Juneau Access Improvements Project
Final Supplemental Environmental Impact Statement

2017 Update to Appendix T
Air Quality Modeling Memorandum

Prepared for:

Alaska Department of Transportation
& Public Facilities
6860 Glacier Highway
Juneau, Alaska 99801-7999

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Federal Project Number: STP-000S(131)

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Acronyms and Abbreviations

AADT	annual average daily traffic
ACF	Alaska Class Ferry
AMHS	Alaska Marine Highway System
CO	carbon monoxide
DEIS	Draft Environmental Impact Statement
DOT&PF	Alaska Department of Transportation and Public Facilities
EIS	Environmental Impact Statement
FEIS	Final Environmental Impact Statement
FHWA	Federal Highway Administration
FVF	Fast Vehicle Ferry
JAI	Juneau Access Improvements
$\mu g/m^3$	micrograms per cubic meter
MSAT	Mobile Source Air Toxic
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NHS	National Highway System
NO_2	nitrogen dioxide
PM	particulate matter
$PM_{2.5}$	particulate matter with aerodynamic diameter equal to or less than 2.5 microns
PM_{10}	particulate matter with aerodynamic diameter equal to or less than 10 microns
ppb	parts per billion
ppm	parts per million
PWADT	peak week average daily traffic
ROD	Record of Decision
SEIS	Supplemental Environmental Impact Statement
SO_2	sulfur dioxide
USACE	U. S. Army Corps of Engineers
vmt	vehicle miles traveled

1. Introduction

This report updates the 2004 *Air Quality Modeling Memorandum* that was prepared by the Alaska Department of Transportation and Public Facilities (DOT&PF) and presented as Appendix T of the 2005 Juneau Access Improvements (JAI) Project Supplemental Draft Environmental Impact Statement (DEIS). The 2004 report analyzed air quality impacts of Alternatives 2, 2A, 2B, 2C, 3, 4B, and 4D. Simplified microscale dispersion modeling was conducted to evaluate carbon monoxide (CO) emissions for all of the build alternatives and the No Action alternative. Marine vessel CO levels were not modeled, but were qualitatively evaluated. A qualitative evaluation was also conducted for particulate matter (PM_{10}) emissions produced under all of the reasonable alternatives.

During the development of the JAI Project 2006 Final EIS (FEIS), the Federal Highway Administration (FHWA) and DOT&PF responded to comments on the 2005 Supplemental Draft EIS, incorporated new data and further analysis for some resources, and incorporated additional mitigation measures to reduce impacts to wildlife and habitat. The FHWA and DOT&PF also made some changes to Alternative 2B and eliminated Alternatives 2, 2A, and 2C from consideration as reasonable alternatives. Many of these changes required updates to supporting technical reports, which DOT&PF prepared and compiled in Appendix W of the 2006 Final EIS. However, changes made after submission of the DEIS did not warrant an updating of the 2004 *Air Quality Modeling Memorandum* at that time.

Eleven years have passed since the 2006 FEIS and Record of Decision (ROD) were published, and the FHWA and DOT&PF recognized the need to update previous technical reports as part of the JAI Project Final Supplemental Environmental Impact Statement (SEIS). Updates were needed to reflect changes in regulations, new information related to the potentially affected environment or conditions, updated analysis, evaluation of the newly added Alternative 1B, and changes in the design or alignment for Alternatives 2B and 3. Three key components that affected changes to the design and alignment of Alternative 2B since the 2006 ROD are: changes during the U.S. Army Corps of Engineers (USACE) permitting process to further avoid and minimize impacts to wetlands and reduce the extent of rock sidecast areas, changes based on advanced geotechnical survey information, and recent changes in 2012 in response to updated bald eagle nest survey data. In addition, minor alignment shifts also were made to Alternative 3 in response to updated bald eagle nest survey data. Postponement of the anticipated project opening year, in addition to the introduction of a new alternative, warranted completion of an updated traffic study. This in turn required that air quality impacts be reassessed, taking into consideration updated traffic projections as well as changes made to air quality regulations.

Additional analysis was also conducted to address comments received from the public concerning ferry vessel emissions. This analysis is included as Attachment A of this memo.

Alterations to Alternatives 2B and 3 are minor and do not occur in areas with potential sensitive receptors; therefore, no new air quality evaluations are needed specifically to address these changes. This update to the 2004 *Air Quality Modeling Memorandum* provides a summary of the changes in the regulatory environment, a summary of the updated traffic forecasts, and a

qualitative evaluation of the validity of the previous air quality evaluations based on new regulations and new traffic forecasts.

As described in the 2004 *Air Quality Modeling Memorandum*, under any build alternative (i.e., Alternatives 2, 2A, 2B, 2C, 3, 4B, and 4D), the JAI Project would not have a noticeable impact on local air quality and no mitigation measures were necessary.

1.1 Project Description

As required by the National Environmental Policy Act (NEPA), this technical report considers the following reasonable alternatives.

1.1.1 Alternative 1 – No Action

The No Action Alternative (Alternative 1) includes a continuation of mainline ferry service in Lynn Canal and incorporates two Day Boat Alaska Class Ferries (ACFs). The Alaska Marine Highway System (AMHS) would continue to be the National Highway System (NHS) route from Juneau to Haines and Skagway, and no new roads or ferry terminals would be built. In addition to the Day Boat ACFs, programmed improvements include improved vehicle and passenger staging areas at the Auke Bay and Haines ferry terminals to optimize traffic flow on and off the Day Boat ACFs as well as expansion of the Haines Ferry Terminal to include a new double bow berth to accommodate the Day Boat ACFs. This alternative is based on the most likely AMHS operations in the absence of any capital improvements specific to the JAI Project.

