A Cost Evaluation of Cross-Border Truck Emissions Testing Using Heavy Duty Remote Sensing Equipment

Final Report 601

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16. Abstract

The objective of this research study was to perform a thorough evaluation of the feasibility and cost implications for initial system installation and ongoing program and maintenance costs for a Land Port of Entry truck emissions program utilizing Heavy Duty Remote Sensing technology. This study includes funding recommendations to maintain such a program. To meet the study objective, project tasks included the following: i) Develop a work plan for approval by the Technical Advisory Committee, 2) Review the literature on cross-border truck traffic, truck emissions, and truck emissions testing, 3) Prepare a detailed data collection plan, 4) Implement the data collection plan and provide detailed discussion and analysis to support the proposed testing program's elements and cost components, 5) Prepare a final report and a four-page research note.

Cost data were developed for each alternative and includes figures for capital equipment installation and five years of operation and maintenance expenses. The present worth costs for each data plan utilizing contract labor ranged from $1,320,828 to $2,177,467. If employees of ADOT or ADEQ are used, the present worth costs range between $1,140,349 and $1,923,247. While it is obvious that the use of employees is less expensive than contract labor, the agency could find it difficult to attract highly skilled employees for a proposed HDRS emissions measurement program at the Arizona-Mexico border. It is important to note that measurement of emissions by remote sensing is still an emerging technology that has limitations in its application.

ADOT can partner with ADEQ to determine if a monitoring program is warranted at the border at this time. ADEQ has an established air quality monitoring program throughout the state and has trained staff, equipment, and facilities to support such a program.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS					APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol	Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH					**LENGTH**		
in	inches	25.4	millimeters	mm	mm	millimeters	0.039	inches	in
ft	feet	0.305	meters	m	m	meters	3.28	feet	ft
yd	yards	0.914	meters	m	m	meters	1.09	yards	yd
mi	miles	1.61	kilometers	km	km	kilometers	0.621	miles	mi
		AREA					**AREA**		
in^2	square inches	645.2	square millimeters	mm^2	mm^2	Square millimeters	0.0016	square inches	in^2
ft^2	square feet	0.093	square meters	m^2	m^2	Square meters	10.764	square feet	ft^2
yd^2	square yards	0.836	square meters	m^2	m^2	Square meters	1.195	square yards	yd^2
ac	acres	0.405	hectares	ha	ha	hectares	2.47	acres	ac
mi^2	square miles	2.59	square kilometers	km^2	km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME					**VOLUME**		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.264	gallons	gal
ft^3	cubic feet	0.028	cubic meters	m^3	m^3	Cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	cubic meters	m^3	m^3	Cubic meters	1.308	cubic yards	yd^3
	NOTE: Volumes greater than 1000L shall be shown in m^3.								
		MASS					**MASS**		
oz	ounces	28.35	grams	g	g	grams	0.035	ounces	oz
lb	pounds	0.454	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000lb)	0.907	megagrams (or “metric ton”)	mg (or “t”)	mg	megagrams (or “metric ton”)	1.102	short tons (2000lb)	T
		TEMPERATURE (exact)					**TEMPERATURE (exact)**		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C	°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION					**ILLUMINATION**		
fc	foot candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2	cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE AND PRESSURE OR STRESS					**FORCE AND PRESSURE OR STRESS**		
lbf	poundforce	4.45	newtons	N	N	newtons	0.225	poundforce	lbf
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380

Table of Contents

List of Figures and Tables

Page Number

List of Figures

List of Tables

Glossary

Abbreviations

hwy	highway

Symbols

%	percent
™	trademark
PbSe	lead selenide or selenide of lead

Units of Measurement

bhp	brake-horsepower
cm	centimeter
^oC	degree Celcius
^oF	degree Farenheit
gm	gram
gal	gallon
h	hour
^oK	degree Kelvin
kg	kilogram
kPa	kilo Pascals
lbs	pounds
m	meter
mi	mile
µg	microgram
µm	micrometer
mm	millimeter
nm	nanometer
ppb	parts per billion
ppm	parts per million
rpm	revolutions per minute

Pollutants

CO	carbon monoxide
CO_2	carbon dioxide
HAP	hazardous air pollutant
HC	hydrocarbons
NH_3	ammonia
NO	nitrogen oxide
NO_2	nitrogen dioxide
NO_X	nitrogen oxides (or oxides of nitrogen)

NMHC	non-methane hydrocarbons
O_3	ozone
PM	particulate matter
$PM_{2.5}$	fine particulate matter of size 2.5 microns or less
PM_{10}	particulate matter of size 10 microns or less
SO_2	sulfur dioxide
THC	total hydrocarbons
VOC	volatile organic carbon

Acronyms

ACE	Automatic Commercial Environment
ADEQ	Arizona Department of Environmental Quality
ADOT	Arizona Department of Transportation
APF	Air Policy Forum
AZACTS	Arizona Alternative Compliance and Testing Study
BAR	Bureau of Automobile Repair (a California agency)
BG	Betty Gray
BTS	Bureau of Transportation Statistics
CAA	Clean Air Act
CAP	Consumer Assistance Program
CARB	California Air Resources Board
CATI	Clean Air Technologies International, Inc.
CBP	Customs and Border Protection
CCDET	California Council on Diesel Education and Technology
CDPHE	Colorado Department of Public Health and Environment
CE-CERT	College of Engineering – Center for Environmental Research and Technology
CEMS	continuous emissions monitoring system
CHP	California Highway Patrol
CMAQ	Congestion Mitigation and Air Quality
COV	coefficient of variations
CPC	condensation particle counter
CRC	Coordinating Research Council
DAQEM	Department of Air Quality and Environmental Management (Clark County)
DOT	Department of Transportation
DPF	diesel particle filters
DPS	Department of Public Safety
DU	Denver University
DUV	dispersive-ultra-violet
DRI	Desert Research Institute
E-56	emissions study number 56
EEA	Energy and Environmental Analysis, Inc.
ECM	electronic control module
EMC	Emissions Measurement Center

EPA	Environmental Protection Agency
ERG	Eastern Research Group
ESP	Environmental System Products
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FEAT	fuel efficient automobile test
FID	flame ionized detector
FTA	Federal Transit Administration
FTE	full-time equivalent
FMCA	Federal Motor Carriers Association
FTIR	Fourier Transform Infrared
FTP	Federal Test Procedure
GEI	gross-emitter identification
GPS	global positioning system
GSA	General Service Administration
GVW	gross vehicle weight
HDGV	heavy duty gasoline vehicles
HDDV	heavy duty diesel vehicles
HDRS	heavy duty remote sensing
HDRSD	heavy duty remote sensing device
HDVIP	Heavy Duty Vehicle Inspection Program (California)
HEP	high emitter profiles
I&M	inspection & maintenance
IR	infrared
JCAP	Japan Clean Air Program
LasIR	laser-Infrared
LII	laser induced incandescence
LIDAR	light detecting and ranging
LORAX	LIDAR on-road aerosol experiment
LPOE	land port of entry
MAG	Maricopa Association of Governments
MARI	Mid-Atlantic Research Institute
MOUDI	micro-orifice uniform deposit impactor
MVD	Motor Vehicle Department
NAFTA	North American Free Trade Agreement
NDIR	non-dispersive-Infrared
NIR	near-Infrared
NJDEP	New Jersey Department of Environmental Protection
NOV	notice of violation
NTSEL	National Traffic Safety and Environmental Laboratory (Japan)
NTRC	National Transportation Research Center
OBD	on board diagnostics
OBDII	on board diagnostics-second generation
ODEQ	Oregon Department of Environmental Quality
OMR	Operations Management Report
OREMS	on-road emissions measurement system

PA	photo acoustic
PART	particulate emissions factor model
PAS	photoelectric aerosol sensor
PEM	portable emissions monitor
POV	privately owned vehicles
PSIP	Periodic Smoke Inspection Program
QCM	quartz crystal microbalance
RAVEM	ride-along vehicle emissions measurement
ROVER	real-time on-board vehicle emissions reporter
RPM-100	real-time PM
RSD	remote sensing device
SAE	Society for Automotive Engineers
SBRC	Santa Barbara Research Center
SDM	source detector module
SIP	State Implementation Plan
SMPS	scanning mobility particle sizer
SNAQS	Southern Nevada Air Quality Study
SPOT	simple portable on-vehicle testing
TAC	Technical Advisory Committee
TCEQ	Texas Commission on Environmental Quality
TDL	tunable diode laser (also TDLas)
TEOM	tapered element oscillating microbalance
TILDAS	tunable infrared laser differential absorption spectrometer
TRC	Transportation Research Center
TTI	Texas Transportation Institute
TXT	text
UDDS	urban dynamometer drive schedule
UV	ultra-violet
VDF	vehicle data file
VERSS	Vehicle Emission Remote Sensing System
VMT	Vehicle miles traveled
VSP	vehicle specific power
VTM	vertical transfer mirror
WVU	West Virginia University

Section 1.0 – Introduction

The Arizona Transportation Research Center (ATRC) prepared a solicitation for a contractor to evaluate the potential and cost for a program of cross-border truck emissions testing using heavy duty remote sensing (HDRS) equipment. Prophecy Consulting Group, LLC (hereafter referred to as Contractor) was awarded the contract for this research study.

1.1 Scope of Work

The objective of this research study was to perform a thorough evaluation of the feasibility and cost implications for a land port of entry (LPOE) truck emissions program covering initial system installation, operation, and maintenance. This study includes funding recommendations to maintain such a program. To meet the study objective, six tasks were identified:

Task 1: Develop a work plan for approval by ADOT's Technical Advisory Committee (TAC).

Task 2: Review the literature on cross-border truck traffic, truck emissions, and truck emissions testing using HDRS equipment. Use this review to develop a preliminary assessment of the potential benefits of employing this technology at an LPOE.

Task 3: Prepare a detailed data collection plan identifying the type of testing program that will be necessary to make a realistic assessment of the cost implications of a successful program. Develop an operational concept (or set of alternatives, if applicable) bringing together the main components of the ideal testing program. Identify the potential sources of information for the key program variables.

Task 4: Implement the data collection plan and provide detailed discussion and analysis to support the proposed testing program's elements and cost components. Provide some insight, if possible, of expected variations in the figures if the program is implemented in one, two, or five years in the future.

Task 5: Submit a Project Final Report and a four-page Research Note to ATRC. Five bound copies of the report shall be submitted to the ATRC Project Manager. The Final Report shall conform to the version of the ATRC document, *Guidelines for Preparing ATRC Research Reports,* in effect at the time the contract is executed.

Task 6: Provide a brief presentation to the Research Council or other audience designated by the TAC. (optional)

1.2 Report Organization

Section 1 – Introduction
The *Introduction* provides a brief statement of the scope of work that is to be completed for this research study and includes an outline of the Project Final Report.

Section 2 – Background
This section provides a summary of the regulatory requirements associated with inspection programs of heavy duty vehicle emissions as well as U.S. vehicle standards for heavy duty diesel engines. An overview is provided on emissions of diesel engines and on remote sensing technology. Existing cross-border emissions testing programs for state and federal agencies are discussed.

Section 3 – Literature Review Summary
The literature on vehicle emissions measurement was reviewed. Research tools such as technical journals, technical reports, newspaper articles, newsletters, and the internet were used to collect relevant information. This section summarizes the relevant remote emissions data capture systems identified during the review.

Section 4 – Data Collection Plan
This section summarizes the steps that were taken to develop three design alternatives for HDRS emission measurement systems at an Arizona LPOE. Also documented within this section are the summary and outcome of the second meeting of the TAC, the site visit to Mariposa LPOE at Nogales, Arizona, and a description of proposed equipment for each HDRS emissions measurement system design.

Section 5 – Cost Analysis
Cost figures gathered from equipment vendors are presented along with assumptions that were made in this analysis.

Section 6 – Conclusions and Recommendations
The results of the research study are presented along with recommendations for potential future work and analysis.

Section 2 – Background Information

This section provides background information on the regulatory requirements and new vehicle standards for heavy duty diesel engines. Background information is provided on diesel engine technology, remote sensing technology, and cross border programs that are currently in place between the United States and Mexico.

2.1 Regulatory Requirements

The Clean Air Act (CAA) gives the Environmental Protection Agency (EPA) authority to regulate emissions from *new* on-road vehicles, including heavy-duty on-road vehicles. California has authority to adopt its own emissions standards for these vehicles, as long as they are at least as stringent as federal standards. Other states can adopt either the California or the federal standards.[1] and localities are free to set their own emissions standards for *existing* on-road vehicles.

