duty trucks (minivans and SUVs), updated the emission deterioration rates (California emission rates were used), and fixed several problems in the benefits of the Phase 1 Cold CO standard. This model was provided to EPA, and EPA made two additional changes to the model:

- EPA revised the method used to estimate the benefits of oxygenated fuels (lowered the benefits based on more recent testing).

- EPA incorporated their draft MOBILE6 CO emission rates into the model, replacing the California emission rates that AIR had supplied. The draft MOBILE6 deterioration rates for Tier 1 and later vehicles equipped with OBD are higher than the California emission rate for the identical vehicles. Along with the draft MOBILE6 emission rates, EPA also supplied a new set of I/M credits that is consistent with the draft emission rates.

EPA has also since renamed the model the "Serious CO Area Model", for its intended use by serious CO areas, like Denver.

The only items affecting CO not included in the Serious CO Area Model are the NLEV standards and fuel sulfur effects for advanced technology vehicles. EPA has not formally released the Serious CO Area Model, but will make the model available to any state or organization that requests the model. EPA will be releasing guidance on the model shortly. EPA's intent is for the model to be used by states that have CO violations that may be required to implement additional programs. As indicated in the Background, Colorado initially seriously considered using the Serious CO Area Model for its Maintenance Plan, but decided against it because of timing considerations and acceptability of the entire Maintenance Plan to the EPA. During its preliminary evaluation of the Serious CO Area Model, CDHPE staff identified two potential problems with using the model:

1. For pre-1985 calendar years, the model's CO emissions increased, and then decreased. This is not consistent with the reductions in vehicle standards.

2. The Staff indicated that some low altitude emission rates were higher than the high altitude emission rates. This is also not consistent with expectations.

We think that problem #1 is caused by the fact that the model did not add off-cycle CO emissions for pre 1981 vehicles. This is not a problem for our analysis, where we are examining 1995 and later calendar years, but would have been a problem for CDHPE if they had used the model to estimate CO emissions from the design value year of 1988 to any projection year, such as 2001, 2006 or 2013.

Regarding the second issue, the Serious CO Area Model only changes 1988 and later basic emission rates. Due to the all altitude standards, the changes were the same for both low and high altitudes. Thus, any differences low and high altitude emission rates must have been in MOBILE5a and MOBILE5b as well.

c. Air Improvement Resource, Inc. Modified MOBILE5 Models

Air Improvement Resource maintains two updated models: the AIR, Inc. Cold CO Model, and the AIR, Inc. HC and NOx model. Both models are very similar in that they use California emission rates for 1988 and later vehicles, and have all of the features of the EPA Serious CO Area Model, except that we have not yet updated the oxygenated fuel effects. Both models have been updated to estimate fuel sulfur effects for advanced technology vehicles. The HC and NOx model has been used extensively to estimate the benefits of the proposed Tier 2 and sulfur standards.

d. Models Used in This Analysis

For CO, we used the EPA Serious CO Area Model because it reflects important items not included in MOBILE5b, which are expected to be included in MOBILE6. However, we remain concerned about EPA's emission rates in the Serious CO Area Model, because the OBD effects are not yet correct, and it does not properly reflect the influence of the NLEV program on CO emissions (see Appendix E for further details).

At this time, EPA has no model incorporating many of the current and future control programs for HC and NOx. As a result, we have used the AIR modified MOBILE model for this projection.

CDHPE staff have pointed out that neither the Serious CO Area Model, nor our own HC and NOx modified MOBILE5 model have been peer reviewed and completely accepted by the EPA, and therefore are not acceptable in an attainment or SIP demonstration to be submitted to the EPA. This is true for our own model, and questionable for the Serious CO Area Model because the latter model is an EPA model, and has been provided to other states (Alaska and Washington). However, we are not attempting to perform SIP-level modeling here, our goal is to portray a more accurate picture of the future, and to contrast some of the different models, and their implications. We could have used a fully accepted MOBILE5b for all of this modeling, but since the model is far outdated, and ignores many of the important regulations and processes that impact CO in Colorado, we rejected this idea. In spite of the fact that both models we are using here are not fully peer-reviewed, we believe they more accurately portray future CO emissions than any fully peer-reviewed model such as MOBILE5a or MOBILE5b.

A more complete discussion of background issues with respect to uncertainty in emission modeling is found in Appendix D, and the attributes of the different models is presented in Appendix E. Our overall view on the usefulness of models is that they are much better at predicting trends in emissions than they are in predicting the absolute emissions in any given year. And, our primary interest is to determine the future trend in emissions, since that will also determine the future trend in air quality.

2. Comparison of MOBILE5b and EPA Serious CO Area Model for CO

The EPA Serious CO Area Model is quite different from MOBILE5B, and changed the benefits of both oxygenated fuels and I/M. To compare the two models, we created three charts showing a projection of CO in g/mi, the I/M benefits, and the benefits of oxygenated fuels, as shown in Figures 6-6 through 6-8. [18] Growth is not included in these charts. The figures show that:

- CO projections are much lower with the Serious CO Area Model
- I/M benefits are much lower with the Serious CO Area Model
- Oxygenated fuel effects are much lower with the Serious CO Area Model

[18] Inputs used were the Colorado registration distributions, a temperature of 35°F, 19.6 mph average speed, and default operating mode mixes. For enhanced I/M, we used the Denver inputs. Although these inputs are simplified from the full list of inputs given to us by CDHPE, the relative differences should be about the same.

Figure 6-6. All Vehicle CO Emission Factors, No I/M

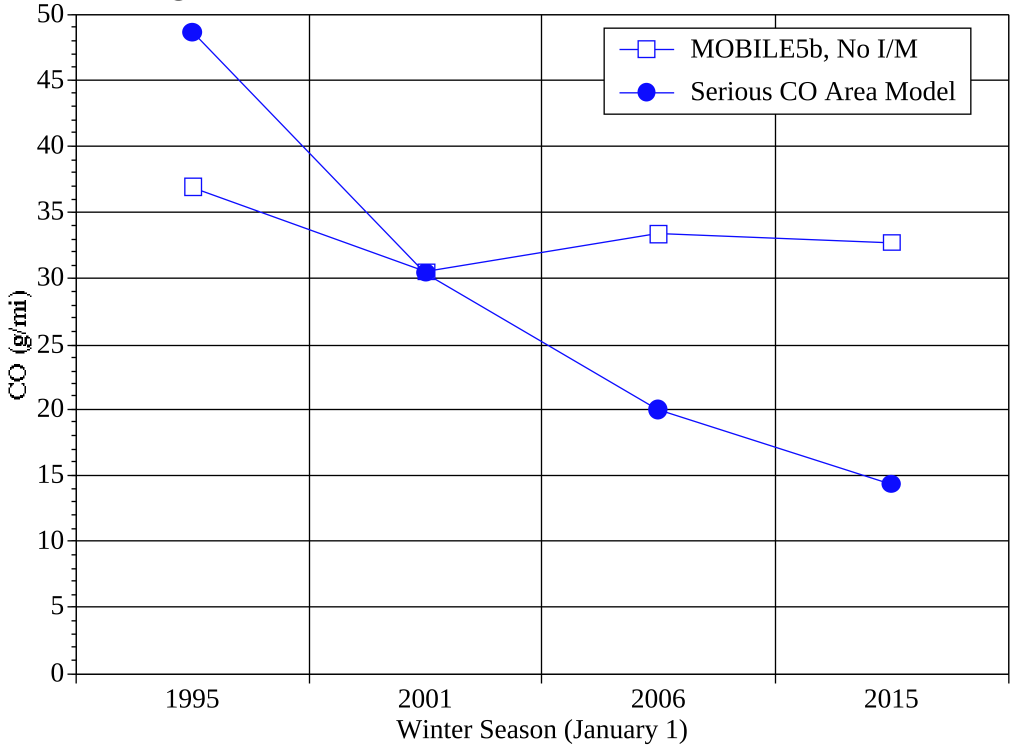


Figure 6-7. All Vehicle CO Emission Factors, Enhanced I/M Benefit

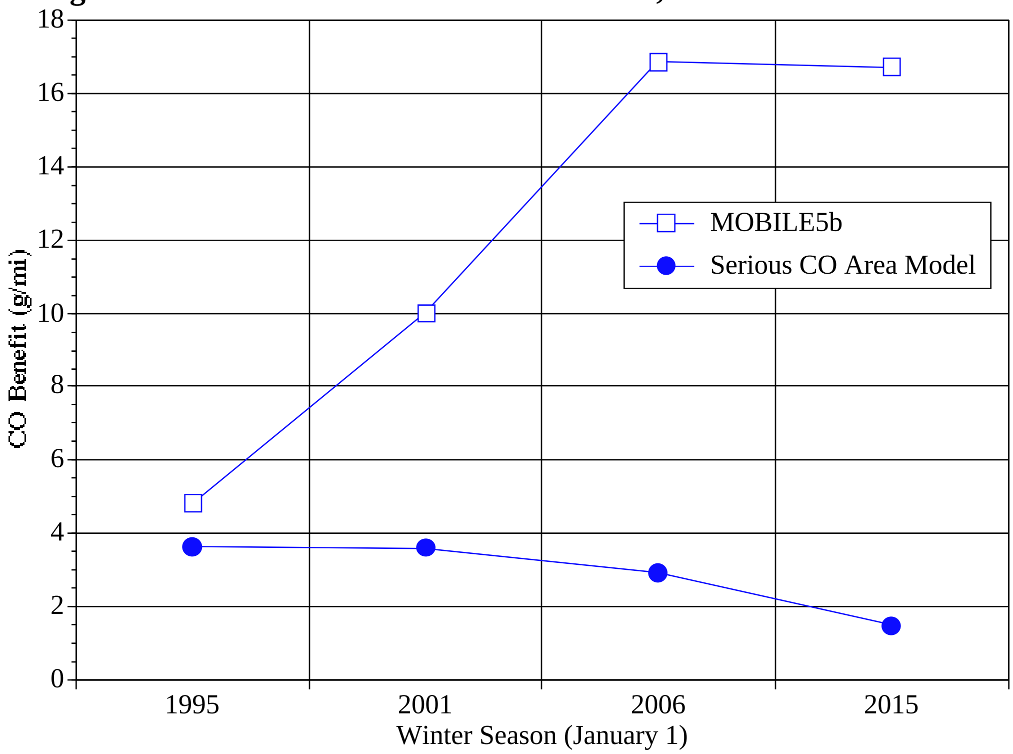
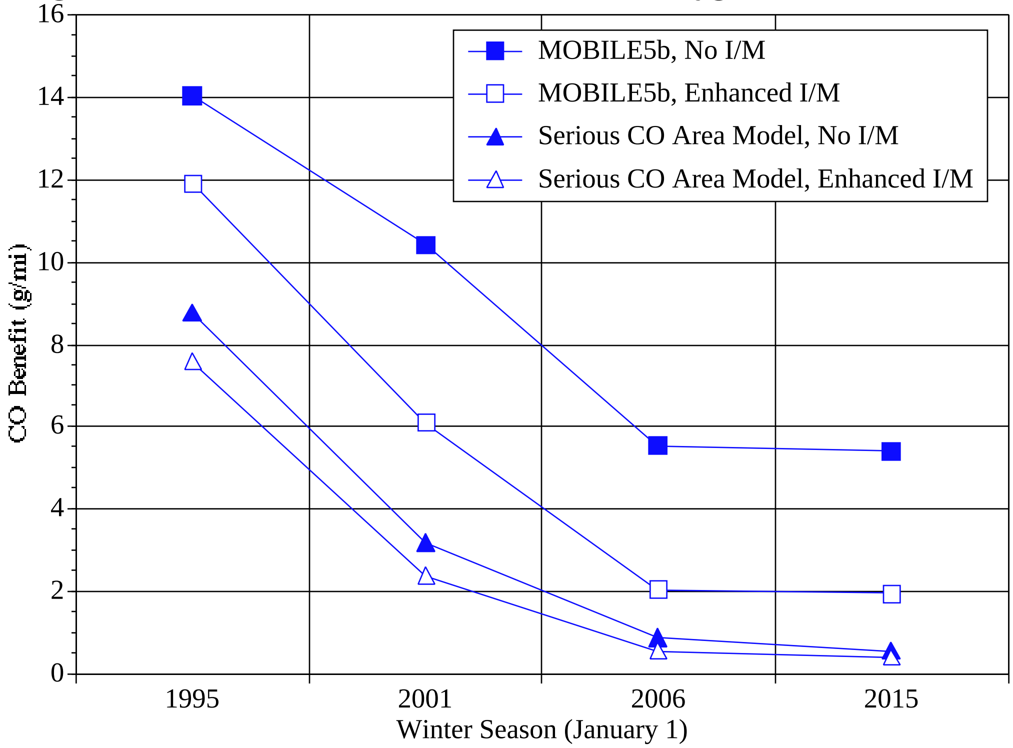


Figure 6-8. All Vehicle CO Emission Factors, Oxygenated Fuel Benefit



This is a preliminary indication of how MOBILE6 likely will look.

3. Inputs and Methods Used for Creating Figures 6-1 through 6-5

CO

For the Denver area, we received a complete set of MOBILE input files and VMT values for four years: 1995, 2001, 2006, and 2013. The MOBILE input files were used for each year, up to the next year that the inputs changed, for example, the 1995 file was used for 1995-2000, the 2001 file was used for 2001-2006, etc. There was one exception to this. For oxygenated fuels, we used the percentages in the Maintenance Plan for each year for 2002 and later. For I/M benefits, we used the input files supplied to us by CDHPE, and let the model estimate the benefits of I/M in each of the years.[19] For CO, we used the Serious CO Area Model.

The Serious CO area model is not capable of estimating the transition impacts of discontinuing I/M, and the gradual buildup, and then scrappage of older, high emitting

[19] As supplied, the modeling input files would have to be processed twice to properly account for both the idle and IM240 tests. Since several hundred model runs encompass each inventory process, we avoided the second round by assuming pre-1982 light duty vehicles underwent the same I/M test (IM240) as 1982-and-later model years. The result is that we have slightly over estimated the benefit of the I/M program, which was preferable since we were using this modeling exercise to develop our upper bound estimate of the Program benefits.

vehicles. For discontinuing I/M, we phased the I/M emissions in with the no I/M emissions line by assuming one-half of the remaining I/M benefit was lost each year. For discontinuing oxygenated fuels, we ran the model with the oxygenated fuel flag off, and assumed the impacts were immediate.

HC and NOx

EPA has not created an HC and NOx equivalent to the Serious CO Area Model for HC and NOx. For this modeling, we used our own modified MOBILE5 HC and NOx model that was consistent with our Cold CO, or EPA's Serious CO Area Model. We have used this model extensively to estimate the emission benefits of Tier 2 and proposed sulfur controls starting in 2004. [25] We obtained summertime temperatures from CDHPE of 58^{o} and 78^{o} and a summertime gasoline fuel RVP of 9.5 psi, but all other inputs were the same as for the winter. The baseline fuel sulfur level assumed in the modeling was 228 ppm, which we determined from analysis of 1998 summer fuel data in Denver.

For I/M benefits for HC and NOx, we assumed an I/M program with 1.2 g/mi HC. The actual HC cutpoint is 2.0 g/mi, but EPA's biennial I/M credits do not encompass a cutpoint that high, therefore, we are slightly overestimating the HC benefit. The NOx benefit is assumed to be zero; in actuality, Chapter 4 indicates a small disbenefit for NOx. Also, like the Serious CO area model, our own model is not capable of estimating the transition impacts of discontinuing I/M, and the gradual buildup and then scrappage of older high emitting vehicles, so for discontinuing I/M, we assumed that one-half of the remaining HC benefit was lost each year.

The current Colorado I/M program is primarily a CO reduction program. However, because of the concern over 8-hour ozone values, we also estimated the impact of a more HC- and NOx-focused program. For this program, we used the EPA I/M credits associated with cutpoints of 0.8 g/mi HC and 2.0 g/mi NOx (the current NOx cutpoint is 6.0 g/mi).

Vehicle Miles Traveled

CDHPE supplied VMT values for the four years above. These values were interpolated between the available years to produce inventory estimates for every year.

C. Review of Colorado CO Projections

The following is a brief review of three other emission studies that used emission inventory modeling for Colorado.

1988 Brown Cloud Forum

The 1988 Brown Cloud Forum was convened to address emission controls that were needed in the late 1980s to bring the State into attainment for CO. As a part of that

Forum, a projection of CO emissions was made, probably using the latest model at that time (MOBILE4.1), from 1980 to 2010. [2] This projection showed the CO inventory in Colorado declining from 1980 until about 1995, where the inventory turned up significantly. Partly as a result of the Forum, the State implemented enhanced I/M in the Denver area, which it did in 1995. Oxygenated fuels implementation predated the Brown Cloud Forum. The projected upward trend in emissions in 1995 and worsening of air quality never materialized. This is probably due to the fact that, either the emissions model was overly pessimistic, the estimated growth was too high, or the control programs were somewhat effective, or some combination of these three reasons. Whether the local control programs were truly needed will never be known, and the question is irrelevant now, but the fact is, the air quality improved, even after 1995.

1998 I/M Audit

The 1998 audit report by Environ contained separate emission projections for many counties in Colorado. [20] The study used EPA's MOBILE5a model (a later EPA version than that used in the Brown Cloud Forum), and VMT inputs supplied by the state. The modeling also assumed the continuation of present I/M programs and the oxygenated fuels program. The estimates for nearly all of the counties showed that on-highway mobile source CO inventories would decline from 1985 to about 2000-2005, at which time the decline in inventories would stop, and the inventory in every county would either flatten-out or start to increase. The projected increase in 2000-2005 is reminiscent of the Brown Cloud Forum projection, so again, the focus needs to be on the emission model being used (MOBILE5a) and VMT estimates, and whether these are overly pessimistic, or for some reason do not include all of the factors affecting CO emissions from motor vehicles. Thus, although the ambient levels seem to verify the MOBILE5a emissions trend in the 1990s, this is not enough to rely completely on MOBILE5 for the next decade's projections.

1999 Maintenance Plan

The 1999 Colorado Maintenance Plan again contains CO emission estimates, based on the EPA model that is approved for use at this time: MOBILE5b. [3] Emission projections are made for 2001, 2006, and 2013, and reflect expected VMT growth. The Plan's conclusions run somewhat counter to those in this document; the Maintenance Plan projects that I/M with remote sensing will be needed through 2013. The Plan anticipates that oxygenated fuels can be phased-out almost completely.

The Maintenance Plan recognizes that the model that the Plan is based on, while being a fully accepted and peer-reviewed EPA model, is outdated and may over predict CO emissions, leading to higher levels of both I/M and oxygenated fuels than may be necessary. Because of this, the Plan anticipates the need to revise the analysis, once MOBILE6 is available.

As stated in the Background section, we are also concerned with another part of the Maintenance Plan that results in high levels of local controls needed to maintain the

CO budget: the use of the 1988 CO design value. The 1988 design value was 16.1 ppm, so strictly on a percentage basis, a 44 percent reduction is need just to reach the 9 ppm level with no margin at all. However, the State has not seen this kind of level in over a decade, the highest levels seen in the 1990s have been in the 9-11.5 ppm range in the earlier 1990s, with 2nd highest values now in the 3-6 ppm range. The use of a lower design value from the 1990s would result in less CO reductions necessary to demonstrate attainment, all other things being equal. For this reason, we believe that that the next revised Maintenance Plan should not only use an updated model like MOBILE6, it should use a design value from the 1990s, perhaps from 1995.

In summary, some of the past model projections have not been confirmed by subsequent air quality results, and others have been borne out by the improvement in air quality. The model has always shown an increase in CO at some point in the future, which has never been shown to occur in the ambient data.

[This page is intentionally blank.]

7. AIR Program Modifications

In this chapter we present the analysis of potential modifications to the enhanced I/M program. We focus on the enhanced area since the basic area is currently proceeding with a remote sensing devise (RSD) clean screen as a supplement to the current I/M program.

The current enhanced program in the Denver-Boulder area consists of a centralized IM240 (transient) test for 1982-and-newer model year light duty vehicles and a two-speed idle test on 1981-and-earlier light duty vehicles and heavy-duty vehicles (all model years). Our evaluation of the effectiveness of the current enhanced program was provided in Chapter 4 of this report. Overall, the IM240 is the primary test type and with time, a greater percentage of the fleet will be tested with the IM240, as the number of older model year light duty vehicles declines. In looking at modifications to the enhanced program, the focus is on improving the efficiency of the IM240. Efficiency is defined as reducing costs as much as possible, while retaining benefits if possible. It is usually expressed as the cost-effectiveness of the program (dollars spent per ton of emissions reductions).

Chapter 4 showed that the IM240 is a more comprehensive test that achieves a greater benefit than the idle test from the repair from a smaller percentage of the fleet. However, the cost per inspection and cost per repair are higher for the IM240 program than for the idle test. Given the higher inspection cost of the IM240 along with the fact that we estimate that 93 percent of the vehicles will pass the initial I/M test (i.e., be tested unnecessarily) in 1999, can some of this unnecessary cost be saved? If some of the initially passing vehicles can be identified and exempted from the I/M requirement prior to incurring inspection costs, the total cost burden would be lowered and the inconvenience to motorists of complying with unnecessary tests would be reduced. In this case, a successful modification would be one in which the net program costs are reduced more than the loss in emissions benefit[20] so that the cost-effectiveness of the program would be improved (fewer dollars spent per ton of emissions reduced).

In the remainder of this chapter, we present the results of our evaluation of the enhanced program alternatives. Alternatives were examined on a 1999 calendar year basis, and we examined two types of short-term modifications, *supplemental modifications* which augment the current I/M program, and *replacement alternatives* which replace the current I/M program with another form of vehicle testing. We also evaluated onboard diagnostics (OBD) separately as OBD integration with I/M is more of a long-term program consideration since only 1996 and later model year vehicles are equipped with OBD. Four sections are included in this chapter addressing the following topics.

- Summary
- Evaluation of supplemental modifications
- Evaluation of replacement alternatives

[20] A loss in emissions benefit may occur due to exempting vehicles that would have failed I/M.

· Evaluation of OBD

A. Summary

We evaluated three types of supplemental modifications: model year exemptions, vehicle profiling and remote sensing device (RSD) clean screening. The primary objective of each is to reduce overall costs by reducing the number of vehicles requiring an I/M test. Of the three alternatives, exempting additional model years costs effectively nothing to implement, there are minimal costs associated with the vehicle profiling, and the costs of RSD screening are more significant, since a new inspection infrastructure must be put into place. For this reason, we recommend that the State maximize the "no cost" screening alternatives before putting in place screening alternatives that cost money. The results of incorporating these modifications into the current transient IM240 enhanced program are presented in Table 7-1.

Table 7-1. Supplemental Modifications to the Enhanced Program
1999 Calendar Year

Program	Net Program Cost (Million $)	Vehicles I/M Tested (Annual)	Vehicles Repaired (Annual)	% of I/M CO Benefit Retained	% Change in CO Cost-Effectiveness ($/ton)[21]
Existing Enhanced Program	$33.4	894,659	61,236	100%	-
4 Model Year Exemption*	$32.0	849,088	60,544	100%	-4%
6 Model Year Exemption*	$28.5	738,185	58,552	98%	-13%
8 Model Year Exemption*	$25.6	651,755	56,031	94%	-18%
Vehicle Profiling	$25.6	636,964	57,170	94%	-18%
80% RSD Clean Screen	$29.5	596,700	52,608	94%	-6%
80% RSD Screen & HEV	$31.9	603,796	55,124	101%	-5%
50% RSD Clean Screen	$30.5	708,434	55,843	96%	-5%
50% RSD Screen & HEV	$31.6	712,870	57,416	101%	-6%

*Exemption from I/M for newest model years except at change in ownership.

Model year exemptions exempt the newest vehicles from the biennial inspection requirement because of their very low failure rates. The current AIR Program has a 4-year model year exemption for the original vehicle owner only.[22] We evaluated an improved exemption strategy where I/M testing for the first 4, 6 and 8 years of vehicle life is exempted, except for the change of ownership requirement.[23] The improved 4-year exemption saves $1.4 million, while retaining over 99 percent of the CO emission reduction benefit. The 6-year exemption saves $4.9 million, while retaining 98 percent of the benefit. Finally, the 8-year exemption saves $7.8 million, while retaining 94 percent

[21] Cost-effectiveness is defined as the dollars spent per ton of CO reduced. A negative percent change in cost-effectiveness signifies an improvement in cost-effectiveness over the current program where fewer dollars are spent per ton of CO removed.
[22] Under the current program, if a vehicle is sold, a change of ownership I/M is required and the vehicle enters a two-year inspection cycle for the new owner and the model year exemption no longer applies.
[23] For example, in an 8-model year exemption, if the vehicle is sold at 4 years, then it only receives one inspection in its first 8 years: at the change of ownership point.

of the benefit of the current program. Overall, the cost-effectiveness of the AIR Program improves with increasing the model year exemption period as the newer vehicles contribute proportionally less to the overall benefit of the program.