Mainline service would include two round trips per week in the summer and one per week in the winter with Auke Bay-Haines-Skagway-Haines-Auke Bay routing. During the summer, one Day Boat ACF would make one round trip between Auke Bay and Haines six days per week, and one would make two round trips per day between Haines and Skagway six days per week. The Day Boat ACFs would not sail on the seventh day because the mainliner is on a similar schedule. In the winter, ferry service in Lynn Canal would be provided primarily by the Day Boat ACFs three times per week. The *M/V Malaspina* would no longer operate as a summer day boat in Lynn Canal.

1.1.2 Alternative 1B – Enhanced Service with Existing AMHS Assets

Alternative 1B includes all of the components of Alternative 1, No Action, but focuses on enhancing service using existing AMHS assets without major initial capital expenditures. Similar to Alternative 1, Alternative 1B includes: a continuation of mainline ferry service in Lynn Canal; the AMHS would continue to be the NHS route from Juneau to Haines and Skagway; no new roads or ferry terminals would be built; and in addition to the Day Boat ACFs, programmed improvements include improved vehicle and passenger staging areas at the Auke Bay and Haines ferry terminals to optimize traffic flow on and off the Day Boat ACFs as well as expansion of the Haines Ferry Terminal to include a new double bow berth to accommodate the Day Boat ACFs. Service to other communities would remain the same as the No Action Alternative. Alternative 1B keeps the *M/V Malaspina* in service after the second Day Boat ACF is brought online to provide additional capacity in Lynn Canal. Enhanced services included as part of Alternative 1B are a 20 percent reduction in fares for trips in Lynn Canal and extended hours of operations for the reservation call center.

Mainline service would include two round trips per week in the summer and one per week in the winter with Auke Bay-Haines-Skagway-Haines-Auke Bay routing. During the summer, the *M/V Malaspina* would make one round trip per day five days per week on a Skagway-Auke Bay-Skagway route. On the sixth day, the *M/V Malaspina* would sail on the Skagway-Auke Bay-Haines-Skagway route, and on the seventh day, it would sail that route in reverse (Skagway-Auke Bay-Haines-Skagway). One Day Boat ACF would make one round trip between Auke Bay and Haines seven days per week. The other Day Boat ACF would make two round trips per day between Haines and Skagway six days per week; it would not sail on the seventh day because the mainliner would be on a similar schedule. In the winter, ferry service in Lynn Canal would be provided primarily by the Day Boat ACFs three times per week.

1.1.3 Alternative 2B – East Lynn Canal Highway to Katzehin, Shuttles to Haines and Skagway

Alternative 2B would construct the East Lynn Canal Highway (50.8 miles, including 47.9 miles of new highway and widening of 2.9 miles of the existing Glacier Highway) from Echo Cove around Berners Bay to a new ferry terminal 2 miles north of the Katzehin River. Ferry service would connect Katzehin to Haines and Skagway. In addition, this alternative includes modifications to the Skagway Ferry Terminal to include a new end berth and construction of a new conventional monohull ferry to operate between Haines and Skagway. Mainline ferry service would end at Auke Bay. This alternative assumes the following improvements will have been made independent of the JAI Project before Alternative 2B would come on-line: two Day Boat ACFs, improved vehicle and passenger staging areas at the Haines Ferry Terminal to optimize traffic flow on and off the Day Boat ACFs, and expansion of the Haines Ferry Terminal to include two new double bow berths.

During the summer months, one Day Boat ACF would make eight round trips per day between Haines and Katzehin, a second Day Boat ACF would make six round trips per day between Skagway and Katzehin, and the Haines-Skagway shuttle ferry would make two trips per day. During the winter, one Day Boat ACF would make six round trips per day between Haines and Katzehin, and a second Day Boat ACF would make four round trips per day between Skagway and Katzehin. The Haines-Skagway shuttle would not operate; travelers going between Haines and Skagway would travel to Katzehin and transfer ferries.

1.1.4 Alternative 3 – West Lynn Canal Highway

Alternative 3 would upgrade/extend the Glacier Highway (5.2 miles, including 2.3 miles of new highway and widening of 2.9 miles of the existing Glacier Highway) from Echo Cove to Sawmill Cove in Berners Bay. New ferry terminals would be constructed at Sawmill Cove in Berners Bay and at William Henry Bay on the west shore of Lynn Canal, and the Skagway Ferry Terminal would be modified to include a new end berth. A new 38.9-mile highway would be constructed from the William Henry Bay Ferry Terminal to Haines with a bridge across the Chilkat River/Inlet connecting into Mud Bay Road. A new conventional monohull ferry would be constructed and would operate between Haines and Skagway. Mainline ferry service would end at Auke Bay. This alternative assumes the following improvements will have been made independent of the JAI Project before Alternative 3 would come on-line: two Day Boat ACFs, improved vehicle and passenger staging areas at the Haines Ferry Terminal to optimize traffic

flow on and off the Day Boat ACFs, and expansion of the Haines Ferry Terminal to include two new double bow berths.

During the summer, two Day Boat ACFs would make six round trips per day between Sawmill Cove and William Henry Bay (total of 12 trips each direction), and the Haines-Skagway shuttle ferry would make six round trips per day. During the winter, one Day Boat ACF would make four round trips per day between Sawmill Cove and William Henry Bay, and the Haines-Skagway shuttle ferry would make four round trips per day.

1.1.5 Alternatives 4A through 4D – Marine Alternatives

All four marine alternatives would include continued mainline ferry service in Lynn Canal with a minimum of two trips per week in the summer and one per week in the winter with Auke Bay-Haines-Skagway-Haines-Auke Bay routing. Each marine alternative includes a new conventional monohull shuttle that would make two round trips per day between Haines and Skagway six days a week in the summer and a minimum of three round trips per week between Haines and Skagway in the winter. The AMHS would continue to be the NHS route from Juneau to Haines and Skagway. These alternatives assume the following improvements will have been made independent of the JAI Project before the alternative comes on-line: improved vehicle and passenger staging areas at the Auke Bay and Haines ferry terminals to optimize traffic flow on and off the Day Boat ACFs, and expansion of the Haines Ferry Terminal to include new double bow berths.