Heavy-duty trucks and buses account for about one-third of the nitrogen oxides (NO_X) emissions and one-quarter of particulate matter (PM) emissions from mobile sources.[2] In some urban areas, the contribution is even greater. EPA's new engine standards program is expected to show PM and NO_X emission levels that are 90%and 95% lower than previous levels. "The results of this historic program are comparable to the advent of the catalytic converter on cars, as the standards will for the first time result in the widespread introduction of exhaust emission control devices on diesel engines."[2] Just as removing lead from gasoline enabled the use of catalytic converters, this program removes sulfur from diesel fuel enabling the use of advanced emission control devices on diesel vehicles.

There have been signs that some lawmakers would like to see more stringent controls for cross-border trucks. On October 8, 2004, a bill to amend Title 49 of the United States Code was presented to the house (and senate) to require motor carriers to comply with vehicle emission performance standards established by the EPA.[3] The senate bill failed.

2.2 New Vehicle Standards

EPA considers any vehicle over 8,500 pounds (lbs) gross vehicle weight (GVW) to be heavy-duty, and therefore, subject to different regulations than light-duty cars and trucks. The exception to this is that under EPA Tier 2 regulations for light-duty vehicles, certain very large sport utility vehicles (SUVs) and passenger vans used for personal transportation (8,500–10,000 lbs GVW) are re-classified as medium-duty passenger vehicles and are subject to the light-duty vehicle rules.[1]

Unlike light-duty vehicles that are tested and certified at the vehicle level using a chassis test, only the engines are certified for heavy-duty vehicles, using an engine test.[2] The numerical emissions limits from heavy-duty engines is expressed as grams per brake-horsepower hour (gm/bhp-hr). This is equivalent to grams of emissions per unit of work done by the engine.

EPA first set exhaust smoke opacity standards for new heavy-duty on-road diesel engines beginning in model year 1970. Starting in model year 1974, new engines were required to meet numeric emissions limits for CO, NO_X, and hydrocarbons (HC); however, PM was not regulated until 1988.[1] As shown in Table 1, between 1988 and 1998, EPA's limits for HC and CO remained the same, but allowable levels of both NO_X and PM were reduced in several steps.

Table 1: EPA Emissions Standards for New Heavy-Duty On-road Diesel Engines (gm/bhp-hr)[1]

Model Year Beginning	HC	CO	NO_X	PM
1988	1.3	15.5	10.7	0.6
1990	1.3	15.5	6.0	0.6
1991	1.3	15.5	5.0	0.25
1993	1.3	15.5	5.0	0.25(0.10[a])
1994	1.3	15.5	5.0	0.10(0.07[a])
1996	1.3	15.5	5.0	0.10(0.05[a])
1998	1.3	15.5	4.0	0.10(0.05[a])
2004	0.5	15.5	2.5[b]	0.10(0.05[a])
2007[c]	0.14	15.5	0.2[d]	0.01

Notes:

a. This lower PM limit applies to urban transit buses only.
b. This limit is for NO_X and non-methane hydrocarbons (NMHC)
c. After 2007, any crankcase emissions must be added to tailpipe emissions subject to these limits.
d. The new NO_x limits are phased in between the 2007 and 2010 model years on a percent-of-sales basis. The 2007 rules also add new steady-state tests and not-to-exceed limits for NO_x.

At 4.0 gm/bhp-hr NO_x and 0.10 gm/bhp-hr PM, the emissions limits for the 1998 model year are 63% and 83% lower, respectively, than those for the 1988 model year. In 1997, EPA adopted an even lower standard for heavy-duty diesel engine NO_X emissions to take effect in the 2004 model year. The next year EPA signed a consent decree with the six major heavy-duty engine manufacturers to settle its claims. According to EPA, manufacturers had for a number of years been using an "emissions defeat device" that modified engine control software to improve fuel economy, but that increased NO_X emissions during certain high-speed steady-state (highway) driving modes. Among other remedies, the consent decree mandated the 2004 NO_X standard of 2.5 gm/bhp-hr for engines built after October 2002. Under the consent decree, engine manufacturers were also required to develop modified software for model year 1993–1998 engines that would reduce off-cycle highway NO_X emissions (this software is often referred to as an electronic control module (ECM) or chip "reflash") and to make this software available to vehicle owners free of charge. The consent decree required that all engines be upgraded with this new software at the time of normal engine overhaul or rebuild, which was assumed to occur after 200,000 to 300,000 miles of service.[1]

In December 2000, EPA adopted a NO_X standard of 0.20 gm/bhp-hr and a PM standard of 0.01 gm/bhp-hr for new on-road heavy-duty diesel engines. This PM standard went into effect for the 2007 model year, while the NO_X standard was to be phased in between 2007 and 2010 on a percent-of sales basis.[1,2]

The 2007 emissions standards introduce additional steady state tests partly to ensure that defeat devices like those that led to the 1998 consent decree will no longer be possible. The 2007 regulations also require control of crankcase vent emissions from all diesel engines.[1] Previously, engines with turbo-chargers were allowed to vent their crankcase emissions, therefore, these emissions are not included in the exhaust limits.

Due to the much slower turnover of on-road heavy-duty fleet vehicles as compared to light-duty fleet, there are still significant numbers of vehicles with unregulated or marginally regulated pre-1990 engines on the road. Even so, over the next 15 years current and pending EPA regulations will begin to have a significant effect. Based on normal fleet turn-over, EPA estimates that annual emissions will continue to decline despite projected growth in annual vehicle miles traveled.

2.3 Diesel Engine Technology

Over the past 20 years, diesel engine technology has improved dramatically. EPA regulations have reduced the NO_X and fine particulate matter of size 2.5 microns or less ($PM_{2.5}$) emissions from new on-road diesel truck and bus engines by 80% and 90%, respectively.[2] To comply with more stringent emissions standards, engine manufacturers have modified diesel engines and equipped these vehicles with exhaust “after-treatment” equipment. Stricter standards that take effect between 2007 and 2010 will further reduce allowable NO_X and $PM_{2.5}$ emissions by 90% and are driving additional changes — primarily the use of even more effective after-treatment technologies.

While much progress has been made to reduce diesel engine emissions over the past decade, there is a large volume of older diesel engines in use on roads and highways today. Many of these engines were made before diesel emissions standards went into effect. Diesel trucks and buses can stay in service for 20 years, while some non-road equipment can last more than 40 years.

The on-road heavy-duty vehicle sector is composed of a wide variety of vehicles, from 18-wheel tractor-trailer combinations, to school and transit buses, to dump trucks and refuse haulers. These vehicles can be found in large numbers on major highways as well as on urban streets. The vast majority are powered by diesel engines.

Heavy-duty vehicles are categorized by weight class (see Table 2).[1] In terms of numbers of vehicles, and especially fuel used annually, the heaviest (Class 8) vehicles dominate. In 2002 there were over 2,082,600 Class 8 trucks on the road in the U.S. which used over 17 billion gallons of diesel fuel

The majority of these Class 8 trucks are long-haul tractor-trailers used to move goods over the nation's highways. Other Class 8 vehicles include transit buses and refuse handlers.

Table 2: Heavy Duty Truck Classification and Statistics[1]

Classification		Statistics		
Class	GVW Rating (lb)	No of Trucks (x1,000)	VMT (million miles)	Fuel Use (million gal)
2B	8,501 – 10,000	396.7	5,031.2	318.2
3	10,001 – 14,000	621.1	8,428.6	1,075.1
4	14,001 – 16,000	287.3	4,184.2	533.7
5	16,001 – 19,500	291.1	3,949.2	503.7
6	19,501 – 26,000	855.8	11,361.3	1,449.1
7	26,001 – 33,000	419.1	5,726.7	995.9
8	>33,000	2,082.6	100,167.0	17,420.3

VMT – vehicle miles traveled

Truck traffic in the U.S. is growing. The number of miles traveled annually by Class 8 trucks is expected to increase by approximately 40% through 2020.[1] While future emissions regulations will mitigate the air quality impacts of increased miles traveled, heavy duty on road vehicles are, and will remain, a significant contributor to $PM_{2.5}$ and other particulate emissions.

While the number of heavy-duty trucks on the road is significantly smaller than the number of light-duty gasoline-fueled cars, their air quality impact is greater because current diesel vehicles emit significantly more $PM_{2.5}$ and NO_X for each gallon of fuel burned than gasoline vehicles. This is partly due to the nature of diesel combustion as well as to a lag in EPA emissions regulations for diesel engines. As discussed earlier, heavy-duty diesel vehicles and engines have a longer service life than light-duty gasoline vehicles and engines. Therefore, it takes longer for more stringent regulations to have a significant impact.

The vast majority of direct $PM_{2.5}$ emissions and $PM_{2.5}$-precursor emissions from heavy-duty on-road vehicles comes from the combustion of diesel fuel in diesel engines. Almost all of the PM emissions in the exhaust of these vehicles is $PM_{2.5}$. Gasoline powered heavy-duty vehicles do exist, but they account for less than 3% of $PM_{2.5}$ and 6% of NO_X emissions from on-road sources. In addition, tire wear and brake wear together account for less than 2% of $PM_{2.5}$ emissions from heavy-duty vehicles.[1]

About a quarter of the PM emissions from tire wear is $PM_{2.5}$, and close to half of the PM emissions from brake wear is $PM_{2.5}$. Exhaust from heavy-duty diesel vehicles accounts for about 65% of direct $PM_{2.5}$ emissions from on-road vehicles (Table 3)[4]. This is less than 2% of the total inventory of direct $PM_{2.5}$ emissions, including stationary sources and non-road vehicles. However, the hazardous nature of diesel exhaust and the proximity of diesel exhaust sources to sensitive populations, particularly in urban areas, magnify the health impact. Diesel exhaust is known to contain over 40 substances listed by EPA as hazardous air pollutants, 15 of which have been listed by the International Agency for Research on Cancer as known, probable or possible human carcinogens. Many of these substances are adsorbed onto emitted diesel exhaust particles. For this reason, the California Air Resources Board (CARB) has formally designated diesel PM as a toxic air contaminant.[4]

Table 3: Diesel Truck and Bus Emissions (2002)[4]

Category	$PM_{2.5}$ (tons/year)	SO_2 (tons/year)	NO_X (tons/year)
Heavy-duty diesel vehicles (highway)	97,000	105,000	3,378,000
% of highway vehicle emissions	65%	38%	46%
% of total mobile source emissions	22%	15%	29%

SO_2 – sulfur dioxide

Exhaust from heavy-duty diesel engines also accounts for about 50% of NO_X emissions from on-road vehicles and about 20% of all NO_X emissions, including those from nonroad diesel and stationary sources.[4,5] All mobile sources, including light- and heavy-duty onroad vehicles and nonroad equipment, produce about 2 to 4% of total SO_2 emissions nationally. Mobile source SO_2 emissions were reduced further beginning in 2006, when allowable fuel sulfur levels for both gasoline and diesel fuel declined by over 90%.[4]

2.4 Remote Sensing Technology

A brief overview of remote sensing technology and its usage as a measurement tool for vehicular exhaust pollution from moving vehicles is provided. This information reflects how this technology is used in the United States with conventional emissions testing programs.

2.4.1 Measurement Techniques

Non-dispersive Infrared (NDIR): Although different types of remote sensing technology are being used and studied, the most frequently used technology is the well-proven and established NDIR technology. NDIR has been used for more than 20 years in thousands of emissions analyzers in fixed facilities, performing more than 30 million CO and carbon dioxide (CO_2) measurements in new vehicle certification systems using the US Federal Test Procedure (FTP). NDIR is a well-proven method of measuring HC, CO and CO_2 in both fixed location analyzers and remote sensing applications. In fixed location analyzers, the exhaust is captured in a small tube, through which the infrared is passed from a low power source to the optically filtered detector. Remote sensing has added complexities such as the long, open path length that requires a higher power source, and favorable weather conditions.

Infrared Tunable Lasers: The near-IR (NIR) low power, tunable lasers operate at a lower wavelength where there is less CO and CO_2 absorption. However, there is negligible HC and NO absorption in the range of the NIR tunable laser, so it is practical for remote sensing of CO and CO_2. In summary, tunable lasers can and are being used for remote sensing applications, however, there are significant cost and implementation penalties associated with measuring gases other than CO and CO_2.

