Petitioner's Exhibit 1c

Shell Offshore Inc.
3601 C Street, Suite 1334
Anchorage, AK 99503

March 26, 2007

Daniel L. Meyer
Office of Air, Waste and Toxics
U.S. EPA, Region 10
1200 Sixth Avenue, OAQ-107
Seattle, WA 98101

Re: Shell Kulluk and Frontier Discoverer – Addendum to Pre-Construction Permit Applications - Beaufort Sea OCS Exploration Drilling Program

Dear Mr. Meyer:

Enclosed is an addendum for the two Shell Offshore Inc. minor OCS source air permit applications, submitted December 29, 2006, and supplemented in a February 7, 2007 letter to you. This addendum addresses several clarifications and revisions to the applications, all of which have already been submitted informally to EPA over the past two months.

Please feel free to contact me (907-770-3700), Gene Pavia (907-339-5482) or Rodger Steen (303-988-2960) regarding any additional detail. We appreciate your attention to and expeditious processing of these applications.

Sincerely yours,

Shell Offshore Inc.

Susan Childs

Susan Childs
Regulatory Coordinator, Alaska

Enclosures:

cc: *Susan Childs, Shell*
Keith Craik, Shell
Bill Walker, ADEC, DAQ
Gene Pavia, AES RTS
Rodger Steen, Air Sciences Inc.

ADDENDUM

OCS Pre-Construction Air Permit Applications
December 29, 2006

Shell Offshore Inc.
3601 C Street, Suite 1334
Anchorage, AK 99503

Shell Kulluk & Frontier Discoverer
Beaufort Sea
Exploratory Drilling Program

AirSci Project 180-15

March 26, 2007

1. Introduction

This addendum provides updates to the applications submitted December 29, 2006 by Shell Offshore Inc. (SOI) for the Shell Kulluk and Frontier Discoverer drilling units. These updates are categorized as:

Revised list of source units,
Inclusion of particulate matter emission controls for some engines,
Decreased maximum SO2 content of the diesel fuel consumed by the small engines on the drill vessels,
Establishment of the ambient boundary at the edge of the drill vessels,
Revised demonstration of synthetic minor status to include load-based emission estimation.
Owner Requested Limit of a minimum 500 meters distance between any two drill sites in any one year.

2. Revised list of source units (engines, heaters, and incinerators)

In the process of upgrading the Kulluk and Frontier Discoverer for 2007 operations, there are changes in some of the source units. The revised lists of source units to be permitted for the two drilling vessels are provided in Tables 1 and 2.

Table 1 – Kulluk drilling unit emission units [a]				
Unit ID	**Unit Description**	**Make/Model**	**Rating**	
K-1	Electrical Generator Engine	EMD / unknown	2,816	hp
K-2	Electrical Generator Engine	EMD / unknown	2,816	hp
K-3	Electrical Generator Engine	EMD / unknown	2,816	hp
K-4	Emergency Generator	Unknown	920	hp
K-5	Air Compressor Engine	leased / Tier 2 or 3	500	hp
K-6	Air Compressor Engine	leased / Tier 2 or 3	500	hp
K-7	Air Compressor Engine	leased / Tier 2 or 3	500	hp
K-8	Deck Crane Engine	Mercedes / OM404	293	kW
K-9	Deck Crane Engine	Mercedes / OM404	293	kW
K-10	Deck Crane Engine	Mercedes / OM404	293	kW
K-11	Thrustmaster Engine	Caterpillar / 3516 B	2,000	hp
K-12	Thrustmaster Engine	Caterpillar / 3516 B	2,000	hp
K-13	HPP Engine	Unknown	< 600	hp
K-14	HPP Engine	Unknown	< 600	hp
K-15	Heat Boiler	Unknown	2.4	mBtu/hr
K-16	Heat Boiler	Unknown	2.4	mBtu/hr
K-17	Hot Water Heat	Unknown	0.54	mBtu/hr
K-18	Hot Water Heat	Unknown	0.54	mBtu/hr
K-19	Incinerator	TeamTec / GS500C	125	kg/hr

[a] All are diesel fueled.

Table 2 – Frontier Discoverer drilling unit emission units [a]				
Unit ID	**Unit Description**	**Make/Model**	**Rating**	
1	Electrical Generator Engine	Caterpillar / D399	976	kW
2	Electrical Generator Engine	Caterpillar / D399	976	kW
3	Electrical Generator Engine	Caterpillar / D399	976	kW
4	Electrical Generator Engine	Caterpillar / D399	976	kW
5	Electrical Generator Engine	Caterpillar / D399	976	kW
6	Electrical Generator Engine	Caterpillar / D399	976	kW
7[b]	Propulsion Engine	Mitsubishi / 6UEC65	5375	kW
8	Emergency Generator	Caterpillar / 3304	90	kW
9	Air Compressor Engine	leased / Tier 2 or 3	500	hp
10	Air Compressor Engine	leased / Tier 2 or 3	500	hp
11	Air Compressor Engine	leased / Tier 2 or 3	500	hp
12	HPP Engine	Unknown	± 250	hp
13	HPP Engine	Unknown	± 250	hp
14	Port Crane Engine	Caterpillar / D343	365	hp
15	Starboard Crane Engine	Caterpillar / D343	365	hp
16	Cementing Unit Engine	Detroit / 8V-71N	335	hp
17	Cementing Unit Engine	Detroit / 8V-71N	335	hp
18	Logging Winch Engine	Detroit / 4-71N	128	hp
19	Logging Genset Engine	John Deere / 4024TF270	36	kW
20	Heat Boiler	Clayton / 200 Boiler HP	7.97	mmBtu/hr
21	Heat Boiler	Clayton / 200 Boiler HP	7.97	mmBtu/hr
22	Incinerator	TeamTec / GS500C	125	kg/hr

[a] All are fueled with diesel fuel oil.
[b] The propulsion engine (not used when stationary), therefore not subject to emissions limits.

3. Inclusion of particulate matter emission controls for some engines.

SOI commits to meet the particulate matter (PM) emission limit of 0.05 grains per dry standard cubic foot for all of its drilling vessel (Kulluk and Frontier Discoverer) diesel fuelled source units. The heaters and boilers meet this standard by design as do the diesel engines greater than 600 hp. The engines under 600 hp that are older than Tier 3, require the use of particulate matter filters in conjunction with low-sulfur (500 ppm) diesel fuel in order to meet this standard. Demonstration of compliance with this standard is provided in Appendix A.

4. Establishment of the Ambient Boundary at the edge of the Kulluk

Through the use of a more realistic impact estimation model (ISC Prime instead of SCREEN3), impacts from the drill vessels and surrounding vessel sources indicate that ambient standards will be met at the drill vessel hulls. It is unnecessary to use any safety exclusion zone boundary as the ambient air boundary. The more current impact modeling by ISC Prime is described in the attached reports, provided in Appendix B. The reports describe how the model was run and impact results. Appendix B includes a supplementary analysis of the maximum impact as a function of load on the drilling generators.

5. Revised demonstration of synthetic minor status to include load-based emission estimation

The Drill vessels are to be permitted as synthetic minor sources and emissions of all the criteria pollutants on a per-drill-site basis will remain below 250 tons per year. Emissions from the drill vessel and associated vessels, including primarily two ice breakers are included in the calculation. Since the primary source units are diesel engines and the fuel will have sulfur content of 0.19 percent or less, it is the NOx emissions that will be the largest for this source, and by limiting the NOx emissions, all other emissions will remain well below 250 tpy. This demonstration is provided in Appendix B, page B-1 of the December 29, 2006 applications. So, tracking of emissions is limited to the NOx emissions and all source units (except the incinerators) will be tracked by a PEMS system based on fuel consumption or engine load. A constant emission from each incinerator is included, based on incinerator operation at capacity.

There will be three classes of source units for this NOx emission tracking system, the units with an assumed constant emission factor (EF) with load, the units with varying emission factors as a function of load (EF[load]), and the incinerators with constant emissions. For the large sources (ice breaker propulsion and drill vessel drilling engines) each engine type is to be stack tested and the measured emission factors are used for estimation of NOx emissions. If SOI chooses to monitor engine load (Kw), the emissions will be determined by an emission factor as a function of load (lb NOx per Kw-hr). If SOI chooses to not monitor load, the emission factors are the maximum measured over the normal engine operating range. The maximum EF (lb NOx per gallon fuel) is used with fuel consumption (gallons) to estimate NOx emissions.

For the small sources, an emission factor (lb NOx per gal fuel) is assumed equal to either the manufacturer's or EPA's estimate (AP42) and emissions are estimated based on this factor and the fuel consumed. The small sources, including the incinerators, account for less than 10 % of the source emissions. In this way, SOI ensures that the estimated NOx emissions will be equal to or higher than actual NOx emissions. SOI also commits to remaining below 245 tons per year, which is 5 tons per year below the major source threshold, thereby allowing for an additional uncertainty in aggregated measurements of 2 percent.

For stack testing purposes, there are to be three tests per engine type and they are to be at the low, middle, and high end of the normal operating ranges for the type of engine. For propulsion engines, the normal range is 35% to 80%. For the drilling generators it is 50 to 100 %. The propulsion ranges are estimates, developed from the ice breaker operators (and Corbett and Koehler, 2003, Updated Emission From Ocean Shipping, JGR, Vol 108, No. D20, Table 7). The drill generator range is estimated by the drillers.

6. Owner Requested Limit of a minimum 500 meters distance between any two drill sites in any one year

In the interest of ensuring that each drill site (the associated activities) remains as a separate and distinct source from other SOI drill sites in the same year, SOI agrees to maintaining a minimum 500 meter distance between well sites in any one year. The conditions related to separate source determination are provided by the January 12, 2007 Wehrum Memo ("Source Determinations for Oil and Gas Industries"). The analytical approach to maintaining separate source status in this memo is related to the degree of source operational dependence and proximity. There will be no operational dependence between drill sites so all drill sites meet this criterion for separation of sources. Regarding proximity, that guidance memo (pages 4 and 5) states:

> After identifying the individual surface site, the permitting authority should consider aggregating pollutant-emitting activities at multiple surface sites, when the surface sites are under common control and located in close proximity to each other. A reviewing authority can consider two surface sites to be in close proximity if they are physically adjacent, or if they are separated by no more than a short distance (e.g. across a highway, separated by a city block or some similar distance). 16
>
> Footnote 16, In making major stationary source determinations for this industry, some southern States apply a rule that generally results in separating pollutant-emitting activities located outside a 1/4 mile radius .