1.1.5.1 Alternative 4A – Fast Vehicle Ferry Service from Auke Bay

Alternative 4A would construct two new fast vehicle ferries (FVFs). No new roads would be built for this alternative, and the Auke Bay Ferry Terminal would be expanded to include a new double stern berth. A new conventional monohull ferry would be constructed and would operate between Haines and Skagway. The *M/V Malaspina* would no longer operate as a summer day boat in Lynn Canal, and the Day Boat ACFs would no longer operate in Lynn Canal. The FVFs would make two round trips between Auke Bay and Haines and two round trips between Auke Bay and Skagway per day in the summer. During the winter, one FVF would make one round trip between Auke Bay and Haines and one round trip between Auke Bay and Skagway each day.

1.1.5.2 Alternative 4B – Fast Vehicle Ferry Service from Berners Bay

Similar to Alternative 4A, Alternative 4B would construct two new FVFs. This alternative would upgrade/extend Glacier Highway (5.2 miles, including 2.3 miles of new highway and widening of 2.9 miles of the existing Glacier Highway) from Echo Cove to Sawmill Cove in Berners Bay, where a new ferry terminal would be constructed. The Auke Bay Ferry Terminal would be expanded to include a new double stern berth. A new conventional monohull ferry would be constructed and would operate between Haines and Skagway. The *M/V Malaspina* would no longer operate as a summer day boat in Lynn Canal, and the Day Boat ACFs would no longer operate in Lynn Canal. In the summer, the FVFs would make two round trips between Sawmill Cove and Haines and two round trips between Sawmill Cove and Skagway per day. During the winter, one FVF would make one round trip between Auke Bay and Haines and one round trip between Auke Bay and Skagway each day.

1.1.5.3 Alternative 4C – Conventional Monohull Service from Auke Bay

Alternative 4C would use Day Boat ACFs to provide additional ferry service in Lynn Canal. No new roads would be built for this alternative. The Auke Bay Ferry Terminal would be expanded to include a new double stern berth, and the Skagway Ferry Terminal would be expanded to include a new end berth. A new conventional monohull ferry would be constructed and would operate between Haines and Skagway. In the summer, one Day Boat ACF would make one round trip per day between Auke Bay and Haines, and one Day Boat ACF would make one round trip per day between Auke Bay and Skagway. During the winter, one Day Boat ACF would alternate between a round trip to Haines one day and a round trip to Skagway the next day.

1.1.5.4 Alternative 4D – Conventional Monohull Service from Berners Bay

Alternative 4D would use Day Boat ACFs to provide additional ferry service in Lynn Canal. This alternative would upgrade/extend Glacier Highway (5.2 miles, including 2.3 miles of new highway and widening of 2.9 miles of the existing Glacier Highway) from Echo Cove to Sawmill Cove in Berners Bay, where a new ferry terminal would be constructed. The Auke Bay Ferry Terminal would be expanded to include a new double stern berth, and the Skagway Ferry Terminal would be expanded to include a new end berth. This alternative includes construction of a new conventional monohull ferry that would operate between Haines and Skagway. In the summer, the Day Boat ACFs would make two trips per day between Sawmill Cove and Haines and two trips per day between Sawmill Cove and Skagway. During the winter, a Day Boat ACF would operate from Auke Bay, alternating between a round trip to Haines one day and to Skagway the next day.

2. 2004 Air Quality Modeling

The 2004 *Air Quality Modeling Memorandum* provided a quantitative CO emission analysis based on dispersion modeling for the projected number of motor vehicles forecasted for the highway project. This analysis was completed for Alternative 2 traffic volumes only since this alternative had the highest traffic volumes relative to the other proposed alternatives for the project. The memorandum also provided a qualitative analysis of particulate emissions for the highway project. Air quality impacts were determined to be minor due to the low projected population within the Lynn Canal area and low traffic volumes estimated for the project.

3. Changes in Air Quality Standards

Since the FEIS and ROD were completed in 2006, numerous air quality regulations have changed, including more stringent National Ambient Air Quality Standards (NAAQS) for a number of pollutants. The NAAQS changes are summarized in Table 3-1.

Table 3-1: Previous and Current NAAQS

Pollutant	NAAQS used in 2006 FEIS	Updated NAAQS (year of update)
Lead	Quarterly average: 1.5 µg/m^3	Rolling 3-month average: 0.15 µg/m^3 (2008)
Nitrogen Dioxide (NO_2)	Annual average: 53 ppb	1-hour average: 100 ppb (2010)
Ozone	1-hour average: 0.12ppm 8-hour average: 0.08 ppm	1-hour average eliminated 8-hour average: 0.070 ppm (2015)
Coarse particulate matter (PM_{10})	Annual average: 50 µg/m^3 24-hour average: 150 µg/m^3	Annual average eliminated 24-hour average: 150 µg/m^3 (2012)
Fine particulate matter ($PM_{2.5}$)	Annual average: 15 µg/m^3 24-hour average: 65 µg/m^3	Annual average: 12 µg/m^3 24-hour average: 35 µg/m^3 (2012)
Sulfur dioxide (SO_2)	24-hour average: 0.14 ppm Annual average: 0.03 ppm	24-hour average eliminated Annual average eliminated 1-hour average at 75 ppb (2010)
Carbon Monoxide (CO)	1-hour average: 35 ppm 8-hour average: 9 ppm	No change

Units: µg/m^3 = micrograms per cubic meter
ppm = parts per million
ppb = part per billion
Note that there were no changes to NAAQS for CO: the 1-hour and 8-hour averages are 35 ppm and 9 ppm, respectively.