Vehicle profiling exempts specific vehicles from I/M testing based on the vehicle's failure rate in previous I/M inspections. To evaluate this option, we estimated failure rates by make, model, model year, and engine displacement while assuming the current model year exemption still applied. Vehicles of unique make, model, model year and displacements with an initial test failure rate of less than 5 percent were assumed to be exempt from testing from the current inspection cycle. Nearly 75 percent of these vehicles were 1990-and-later model years and 25 percent were pre-1990s. In applying this example profile, we estimate a net program savings of $7.8 million, while retaining 94 percent of the current program benefit. Vehicle profiling could also be combined with model year exemptions for further savings without a significant loss of benefit (since 25 percent of the vehicles profiled, pre-1990 model years, would not be included in the proposed model year exemption strategies).

Supplementing the current program with an RSD clean screen program also removes a significant number of vehicles from I/M testing. Two levels of fleet coverage were examined, 80 and 50 percent.[24] There is a cost savings due to reduced I/M inspection costs for vehicles that are clean-screened; however, the cost of setting up and operating the RSD infrastructure is significant, and the net program savings are much less than the other supplemental modifications described above. Based on our analysis, an 80 percent clean screen program saves $3.9 million and retains 94 percent of the current I/M program benefit. A 50 percent clean screen program saves $2.9 million and retains 96 percent of the benefit. The RSD system can also be used to fail identified high emitting vehicles (HEVs) between inspection cycles. When HEV identification is added to a clean screen, the I/M program benefits increase (to a level greater than the current program), but costs increase as well.

We also examined replacement alternatives to the enhanced area I/M program in which the current centralized transient test would be completely replaced. We evaluated three replacement alternatives: decentralized transient I/M, two-speed idle-test I/M, and RSD HEV identification with either IM240 or idle confirmatory testing. Results are shown in Table 7-2.

[24] Fleet coverage signifies the portion of the fleet measured at least twice over a 1-year period by RSD.

Table 7-2. Replacement Alternatives to the Enhanced Program 1999 Calendar Year					
Program	Net Program Cost (Million $)	Vehicles I/M Tested (Annual)	Vehicles Repaired (Annual)	% of I/M CO Benefit Retained	% Change in CO Cost-Effectiveness ($/ton) [25]
Existing Enhanced Program	$33.4	894,659	61,236	100%	-
Decentralized Transient	$33.4	894,659	61,236	100%	0%
Idle Program	$28.7	894,659	138,404	74%	16%
80% RSD HEV with IM240	$17.4	151,462	26,178	65%	-20%
50% RSD HEV with IM240	$11.2	94,664	16,361	42%	-21%
80% RSD HEV with Idle	$18.0	151,462	50,277	48%	11%
50% RSD HEV with Idle	$11.6	94,664	31,423	30%	15%

The current program is a centralized (single I/M test contractor) transient I/M program. If this were replaced with a decentralized transient I/M test, costs and benefits would probably remain about the same. Theoretically, there would be more inspection facilities, but each facility would test fewer vehicles.

Under the two-speed idle replacement alternative, we assumed an I/M program similar to that currently operating in the basic I/M area would be implemented. We estimate that the net program cost would be reduced by $4.7 million due to lower inspection fees, with 74 percent of the benefit retained. The estimated cost-effectiveness of CO control increases by 17 percent indicating that more money would be spent per ton of CO reduced under this option.

Under the RSD HEV identification with IM240 confirmatory testing, only those vehicles identified as high emitters would be subject to I/M testing requirements. We examined two levels of fleet coverage, 80 and 50 percent. These replacement alternatives significantly reduce the number of vehicles requiring I/M and there is an estimated net savings of $16.0 million for the 80 percent program and $22.2 million for the 50 percent fleet coverage, respectively. Benefits are estimated at 65 and 42 percent of the current program for 80 and 50 percent coverage, respectively. RSD HEV identification with IM240 confirmatory testing is the most cost-effective I/M option examined with an estimated 20 percent reduction in dollars spent per ton of CO reduced.

The RSD HEV identification with idle confirmatory testing identifies the same number of vehicles as above, and the net program savings are similar, $15.4 and $21.8 million for 80 and 50 percent fleet coverage, respectively. However, under the idle confirmatory test, there is less benefit. We estimated that 48 and 30 percent of the benefits would be retained by under 80 and 50 percent fleet coverage, respectively. The

[25] Cost-effectiveness is defined as the dollars spent per ton of CO reduced. A negative percent change in cost-effectiveness signifies an improvement in cost-effectiveness over the current program where fewer dollars are spent per ton of CO removed.

cost-effectiveness of CO control for the RSD HEV program is higher than that of the current I/M program.

Overall, the results summarized above show that the most cost-effective supplement to the current Program would be a continuation with the current transient I/M test, while maximizing no- or very low-cost ways of exempting additional vehicles such as improved and expanded model year exemptions and vehicle profiling. RSD clean screening is fundamentally more expensive, and should perhaps be pursued (on a limited basis at first) after model year exemptions and profiling is maximized.

The most cost-effective replacement control strategy would be to replace the current I/M program with RSD HEV identification and IM240 confirmatory testing. This represents a more significant scaling back of the I/M program than implementing expanded model year exemptions or vehicle profiling. The net program cost savings would be 48 and 66 percent for 80 and 50 percent fleet coverage, respectively. Program benefits would be significantly lower. Also, there are significant implementation issues with this approach, including building a new RSD infrastructure to obtain at least 2 measurements on 50 to 80 percent of the fleet, and how to fund the new infrastructure. It is doubtful that just the failed vehicles which receive IM240 testing can carry the entire cost – it is likely that registration fees would have to be raised to fund this option.

B. Evaluation of Supplemental Modifications

We evaluated the impacts of three types of supplemental modifications: model year exemptions, vehicle profiling, and RSD clean screening. The following discusses the results and implementation issues for each of the individual modifications.

1. Model Year Exemption

Model year exemptions take advantage of the fact that newer vehicles fail I/M at a significantly lower rate and thus contribute little to the I/M program benefit. This is demonstrated by the data presented in Table 7-3. This table shows the cumulative vehicles tested, vehicles repaired and the emissions benefit by model year of the current IM240 program in 1999. Table 7-3 shows that over 60 percent of the vehicles tested are 1991-and-newer model years, yet these vehicles account for about 15 percent of the CO and HC emissions benefit. By reducing the number of newest model year tests, the costs of the program can be reduced significantly, while retaining most of the I/M program benefit.

In the current AIR Program, there is a 4-year exemption, which applies to the mandatory biennial I/M test for those vehicles with their original owners. If a vehicle is sold when it is two years old, for instance, there is a change of ownership I/M requirement and the new owner will be required to have an I/M inspection two years later. An alternative to this is to have model year exemptions be independent of vehicle owner. Under these conditions, no vehicle would be tested until it is 4 years old unless it was change of ownership case. Similarly, under a 6-year exemption, no vehicle would be tested until it is 6 years old, unless it changed ownership.

In this analysis, model year exemptions were examined for 4, 6, and 8 years under the current rules, and under modified rules that would exempt vehicles for the entire period, unless they changed ownership.

We relied on the AIR Program data to determine how many vehicles would be removed from biennial I/M testing requirement and to determine the net emissions benefit once the exempted vehicles were removed. For the 1999 calendar year, we estimated that the 4, 6, and 8 year exemption (by our recommended exemption methodology) would yield 45,571, 156,473 and 242,904 fewer vehicle I/M inspections in the enhanced area. Comparatively, we estimated that the extension of the current exemption approach to 6 and 8 years results in 41,440 and 70,231 additional exemptions. The fewer number of exemptions under the current approach is due to the fact that we estimate that about 45 and 35 percent of vehicles are still maintained by their original owners by the time that they are 6 and 8 years old, respectively.

One key advantage to proposed model year exemptions is that there are no significant additional costs to implementing these modifications, as they are simple enhancements to the current program. There will be a one-time cost in the thousands of dollars that will be needed to reprogram computers that track vehicle registration and I/M requirements. We felt that these costs were insignificant compared to the total program cost and have not included this cost in our estimate for this modification.

A second key advantage is that there are not any significant implementation issues for this modification. All of the infrastructure and procedures for this modification are established in the current program.

The details of our evaluation of number of vehicles exempted and the emissions benefit is found in Appendix F of this report for each of the exemption strategies.

Table 7-3. Cumulative Number of Vehicles tested, Vehicles Repaired, CO benefits and HC Benefits by Model Year for the IM240 Test in 1999				
Model Year	**Vehicles Tested**	**Vehicles Repaired**	**CO Benefit**	**HC Benefit**
1999	1.2%	0.2%	0.0%	0.1%
1998	5.8%	0.7%	0.1%	0.1%
1997	11.3%	2.1%	0.4%	0.3%
1996	18.1%	4.3%	0.6%	0.4%
1995	28.7%	7.8%	2.1%	2.1%
1994	37.2%	10.4%	3.5%	3.7%
1993	46.2%	14.5%	6.7%	6.3%
1992	52.2%	18.8%	9.4%	9.3%
1991	60.6%	24.8%	14.7%	14.4%
1990	66.5%	32.0%	20.8%	20.5%
1989	73.9%	40.9%	28.9%	29.5%
1988	79.2%	49.4%	37.0%	38.3%
1987	85.1%	60.0%	48.0%	48.7%
1986	89.4%	69.8%	58.8%	59.4%
1985	93.9%	82.8%	75.2%	75.1%
1984	96.7%	90.6%	86.1%	85.4%
1983	98.8%	96.9%	95.2%	94.0%
1982	100.0%	100.0%	100.0%	100.0%

2. Vehicle Profiling

Vehicle profiling involves the examination of the I/M data record to identify vehicles of specific makes, models, and engine displacement not likely to fail I/M.[26] Those vehicles identified would then be exempted from the mandatory biennial inspection; however, the change of ownership I/M would still be required. The I/M data record would be reviewed annually to update the vehicle profile of exempted vehicles.

We examined a simple vehicle profile in which vehicles with a 5 percent or lower probability of failing the I/M test were exempted based on the 1999 calendar year AIR Program data. We examined only the IM240-tested fleet, as these were the vehicles with the lowest failure rate that would realize the greatest benefit from vehicle profiling. A group of vehicles was identified by the unique combination of make, model, model year and engine displacement. Those groups with a 5 percent or lower failure rate on the initial I/M test were then exempted from their biennial I/M inspection. The selection of the 5 percent level is somewhat arbitrary – the State could select 4, 10, or whatever

[26] Engine displacement was included as a profile variable at the recommendation of the CDPHE.

percent it felt was appropriate. The failure rate cutoff cannot be too low, such that it brings all of the vehicles in for testing.

Based on a 5 percent cutoff, we estimated that 257,694 vehicles (35 percent of the IM240-tested vehicles) would be exempted from I/M in 1999. This resulted in a significant savings in net program costs ($7.8 million) and a small loss in benefit (94 percent retention of current program benefit), as shown in Table 7-1.

One advantage to vehicle profiling is that the costs for implementing a vehicle profile exemption are small. We estimated that there would be the need for a half-time equivalent staff person at the Department of Public Health and Environment to oversee the annual evaluation of the vehicle profile ($50,000 per year). We have also included a nominal $0.20 per registered vehicle would be required by the county clerks offices to handle a more complex exemption process than the current one based solely on model year. This cost may or may not be needed depending on the actual profile implemented. The estimated additional annual cost in 1999 for the proposed vehicle profile is $390,000.

The only potential implementation issue for this modification is that it may require some record of engine size in the State's registration database and that record should correspond to a similar record in the I/M program database. Engine size could be tracked by engine displacement, number of cylinders or engine family, as these are all currently included in the AIR Program database. Alternatively, a VIN decoder could be employed to provide the necessary engine displacement information. Lastly, vehicle profiling without engine displacement may also be a viable option that should be studied further.

Details of the evaluation of number of vehicles exempted and the emissions benefit are provided in Appendix G.

3. RSD Clean Screen

Clean screening refers to examining vehicles with RSDs, and if it is determined that (1) a vehicle is clean, and (2) it is within a few months of its next inspection, then the vehicle is exempted from the inspection. Exactly "how" the vehicle gets exempted is another matter; we are assuming that the RSD systems will also be reading license plates, and that at the end of a measurement day, the data can be integrated with the vehicle registration system, so that when notification of vehicle registration requirement is mailed to the owner, he or she can be notified of whether or not a test is required. If there are no RSD readings for his vehicle, or only one low reading, or 1 or more high readings, the vehicle must be tested. If there are two or more low readings within a few months of the registration renewal, then the vehicle would be exempted. The vehicle owner could be charged a fee for being exempted, and the fee could be used to finance clean screening. The major advantage to the vehicle owner is not having to present the vehicle for inspection.

We examined RSD clean screening where an RSD infrastructure is used to identify clean vehicles and exempt them from mandatory I/M testing. We evaluated RSD infrastructures that covered 50 and 80 percent of the in-use fleet. In our evaluation, we required that valid RSD measurements cover each vehicle twice over a 1-year period.

The data collected for an RSD clean screen can also be used to identify HEVs which are then required to submit to an I/M test, if not already scheduled to do so. We examined the RSD clean screen costs and benefits with and without coupled HEV identification.

We analyzed the RSD data recently collected in Denver for the Coordinating Research Council (CRC) Project E-23[13], with matched RSD and IM240 measurements to determine the effectiveness of various RSD cutpoints to identify clean and high-emitting vehicles.[27] We selected a clean screen that screened the greatest number of vehicles with a small loss in I/M program benefit (66 percent of the 1982-and-newer model year fleet were estimated to be screened) as screening a large number of vehicles is the primary objective of the clean screen.

Based on our analysis of CRC Project E-23 data and the current cutpoints of the AIR Program, we estimated that nearly 300,000 vehicles could be exempted annually from I/M testing through clean screening as shown in Table 7-4. The increase in vehicle I/M tests due to HEV identification represent the estimated number of HEVs identified that were not already scheduled for I/M inspection in the year.

Table 7-4. Change in Vehicle Receiving I/M Test Due to RSD Clean Screening 1999 Calendar Year

	Clean Screen Only		Clean Screen with HEV Identification	
	50% Fleet Coverage	80% Fleet Coverage	50% Fleet Coverage	80% Fleet Coverage
Change in Vehicles Receiving I/M Due to Clean Screen	-186,217	-297,952	-186,217	-297,952
Change in Vehicles Receiving I/M Due to HEV Identification	0	0	4,436	7,097
Net Change in Vehicles Receiving I/M	-186,217	-297,952	-181,782	-290,855

The reduction in the number of vehicles receiving I/M results in a reduction in I/M inspection costs to the implementation of RSD clean screens. However, unlike the previous two modifications (model year and vehicle profiling exemptions), there is also a significant infrastructure investment cost which offsets much of the I/M inspection cost savings, and overall, there is generally a net program cost benefit as reported in Table 7-1.

[27] The results of the analysis of RSD cutpoints are further documented in Appendix H of this report.

Estimates of the additional costs for implementing an RSD infrastructure in the enhanced I/M area is presented in Table 7-5. There are several assumptions and factors that are accounted for in the estimated costs shown, which are documented and described in Appendix H of this report. Overall, since a RSD clean screen program of the scale proposed here has never been implemented, there is a higher level of uncertainty associated with the estimated costs. Yet, clearly the costs of a RSD clean screen will be several millions of dollars, which will significantly reduce any costs savings associated with the exemption of vehicles from I/M testing.

Table 7-5. Additional Costs for Implementing RSD Clean Screening 1999 Calendar Year (millions)

	Clean Screen Only		Clean Screen with HEV Identification	
	50% Fleet Coverage	80% Fleet Coverage	50% Fleet Coverage	80% Fleet Coverage
Infrastructure Costs	$2.0	$4.1	$2.7	$5.9
Administrative Costs	$1.7	$1.7	$1.7	$1.7
Total RSD Costs	$3.7	$5.8	$4.4	$7.7

There are also significant implementation issues for RSD clean screening. The primary implementation issue is the additional cost required for the RSD clean screen infrastructure and administration. A second implementation issue is how to pay for additional costs of a RSD clean screen. If this program were to be implemented, the mechanism for recovering the costs of the RSD clean screen would need to be established. One possibility is to add a charge to the vehicle's registration fee for those that are screened.

A third implementation issue is to determine whether or not to include the HEV identification portion of the RSD clean screen. Including HEV identification improves the emissions performance of the RSD clean screen; however, there may be a significant negative public reaction to the HEV identification component. Not all of the vehicles identified as HEV will fail the I/M confirmatory test. We estimate that, at best, 50 percent of the vehicles identified by RSD as HEVs will still pass a subsequent I/M confirmatory test, thus there may be a significant number of complaints associated with the *additional* I/M requirement for HEVs.

We provide the details of our evaluation of RSD options Appendix H of this report including the documentation of estimated costs and cost-effectiveness.

C. Evaluation of Replacement Alternatives

Three replacement alternatives were examined: a decentralized transient I/M program, a two-speed idle program, and a RSD HEV identification program with either transient or idle confirmatory testing. Specific results for individual alternatives are discussed further below.

1. Decentralized Transient I/M

This option continues with a transient I/M test but does not restrict the testing business to a single contractor (centralized I/M) and relies on multiple contractors (decentralized I/M) to perform I/M testing.

The emissions benefits of this option are essentially equal to a centralized IM240; however, equipment costs are less allowing for more numerous, smaller-scale facilities. One advantage to this alternative is that there may be a motorist convenience factor associated with the additional number of testing facilities.

For this alternative, inspection costs were assumed to be capped at their present levels, and thus the performance of the decentralized transient I/M mirrors that of the current centralized IM240 program as was shown in Table 7-2. The derivation of program benefits, costs and cost-effectiveness for the current centralized enhanced program were documented in Chapter 4 or this report and are not repeated here.

In practice, the inspection costs of a decentralized program could be lower or higher, depending on the vehicle throughput per I/M testing unit. Inspection costs from other states with decentralized transient tests are typically more than those of the current AIR Program suggesting that there will not be a cost savings due to a decentralized program. In addition, the CDPHE has indicated that additional agency staff resources were required to administer the previous decentralized I/M program in the Denver area. This potential additional cost has not been factored into this analysis.

There are implementation issues associated with this replacement option. First, to properly handle the transition period from the current program to the decentralized program, it is likely that some portion of the centralized capacity should be kept in operation in case a sufficient number of decentralized facilities do not come on-line in time. We have not estimated any increased costs or losses in benefit due to potential transition difficulties. Other transition issues include the retraining of inspection staff and establishing a communications network.

A second implementation issue is that there may be significant reluctance from the business community that would perform testing to enter into the I/M market. This could be an issue if there is a perceived lack of support for continuing the I/M program. In addition, if the centralized facilities are allowed to continue operating, new decentralized facilities may be at a competitive disadvantage since the centralized facilities have already recouped the capital investment costs for the I/M testing equipment.

A third issue involves whether to implement test-only or test-and-repair facilities. Stations that combine test and repair allow for greater convenience to the motorist. In this case the motorist does not need to travel to and from a separate establishment to obtain repairs if failing the initial I/M test. However, there may be a higher incidence of fraudulent practices at test-and-repair facilities since there are direct economic consequences for the facility tied to whether the vehicle passes or fails the inspection. As a result of fraudulent practices, there would be a loss in program effectiveness. The degree by which this would occur depends on training and enforcement of the program.

2. Idle I/M

This alternative would be a return to a decentralized two-speed idle test for all vehicles in the enhanced area. There are two idle I/M program types possible, test-only (separate test and repair facilities) and test-and-repair programs. We have estimated equivalent I/M effectiveness for both types,[28] but there is the potential for differences to occur, as discussed in the implementation issues below.

We based the emission benefit, costs and cost-effectiveness of implementing a two-speed idle program in the enhanced area on our evaluation of basic I/M area completed in Chapter 4 of this report. Table 7-6 presents the results of applying the basic I/M area performance to the enhanced area. The current enhanced program performance is also shown in Table 7-6 for comparative purposes.

[28] Current EPA guidelines give equivalent benefit to test-only and test-and-repair facilities.

Table 7-6. Comparison Between Current Enhanced Program and Proposed Idle Replacement Alternative, 1999 Calendar Year		
	Current Enhanced IM240/Idle	Proposed Idle Replacement Alternative
Total Vehicles Inspected	894,659	894,659
I/M Failures	79,461	138,404
I/M Repairs	61,235	108,546
I/M Waivers	349	600
Repair Cost per Repaired Vehicle	$194.81	$114.51
Repair Cost per Waived Vehicle	$367.51	$263.96
Inspection Fee $/inspected vehicle	$22.57	$15.00
Administrative Cost $/registered vehicle	$2.20	$2.20
Inspection Costs $	$20,193,242	$13,419,878
I/M Administrative Costs $	$3,962,414	$3,738,751
I/M Repair Costs $	$12,057,506	$12,588,042
I/M Fuel Economy Improvement Cost $	-$2,552,374	-$1,025,063
Total Cost	$33,660,788	$28,721,607
CO Benefit (Percent of Current I/M Benefit)	100%	74.0%
HC Benefit (Percent of Current I/M Benefit)	100%	70.1%

Replacing the current program with the idle alternative option would test the same number of vehicles of which more would fail and require repairs. The Program would realize a net cost savings of $4.7 million primarily due to reduced inspection costs, but more motorists would be inconvenienced by having to seek repairs. Even though more repairs would occur, the CO benefit would be reduced (since the per repair estimate is less for the idle test, see Chapter 4); we estimate a 74 percent retention of the CO benefit.

There are implementation issues associated with this replacement option. First, to properly handle the transition period from the current program to the decentralized idle program, it is highly likely that some portion of the centralized capacity should be kept in operation in case a sufficient number of decentralized facilities do not come on-line in time. We have not estimated a cost for potential transition difficulties. Other transition issues include the retraining of inspection staff and establishing the communications network.

The second issue is to decide on whether to implement test-only or test-and-repair facilities. Stations that combine test and repair allow for greater convenience to the motorist; however, there may be a higher incidence of fraudulent practices at test-and-repair facilities (as described above in the discussion of decentralized transient I/M). As a result of fraudulent practices, there would be a loss in program effectiveness. The degree by which this would occur depends on training and enforcement of the idle-based program.

3. RSD HEV Identification

We examined a RSD HEV identification program where only those vehicles identified as a high emitting vehicle (HEV) by a RSD would be required to pass an I/M confirmatory test. We examined two types of confirmatory testing, a transient test (such as an IM240) and a two-speed idle test. We also examined two levels of fleet coverage, 50 and 80 percent coverage, where each vehicle is measured twice by RSD over a 1-year period.

We analyzed the RSD data recently collected in Denver for the Coordinating Research Council (CRC) Project E-23[13] to determine the effectiveness of various RSD cutpoints to identify high emitting vehicles.[29] We selected cutpoints that would identify a significant portion of the current I/M program benefit from the measured vehicles. The HEV cutpoints of HC>250 ppm or CO>2.5 percent were selected, which were estimated to classify 8.7 percent of the 1982-and-newer model year fleet as HEVs. Those vehicles would then be subject to I/M testing requirements.

There are advantages to this alternative. First, it removes the greatest number of vehicles from I/M testing and thus realizes the greatest cost savings of any of the alternatives examined. Second, although only a few vehicles are receiving I/M testing, there is a significant program benefit since those vehicles tested tend to be the higher emitters.

The cost savings of this alternative, due to fewer vehicles receiving I/M testing, are partially offset by the costs for implementing and administering the RSD program. Our estimate of the RSD infrastructure costs for an HEV identification alternative to I/M is presented in Table 7-7. The RSD cost for a 50 and 80 percent fleet coverage are estimated to be $4.8 and $8.2 million, respectively (total program costs including confirmatory I/M testing are provided in Appendix H).

Table 7-7. RSD Costs for a HEV Identification Alternative to the Current I/M Program, 1999 Calendar Year

	RSD HEV Identification	
	50% Fleet Coverage	80% Fleet Coverage
Infrastructure Costs	$3.1	$6.5
Administrative Costs	$1.7	$1.7
Total RSD Costs	$4.8	$8.2

There are implementation issues for RSD HEV identification as a replacement alternative to the current I/M program. First, as was noted in the discussion of RSD as a supplemental modification, there is a degree of risk associated with the RSD program. Because a program of this size has not been implemented, there is a greater level of uncertainty with the estimated costs of the RSD HEV program.

[29] The results of the analysis of RSD cutpoints are further documented in Appendix H of this report.