SOI commits to a minimum spacing of 500 meters between sites in any one year, which is greater than the suggested quarter mile radius. Furthermore, from an impact analysis perspective, this distance is sufficient even under the worst combinations of source locations and winds to avoid impact aggregation.

Appendix A

Demonstration of Compliance with Alaska Fuel-Burning Source
Particulate Matter Standard

AIR SCIENCES INC. DENVER • PORTLAND	Air Sciences Inc. CALCULATIONS	PROJECT TITLE: Kulluk	BY: D. Young
		PROJECT NO: 180-15	PAGE 1 OF 2 SHEET 1
		SUBJECT: PM Emissions & Standard	DATE: 3/26/2007

Kulluk drilling rig

Emissions units subject to the fuel burning PM standard

Emission Unit Description	Unit's Manufacturer	Unit's capacity (hourly)		Total sources	Unit's PM Emissions (Ref.)		PM^ Standard		Add-on PM Filter	Meet Standard
Genset engine	EMD	2,816	hp	3	0.27	g/hp·hr (1)	0.37	g/hp·hr	No	Yes
Emergency genset	unknown	920	hp	1	0.0697	lb/mmBtu (2)	0.1153	lb/mmBtu	No	Yes
Air compressor engine	leased	500	hp	3	0.20	g/kW·hr (3)	0.49	g/kW·hr	No	Yes
HPP engine	unknown	< 600	hp	2	0.00066	lb/hp·hr (4)	0.00081	lb/hp·hr	Yes	Yes
Deck crane engine	Mercedes	293	kW	3	0.00066	lb/hp·hr (4)	0.00081	lb/hp·hr	Yes	Yes
Thrustmaster engine	Caterpillar	2,000	Hp	2	0.0697	lb/mmBtu (2)	0.1153	lb/mmBtu	No	Yes
Heat boiler	unknown	2.4	mmBtu	2	0.0236	lb/mmBtu (5)	0.08	lb/mmBtu	No	Yes
Hot water heater	unknown	0.54	mmBtu	2	0.0236	lb/mmBtu (5)	0.08	lb/mmBtu	No	Yes

References for unit's PM emissions

(1) Vendor data for CBOI injectors.

(2) AP42 Table 3.4-2, 10/96, engines greater than 600 hp.

(3) Tier 2 or 3, CFR § 89.112 (a).

(4) AP42 Sec 3.3 10/96 (0.0022 lb/hp·hr) and an add-on particulate matter filter for diesel fueled engines:
At least 70% PM control efficiency with diesel fuel sulfur content less than 500 ppm.
California Air Resources Board, PM Level 3 verified technology listing last updated 2/21/2007.
(http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm)

(5) AP42 Tbl 1.3-1 9/98.

^ Calculations of the PM Standard are on the next page.

AIR SCIENCES INC. DENVER • PORTLAND	Air Sciences Inc. CALCULATIONS	PROJECT TITLE: Kulluk	BY: D. Young
		PROJECT NO: 180-15	PAGE 2 OF 2
			SHEET 1
		SUBJECT: PM Emissions & Standard	DATE: 3/25/2007

PM Standard

0.05 grain/dscf Particulate matter, per cubic foot of exhaust gas corrected to standard conditions and averaged over three hours. [18 AAC 50.055(b)(1)]

Standard conditions means dry gas at 68° F and an absolute pressure of 760 millimeters of mercury. [18 AAC 50.990(102)]

18 AAC 50.220. Enforceable test methods. (b) Unless otherwise specified by an applicable requirement or test method, an air pollutant emission test must be performed (1) at a point or points that characterize the actual discharge into the ambient air; and (2) at the maximum rated burning or operating capacity of the emission unit or another rate determined by the department to characterize the actual discharge into the ambient air.

Measured at stack O_2 concentration.

Fd = 9,190 dscf/mmBtu, at 0% O_2

Fd, oil fuel, from Table 19-2, Method 19, appendix A-7 to 40 CFR Part 60.

Fd = Volume of dry effluent gas per unit of content, dscf/10^6 Btu.

Determined at standard conditions: 20 °C (68 °F) and 760 mm Hg (29.92 in Hg)

Conversion Factors:

7000 grains/pound 453.6 g/lb 1.341 hp/kW

7,000 btu/hp·hr Assumed heat input (AP42 for small engines)

PM standard at stack O_2 for a IC engine

9 % O_2, typical stack O_2 concentration for an ICE

$$\frac{0.05\ \text{gr}}{\text{dscf}} \times \frac{9{,}190\ \text{dscf}}{\text{mmBtu}} \times \frac{20.9}{20.9 - 9} \times \frac{1\ \text{lb}}{7000\ \text{grains}} = \mathbf{0.1153\ lb/mmBtu}$$

$$\frac{0.1153\ \text{lb}}{1{,}000{,}000\ \text{Btu}} \times \frac{7{,}000\ \text{Btu}}{\text{hp·hr}} \times \frac{453.6\ \text{g}}{\text{lb}} = \mathbf{0.37\ g/hp·hr}$$

$$\frac{0.1153\ \text{lb}}{1{,}000{,}000\ \text{Btu}} \times \frac{7{,}000\ \text{Btu}}{\text{hp·hr}} \times \frac{453.6\ \text{g}}{\text{lb}} \times \frac{1.341\ \text{hp}}{\text{kW}} = \mathbf{0.49\ g/kW·hr}$$

$$\frac{0.1153\ \text{lb}}{1{,}000{,}000\ \text{Btu}} \times \frac{7{,}000\ \text{Btu}}{\text{hp·hr}} = \mathbf{0.00081\ lb/hp·hr}$$

PM standard at stack O_2 for a Boiler

3 % O_2, typical stack O_2 concentration for a boiler.

$$\frac{0.05\ \text{gr}}{\text{dscf}} \times \frac{9{,}190\ \text{dscf}}{\text{mmBtu}} \times \frac{20.9}{20.9 - 3} \times \frac{1\ \text{lb}}{7000\ \text{grains}} = \mathbf{0.08\ lb/mmBtu}$$

Air Sciences Inc.	PROJECT TITLE: Discoverer	BY: D. Young
AIR SCIENCES INC. DENVER • PORTLAND	PROJECT NO: 180-15	PAGE 1 OF 2 SHEET 1
CALCULATIONS	SUBJECT: PM Emissions & Standard	DATE: 3/25/2007

Frontier Discoverer drilling ship

Emissions units subject to the fuel burning PM standard

Emission Unit Description	Unit's Manufacturer	Unit's capacity (hourly)		Total sources	Unit's PM Emissions (Ref.)		PM^ Standard		Add-on PM Filter	Meet Standard
Genset engine	Caterpillar	976	kW	6	0.26	g/kW·hr (1)	0.49	g/kW·hr	No	Yes
Emergency genset	Caterpillar	90	kW	1	0.00066	lb/hp·hr (2)	0.00081	lb/hp·hr	Yes	Yes
Air Compressor engine	leased	500	hp	3	0.20	g/kW·hr (3)	0.49	g/kW·hr	No	Yes
HPP engine	unknown	250	hp	2	0.00066	lb/hp·hr (2)	0.00081	lb/hp·hr	Yes	Yes
Deck Crane engine	Caterpillar	365	hp	2	0.00066	lb/hp·hr (2)	0.00081	lb/hp·hr	Yes	Yes
Cementing unit engine	Detroit	335	hp	2	0.00066	lb/hp·hr (2)	0.00081	lb/hp·hr	Yes	Yes
Logging winch engine	Detroit	128	hp	1	0.00066	lb/hp·hr (2)	0.00081	lb/hp·hr	Yes	Yes
Logging genset engine	John Deere	36	kW	1	0.18	g/kW·hr (4)	0.49	g/kW·hr	Yes	Yes
Heat Boiler	unknown	7.97	mmBtu	2	0.0236	lb/mmBtu (5)	0.08	lb/mmBtu	No	Yes

References for unit's PM emissions

(1) Manufacturer's data for D399 SCAC, 1200 rpm at 100% load:

$$\frac{251.2 \text{ g PM}}{\text{hr}} \left| \frac{\text{Max. load}}{976.1 \text{ kW}} \right. = 0.26 \text{ g/kW·hr}$$

(2) AP42 Sec 3.3 10/96 (0.0022 lb/hp·hr) and an add-on particulate matter filter for diesel fueled engines:
At least 70% PM control efficiency with diesel fuel sulfur content less than 500 ppm.
California Air Resources Board, PM Level 3 verified technology listing last updated 2/21/2007.
(http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm)

(3) Tier 2 or 3, CFR § 89.112 (a).

(4) Tier 2 CFR § 89.112 (a), (0.60 g/kW·hr) and an add-on particulate matter filter for diesel fueled engines:
At least 70% PM control efficiency with diesel fuel sulfur content less than 500 ppm.
California Air Resources Board, PM Level 3 verified technology listing last updated 2/21/2007.
(http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm)

(5) AP42 Tbl 1.3-1 9/98.

^ Calculations of the PM Standard are on the next page.

AIR SCIENCES INC.	Air Sciences Inc.	PROJECT TITLE: Discoverer	BY: D. Young
		PROJECT NO: 180-15	PAGE 2 OF 2
	CALCULATIONS		SHEET 1
DENVER • PORTLAND		SUBJECT: PM Emissions & Standard	DATE: 3/25/2007

PM Standard

0.05 **grain/dscf** Particulate matter, per cubic foot of exhaust gas corrected to standard conditions and averaged over three hours. [18 AAC 50.055(b)(1)]

Standard conditions means dry gas at 68° F and an absolute pressure of 760 millimeters of mercury. [18 AAC 50.990(102)]

18 AAC 50.220. Enforceable test methods. (b) Unless otherwise specified by an applicable requirement or test method, an air pollutant emission test must be performed (1) at a point or points that characterize the actual discharge into the ambient air; and (2) at the maximum rated burning or operating capacity of the emission unit or another rate determined by the department to characterize the actual discharge into the ambient air.

Measured at stack O_2 concentration.

Fd = 9,190 dscf/mmBtu, at 0% O_2

Fd, oil fuel, from Table 19-2, Method 19, appendix A-7 to 40 CFR Part 60.