Ultra-Violet (UV) Light: The wavelengths of HC and NO_X are measurable in remote sensing applications by UV spectroscopy over a broad frequency spectrum. This enables higher accuracy since the measurements are taken over a range of wavelengths. As with NDIR, this is a well-proven and practical technology that has been used and perfected in remote sensing applications during the past seven years.

2.4.2 Using Remote Sensing

Road Set-Up: Remote sensing of emissions provides an analysis of the exhaust of a particular vehicle as it passes by on the road. To correlate the emissions readings with the specific vehicle a video capture of the vehicle license plate can be part of the setup if desired. In addition to reading the license plate and taking the emissions readings, vehicle speed and acceleration are measured for the vehicle-specific power calculation. A typical remote sensing road set-up for light-duty vehicles is shown in Figure 1.[6]

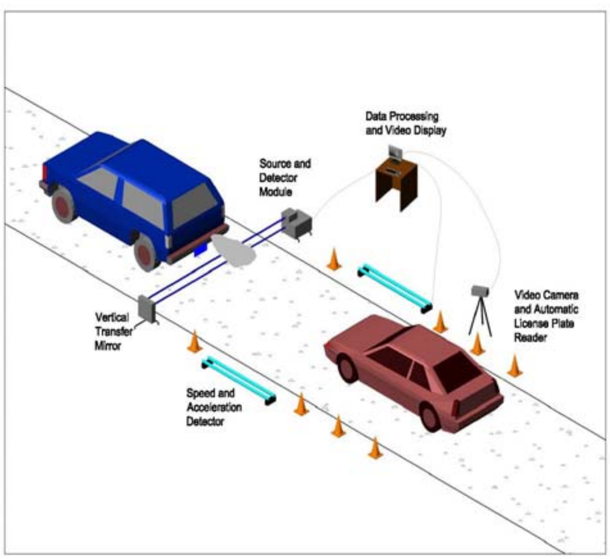

Figure1: Illustration of On-road Remote Sensing Set-up[6]

Most vehicle emission tests (including the Inspection and Maintenance (I&M) 240 Test and the FTP that is used in the U.S. to certify new vehicles) measure vehicle performance over a range of speeds and accelerations. It is the combination of speed and acceleration that defines the specific power output of the vehicle engine. It is critical to know the specific power output of the engine at the time the vehicle's exhaust is measured to properly evaluate the vehicle's exhaust emissions. In an on-road situation, the road grade must also be taken into account as a component of specific power. Road grade, vehicle speed, and vehicle acceleration are used to compute the specific power for each measured vehicle and to validate the emissions readings.

Weather Considerations: Inclement weather can affect the productivity, but not the accuracy of remote sensing systems. Adverse weather conditions do not compromise the quality of the data collected, but rain and fog can affect the measurement productivity of remote sensing by lowering the valid measurement capture rate.[6]

Vehicle Identification: As vehicles pass the remote sensing system, a digital video photograph of the vehicle license plate is taken, correlated with the emissions readings and stored on a computer hard drive. At the end of each day's testing, the digital video images and emissions data are converted to data files using a patented post-processing method called Tag Edit™. Personnel read the license plate from the video image (digital photograph) and enter it at a keyboard. The Tag Edit™ software ensures that all valuable information is extracted from a vehicle record. Figure 2 shows an example of a Tag Edit™ screen.[6]

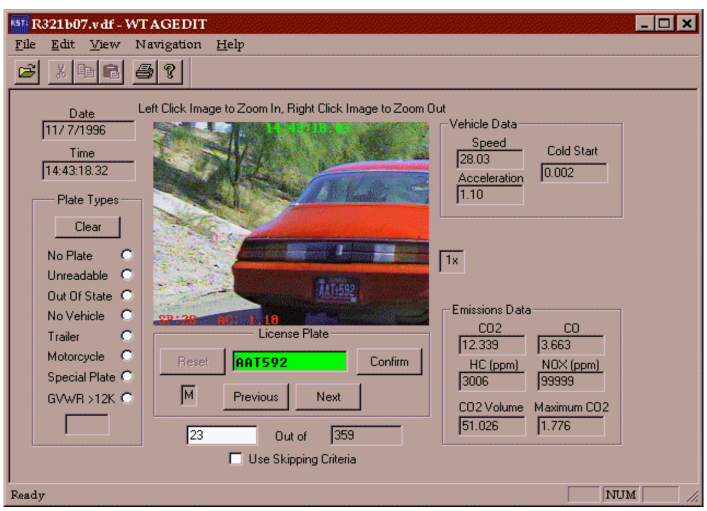

Figure 2: Example of a Tag Edit™ Computer Screen[6]

Data Processing: The software creates a machine-readable version of the emissions data received from the field and stores it in a Vehicle Data File (".VDF"). The VDF file can be exported to a database or spreadsheet (Access, Paradox, dBase, Excel, Quattro Pro, Lotus, etc.) by creating a text file with the file extension of ".TXT". A text file can be created for just about any field measured.

Certification and Quality Assurance: The only existing certification standard for remote sensing is that available from the California Bureau of Automotive Repair (BAR).[6] Quality assurance to ensure continuous improvement of equipment, operation and data is essential to the success of any remote sensing program. To minimize equipment downtime and to ensure data quality, the remote sensing software uses a statistical database with information from the operators, data processors, and auditors.

2.5 Cross Border Programs

Air quality along the 1,952-mile international border that separates the United States and Mexico is of great concern due to its effect on public health. All or parts of several major metropolitan areas do not meet EPA's standards for maximum allowable levels of one of three air pollutants: ozone (O_3), CO and PM_{10}. The U.S. Department of Transportation's (USDOT) Bureau of Transportation Statistics (BTS) reports that passenger vehicle crossings into the U.S. increased by about 38% between 1995 and 2004, from 66.4 million to 91.3 million. BTS estimates that between 1995 and 2004, truck crossings from Mexico to the U.S. rose by about 57%, from 2.86 million to 4.5 million.[7]

2.5.1 State Programs

The North American Free Trade Agreement (NAFTA) was implemented on January 1, 1994.[8] In preparation for its implementation, the State of California enacted legislation (Senate Bill 270, Chapter 727, Statutes of 1998) that requires CARB to maintain inspection operations at two California-Mexico border crossings (i.e., Otay Mesa in the San Diego region and Calexico in Imperial County), and to perform random roadside inspections in the border area. This inspection program is referred to as heavy duty vehicle inspection program (HDVIP). These two stations have been on-line since 1999 and have tested over 13,000 vehicles. The opacity test failure rate in the border region has consistently been higher than throughout the rest of the state, which lends credence to the generally held assumption that Mexican commercial vehicles are older and dirtier than those registered in California. CARB prepared a report for the California Legislature (January 2006)[9], to address specific air quality concerns relating to the implementation of the transportation provisions of NAFTA, and to address specific questions from the California Legislature.

Enactment of NAFTA is largely responsible for this increase in vehicle and truck crossings. NAFTA is a regional agreement between the governments of Canada, the United Mexican States and the United States of America to implement a free trade area.[8] The agreement between the three countries became effective on January 1, 1994 and all provisions are be fully implemented by 2008. This agreement removes most barriers to trade and investment among the United States, Canada, and Mexico.

In its January 2005 report, CARB provides a summary of the anticipated emissions and air quality impacts of increased Mexican commercial vehicle travel into the U.S.[10]:

- It is estimated that approximately 30,000 additional trucks will cross daily into the four border states—Texas, New Mexico, Arizona and California—based on projections from current border crossing activity and surveys of Mexican fleets. For the calendar year ending December 31, 2006, the largest crossings for each LPOE is reported: commercial trucks - 1,526,623 at Laredo, TX, buses - 99,057 at San Ysidro, CA, and privately owned vehicles (POV) – 17,073,761 at San Ysidro followed by 15,837,947 POVs at El Paso. [Note: 2006 data provided by the ADOT Mariposa LPOE Operations Management Reporting System.]

- Currently, 3,500 trucks cross into California each day (approximately 3,000 at Otay Mesa and 500 at Calexico/Mexicali). These trucks are limited to travel in a 20-mile commercial zone. These crossings could increase two to five times to 7,000 to 17,500 per day if the 20-mile commercial zone limit is lifted.

- Increased crossings at the California/Arizona border on Interstate 8 are anticipated as Mexican trucks from the Nogales region and beyond plus trucks from Texas and New Mexico come west to use the Port of Los Angeles. Baja California does not have a comparable large shipping port. In anticipation of this increased traffic, and increased shipping demand from the Asian market, the Port of Los Angeles is undergoing significant expansion and will double its capacity in the next two to five years. It is already the second largest and busiest port in the U.S. The surrounding freeways that service this port (Interstate 110 and Interstate 710) are already severely impacted by truck traffic.

It is important to note that the above impacts are from various studies and many assumptions underlie them. Actual emissions and air quality impacts will be determined once NAFTA is fully implemented.

The CARB report also provides a profile of the Mexican Truck Fleet and the country's emissions standards:

- 66% of the Mexican truck fleet is 1993 model year and older (1993 was when the diesel engine fleet was close to 100% electronic conversion. Engines built in 1993 and later typically use electronic fuel injection and computer controls to reduce emissions, improve performance and fuel economy).

- 25% of the Mexican truck fleet is pre-1980 model year (these engines emit very high levels of NO_X and PM emissions on average).

- Mexican diesel engine emission standards were aligned with EPA's standards for the 1994 to 2003 model years. Mexico has not revised its emission standards to reflect recent U.S. standards which require a 50% reduction in NO_X for 2004-2007 engines and a 90% reduction in NO_X and PM for 2007 and subsequent model year engines. The 2007 engine standards also require the use of ultra low sulfur diesel fuel (15 parts per million (ppm) sulfur), which is not yet required in Mexico.

The actual increases in emissions resulting from free commercial-vehicle travel between the United States and Mexico as a result of NAFTA implementation are unknown. Cross-border travel has been limited to the restricted commercial zone with the exception of the preliminary or test registration program that allows a limited number of large Mexican trucks to travel beyond the 20 mile zone. This test registration program began in September 2007. CARB conducted a survey of heavy-duty commercial vehicles in the California-Mexico border region to determine the certification profile of the engines that will be subject to the regulations. Using these preliminary fleet characteristics as well as assumptions from existing studies and models, CARB estimates that implementation of HDVIP regulations would potentially prevent emission increases of NO_X and PM in the following concentrations[9]:

- Statewide: 2.9 tons/day NO_x, 0.12 tons/day PM
- South Coast Air Basin: 1.1 tons/day NO_x , 0.04 tons/day PM

As the HDVIP regulation was under development, emission reductions were modeled for NO_X and PM based on the projected fleet profile for 2010. The model assumed that 100% compliance would yield 14 tons/day emission reductions of NO_X (statewide) and 3.2 tons/day reductions of PM. Extrapolating from these modeled reductions, and assuming that 27% of all inspections take place at the ports and in the border areas, 100% compliance (i.e., all vehicles that failed the inspection were repaired and all citations were cleared) would yield 3.8 tons/day emission reductions in NO_X and 0.86 tons/day of PM. In reality, of the vehicles tested in border regions and at the ports, approximately 50% of the citations remain delinquent (i.e., the engines have not been repaired and the citations have not been cleared). A 50% rate of "full compliance" would yield emission reduction estimates of 1.9 tons/day NO_X and 0.43 tons/day of PM for the border regions and ports.

CARB is an active participant in the Border 2012 U.S.-Mexico Environmental Program (Border 2012), a 10-year environmental cooperation program launched in 2003 by the governments of Mexico and the U.S. in response to the continuing environmental and public health problems in the region. CARB has secured a $100,000 grant from the EPA to characterize the Mexican truck fleets operating in California. Current estimates of the impact of Mexico's trucks on California's air quality rely heavily upon assumptions regarding the size and composition of the Mexican commercial fleet that will travel through the state, how these vehicles will be driven, and how far north into the state these vehicles will travel. CARB is designing a study to better estimate the impact of these vehicles on the state's air quality. Information will be collected from roadside surveys, vehicle inspections, fuel samples, and from databases maintained by Immigration and Customs Enforcement (ICE) - a Division of the U.S. Department of Homeland Security, the ports of Los Angeles and Long Beach, and the California Highway Patrol.[9]

CARB is also a major partner in the West Coast Diesel Collaborative, a consortium of federal, state and local government agencies, non-profits and industry working together to find voluntary solutions, incentives and shared approaches to reducing diesel pollution along the west coasts of Canada, the United States, and Mexico. Through the West Coast Diesel Collaborative, US EPA awarded the San Diego County Air Pollution Control

District $150,000 for a demonstration project on the feasibility and effectiveness of diesel retrofit technologies on heavy-duty diesel vehicles that operate in the San Diego-Tijuana region. The West Coast Diesel Collaborative's goal is to ultimately secure $100 million through public/private partnerships to address and solve the diesel pollution problems along the west coast.[10]

In addition, CARB has actively participated in the U.S.-Mexico Air Policy Forum (APF), one of the coordinating bodies under Border 2012, which is responsible for prioritizing federal policies on border-wide air quality issues. CARB, along with air quality agencies from other border states, has successfully advocated for the recognition of cross-border heavy duty diesel truck emissions as one of the issues requiring ongoing dialogue between the two countries, and which should be at the forefront of the APF's funding priorities. CARB plans to seek funds allocated through the APF's prioritization process to address the impact of Mexico's commercial vehicles on the state's air quality.