A second implementation issue is how to pay for the costs of the RSD program. If this program were to be implemented, the mechanism for recovering the costs of the RSD program would need to be established. One possibility is to add a fee to the registration of every vehicle.

We provide the details of our evaluation of RSD replacement alternatives in Appendix H of this report including the documentation of estimated costs and cost-effectiveness.

D. Evaluation of Onboard Diagnostics (OBD)

The second generation of onboard diagnostics (OBD) systems is present on all 1996-and-later model year cars and light duty trucks. These systems were discussed in Chapter 5. They represent a long-term solution to I/M, because they are designed to notify the driver of emission control system problems, so that driver has an opportunity to fix the vehicle before serious emission control system damage occurs. If the systems work as they are designed, and if all or most vehicles respond to the systems, then there should be far fewer high emitting vehicles in the future, as OBD-equipped vehicles replace older vehicles without OBD. If the systems do not operate as designed, or if drivers do not respond to the systems, or both, then some believe there will be little reduction in the number of high emitters. However, the authors believe that the systems will perform quite well, that most drivers will respond to the malfunction indicator light (MIL) when illuminated, and that this will lead to a reduction in the number of high emitting vehicles.[30] Furthermore, the authors believe that competitive pressures between manufacturers will be a strong motivator for manufacturers to build very durable emission controls systems so that MILs do not illuminate.

Colorado has already integrated OBD checks with the I/M program. Because of the 4-model year exemption, OBD-equipped vehicles are not yet regularly tested; however, many OBD-equipped vehicles have been tested under the change-of-ownership requirement. While the data is on relatively low-mileage vehicles (the real test of OBD is on higher mileage vehicles), it is still useful to examine the Colorado data for OBD-equipped vehicles.

We have summarized the data on OBD-equipped vehicles in Table 7-8.

[30] Motorist response may decline somewhat with vehicle age and resale value.

Table 7-8. Results on 1996-99 Model Year OBD-Equipped Cars and Light Duty Trucks in Calendar Year 1999 AIR Program Data					
Initial Exhaust Test	OBD Result	Basic Idle		Enhanced IM240	
		Count	%	Count	%
Fail	Fail	53	0.3	229	0.5
	Pass	168	0.8	188	0.4
	Unknown	56	0.3	0	0.0
	Error	0	0.0	139	0.3
Pass	Fail	681	3.2	112	0.2
	Pass	16,142	76.7	38,551	76.0
	Unknown	3,950	18.8	0	0
	Error	0	0.0	11,476	22.6
Total		21,050		50,695	

The first column shows pass or fail status for the initial exhaust test. The second column shows the OBD result. The OBD categories are fail, pass, unknown, or communication error (shown as "error" in Table 7-8). Communication error refers to the inability to establish communication between the vehicle and the OBD scan tool.

For the idle test, the first thing to note is an extremely low failure rate of only 1.4%. Of the 1.4% that failed, only 0.3% out of the 1.4% also failed the OBD check, with either the MIL being on, or there being stored trouble codes in the vehicle computer. The rest were "unknown." Of the vehicles that passed the idle test (98.4%), most did not indicate an OBD problem. About 3% of the vehicles that passed the idle test appeared to fail the OBD check. Thus, while the idle test failure rate was 1.4%, the indicated overall OBD fail rate for OBD-equipped vehicles in the basic I/M areas was about 3.5%.

We would expect that the OBD fail rate would be higher than the idle test failure rate, because the apparent cutpoints are much more stringent than the Idle test cutpoints (see Chapter 5). We are assuming that most of the vehicles that fail the idle test, and do not fail the OBD cutpoints (almost two thirds of the idle test failures), are probably "errors of commission," or should not have been failed by the idle test. There could be a problem with inadequate preconditioning.

For the IM240 test, again, only 1.2% fail the IM240 exhaust test. Of these, 0.5%, or just under one-half, also fail the OBD check. Interestingly, of the 98.8% of vehicles that pass the IM240, only 0.2 % of these fail the OBD check. Thus, while the IM240 fail rate is 1.2%, the OBD fail rate is about 0.7%. We are again assuming that most of the vehicles that failed the IM240 and did not fail the OBD check were errors of commission, and should not have failed the IM240. Vehicles that failed the OBD check but not the IM240 again probably did so because of the apparent tighter stringency of the OBD cutpoints.

We are concerned about the difference in the indicated OBD fail rates between the Basic Idle program, and the IM240 program. At least 5 times as many vehicles in the

Basic Idle area are being marked as fail OBD, even though the number of vehicles tested is one-half that of the enhanced area. Staff should check to ensure that the consistent criteria are being used to determine and OBD failure between the Basic Idle and IM240 areas.

Although the vehicles equipped with OBD2 systems are quite young, the failure rates are very low. This indicates that either vehicles are not failing, or some are failing, and vehicle owners are taking them in for repair prior to their I/M test. Many vehicles that are failing the idle test are not failing the OBD test. We asked EPA about this situation, and EPA believes these are false I/M test failures, where vehicle preconditioning may still be a problem. Of the vehicles that pass the I/M test, but fail OBD, these appear to be vehicles that are failing the more stringent cutpoints of the OBD system check. Thus, the OBD system appears to conduct a better test than a traditional I/M test, and a more stringent test as well. If most people respond to the OBD system throughout most of the vehicle's life, then the number of high emitters on the road should be much less in the future, as increasing fractions of the fleet are equipped with these systems.

[This page is intentionally blank.]

8. Methods of Evaluating the Effects of Program Changes

Since the I/M program and the oxygenated fuels programs could be changed in the future, this chapter identifies research that could be undertaken to better characterize the emissions of the fleet, and to assess the effects of program changes.

This report did include an assessment of a program change: in 1999, the CO emission standards for the IM240 test were lowered (i.e., made more stringent). Our analysis of the annual benefit of the I/M program increased from 6% in 1998 to 8% in 1999, largely as a result of this emission standard change. Thus, it could be stated that the emission standard change resulted in a 25% improvement in the benefit of the IM240 program. This illustrates one of the tools already available to the state: the use of the IM240 data it already has.

This effort has raised several important questions that could be studied further. We will pose the questions, and then suggest ways in which the questions could be answered.

1. What are the cumulative benefits of I/M, as the fleet of vehicles turns-over?

Vehicle technology in the on-road fleet is changing very rapidly. Cumulative benefits can be estimated with EPA's emission models, but if the models are not updated frequently enough, which is often the case, then the results are suspect. A method is needed to estimate cumulative benefits using local data, if possible, to compare with the currently approved EPA model.

2. What are the effects of program changes, for example, increased model year exemptions, changes in cutpoints, changes in the change of ownership program, changes in oxygenated fuels, etc?

The State often contemplates these changes, and again, the State often uses EPA models to estimate the impacts. Use of local data as a comparison would again be helpful.

3. What are the average emissions of vehicles on the road, and how are they changing, due to fleet turnover?

Once again, the current EPA model has an answer, but a comparison with local data would very helpful.

4. How are the vehicles with OBD2 responding to I/M?

This is a very critical long-term question that needs to be assessed on an annual basis.

There are probably many more questions that are also important, but we will start with these four, and suggest ways to answer these. Perhaps the methods will be similar for other questions we have not yet posed.

What are the cumulative benefits of I/M in Colorado, and is there a way to determine this on an annual or periodic basis?

This is a difficult question, and one that we struggled with how to estimate in the report. We are honestly not sure it is worth the effort to try to answer it. If CO is the problem, the State is already quite far below the CO standard, and whether the real long-term cumulative benefit at this time of I/M is 10%, 15%, or 20%, or 25%, may not be too important. Whatever it is, it is probably declining due to the much lower failure rate of new technology vehicles. And, if I/M is discontinued or phased-out in some manner, then state officials can closely monitor the air quality situation and assess the impact, if there is any. One thing we do know is that if the State abruptly stopped the I/M program, emissions would not increase immediately, instead it would take time for vehicles to become high emitters and build up in the fleet. And, it is most likely the older vehicles that would become high emitters, which on average are not driven as far as the newer vehicles. Eventually, they are also retired from the fleet much sooner than the younger, cleaner vehicles. Therefore, if the I/M program were ramped down, there would be time to ramp it up again in the unlikely event that the air quality started trending in the upward direction. For these reasons, and the fact that it is very difficult to produce a defensible analysis of the cumulative benefits of I/M, we think that the State should not spend a great deal of effort here. Finally, EPA’s vote on this seems to count more than everybody else’s vote, so even if a fairly definitive answer were produced, if it differed from EPA’s there would be a lively debate.

If ozone becomes an air quality problem in the future, an I/M program that focuses on HC and NOx reductions may be one of several options for the State to consider. In this case, the State would also need to carefully evaluate sources other than motor vehicles, which contribute significantly to ozone precursor emissions. The State should keep in mind that even without I/M, on-road HC and NOx emissions will be reduced by about 33% from now until 2010, even without proposed Tier 2/Sulfur controls. With Tier 2/Sulfur controls, HC/NOx reductions from on-road mobile sources appear to be about 45%. If an HC/NOx focused program is deemed necessary down the road, the issue of determining the cumulative benefits of I/M may reemerge.

If the State still wants to estimate the cumulative benefits of I/M, probably the best way is through remote sensing. These studies have already been tried, but what we are talking about here is a study in which RSD readings are taken in 3 different parts of the State (enhanced, basic, and no I/M) simultaneously (with the usual license plate identification), with the goal of obtaining approximately equal sample sizes of no I/M, Basic I/M, and Enhanced I/M. In the current studies, the surveys are always at different times, and the sample sizes are not adequately balanced. However, even if these two problems are solved, then we still have the concern that RSD measurements, at only about one-half second per vehicle under lightly loaded conditions, are not very representative of vehicle operation over cold starts, heavy accelerations, no load and idle conditions, etc. If the State wants to answer this question, it could select a random sample of 100 vehicles at each site, and conduct dynamometer testing of all 300 using a self-weighted cycle like the California Unified Cycle, to determine how the percent difference in RSD measurements between sites (assuming there are differences) translate to real world inventory differences. Unfortunately, this gets very expensive.

Perhaps another, and much less expensive method to arrive at the cumulative benefits, at least just for the IM240 program, is to select at random from the IM240 data, 1000 vehicles from each model year or small model year group that have been repaired, and follow their IM240 results for several inspection cycles. The goal of this analysis would be to determine on average how long the repairs last. One would also want to know the distribution, i.e., some last 2 years, some 4, some 6, some not at all. If a RSD program were implemented on a wider scale in the area, perhaps RSD readings would provide interim results on the same vehicles. This is similar to the work conducted by Wenzel. It would be important to do this by distinct model year groupings, because of the dramatic changes in technology that have taken place. This analysis may determine that the average IM240 repair lasts 3.4 years. In this case, the annual benefit we have estimate in this report could be combined with the average length of repair to estimate a cumulative benefit. This type of analysis may work reasonably well on the IM240 data because it is mass emissions over a nominal 240-second cycle, but we do not recommend using it with idle test data.

What are the effects of program changes, for example, increased model year exemptions, changes in cutpoints, changes in the change of ownership program, changes in oxygenated fuels, etc?

Fortunately, this may be easier to answer than the cumulative benefit question. We think we have demonstrated in this analysis the technique of estimating the impacts of cutpoint changes with the IM240 data. Although our benefit was an annual benefit, we determined it increased by about 25% from 6% to 8% from 1998 to 1999. Thus, if the cumulative benefits of I/M are really 15%, then the cutpoint change should increase the cumulative benefits also from 15% to about 19%.

Interestingly, we believe this approach would work very well for estimating the real benefits of oxygenated fuels year after year. We already know from previous analysis that the fail rate drops in the winter, most likely due to the oxygenated fuel program. Thus, someone should (if they have not already) plot average CO emissions at all IM240 stations by day or week, to see how much they are reduced during the oxygenated fuel season. The first few days of the season, there should be a trend down as more and more vehicles refuel with oxygenated fuels. Two weeks into the season, nearly all vehicles that come in for inspection should be operating on oxygenated fuels. The approximate percent benefit should be determined by the difference in average emissions before and after the start of the season. To keep the very clean vehicles from completely washing-out this effect, the analysis may need to be carried out for different as-received emissions levels, and then re-weighted. But this could be attempted for one year, and if it worked, it could be repeated every year to determine if the benefit is declining as the fleet gets cleaner. If the technique did not work at all for one year, then the technique could be abandoned without great expense having been wasted. If it did work, this would provide valuable information on the effects of the oxygenated fuel program as it is phased-out.

Regarding tracing the effects of expanded model year exemptions, in addition to the technique used for the cutpoint change as described above which would work equally well here, this could be also estimated by following the average emissions from year-to-year of the change of ownership vehicles of the newly exempted model years.

What are the average emissions of vehicles on the road, and how are they changing, due to fleet turnover?

The State has had the IM240 program in place since 1995. This question could be answered by examining the trend in average IM240 emissions of initial tests by year, by month, or both. This could be expanded to further reexamine the average emissions of passing vehicles, failing vehicles, repaired vehicles, etc. These could be compared with its MOBILE model predictions and the air quality trends.

How are the vehicles with OBD2 responding to I/M?

We have already analyzed the IM240 data and basic idle data to start to determine this. The analysis has shown a need to examine the coding of the various OBD responses, but overall, OBD is probably doing a good job of identifying failures. This basic analysis could be continued, but there are probably several other analyses that could be conducted. For example, what are the average CO, HC, and NOx emissions of vehicles that are failing the OBD checks? Is it primarily for HC, CO, or NOx? EPA's evidence is that the most common causes of failure are gas cap checks and misfire. But what are the average emissions by pollutant? Are there particular vehicles, or manufacturers that are failing? The purpose in doing these analyses is twofold: to provide additional information to the Colorado inspection and repair industry on how to deal quickly and efficiently with OBD failures, and also to provide the data to EPA and the industry groups, in case improvements in OBD design are needed.

Summary

We think there are quite a few questions that could be answered by the analysis of the IM240 data in Colorado. This is a relatively inexpensive starting point, because the data is already available.

References

1. “Performance Audit of the Colorado AIR Program,” Environ Corporation, March 1998.

2. “Report to the Colorado General Assembly on the Automobile Inspection and Readjustment Program” (Final Report), Colorado Air Quality Control Commission, September 1, 1999.

3. “Proposed Carbon Monoxide Redesignation Request and Maintenance Plan for the Denver Metropolitan Area,” Regional Air Quality Council, September 27, 1999.

4. “Tracking Vehicles Over Time in the Phoenix I/M Program,” Tom Wenzel, Lawrence Berkeley National Laboratory, July 27, 1999.

5. “Our Nations Highways,” Federal Highway Administration, U.S. Department of Transportation, Publication No. FHWA-PL-98-015, 1998.

6. “Petroleum Marketing Annual 1997,” Energy Information Administration, US DOE, DOE/EIA-0487(97), December 1998.

7. 1990 Clean Air Act Amendments.

8. “Inspection and Maintenance (I/M) Program Effectiveness Methodologies,” EPA, Office of Air and Radiation, EPA420-S-98-015, October 1998.

9. “Development of a Proposed Procedure for Determining the Equivalency of Alternative Inspection and Maintenance Programs,” prepared for EPA by Sierra Research, November 10, 1997.

10. “On-Road Evaluation of An Automobile Emission Test Program,” D.H. Stedman, G.A. Bishop, P. Aldrete, R.S. Slott, *Environmental Science & Technology*, 1997, 31, 927-931.

11. “The Use of Remote Sensing Measurements to Evaluate Control Strategies: Measurements at the End of the First and Second Year of Colorado’s Biennial Enhanced I/M Program,” Don Stedman, Gary Bishop, Robert Slott, 8th CRC On-Road Vehicle Emissions Workshop, April 20-22, 1998.

12. “The Colorado Enhanced I/M Program 0.5% Sample Annual Report,” RSTi, January 1997.

13. “Remote Sensing Measurements of Real World High Exhaust Emitters,” CRC Project E-23, RSTi, March 1999.

14. “Regulatory Announcement for Final Rule Amendment to On-Board Diagnostic Checks Requirement for I/M Programs,” U.S. EPA, April 1998.

15. “Control of Air Pollution from New motor Vehicles; Proposed Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements,” U.S. EPA, May 1999.

16. 1999 Alliance of Automobile Manufacturers Fuel Survey.

17. “Users Guide to MOBILE5 Mobile Source Emissions Factor Model,” U.S. EPA, May 1994.

18. “Recommendations for WRAP Comments to EPA on Proposed Tier 2 Motor Vehicle Emission Standards and Gasoline Sulfur Control Requirements,” proposed August 13, 1999, and amended September 1, 1999.

19. “Development of an Updated Cold CO Model,” by Air Improvement Resource for the American Automobile Manufacturers Association, March 21, 1998.

20. “Proceedings of the Brown Cloud Forum,” University of Denver, Atmospheric Sciences Center, Technical Paper 1988-1, February 8, 1988.

21. “Evaluation of the California Pilot I/M Program,” Sandeep Kishan, Rick Baker, Andrew Burnette, Joel McFarland, Radian Corporation, March 31, 1995.

22. “Remote Sensing Feasibility Study in the Northern Virginia Enhanced I/M Program Area,” RSTi, January 1998.

23. “The Greeley Remote Sensing Pilot Project,” Rob Klausmeier (de la Torre Klausmeier Consulting, Inc.) and Peter McClintock (Applied Analysis), January 5, 1998.

24. “National Air Pollutant Emission Trends Update: 1970 – 1997,” US EPA, EPA 454/E-98-007, December 1998.

25. “Nationwide and State-by-State Emission Benefits of a Gasoline Sulfur Limit,” Air Improvement Resource, Inc., December, 1998.

Appendix A: Trends in Air Quality

Internal Memorandum, Colorado Department of Public Health and Environment

*M*EMO

TO: Richard Barrett

FROM: Kim Bruce Livo

DATE: October 5, 1999

RE: air quality trends in the Colorado Front Range area

Air quality along the Front Range has been improving, for most emissions, for the past two decades, or longer. Generally, the area is now attaining all national ambient air quality standards (though just barely for ozone). In the past, the Front Range area has not met the national ambient air quality standards for CO, ozone, and particulate matter.

Carbon Monoxide

Carbon Monoxide has traditionally been a serious air quality concern for the Front Range area. Through the 1980s into the 1990s, the Front Range violated both the federal eight-hour and one-hour standards. Until the mid 1980s, it was common for the CAMP station in downtown Denver to record concentrations of over three times the federal eight hour average. Since then, however, there has been a long term steady decline in recorded values.

The last violation of the national ambient air quality standards for CO was in Denver at the CAMP station in December 1995. For the last few years all monitors have shown significant reductions in one-hour and eight-hour concentrations. The last one-hour violation occurred in the mid-1980s.

Currently most monitors are registering a second maximum between two and six ppm, with the eight-hour standard being nine ppm. These values are well under values recorded just a few years ago. In fact, it is interesting that the CAMP monitor site, usually the site recording the highest CO concentrations in Colorado, did not record the highest one-hour or eight-hour CO reading in calendar year 1998. Instead areas outside of the Denver metro area recorded the highest one-hour and eight hour readings. Colorado Springs recorded a 6.2 ppm 8-hr. max, and 6.1 ppm 8-hr. 2^{nd} max. Grand Junction recorded a 6.1 ppm 8-hr. max and a 5.3 ppm 2^{nd} 8-hr. max. This compares to Denver's CAMP station which recorded a 5.8 ppm 8-hr. max and a 4.7 ppm 2^{nd} 8-hr. max. For peak one-hour concentrations, Fort Collins registered a 12.7 ppm one-hour max, and a 10.9 ppm one-hour 2^{nd} max, compared to CAMP's 11.6 ppm one-hour max, and 9.9 ppm one-hour 2^{nd} max. Both Colorado Springs and Fort Collins operate basic I/M programs. There is no I/M program or oxygenated gasoline program in Grand Junction.

Ozone

The Denver area has for the last decade been in compliance with the previous federal 1-hr. ozone standard of 0.12 ppm. During this time, monitored concentrations have been on a slightly downward trend. Several years ago a maintenance SIP and a request for redesignation as an attainment area were submitted to the U.S. EPA for their consideration. This request, however, was withdrawn when the one-hour federal ozone standard was replaced with the current 8-hr. ozone standard. The Denver area is thus still considered a non-attainment area for ozone.

Denver and the Front Range area continue to show attainment with the previous federal one-hour standard and the new 8-hour standard. The last one-hour exceedance (not violation) occurred at the Chatfield monitor in July 1998, when a one-hour peak reading of 0.132 ppm was registered. The second max at this site was last year at 0.112 ppm, slightly under the 0.12 ppm standard.

There is a new EPA 8-hour ozone standard of 0.08 ppm. The Front Range has for the past three years been just in compliance with this standard, which averages the fourth yearly maximum per monitoring station, averaged over three years. However, ozone levels for 1998 were quite elevated, with the fourth max at the NREL station in Golden being 0.095 ppm. Readings at other ozone monitoring stations were also elevated, particularly those at Chatfield, Rocky Flats, and south Boulder Creek. The NREL station is however the station most likely to exceed the standard next year. This summer its fourth maximum reading was 0.080 ppm; in 1997 it was 0.076 ppm. A three year average for this location is 0.084 ppm. To violate the 0.08 ppm standard requires a three year average of 0.085 since it is rounded to two significant numbers. To avoid a violation of the eight-hour standard next summer, the NREL monitor must register a eight-hour fourth maximum reading of less than 0.080 next summer.

Particulate Matter

The Denver metro area and Colorado Springs last exceeded the PM10 standards in 1993. Fort Collins has not exceeded the 24-hr. standard over the last ten years. With the exception of the Adams County monitor, all Denver area monitors which previously recorded 24-hr. exceedances have shown significant ambient reductions over the last 5-6 years. Measured concentrations are less than half the 24-hr. standard of 150ug/m3 for most monitors. The Adams County monitor continues to measure elevated 24-hr. concentrations (about 75% of the 24-hr. standard). All Front Range monitors have been well under the annual standard of 50ug/m3 for the last ten years. Most show a slight declining trend in measured PM concentrations.

Table 2.2

CARBON MONOXIDE 1998
DATA SUMMARY

Standards

1-hour - 35 ppm * 8-hour - 9 ppm **

County	Location	No. of Days Sampled	1-Hour		8-Hour	
			Maximum ppm	2nd Maximum ppm	Maximum ppm	2nd Maximum ppm
Adams	Welby, 78th Ave. & Steele St.	362	6.6	6.1	3.7	3.5
Boulder	Longmont, 440 Main St.	345	10.8	9.2	4.9	4.7
	Boulder, 2320 Marine St.	358	5.2	4.1	2.5	2.1
	Boulder, 2150 28th St.	363	11.1	10.6	5.1	4.8
Denver	Denver CAMP, 2105 Broadway	354	11.6	9.9	5.8	4.7
	Denver NJH, 14th Ave. & Albion St.	362	8.5	8.1	4.3	4.3
	Denver Carriage, 23rd Ave & Julian St	362	8.3	8.1	5.0	4.4
	Denver Fire House #6, 1300 Blake St.	350	10.1	10.1	5.6	5.2
Jefferson	Arvada, 57th Ave & Garrison St.	362	7.2	6.6	3.7	3.6
El Paso	Colorado Springs, 690 W. Hwy 24	43	(9.3)	(8.8)	(6.2)	(6.1)
	Colorado Springs, I-25 & Uintah Ave.	360	9.3	7.7	4.2	3.8
Larimer	Fort Collins, 708 S. Mason St.	363	12.7	10.9	5.3	4.1
Weld	Greeley, 811 15th St.	353	7.2	7.1	4.8	4.4
Mesa	Grand Junction, 12th St. & North Ave.	351	6.5	6.5	6.1	5.3

* Due to mathematical rounding, a value of 35.5 ppm or greater is necessary to exceed the standard.

** Due to mathematical rounding a value of 9.5 ppm or greater is necessary to exceed the standard.

() Less than 75 percent data recovery.

There were no exceedances of either the 1-hour or the 8-hour standard in 1996, 1997 or in 1998.