Fd = Volume of dry effluent gas per unit of content, dscf/10^6 Btu.

Determined at standard conditions: 20 °C (68 °F) and 760 mm Hg (29.92 in Hg)

Conversion Factors:

7000 grains/pound   453.6 g/lb   1.341 hp/kW

7,000 btu/hp·hr Assumed heat input (AP42 for small engines)

PM standard at stack O_2 for a IC engine

9 % O_2, typical stack O_2 concentration for an ICE

$$\frac{0.05\ \text{gr}}{\text{dscf}} \times \frac{9{,}190\ \text{dscf}}{\text{mmBtu}} \times \frac{20.9}{20.9 - 9} \times \frac{1\ \text{lb}}{7000\ \text{grains}} = \mathbf{0.1153\ lb/mmBtu}$$

$$\frac{0.1153\ \text{lb}}{1{,}000{,}000\ \text{Btu}} \times \frac{7{,}000\ \text{Btu}}{\text{hp·hr}} \times \frac{453.6\ \text{g}}{\text{lb}} \times \frac{1.341\ \text{hp}}{\text{kW}} = \mathbf{0.49\ g/kW·hr}$$

$$\frac{0.1153\ \text{lb}}{1{,}000{,}000\ \text{Btu}} \times \frac{7{,}000\ \text{Btu}}{\text{hp·hr}} = \mathbf{0.00081\ lb/hp·hr}$$

PM standard at stack O_2 for a Boiler

3 % O_2, typical stack O_2 concentration for a boiler.

$$\frac{0.05\ \text{gr}}{\text{dscf}} \times \frac{9{,}190\ \text{dscf}}{\text{mmBtu}} \times \frac{20.9}{20.9 - 3} \times \frac{1\ \text{lb}}{7000\ \text{grains}} = \mathbf{0.08\ lb/mmBtu}$$

Appendix B

Demonstration of Compliance with Ambient Air Quality Standards

Air Quality Impact Evaluation Report – No Exclusion Zone

Shell Kulluk Beaufort Sea Exploratory Drilling Program

Prepared for:

SHELL OFFSHORE, INC.

PROJECT 180-15
FEBRUARY 19, 2007

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SECTION 1

INTRODUCTION

On December 29, 2006, Shell Offshore, Inc. (SOI) submitted an application to U.S. EPA's Region 10 (EPA) office, pursuant to the requirements of Outer Continental Shelf Air Regulations, 40 CFR Part 55. SOI wishes to conduct exploratory drilling activity at its oil and gas lease blocks on Outer Continental Shelf (OCS) waters in the Beaufort Sea using the Shell Kulluk drilling vessel and associated support vessels.

This air quality impact report supersedes the impact analysis of the December 29, 2006, permit application and provides an ambient impact analysis demonstrating that the proposed project complies with the National Ambient Air Quality Standards (NAAQS) without consideration of a probable exclusion zone around the Shell Kulluk and associated support vessels. For this analysis, the primary difference is the dispersion model used which is now the ISC-PRIME model, which replaces the SCREEN3 model.

There are a few minor changes in source assumptions in this analysis and these are highlighted in this report. Otherwise, the reader is referred to the permit application for details regarding the proposed project. Electronic modeling files for this analysis are provided to EPA by e-mail.

SECTION 2

AMBIENT IMPACT ANALYSIS (DISPERSION MODELING)

This section describes the ambient standards to be addressed for the exploration drilling activities, the model selected for use in addressing these standards, and the selection of inputs to the model in a manner consistent with acceptable EPA and Alaska Department of Environmental Conservation (ADEC) modeling methods.

The Outer Continental Shelf (OCS) permitting requirements of 40 CFR Part 55.14 require that a permit application address the Corresponding Onshore Area (COA) requirements, which for the Shell Kulluk Exploratory Drilling Program are the ADEC requirements for the Northern Alaska Intrastate Air Quality Control Region (AQCR) 9. This region is designated attainment or unclassifiable for all criteria pollutants pursuant to 40 CFR 81.302. This area is designated as a Prevention of Significant Deterioration (PSD) Class II Area per 18 AAC 50.015. There are no Class I areas within 300 kilometers of the project location. The nearest Class I area (Denali National Park) is located approximately 700 kilometers to the south of the project location.

Emissions from the project will not exceed the 250-ton-per-year Prevention of Significant Deterioration (PSD) major source review threshold. However, because the project is considered a portable oil and gas operation by the ADEC, a minor permit is required per ADEC Regulation 18 AAC 50.502(c)(2)(A). As a result, a National Ambient Air Quality Standards (NAAQS) modeling analysis for SO_2, NO_x, and PM_{10} is required per ADEC Regulation 18 AAC 50.540(c)(2)(B). For the impact analysis, emissions from the stationary source (the Shell Kulluk) and the associated mobile sources (i.e., icebreakers, oil spill response vessels, and a re-supply vessel) were modeled for impact.

2.1 Source Characterization

The worst-case modeling impact scenario is expected to be with the Shell Kulluk drilling and generators operating at maximum power output. During Shell Kulluk's maximum drilling operations, impacts from the oil spill response (OSR) fleet, operating near the Shell Kulluk, and the Jim Kilabuk re-supply vessel operating adjacent to the Shell Kulluk are considered. The emissions from the propulsion engines on the Shell Kulluk and the Jim Kilabuk are not considered in the assessment, since these propulsion engines will be used very briefly to maneuver the Shell Kulluk when it is being anchored or to maneuver the Jim Kilabuk when it is near the Shell Kulluk drill rig. For the Jim Kilabuk, emissions from the two main (non-propulsion) engines and a generator, operating at less than 25 percent capacity, are considered for modeling. In addition, primary and secondary icebreaker impacts are also included under full power, several kilometers upwind of the rig, and in heavy ice (worst-case emissions) for the duration of the project. The only other operating scenario involving large engines operating at capacity is when the Shell Kulluk is being towed between drilling locations. Under this scenario, when the rig is being towed, the Shell Kulluk no longer qualifies as a stationary source.

SOI has estimated that the duration at a given drill site is expected to be less than 60 days. Even though the Shell Kulluk Exploratory Drilling Program will be permitted as a minor source and will not trigger PSD requirements, the modeling analysis considers sources operating 24 hours per day and 60 days per year. These assumptions combined with the use of the ISC-PRIME model utilizing screening meteorological data are expected to overestimate real-world impacts from the project.

Shell Kulluk Drill Rig

For modeling, some sources on the Shell Kulluk were merged together because of size and location considerations. Many identical sources/stacks are located near each other and were collocated so that single-source stack parameters with combined emissions were used. The locations of the collocated stacks were placed at the actual stack location nearest the ambient air boundary, which will be the hull of the vessel.

The following sources on the Shell Kulluk were collocated: two main engines (stack #1), two air compressors (stack #2), two HPP engines (stack #3), and three deck cranes (stack #4). The boiler used for space heating emits to the atmosphere via a single stack (stack #5). Emissions from the small 2.4 mmBTU hot water heater were added to the boiler emissions (stack #5) because the boiler has low dispersion characteristics compared with the other sources. A logging winch also emits to the atmosphere via a single stack (stack #6). A single trash incinerator located on the Shell Kulluk (not included in the permit application) emits to the atmosphere via a single stack (stack #7). More information regarding emissions and stack release parameters for the trash incinerator are provided in Appendix A. These seven stacks were considered as point sources in the modeling analysis.

The two main engine stacks (stack #1), boiler stack (stack #5), and trash incinerator stack (stack #7) emit horizontally. These stacks were modeled in accordance with ADEC's recommendations. ADEC's recommended adjustments provide for the retention of buoyancy while addressing the impediment to the vertical momentum of the release. The following procedure was utilized to model horizontally emitting stacks:

- Set the actual stack velocity (V_{actual}) to an adjusted stack exit velocity ($V_{adjusted}$) of 0.001 meters per second.
- To conserve volumetric flow, determine an adjusted stack diameter ($D_{adjusted}$) by adjusting the actual stack inside diameter (D_{actual}) to account for buoyancy of the plume by using the following equation:

$$D_{adjusted} = 31.6(D_{actual})(V_{actual})^{0.5}$$

- Use the adjusted parameters, $V_{adjusted}$ and $D_{adjusted}$, in the modeling analysis.

The physical characteristics of the stacks on the Shell Kulluk are provided in Table 1. The configuration of the sources on the Shell Kulluk deck is shown on Figure 1.

Table 1: Shell Kulluk Source Stack Parameters

Source Description	Model Source ID	Source Type	Vertical or Horizontal?	Release Ht. [1] (ft)	Release Ht. [1] (m)	Stack Dia. (ft)	Stack Dia. (m)	Exit Temp. (deg F)	Exit Temp. (deg K)	Exit Vel. (m/s)
Stack #1: 2 Main Engines [A]	MAINENGS	Point	horizontal	34.5	10.52	318.6	97.1	750	672	0.001
Stack #2: 2 Air Compressors	COMPENGS	Point	vertical	8.0	2.44	0.69	0.21	800	700	40.0
Stack #3: 2 HPP Engines	HPPENGS	Point	vertical	8.0	2.44	0.60	0.18	800	700	40.0
Stack #4: 3 Crane Engines	DECKCRNS	Point	vertical	50.0	15.24	0.83	0.25	750	672	20.1
Stack #5: 1 Boiler / 1 Water Heater [B]	BOILHEAT	Point	horizontal	28.0	8.53	62.4	19.0	200	366	0.001
Stack #6: 1 Logging Winch	LOGWNCH	Point	vertical	10.3	3.12	0.33	0.10	820	711	53.0
Stack #7: 1 Incinerator [C]	INCIN_K	Point	horizontal	34.5	10.52	149.9	45.7	662	623	0.001