In addition, in 2016 the FHWA issued an update to their *Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA Documents* (FHWA, 2016), which provides guidance on including analyses of MSATs under the NEPA review process for highway projects. FHWA has developed a three-tiered approach for analyzing MSATs in NEPA documents, depending on specific project circumstances. The three levels of analysis are:

1. No analysis for projects with no potential for meaningful MSAT effects
2. A qualitative analysis for projects with a low potential for MSAT effects

3. A quantitative analysis to differentiate alternatives for projects with higher potential MSAT effects

The updated air quality impact assessment takes into account the regulatory changes discussed above and utilizes the *Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA Documents* to determine the MSAT potential associated with the JAI Project.

4. Updated Air Quality Impact Assessment

In determining potential impacts of the JAI Project on air quality, all factors considered in the 2004 dispersion modeling remain unchanged, with the exception of the projected traffic volumes. Traffic volumes used in the 2004 air quality analysis were derived from the 2004 *Traffic Forecast Report*. Due to the fact that air pollutant concentrations at a given location are directly related to traffic volumes and vehicle travel speeds (for example, a 20 percent increase in traffic volumes results in a 20 percent increase in pollutant concentrations, assuming travel speeds remain the same), a new analysis of projected air quality impacts had to be conducted that took into account updated traffic forecasts for the project. In addition, changes in air quality standards required that the potential for MSAT impacts be assessed. The revised projected air quality impacts and an MSAT impacts analysis are provided below.

4.1 Projected Air Quality Impacts

Opening year and 30-year projected traffic volumes have been revised for the JAI Project Final SEIS (DOT&PF, 2017). The 2017 traffic forecasts relied on a different methodology than what was used for the 2005 Supplemental Draft EIS and 2006 FEIS. The opening year considered in the 2006 FEIS was 2008 and the opening year for this Final SEIS traffic forecast is projected to be 2025. To determine whether new dispersion modeling was needed to assess project impacts related to air quality for this Final SEIS, project analysts compared updated 2017 traffic forecast volumes to traffic volumes used in the 2004 dispersion modeling. The most conservative values were assumed for the 2004 dispersion model inputs so that a worst-case scenario for CO emissions could be developed.

The most conservative values calculated for traffic inputs were peak week average daily traffic (PWADT) volumes, which is average daily bidirectional traffic during the busiest week of the year. The PWADT volumes presented in the 2004 evaluation and updated 2017 traffic forecasts are shown in Table 4-1. As stated above in Section 2, the 2004 air quality modeling assessment was based on Alternative 2 traffic volumes because this alternative was projected to have the highest traffic volumes of any alternatives under consideration at that time. The Alternative 2 PWADT volumes used in the 2004 study were 1,800 for 2008 and 3,250 for 2038 (see Table 4-1).

Table 4-1: Opening Year and 30-Year PWADT Forecasts

	2006 FEIS Traffic Forecasts from 2004 Traffic Forecast Report		**Current Final SEIS Traffic Forecasts from 2017 *Traffic Forecast Report* (Appendix AA)**	
Alternative	**Opening Year: 2008**	**+ 30 years: 2038**	**Opening Year: 2025**	**+ 30 years: 2055**
1	330	460	300	300
1B	NA	NA	505	505
2	1,800	3,250	NA	NA
2B	1,340	2,350	3,090	3,115

Alternative	2006 FEIS Traffic Forecasts from 2004 Traffic Forecast Report		Current Final SEIS Traffic Forecasts from 2017 *Traffic Forecast Report* (Appendix AA)	
	Opening Year: 2008	+ 30 years: 2038	Opening Year: 2025	+ 30 years: 2055
3	1,100	1,860	2,520	2,545
4A	490	780	545	550
4B	580	940	905	910
4C	360	520	365	370
4D	460	690	840	850

All of the PWADT + 30-year (2055) volumes predicted in the 2017 *Traffic Forecast Report* (Appendix AA of this Final SEIS) are lower than the highest volume used in the 2004 + 30-year (2038) air quality modeling assessment for Alternative 2.

The maximum 1-hour CO concentrations in the 2004 analysis (based on the 30-year PWADT for Alternative 2) were approximately 3.0 ppm, compared with an NAAQS of 35.0 ppm. Because the highest updated (2017) 30-year PWADT volumes are slightly lower than the Alternative 2 traffic volumes, CO emissions would be slightly lower or approximately equal to the 2004 modeled results. Therefore, the findings of the 2006 FEIS with respect to air quality impacts for Alternatives 1, 2B, 3, 4A, 4B, 4C, and 4D remain valid: these JAI Project alternatives would have no noticeable impact on local air quality based on updated traffic forecasts.

Alternative 1B was not evaluated in the 2006 FEIS. It is similar to Alternative 1 in that it would not include a new road or ferry construction. The 2017 traffic forecasts for Alternative 1B are similar to the 2006 FEIS traffic forecasts for Alternative 1, No Action; therefore, potential air quality impacts from Alternative 1B would be similar to those identified for Alternative 1 in the 2006 FEIS.

4.2 Mobile Source Air Toxics

In 2016, FHWA issued an update to their *Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA Documents* (FHWA, 2016), which provides guidance on including analyses of MSATs under the NEPA review process for highway projects. Based on this guidance, the JAI Project is classified as a project with a low potential for MSAT effects. Category 2 projects include those that serve to improve operations of highway, transit, or freight without adding substantial new capacity or without creating a facility that is likely to meaningfully increase MSAT emissions. This category includes projects where the design year traffic is projected to be less than 140,000 to 150,000 annual average daily traffic (AADT). Traffic volumes forecasted for JAI Project are highest for Alternative 2B: 810 AADT in 2025 and 820 AADT in 2055, both of which are well below the 150,000-AADT threshold that would potentially trigger the need for a quantitative MSAT analysis.

For each alternative, the amount of MSATs emitted would be proportional to the vehicle miles traveled, or VMT, assuming that other variables such as fleet mix are the same for each

alternative, as well as the type, travel distance, and travel speed of each marine vessel.[1] Although the VMT between alternatives varies, the magnitude of those differences is small and would not result in meaningful or appreciable differences in MSAT emissions between the alternatives, especially when considering the low AADT associated with each alternative.