Figure 2.4

Carbon Monoxide Trends

Denver CAMP, 2105 Broadway

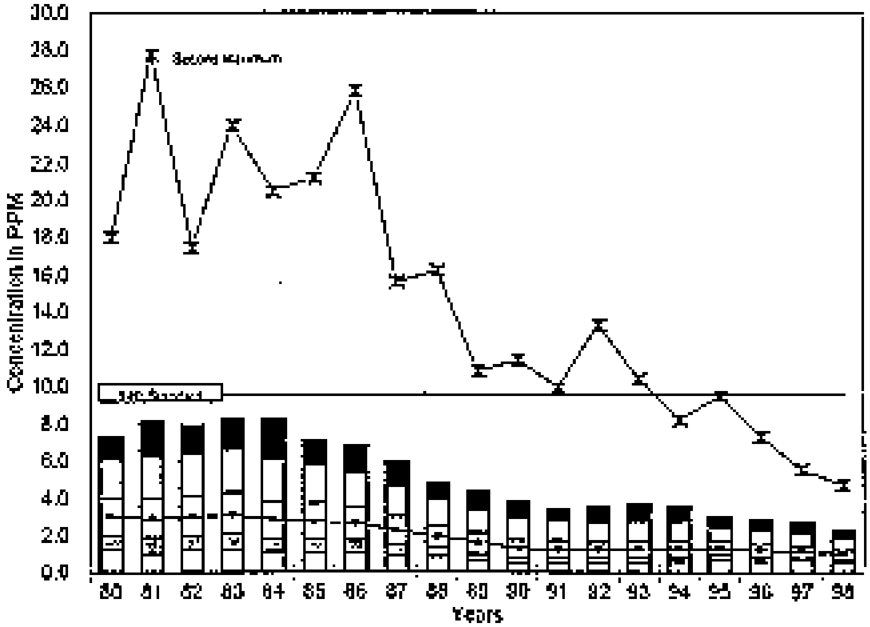


Figure 2.3

CARBON MONOXIDE HISTORICAL COMPARISONS

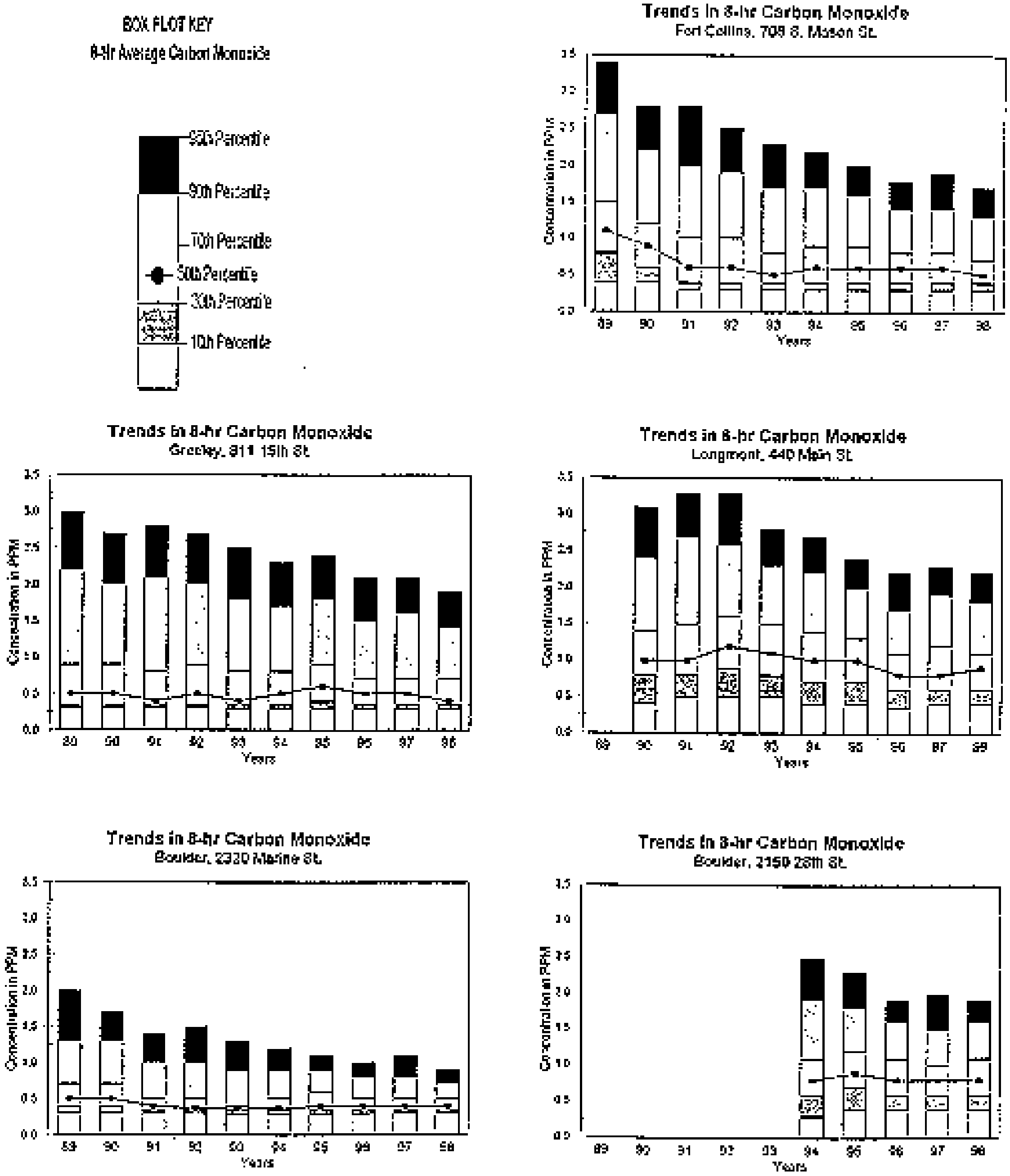


Figure 2.3 (Continued)

CARBON MONOXIDE HISTORICAL COMPARISONS

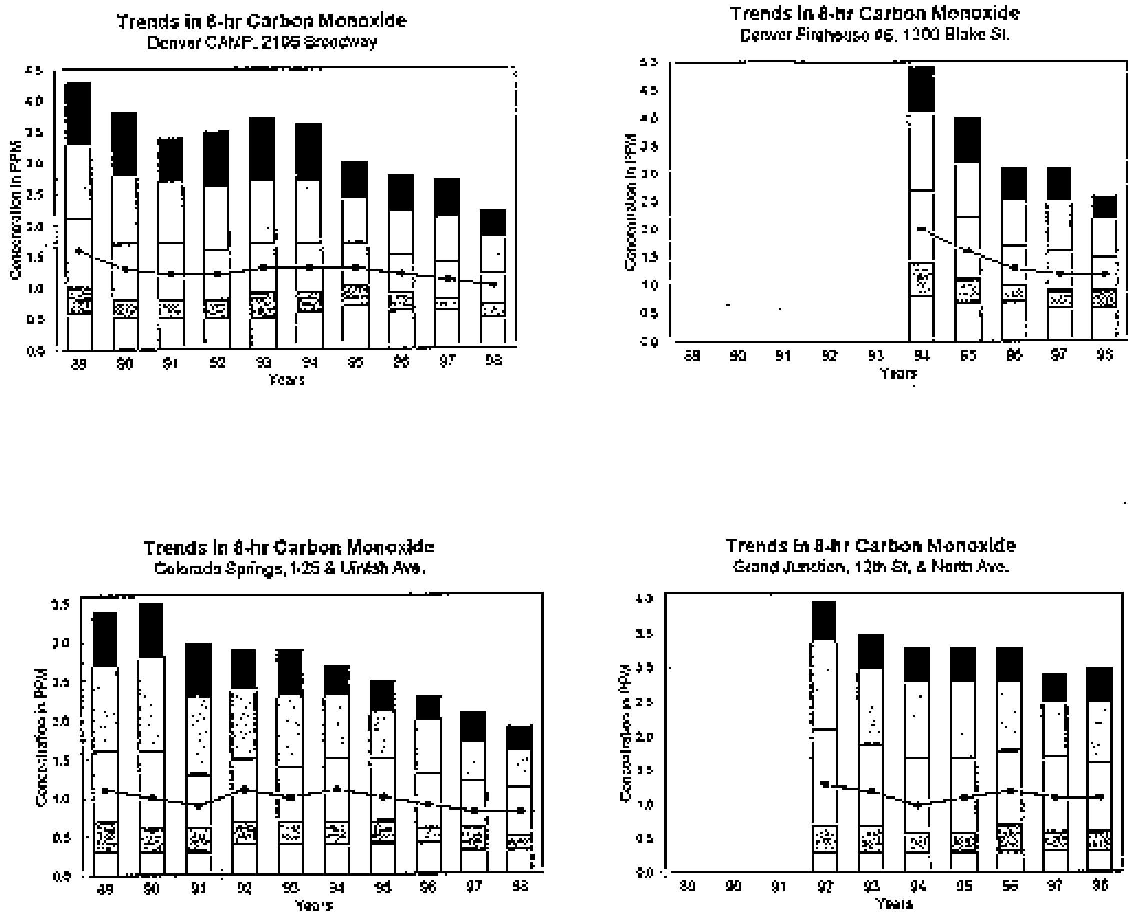


Table 3.4

8-Hour AVERAGE OZONE 1998
DATA SUMMARY (New Standard)

Standard
8-hour - 0.08 ppm*

County	Location	1st Max	2nd Max	3rd Max	4th Max	3-yr Avg of 4th Max
Adams	Welby, 78th Ave. & Steele St.	0.095	0.094	0.083	0.083	0.076
Arapahoe	Highland Reservoir	0.096	0.085	0.084	0.084	0.074
Boulder	Boulder, 2320 Marine St.	0.086	0.085	0.084	0.080	0.074
	Boulder, 1402 ½ Foothills Rd.	0.096	0.091	0.090	0.089	0.078
Denver	Carriage, 23rd Ave. & Julian St.	0.088	0.087	0.086	0.085	0.073
Douglas	Chatfield Reservoir	0.097	0.090	0.086	0.081	0.078
Jefferson	Arvada, 57th Ave. & Garrison St.	0.094	0.093	0.090	0.089	0.077
	NREL, 20th Ave. & Quaker St.	0.103	0.102	0.099	0.095	0.084
	Welch, 12400 W. Hwy. 285	0.083	0.080	0.080	0.080	0.072
	Rocky Flats, 16600 Hwy 128	0.100	0.099	0.093	0.092	0.083
El Paso	USAF Academy, Rd 640	0.073	0.065	0.065	0.062	0.059
Larimer	Fort Collins, 708 S. Mason St.	0.078	0.077	0.074	0.072	0.067
Weld	Greeley, 811 15th Ave.	0.082	0.080	0.076	0.075	0.071

* Due to mathematical rounding, a value of 0.085 or greater is necessary to exceed the standard.

Table 3.1
1-HOUR OZONE 1998
DATA SUMMARY

County	Location	Annual Exceedances: Estimated for 1998	Annual Exceedances: 3-year Average	No. of Days Sampled	Max ppm	2nd Max ppm
Adams	Welby, 78th Ave. & Steele St.	0.0	0.00	363	0.123	0.104
Arapahoe	Highland Reservoir	0.0	0.00	353	0.124	0.113
Boulder	Boulder, 2320 Marine St.	0.0	0.00	354	0.100	0.100
	Boulder, 1402 ½ Foothills Rd.	0.0	0.00	363	0.112	0.111
Denver	Carriage, 23rd Ave. & Julian St.	0.0	0.00	362	0.120	0.107
Douglas	Chatfield Reservoir	0.0	0.00	213	0.132	0.112
Jefferson	Arvada, 57th Ave. & Garrison St.	0.0	0.00	363	0.111	0.108
	NREL, 20th Ave. & Quaker St.	1.2	0.40	363	0.121	0.113
	Welch, 12400 W. Hwy. 285	0.0	0.00	361	0.103	0.091
	Rocky Flats, 16600 Hwy. 128	0.0	0.00	353	0.120	0.118
El Paso	USAF Academy , Rd 640	0.0	0.00	363	0.074	0.071
Larimer	Fort Collins, 708 S. Mason St.	0.0	0.00	363	0.96	0.092
Weld	Greeley, 811 15th Ave.	0.0	0.00	360	0.104	0.102

Figure 3.1

1-HOUR OZONE HISTORICAL COMPARISONS

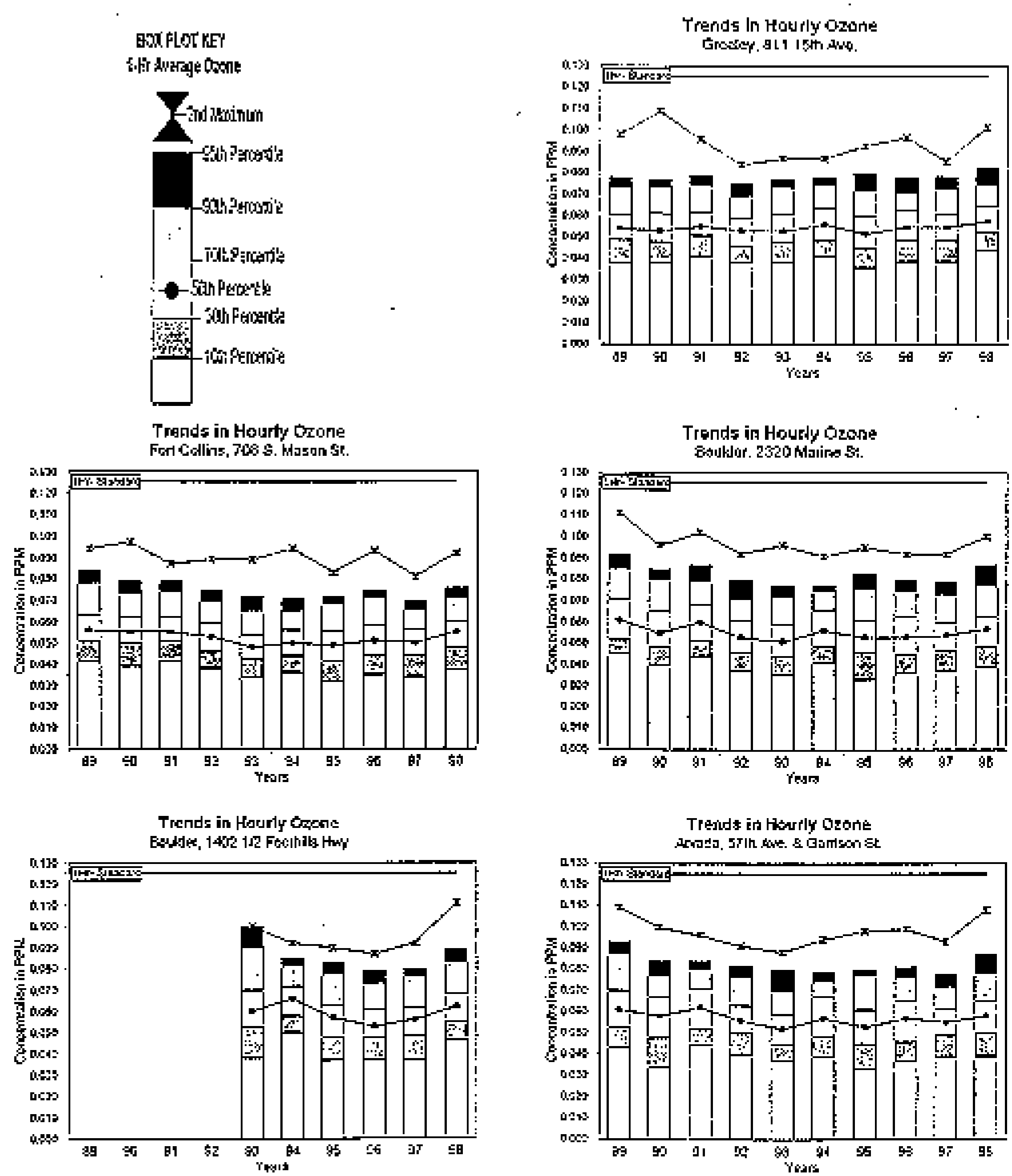
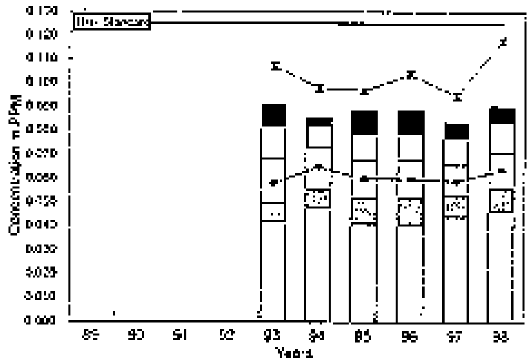


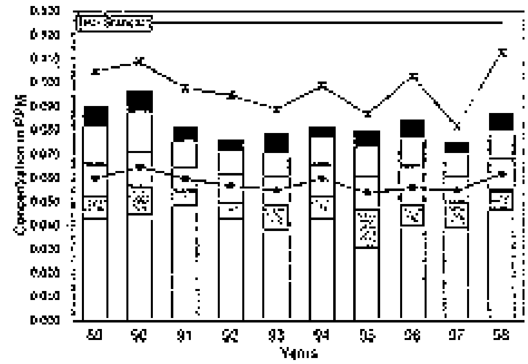
Figure 3.1 (Continued)

1-HOUR OZONE HISTORICAL COMPARISONS

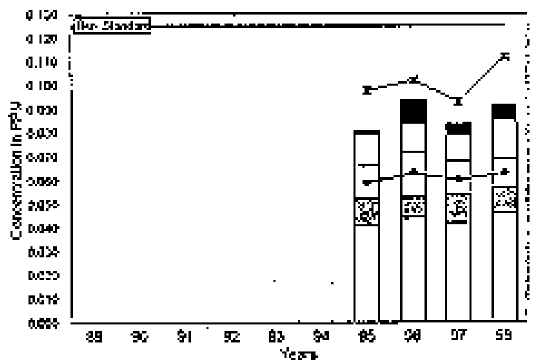
Trends in Hourly Ozone
Rocky Flats, 16600 Hwy 128



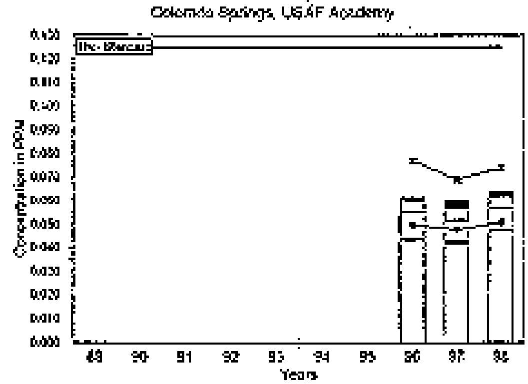
Trends in Hourly Ozone
Highland Reservoir, 8100 S. University



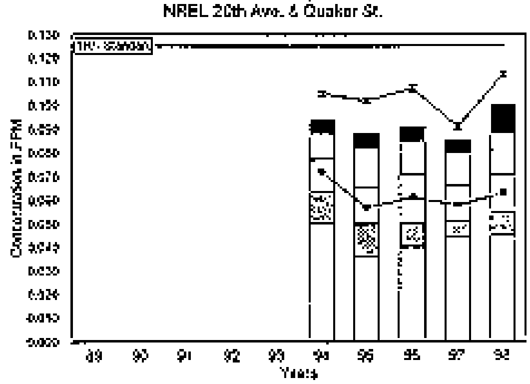
Trends in Hourly Ozone
Chatfield Reservoir



Trends in Hourly Ozone
Colorado Springs, USAF Academy



Trends in Hourly Ozone
NREL 20th Ave. & Quaker St.



Trends in Hourly Ozone
Welby, 78th Ave. & Steele St.

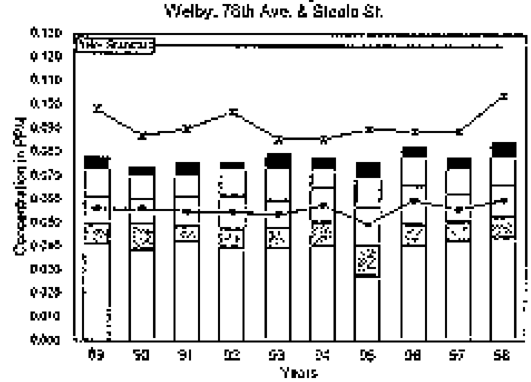


Table 8.1

PM_{10} 1998 DATA SUMMARY

Standards

24-hour - 150 $\mu g/m^3$ Annual average - 50 $\mu g/m^3$

County	Location	Days Sampled/ Scheduled	24-hr Max $\mu g/m^3$	24-hr Expected Exceedances		Annual Average $\mu g/m^3$	
				1998	3-yr Avg.	1998	3-yr Avg.
Adams	Adams City	344	118	0.00	0.00	35	35.0
	Brighton	114	64	0.00	0.00	21	23.3
	Welby 78th Ave. & Steele St.	58	40	0.00	0.00	22	21.7
	Welby (Hourly PM_{10})	326	62	0.00	0.00	19	19.3
Alamosa	Adams State College	332	101	0.00	0.00	23	22.0
Archuleta	Pagosa Springs, 486 San Juan St.	335	66	0.00	0.00	27	29.3
Boulder	Boulder, 2440 Pearl St.	58	47	0.00	0.00	24	21.7
	Longmont, 3rd Ave. & Kimbark St	103	50	0.00	0.00	19	18.7
	Hygiene, 17024 Ute Hwy	16	30	0.00	n/a	13	n/a
Delta	Delta, 560 Dodge St.	50	64	0.00	0.00	23	24.0
	Paonia, High School	59	45	0.00	n/a	18	n/a
	Hotchkiss, 222 W. Bridge St	53	77	0.00	0.00	25	25.3
Denver	CAMP, 2105 Broadway	53	49	0.00	0.00	27	27.0
	CAMP (Hourly PM_{10})	361	108	0.00	0.00	31	24.7
	Gates 1050 S. Broadway	55	71	0.00	0.00	27	28.0
	Visitor Center, 225 W. Colfax Ave.	310	77	0.00	0.00	30	26.0
Douglas	Castle Rock, 310 3rd St.	48	51	0.00	0.00	16	17.3
Eagle	Vail, 846 Forest Rd.	43	94	0.00	0.00	16	15.7
El Paso (Colorado Springs)	3730 Meadowlands Dr.	112	80	0.00	0.00	20	21.3
	701 N. Circle St.	56	37	0.00	0.00	22	20.0
	101 W. Costilla St.	60	47	0.00	0.00	26	25.3
Fremont	Cañon City, 7th Ave. & Macon St.	58	73	0.00	0.00	16	16.3
Garfield	Rifle, 200 W. 3rd St.	58	70	0.00	0.00	24	29.0
	Glenwood Spgs, 806 Cooper St.	47	72	0.00	0.00	20	18.7
Gunnison	Crested Butte, 136 & Whiterock	114	137	0.00	0.00	29	45.3
	Mt Crested Butte	322	207	1.26	3.65	38	31.3
Jefferson	Arvada, 8101 Ralston Rd.	56	47	0.00	0.00	23	21.3

Table 5.1 (Continued)

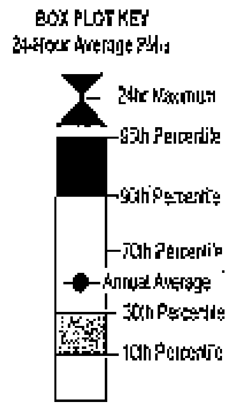
PM_{10} 1998 DATA SUMMARY

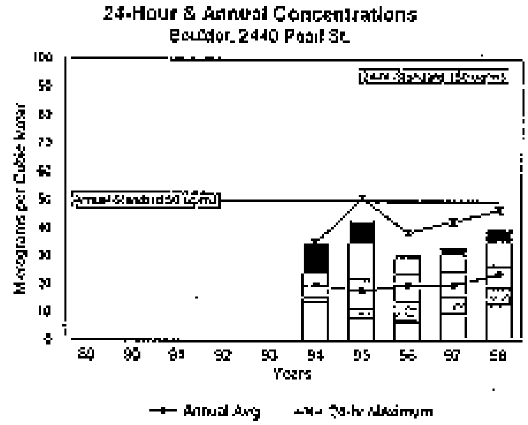
County	Location	Days Sampled/ Scheduled	24-hr Max µg/m³	24-hr Expected Exceedances		Annual Average µg/m³	
				1998	3-yr Avg.	1998	3-yr Avg.
Jefferson	Rocky Flats 10600 Hwy 128	59	37	0.00	0.00	13	11.3
	Rocky Flats 11501 Indiana St.	61	37	0.00	0.00	14	12.6
	Rocky Flats 9901 Indiana St.	59	37	0.00	0.00	14	12.6
	Rocky Flats 18000 W. Hwy. 72	60	37	0.00	0.00	13	12.3
	Rocky Flats 11190 N. Hwy. 93	56	38	0.00	0.00	15	13.7
La Plata	Durango, 277 3rd Ave.	254	206	1.25	(0.42)	30	(36.7)
	Durango, 623 E. 5th Ave	179	93	0.00	(0.00)	18	(17.0)
	Durango, 1060 E. 2nd Ave.	168	94	0.00	0.00	18	18.0
Larimer	Fort Collins, 200 W. Oak St.	102	34	0.00	0.00	16	17.3
Mesa	5th St. & Rood Ave.	45	51	0.00	0.00	23	22.3
	12th Ave & North, Stocker Stadium	53	71	0.00	0.00	20	19.3
	Stocker Stadium (Hourly PM_{10})	337	55	0.00	0.00	20	20.3
Montrose	Montrose, 125 S. Townsend Rd.	39	50	0.00	0.00	(25)	26.6
	Olathe, 327 4th St.	113	79	0.00	0.00	35	(25.7
Pitkin	Aspen, 420 E. Main St.	340	68	0.00	0.00	20	20.0
	Aspen, (Hourly PM_{10})	282	62	0.00	0.00	23	(23.0)
Prowers	Lamar, 100 2nd Ave.	351	137	0.00	0.00	26	24.3
	Lamar, 104 Parmenter St.	323	63	0.00	0.00	21	19.0
Pueblo	Pueblo, 151 Central Main St.	31	51	0.00	0.00	(22)	(25.0)
	Pueblo, 211 D St.	53	60	0.00	n/a	(25)	n/a
Routt	Steamboat Spgs, 136 6th Ave.	352	82	0.00	0.00	26	25.7
San Miguel	Telluride, 333 W. Colorado Ave.	315	70	0.00	0.00	24	25.0
	Telluride, (Hourly PM_{10})	362	90	0.00	0.00	26	23.7
Summit	Breckenridge, 501 N. Park Ave.	110	125	0.00	0.00	16	16.3
	Silverthorne, 151 4th St.	50	47	0.00	0.00	22	22.0
Teller	Cripple Creek, Bennet Ave & 2nd St	249	139	0.00	1.79	41	40.0
Weld	Greeley, 1516 Hospital Rd.	107	40	0.00	0.00	17	17.6

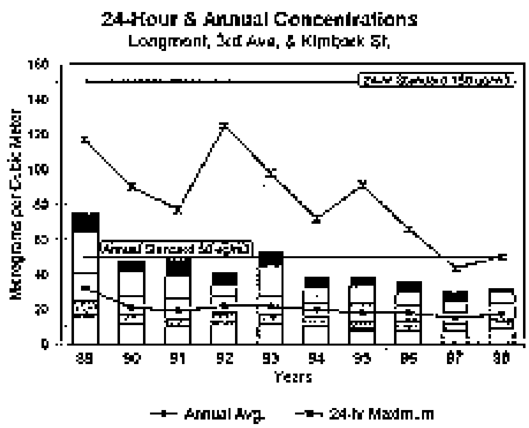
() Less than 75 percent data recovery.