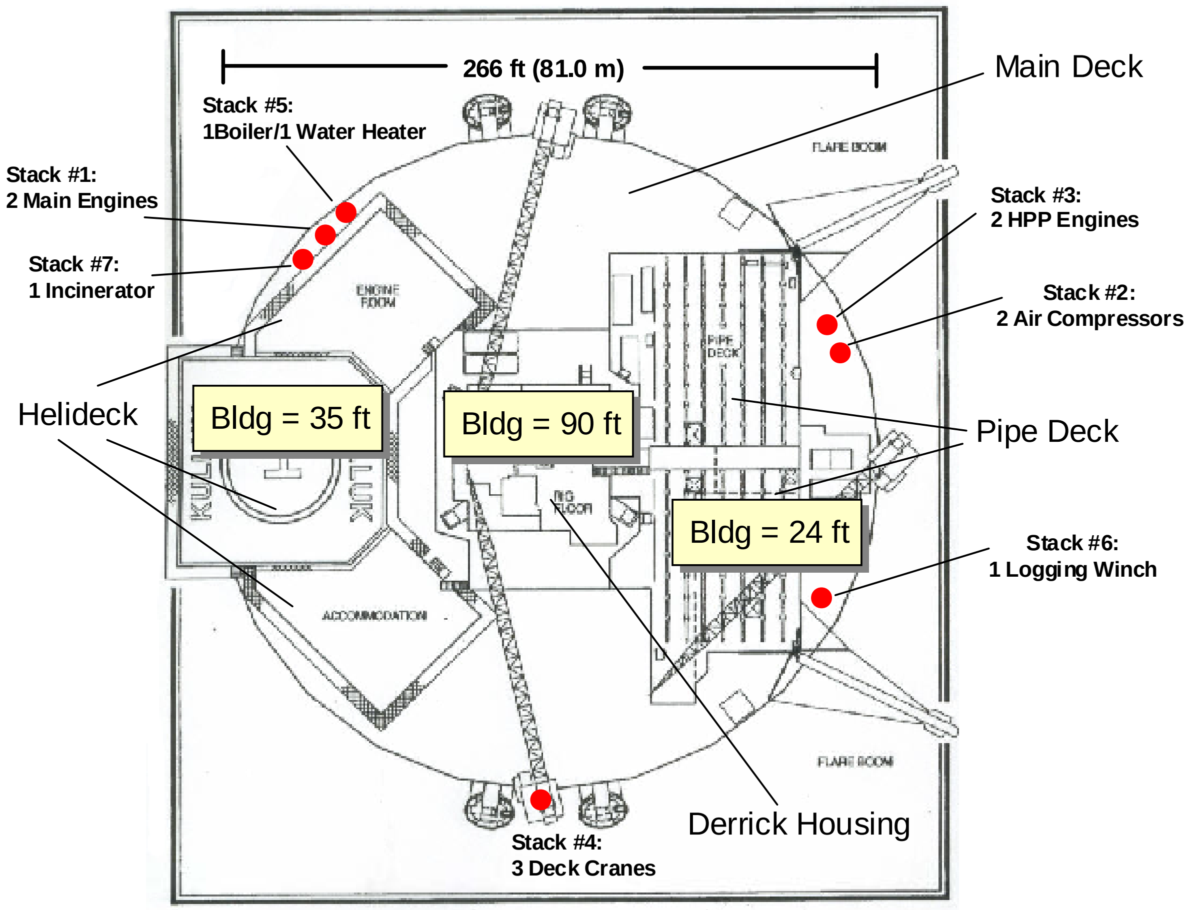
[A] Diameter and exit velocity are adjusted since stacks emit horizontally.
Non-adjusted stack diameter is 1.67 feet (0.51 meters) and non-adjusted exit velocity is 36.6 m/sec.

[B] Diameter and exit velocity are adjusted since stacks emit horizontally.
Non-adjusted stack diameter is 0.5 feet (0.15 meters) and non-adjusted exit velocity is 16.1 m/sec.

[C] Diameter and exit velocity are adjusted since stacks emit horizontally.
Non-adjusted stack diameter is 1.5 feet (0.46 meters) and non-adjusted exit velocity is 10 m/sec.

[1] Above main deck that is approximately 7.3 meters (24 feet) above the water surface.

Figure 1: Configuration of Platform Equipment



Given the configuration of the stacks and structures on the Shell Kulluk, it is expected that the plumes will be down-washed and pulled into the wake of the Shell Kulluk and adjacent Jim Kilabuk. In ISC-PRIME, the dimensions of buildings in proximity to the stacks are needed to simulate building downwash. A building analysis (i.e., BPIP analysis) was performed for the modeling analysis using the BPIP Prime program (Version: 04274).

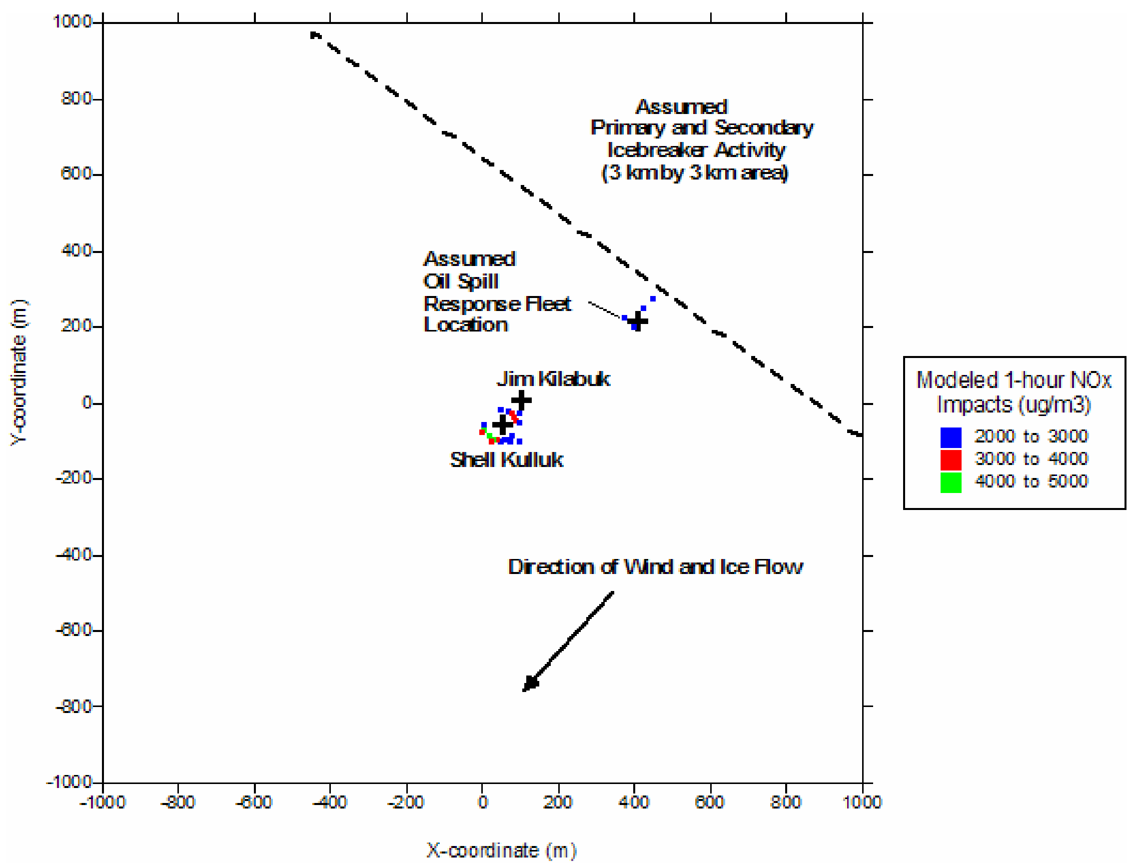
Jim Kilabuk – Re-Supply Ship

In this replacement impact analysis, which addresses the support vessels near the Shell Kulluk, building downwash is considered for the Jim Kilabuk as if docked to the rig in idle/standby mod, which we define as less than 25 percent power load. The Jim Kilabuk is a re-supply vessel that will visit the drill rig approximately once every two weeks, for a 24-hour load transfer in idle/standby mode. For this modeling analysis, it is assumed that the Jim Kilabuk is located next to the Shell Kulluk 24 hours per day for the duration of the drilling project.

OSR Fleet

Regarding the OSR fleet, only in rare cases would the OSR fleet need to approach the drill vessel. Typically, the OSR fleet will be moving and ranging within a few miles of the drill rigs. It is unlikely that the OSR fleet and the Jim Kilabuk would be at or near the drilling vessel simultaneously, and in this scenario the OSR fleet could be represented by an elevated area source (further from the drill rig), but was modeled as a nearby point source to concentrate emissions directly upwind of the drill vessel for the duration of the project. The maximum 1-hour NO_x impacts from the Shell Kulluk and Jim Kilabuk were analyzed, and the OSR fleet was then positioned in an area of high impacts upwind of drill rig as shown in Figure 2.

Figure 2: Source Configuration Based on NO_x Modeling of the Shell Kulluk and Jim Kilabuk Only



Icebreakers

For the worst-case modeling scenario, the primary and secondary icebreakers are assumed to be operating in heavy ice, which results in maximum emissions from these vessels. The distance the icebreakers operate from the drill rig is variable based on the character of the ice, the drift rate of the ice, and the weather forecast/conditions. In general, the icebreakers will break ice directly upstream from the drill rig. The primary icebreaker will range from approximately 5 km to 20 km upstream from the drill rig. The primary icebreaker will move back and forth perpendicular to the drift line approximately 5 km either side of the drift line to the rig. The secondary icebreaker will range from the buoy pattern of the drill rig up to 10 km upstream of the rig. The secondary icebreaker will move back and forth perpendicular to the drift line approximately 2.5 km either side of the drift line to the rig. Secondary ice management could be performed by several different icebreakers, of which the highest emissions would be from the Fennica/Nordica. Therefore, the Fennica/Nordica emissions were used in the modeling analysis.

For this modeling analysis, both the primary and secondary icebreaking activity is assumed to be concentrated close to the drill rig, between 500 meters and 3 kilometers from the rig. Given the mobile nature of the icebreakers, and the ISC-PRIME model's limitations regarding mobile sources, the sources were modeled as an elevated area source rather than point sources. Each icebreaker was initially modeled as a point source with SCREEN3 (a tool used to determine plume rise) to account for mechanical and buoyant lift from the ship's stacks. The final plume rise for the icebreakers was determined, and the emissions from each icebreaker were then modeled as an elevated area source (based on the lowest final plume height of the two breakers) covering the assumed ice management area for the icebreakers.

For the support vessels, stack heights were estimated from photographs and ship diagrams. Other stack parameters were determined using ship-specific information, engineering judgment, and data for comparable sources. Emissions from each ship are assumed to be released to the atmosphere via a single stack.

The physical characteristics of the stacks on the support vessels are provided in Table 2.