The San Diego Union-Tribune reported that 50 tons of smog will be produced by the additional trucks, which is the equivalent of 2.2 million cars. Air quality within the area is expected to be seriously impacted, and emissions reductions in non-attainment areas will have to come form other local sources.[11] Mexico has stated that it will require the use of low-sulfur diesel fuel starting in 2007 in the border regions, and countrywide by 2009. Environmental officials south of the border expect that long-haul trucks are more likely to be newer and cleaner than vehicles that only operate within the 20-mile zone around the border. The article also refers to inspection stations that were set-up in 1998 for Mexican trucks in California near Otay Mesa and Calexico. No specific information on the type of emissions testing was provided nor was data provided for implementation or cost.

New Mexico reports that it has no current plans for additional emissions testing along its border because the state has so little border traffic.[12] Similarly, a spokesperson for the Texas Commission on Environmental Quality (TCEQ), indicated that it is not pursuing heavy duty remote sensing or other related emissions testing at its border, and is waiting to receive more information from EPA before pursuing a course of action.[13] However, the El Paso Metropolitan Planning Authority (MPA), states that Texas currently performs safety inspections at the commercial ports of entry and they will continue. These inspections currently do not involve any tests or checks for emissions. Most likely this will change if new cross-border emissions requirements are promulgated. At the MPA level, they are proposing to retrofit 30 diesel engines using Congestion Mitigation and Air Quality Improvement Program (CMAQ) funds.[14]

2.5.2 U.S. Mexico Border Programs

The document, Advancing US-Mexico Border 2012 Air Policy Forum Priorities[15], sets forth the current priorities relating to air quality: reducing emissions from diesel sources, increasing the availability of ultra low sulfur diesel in the border region, and conducting training sessions on I&M programs. Two HDRS projects are discussed: a study led by the Texas Transportation Institute (TTI) at Texas A&M University and the Nogales, AZ, border study. The TTI study focused on quantifying emissions from trucks in the idle and creep drive cycles which is typical of border crossings. The Nogales, AZ, study, although not identified as such, uses HDRS for measurement of emissions from commercial trucks, along with corroborating measurements from portable emissions monitors (PEM) and opacimeters. The APF planned a workshop on truck emissions at border crossings, including use of opacimeters, portable emissions monitors (PEMs), remote sensing technology, and retrofit technology.

In its ninth report, the Good Neighbor Environmental Board[7] suggests the following recommendations to both retain good air quality and support transportation activities along the U.S.-Mexico border:

- Bolster stations and transportation infrastructure – bolster infrastructure, technology, personnel and related activities through substantial new funding, and intensify long-range planning and coordination at the bi-national, national, state and local levels to cope with the congestion at border crossings, and thus reduce air pollution.

- Emissions – harness new and emerging technologies and fuels to reduce emissions from diesel trucks, buses, municipal and private fleets and passenger vehicles, and identify private/public funding sources to accelerate the process.

- Public transit and alternatives to single occupant driving – encourage public transportation, ridesharing, biking and walking in border cities so that fewer people will drive alone, thus reducing motor vehicle trips and the emissions of pollutants.

This document includes information on a project called Cyber Port at the Nogales Mariposa LPOE. The program seeks to improve the flow of trade from the point of origin to the point of destination. It features innovations in intelligent transportation systems that monitor trucks through the federal and state inspection processes, as well as "Super-Booths" where federal and state officials work side-by-side to perform primary inspection of trucks.

Section 3

Literature Review Summary

In this section, diesel emissions measurement studies and related research that utilized Remote Sensing Devices (RSDs) or other equipment are summarized in Table 4 along with the measured pollutant(s). If available, vendor and product information are also provided in Table 4.

The review of the literature identified emission measurement studies in the U.S. as well as international locations.[16, 17, 18, & 19] Several studies occurred within the southwest, including Arizona. Two studies have taken place at the U.S.-Mexico border: San Diego, CA (1997) and Nogales, AZ (2005). The primary emissions of concern are CO/CO_2, HC, and NO_X, followed by PM and Hazardous Air Pollutants (HAPs)

These studies represent a combination of existing and emerging technologies capable of measuring in-use vehicle emissions. HDRSD is still an emerging technology although significant advances have been made over the last 10 years. During the recent 2005 Nogales, AZ border study, HDRSD technology performed well as an emissions screening tool, and demonstrated the capability to capture emissions and vehicle data snapshots from a large number of trucks in a short time frame. Identifying deployment and set-up strategies for varying truck traffic continues to be a challenge.

Numerous vendors of emissions measuring equipment are available in the market place. However, when the criteria is narrowed to vendors providing remote sensing equipment, especially instruments designed to measure emissions from heavy duty diesel engines, the field is narrowed to a handful of suppliers. Those vendors found from a review of the literature are:

- University of Denver – Remote Sensing Unit
- Santa Barbara Research Center – Smog Dog
- Banner Engineering Corporation – Ultra Beam and Maxi-Beam Sensors
- MD Laser Tech – Remote Sensing Unit
- ESP – AccuScan RSD 3000™ & 4000™ units

Although the Desert Research Institute (DRI –Las Vegas, NV) has developed and patented several equipment prototypes, this equipment may not be readily available for purchase or long-term use. For the purposes of this cost study, the research team only reviewed “off-the shelf products” (products that can be purchased and are readily available in the market place).

Table 4 - Summary of Diesel Emissions Measurement Technology and Equipment

Application	CO/CO2	HC	NOx	PM	HAPs	Vendor/Product
Southern California Study - 1994	UV	UV	--	--	--	University of Denver/ Remote Sensing Unit
US Mexico Border, San Diego - 1997	UV	UV	UV	Opacity Meter	--	University of Denver/ FEAT
Austin-San Marcos, TX – 1998	UV	UV	UV	Opacity Meter	--	Unknown
Los Angeles – 1999	IR	IR	IR – Laser	--	--	SBRC/Smog Dog & DRI/TILDAS
US & European Truck Study: 1997-1999						
Light Duty Trucks	rr-IR	rr-IR	NDIR/DUV	--	--	University of Denver/FEAT
Heavy Duty Trucks	rr-IR	rr-IR	NDIR/DUV	--	--	Banner Engineering Co
Oregon DEQ Three City Study – 2003	IR	IR	UV	--	--	MD Laser Tech Remote Sensor
Remote Sensing Clean Screen Program in Arizona: 1995-2000	IR-Laser	IR-Laser	UV-Laser	--	--	SBRC/Smog Dog
Southern Nevada Air Quality Study						
EPA On-road Test Facility, since 2000 est.						
Colorado Rapid Screen Testing Program -2003	IR-Laser	IR-Laser	UV-Laser	--	--	EnviroTest Systems –/Remote Testing Unit
Phoenix Multi-Year Remote Sensing Study (Initiated in 1998)	NDIR	NDIR	DUV	--	--	University of Denver/ Remote Sensing Unit
EPA/ADEQ Cross Border Pilot Study, March 2005	IR-Laser	IR-Laser	UV-Laser	Opacity Meter	--	ESP/AccuScan RSD4000, Robert H. Wager/ Opacimeter
Phoenix Remote Sensing Study – November 2005	NDIR	NDIR	DUV	--	--	University of Denver/ Remote Sensing Unit
Auckland Vehicle Study – April 2003	NDIR	NDIR	DUV	--	--	University of Denver/ Remote Sensing Unit
NJDEP Clean Bus Study – Initiated in ‘06	NDIR	NDIR	DUV	Opacity Meter	--	ESP/AccuScan RSD4000
EPA Instrumented Heavy Duty Diesel Trucks Study, ongoing	FTIR	FTIR	FTIR	--	FTIR	Various Vendors
Limited Studies or Applications	--	--	--	LIDAR/ LORAX	--	Patented by DRI (remote sensing for PM
Limited Studies or Applications	--	--	--	LII	--	Patented by DRI
Limited Studies or Applications	--	--	PA Analyser	PA Analyser	--	Patented by DRI (detects and quantifies light absorbing particles in real time)

Table 4 - Summary of Diesel Emissions Measurement Technology and Equipment

Study	CO/CO2	HC	NOx	PM	HAPs	Vendor/Product
Various Studies or Applications	--	--	--	TEOM, QCM	--	Several Vendors produce this equipment
Various Studies or Applications	--	--	--	Aetholometer, Nephelemeter, Photoacoustic instrument, laser-end incandescence, and Fast FID	--	Various vendors in the market place manufacture these instruments for the measurement of PM or Opacity

FEAT was first patented and used by the University of Denver. It is now produced by ESP.

Section 4

Data Collection Plan

Using the findings from the literature review and the summary of remote sensing studies identified in Section 3, an HDRS data collection system or plan was developed for ADOT that can be used along one or more LPOEs at the Arizona-Mexico border. The data collection plan includes sufficient detail to identify the ideal components of an HDRS system. The detail in the data collection plan is also sufficient to provide the necessary input for operating a successful program.

Prior to the development of the data collection plan, the Contractor visited the Mariposa LPOE in Nogales, Arizona. This LPOE was chosen because of its accessibility and relatively short distance from the Phoenix metropolitan area. The facility borders Nogales, Sonora and supports pedestrian, passenger vehicle, and commercial vehicle crossings. The Nogales-Mariposa LPOE also has the largest volume of traffic for all Arizona-Mexico border crossings.

4.1 Nogales-Mariposa LPOE Visit

The site visit to the Nogales-Mariposa LPOE occurred on Monday, November 6, 2006. Vi Brown, study director, and Darcy Anderson, principal researcher, met with Scott Williams, Automatic Commercial Environment (ACE) Ambassador, and Jesus T. Cruz, Customs and Border Protection (CBP) Chief Cargo Officer. A tour of the facility was provided. The current facility was designed for 600 trucks per day and completed in 1975. The volume of commercial vehicles entering the LPOE in 2007 is greater than 291,000 and peak truck traffic is about 1400 trucks per day. Truck, bus, and private vehicle traffic data for each U.S.-Mexico southern border LPOE is provided in Appendix 1.

Some of the government agencies operating at the Nogales-Mariposa LPOE are Federal Motor Carrier Safety Administration (FMCA), Department of Public Safety (DPS), Federal Aviation Administration (FAA), ADOT Motor Vehicle Division (MVD), and Food and Drug Administration (FDA). Each truck entering the LPOE goes through some level of inspection. Some trucks are tagged for additional inspection. The current facility does not promote efficiency of inspections between agencies. Winter traffic (between October and May) represents the busiest season for the LPOE. The majority of the trucks transport produce from Mexico.