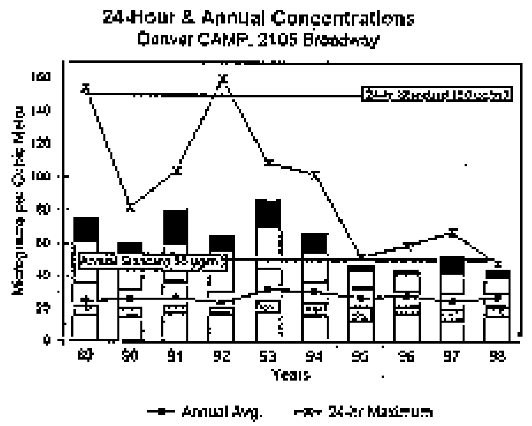
Figure 6.2 (Continued)

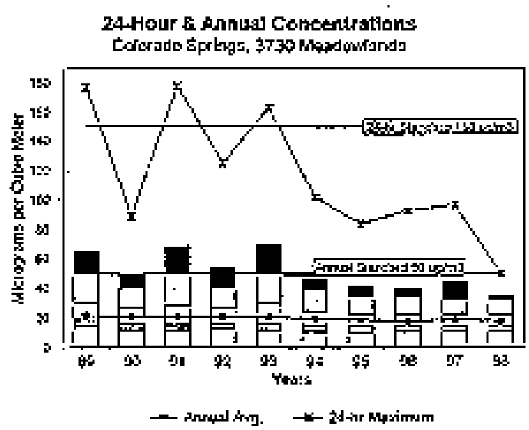
PM_{10} HISTORICAL COMPARISONS











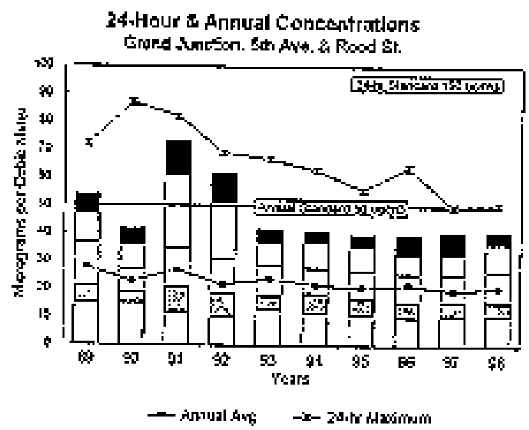
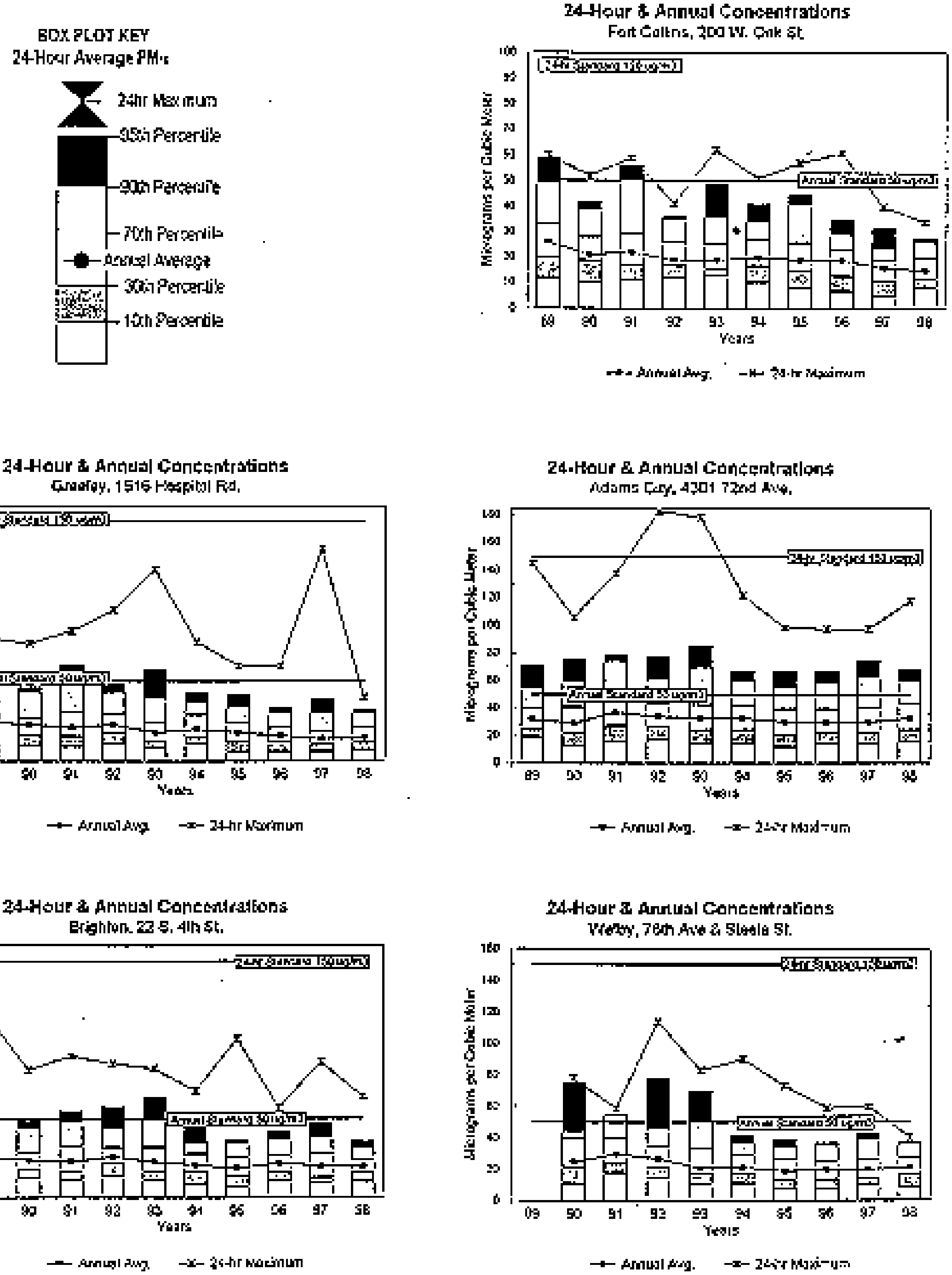


Figure 6.2

PM_{10} HISTORICAL COMPARISONS



[This page is intentionally blank.]

Appendix B: Further Details on I/M Benefits Method

The following process was used in estimating the I/M benefit:

1. The analysis period was determined (for example, all of 1998).

2. I/M data were obtained from the CDPHE for the analysis period. For the 1998 analysis, the 1999 data were also examined to account for vehicles that failed at the end of the 1998, and were repaired in 1999.

3. Failed vehicles and all of their emission tests were identified. Failed vehicles fell into three categories: eventually passed, waived, or unresolved.

4. I/M emission reductions in g/mi (ppm and % for the basic idle) were estimated for the passed and waived vehicles (many waived vehicles also received some repairs).

5. These I/M reductions for passed and waived vehicles were translated into Federal Tests Procedure emission g/mi reductions using the El Monte dataset for the IM240, and the California 1990 I/M evaluation for the Basic I/M test.

6. The g/mi (ppm, % for basic idle) reductions were translated into percent FTP reductions by dividing by the average FTP emissions of failing vehicles in the above datasets.

7. The percent FTP reductions for repaired vehicles were adjusted to a percent change in tested vehicles by weighting the reductions for passed and waived vehicles by the fraction of emissions in these categories in the initial I/M tests.

8. The percent benefit for vehicles tested was adjusted to account for the fraction of the fleet by model year that was not tested in the period (in the case of biennial I/M). The result is a percent benefit for all gasoline vehicles. This percent benefit can be directly compared to the other methods (i.e., RSD, MOBILE model).

9. Finally, the percent benefit for all gasoline vehicles was adjusted to account for vehicles not tested for CO, i.e., diesels and motorcycles. The result is the percent benefit on all on-road CO, which can then be multiplied by an estimate of total on-road CO, to derived the mass emission benefit in tons per day.

Data Processing

The AIR Program data were extracted and processed for the purposes of estimating the benefits of I/M. The AIR Program data from 1995 through the end of May of 1999 were provided by the CDPHE on CD-ROM. From this record, we examined the data from all of 1998 and January through May 1999.

The processing steps taken were as follows. The data for the period of study were extracted from the AIR Program database. In completing this, the only fields of interest for this study were extracted. The data were separated into three test types, enhanced IM240, enhanced idle and basic idle. Unusable records were filtered out. These included test results recorded as "abort," fuel types other than gasoline, non-mandatory test records (e.g., state audits or other official testing). Data were sorted by vehicle identification and test date to identify unique vehicles in chronological order. Only initial and final test records were retained and intermediary test records were removed. Additional vehicles were removed when inconsistencies were observed between vehicle class or model year between the initial and final tests. This filter removed only a few hundred vehicles from the data record.

The total number of unique vehicles extracted from the AIR Program database used in our estimation of I/M benefits is presented in Table B-1. For the full-year 1998, about 1.2 million vehicles were tested and used in our analysis. For the partial-year 1999, about 500,000 vehicles were used in our analysis. Table B-1 also includes our estimate of the number of tests expected for the full year 1999. We estimate that there will be about a 6 percent increase in the number of vehicles tested in 1999.

Table B-1. Unique Vehicles Extracted From AIR Program Data Used to Estimate the Benefits of I/M

Program Area	Model Year and Test Type	1998	1999, January through May	1999, Full Year Estimate
Enhanced Area	Pre-82 Idle	137,520	54,308	131,274
	1982+ Idle	26,204	12,873	31,117
	1982+ IM240	678,483	302,938	732,267
	Total	842,207	370,119	894,659
Basic Area	Pre-82 Idle	59,673	21,638	52,304
	1982+ Idle	260,956	120,258	290,690
	Total	320,629	141,896	342,994
Total		1,162,836	512,015	1,237,652

The data for these vehicles were then analyzed to estimate the benefits of the I/M program. First the quantity of vehicles failing the inspection were quantified. Second, the fate of the failing vehicles was determined. Most failing vehicles receive repairs and some receive a waiver from the program requirements. Some failing vehicles are never seen again; these vehicles are referred to as unresolved failures. Third, the emissions benefit is assessed for the vehicle receiving repairs. In addition to the emission data, cost of repair and inspection fee data were also extracted from the database. These were used in the analysis to estimate total costs of the AIR Program.

Converting I/M Emission Benefits to FTP Benefits

For vehicle receiving repairs, there is an improvement in the I/M test score. The change in I/M score, however, does not necessarily correspond to an equivalent change in in-use emissions. To address this, the changes in I/M test scores were converted to a Federal Test Procedure (FTP) basis, as the FTP better reflects in-use operating conditions.

In order to complete this task, we relied on test data for vehicles failing an I/M test and receiving repairs for which both I/M and FTP tests before and after repair were recorded. There are a small number of databases that include test data and vehicles meeting this requirement.[31] For the IM240 test, we relied on the 1995 California Pilot I/M Program study and for the idle test, we relied on the 1990 Evaluation of the California I/M program. The use of data from these two programs is discussed separately below.

In general, we examined the relationship between the change in FTP (denoted as ΔFTP) and the change in I/M test (either ΔIM240 or ΔIdle) due to vehicle repair. This was done because ΔFTP is the parameter of interest to the estimation of the I/M benefit.[32]

The 1995 California Pilot I/M Program included the evaluation of the effectiveness of the IM240 test type as one of the options under consideration for enhanced I/M in California. [21] We identified 120 1982-and-later model year vehicles that failed the IM240 and had matching IM240 and FTP measurements before and after repair. Of these, 75 used the ASM I/M test to define passing and 45 used the IM240 test to define passing. We developed a linear regression between ΔFTP and ΔIM240 using the 45-vehicle database as the testing criteria most closely matches that in place in the AIR Program. The results of our analysis are shown in the following figures. Overall, the data appear to fit a linear model well and the R-squared coefficients show very good agreement from 0.54 for NOx to 0.91 for HC which signifies that 54% to 91% of the variation in ΔFTP and can be measured by ΔIM240.

[31] We considered Colorado specific databases, but found none that contained matched I/M and FTP data before and after vehicle repair.
[32] Most researchers, such as Environ in the previous audit, have examined the direct relationship between I/M test and FTP. [1]

Figure B-1. ΔIM240 vs. ΔFTP, CO, 1982+ Model Years

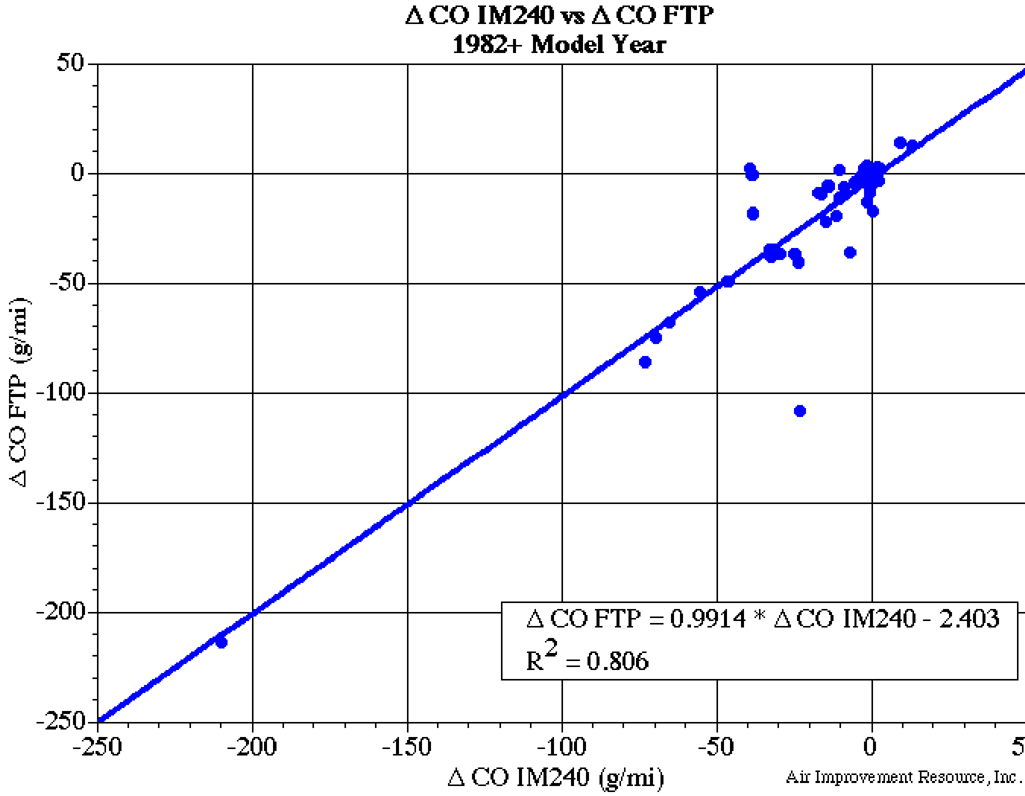


Figure B-2. ΔIM240 vs. ΔFTP, HC, 1982+ Model Years

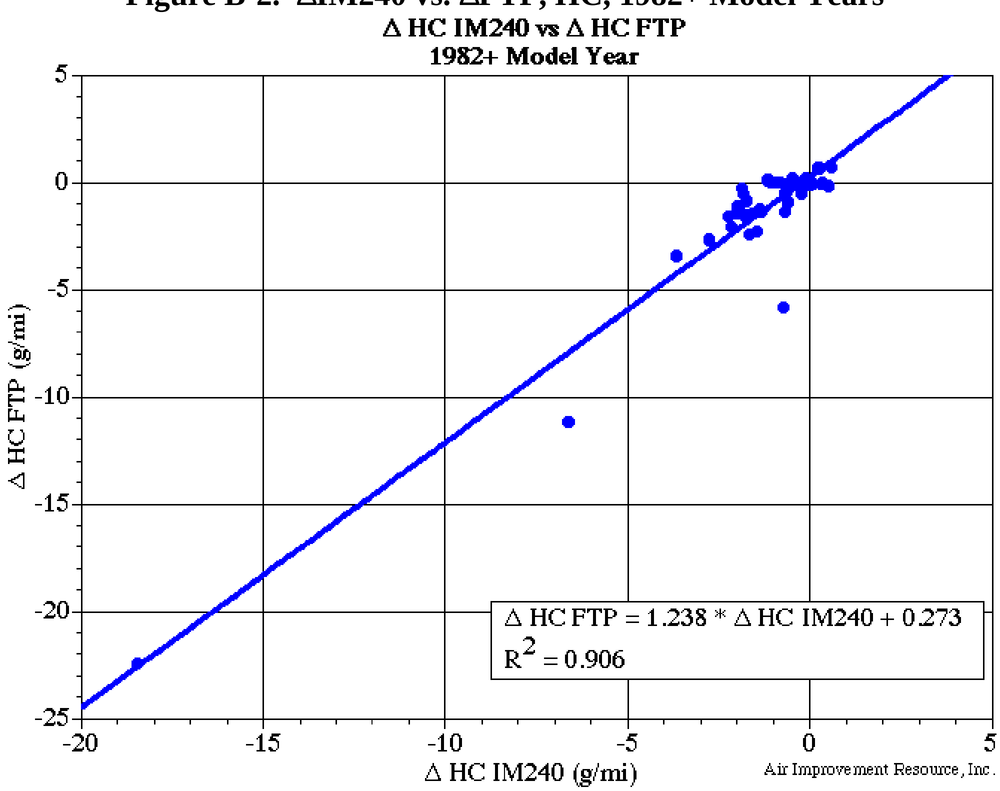
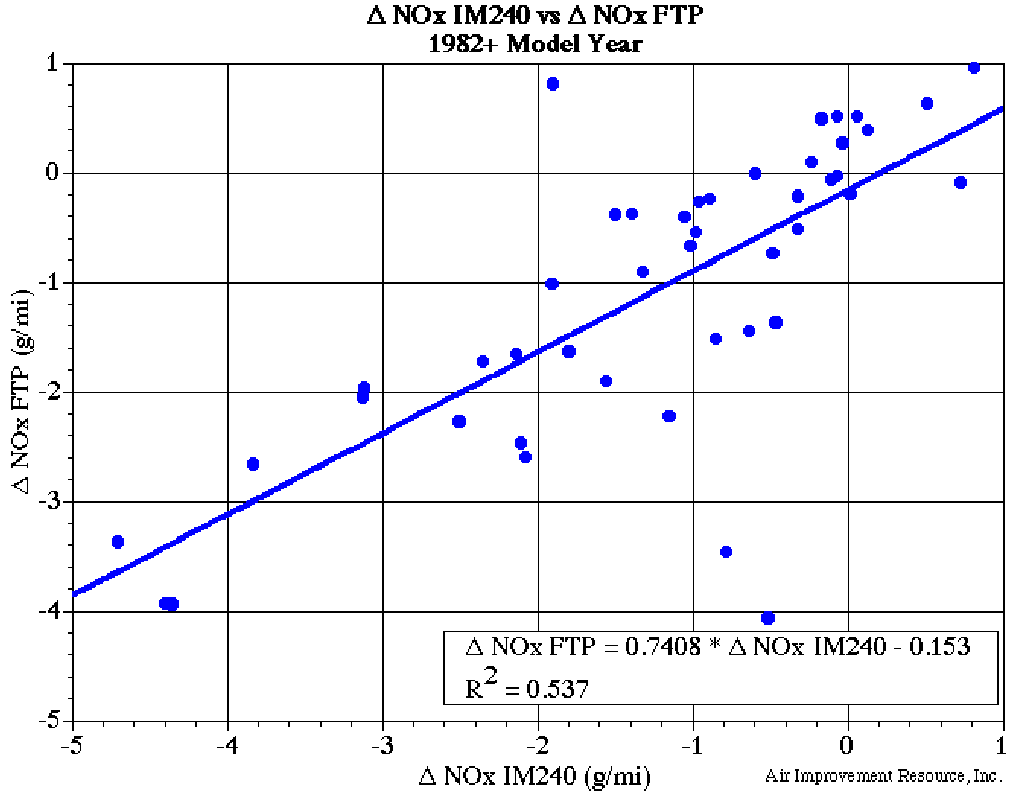


Figure B-3. ΔIM240 vs. ΔFTP, NOx, 1982+ Model Years



The 1990 Evaluation of the California I/M Program was completed by the California ARB. In this program, approximately 1,100 known high emitters were covertly sent through I/M testing to ascertain the program effectiveness using the two-speed idle test. We identified 581 pre-1982 model year and 348 1982-and-later model year vehicles that failed the idle test and had matching idle and FTP measurements before and after repair. We developed a linear regression between ΔFTP and ΔIdle using the test data from these vehicles.[33] The data were separated into the two model year groups, to allow for examining the enhanced idle test which is performed only pre-1982 model years for the light duty fleet.

The results of our analysis for pre-19782 vehicles are shown in the following figures. Overall, the linear model does not fit the data as well as for the IM240. The R-squared coefficients range from 0.15 to 0.36. The higher R-squared coefficients of the ΔIM240 measurement over the Δidle measurement indicate that the IM240 is a better predictor of FTP-based emissions. This result was expected as the IM240 is a transient test developed from the FTP, whereas, the idle test represent emissions at engine idle. The lower R-squared coefficients for the idle test signify that there is greater uncertainty with the benefit assessment of this test type. The ΔFTP and ΔI/M regressions were used

[33] We examined both the idle (low speed) and 2500 rpm (high speed) measurements and found that the correlation did not differ much when both I/M tests were included. However, the 2500 rpm measurement was only taken on 1980-and-later model year vehicles, so to retain the maximum number of vehicles, the regressions were based solely on the low-speed idle test data.

in our evaluation to convert the change in I/M test due to repair to a change in FTP-based measurement.