Under all build alternatives in the 2025 design year, it is expected that there would be the same or slightly higher MSAT emissions in the project area compared to the No Action Alternative. Motor vehicle emissions are virtually certain to be lower for all alternatives in the future as a result of the EPA's national control programs that are projected to reduce annual MSAT emissions by 72 percent from 1999 to 2050. Local conditions could differ from these national projections in terms of fleet mix and turnover, VMT growth rates, and local control measures; however, the magnitude of the EPA-projected reductions is so great (even after accounting for VMT growth) that MSAT emissions in the project area are likely to be lower in the future than they are today.

Information is incomplete or unavailable to credibly predict the project-specific health impacts due to changes in MSAT emissions associated with the build alternatives. This update to the 2004 *Air Quality Modeling Memorandum* reaffirms the conclusions that implementation of any of the build alternatives would not result in a noticeable impact on local air quality. Due to the limitations of methodologies for forecasting health impacts, any predicted difference in health impacts between alternatives is likely to be much smaller than the uncertainties associated with predicting the impacts. Consequently, the result of such an assessment is not useful in weighing this information against project benefits.

[1] Marine vessel emissions were not modeled in the 2004 *Air Quality Modeling Memorandum*, but rather were qualitatively compared. Marine vessel emissions were analyzed in this 2017 update (see Attachment A). Based on the findings, no impacts to air quality were predicted and no mitigation measures were necessary.

5. Conclusions

Since the 2004 *Air Quality Modeling Memorandum* was issued as part of the 2006 FEIS, there have been changes to the NAAQS, changes to some of the project alternatives, and updated traffic volume forecasts for all alternatives, all of which could alter the assessment of impacts to air quality resulting from the JAI Project. The 2017 traffic forecasts are similar to traffic forecasts used in the 2004 air quality modeling and would generally result in similar projected emissions and pollutant concentrations to those presented in the 2006 FEIS, which were shown to have no noticeable impact on local air quality. Ferry vessel emissions for the Project were evaluated in a separate document which is included as Attachment A of this memo. No new air quality modeling or mitigation measures are necessary based on the findings of this evaluation for the JAI Project Final SEIS.

6. References

Alaska Department of Transportation and Public Facilities (DOT&PF). 2004. *Appendix T, Air Quality Modeling Memorandum.* Prepared by the URS Corporation as part of the Juneau Access Improvements Project Supplemental Draft Environmental Impact Statement. Available online at http://dot.alaska.gov/sereg/projects/juneau_access/assets/SDEIS_JAN05/Appendix_T.pdf

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Federal Highway Administration (FHWA). 2016. *Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA Documents.* October 19, 2016. Available online at https://www.fhwa.dot.gov/environment/air_quality/air_toxics/policy_and_guidance/aqintguidapd.cfm .

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Attachment A

Ferry Vessel Air Quality Analysis

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Memo

Date:	Thursday, January 19, 2017
Project:	Juneau Access Improvements Project SEIS
To:	Gary Hogins Jason Bluhm
From:	Kevin Doyle Scott Noel
Subject:	**Ferry Vessel Air Quality Analysis**

1.0 Introduction

In comments received on the Juneau Access Improvements (JAI) Project Draft Supplemental Environmental Impact Statement (SEIS), it was noted that the air quality analysis did not address ferry vessel emissions for each of the alternatives or how those emissions would affect air quality. In particular, the addition of new ferry vessels idling at active marine centers could contribute to a cumulative effect on air quality at those locations. HDR investigated potential emissions from ferries associated with each of the project alternatives. This technical memorandum describes the analysis of ferry emissions and the potential effects of those emissions on emissions burden and ambient air quality at port and terminal locations.

2.0 Ambient Air Quality

As a first step in the analysis, the HDR team reviewed ambient air quality monitoring data and published ambient emissions estimates to update baseline information for the SEIS. As noted in the Draft SEIS, the only monitoring data available for the Project area are collected by a particulate matter (PM) monitor located in Juneau, Alaska. Recent data from the monitor were obtained from the United States Environmental Protection Agency (EPA) AirData website (EPA, 2016). The data collected relate to National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ (particles 2.5 micrometers in diameter and smaller, such as those found in smoke and haze) and PM_{10} (particles smaller than 10 micrometers) and are summarized in Table 1. The data confirm that the Juneau PM levels are below the NAAQS, as reported in the Draft SEIS.

Table 1. Juneau $PM_{2.5}$ and PM_{10} 3-Year Monitoring Results

Pollutant	Averaging Time	NAAQS Level ($\mu g/m^3$)	2012 ($\mu g/m^3$)	2013 ($\mu g/m^3$)	2014 ($\mu g/m^3$)
$PM_{2.5}$	Annual[a]	12.0 (primary) 15.0 (secondary)	6.4	5.9	7.6
	24-hour[b]	35	24	23	28
PM_{10}	24-hour[c]	150	81	36	44

Source: EPA, 2016.

[a] Annual mean, averaged over 3 years.

[b] 98th percentile, averaged over 3 years.

[C] Maximum, not to be exceeded more than once per year on average over 3 years.

Note: $\mu g/m^3$ =micrograms per cubic meter.