The proposed renovation of the Nogales-Mariposa LPOE was also discussed during this visit. The General Services Administration's (GSA) Property Development Division estimates construction and renovation costs to expand and modernize the LPOE at $100- to $150 million. Construction is scheduled to begin in 2009 and to be completed in 2013.[20] The September 2007 proposed layout for the construction project is provided in Figure 3.[21]

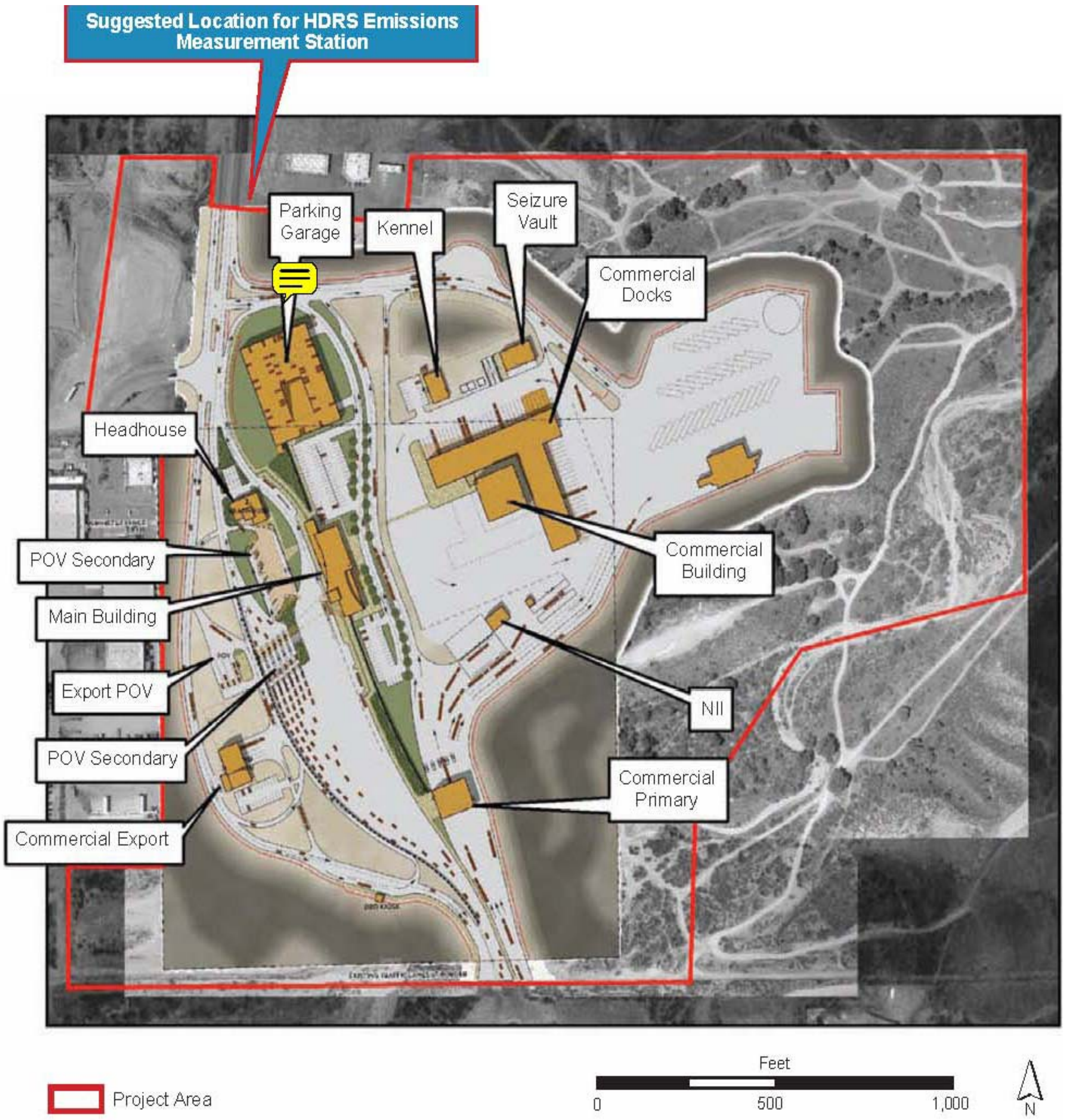

Figure 3: Illustration of Proposed Expansion Layout for Nogales-Mariposa LPOE (September 2007)[18]

While touring the facility, the Contractor's team scanned the site for a suitable location to set up a heavy duty monitoring station keeping in mind that the facility is proposed for renovation and expansion. After considerable discussion about the objectives of a HDRS monitoring site for cross border trucks, the directional flow of truck traffic into and through the LPOE, and incorporating proposed expansion plans, it was agreed that the ideal location for HDRS equipment would be on the perimeter road north of the facility and near the exit for the facility. The exit road is also the entry point into the U.S. It has a slight uphill grade. This location also works well for emissions measurement purposes.

4.2 Data Collection System

There are many configurations that were considered and discussed, with the fundamental goal of measuring the key pollutants identified in Scenario 1 (HC, CO, NO_X and PM). The systems described below and the cost estimates included in Section 5 are designed to give ADOT a summary of options considered relevant for the project.

One of the outcomes of the literature review was the identification of two instruments that will provide the type of HDRS emissions measurements that meet the project goals and objectives. The two are ESP's AccuScan™ products and FTIR instruments (available through several manufacturers). Both instruments provide optical-based measurements with near real-time output. The AccuScan™ products are the only instruments specifically designed for this type of deployment. The cost estimates in Section 5 are based on the Accuscan™ RSD system.

Arcadis was recently contracted by the EPA to test FTIR instruments in the Phoenix area. The firm was contacted about the potential for use of FTIR for HDRS emissions measurement. They responded that it is possible to custom-design an application using commercially available FTIR instruments. The commercially available FTIR instruments are less expensive than the ESP AccuScan™ instruments, but are not specifically designed for the type of application needed at a border crossing.[22] DRI also has developed several custom-designed instruments that may be available and appropriate to test at the border crossing. The fully-integrated system that is discussed later in this section is designed to allow flexibility for testing and comparing additional instrumentation.

Three alternatives for HDRS equipment measurement systems are included in the cost study. For each system presented below, the instruments selected will need to be connected to a data-logger or computer, and the data will need to be transmitted – ideally by high speed internet or a T-1 line, but also possibly by modem from a land line or mobile phone. Each of the HDRS systems described below includes one operating and one spare remote-sensing device to minimize down time associated with equipment failure or malfunction.

4.2.1 Basic HDRS Emissions Measurement System

The most basic HDRS emissions measurement system would consist of:

- two remote sensing transmitter units (one operating and one spare) mounted on a tower
- a receiver and computer (inside a basic shelter) mounted on a tower on the opposite side of the Commercial Roadway exit for the Nogales-Mariposa LPOE

This system would require power (110 volts, separate circuits) on each side of the roadway, and space for mounting towers high enough to send a beam through the truck exhaust. The towers could potentially accommodate additional equipment if desired for routine measurement or special studies.

4.2.2 Intermediate HDRS Emissions Measurement System

The intermediate HDRS emissions measurement system builds on the basic model. It consists of:

- two remote sensing transmitter units (one operating and one spare) mounted on a tower
- a receiver and computer (inside a basic shelter) mounted on a tower on the opposite side of the Commercial Roadway exit.
- a continuous particulate monitor (PM_{10} or a modification to measure $PM_{2.5}$)
- an aethalometer, that provides continuous measurement of diesel particulate matter (black carbon).

Power and mounting requirements are similar to the basic system. The towers and the shelter could potentially accommodate additional equipment for future monitoring activities.

4.2.3 Fully-Integrated HDRS Emissions Measurement Systems

The fully-integrated HDRS emissions measurement system builds on the intermediate design and includes:

- two remote sensing transmitter units (one operating and one spare) mounted on an exterior column of a *pole barn* (roadway canopy), or mounted from the inside roof beams of the pole barn that would be built across the Commercial Roadway exit
- a third remote sensing unit would be placed inside a mobile equipment shelter and deployed at a specific distance from the units in the pole barn to capture exhaust under acceleration
- a continuous particulate monitor (PM_{10} or $PM_{2.5}$)
- rack mounted and portable aethalometers that provide continuous measurement of diesel particulate matter (black carbon)
- a continuous nitrogen oxides (NO_X) monitor
- a continuous sulfur dioxide (SO_2) monitor
- the option for measuring speciated hydrocarbons as needed

The intermediate system requires 110 volts of power on each side of the roadway. Space is required to mount the transmitter and receiver high enough to send a light beam through the truck exhaust. Equipment can be mounted either from vertical beams on the side of the pole barn, or from the inside ceiling of the structure. Roof options are discussed in more detail in Section 5. A sample collection hood could also be mounted from the ceiling of the pole barn to capture truck exhaust for more extensive component measurement (e.g. air toxics or HAPs). The building could easily accommodate additional equipment and personnel, if desired, for special studies.

A cost estimate for each system is presented in Section 5.

Section 5

Cost Estimate

One of the requirements for this research study is to develop a conceptual cost estimate of an ideal HDRS testing program for cross-border truck emissions at a LPOE. This section provides information on the cost estimating methodologies that were used for this study, identifies some of the assumptions and decisions that were utilized, and provides a cost estimate for each data plan that was discussed in Section 5.

5.1 Cost Estimating Methodology

In the field of cost engineering, there are several types of cost estimates. In most cases, the type of estimate reflects the amount of data and other information that is available at the time. A brief description is provided of three cost estimating techniques that were considered for this study, and are used uniformly within the engineering and construction industries. Two other cost estimating techniques were also reviewed - budget cost estimate and detailed construction estimate - however, they are beyond the scope of this project. The cost descriptions were provided by Industrial Cost Engineering[23].

5.1.1 Order-of-Magnitude or Ball Park Estimate

A limited amount of information is used to develop this type of "ball park estimate." The estimate is prepared from in-house data available from past jobs or similar projects. From these actual jobs, the proposed plant or equipment is scaled to derive new cost data sets that are then adjusted for inflation. A cost estimate determined in this way is only valid for a similar plant or equipment. The accuracy of this type of estimate is highly dependent upon the scope and time allotted to its preparation. This estimate has a probable accuracy of about -50% to +50%, or worse.

5.1.2 Factored Estimate

A factored estimate requires the identification of a price for each process or individual type of analytical equipment. This estimate is produced by taking the cost of individual types of equipment, and multiplying it by an "installation factor" to arrive at the Total Direct Equipment Cost. The process installation factors include all subcontracted costs plus all of the associated direct field labor and bulk materials that are required to install these items. These "installation factors" produce the Total Direct Equipment Costs only.

Adjustments must be made to the estimate for offsite facilities, extensive piling, unusual site conditions, long runs of interconnecting piping/conduit, etc. The accuracy of this type of estimate depends on the definition of scope, equipment costs, and known equipment and site factors. This estimate has a probable accuracy of -25% to +30%.

5.1.3 Study or Preliminary Estimate

This type of cost estimate is prepared after the technical staff has completed the conceptual design, the equipment list by size and category, the preliminary process flow diagrams, and engineering design is 1% to 10% complete. The following documents serve as the basis for this type of estimate:

- reasonably defined equipment list by size and category, including onsite and offsite equipment.
- preliminary overall plot-plans.
- known general site conditions such as location, utility requirements, site survey, utility distribution (sewers, power feeders, etc.), labor productivity, availability of skilled workers, and availability of construction materials.
- overall process flow diagrams.

Industrial building estimates are derived from quotations or approximated from their size and type of construction. Equipment is priced via cost curves or six-tenths factors. If the cost information is not available, outside price quotations are solicited from vendors by telephone or correspondence. The total direct cost of the project is derived from quotations or in-house information on equipment and bulk material costs including labor hours and costs. The total indirect cost is determined by applying a factor to the direct cost. Labor and installation of material costs are obtained from ratios based upon experience from past projects of similar type. To arrive at the total project cost, the following items must be added: start-up, land, supervision and overhead, escalation, adjustment for labor productivity, building, and site development, if applicable. In some cases, it's not possible to use factors for offsite facilities. A more detailed estimate will be necessary.

The accuracy of this type of estimate depends upon the definition of scope and the time allotted to its preparation and is most probably between -15% to +20%.

5.2 Cost Information, Assumptions, and Issues

Price quotes for the analytical equipment were obtained from established vendors in the emissions measurement equipment market and by contacting a consultant who performed a similar and recent study near the Arizona-Mexico border. Installed costs were either included with equipment cost (based on previous study), or a dollar value for labor cost is provided separately for equipment installation.

5.2.1 Operation and Maintenance Costs

Capital equipment for an HDRS emissions measurement system must be installed, commissioned, and maintained to ensure the quality of the data that is captured and integrity of the operating system. Each of the HDRS emissions measurement systems that are proposed require a trained technician to operate. Each system will require more labor the first year of installation and commissioning.

Outside of the installation and commissioning stage, ongoing operations for an HDRS Emissions Measurement System will require the knowledge and skill of experienced employee(s) or contractor(s). At this time, due to the limitations of staff with the specialized skills and experience within ADOT, and the limited activity at the border by ADEQ personnel, a contractor may be the most likely choice to fill this position. For each alternative considered, a contract labor rate of $75.00 per hour per full-time-equivalent (FTE) is assumed.

Each system will also require electricity, phone or other data communications medium, calibration gases, travel related expenses, and other expenses such as stationery and office supplies to maintain operations.