Figure B-4. ΔIdle vs. ΔFTP, CO, Pre-1982 Model Years

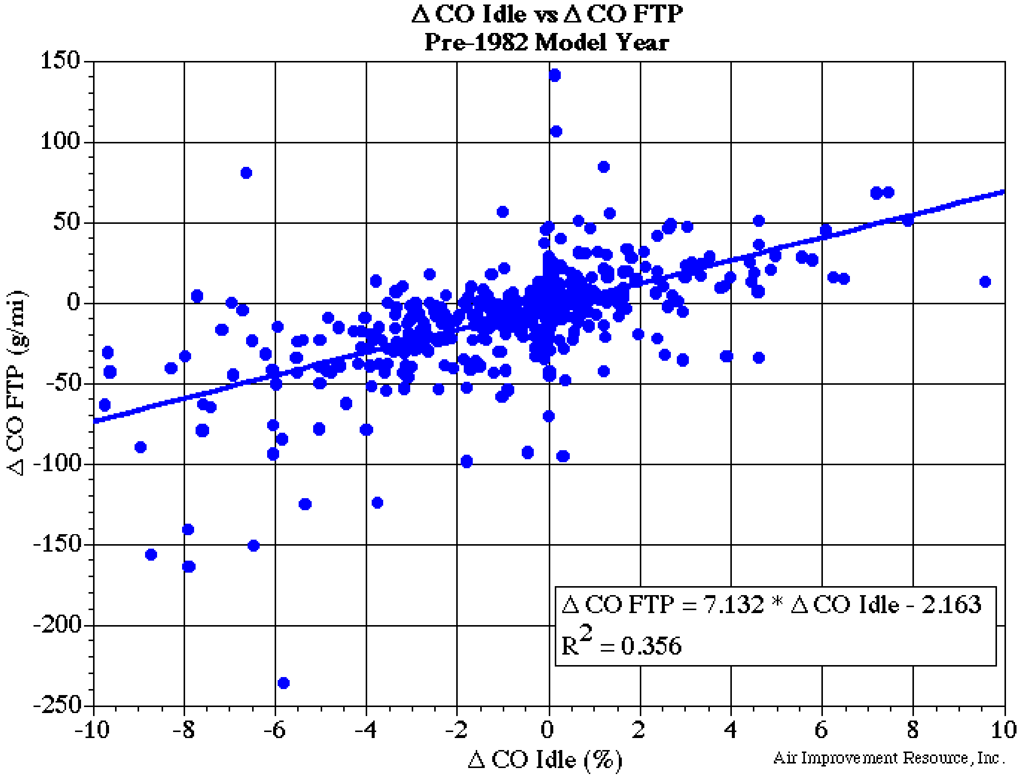


Figure B-5. ΔIdle vs. ΔFTP, HC, Pre-1982 Model Years

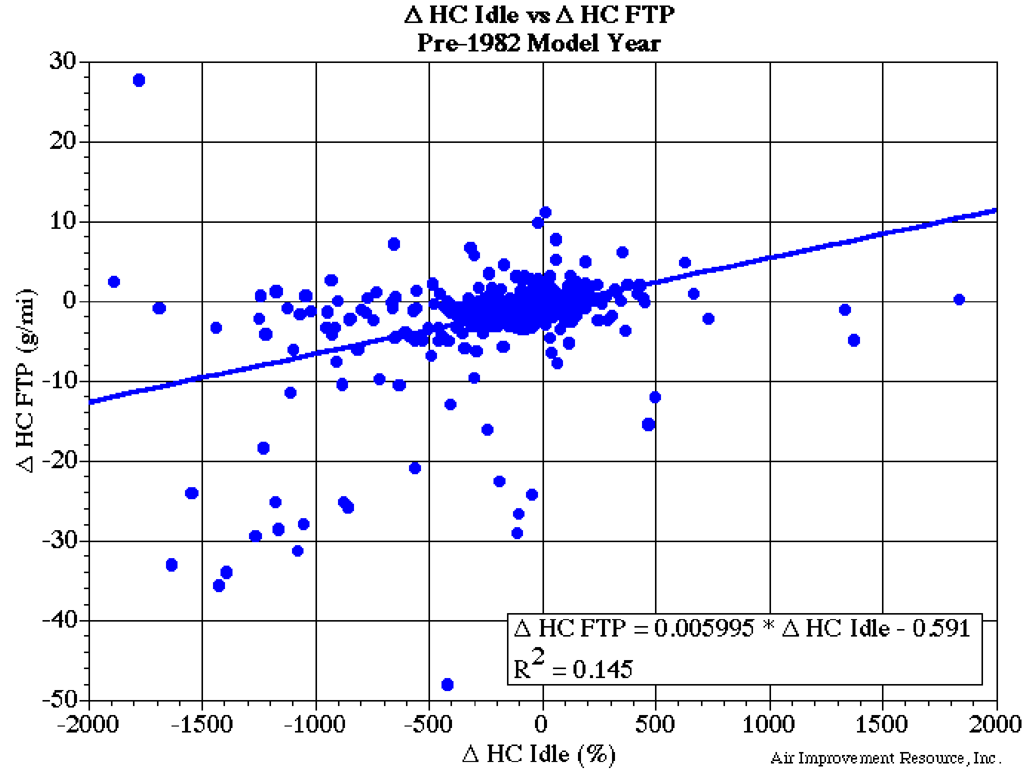


Figure B-6. ΔIdle vs. ΔFTP, CO, 1982+ Model Years

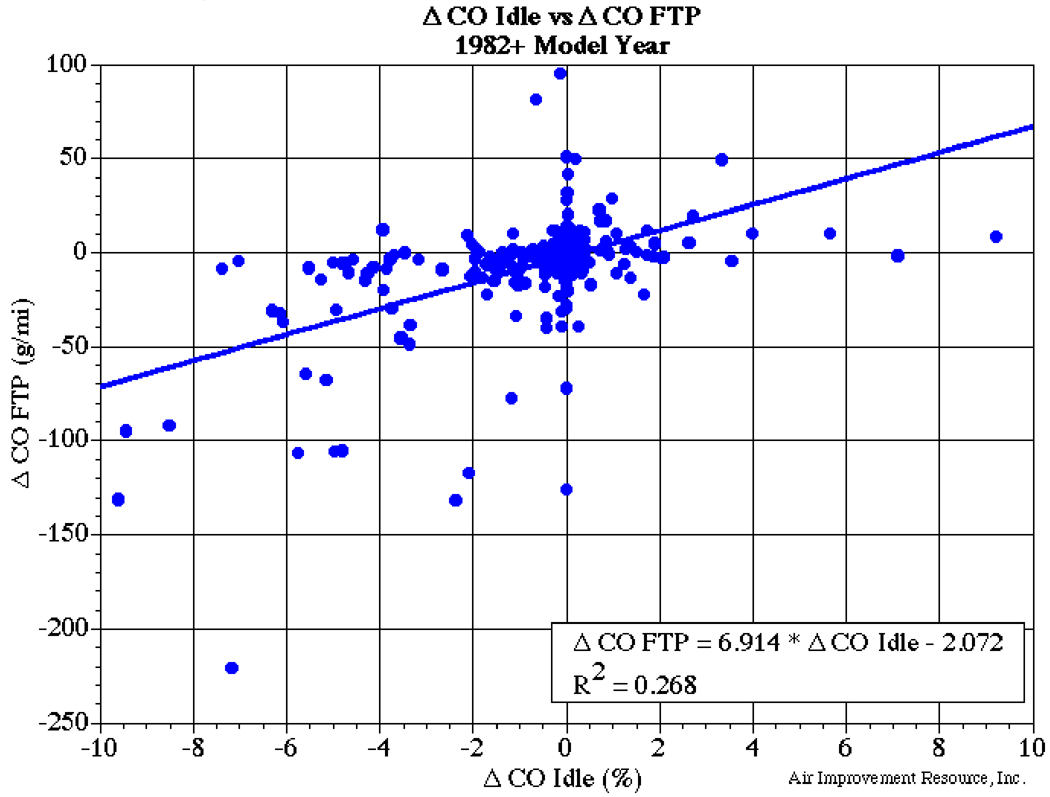
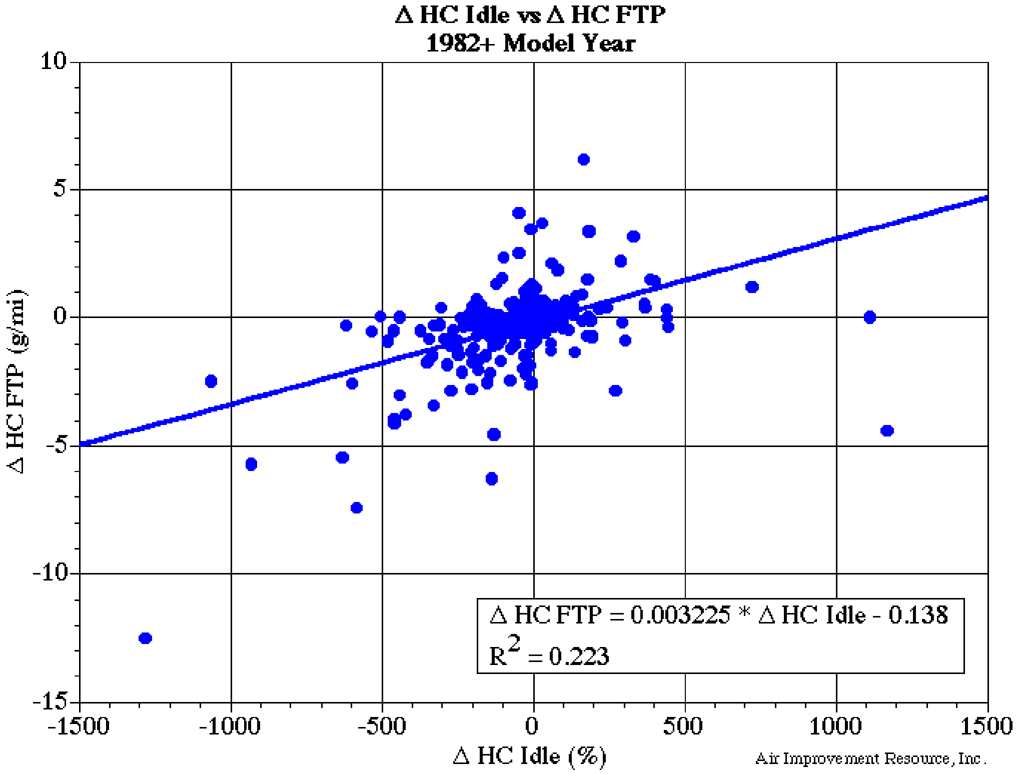


Figure B-7. ΔIdle vs. ΔFTP, HC, 1982+ Model Years



The Colorado I/M emission benefits were converted into FTP benefits using the regressions presented in the preceding figures. The process used was to estimate the I/M benefit for each vehicle type, test type, and for repaired and waived vehicles separately. These benefits were converted into FTP benefits using the regressions. The FTP benefits for failed vehicles were converted to percent FTP benefits by dividing by the FTP emissions of the FTP sample. Finally, the percent benefits for failed and waived vehicles were converted into fleet benefits by weighting the benefits by the percent of I/M emissions for the initial I/M test in the repaired and waived categories. This is illustrated in Table B-2 for LDGV CO under the IM240 test in 1998.

Table B-2. Conversion of I/M Benefits to Percent FTP Benefits for the Tested Fleet 1998 Calendar Year, 1982 and later model year LDGV, IM240 Test, CO

I/M Test Status	Delta IM240, Repair (g/mi)	Delta FTP, Repair (g/mi)	% FTP Benefit	% Emissions (Initial I/M)	Fleet Wtd. Percent Benefit
Failed/Unresolved	0.0	0.0	0.0	5.5%	0.0%
Failed/Failed/ Unresolved	0.982	5.5	11.7	3.3%	0.4%
Failed/Repaired	31.185	30.0	63.6	18.7%	11.9%
Failed/Waived	6.199	9.7	20.6	0.2%	0.04%
Passed	0.0	0.0	0.0	72.2%	0.0%
Total				100.0%	12.3%

In the table above, the IM240 benefits of 1, 31 and 6 g/mi for the IM240 convert to FTP benefits of 5.5, 30, and 9.7 g/mi, for failed/failed/unresolved, repaired, and waived vehicles. The percent FTP benefit for these three categories of vehicles is about 12%, 64% and 21%. The initial IM240 tests show that 3% of emissions are from failed/unresolved vehicles, 19% of the emissions are from failed, repaired vehicles, and 0.2% are from waived vehicles. Weighting the % FTP benefits by the distribution of emissions in the initial test results in a 12.3% overall FTP benefit for the tested vehicles.

The 12.3% FTP benefit is for the group of tested vehicles; however, because of biennial I/M cycle, not all vehicles are tested. This value must be adjusted to a % FTP benefit for all LDGVs so that the benefit for the on-road fleet of vehicles can be obtained.[34] To do this, we examined R.L. Polk data and I/M program data by model year to determine the fraction of total vehicles tested by model year. These values are shown in Table B-3. Table B-3 shows that overall, about 56% of the vehicles are tested each year. The number is higher than 50% due to change of ownership requirements and due to annual testing for older model years. The data in Table B-3 were used to adjust the percent benefits by model year.

[34] As described in Section 4 of this report, we are only estimating the benefit of the current inspection cycle. As such, we have assumed no benefit has accumulated from vehicle untested in the previous inspection cycle.

Table B-3. Percent of Model Years Tested in Enhanced I/M Area in 1998			
Model Year	R.L. Polk Gasoline Vehicle Counts (January 1, 1999)	1998 AIR Program Data	Percent I/M Tested in 1998
1999	42,044	1,034	2%
1998	133,407	18,783	14%
1997	112,554	31,978	28%
1996	103,620	40,247	39%
1995	111,121	53,553	48%
1994	98,472	54,035	55%
1993	94,958	45,751	48%
1992	83,338	69,335	83%
1991	87,372	41,373	47%
1990	82,150	69,066	84%
1989	80,124	39,628	49%
1988	74,534	62,703	84%
1987	65,214	33,148	51%
1986	61,484	51,228	83%
1985	53,176	27,342	51%
1984	43,413	36,266	84%
1983	26,961	13,908	52%
1982	18,749	15,307	82%
Pre-82	155,315	157,633	101%
Total	1,528,006	862,318	56%

Continuing with the example provided in Table B-2, where the 1982 and later model year LDGV CO IM240 benefit of tested vehicles was estimated to be 12.3 percent, applying the data of Table B-3, results in a LDGV CO IM240 benefit of 7.4 percent (tested and untested LDGVs) in 1998. The 7.4 percent benefit for 1982 and later LDGVs is combined with the benefits of the other vehicle classes and test types to yield the fleetwide benefit of 6.1 percent reported in Table 4-5 of the main body of this report.

Adjusting for Other Vehicle Types Not Covered by I/M

The benefits reported in Chapter 4 of this report represent those benefits for the vehicle classes undergoing I/M testing. The fleet subject to I/M is the light duty gasoline fleet in both areas plus heavy-duty gasoline vehicles in the enhanced area. The impact of the AIR Program on the total on-road fleet emissions (including diesel vehicles and motorcycles) can be determined by factoring out the emissions from the remaining vehicle classes not affected by the I/M program. An estimate of these emissions is provided in Table B-4. The data in Table B-4, obtained from a MOBILE5b run using Colorado inputs, shows weighting factors by emissions and vehicle class that were used to estimate an overall on-road fleet CO benefit for the AIR Program. For example in 1999 for the enhanced area, we estimated that 95, 88 and 60 percent of the exhaust emissions of CO, HC and NOx, respectively, are from the vehicle classes subject to I/M.

Table B-4. Percent of Emissions from Vehicle Classes Not Covered by AIR Program

Program Area	Vehicle Classes Not Covered by I/M	Calendar Year	Percent of Emissions by Vehicles Not Covered by I/M Requirements		
			% CO	% HC	% NOx
Enhanced I/M	Diesel and Motorcycles	1998	4.3%	11.1%	39.6%
		1999	4.6%	12.3%	39.7%
Basic I/M	Diesel, Heavy-Duty Gasoline and Motorcycles	1998	11.7%	16.7%	46.4%
		1999	11.6%	17.9%	46.5%

[This page is intentionally blank.]

Appendix C: I/M Cutpoints (Emission Standards)

Table C-1. Idle Test Cutpoints for AIR Program (Enhanced and Basic Areas)

Vehicle Class	Model Year	CO (%)	HC (ppm)
Light-Duty Vehicles and Trucks	Pre-1971	5.5	1000
	1971-1974	4.5	1000
	1975-1978	3.5	800
	1979	3.0	400
	1980-1988	1.5	400
	1989+	1.2	220
Heavy-Duty Trucks	Pre-1968	7.0	1500
	1968-1969	6.5	1200
	1970-1978	6.0	1200
	1979	5.0	1000
	1980	4.0	1000
	1981-1985	3.5	800
	1986+	3.0	300

Table C-2. 1998 IM240 Test Cutpoints for AIR Program

Vehicle Class	Model Year	CO (g/mi)	HC (g/mi)	NOx (g/mi)
Light-Duty Vehicles	1982	65	5	8
	1983-1984	50	5	8
	1985	25	5	8
	1986-1990	25	4	6
	1991-1994	20	4	6
	1995+	20	4	4
Light-Duty Trucks	1982-1983	107	8	12
	1984-1985	86	8	12
	1986-1990	67	6	9
	1991+	53	6	9

Table C-3. 1999 IM240 Test Cutpoints for AIR Program				
Vehicle Class	Model Year	CO (g/mi)	HC (g/mi)	NOx (g/mi)
Light-Duty Vehicles	1982	45	4	8
	1983-1984	30	4	8
	1985	20	4	8
	1986-1990	20	3	6
	1991-1993	20	2.5	6
	1994	20	2	6
	1995+	20	2	4
Light-Duty Trucks	1982	65	8	12
	1983	65	6	12
	1984	55	6	12
	1985	45	6	12
	1986	40	6	9
	1987	30	4	9
	1988-1993	25	4	9
	1994+	20	4	9

Appendix D: Accuracy of Models to Project the Future

The accuracy of the models as we are defining here is the ability of the emission model, for example, EPA's MOBILE5 model, to predict fleet emissions accurately within any given year. For example, the model produces emissions in g/mi by vehicle class by calendar year, and weights these together to produce a fleet-weighted estimate in g/mi. Suppose that the fleet-weighted CO emissions in Denver in calendar year 1999 is 12 g/mi. The issue with respect to accuracy is how close that 12 g/mi represents the actual real-world emissions on a given day. The ability of the models to predict the future is a different concept, and it relates to the ability of the models to estimate trends, or incremental effects of fundamental programs that are causing the trends. The model's outputs, when combined with VMT estimates, may say CO emissions on average decline by 30% over the next 6 years. This is different than saying that the fleet emissions in 1999 are 12 g/mi.

The reason we are drawing a distinction in these two concepts, is that (1) it is possible for a model to be inaccurate, but predict trends correctly, and (2) it is the trends we are most interested in, not the absolute emission level in any given year. We are most interested in whether the present trend in emissions, which is downward, will continue, thereby leading to a continued downtrend in CO levels. It really does not matter whether the CO emissions are 12 g/mi in 1999 or 20 g/mi: the ambient air knows what the emissions are, and in the 1999 winter season, there were no exceedances of the CO standard, *so whatever they were*, *they were not a problem.* And, if emissions are going lower from here, they will still not be a problem.

The above concepts being established, it is correct to say that the *accuracy* of the emissions models, such as MOBILE5, have never been adequately verified. Many attempts have been made here – researchers have used a variety of techniques to quantify real world emissions and compare them to model estimates. These techniques have ranged from putting instruments in the trunks of cars[35], analyzing remote sensing measurements and comparing them with the models, estimating emissions in tunnels, where the emissions are due primarily to the mobile sources passing through, and estimating VOC/NOx ratios at monitors near freeways and comparing the results to emission results during laboratory testing. Some of these studies have shown that exhaust emissions from the models are very low for HC and CO, and others have shown that the models are fairly close. But anyone who reviews these studies usually comes away with the impression that the models, including MOBILE5, could be quite inaccurate in any given year or situation.

Other evidence for the inaccuracy of the models comes from model revisions themselves: the models are constantly being updated with new information, and it can

[35] A trunk-based measurement system was used by a GM researcher in the late 1980s to quantify off-cycle CO emissions on highway on-ramps in California. This research was shared with the regulatory agencies (EPA and ARB), which ultimately led to the changes in the Federal Test Procedure adopted by the EPA and ARB in 1995 and 1996, which will be implemented starting in 2000.

change emission estimates substantially. This leads to legitimate questions about the usefulness of the models to predict anything at all.

An example of this is the EMFAC99 model being prepared by the Air Resources Board modeling staff at this time. CO emissions have been increased substantially in a late model draft from the previous version. However, just because emissions are changed dramatically from one model revision to the next, does not usually mean that the basic emission trends have changed. In the previous ARB model, the CO inventory declined by 66% from 2000 to 2020. In the new model, although the CO inventory has increased threefold for 2000, the downward trend in emissions is still intact: CO inventories in the new model are reduced by 80%, as compared to 66% in the previous model. The change in the trend is not nearly as dramatic as the change in absolute inventory in any given year, although the reduction in CO in California appears to be accelerating (AIR believes that much of this is due to the implementation of off-cycle controls, which are being implemented in Colorado as well).

This leads to an important tenet of emission modeling that is extremely useful: one reason that models tend to be more consistent with respect to trends, than absolute emissions, is that there is much less involved in predicting the trend than absolute emissions. There are really only several things that affect CO emissions in the future compared to now: VMT growth, vehicle technology, fleet turnover, and local control programs such as I/M and oxygenated fuels. It is therefore easier to quantify the relative effects of these programs, than it is to assemble all of the data needed to make an accurate prediction of emissions in any one year.

What about Colorado, and the use of the MOBILE model? The Environ analysis showed that the nearly equivalent slope of the downward trend in ambient levels and the MOBILE5 model over the 1986-97 period are not a coincidence: the ambient data are, in effect, serving to validate the trend in emissions from the model over that time period. The ambient data do in no way validate the emissions in any given year, they only serve to validate the trend. For whatever the reason, the trend in MOBILE emissions over that time period is not contradicted by the ambient data. Beyond 1997, however, we know that there are many factors that the MOBILE model does not contain (see Appendix E), therefore, we suspect that the MOBILE5 trend is not correct.

The above points at the value of emission modeling in this study: not to predict emissions accurately in any given year, but to determine, as nearly as we can, whether the downward trend in CO emissions is still intact, and to determine the incremental changes in the trend for various regulations on the horizon; for example Tier 2/Sulfur, and potential changes in the I/M and oxygenated fuels programs. Our conclusion is that as long as the model we use tries to account for the fundamental forces driving emissions, we can be reasonably sure that ambient levels will follow that trend, whether our prediction of absolute emissions in any given year is correct or not.

Appendix E: Comparison of Models

This appendix contains a more complete discussion of the attributes of the various models. The table below shows which technologies and fuel effects are included in the various emission models.

Table E-1. Technology Effects Included in Various Models

Technology	Pollutants Affected	Effects included in			
		MOBILE5a	MOBILE5b	EPA Serious Area CO	AIR, Inc. MOBILE
Oxygenated Fuel Effects	CO	Yes	Yes	Revised	Yes, not revised
Fuel Sulfur Effects/ Advanced Tech.	HC, CO, NOx	No	No	No	Yes
Cold CO Standards	CO	Yes	Yes	Revised	Revised
Off-cycle controls	CO	No	No	Yes	Yes
Onboard diagnostics	HC, CO, NOx	No	No	Yes	Yes
National LEV standards	HC, CO, NOx	No	No	No	Yes
Enhanced evaporative controls	HC	Yes	Yes	Yes	Yes
Onboard vapor recovery	HC	Yes	Yes	Yes	Yes
2004 Heavy-duty vehicle standards	NOx	No	No	No	Yes
Heavy-duty off-cycle standards	NOx	No	No	No	No

Oxygenated Fuels – Oxygenated fuel effects are in MOBILE5a and MOBILE5b, but were revised by Sierra Research in the EPA Serious CO Area Model. The CO emission benefits of oxygenated fuels were reduced, because there is little benefit for late model vehicles. The AIR, Inc. model has not yet been updated for these effects.

Fuel Sulfur Effects on Advanced Technology Vehicles (NLEVs and Tier 2) – The only model that currently includes fuel sulfur effects for advanced technology vehicles is the AIR, Inc. model.

Cold CO Standards - The effects of the Phase 1 standards were included in MOBILE5, but AIR reviewed how MOBILE5 estimates CO emissions for the automakers, and concluded that the algorithms for including the Phase 1 Cold CO effects significantly understated the benefits of the standards. EPA reviewed AIR's analysis and agreed. EPA has made the changes to these methods in their new Serious CO Area Model, and plans to carry-over these changes into MOBILE6. The revised effects are identical between the EPA Serious Area CO Model and the AIR, Inc. model.

Off-Cycle Controls - Neither the effects of off-cycle emissions, nor the controls, have been included in MOBILE5a or MOBILE5b. These have been added to the Serious CO Area Model and the AIR, Inc. model, and both will be added to MOBILE6. The ambient air quality results, however, already include off-cycle emissions. Thus, control of off-cycle CO emissions, which will start next year and continue for a number of years as these vehicles are phased-into the fleet, should further reduce ambient CO levels.