The HDR team also reviewed the *Alaska Rural Communities Emission Inventory* (ADEC, 2007). This document provides estimates of commercial marine vessel emissions and total emissions for rural areas of Alaska. The inventoried areas include Haines and Skagway-Angoon. The daily and annual marine and total emissions estimates for the year 2005 are provided in Table 2 (Haines) and Table 3 (Skagway-Angoon). While the Alaska Department of Environmental Conservation (ADEC) report does not provide analysis of attainment status relative to the NAAQS, these emissions demonstrate the magnitude of marine vessel emissions relative to other emissions in the JAI Project area. Specifically, the data show that commercial marine vessels account for a relatively large percentage of total emissions of nitrogen oxides (NO_X) and sulfur dioxide (SO_2). Relative to other criteria pollutants, such as carbon monoxide (CO), $PM_{2.5}$, and PM_{10}, however, commercial marine vessels account for a relatively small percent of total emissions. Part of the reason for the high concentration of SO_2 is the relatively high concentration of sulfur in diesel fuels at the time of the analysis (e.g., 3,000 parts per million in 2005). Since then, new fuel standards have limited sulfur content in diesel fuel to 15 parts per million. It should be noted that the ADEC report provides air pollutant emissions in rural areas of Alaska that are not represented by the monitoring system, which is focused on higher population areas such as Anchorage and Juneau. The report indicates that rural areas of the state would be characterized as being in “attainment” with NAAQS, given their relatively low emissions compared to larger urban areas that do have monitoring.

Table 2. Emissions Inventory (tons/year) Haines, Alaska (2005)

Community	HC[a]	CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2
Marine Vessel	6.12	46.45	285.32	12.69	12.30	103.75
Other Emissions[b]	1,945	2,110	111	1,472	378	10
Total	1,951	2,156	396	1,485	390	114
Marine Vessel % of Total	0.3%	2.2%	72.0%	0.9%	3.2%	91.2%

Source: Alaska Department of Environmental Quality (ADEC), 2007

[a]ADEC did not calculate emissions of volatile organic compounds (VOC), instead they included hydrocarbons (HC). Generally VOCs for marine vessels are about 105% of HC emissions.

[b] Excludes point sources and aviation.

Table 3. Emissions Inventory (tons/year) Skagway-Angoon, Alaska (2005)

Community	HC[a]	CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2
Marine Vessel	36.84	204.84	1,379.81	78.69	76.32	570.64
Other Emissions[b]	2,839	3,264	166	2,100	540	14
Total	2,876	3,469	1,546	2,179	616	585
Marine Vessel % of Total	1.28%	5.91%	89.26%	3.61%	12.38%	97.61%

Source: ADEC, 2007.

[a] ADEC did not calculate emissions of VOC, instead they included HC. Generally VOCs for marine vessels are about 105% of HC emissions.

[b] Excludes point sources and aviation.

Based on monitored ambient air quality data from Juneau and the estimated emissions for Haines and Skagway-Angoon, current air quality can be assumed to be relatively good in the project area and in attainment with NAAQS.

3.0 Air Pollutant Emissions Estimates of Ferries

3.1 Method for Estimating Ferry Emissions

Air pollutant emissions factors for ferry vessel engines proposed for each of the alternatives were obtained from the manufacturer (ElectroMotive, 2012) and are provided in Attachment A of this report. Total annual emissions of CO, NO_X, hydrocarbons, and PM_{10} were calculated using the same method used in the Alaska Rural Communities Emissions Inventory (ADEC, 2007). The method uses the following equation:

$$\text{Emissions}_{\text{mode}} = \frac{\text{calls}}{\text{season}} \times \frac{\text{hr}_{\text{mode}}}{\text{call}} \times \text{EF}_{\text{mode}} \left(\frac{\text{grams}}{\text{hp} - \text{hr}} \right) \times \text{RatedPower}(\text{hp}) \times \text{LF}_{\text{mode}} \times \frac{1\,\text{ton}}{907185\,\text{grams}}$$

Where:

$\text{Emissions}_{\text{mode}}$ = Ferry vessels emissions

EF_{mode} = Emission factor for ferry vessel

LF_{mode} = Load factor for ferry vessel

Information related to ferry operations for each alternative, such as the number of port calls per season, duration of trips, and idling time in each port, was calculated by the project's traffic engineers and used in this analysis.

While ships are at port, it is assumed that their engines would idle to provide electricity for lights, heating, air conditioning, and similar needs. The ADEC report does not provide methodology for calculating such emissions; however, the number of minutes that each ferry vessel would sit idling at port was calculated by the project's traffic engineers, and the percent load during engine idle (i.e., hoteling) was adjusted and implemented in the ADEC equation above.

3.2 Ferry Vessel Emissions

The vessels proposed for the JAI Project alternatives would operate with Category 2 – Tier 3 engines per 40 Code of Federal Regulation (CFR) 1042.505(b)(1) and (5)(i). The emissions factors for these engines, as well as the annual duration of vessel trips within 25 miles of each port of call and the duration of time that ferries would idle at each port annually, were used to calculate the ferry emissions for each alternative. For origins and destinations that are within a distance less than 25 miles from one another, such as Skagway and Haines, the duration of vessel trips between the two ports were split evenly between them. This analysis also assumes that each vessel's engine would operate at 80 percent load while in transit during a given trip and 20 percent load while hoteling at port, similar to how other vessels have been found to operate (Entec UK Limited, 2002).

Total annual ferry emissions associated with each alternative and port analyzed in the SEIS are provided in Table 4 for vessels in transit and in Table 5 for vessels hoteling (e.g., idling) at port. Generally, the highest emissions would be associated with Alternative 3 and the lowest emissions associated with Alternatives 1 (No Action), 1B, and 4C. Note that the emissions associated with each potential action alternative would displace the emissions estimated for existing Lynn Canal ferry vessels in 2005 in the Alaska Rural Communities Emission Inventory (Alternative 1).