5.2.2 Cost for Roadway Steel Structure

Two renderings of a proposed design for the pole barn or roadway ramada are provided in Appendix 2. The Orlando Ramada has a gable roof (two-sided). The Mesa Ramada has a hip roof (four-sided). Either structure can be used for the installation. However, the Mesa Ramada appears to provide additional depth in the roof section by raising the height that equipment can be mounted from. This design also provides for better venting of the diesel exhaust through the center and top of the roof.

The Mesa Ramada is about 20% more expensive to construct than the Orlando Ramada.

5.3 Data Plan Cost Estimates

Stated earlier, a conceptual cost estimate is required for this research study. However, numerous elements of the data gathering process for the development of a cost estimate are more reflective of the “study estimate” defined in Section 5.1. Price quotes were obtained from equipment vendors. A former contractor for an ADEQ emissions study was consulted, and ADEQ’s emissions monitoring unit staff were consulted for input in developing the cost estimates.

5.3.1 Basic HDRS Emissions Measurement System Cost Estimate

The cost estimate for the Basic HDRS Emissions Measurement System is based on the use of an AccuScan™ 4000 at the Nogales-Mariposa LPOE. This option proposes to test all heavy duty diesel vehicles (HDDV) that cross the border five (5) days per week for 50 weeks per year with a fixed RSD installation or station. It is proposed that the emissions measurement system and monitoring station be placed near the exit of the Commercial Road for the proposed expansion layout of the Nogales-Mariposa LPOE (Figure 3).

One spare RSD will be maintained at the site to maximize the up-time of the monitoring station. This option assumes one contracted full-time equivalent (FTE) will work an 8-hour day five days per week for 50 weeks each year. One-half FTE from ADEQ is recommended to ensure that the department has familiarity with the equipment, site operations and issues, and regularly reviews the data and other information collected as a part of the State of Arizona’s monitoring network. It is also assumed that the maximum level of effort in labor hours will be required by ADEQ and contract personnel during the first year of installation, start-up, and operation of all proposed monitoring systems.

Operations and maintenance (O&M) costs were developed based on similar activities for the Cross Border In-Use Emissions Study for Heavy Duty Vehicles, Nogales, Arizona[24] and operating costs reported by ADEQ staff for air quality monitoring stations. Assumptions related to the development of the O&M costs are provided as follows:

- Contract Labor: One contractor at 2,080 hours per year for Year 1 is assumed. For Years 2 through 5, it is assumed that the contractor will utilize 80% of the hours in Year 1. An escalation factor of 3.5% was added to the contract labor for Years 3 through 5.

- Contractor Expenses: $30,000 for Year 1, 80% of the cost for Year 2, and a cost escalation factor of 3.0% for Years 3 through 5.

- Electricity and telephone: $1,200 or $100 per month in Year 1, and a 3% cost escalation factor for Years 2 through 5.

- Miscellaneous/Incidental Costs: $1,000 for Years 1 and 2, a 10% escalation in cost or $1,100 for Years 3 and 4, and a 20% escalation in cost for Year 5 or $1,200.

The total costs for the Basic HDRS Emissions Measurement System are estimated at $1,389,254. Data for the cost estimate is provided in Table A-2.

5.3.2 Intermediate HDRS Emissions Measurement System Cost Estimate

The cost estimate for the Intermediate HDRS Emissions Measurement System is based on the use of an AccuScan™ 4000 RSD at the Nogales-Mariposa LPOE. The operations for the intermediate system are very similar to the basic system, except that two additional pieces of equipment have been added to the monitoring station: a PM_{10} monitor and an aethalometer. A cost estimate for the Intermediate HDRS Emissions Measurement System was prepared and is provided in Table A-3. Total costs for the intermediate system are estimated at $1,804,017. The annual contracted labor is projected to increase from 1.0 to 1.2 FTE. Similar assumptions used in the basic system were used to project O&M costs for the intermediate system.

5.3.3 Fully-Integrated HDRS Emissions Measurement System Cost Estimate

This alternative proposes to test all HDDVs five days per week for 50 weeks per year. A roadway ramada (or pole barn) is included with this option and will be used to mount monitoring equipment from the roof of the structure. This system also includes several portable structures: an equipment shelter, a portable equipment unit for mobile monitoring, and an office building for personnel.

The system design proposes the use of two fixed RSDs, one as a spare unit, installed to enhance capture and characterization of each passing vehicle. More than likely this equipment will be mounted from the roof of the pole barn. A PM_{10} monitor and a fixed aethalameter will also be included in the equipment inventory. With the increase in equipment, an additional data-logger has been added as a backup and to ensure data capture for all emissions that will be measured.

The fully-integrated system includes the use of one mobile unit for part-time use at remote locations. The mobile unit will include an RSD, a portable aethalometer, a NO_X analyzer and an SO_2 analyzer. The addition of an office building has also been done to assist the onsite workers in completing their data gathering and analysis, record keeping, and communication tasks.

This option assumes the use of 1.5 contract FTEs working eight hours per day, five days per week for 50 weeks per year. As expected, with more equipment and personnel, the fully-integrated monitoring station is the most costly of the three proposed HDRS data collection systems. A cost estimate for the Fully-Integrated HDRS Emissions Measurement System was prepared and is provided in Table A-4. Total costs for the intermediate system are estimated at $2,280,025.

5.4 Present Worth Costs

The total cost for each alternative – the present capital equipment costs and projected annual O&M costs for Years 1 through 5 – was provided in Section 5.3. The present worth of the total cost was developed for each alternative and is provided in Table 5. The present worth reflects the equivalent value of each alternative in today's dollars. An interest rate of 3% is assumed.

Table 5: HDRS Emissions Measurement Systems – Present Worth Cost

HDRS Emissions Measurement System	Capital Cost and O&M Costs (Years 1 to 5)	Present Worth
Basic System	$1,389,254.00	$1,320,828.00
Intermediate System	$1,804,017.00	$1,699,646.00
Fully-Integrated System	$2,280,025.00	$2,177,467.00

As expected, the present worth cost for each HDRS emissions measurement alternative is less than the projected total cost

5.5 Future Cost Projections

A cost estimate has been developed for the three alternative systems. However, it is beyond the scope of work for this research study to identify specific future costs for a yet to be determined program date. It is not known if the project will be funded, and if so when. In the event that ADOT decides to fund this program, the actual installation and operation may occur one, two, five or more years into the future.

Some basic assumptions were made in developing future cost projections for each HDRS emissions measurement system for one-, two-, and five-years out from Calendar Year 2008. Table 6 shows the impact of the cost of capital over time.

Table 6: HDRS Emissions Measurement Systems – Future Cost Projections

HDRS Emissions Measurement System	Present Worth (2008)	1-Year (2009)	2 Years (2010)	Five Years (2013)
Basic System				
Equipment	$564,808.00	$564,808.00	$564,808.00	$649,529.00
O&M Costs	756,020.00	782,481.00	809,868.00	897,515.00
Total	$1,320,828.00	$1,347,289.00	$1,374676.00	$1,547,044.00
Intermediate System				
Equipment	$613,008.00	$613,008.00	$613,008.00	$704,959.00
O&M Costs	1,086,638.00	1,124,670.00	1,164,034.00	1,290,585.00
Total	$1,699,646.00	$1,737678.00	$1,777,042.00	$1,995,544.00
Fully-Integrated System				
Equipment	$1,044,524.00	$1,042,524.00	$1,042,524.00	$1,198,903.00
O&M Costs	1,132,943.00	1,172,596.00	1,213,637.00	1,345,581.00
Total	$2,177,467.00	$2,215,117.00	$2,256,161.00	$2,544,484.00

The following assumptions were made in developing the future cost projections:

Years 1 & 2 - no change in equipment cost
- a cost escalation factor of 3.5% was added to O&M costs

Year 5: - an escalation factor of 15% was added to equipment cost
- an escalation factor of 3.5% was added to O&M costs

Historically, cost for analytical equipment does not vary from year to year. In many cases, these costs may decrease as current technology ages or new technology is introduced. The general assumptions in projecting future costs for the proposed alternatives is that the current technology will be the same two years from now; however, equipment upgrades are expected beyond that time. Labor and utility costs are expected to rise annually. A level of uncertainty always exists in projecting future costs since the future is not here yet.

5.6 Alternate Cost Analysis - Employee Labor

At the request of the TAC, the research team developed a similar cost analysis using internal employees in place of contractors to operate and maintain each of the three HDRS systems proposed in Sections 6.3 to 6.5. An administrator of ADEQ was contacted to identify a projected salary for a highly skilled FTE that would be capable of operating the sophisticated remote sensing equipment along with the other monitors and computer systems. A projected annual salary of $90,000 was quoted, which includes employee benefits, and is based on the 2008 calendar year.[25]

5.6.1 Alternate Cost Analysis - Basic HDRS Emissions Measurement System

The alternate cost estimate for the Basic HDRS Emissions Measurement System proposes the same equipment and operating schedule as in Section 6.3.1. One FTE will be used to operate and maintain the monitoring station, with an assumed work schedule of 8-hour day, five (5) days per week for 50 weeks each year. The FTE may be an employee of ADOT or ADEQ. Some oversight by ADEQ is recommended to ensure that the department has familiarity with the equipment, site operations and issues, and regularly reviews the data and other information collected as a part of the State of Arizona's monitoring network.

O&M costs were developed based on similar activities for the Cross Border In-Use Emissions Study for Heavy Duty Vehicles, Nogales, Arizona[24] and operating costs reported by ADEQ staff for air quality monitoring stations. Assumptions related to the development of the O&M costs are provided:

- Employee Labor: One FTE at $90,000 per year for Year 1 is assumed. For Years 2 through 5, a 4% escalation factor is added for labor costs.

- Contractor Expenses, Electricity and Phone, and Miscellaneous/Incidental Costs: no changes are projected for these expenses.

The total costs for the Basic HDRS Emissions Measurement System utilizing in-house employees are $1,194,198.

5.6.2 Alternate Cost Analysis - Intermediate HDRS Emissions Measurement System

The alternate cost estimate for the Intermediate HDRS Emissions Measurement System is $1,363,176 using internal employees. The annual labor is projected to increase from 1.0 to 1.2 FTE. Similar assumptions for O&M costs that are defined in the basic system are applied to the intermediate system.

5.6.3 Alternate Cost Analysis - Fully-Integrated HDRS Emissions Measurement System

This alternative proposes to test all HDDVs crossing the border five days per week for 50 weeks per year. All equipment identified in Section 5.3 is included in this cost analysis.

This option assumes the use of 1.5 FTEs working eight hours per day, five days per week for 50 weeks per year. Total costs for the intermediate system are estimated at $2,004,296.

5.7 Alternate Cost Analysis - Present Worth

The total cost for each HDRS system – the present capital equipment costs and projected annual O&M costs utilizing employees of ADOT, ADEQ, or a combination of the two agencies for Years 1 through 5 – was provided in Section 5.6. The present worth of the total cost was developed for each system and is provided in Table 7. The present worth reflects the equivalent value of each alternative in 2008 dollars. An interest rate of 3% is assumed.

Table 7: HDRS Emissions Measurement Systems
Alternate Cost Analysis - Present Worth

HDRS Emissions Measurement System	Capital Cost and O&M Costs (Years 1 to 5)	Present Worth
Basic System	$1,194,198.00	$1,140,349.00
Intermediate System	$1,363,176.00	$1,298,892.00
Fully-Integrated System	$2,004,296.00	$1,923,247.00

As expected, the present worth costs for each HDRS emissions system is less than the total costs for capital equipment and O&M costs for Years 1 to 5.

Also, utilizing employees of the agency to perform some of the installation and all of the O&M labor lowers the costs for each proposed HDRS system.

5.8 Alternate Cost Analysis - Future Projections

An alternate cost analysis was also performed to project the future cost, or the cost of waiting, for each HDRS emissions measurement system for one-, two-, and five-years out from Calendar Year 2008. Table 8 shows the impact of the cost of capital over time.

Table 8: HDRS Emissions Measurement Systems
Alternate Cost Analysis – Future Projections

HDRS Emissions Measurement System	Present Worth (2008)	1-Year (2009)	2 Years (2010)	Five Years (2013)
Basic System				
Equipment	$564,308.00	$564,308.00	$564,308.00	$648,954.00
O&M Costs	576,041.00	596,203.00	617,070.00	684,156.00
Total	$1,140,349.00	$1,160,511.00	$1,181,378.00	$1,333,110.00
Intermediate System				
Equipment	$611,308.00	$611,308.00	$611,308.00	$703,004.00
O&M Costs	687,584.00	711,650.00	736,557.00	816,634.00
Total	$1,298,892.00	$1,322,958.00	$1,347,865.00	$1,519,638.00
Fully-Integrated System				
Equipment	$1,056,524.00	$1,056,524.00	$1,056,524.00	$1,215,003.00
O&M Costs	866,723.00	897,058.00	928,455.00	1,029,395.00
Total	$1,923,247.00	$1,953,582.00	$1,984,979.00	$2,244,398.00

The same assumptions that are used in Section 5.5 apply here.