Table 2: Support Vessel Source Stack Parameters

Source Description	Model Source ID	Source Type	Ship Type	Release Ht. [1] (ft)	Release Ht. [1] (m)	Stack Dia. (ft)	Stack Dia. (m)	Exit Temp. (deg F)	Exit Temp. (deg K)	Exit Vel. (m/s)
Vladimir Ignatjuk [3,4]	VLADIMIR/BREAKERS	Point/Area	Primary Icebreaker	80.0	24.38	1.31	0.40	662	623	18.7
Fennica/Nordica [3,5,6]	FENNICA/BREAKERS	Point/Area	Secondary Icebreaker	105.0	32.00	0.87	0.27	572	573	36.0
Oil Response Ships – Shell Kulluk [2]	OILSPILL	Point	Oil Spill Response Fleet	50.0	15.24	0.60	0.18	800	700	40.0
Jim Kilabuk – Shell Kulluk	KILABUK	Point	Re-supply Ship	50.0	15.24	0.60	0.18	800	700	40.0

[1] Absolute height above water.
[2] Assume same stack parameters as the Jim Kilabuk re-supply ship.
[3] These sources are constantly moving to break ice upstream of the drill rig. To account for movement of the vessels, the plume rise for each icebreaker was determined by modeling each ship as a point source. Then, the emissions for each icebreaker were modeled as an elevated area source (based on plume rise) covering the ice management area for each ship.
[4] Vladimir Ignatjuk ice management activity covers 9,000,000 sq. meters; final plume rise used for area source release height is 57.2 meters.
[5] Fennica/Nordica ice management activity covers 9,000,000 sq. meters; final plume rise used for area source release height is 57.2 meters.
[6] The Fennica/Nordica was considered in the modeling analysis since this ship has the highest emissions of any secondary icebreaker.

2.2 Modeled Emissions

The modeling analysis considers all emission sources operating 24 hours per day and 60 days per year even though actual durations at a given drill site will be significantly less.

As described in Section 2.1, a single trash incinerator (125 kg/hr) is now considered on the Shell Kulluk. In addition, a similar trash incinerator (125 kg/hr) is also located on the OSR fleet. These incinerators were not included in the permit application. More information regarding emissions for the trash incinerators is provided in Appendix A.

Tables 3, 4, and 5 present the modeled emissions for NO_x, PM_{10}, and SO_2, respectively.

Table 3: Modeled NO_x Emissions

	#	Operations		Emissions Max. 1-Hour	
Source ID	Stacks	hr/day	hr/yr	(lb/hr)	(g/sec)
Drill Rig: Shell Kulluk					
Stack #1: 2 Main Engines	1	24	1,440	87.86	1.11E+01
Stack #2: 2 Air Compressors	1	24	1,440	6.58	8.29E-01
Stack #3: 2 HPP Engines	1	24	1,440	15.50	1.95E+00
Stack #4: 3 Crane Engines	1	24	1,440	31.62	3.98E+00
Stack #5: 1 Boiler/1 Water Heater	1	24	1,440	0.42	5.30E-02
Stack #6: 1 Logging Winch	1	24	1,440	4.34	5.47E-01
Stack #7: 1 Incinerator	1	24	1,440	0.41	5.20E-02
Support Vessels: Shell Kulluk Fleet					
Vladimir Ignatjuk	1	24	1,440	591.66	7.45E+01
Fennica/Nordica	1	24	1,440	523.07	6.59E+01
Oil Response Ships – Shell Kulluk [1]	1	24	1,440	202.64	2.55E+01
Jim Kilabuk – Shell Kulluk [2]	1	24	1,440	45.46	5.73E+00

[1] Emissions include a trash incinerator (125 kg/hr) which was not included in the permit application.
[2] Will be in standby mode while docked to rig. To be conservative, assume 25-percent utilization for modeling purposes.

Table 4: Modeled PM_{10} Emissions

	#	Operations		Emissions Max. 1-Hour	
Source ID	Stacks	hr/day	hr/yr	(lb/hr)	(g/sec)
Drill Rig: Shell Kulluk					
Stack #1: 2 Main Engines	1	24	1,440	3.97	5.00E-01
Stack #2: 2 Air Compressors	1	24	1,440	0.33	4.15E-02
Stack #3: 2 HPP Engines	1	24	1,440	1.10	1.39E-01
Stack #4: 3 Crane Engines	1	24	1,440	2.24	2.83E-01
Stack #5: 1 Boiler/1 Water Heater	1	24	1,440	0.07	8.74E-03
Stack #6: 1 Logging Winch	1	24	1,440	0.31	3.88E-02
Stack #7: 1 Incinerator	1	24	1,440	0.96	1.21E-01
Support Vessels: Shell Kulluk Fleet					
Vladimir Ignatjuk	1	24	1,440	11.10	1.40E+00
Fennica/Nordica	1	24	1,440	11.27	1.42E+00
Oil Response Ships - Shell Kulluk [1]	1	24	1,440	6.17	7.78E-01
Jim Kilabuk – Shell Kulluk [2]	1	24	1,440	0.88	1.11E-01

[1] Emissions include a trash incinerator (125 kg/hr) which was not included in the permit application.
[2] Will be in standby mode while docked to rig. To be conservative, assume 25-percent utilization for modeling purposes.

Table 5: Modeled SO_2 Emissions

	#	Operations		Emissions Max. 1-Hour	
Source ID	Stacks	hr/day	hr/yr	(lb/hr)	(g/sec)
Drill Rig: Shell Kulluk					
Stack #1: 2 Main Engines	1	24	1,440	8.66	1.09E+00
Stack #2: 2 Air Compressors	1	24	1,440	1.54	1.94E-01
Stack #3: 2 HPP Engines	1	24	1,440	0.77	9.68E-02
Stack #4: 3 Crane Engines	1	24	1,440	1.57	1.98E-01
Stack #5: 1 Boiler/1 Water Heater	1	24	1,440	0.08	1.01E-02
Stack #6: 1 Logging Winch	1	24	1,440	0.22	2.71E-02
Stack #7: 1 Incinerator	1	24	1,440	0.34	4.33E-02
Support Vessels: Shell Kulluk Fleet					
Vladimir Ignatjuk	1	24	1,440	38.02	4.79E+00
Fennica/Nordica	1	24	1,440	34.74	4.38E+00
Oil Response Ships - Shell Kulluk [1]	1	24	1,440	19.08	2.40E+00
Jim Kilabuk – Shell Kulluk [2]	1	24	1,440	2.88	3.63E-01

[1] Emissions include a trash incinerator (125 kg/hr) which was not included in the permit application.
[2] Will be in standby mode while docked to rig. To be conservative, assume 25-percent utilization for modeling purposes.

2.3 Model Selection

After research into the availability of meteorological data for use in modeling, it was determined that representative meteorological data meeting U.S. EPA's requirements is not available for the project location. This issue has been discussed with EPA Region 10 and on February 9, 2007, EPA Region 10 approved the use of the ISC-PRIME model with screening meteorological data (i.e., worst-case meteorological data) for this modeling analysis.

The most recent version (04269) of the ISC-PRIME dispersion model was used to estimate the air quality impacts resulting from the project's air emissions. The ISC-PRIME model is a U.S. EPA-approved, steady-state, multiple-source, Gaussian plume model which is appropriate for applications affected by building wake effects. ISC-PRIME can be used to estimate pollutant concentrations at receptors located in simple terrain and complex terrain (within 50 km of a source) due to emissions from a wide variety of sources associated with an industrial source complex. The model is based on the Industrial Source Complex (ISC) model, with the PRIME (Plume RIse Model Enhancements) algorithm added for improved treatment of building downwash.

2.4 Meteorological Data

For this analysis, an ISC-PRIME compatible meteorological data set was generated using the SCREEN3 model's full array of screening meteorological data. Screening meteorological data are the meteorological categories listed in U.S. EPA's "SCREEN3 Model User's Guide" (EPA-454/B-95-004) and as shown in Table 6. A total of 72 wind directions, at 5-degree intervals, are used. Thus, the screening meteorological file contains all combinations of meteorological conditions and wind directions. This meteorological data considers theoretical worst-case conditions regardless if these conditions will actually occur at the project locations.

Table 6: Wind Speed and Stability Class Combinations Used For Screening Modeling

	Wind Speed (m/sec)												
Stability	1	1.5	2	2.5	3	3.5	4	4.5	5	8	10	15	20
A	*	*	*	*	*								
B	*	*	*	*	*	*	*	*	*				
C	*	*	*	*	*	*	*	*	*	*	*		
D	*	*	*	*	*	*	*	*	*	*	*	*	*
E	*	*	*	*	*	*	*	*	*				
F	*	*	*	*	*	*	*						

SCREEN3's default ambient temperature of 293 K was utilized. In addition, the guidance provided in the SCREEN3 Model User's Guide for mixing heights was utilized.

The mixing height used in SCREEN3 for neutral and unstable conditions (classes A-D) is based on an estimate of the mechanically driven mixing height. The mechanical mixing height for these conditions equals 320 times the wind speed. For stable conditions (classes E-F), the mixing height is set equal to 10,000 meters to represent unlimited mixing.

2.5 Background Concentrations

When comparing a project's impact to the ambient air quality standards, an ambient background concentration is needed. For the project, ADEC recommended ambient background concentrations from BP's Arctic North Slope Eastern Region (ANSER) monitoring program, which took place east of BP's Badami facility in 1999. The data is considered representative of the SOI project locations and has been reviewed and approved by ADEC. ADEC considers this data the best available regional data set for a North Slope project located 10 to 20 km or further offshore. Table 7 presents the background concentrations for use in the modeling analysis.

Table 7: Background Concentrations

Pollutant	Averaging Period	Background Concentration (μg/m^3)
NO_2	Annual	3.0
PM_{10}	24-hour	7.9
	Annual	1.8
SO_2	3-hour	9.8
	24-hour	7.2
	Annual	2.6

ADEC was also consulted regarding existing industrial sources in the vicinity of the project. Because of the remote offshore location of the project, impacts from other sources are anticipated to be insignificant and are not included in the modeling assessment.

2.6 Evaluation Methodology

When using screening meteorological data in ISC-PRIME, the model can only be used to predict maximum 1-hour concentrations from the modeled sources.