Table 4. Annual Ferry Emissions while in Transit (tons/year)

Alternative	Port	CO	NO_X	VOC	PM	SO_X	CO_2e
1	Auke Bay	1.10	11.33	0.12	0.11	0.01	1,294.2
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.71	7.35	0.07	0.07	0.01	839.8
	Skagway	1.10	11.33	0.12	0.11	0.01	1,294.2
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**2.90**	**30.02**	**0.31**	**0.29**	**0.04**	**3,428.1**
1B	Auke Bay	1.92	19.83	0.20	0.19	0.02	2,264.5
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	1.20	12.44	0.13	0.12	0.01	1,420.2
	Skagway	1.92	19.83	0.20	0.19	0.02	2,264.5
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**5.04**	**52.10**	**0.53**	**0.50**	**0.06**	**5,949.3**
2B	Auke Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Katzehin	6.94	71.69	0.73	0.69	0.09	8,187.5
	Haines	1.59	16.48	0.17	0.16	0.02	1,882.1
	Skagway	6.94	71.69	0.73	0.69	0.09	8,187.5
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**15.47**	**159.87**	**1.63**	**1.55**	**0.19**	**1,8257.1**
3	Auke Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	1.85	19.08	0.19	0.18	0.02	2,179.0
	Skagway	1.85	19.08	0.19	0.18	0.02	2,179.0
	Port Sawmill Cove	6.27	64.80	0.66	0.63	0.08	7,400.2
	Port William Henry Bay	6.27	64.80	0.66	0.63	0.08	7,400.2
	Total	**16.24**	**167.76**	**1.71**	**1.62**	**0.20**	**19,158.4**
4A	Auke Bay	6.84	70.63	0.72	0.68	0.08	8,066.0
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	1.81	18.67	0.19	0.18	0.02	2,132.1
	Skagway	6.84	70.63	0.72	0.68	0.08	8,066.0
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**15.48**	**159.93**	**1.63**	**1.55**	**0.19**	**18,264.0**

Table 4. Annual Ferry Emissions while in Transit (tons/year)

Alternative	Port	CO	NO_X	VOC	PM	SO_X	CO_2e
4B	Auke Bay	2.54	26.23	0.27	0.25	0.03	2,995.4
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	2.37	24.52	0.25	0.24	0.03	2,800.7
	Skagway	3.81	39.34	0.40	0.38	0.05	4,492.0
	Port Sawmill Cove	2.54	26.28	0.27	0.25	0.03	3,001.3
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**11.26**	**116.37**	**1.19**	**1.13**	**0.14**	**13,289.4**
4C	Auke Bay	2.25	23.24	0.24	0.22	0.03	2,654.5
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.62	6.43	0.07	0.06	0.01	734.4
	Skagway	2.25	23.24	0.24	0.22	0.03	2,654.5
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**5.12**	**52.92**	**0.54**	**0.51**	**0.06**	**6,043.5**
4D	Auke Bay	1.18	12.23	0.12	0.12	0.01	1,396.2
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	1.51	15.57	0.16	0.15	0.02	1,778.4
	Skagway	2.16	22.32	0.23	0.22	0.03	2,548.8
	Port Sawmill Cove	1.97	20.33	0.21	0.20	0.02	2,321.4
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**6.82**	**70.44**	**0.72**	**0.68**	**0.08**	**8,044.8**

Table 5. Annual Ferry Emissions while at Port Hoteling (tons/year)

Alternative	Port	CO	NO_X	VOC	PM	SO_X	CO_2e
1	Auke Bay	0.02	2.77	0.03	0.05	0.00	261.9
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.05	3.44	0.03	0.06	0.00	325.2
	Skagway	0.03	2.22	0.02	0.04	0.00	209.9
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**0.10**	**8.44**	**0.08**	**0.15**	**0.01**	**797.0**
1B	Auke Bay	0.09	6.63	0.07	0.11	0.01	625.9
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.08	5.74	0.06	0.10	0.01	541.9

Table 5. Annual Ferry Emissions while at Port Hoteling (tons/year)

Alternative	Port	CO	NO_X	VOC	PM	SO_X	CO_2e
	Skagway	0.13	9.91	0.10	0.17	0.01	935.5
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**0.30**	**22.28**	**0.22**	**0.39**	**0.02**	**2,103.3**
2B	Auke Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Katzehin	0.11	8.19	0.08	0.14	0.01	773.2
	Haines	0.15	11.56	0.11	0.20	0.01	1,091.2
	Skagway	0.09	7.02	0.07	0.12	0.01	662.9
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**0.36**	**26.77**	**0.26**	**0.46**	**0.03**	**2,527.2**
3	Auke Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.25	18.59	0.18	0.32	0.02	1,755.1
	Skagway	0.20	15.25	0.15	0.26	0.02	1,439.3
	Port Sawmill Cove	0.11	7.88	0.08	0.14	0.01	744.1
	Port William Henry Bay	0.09	6.82	0.07	0.12	0.01	643.4
	Total	**0.65**	**48.54**	**0.48**	**0.84**	**0.05**	**4,582.0**
4A	Auke Bay	0.81	60.61	0.60	1.05	0.06	5,721.8
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.35	26.00	0.26	0.45	0.03	2,454.8
	Skagway	0.28	21.02	0.21	0.36	0.02	1,984.3
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**1.44**	**107.63**	**1.06**	**1.87**	**0.11**	**10,160.9**
4B	Auke Bay	0.44	32.63	0.32	0.57	0.03	3,080.3
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.41	30.75	0.30	0.53	0.03	2,902.6
	Skagway	0.36	26.65	0.26	0.46	0.03	2,516.3
	Port Sawmill Cove	0.50	37.68	0.37	0.65	0.04	3,557.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**1.70**	**127.71**	**1.26**	**2.21**	**0.13**	**12,056.2**
4C	Auke Bay	0.06	4.53	0.04	0.08	0.00	427.2
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.11	8.57	0.08	0.15	0.01	808.6

Table 5. Annual Ferry Emissions while at Port Hoteling (tons/year)

Alternative	Port	CO	NO_X	VOC	PM	SO_X	CO_2e
	Skagway	0.06	4.44	0.04	0.08	0.00	419.3
	Port Sawmill Cove	0.00	0.00	0.00	0.00	0.00	0.0
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**0.23**	**17.53**	**0.17**	**0.30**	**0.02**	**1,655.1**
4D	Auke Bay	0.04	2.81	0.03	0.05	0.00	265.2
	Katzehin	0.00	0.00	0.00	0.00	0.00	0.0
	Haines	0.12	8.90	0.09	0.15	0.01	839.9
	Skagway	0.06	4.77	0.05	0.08	0.00	450.7
	Port Sawmill Cove	0.03	2.31	0.02	0.04	0.00	217.7
	Port William Henry Bay	0.00	0.00	0.00	0.00	0.00	0.0
	Total	**0.25**	**18.79**	**0.18**	**0.33**	**0.02**	**1,773.5**

Table 6 provides a comparison between total marine vessel emissions in 2005 in Haines and Skagway and ferry vessel emissions for each of the alternatives under consideration. Note that in the existing emissions for Skagway include emissions from all the smaller populated areas that are within the Census 2000 Skagway-Angoon borough and are therefore slightly higher than those only in Skagway. As Table 6 indicates, the amount of ferry vessel emissions under each alternative comprises a small portion of the existing emissions for each of these communities.