Section 6

Conclusions and Recommendations

Research of HDRS emissions measurement equipment and technology was undertaken to develop a design and cost estimate for an emissions monitoring station at an Arizona LPOE. Field tests of HDRS emissions measurement equipment and data were reviewed and cost data were requested from several equipment vendors. ADEQ staff and consultants were also contacted for cost data and other information.

6.1 Conclusions

Emissions measurement systems and programs for light-duty vehicles are well defined in the literature and demonstrated within the Arizona, nationally and globally. Most of these systems rely on an I&M program that is tied to a vehicle registration program. In the U.S., most states use the SAE J1667 snap-acceleration test to measure gaseous pollutants and opacity. A cup-like device is used to capture emissions from the vehicle's exhaust prior to screening by equipment.

Unlike I&M programs, remote sensing is the measurement or acquisition of information about an object by a recording device that is not in contact with the object. An RSD can be designed to estimate emissions from heavy duty vehicles. As an example, the HDRS technology used for the Nogales, AZ border study utilized both ultraviolet and infrared light beams to instantaneously measure HC, CO, NO_X, and $PM_{2.5}$ from heavy duty truck exhaust. Although HDRS emissions measurement is not used on a large scale, the technology has been around for about 15 years and its efficiency continues to improve.

HDRSD is still an emerging technology although significant advances have been made over the last 10 years. HDRSD technology has performed well as an emissions screening tool, but has not been used as a primary emissions program. Identifying deployment and set-up strategies for varying truck traffic continues to be a challenge. One such challenge is the varying height and location of the exhaust muffler on many heavy duty diesel trucks.

The review of the literature identified numerous vendors of emissions measuring equipment in the market place. However, when the criteria is narrowed to vendors providing remote sensing equipment, especially instruments designed to measure emissions from heavy duty diesel engines, the field is narrowed to a handful of suppliers. Three alternatives were developed for a HDRS emissions measurement system data plan:

- *Basic*: this is a bare-bones monitoring system that includes HDRS emissions measurement equipment with data collection and communication.

- *Intermediate:* this system builds on the basic system by including particulate monitoring equipment and an aethalometer to measure diesel particulates.

– *Fully-integrated*: this system is the most robust of the alternatives and provides for a stationary monitoring system (proposed in the basic and intermediate set-up) as well as a portable monitoring unit.

Cost data were developed for each alternative and includes figures for capital equipment installation and five years of O&M expenses. The present worth costs for each data plan utilizing contract labor ranged from $1,320,828 to $2,177,467. If employees of ADOT or ADEQ are used, the present worth costs range between $1,140,349.00 and $1,923,247. While it is obvious that the use of employees is less expensive than contract labor, the agency could find it difficult to attract highly skilled employees for a proposed HDRS emissions measurement program at the Arizona-Mexico border.

ADOT has not stated that it will install an HDRS emissions monitoring station at an Arizona LPOE. However, traffic has increased at the border for all vehicle types: POVs, buses, and large trucks. The increase in border crossings over the years along with the need for more secure border stations has prompted the federal GSA to approve a modernization and renovation construction project for the Nogales-Mariposa LPOE. Bids are being solicited for the construction project, estimated at $100 to $150 million. Construction is expected to begin in 2009.

6.2 Recommendations

6.2.1 Partner with ADEQ

ADOT can partner with ADEQ to determine if an HDDV monitoring program is warranted at the border at this time. ADEQ has an established air quality monitoring program throughout the state and has trained staff, equipment, and facilities to support the program. Also ADEQ may have planned or mandated needs to measure air quality at or near the U.S.-Mexico border as a part of the State Implementation Plan (SIP). A partnership between the two agencies will provide for coordinated work efforts, possibly shared costs for equipment and staffing, and better use of resources within each agency. ADEQ, or ADEQ and ADOT jointly, may be eligible for grant funding to establish a new monitoring program at the Arizona border.

More than likely truck traffic across all U.S-Mexico LPOEs will increase. In February 2007, the Secretary of the U.S. DOT announced the beginning of a cross-border trucking pilot program between the United States and Mexico. Since 1982, Mexican trucks have been restricted to the border commercial zones in California, Arizona, New Mexico, and Texas.[26] The new cross-border pilot program has been vocally opposed by a number of groups, however as of this report’s date, the program is still in-place. Increased traffic at the LPOEs will lead to increased pollution.

ADEQ is responsible for the state’s motor vehicle I&M program. Adding a vehicle emissions monitoring station at the border, other than as a pilot program for clean screening, would need to adhere to the existing regulations, policies and procedures that are in-place. Utilizing an HDRS emissions measurement system as a gross emitter screening program may also be an effective control strategy although the current program is based on Arizona license plates only.

6.2.2. Implement Screening Program

Due to current limitations with the emerging HDRSD technology, ADOT may consider pursuing an emissions screening program for heavy duty diesel trucks at one of its LPOEs. The proposed screening program may operate during the peak season (October to May) when truck traffic is at its maximum. In this way, enough trucks are screened, but not all trucks are screened. Continued screening and testing of HDRSD technology and equipment by ADOT, ADEQ, and other organizations will eventually resolve many of the current challenges associated with the deployment and set-up strategies for varying truck traffic. Improved emissions measurement is certainly expected to be one objective of an HDRSD program.

6.2.2 Seek Program Funding.

The results of the research show that installing an HDRS emissions measurement system at the border is not an inexpensive project. As stated earlier, grant funding may be available to install and operate a HDDV clean screen program. The Arizona Legislature may also be petitioned as a funding source for a project of this type.

A vehicle entering the U.S. through an LPOE is assessed a duty or fee. Table A-5 (Appendix 4) provides a list of current fees at all U.S. border facilities. ADOT should investigate the option of assessing a fee on HDDVs entering the LPOE, or adding a surcharge on gross emitting vehicles that enter the U.S.

References

1. M.J. Bradley & Associate. *A Menu of Options: Controlling Fine Particulate Matter under the Clean Air Act*. STAPPA/ALAPCO, March 2006.

2. United States. Environmental Protection Agency. Office of Transportation and Air Quality. *Regulatory Announcement: Heavy Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements*. EPA420-F-00-057. Washington, D.C. , December 2000.

3. GovTrack.us. H.R. 5314 / S 2842--108th Congress (2004): Clean Trucks Act of 2004, *GovTrack.us (database of federal legislation)* <http://www.govtrack.us/congress/bill.xpd?bill=h108-5314&tab=related> (accessed Sep 29, 2008)

4. United States. Environmental Protection Agency. Office of Transportation and Air Quality. V*oluntary Diesel Retrofit Program.* www.epa.gov/otaq/retrofit/retroverifiedlist.htm. Last viewed March 11, 2007.

5. United States. Environmental Protection Agency. "1970-2002 Average Annual Emissions, All Criteria Pollutants," *National Emissions Inventory (NEI) Air Pollutant Emissions Trends Data*, July 2005. www.epa.gov/ttn/chief/trends/index.html, last viewed march 11, 2007.

6. Cross, Thomas, "Remote Sensing Technology" presented at the Better Air Quality Motor Vehicle Control & Technology Workshop, 2000.

7. The Good Neighbor Environmental Board. *Ninth Report to the Good Neighbor Environmental Board to the President and Congress of the United States*.Washington, D.C., March 2006.

8. School of Law website, Duke University – on NAFTA. http://www.law.duke.edu/lib/researchguides/nafta.html, last viewed March 11, 2007.

9. California Air Resources Board.). *Air Quality Concerns Relating to the North American Free Trade Agreement (NAFTA) and Free Commercial Vehicle Travel in California – Report to the California Legislature*. Sacramento, Calif., January 2006.

10. *NAFTA/Mexican Truck Emission Overview*. Sacramento, California., November 12, 2004, Revised January 21, 2005.

11. Gardner, Michael. "A surge in smog over the long haul: Coming influx of Mexican trucks 'serious.'" *The San Diego Union-Tribune*, March 15, 2006.

12. Phone conversation with staff member at the Air Quality Bureau, New Mexico Environmental Department, February 2007.

13. Phone conversation with staff member at the Texas Commission on Environment, February 2007..

14. Phone conversation with staff member at the El Paso Metropolitan Planning Authority, February 2007.

15. United States. Environmental Protection Agency/ Mexico. Secretaría de Medio Ambiente y Recursos Naturales. *Advancing US-Mexico Border 2012 Air Policy Forum Priorities*. October 7, 2005.

16. Stedman, Donald, H., "*On-Road Remote Sensing of CO and HC Emissions in California",* University of Denver, Feb 1994.

17. Kazimi, Camilla; Felipe Cuamea, Juan Alvarez, Alan Sweedler, and Matt Fertig, *"Emissions from Heavy-Duty Trucks at the San Diego – Tijuana Border Crossing",* San Diego State University, Universidad Autonoma de Baja California, 1997.

18. Morris, Jerome, et. al, *"On-Road Remote Sensing of Heavy-duty Truck Emissions in the Austin-San Marcos Area"*, University of Denver, August 1998.

19. Santa Barbara Research Center, *"Smog Sensor Detects Pollution-Prone Cars",* Journal of Air & Waste Management Association (AWMA), April 1999.

20. General Services Administration, Public Buildings Service, Property Development Division *Pre-solicitation Notice, November 14, 2007*. San Francisco, Calif., 2007.

21. AZTEC Engineering Arizona. *Nogales Mariposa U.S. Port of Entry: Draft Environmental Assessment, Nogales, AZ*. United States. Government Services Agency, September 27, 2007.

22. Meeting with Jim Fraser of Arcadis, January 17, 2007, in Tucson, Arizona.

23. Industrial Cost Engineering, "Process Cost Estimating", www.costestimating.com, last viewed March 11, 2007.

24. Vescio, Nirajan, et. al., "*Heavy-Duty Remote Sensing Demonstration Project in Nogales: Cross Border In-Use Emissions Study for Heavy Duty Vehicles, Nogales, AZ."* prepared for ADEQ and USEPA, Final Report, June 2006.

25. Conversation with Ira Domsky, Deputy Director, Arizona Department of Environmental Quality, March 19, 2008.

26. U.S. DOT News Release. *Cross Border Truck Safety Inspection Program*. Remarks by the Honorable Mary E. Peters, Secretary of Transportation, El Paso, TX, February 23, 2007.