Onboard Diagnostics - Neither the MOBILE5a nor the MOBILE5b model include the effects of onboard diagnostics, but EPA has added these effects with their draft MOBILE6 emission rates into the Serious Area CO Model. EPA has included updated I/M credits to go along with these emission rates.

The manner in which EPA includes OBD into the model has important implications for Colorado and its I/M programs, because both programs are reducing in-use emissions. The better that OBD performs, the less that I/M is needed over the long term. AIR has reviewed how EPA incorporated the effects of OBD, and believes that EPA's assumptions concerning the effectiveness of OBD are too pessimistic. Basically, EPA is assuming that vehicles become high emitters at the same rate that they do without OBD. It is very likely, however, that the rate at which vehicles become high emitters will be reduced significantly, since auto manufacturers are concerned not only about warranty costs, but also about motorist inconvenience.

EPA's assumptions about owners' responses to MILs are also questionable. EPA assumes that for the first 36,000 miles of a vehicle's life, 90% of vehicles that become high emitters are fixed immediately. The percentage is not 100% because EPA is assuming that 10% of the vehicles that become high emitters will not illuminate the OBD light, thus, the owners will not know that they are high emitters. In those vehicles where the OBD light is illuminated, EPA is assuming that they get fixed because they are still under the common "bumper-to-bumper" warranties. This assumption is reasonable, although we there are a number of factors that could contribute to the percentage of vehicles being fixed being higher than 90%.

We are most concerned with EPA's assumption about vehicles after 36,000 miles. Between 36,000 miles and 80,000 miles, in an area without I/M, EPA is assuming that 90% of the vehicles with illuminated MILs are never repaired, and that the owners ignore the MILs. They stay broken *forever*. If however, these vehicles are in an I/M area, 90% of them are repaired *immediately*, whether the I/M program is annual or biennial. We believe these assumptions are very biased, especially in a no-I/M area, and ignore basic economics of the value of vehicles when they are only 3-8 years old. We can understand some or many owners ignoring lights when the vehicle has high mileage and commands a much lower resale value, but not at 36,001 miles. Based on ours and others' comments on this issue, EPA may revise its assumptions for MOBILE6. In the meantime, we will use the Tier 1 and NLEV emission rates with EPA's OBD assumptions as is, with the notion that they will likely be revised downward in the near future, thus lowering future CO projections without I/M.

For the AIR, Inc. model, OBD effectiveness is based on the California emission rates.

National LEV Standards – All three models allow the user to select implement the NLEV program in 2001. However, since the NLEV standard is the same as the Tier 1 standard at 3.4 g/mi, EPA assumes that the CO emissions of NLEVs are exactly the same as Tier 1 vehicles, thereby ignoring its own certification data as presented in Section IV-D. For this reason, we believe that none of the available EPA models currently accurately reflect the NLEV effect for CO. This effect is included in the AIR, Inc. model.

Enhanced Evaporative Controls and ORVR – These are included in all four models.

2004 Heavy Duty Vehicle NOx Standards – These are not in any of the EPA models, but can be easily added. If added, the effect is to reduce fleet NOx from heavy-duty vehicles after 2004. The effect is included in the AIR, Inc. model.

Heavy Duty Vehicle Off-cycle Emissions and Standards – Neither the off-cycle emissions or off-cycle controls are included in any of the models. If these were added, NOx from heavy-duty vehicles would increase in all years. When the controls are applied (2002 and later), 2002 and later fleet NOx emissions from HD vehicles would decline.

[This page is intentionally blank.]

Appendix F: Analysis of Model Year Based I/M Exemptions

Model year exemptions take advantage of the fact that newer vehicles fail I/M at a significantly lower rate and thus contribute little to the I/M program benefit. The contribution of newer model year vehicles to the I/M benefit was demonstrated by the data presented in Table 7-4 of this report. This table shows the cumulative vehicles tested, vehicles repaired and the emissions benefit by model year of the current IM240 program in 1999. Table 7-4 shows that over 60 percent of the vehicles tested are 1991-and-newer model years, yet these vehicles account for about 15 percent of the CO and HC emissions benefit. By reducing the number of newest model year tests, the costs of the program can be reduced significantly, while retaining most of the I/M program benefit.

In the current AIR Program, there is a 4-year exemption, which applies to the mandatory biennial I/M test for those vehicles with their original owners. Estimating the first year a vehicle is required to submit to an I/M test is rather simple. Take the model year and add 4 and that is the first year the vehicle sees testing. So, a 1998 model year vehicle will be first tested in 2002. This method is independent of what year it was purchased in, so vehicles sold in the year prior to the model year get an extra registration exemption cycle.

If a vehicle is sold, there is a change of ownership I/M requirement and the new owner will be required to have an I/M inspection two years later independent of whether the vehicle still falls within the exemption period. We recommend modifying the model year exemption such that the exemption applies to the biennial inspection for all vehicles (independent of whether the vehicle is owned by the original owner or not). We recommend continuing the change of ownership I/M test. Using these criteria to define the model year exemption, we evaluated the impacts of 4, 6 and 8 year exemptions.

We also evaluated the extension of the current AIR exemption approach to 6 and 8 year exemptions. Again the current AIR approach is one where the biennial I/M is exempted for those vehicles still maintained by their original owners.

In order to estimate the benefits of the proposed model year exemptions, we needed to identify the proportion of vehicles undergoing change of ownership I/M, as these inspections would still be retained. We reviewed the AIR Program data and vehicle registration data for 1998 and estimated the fraction of each model year undergoing change of ownership I/M. The data and results are presented in Table F-1. We used 1998 as this was the last year for which a complete year's worth of I/M data were available.

Table F-1. Data and Results of Estimated Change in Ownership Frequency by Model Year in 1998				
Model Year	**R.L. Polk Registered Gasoline Vehicles (Jan. 1 1999)**	**Vehicles in AIR Database in 1998**	**% I/M Tested**	**Estimated % Change of Ownership**
1982	18,749	15,307	81.6%	15.5%
1983	26,961	13,908	51.6%	15.5%
1984	43,413	36,266	83.5%	15.5%
1985	53,176	27,342	51.4%	15.5%
1986	61,484	51,228	83.3%	15.5%
1987	65,214	33,148	50.8%	15.5%
1988	74,534	62,703	84.1%	15.5%
1989	80,124	39,628	49.5%	15.5%
1990	82,150	69,066	84.1%	15.5%
1991	87,372	41,373	47.4%	15.5%
1992	83,338	69,335	83.2%	15.5%
1993	94,958	45,751	48.2%	15.5%
1994	98,472	54,035	54.9%	15.5%
1995	111,121	53,553	48.2%	22.2%
1996	103,620	40,247	38.8%	24.8%
1997	112,554	31,978	28.4%	26.4%
1998	133,407	18,783	14.1%	14.1%
1999	42,044	1,034	2.5%	2.5%

As can be seen from these data, a significant number of 2 and 3 year old vehicles are sold (possibly due in part to the completion of lease agreements). For vehicles 4 years and older it was not possible to determine the fraction of change of ownership I/M, so we assumed 15.5 percent which is the average number of additional inspections observed in the I/M data after subtracting out the biennial inspections.[36]

Of concern to this analysis was the 1994 model year as it appears in the 1998 AIR Program database. The 1994 model year was treated as an exception in the introduction of the enhanced I/M program. 1994 model year vehicles, if still with the same owner at the program commencement, are on an odd year inspection cycle (other even model years are on an even year inspection cycle if with the same owner). As such, there are notably fewer 1994 model year vehicles in the I/M record than observed for other even model years (see Table F-1). Since we are interested in evaluating the model year exemption

[36] This average was taken over the 1995 to 1982 model years (in order to have an equal number of even and odd model years). The number of biennial inspections was estimated at 50 percent of the total number of registered vehicles as estimated by R.L. Polk.

generally (and not just for 1998), we estimated the number of 1994 model year inspections that would have occurred if this exception had not occurred. Our estimate of the adjusted number of 1994 model year tests in 1998 is 86,655.

Using the data of Table F-1, with the adjusted number of tests for the 1994 model year noted above, we estimated the number of exemptions for the options under consideration. The results are provided in Table F-2. In completing this, we assumed that 60, 45 and 35 percent of vehicles remained with their original owner at ages 4, 6, and 8. These values are based on our review of the I/M data record. The 1994 model year adjustment affects the estimated number of exemptions for 6 and 8-year exemption periods but not that estimated for the 4 year exemption. We estimate that the current model year exemption exempted over 62 thousand vehicles in 1998.

Table F-2. Estimated Exemptions in 1998 Including 1994 Model Year Adjustment

	Age at First Test Year	Estimated Exemptions	Additional Exemptions over Current
Original Owner Exemption	4	62,172	0
	6	106,484	44,312
	8	135,653	73,481
Any Owner Exemption	4	107,821	45,649
	6	210,246	148,074
	8	294,494	232,322

In this analysis, we were interesting in evaluating the most recent year available, 1999. We estimated the number of exemption expected in 1999 by assuming the same proportion of vehicle exemptions observed in 1998 would occur in 1999 (based on vehicle age). Our estimate of the number of vehicle exemptions in 1999 is provided in Table F-3. It is the exemptions of Table F-3, which were carried through the cost and emissions benefit analysis for the year 1999.

Table F-3. Estimated Exemptions in 1999		
	Age at First Test Year	Additional Exemptions over Current
Original Owner Exemption	4	0
	6	39,744
	8	67,362
Any Owner Exemption	4	43,706
	6	150,088
	8	232,996

One key advantage to proposed model year exemptions are that there are no significant additional costs to implementing these modifications, as they are simple enhancements to the current program in place. There will be a one-time cost in the tens of thousands of dollars that will be needed to reprogram the computers that track vehicle registration and I/M requirements. We felt that these costs were insignificant compared to the total program cost and have not included this cost in our estimate for this modification.

We applied the 5 proposed model year exemptions to the current enhanced area I/M program in 1999. We then estimated the overall program costs and cost-effectiveness. The results of this analysis are shown in the following 5 tables. The emissions benefit of each program was determined as a percent of the current program benefit retained. The loss in benefit was estimated by removing the proportion of I/M tests shown in Table F-3 from the analysis of the 1999 program data.

Table F-4 Cost and benefits of 6-year model year exemption for original owners under IM240/idle enhanced program

Table F-5 Cost and benefits of 8-year model year exemption for original owners under IM240/idle enhanced program

Table F-6 Cost and benefits of 4-year model year exemption for all owners under IM240/idle enhanced program

Table F-7 Cost and benefits of 6-year model year exemption for all owners under IM240/idle enhanced program

Table F-8 Cost and benefits of 8-year model year exemption for all owners under IM240/idle enhanced program

We also applied the 5 proposed model year exemptions to a hypothetical enhanced area I/M program that used only an idle I/M test (the idle test is one of the replacement I/M options examined in Chapter 7). The results of this analysis for all 5 proposed exemptions are shown in Table F-9. Note that the emissions benefit are estimated relative to the current enhanced program (with IM240 and idle). The loss in benefit associated with switching to an all-idle enhanced program under the current exemption policy was summarized in Table 7-6 in the main body of the report.

Table F-4. Cost and Benefits of 6-Year Model Year Exemption for Original Owners Under IM240/Idle Enhanced Program
1999 Calendar Year

	IM240	Idle	Total
Total Vehicles Inspected	692,524	160,695	853,219
I/M Failures	48,598	30,088	78,686
I/M Repairs	37,140	23,336	60,476
I/M Waivers	301	45	346
Repair Cost per Repaired Vehicle	$243.84	$115.66	$194.38
Repair Cost per Waived Vehicle	$346.50	$503.67	$366.96
Inspection Fee $/inspected vehicle	$24.25	$15.00	$22.51
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$16,793,698	$2,410,427	$19,204,124
I/M Administrative Costs $	$2,894,035	$671,540	$3,738,751
I/M Repair Costs $	$9,160,485	$2,721,764	$11,882,249
I/M Fuel Economy Improvement Cost $	-$1,653,461	-$865,774	-$2,519,235
Total Cost	$27,194,757	$4,937,957	$32,132,714
CO Benefit (Percent of Current I/M Benefit)			99.3%
HC Benefit (Percent of Current I/M Benefit)			99.3%

Table F-5. Cost and Benefits of 8-Year Model Year Exemption for Original Owners Under IM240/Idle Enhanced Program 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	664,906	159,522	824,427
I/M Failures	47,921	30,040	77,961
I/M Repairs	36,480	23,295	59,775
I/M Waivers	299	45	344
Repair Cost per Repaired Vehicle	$243.84	$115.66	$193.89
Repair Cost per Waived Vehicle	$346.50	$503.67	$367.07
Inspection Fee $/inspected vehicle	$24.25	$15.00	$22.46
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$16,123,965	$2,392,824	$18,516,789
I/M Administrative Costs $	$2,778,621	$666,636	$3,738,751
I/M Repair Costs $	$8,998,912	$2,716,977	$11,715,889
I/M Fuel Economy Improvement Cost $	-$1,624,080	-$864,238	-$2,488,319
Total Cost	$26,277,418	$4,912,198	$31,189,616
CO Benefit (Percent of Current I/M Benefit)			98.2%
HC Benefit (Percent of Current I/M Benefit)			98.3%

Table F-6. Cost and Benefits of 4-Year Model Year Exemption for All Owners Under IM240/Idle Enhanced Program 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	688,561	160,527	849,088
I/M Failures	48,644	30,151	78,795
I/M Repairs	37,148	23,395	60,544
I/M Waivers	302	47	349
Repair Cost per Repaired Vehicle	$243.84	$115.66	$194.31
Repair Cost per Waived Vehicle	$346.50	$503.67	$367.51
Inspection Fee $/inspected vehicle	$24.25	$15.00	$22.50
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$16,697,605	$2,407,901	$19,105,506
I/M Administrative Costs $	$2,877,476	$670,836	$3,738,751
I/M Repair Costs $	$9,162,991	$2,729,384	$11,892,374
I/M Fuel Economy Improvement Cost $	-$1,653,846	-$867,961	-$2,521,807
Total Cost	$27,084,226	$4,940,160	$32,024,386
CO Benefit (Percent of Current I/M Benefit)			99.8%
HC Benefit (Percent of Current I/M Benefit)			99.8%

Table F-7. Cost and Benefits of 6-Year Model Year Exemption for All Owners Under IM240/Idle Enhanced Program 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	582,179	156,006	738,185
I/M Failures	46,872	29,882	76,754
I/M Repairs	35,390	23,161	58,552
I/M Waivers	299	44	343
Repair Cost per Repaired Vehicle	$243.84	$115.66	$193.14
Repair Cost per Waived Vehicle	$346.50	$503.67	$366.70
Inspection Fee $/inspected vehicle	$24.25	$15.00	$22.30
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$14,117,841	$2,340,095	$16,457,936
I/M Administrative Costs $	$2,432,908	$651,946	$3,738,751
I/M Repair Costs $	$8,733,149	$2,701,031	$11,434,181
I/M Fuel Economy Improvement Cost $	-$1,575,579	-$859,281	-$2,434,859
Total Cost	$23,708,320	$4,833,792	$28,542,112
CO Benefit (Percent of Current I/M Benefit)			97.8%
HC Benefit (Percent of Current I/M Benefit)			97.7%

Table F-8. Cost and Benefits of 8-Year Model Year Exemption for All Owners Under IM240/Idle Enhanced Program 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	499,271	152,483	651,755
I/M Failures	44,360	29,703	74,064
I/M Repairs	33,019	23,012	56,031
I/M Waivers	289	44	333
Repair Cost per Repaired Vehicle	$243.84	$115.66	$191.20
Repair Cost per Waived Vehicle	$346.50	$503.67	$367.29
Inspection Fee $/inspected vehicle	$24.25	$15.00	$22.09
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$12,107,329	$2,287,252	$14,394,580
I/M Administrative Costs $	$2,086,440	$637,224	$3,738,751
I/M Repair Costs $	$8,151,638	$2,683,751	$10,835,389
I/M Fuel Economy Improvement Cost $	-$1,470,019	-$853,738	-$2,323,756
Total Cost	$20,875,387	$4,754,489	$25,629,876
CO Benefit (Percent of Current I/M Benefit)			93.9%
HC Benefit (Percent of Current I/M Benefit)			93.9%

Table F-9. Cost and Benefits of 5 Proposed Model Year Exemption for Under an All Idle Enhanced I/M Program 1999 Calendar Year					
	6-Year, Original Owners	8-Year, Original Owners	4-Year, All Owners	6-Year, All Owners	8-Year, All Owners
Total Vehicles Inspected	853,219	824,427	849,088	738,185	651,755
I/M Failures	136,629	132,559	140,044	130,872	118,725
I/M Repairs	107,000	103,685	109,648	101,905	91,913
I/M Waivers	601	588	617	592	556
Repair Cost per Repaired Vehicle	$114.51	$114.51	$114.51	$114.51	$114.51
Repair Cost per Waived Vehicle	$263.96	$263.96	$263.96	$263.96	$263.96
Inspection Fee $/inspected vehicle	$15.00	$15.00	$15.00	$15.00	$15.00
Administrative Cost $/reg. veh.	$2.20	$2.20	$2.20	$2.20	$2.20
Inspection Costs $	$12,798,281	$12,366,410	$12,736,317	$11,072,780	$9,776,321
I/M Administrative Costs $	$3,738,751	$3,738,751	$3,738,751	$3,738,751	$3,738,751
I/M Repair Costs $	$12,411,267	$12,028,158	$12,718,683	$11,825,274	$10,671,660
I/M Fuel Economy Imp. Cost $	-$1,010,462	-$979,158	-$1,035,469	-$962,348	-$867,987
Total Cost $	$27,937,836	$27,154,161	$28,158,281	$25,674,458	$23,318,744
CO Benefit (% of Current I/M Benefit)	73.3%	71.9%	73.3%	70.2%	64.7%
HC Benefit (% of Current I/M Benefit)	69.2%	67.8%	69.2%	65.7%	59.8%

Appendix G: Analysis of Vehicle Profiling Based I/M Exemptions

Vehicle profiling involves the examination of the I/M data record to identify individual vehicle makes and models not likely to fail I/M. Those makes and models identified would then be exempted from the mandatory biennial inspection; however, we have assumed that the change of ownership I/M would still be required. If implemented, vehicle profiling would require an annual review of the I/M data record to update which makes and models should be exempted each year. By retaining the change in ownership I/M, there is a source of failure rate data for those makes and models that were exempted in the prior year so that it can be determine whether these vehicles should continue to be exempted or not.

We examined a vehicle profile in which vehicles with a 5 percent or lower probability of failing the I/M test were exempted where the probability of failure is based on an analysis of the 1999 calendar year AIR Program data (January through May). We intentionally did not include the emissions test data in the development of the profile. Including the emissions test data may improve the profile's ability to exempt the cleanest portion of the fleets; however, when a profile is based on emissions, the computations become significantly complex such that it may prohibit the practical application of this approach in the enhanced I/M area. By examining a profile based on the probability of failing the initial I/M test, the profile is simple to develop and apply and can produce an efficient means to exclude a large number of vehicles from I/M testing requirements.

In our evaluation, we examined only the IM240-tested fleet, as the lower initial test failure rate associated with the IM240 test is why there is the need to improve the efficiency of this test. The objective of the profile is to remove a portion of the fleet likely to pass the IM240 test making the test more efficient by those removing vehicles that do not need to undergo testing.

We took the 1999 IM240 data and grouped vehicles by each unique combination of make, model, model year and engine displacement. The engine displacement parameter was included at the request of the Department of Public Health and Environment, who had found that engine size was key in identifying those vehicles likely to fail I/M.

Those groups with a 5 percent or lower failure rate on the initial I/M test were then exempted from their biennial I/M inspection. For those groups with fewer than 10 vehicles, we recommend that these vehicles be *included* in the fleet requiring I/M as there is insufficient data to determine whether or not these vehicles are likely to fail. A total of 12,887 vehicles of the total 302,938 vehicles in the 1999 IM240 database fell into these groups with less than 10 vehicles (4 percent of the vehicles).

The results of applying our profiling criteria on the 1999 IM240 data are shown in Table G-1. In total, we determined that 35 percent of the vehicles would have been exempted under the proposed vehicle profile. The data of 1999 represent the partial year of January through May. On a full-year 1999 basis, we estimated the profile to exclude

257,694 vehicles from the estimated total of 732,267 vehicles expected to be tested in 1999.

Table G-1. Vehicle Identification by Model Year of Proposed Vehicle Profile			
Model Year	Vehicles Receiving I/M in 1999 (January - May)	Vehicles with Biennial I/M and Probability of Failure Less than 5%	Remaining Vehicle I/M Tests
1982	3,513	320	3,193
1983	6,460	428	6,032
1984	8,457	568	7,889
1985	13,727	686	13,041
1986	12,831	1,658	11,173
1987	17,919	3,589	14,330
1988	16,281	3,921	12,360
1989	22,256	7,428	14,828
1990	17,786	6,988	10,798
1991	25,639	12,436	13,203
1992	18,136	11,105	7,031
1993	27,159	15,830	11,329
1994	25,830	17,372	8,458
1995	32,153	16,146	16,007
1996	20,661	6,801	13,860
1997	16,488	1,331	15,157
1998	14,088	0	14,088
1999	3,553	0	3,553
2000	1	0	1
Total	302,938	106,608	196,330

We then estimated the benefits of the IM240 program in 1999 with the exclusion of the profiled vehicles. The results are shown in Table G-2, where the benefit of the I/M program with the profile is expressed in terms of the percent of benefit retained (relative to the current I/M program without the profile). Our evaluation showed that 93 to 94 percent of the CO and HC benefit (for the IM240 tested fleet), respectively, would be retained by the proposed while allowing for exempting 35 percent of the vehicles undergoing an IM240 test.

Table G-2. Percent of Benefit Retained for Implementation of Proposed Vehicle Profile, IM240 Tested Fleet, 1999 Calendar Year		
CO	HC	NOx
92.5%	93.9%	100%[37]

The results of Table G-2 are for the IM240 tested portion of the fleet only. We assumed no change in the idle tested portion of the fleet (i.e., that these vehicle would not be profiled). Given that 100 percent of the idle test benefit would be retained, the percent of benefit retained for the enhanced program is slightly larger than that reported in Table G-2. The percent of the enhanced program benefit retained is shown in Table G-3.

Table G-3. Percent of Benefit Retained for Implementation of Proposed Vehicle Profile, Enhanced Fleet, 1999 Calendar Year		
CO	HC	NOx
93.6%	94.7%	100%

We estimated the costs for implementing the vehicle profile in order to estimate overall program costs and cost-effectiveness. We estimated that there would be the need for a half-time equivalent staff person at the Department of Public Health and Environment to oversee the annual evaluation of the vehicle profile ($50,000 per year with benefits) and that an additional $0.20 per registered vehicle would be required by the county clerks offices to handle a more complex exemption process than the current one based solely on model year. With an estimated 1,699,432 registered vehicles in the enhanced area in 1999, we estimated the additional annual cost in 1999 for the proposed vehicle profile is $389,886.

We combined the estimated emissions benefit results shown in Table G-3 and the estimated costs into an estimated net program costs. The results of this analysis are shown in Table G-4.

[37] In the current enhanced area I/M program, there is a small NOx disbenefit (i.e., increase in emissions) due to I/M. We estimated that essentially 100 percent of the NOx disbenefit would remain.

Table G-4. Cost and Benefits of Proposed Vehicle Profile (Supplemental I/M Modification) 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	474,573	162,391	636,964
I/M Failures	45,009	30,189	75,197
I/M Repairs	33,747	23,422	57,170
I/M Waivers	295	47	341
Repair Cost per Repaired Vehicle	$210.62	$115.66	$171.72
Repair Cost per Waived Vehicle	$334.18	$503.67	$357.33
Inspection Fee $/inspected vehicle	$24.25	$15.00	$21.89
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$11,508,395	$2,435,759	$13,944,154
I/M Administrative Costs $			$3,738,751
I/M Repair Costs $	$7,206,491	$2,732,403	$9,938,894
I/M Fuel Economy Improvement Cost $	-$1,502,432	-$868,930	-$2,371,362
Additional Cost for Vehicle Profile			$389,886
Total Cost			$25,640,323
CO Benefit (Percent of Current I/M Benefit)			93.6%
HC Benefit (Percent of Current I/M Benefit)			94.7%

Appendix H: Analysis of RSD Based I/M Modifications

On-road RSD units measure tailpipe exhaust plumes for a fraction of a second as vehicles pass by the unit. HC, CO and NOx pollutant emissions are determined by relative concentrations to the concentration of CO2 seen in the vehicle exhaust plume. The RSD unit does not measure the volume of exhaust gases produced or the absolute amount of HC, CO and NOx emitted.