Table 6. Ferry Vessel Emissions Compared to Existing Marine Vessel Emissions (tons/year)

Port/ Community[a]	Scenario	Pollutant					
		CO	NO_x	VOC	PM	SO_x	GHGs (CO_2e)
Haines	Existing Conditions (2005)	46.45	285.32	6.426	12.69	103.75	N/A
	Alternative 1	0.76	10.80	0.11	0.13	0.01	1,164.95
	Alternative 1B	1.28	18.18	0.18	0.22	0.02	1,962.12
	Alternative 2B	1.75	28.04	0.28	0.36	0.03	2,973.29
	Alternative 3	2.09	37.67	0.38	0.51	0.04	3,934.07
	Alternative 4A	2.15	44.67	0.45	0.63	0.05	4,586.92
	Alternative 4B	2.78	55.27	0.55	0.77	0.06	5,703.25
	Alternative 4C	0.74	15.00	0.15	0.21	0.02	1,543.03
	Alternative 4D	1.63	24.47	0.25	0.30	0.03	2,618.31
Skagway-Angoon	Existing Conditions (2005)	204.84	1379.81	38.682	78.69	570.64	N/A
	Alternative 1	1.13	13.56	0.14	0.15	0.02	1,504.09
	Alternative 1B	2.05	29.74	0.30	0.36	0.03	3,200.06
	Alternative 2B	7.03	78.72	0.80	0.82	0.09	8,850.35

Table 6. Ferry Vessel Emissions Compared to Existing Marine Vessel Emissions (tons/year)

Port/ Community[a]	Scenario	Pollutant					
		CO	NO_x	VOC	PM	SO_x	GHGs (CO_2e)
	Alternative 3	2.05	34.33	0.34	0.45	0.04	3,618.28
	Alternative 4A	7.12	91.65	0.93	1.05	0.10	10,050.25
	Alternative 4B	4.16	65.99	0.66	0.84	0.07	7,008.37
	Alternative 4C	2.31	27.69	0.28	0.30	0.03	3,073.84
	Alternative 4D	2.22	27.09	0.27	0.30	0.03	2,999.51

[a] The 2005 ADEQ emissions estimates were not conducted for marine vessel traffic in smaller communities serviced by ferry vessel traffic under some of the alternatives.

Note: CO_2e = carbon dioxide equivalent; GHGs = greenhouse gases.

4.0 References

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Attachment A.
Air Pollutant Emissions Factors for Ferry Vessel Engines

ELECTRO-MOTIVE
9301 W 55th St
LaGrange IL 60525 USA
www.emdiesels.com

Emissions Data
Series 710GC-T3

EPA Standard:	Category 2 - Tier 3
Regulation:	40CFR1042.505(b)(1) & (5)(i)
Cycle:	E3 @ 900 RPM
Cycle Description:	General & Variable-Speed Auxiliary (propeller law)
Engine Speed:	Variable

EMD CERTIFICATION LEVELS

(g/kW-hr)

Measured Emission		EPA Standard	Certification Level (1)
NOx + Total Hydrocarbon	NO_x + HC	7.8	7.4
Particulate	PM	0.14	0.06
Carbon Monoxide	CO	5.0	0.4

ENGINE CONTINUOUS RATING (@ 900 RPM)

No. of Cylinders	8	12	16	20
BHP	2000	3000	4000	5000
kW	1491	2237	2983	3729

SELECT FAMILY INFO

EMD Family:	710GC-T3	EPA Family:	CEMDN233.GT3
Cycle:	2-stroke	Category:	2
Cylinders:	8, 12, 16, or 20	Type:	Marine CI Commercial
Test Fuel:	No. 2 Ultra Low Sulfur Diesel	Usage:	Propulsion & Auxiliary
Regulation:	40CFR1065.703 Table 1	A B & T :	No
System Type:	Electronic Direct Injection	NTE:	1.2 x Std & 1.5 x Std
Aspiration:	Turbo Air-to-Water	EPA Useful Life:	10 yrs or 20,000 hrs

EMD TEST DATA - DUTY CYCLE SUMMARY (2)

	CO	NOx	HC	NOx + HC	PM
g/kW-hr	0.4	7.3	0.08	7.4	0.06

MODE DETAIL - EMD TEST DATA (Family Representative Values)

Mode (#)	Weight (%)	Power (3) (% of MTP)	Speed (RPM)	Power (kW)				Emission (g/kW-hr)			
				8-Cyl	12-Cyl	16-Cyl	20-Cyl	CO	NO_x	HC	PM
1	20%	100%	928	1641	2461	3274	4046	0.6	6.2	0.06	0.06
2	50%	75%	845	1230	1846	2454	3035	0.4	7.5	0.08	0.06
3	15%	50%	743	820	1230	1634	2023	0.1	7.5	0.07	0.04
4	15%	25%	585	410	615	819	1012	0.1	10.9	0.13	0.04

Notes:
1) Deteriorated Test Results
2) Calculated from EMD Actual Engine Test Data
3) MTP = Maximum Test Power = EMD Continuous x 110% x 90%