27. United States Customs and Border Protection, http://www.cbp.gov, last viewed March 11, 2007.

Appendix 1

Southern Border LPOE Traffic Data

Table A-1: United States – Mexico Vehicle Border Crossings, FY 2005 to FY2007

Locations		FY2007	FY2007	FY2007	FY2006	FY2006	FY2006	FY2005	FY2005	FY2005
Port	Code	Trucks	Buses	POVs	Trucks	Buses	POVs	Trucks	Buses	POVs
Brownsville, TX	2301	236,134	8,537	6,581,484	246,124	9,207	7,000,796	231,120	8,925	7,141,808
Del Rio, TX	2302	63,389	2,565	1,648,302	67,064	1,127	1,777,903	62,514	1,954	1,827,314
Eagle Pass, TX	2303	99,177	1,319	3,315,044	96,819	1,030	3,642,679	98,497	974	3,664,343
Hidalgo, TX	2305	475,864	29,143	6,761,389	471,224	26,391	6,525,633	479,727	30,374	7,103,550
Laredo, TX	2304	1,554,296	36,530	5,589,525	1,526,623	36,991	6,160,256	1,409,834	35,906	6,313,562
Progreso, TX	2309	38,521	316	995,068	30,390	316	1,013,621	23,322	281	1,015,962
Rio Grande City, TX	2307	35,555		607,971	45,812	7	637,186	45,435		673,893
Roma, TX	2310	7,380	840	997,078	8,549	1,177	1,188,947	8,417	1,804	1,211,365
El Paso, TX	2402	758,764	17,196	14,280,491	773,265	28,670	15,837,947	725,340	15,723	15,788,048
Fabens, TX	2404			307,570			591,723			640,784
Presidio, TX	2403	7,414	316	714,554	6,616	1,273	736,218	5,868	488	717,395
Columbus, NM	2406	5,778	2,859	395,085	5,250	1,983	374,665	4,282	1,102	359,780
Santa Teresa, NM	2408	34,398	187	387,765	36,950	114	296,645	33,166	122	243,692
Douglas, AZ	2601	27,585	2,593	1,803,880	27,845	3,206	2,181,807	28,959	3,998	2,120,370
Lukeville, AZ	2602	533	1,805	451,055	752	3,703	426,248	965	151	401,032
Naco, AZ	2603	4,711	162	338,164	3,997	202	317,717	4,513	499	316,661

Table A-1: United States – Mexico Vehicle Border Crossings, FY 2005 to FY2007

Locations		FY2007	FY2007	FY2007	FY2006	FY2006	FY2006	FY2005	FY2005	FY2005
Port	**Code**	**Trucks**	**Buses**	**POVs**	**Trucks**	**Buses**	**POVs**	**Trucks**	**Buses**	**POVs**
Nogales, AZ	2604	291,429	12,278	3,191,496	288,144	10,789	3,296,351	261,210	8,606	3,477,290
San Luis, AZ	2608	43,869	59	2,484,563	46,184	88	2,859,449	45,183	100	3,671,205
Sasabe, AZ	2606	309		33,349	408		35,799	544		39,105
San Ysidro, CA	2504		99,259	16,075,613		99,057	17,073,761		105,701	16,961,998
Otay Mesa, CA	2506	733,163	46,444	4,788,045	745,974	41,650	6,000,699	727,245	38,957	6,822,796
Tecate, CA	2505	80,247	212	883,972	72,617	366	998,649	66,606	332	1,030,014
Andrade, CA	2502	561	7	561,072	1,777	14	680,312	2,711	13	736,172
Calexico, CA	2503		1,078	5,993,119		2,130	5,902,308		1,817	6,202,717
Calexico East, CA	2507	317,588	1,277	3,465,594	311,008	1,188	3,812,842	322,464	311	3,157,102

Source: Department of Homeland Security, Customs and Border Protection, Operations Management Report (OMR) System, December 12, 2007

LPOE – land port of entry

POV – privately owned vehicles

Appendix 2

Roadway Steel Structure Design Options

Figure A-1: Roadway Steel Structure – Orlando Design

Appendix 2

Roadway Steel Structure Design Options

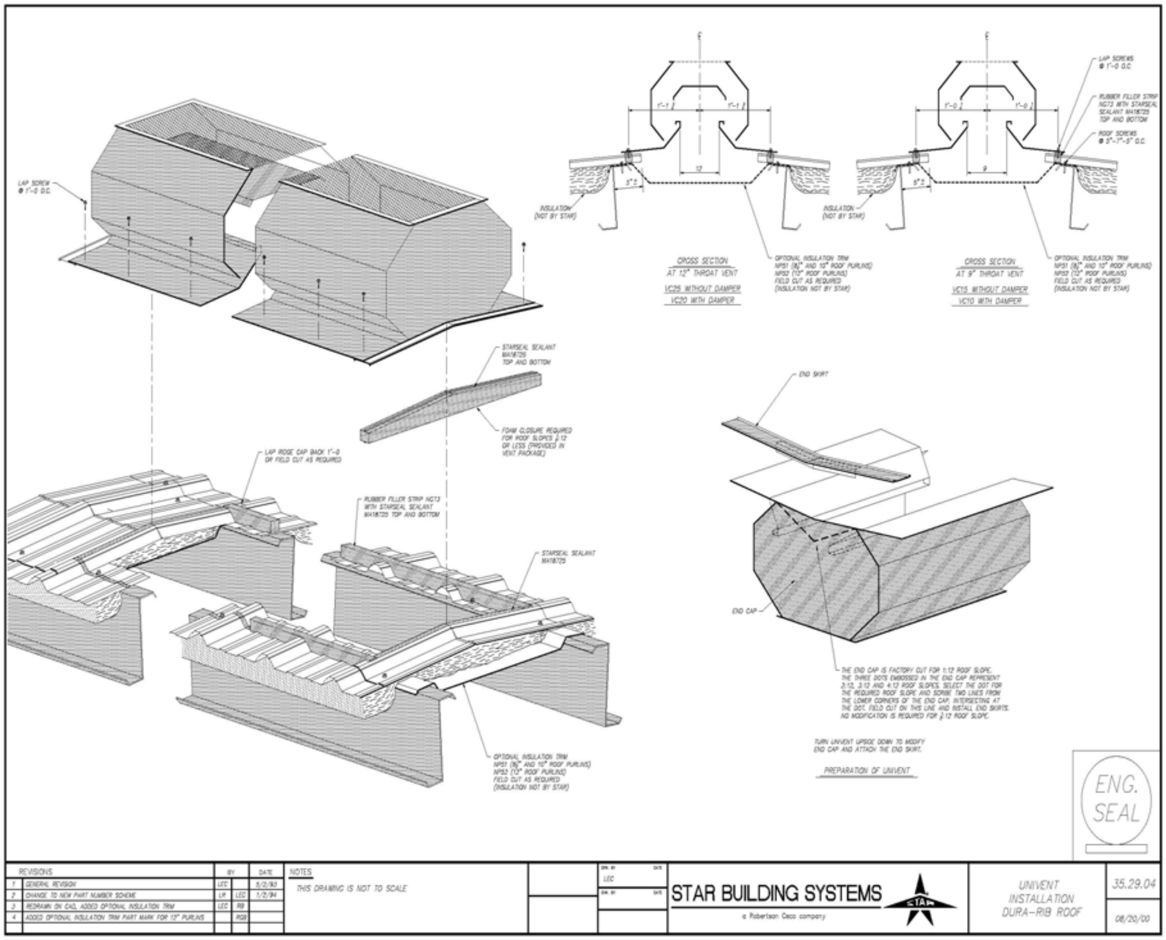

Figure A-2: Roadway Steel Structure – Mesa Ridge Vent Design

Appendix 3

Cost Data Sheets

Table A-2: Basic HDRS Emissions Measurement System Cost Estimate

Equipment	No	Equip. Cost	Labor Cost	Installed Cost	Annual Operating Costs					
					Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs
I-A. Capital Equipment Costs										
Remote Sensing Devices (RSD) and Engineering[a]	2			$501,536.00						$501,536.00
Includes Tower	1									
Includes Receiver	1									
Includes Computer	1									
Basic Equipment Shelter	1			$55,272.00						$55,272.00
Data Logger	1			$8,000.00						$8,000.00
Total Capital Costs				***$564,808.00***						**$564,808.00**
I-B. O&M Cost	FTE									
Contract Labor	1.0				$156,000.00	$124,800.00	$129,168.00	$133,688.88	$138,367.99	$682,024.87
Contractor expenses (travel, calibration gases, etc.)					$30,000.00	$24,000.00	$24,720.00	$25,461.60	$26,225.45	$130,407.05
In-Kind Labor (ADEQ Staff)	0.5				$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Electricity and Phone (~$100.00/mo)					$1,200.00	$1,236.00	$1,273.08	$1,311.27	$1,593.49	$6,613.84
Misc./Incidental Costs					$1,000.00	$1,000.00	$1,100.00	$1,100.00	$1,200.00	$5,400.00
Total O&M Costs					$188,200.00	$151,036.00	$156,261.08	$161,561.75	$167,386.93	**$824,445.76**
				Total Costs (Capital & O&M)						**$1,389,253.76**

[a] Includes one operating RSD and one spare

Table A-3: Intermediate HDRS Emissions Measurement System Cost Estimate

Equipment	No	Equip. Cost	Labor Cost	Installed Cost	Annual Operating Costs					
					Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs
II-A. Capital Equipment Costs										
Remote Sensing Devices (RSD) and Engineering[a]	2			$501,536.00						$501,536.00
Includes Tower										
Includes Receiver										
Includes Computer										
Other Equipment:										
PM_{10} Particulate Monitor	1	$21,000.00	$600.00	$21,600.00						$21,600.00
Aethalometer	1	$26,000.00	$600.00	$26,600.00						$26,600.00
Basic Equipment Shelter	1			$55,272.00						$55,272.00
Data Logger	1			$8,000.00						$8,000.00
Total Capital Costs				***$613,008.00***						**$613,008.00**
II-B. O&M Cost										
	FTE									
Contract Labor	1.2				$187,200.00	$149,760.00	$229,048.02	$229,048.02	$229,048.02	$1,024,104.05
Contractor expenses (travel, calibration gases, etc.)					$35,000.00	$28,000.00	$28,840.00	$29,705.20	$30,596.36	$152,141.56
Labor - In-Kind ADEQ Staff	0.5				$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Electricity and Phone (~$125/mo)					$1,500.00	$1,545.00	$1,591.35	$1,639.09	$1,688.26	$7,963.70
Misc./Incidental Costs					$1,200.00	$1,200.00	$1,400.00	$1,400.00	$1,600.00	$6,800.00
Total O&M Costs					$224,900.00	$180,505.00	$260,879.37	$261,792.31	$262,932.64	**$1,191,009.31**
Total Costs (Capital & O&M)										**$1,804,017.31**

[a] Includes one operating RSD and one spare

Table A-4: Fully-Integrated HDRS Emissions Measurement System Cost Estimate

Equipment	No	Equip. Cost	Labor Cost	Installed Cost	Annual Operating Costs					
					Year 1	Year 2	Year 3	Year 4	Year 5	Total Costs
III-A. Capital Equipment Cost										
Remote Sensing Devices										
(RSD) and engineering[b]	3			$688,935.00						$688,935.00
Tower	0									
Receiver	1									
Computer	2									
Other Equipment:										
PM_{10} Particulate Monitor	1	$21,000.00	$600.00							$21,600.00
Aethalometer[c]	2	$46,000.00	$600.00							$46,600.00
NO_X Analyzer	1	$11,225.00	$400.00							$11,625.00
SO_2 Analyzer	1	$10,500.00	$400.00							$10,900.00
Pole Barn (roadway canopy)	1			$60,000.00						$60,000.00
Foundation & Anchor Bolts				$10,000.00						$10,000.00
Equipment Shelter	1			$55,272.00						$55,272.00
Portable Equipment Unit	1			$73,592.00						$73,592.00
Office Building (shelter)	1			$50,000.00						$50,000.00
Data Logger	2			$16,000.00						$16,000.00
Total Capital Costs										**$1,044,524.00**
III-B. O&M Cost	FTE									
Contract Labor	1.5				$234,900.00	$187,920.00	$186,458.06	$201,304.60	$208,350.26	$1,018,932.92
Contractor expenses (travel, calibration gases, etc.)					$45,000.00	$36,000.00	$37,080.00	$38,192.40	$39,913.84	$196,186.24
Labor, In-kind ADEQ Staff	0.5				$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Electricity & Phone					$2,100.00	$2,163.00	$2,227.89	$2,294.73	$2,363.57	$11,149.19
Other Utilities					$25.00	$25.75	$26.52	$27.32	$28.14	$132.73
Misc./Incidental Costs					$1,600.00	$1,600.00	$1,900.00	$1,900.00	$2,100.00	$9,100.00
Total O&M Costs					$283,625.00	$227,708.75	$227,692.47	$243,719.05	$252,755.81	**$1,235,501.08**
Total Costs (Capital & O&M)										**$2,280,025.08**

[b]Includes 2 operating RSDs and 1 spare

[c]Fixed and portable Aethalometer analyzers for measuring diesel carbon

Appendix 4

U.S. Custom and Border Patrol Fee Schedule

Table A-5: Summary of New Fee Rates[27]

CUSTOMS DUTIES	Old Fee Rates Prior to April 1, 2007 (Unit Fee/Annual Cap)	New Fee Rates On/After April 1, 2007 (Unit Fee/Annual Cap)
Commercial Vessels	$397.00/$5,955	$437.00/$5,955
Commercial Trucks	$5.00/$100.00	$5.50/$100.00
Railroad Cars	$7.50/$100.00	$8.25/$100.00
Private Aircraft (Decal)	$25.00	$27.50
Private Vessel (Decal)	$25.00	$27.50
Commercial Aircraft Passenger (User Fee)	$5.00	$5.50
Commercial Vessel Passenger (User Fee-Non Exempt)	$5.00	$5.50
Commercial Vessel Passenger	$1.75	$1.93
Dutiable Mail	$5.00	$5.50
Broker Permit	$125.00	$138.00
Barges and other bulk carriers	$100.00/$1,500	$110.00/$1,500

Reference: United States Customs and Border Protection