Conversion factors, also referred to as persistence factors, are needed to convert maximum 1-hour values to other averaging periods of concern. Table 8 presents the U.S. EPA's recommended conversion factors when using screening meteorological data.

Table 8: Conversion Factors for Modeling With Screening Meteorological Data

	Desired Averaging Period						
Model Output	1-hr	3-hr	8-hr	24-hr	Month	Quarter	Annual
Simple Terrain	1	0.9	0.7	0.4	0.18	0.13	0.08

For short-term averaging periods, no further adjustments are made to the modeled calculations since 24 hours per day operations are assumed for the project. On the other hand, annual impacts consider the totality of emissions over a 60-day project duration. Because emissions used in the analysis are based on a 60-day operating period, the annual emissions from the project are distributed over 60 days (rather than 365) and a factor of 0.1644 (60 days/365 days) is applied to annualize the subsequent impacts.

Flat terrain and rural dispersion coefficients were used in the modeling analysis. For this modeling analysis, it was assumed that the ambient air boundary for the Shell Kulluk is the side of the Shell Kulluk (i.e., no exclusion zone). Receptors were spaced approximately every 10 meters around the Shell Kulluk, at 25-meter resolution within one kilometer of the Shell Kulluk, and at 50-meter resolution between 1 kilometer and 6 kilometers from the Shell Kulluk, covering the nearby ice management activity.

2.7 Modeling Results

Table 9 summarizes the results of the ISC-PRIME modeling analysis. Based on the modeling analysis results in Table 9, the predicted impacts from the SOI project comply with the National Ambient Air Quality Standards. The maximum impacts are located adjacent to the Shell Kulluk and are dominated by sources on the Shell Kulluk and the Jim Kilabuk. For any pollutant, the primary and secondary icebreakers account for less than two percent of the maximum impact.

Table 9: Modeling Analysis Results

Pollutant	Averaging Period	Max. Modeled 1-Hour Impact (μg/m³)	Persistence Factor	Emissions Adjustment [B]	Background Concentration (μg/m³)	Total Impact [C] (μg/m³)	NAAQS (μg/m³)	Comply?
NO_2 [A]	Annual	6,554.2	0.08	0.1644	3.0	67.6	100	Yes
PM_{10}	24-hour	258.1	0.4	1	7.9	111.1	150	Yes
	Annual	258.1	0.08	0.1644	1.8	5.2	50	Yes
SO_2	3-hour	512.2	0.9	1	9.8	470.8	1,300	Yes
	24-hour	512.2	0.4	1	7.2	212.1	365	Yes
	Annual	512.2	0.08	0.1644	2.6	9.3	80	Yes

[A] Assume that all NO_2 = NOx * 0.75

[B] Annual emissions adjustment to modeled hourly emissions to account for duration at each drill site (i.e., 60 days per site/365 days = 0.1644). Short-term emissions are not adjusted since 24 hours per day operations are considered.

[C] Total modeled impact is the product of the maximum modeled 1-hour impacts, meteorological persistence, and emissions adjustments plus background concentrations.

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APPENDIX A
Incinerator Stack Parameters

AIR SCIENCES INC. DENVER • PORTLAND	Air Sciences Inc. CALCULATIONS	PROJECT TITLE: Shell Kulluk	BY: T. Martin
		PROJECT NO: 180-15	PAGE 1 OF 1 SHEET 0
		SUBJECT: Drill Rig Incineration	DATE: 2/19/2007

Emissions

Incinerator Rating: 125 kg/hr, 275 lb/hr, 0.14 ton/hr

Operating Schedule: 24 hrs/day, 60 days/yr

Pollutant	# Stacks	Emission Factor (lb/ton) [1]	Emissions Max. 1-Hour (lb/hr)	Max. 1-Hour (g/sec)	Max. 24-Hour (lb/day)	Max. 24-Hour (g/sec) *	Annual Average (tons/yr)	Annual Average (g/sec) *
NOx	1	3.0	0.41	5.20E-02	9.9	5.20E-02	0.30	8.54E-03
PM_{10}	1	7.0	0.96	1.21E-01	23.1	1.21E-01	0.69	1.99E-02
SO_2	1	2.5	0.34	4.33E-02	8.3	4.33E-02	0.25	7.12E-03

[1] Emission factor from AP-42, Table 2.1-12; industrial/commercial, multiple chamber combustors.
* Emission rate (in g/s) for annual periods is adjusted to account for a maximum of 60 days at each drill site

Stack Parameters For Modeling

Shell Kulluk

Source Description	Model ID	Source Type	Vertical or Horizontal?	Release Ht. [1] (ft)	Release Ht. (m)	Stack Dia. (ft)	Stack Dia. (m)	Exit Temp. (deg F)	Exit Temp. (deg K)	Exit Vel. (m/s)
Stack #7: 1 Incinerator [A, 2]	INCIN_K	POINT	Horizontal	34.5	10.52	149.9	45.7	662	623	0.001

[A] Diameter and exit velocity adjusted since stack emits horizontally.
Non-adjusted stack dia. is 1.5 feet (0.46 meters) and non-adjusted exit velocity is 10 m/sec.
[1] Above main deck which is approximately 7.31 meters (24 feet) above the water surface.
[2] Assume stack is located near main engine stack on rig and is affected by same building downwash as main engine stack.

Input values are denoted in blue.

Air Quality Impact Evaluation Report – No Exclusion Zone

Frontier Discoverer Beaufort Sea Exploratory Drilling Program

Prepared for:

SHELL OFFSHORE, INC.

PROJECT 180-15
FEBRUARY 19, 2007

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SECTION 1

INTRODUCTION

On December 29, 2006, Shell Offshore, Inc. (SOI) submitted an application to U.S. EPA's Region 10 (EPA) office, pursuant to the requirements of Outer Continental Shelf Air Regulations, 40 CFR Part 55. SOI wishes to conduct exploratory drilling activity at its oil and gas lease blocks on Outer Continental Shelf (OCS) waters in the Beaufort Sea using the Frontier Discoverer drilling vessel and associated support vessels.

This air quality impact report supersedes the impact analysis of the December 29, 2006, permit application and provides an ambient impact analysis demonstrating that the proposed project complies with the National Ambient Air Quality Standards (NAAQS) without consideration of a probable exclusion zone around the Frontier Discoverer and associated support vessels. For this analysis, the primary difference is the dispersion model used which is now the ISC-PRIME model, which replaces the SCREEN3 model.

There are a few minor changes in source assumptions in this analysis and these are highlighted in this report. Otherwise, the reader is referred to the permit application for details regarding the proposed project. Electronic modeling files for this analysis are provided to EPA by e-mail.

SECTION 2

AMBIENT IMPACT ANALYSIS (DISPERSION MODELING)

This section describes the ambient standards to be addressed for the exploration drilling activities, the model selected for use in addressing these standards, and the selection of inputs to the model in a manner consistent with acceptable EPA and Alaska Department of Environmental Conservation (ADEC) modeling methods.

The Outer Continental Shelf (OCS) permitting requirements of 40 CFR Part 55.14 require that a permit application address the Corresponding Onshore Area (COA) requirements, which for the Frontier Discoverer Exploratory Drilling Program are the ADEC requirements for the Northern Alaska Intrastate Air Quality Control Region (AQCR) 9. This region is designated attainment or unclassifiable for all criteria pollutants pursuant to 40 CFR 81.302. This area is designated as a Prevention of Significant Deterioration (PSD) Class II Area per 18 AAC 50.015. There are no Class I areas within 300 kilometers of the project location. The nearest Class I area (Denali National Park) is located approximately 700 kilometers to the south of the project location.

Emissions from the project will not exceed the 250-ton-per-year Prevention of Significant Deterioration (PSD) major source review threshold. However, because the project is considered a portable oil and gas operation by the ADEC, a minor permit is required per ADEC Regulation 18 AAC 50.502(c)(2)(A). As a result, a National Ambient Air Quality Standards (NAAQS) modeling analysis for SO_2, NO_x, and PM_{10} is required per ADEC Regulation 18 AAC 50.540(c)(2)(B). For the impact analysis, emissions from the stationary source (the Frontier Discoverer) and the associated mobile sources (i.e., icebreakers, oil spill response vessels, and a re-supply vessel) were modeled for impact.

2.1 Source Characterization

The worst-case modeling impact scenario is expected to be with the Frontier Discoverer drilling and generators operating at maximum power output. During Frontier Discoverer’s maximum drilling operations, impacts from the oil spill response (OSR) fleet, operating near the drill rig, and the Jim Kilabuk re-supply vessel operating adjacent to the drill rig are considered. The emissions from the propulsion engines on the Frontier Discoverer and the Jim Kilabuk are not considered in the assessment, since these propulsion engines will be used very briefly to maneuver the Frontier Discoverer when it is being anchored or to maneuver the Jim Kilabuk when it is near the Frontier Discoverer drill rig. For the Jim Kilabuk, emissions from the two main (non-propulsion) engines and a generator, operating at less than 25 percent capacity, are considered for modeling. In addition, primary and secondary icebreaker impacts are also included under full power, several kilometers upwind of the drill rig, and in heavy ice (worst-case emissions) for the duration of the project. The only other operating scenario involving large engines operating at capacity is when the Frontier Discoverer is being towed between drilling locations. Under this scenario, when the rig is being towed, the Frontier Discoverer no longer qualifies as a stationary source.

SOI has estimated that the duration at a given drill site is expected to be less than 45 days. Even though the Frontier Discoverer Exploratory Drilling Program will be permitted as a minor source and will not trigger PSD requirements, the modeling analysis considers sources operating 24 hours per day and 45 days per year. These assumptions combined with the use of the ISC-PRIME model utilizing screening meteorological data are expected to overestimate real-world impacts from the project.

Frontier Discoverer Drill Rig

For modeling, some sources on the Frontier Discoverer were merged together because of size and location considerations. Many identical sources/stacks are located near each other and were collocated so that single-source stack parameters with combined emissions were used. The locations of the collocated stacks were placed at the actual stack location nearest the ambient air boundary, which will be the hull of the vessel.