We examined how well RSD can identify clean and dirty vehicles by matching the RSD measurements to the AIR Program data record. Using RSD to find clean vehicles is called a *clean-screen* because you exempt the clean vehicles from the I/M requirements. RSD can also be used for high-emitting vehicle (HEV) identification. HEV identified by RSD are then subject to an inspection.

Topics addressed in this appendix are as follows.

- Measurement limitations
- Definition of excess emissions
- Cost assumptions
- RSD Data analysis
- RSD Modeling Scenario Results

Measurement Limitations

Before evaluating a RSD program, it is important to understand that a number of circumstances can elevate the RSD observed emission levels relative to an IM240 test on the same vehicle. This discrepancy results from the fact that RSD measures emissions for a fraction of a second and that even clean vehicles can have brief models of operation where CO and HC are high.

When a motorist lifts his/her foot off the gas pedal (deceleration), the volume of air and fuel flowing through the vehicle engine and exhaust system is suddenly reduced. Under these circumstances, the ratio of HC and CO to the now reduced level of CO2 is normally increased. Thus, although the volume and mass of emissions are substantially reduced when a driver lifts off the gas, to the RSD unit, the ratios of the concentration of HC and CO pollutants to CO2 is actually higher and a higher emissions value is recorded that is not typical of the vehicle's operation.

When a motorist presses sharply on the accelerator, the vehicle may go into what is termed an 'off-cycle' condition. The current generation of vehicles has been certified using the Federal Test Procedure that exercises vehicles over a longer test cycle similar to the IM240 test.[38] This test does not cover the full power range of the vehicle. Consequently, vehicles were designed to minimize emissions only over the power range tested in the certification cycle. At higher powers (e.g., hard accelerations), so called

[38] Starting with the 1998 model year, vehicles are required to pass a 'Supplemental' FTP that tests vehicles at higher power levels.

‘off-cycle’ emissions often increase dramatically although the vehicle is functioning as designed. Under these circumstances, a vehicle can have instantaneous high emissions when measured by RSD but may meet the I/M inspection requirements.

When a vehicle is cold, emissions are increased because of deliberate enrichment to promote combustion and because the catalytic converter is not hot enough to burn off the excess HC and CO emissions. Therefore, cold vehicles will have high emissions when measured by RSD but will have lower emissions when inspected at their warmed-up operating temperature.

As a result of these factors, multiple RSD measurements for the same vehicle vary considerably depending upon the operating mode of the vehicle at the time of the measurement. RSD measurements are sometimes higher than is characteristic for the vehicle. Therefore elevated levels measured by RSD are not always an indication of vehicle malfunction. These circumstances affect the reliability of RSD for HEV identification. RSD is generally a more effective tool for identifying clean vehicles rather than dirty vehicles.

Definition of Excess Emissions

Common to both clean screen and HEV identification analyses, is the quantity known as *excess emissions*. Excess emissions are the differences between the IM240 test and the IM240 cutpoint as shown below.

If the vehicle IM240 test is below the standard, Excess = 0.

If the vehicle IM240 test is above the standard, Excess = IM240 – I/M Cutpoint.

Excess emissions were determined for HC and CO emissions. Excess NOx emissions did not need to be estimated, as there are so few NOx failures (cutpoints are intentionally high). As a result there is actually a NOx increase due to the I/M program. We define excess emissions to measure how well an RSD program performs relative to an I/M program.

Cost Assumptions

To estimate the cost required for establishing a RSD infrastructure, several assumptions are required. These are documented below. We examined two levels of RSD infrastructure, one that covers 50 percent of the fleet with two valid measurements per vehicle per year and one that covers 80 percent of the fleet with two valid measurements per vehicle per year. Our assumptions are as follows.

1. *Valid readings per registered vehicle* - to cover 50 and 80 percent of the fleet the Northern Virginia RSD feasibility study [22] indicated that multiplies of 2.5 to 5.5 are needed, respectively, where the multiplier equals the number of valid RSD

readings per registered vehicle.[39] [23] We have assumed that through education and notification to the public that these factors can be improved upon since there is incentive for motorists to want to travel by the RSD for the clean screening scenarios (to eliminate I/M requirements). We have assumed that a 10 percent reduction in these ratios for clean screen with HEV identification RSD program and a 20 percent reduction for a clean screen only RSD program. We assume less of an improvement when HEV identification is included, as this is a negative incentive for motorist to be measured. We assume no improvement in these values for a HEV identification only scenario, as there is no positive incentive for motorists to be measured.

2. *% of total RSD readings that are valid* - based on CRC Project E-23, 30.0 percent of the total RSD readings in Denver were valid when the factors of readable plate, registration matching, valid HC/CO measurements, valid speed/acceleration measurement, vehicle load in proper range, and vehicle registered in enhanced area were taken into consideration. 30 percent is applicable to a clean screen with HEV identification program. For a clean screen only program, valid speed/acceleration and proper load range are not required. In this case, the 37.9 percent of the total RSD readings in Denver were valid. For this study, we have assumed a 10 percent improvement in the percent of valid readings would be realized by the time a new Denver program would be implemented. This corresponds to percent valid readings of 33.0 and 41.7 percent for clean screen with HEV identification and clean screen only, respectively.

3. *RSD Productivity* – based on the Northern Virginia feasibility study 3,584 readings was the average daily RSD measurement productivity. Assuming 220 days of operation per year, this equals 788,509 measurements per year per RSD unit.

4. *Cost per RSD unit* – the annual cost of data collection and processing per RSD unit varies according to the references examined. Estimates cited were $150,000, $171,000 and $250,000 for Arizona, Greeley [23] and Northern Virginia. [22] In the CO redesignation request, [3] the RAQC recently assumed $180,000, and this value seemed to be a reasonable average given potential improvements in efficiency and economies of scale for the significant number of units that would be required in Denver. We also used the $180,000 per unit cost in our evaluation.

We have estimated the number of RSD units required based on these assumptions and estimated the total infrastructure costs. The results are shown in Table H-1 below. Total number of RSD units is estimated to be between 11 and 36 and total measurement costs are roughly between $2 and $7 million per year. These costs do not include the costs of administration and follow up I/M and repair.

[39] These multiplier values reported in the Northern Virginia themselves are extrapolations from the data collected during the Greeley RSD pilot study.

Table H-1. Infrastructure Costs for RSD I/M Scenarios, 1999 Calendar Year						
	Clean Screen and HEV Identification		Clean Screen Only		HEV Identification Only	
	50% Coverage	80% Coverage	50% Coverage	80% Coverage	50% Coverage	80% Coverage
Registered vehicles	1,699,432	1,699,432	1,699,432	1,699,432	1,699,432	1,699,432
Valid RSD readings/registered vehicle	2.25	4.95	2	4.4	2.5	5.5
Valid readings	3,823,722	8,412,189	3,398,864	7,477,502	4,248,581	9,346,877
% of total measurements that are valid	33.0%	33.0%	41.7%	41.7%	33.0%	33.0%
Total measurements	11,599,132	25,518,090	8,160,433	17,952,952	12,887,924	28,353,433
RSD productivity (measurements/van-year)	788,509	788,509	788,509	788,509	788,509	788,509
Number of RSD vans needed, rounded up	15	33	11	23	17	36
Cost of data collection & processing $/van-year	180,000	180,000	180,000	180,000	180,000	180,000
Cost of data collection & processing ($/year)	$2,700,000	$5,940,000	$1,980,000	$4,140,000	$3,060,000	$6,480,000

For I/M and repair, costs are a function of the number of vehicles undergoing I/M testing and the I/M and repair costs (on a per vehicle basis) are based on our evaluation of the AIR Program described in Chapter 4 of this report. These costs are included in the total program costs, which are summarized at the end of this appendix.

For administrative costs, the Greeley Pilot Study estimated governmental costs that corresponded to $2 per registered vehicle. [23] We assumed that this could be improved upon given the larger scale of a Denver program We assumed that the administrative costs would be $1 per registered vehicle plus $2 for every HEV notification since HEV notification requires obtaining address information from county clerks and a separate mailing. These costs are included in the total program costs, which are summarized at the end of this appendix.

RSD Data Analysis

For this study, we considered the two most resent analyses of RSD in Denver were the Colorado 0.5% Study [12] and Coordinating Research Council (CRC) Project E-23 [13] were considered for evaluation. We could not directly use the results of these studies as reported for our evaluations because these studies did not use the AIR Program I/M cutpoints to define when a vehicle failed I/M.[40] We selected the data from CRC Project E-23 as the basis for our RSD evaluations since these data were the most recent

[40] These studies were completed for a broader audience outside Colorado and used EPA guidance cutpoints, which are significantly different from those of the AIR Program.

and these data include the collection of vehicle speed and acceleration, critical parameters needed for proper HEV identification.

We reexamined the CRC Project E-23 data using the current 1999 AIR Program cutpoints (provided in Appendix C). We selected vehicle data records that matched the following criteria.

- Vehicles had matched RSD (valid CO and HC) and IM240 records.
- Two RSD readings were measured *prior* to the initial IM240 test.
- RSD readings included matching speed and acceleration from which estimated vehicle load was found to be between 5 and 25 kW/t (range required for HEV identification).

We identified 1,234 vehicles that met these criteria in the CRC databases.

Clean Screening Analysis

We examined three clean screens with the 1,234-vehicle database. A vehicle was defined as clean when *both* RSD HC and CO measurements fall below the clean screen cutpoints shown below.

1. CO<0.5% and HC<300 ppm
2. CO<0.3% and HC<300 ppm
3. CO<0.2% and HC<300 ppm

Because RSD is not 100% reliable, some fraction of vehicles defined as clean would have failed the I/M test. We analyzed the data and estimated the quantity of excess emissions lost due to incorrect screening for each clean screen. The results of this analysis are shown in Table H-2.

Table H-2. Clean Screen Analysis Results

Screen	Percent of Fleet Clean Screened	Excess Emissions Lost	
		HC[41]	CO
CO<0.5% and HC<300 ppm	66.0%	17.9%	20.7%
CO<0.3% and HC<300 ppm	52.8%	17.9%	13.4%
CO<0.2% and HC<300 ppm	42.2%	0.0%	6.9%

Of the screens examined, we selected the first screen (CO<0.5 and HC<300) since the primary objective of the screen is to remove a significant quantity of vehicles from

[41] The HC data are affected by a single high emitting vehicle. The 17.9 percent of excess emissions shown for the first two screens actually represents the emissions of just one vehicle, which was included in the first two screens shown. This vehicle was not screened out in the third screen. Hence, the third screen falls to the ideal case of zero percent excess emissions lost. These data illustrate the impact a single high emitting vehicle can have on the modeling results.

I/M testing requirements. For this screen, we examined the percent of fleet screened on a model year basis, since this is not a constant across model years. The results are shown in Table H-3.

Table H-3. Percent of Fleet Screened by Model Year for the Screen of CO<0.5 and HC<300			
Model Year	**CO<0.5 and HC<300**	**CO<0.3 and HC<300**	**CO<0.2 and HC<300**
Pre-1982	ND	ND	ND
1982-1985	38.8%	29.1%	21.4%
1986-1991	54.1%	39.9%	28.7%
1990+	73.8%	60.5%	49.8%

ND = not determined.

HEV Identification Data Analysis

We defined as an HEV when the *average* of both RSD measurements met the following criteria.

1. CO>5%
2. HC>450 ppm or CO>5%
3. HC>400 ppm or CO>5%
4. HC>300 ppm or CO>5%
5. HC>300 ppm or CO>3%
6. HC>250 ppm or CO>3%
7. HC>250 ppm or CO>2.5%

The effectiveness of each of these HEV identifying criteria was examined with the results shown in Table H-4.

Table H-4. Effectiveness of RSD Cutpoints Used to Identify HEVs							
HEV Criteria	Percent of Fleet Identified by RSD as HEV	Percent of I/M Excess Emissions Contained in RSD HEVs		RSD HEV IM240 Result		Percent of Fleet that Fail RSD and Pass IM240	Percent of Fleet that Fail RSD and Fail IM240
		HC	CO	Passing	Failing		
CO>5	0.6%	3.3%	15.9%	50.0%	50.0%	0.3%	0.3%
HC>450 or CO>5	1.1%	5.4%	16.6%	53.8%	46.2%	0.6%	0.5%
HC>400 or CO>5	1.5%	6.1%	21.8%	57.9%	42.1%	0.9%	0.6%
HC>300 or CO>5	4.2%	20.4%	25.5%	69.2%	30.8%	2.9%	1.3%
HC>300 or CO>3	5.4%	20.7%	37.8%	71.6%	28.4%	3.9%	1.5%
HC>250 or CO>3	7.3%	40.9%	41.4%	73.3%	26.7%	5.3%	1.9%
HC>250 or CO>2.5	8.7%	40.9%	46.1%	75.7%	24.3%	6.6%	2.1%

For the I/M replacement options (described in Chapter 7), the RSD program is an HEV identification only type program. In this case, we assumed that the program would want to target a higher percentage of excess emissions in order to achieve a reasonable amount of CO emission control. For this reason, we selected the cutpoints of HC>250 ppm or CO>2.5% for the RSD HEV identification only program (I/M replacement option).

For the I/M supplemental options of clean screening with HEV identification (described in Chapter 7), the program requires an *additional* I/M for HEVs (in addition to the existing I/M). In this case, we thought it was most advantageous to focus on the highest emitting vehicles given the existence of the I/M program and the desire to eliminate unnecessary testing. For this reason, we selected the cutpoints of HC>450 ppm or CO>5% for HEV identification with RSD clean screening.

RSD Modeling Scenario Results

The first step in evaluating each of the RSD I/M scenarios, we needed to estimate the number of vehicles measured by RSD by model year. The results are shown in Table H-5. This analysis takes into consideration that older model years are driven considerably less than newer vehicles (by a factor of 3 to 4 lower) and thus are less likely to measured by an RSD.

Table H-5. Vehicles Measured by RSD by Model Year, 1999 Calendar Year					
Model Year	1999 Gasoline Fleet	Model Year Measurement Rates		Vehicles Measured by RSD by Model year	
		80% Fleet Coverage	50% Fleet Coverage	80% Fleet Coverage	50% Fleet Coverage
1990-1999	949,036	93.7%	58.6%	889,538	555,961
1986-1989	281,356	71.8%	44.9%	201,921	126,200
1982-1985	142,299	61.3%	38.3%	87,205	54,503
Pre-1982	174,064	28.1%	17.6%	48,918	30,574

Our evaluation of costs and benefits for each RSD scenario is shown in Tables H-6 through H-13. These tables contain the following scenarios.

Table H-6 Cost and benefits of 80% RSD clean screen (supplemental I/M modification)

Table H-7 Cost and benefits of 80% RSD clean screen with HEV identification (supplemental I/M modification)

Table H-8 Cost and benefits of 50% RSD clean screen (supplemental I/M modification)

Table H-9 Cost and benefits of 50% RSD clean screen with HEV identification (supplemental I/M modification)

Table H-10 Cost and benefits of 80% RSD HEV identification with IM240 confirmatory testing (replacement I/M alternative)

Table H-11 Cost and benefits of 50% RSD HEV identification with IM240 confirmatory testing (replacement I/M alternative)

Table H-12 Cost and benefits of 80% RSD HEV identification with idle confirmatory testing (replacement I/M alternative)

Table H-13 Cost and benefits of 50% RSD HEV identification with idle confirmatory testing (replacement I/M alternative)

Table H-6. Cost and Benefits of 80% RSD Clean Screen (Supplemental I/M Modification) 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	444,092	152,607	596,700
I/M Failures	39,015	29,215	68,230
I/M Repairs	29,940	22,667	52,608
I/M Waivers	239	45	284
Repair Cost per Repaired Vehicle	$210.62	$115.66	$169.71
Repair Cost per Waived Vehicle	$334.18	$503.67	$361.08
Inspection Fee $/inspected vehicle	$24.25	$15.00	$21.88
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$10,769,231	$2,289,112	$13,058,344
I/M Administrative Costs $			$3,738,751
I/M Repair Costs $	$6,386,103	$2,644,423	$9,030,526
I/M Fuel Economy Improvement Cost $	-$1,332,946	-$840,914	-$2,173,860
RSD Infrastructure Costs			$4,140,000
RSD Administrative Costs			$1,699,432
Total Cost			$29,493,193
CO Benefit (Percent of Current I/M Benefit)			94.1%
HC Benefit (Percent of Current I/M Benefit)			94.8%

Table H-7. Cost and Benefits of 80% RSD Clean Screen with HEV Identification (Supplemental I/M Modification) 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	451,189	152,607	603,796
I/M Failures	42,294	29,215	71,509
I/M Repairs	32,457	22,667	55,124
I/M Waivers	259	45	305
Repair Cost per Repaired Vehicle	$210.62	$115.66	$171.57
Repair Cost per Waived Vehicle	$334.18	$503.67	$359.30
Inspection Fee $/inspected vehicle	$24.25	$15.00	$21.91
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$10,941,329	$2,289,112	$13,230,441
I/M Administrative Costs $			$3,738,751
I/M Repair Costs $	$6,922,773	$2,644,423	$9,567,196
I/M Fuel Economy Improvement Cost $	-$1,444,963	-$840,914	-$2,285,877
RSD Infrastructure Costs			$5,940,000
RSD Administrative Costs			$1,713,626
Total Cost			$31,904,137
CO Benefit (Percent of Current I/M Benefit)			101.0%
HC Benefit (Percent of Current I/M Benefit)			97.2%

Table H-8. Cost and Benefits of 50% RSD Clean Screen (Supplemental I/M Modification) 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	552,158	156,276	708,434
I/M Failures	42,862	29,580	72,443
I/M Repairs	32,893	22,950	55,843
I/M Waivers	263	46	309
Repair Cost per Repaired Vehicle	$210.62	$115.66	$171.60
Repair Cost per Waived Vehicle	$334.18	$503.67	$359.28
Inspection Fee $/inspected vehicle	$24.25	$15.00	$22.21
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$13,389,826	$2,344,146	$15,733,971
I/M Administrative Costs $			$3,738,751
I/M Repair Costs $	$7,015,812	$2,677,461	$9,693,273
I/M Fuel Economy Improvement Cost $	-$1,464,383	-$851,420	-$2,315,803
RSD Infrastructure Costs			$1,980,000
RSD Administrative Costs			$1,699,432
Total Cost			$30,529,625
CO Benefit (Percent of Current I/M Benefit)			96.3%
HC Benefit (Percent of Current I/M Benefit)			96.8%

Table H-9. Cost and Benefits of 50% RSD Clean Screen with HEV Identification (Supplemental I/M Modification) 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	556,593	156,276	712,870
I/M Failures	44,912	29,580	74,492
I/M Repairs	34,465	22,950	57,416
I/M Waivers	275	46	321
Repair Cost per Repaired Vehicle	$210.62	$115.66	$172.66
Repair Cost per Waived Vehicle	$334.18	$503.67	$358.30
Inspection Fee $/inspected vehicle	$24.25	$15.00	$22.22
Administrative Cost $/registered vehicle	$2.20	$2.20	$2.20
Inspection Costs $	$13,497,387	$2,344,146	$15,841,532
I/M Administrative Costs $			$3,738,751
I/M Repair Costs $	$7,351,231	$2,677,461	$10,028,692
I/M Fuel Economy Improvement Cost $	-$1,534,393	-$851,420	-$2,385,813
RSD Infrastructure Costs			$2,700,000
RSD Administrative Costs			$1,708,303
Total Cost			$31,631,465
CO Benefit (Percent of Current I/M Benefit)			100.6%
HC Benefit (Percent of Current I/M Benefit)			98.3%

Table H-10. Cost and Benefits of 80% RSD HEV Identification with IM240/Idle Confirmatory Testing (Replacement I/M Alternative) 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	102,544	48,918	151,462
I/M Failures	24,918	9,094	34,012
I/M Repairs	19,122	7,056	26,178
I/M Waivers	128	14	142
Repair Cost per Repaired Vehicle	$210.62	$115.66	$185.03
Repair Cost per Waived Vehicle	$334.18	$503.67	$350.93
Inspection Fee $/inspected vehicle	$24.25	$15.00	$21.26
Administrative Cost $/registered vehicle	$1.10	$1.10	$1.10
Inspection Costs $	$2,486,685	$733,775	$3,220,460
I/M Administrative Costs $			$1,869,375
I/M Repair Costs $	$4,070,416	$823,139	$4,893,556
I/M Fuel Economy Improvement Cost $	-$851,322	-$261,754	-$1,113,076
RSD Infrastructure Costs			$6,480,000
RSD Administrative Costs			$2,002,356
Total Cost			$17,352,671
CO Benefit (Percent of Current I/M Benefit)			65.4%
HC Benefit (Percent of Current I/M Benefit)			58.9%

Table H-11. Cost and Benefits of 50% RSD HEV Identification with IM240/Idle Confirmatory Testing (Replacement I/M Alternative) 1999 Calendar Year			
	IM240	Idle	Total
Total Vehicles Inspected	64,090	30,574	94,664
I/M Failures	15,574	5,684	21,258
I/M Repairs	11,951	4,410	16,361
I/M Waivers	80	9	89
Repair Cost per Repaired Vehicle	$210.62	$115.66	$185.03
Repair Cost per Waived Vehicle	$334.18	$503.67	$350.93
Inspection Fee $/inspected vehicle	$24.25	$15.00	$21.26
Administrative Cost $/registered vehicle	$1.10	$1.10	$1.10
Inspection Costs $	$1,554,178	$458,609	$2,012,787
I/M Administrative Costs $			$1,869,375
I/M Repair Costs $	$2,544,010	$514,462	$3,058,472
I/M Fuel Economy Improvement Cost $	-$532,076	-$163,597	-$695,673
RSD Infrastructure Costs			$3,060,000
RSD Administrative Costs			$1,888,760
Total Cost			$11,193,722
CO Benefit (Percent of Current I/M Benefit)			42.3%
HC Benefit (Percent of Current I/M Benefit)			38.0%

Table H-12. Cost and Benefits of 80% RSD HEV Identification with All Idle Confirmatory Testing (Replacement I/M Alternative) 1999 Calendar Year	
	All Idle
Total Vehicles Inspected	151,462
I/M Failures	64,106
I/M Repairs	50,277
I/M Waivers	278
Repair Cost per Repaired Vehicle	$114.51
Repair Cost per Waived Vehicle	$263.96
Inspection Fee $/inspected vehicle	$15.00
Administrative Cost $/registered vehicle	$1.10
Inspection Costs $	$2,271,931
I/M Administrative Costs $	$1,869,375
I/M Repair Costs $	$5,830,581
I/M Fuel Economy Improvement Cost $	-$474,793
RSD Infrastructure Costs	$6,480,000
RSD Administrative Costs	$2,002,356
Total Cost	$17,979,450
CO Benefit (Percent of Current I/M Benefit)	48.4%
HC Benefit (Percent of Current I/M Benefit)	41.3%

Table H-13. Cost and Benefits of 50% RSD HEV Identification with All Idle Confirmatory Testing (Replacement I/M Alternative) 1999 Calendar Year	
	All Idle
Total Vehicles Inspected	94,664
I/M Failures	40,066
I/M Repairs	31,423
I/M Waivers	174
Repair Cost per Repaired Vehicle	$114.51
Repair Cost per Waived Vehicle	$263.96
Inspection Fee $/inspected vehicle	$15.00
Administrative Cost $/registered vehicle	$1.10
Inspection Costs $	$1,419,957
I/M Administrative Costs $	$1,869,375
I/M Repair Costs $	$3,644,113
I/M Fuel Economy Improvement Cost $	-$296,746
RSD Infrastructure Costs	$3,060,000
RSD Administrative Costs	$1,888,760
Total Cost	$11,585,459
CO Benefit (Percent of Current I/M Benefit)	30.2%
HC Benefit (Percent of Current I/M Benefit)	25.8%

Appendix I: Distribution List

Copies of this report have been distributed to:

Legislative Audit Committee (12)
Department of Public Health and Environment (15)
Department of Revenue (5)
Air Quality Control Commission (12)
Regional Air Quality Council (3)
Joint Budget Committee (2)
Department of Personnel (d.b.a. General Support Services)
    Executive Director (2)
    State Controller (2)
Honorable Bill Owens, Governor
Office of State Planning and Budgeting (2)
Depository Center, Colorado State Library (4)
Joint Legislative Library (6)
State Archivist (permanent copy)
National Conference of State Legislators
Auraria Library
Colorado State University Library

Copies of the report Executive Summary have been distributed to:

Members of the National Legislative Program Evaluation Society
Members of the Colorado General Assembly
National Association of State Auditors, Controllers and Treasurers

Report Control Number 1212