The following sources on the Frontier Discoverer were collocated: six main drilling engines (stack #1), two air compressors (stack #2), two HPP engines (stack #3), three diesel crane engines (stack #4), and two heat boilers (stack #5). Because stack parameters for the two cementing units are unknown at this time, the emissions from two cementing units (which are similar in size to the HPP engines) were modeled out of the HPP engine stack (stack #3). A logging winch emits to the atmosphere via a single stack (stack #6). A single trash incinerator located on the Frontier Discoverer (not included in the permit application) emits to the atmosphere via a single stack (stack #7). More information regarding emissions and stack release parameters for the trash incinerator are provided in Appendix A. These seven stacks were considered as point sources in the modeling analysis.

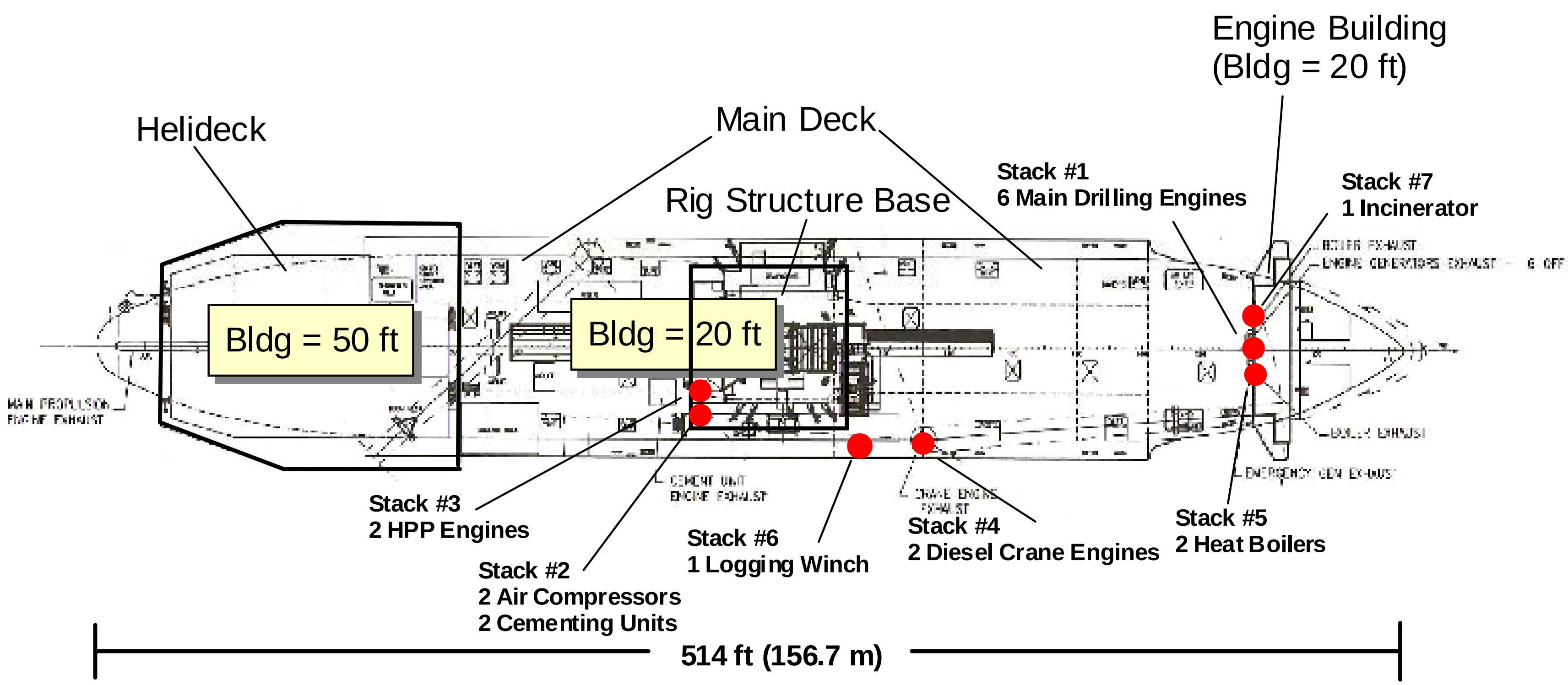
The physical characteristics of the stacks on the Frontier Discoverer are provided in Table 1. The configuration of the sources on the Frontier Discoverer deck is shown on Figure 1.

Table 1: Frontier Discoverer Source Stack Parameters

Source Description	Model Source ID	Source Type	Vertical or Horizontal?	Release Ht.[1] (ft)	Release Ht.[1] (m)	Stack Dia. (ft)	Stack Dia. (m)	Exit Temp. (deg. F)	Exit Temp. (deg. K)	Exit Vel. (m/s)
Stack #1: 6 Main Drilling Engines	MAINENGS	Point	vertical	42.1	12.83	1.15	0.35	437	498	63.3
Stack #2: 2 Air Compressors	COMPENGS	Point	vertical	28.0	8.53	0.69	0.21	800	700	40.0
Stack #3: 2 HPP Engines[2]	HPPENGS	Point	vertical	28.0	8.53	0.60	0.18	800	700	40.0
Stack #4: 2 Crane Engines	DECKCRNS	Point	vertical	45.0	13.72	0.83	0.25	750	672	20.1
Stack #5: 2 Heat Boilers	HEATBOIL	Point	vertical	42.1	12.83	1.50	0.46	200	366	7.3
Stack #6: 1 Logging Winch	LOGWNCH	Point	vertical	10.3	3.12	0.33	0.10	820	711	53.0
Stack #7: 1 Incinerator	INCIN_D	Point	vertical	42.1	12.83	1.50	0.46	662	623	10.0

[1] Above main deck that is approximately 4.57 meters (15 feet) above the water surface.
[2] Also includes emissions from two cementing units.

Figure 1: Configuration of Platform Equipment



Given the configuration of the stacks and structures on the Frontier Discoverer, it is expected that the plumes will be down-washed and pulled into the wake of the Frontier Discoverer and adjacent Jim Kilabuk. In ISC-PRIME, the dimensions of buildings in proximity to the stacks are needed to simulate building downwash. A building analysis (i.e., BPIP analysis) was performed for the modeling analysis using the BPIP Prime program (Version: 04274).

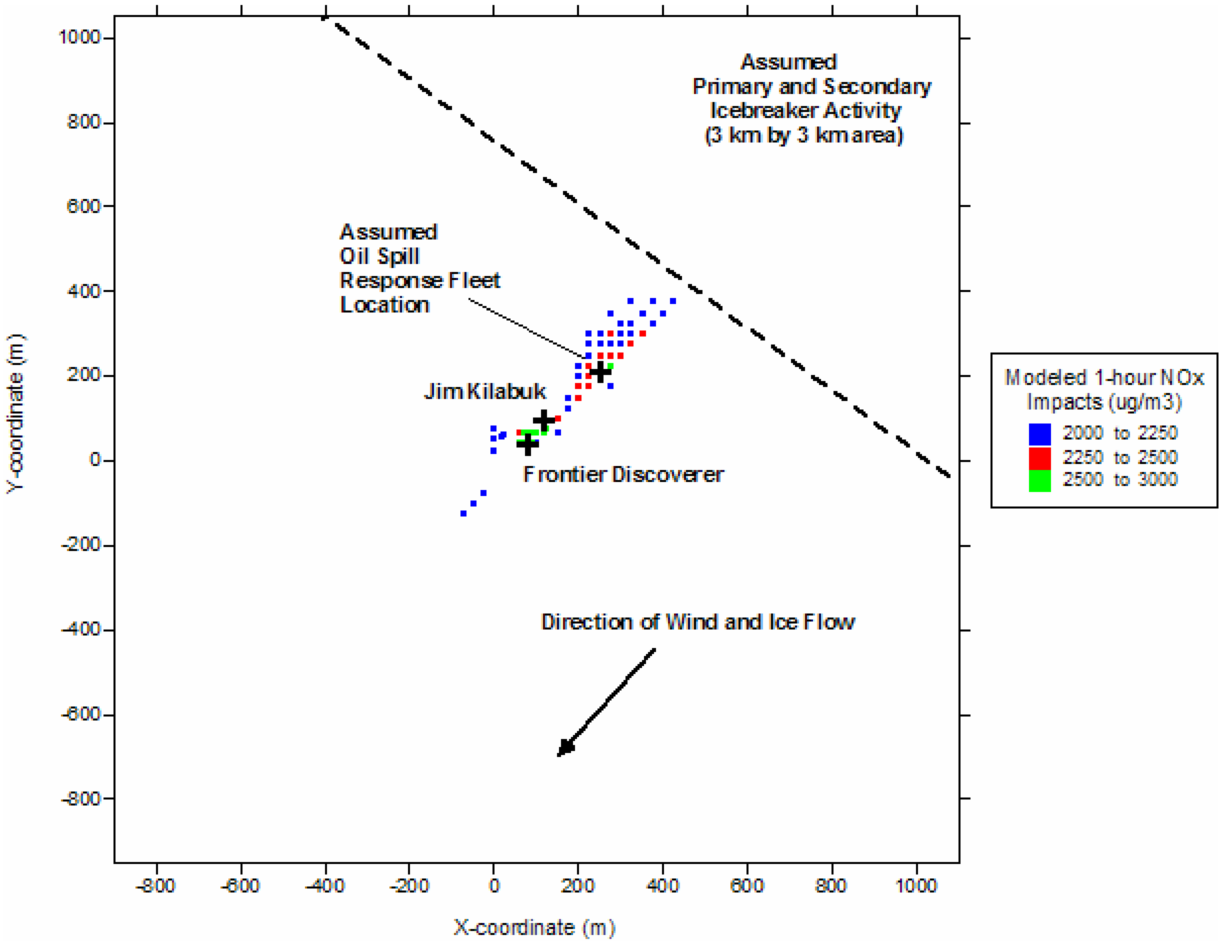
Jim Kilabuk – Re-Supply Ship

In this replacement impact analysis, which addresses the support vessels near the Frontier Discoverer, building downwash is considered for the Jim Kilabuk as if docked to the rig in idle/standby mode, which we define as less than 25 percent power load. The Jim Kilabuk is a re-supply vessel that will visit the drill rig approximately once every two weeks, for a 24-hour load transfer in idle/standby mode. For this modeling analysis, it is assumed that the Jim Kilabuk is located next to the Frontier Discoverer 24 hours per day for the duration of the drilling project.

OSR Fleet

Regarding the OSR fleet, only in rare cases would the OSR fleet need to approach the drill vessel. Typically, the OSR fleet will be moving and ranging within a few miles of the drill rigs. It is unlikely that the OSR fleet and the Jim Kilabuk would be at or near the drilling vessel simultaneously, and in this scenario the OSR fleet could be represented by an elevated area source (further from the drill rig), but was modeled as a nearby point source to concentrate emissions directly upwind of the drill vessel for the duration of the project. The maximum 1-hour NO_x impacts from the Frontier Discoverer and Jim Kilabuk were analyzed, and the OSR fleet was then positioned in an area of high impacts upwind of drill rig as shown in Figure 2.

Figure 2: Source Configuration Based on NO_x Modeling of the Frontier Discoverer and Jim Kilabuk Only



Icebreakers

For the worst-case modeling scenario, the primary and secondary icebreakers are assumed to be operating in heavy ice, which results in maximum emissions from these vessels. The distance the icebreakers operate from the drill rig is variable based on the character of the ice, the drift rate of the ice, and the weather forecast/conditions. In general, the icebreakers will break ice directly upstream from the drill rig. The primary icebreaker will range from approximately 5 km to 20 km upstream from the drill rig. The primary icebreaker will move back and forth perpendicular to the drift line approximately 5 km either side of the drift line to the rig. The secondary icebreaker will range from the buoy pattern of the drill rig up to 10 km upstream of the rig. The secondary icebreaker will move back and forth perpendicular to the drift line approximately 2.5 km either side of the drift line to the rig. Secondary ice management could be performed by several different icebreakers, of which the highest emissions would be from the Fennica/Nordica. Therefore, the Fennica/Nordica emissions were used in the modeling analysis.

For this modeling analysis, both the primary and secondary icebreaking activity is assumed to be concentrated close to the drill rig, between 500 meters and 3 kilometers from the rig. Given the mobile nature of the icebreakers, and the ISC-PRIME model's limitations regarding mobile sources, the sources were modeled as an elevated area source rather than point sources. Each icebreaker was initially modeled as a point source with SCREEN3 (a tool used to determine plume rise) to account for mechanical and buoyant lift from the ship's stacks. The final plume rise for the icebreakers was determined, and the emissions from each icebreaker were then modeled as an elevated area source (based on the lowest final plume height of the two breakers) covering the assumed ice management area for the icebreakers.

For the support vessels, stack heights were estimated from photographs and ship diagrams. Other stack parameters were determined using ship-specific information, engineering judgment, and data for comparable sources. Emissions from each ship are assumed to be released to the atmosphere via a single stack.

The physical characteristics of the stacks on the support vessels are provided in Table 2.

Table 2: Support Vessel Source Stack Parameters

Source Description	Model Source ID	Source Type	Ship Type	Release Ht. [1] (ft)	Release Ht. [1] (m)	Stack Dia. (ft)	Stack Dia. (m)	Exit Temp. (deg F)	Exit Temp. (deg K)	Exit Vel. (m/s)
Kapitan Dranitsyn [3, 4]	KAPITAN/BREAKERS	Point/Area	Primary Icebreaker	115.0	35.05	1.05	0.32	482	523	41.5
Fennica/Nordica [3, 5, 6]	FENNICA/BREAKERS	Point/Area	Secondary Icebreaker	105.0	32.00	0.87	0.27	572	573	36.0
Oil Response Ships – Frontier Discoverer [2]	OILSPILL	Point	Oil Spill Response Fleet	50.0	15.24	0.60	0.18	800	700	40.0
Jim Kilabuk – Frontier Discoverer	KILABUK	Point	Re-supply Ship	50.0	15.24	0.60	0.18	800	700	40.0

1 Absolute height above water.
2 Assume same stack parameters as the Jim Kilabuk re-supply ship.
3 These sources are constantly moving to break ice upstream of the drill rig. To account for movement of the vessels, the plume rise for each icebreaker was determined by modeling each ship as a point source. Then, the emissions for each icebreaker were modeled as an elevated area source (based on plume rise) covering the ice management area for each ship.
4 Kapitan Dranitsyn ice management activity covers 9,000,000 sq. meters; final plume rise used for area source release height is 60.9 meters.
5 Fennica/Nordica ice management activity covers 9,000,000 sq. meters; final plume rise used for area source release height is 60.9 meters.
6 The Fennica/Nordica was considered in the modeling analysis since this ship has the highest emissions of any secondary icebreaker.

2.2 Modeled Emissions

The modeling analysis conservatively considers all emission sources operating 24 hours per day and 45 days per year even though actual durations at a given drill site will be significantly less.

As described in Section 2.1, a single trash incinerator (125 kg/hr) is now considered on the Shell Frontier Discoverer. In addition, a similar trash incinerator (125 kg/hr) is also located on the OSR fleet. These incinerators were not included in the permit application. More information regarding emissions for the trash incinerators is provided in Appendix A.

Tables 3, 4, and 5 present the modeled emissions for NO_x, PM_{10}, and SO_2, respectively.

Table 3: Modeled NO_x Emissions

Source ID	# Stacks	Operations hr/day	Operations hr/yr	Emissions Max. 1-Hour (lb/hr)	Emissions Max. 1-Hour (g/sec)
Drill Rig: Frontier Discoverer					
Stack #1: 6 Main Drilling Engines	1	24	1,080	124.30	1.57E+01
Stack #2: 2 Air Compressors	1	24	1,080	6.58	8.29E-01
Stack #3: 2 HPP Engines [1]	1	24	1,080	35.65	4.49E+00
Stack #4: 2 Diesel Crane Engines	1	24	1,080	22.63	2.85E+00
Stack #5: 2 Heat Boilers	1	24	1,080	3.20	4.04E-01
Stack #6: 1 Logging Winch	1	24	1,080	4.34	5.47E-01
Stack #7: 1 Incinerator	1	24	1,080	0.41	5.20E-02
Support Vessels: Frontier Discoverer Fleet					
Kapitan Dranitsyn	1	24	1,080	699.77	8.82E+01
Fennica/Nordica	1	24	1,080	523.07	6.59E+01
Oil Response Ships – Frontier Discoverer [2]	1	24	1,080	151.62	1.91E+01
Jim Kilabuk – Frontier Discoverer [3]	1	24	1,080	45.46	5.73E+00

[1] Also includes emissions from two cementing units.
[2] Emissions include a trash incinerator (125 kg/hr) which was not included in the permit application.
[3] Will be in standby mode while docked to rig. To be conservative, assume 25% utilization for modeling purposes.

Table 4: Modeled PM_{10} Emissions

Source ID	# Stacks	Operations hr/day	Operations hr/yr	Emissions Max. 1-Hour (lb/hr)	Emissions Max. 1-Hour (g/sec)
Drill Rig: Frontier Discoverer					
Stack #1: 6 Main Drilling Engines	1	24	1,080	3.91	4.92E-01
Stack #2: 2 Air Compressors	1	24	1,080	0.33	4.15E-02
Stack #3: 2 HPP Engines [1]	1	24	1,080	2.53	3.19E-01
Stack #4: 2 Diesel Crane Engines	1	24	1,080	1.61	2.02E-01
Stack #5: 2 Heat Boilers	1	24	1,080	0.37	4.72E-02
Stack #6: 1 Logging Winch	1	24	1,080	0.31	3.88E-02
Stack #7: 1 Incinerator	1	24	1,080	0.96	1.21E-01
Support Vessels: Frontier Discoverer Fleet					
Kapitan Dranitsyn	1	24	1,080	14.76	1.86E+00
Fennica/Nordica	1	24	1,080	11.27	1.42E+00
Oil Response Ships – Frontier Discoverer [2]	1	24	1,080	4.18	5.27E-01
Jim Kilabuk – Frontier Discoverer [3]	1	24	1,080	0.88	1.11E-01

[1] Also includes emissions from two cementing units.
[2] Emissions include a trash incinerator (125 kg/hr) which was not included in the permit application.
[3] Will be in standby mode while docked to rig. To be conservative, assume 25% utilization for modeling purposes.

Table 5: Modeled SO_2 Emissions

Source ID	# Stacks	Operations hr/day	Operations hr/yr	Emissions Max. 1-Hour (lb/hr)	Emissions Max. 1-Hour (g/sec)
Drill Rig: Frontier Discoverer					
Stack #1: 6 Main Drilling Engines	1	24	1,080	11.82	1.49E+00
Stack #2: 2 Air Compressors	1	24	1,080	1.54	1.94E-01
Stack #3: 2 HPP Engines [1]	1	24	1,080	1.77	2.23E-01
Stack #4: 2 Diesel Crane Engines	1	24	1,080	1.12	1.41E-01
Stack #5: 2 Heat Boilers	1	24	1,080	0.44	5.49E-02
Stack #6: 1 Logging Winch	1	24	1,080	0.22	2.71E-02
Stack #7: 1 Incinerator	1	24	1,080	0.34	4.33E-02
Support Vessels: Frontier Discoverer Fleet					
Kapitan Dranitsyn	1	24	1,080	45.32	5.71E+00
Fennica/Nordica	1	24	1,080	34.74	4.38E+00
Oil Response Ships - Frontier Discoverer [2]	1	24	1,080	15.64	1.97E+00
Jim Kilabuk – Frontier Discoverer [3]	1	24	1,080	2.88	3.63E-01

[1] Also includes emissions from two cementing units.
[2] Emissions include a trash incinerator (125 kg/hr) which was not included in the permit application.
[3] Will be in standby mode while docked to rig. To be conservative, assume 25% utilization for modeling purposes.

2.3 Model Selection

After research into the availability of meteorological data for use in modeling, it was determined that representative meteorological data meeting U.S. EPA's requirements is not available for the project location. This issue has been discussed with EPA Region 10 and on February 9, 2007, EPA Region 10 approved the use of the ISC-PRIME model with screening meteorological data (i.e., worst-case meteorological data) for this modeling analysis.

The most recent version (04269) of the ISC-PRIME dispersion model was used to estimate the air quality impacts resulting from the project's air emissions. The ISC-PRIME model is a U.S. EPA-approved, steady-state, multiple-source, Gaussian plume model which is appropriate for applications affected by building wake effects. ISC-PRIME can be used to estimate pollutant concentrations at receptors located in simple terrain and complex terrain (within 50 km of a source) due to emissions from a wide variety of sources associated with an industrial source complex. The model is based on the Industrial Source Complex (ISC) model, with the PRIME (Plume RIse Model Enhancements) algorithm added for improved treatment of building downwash.

2.4 Meteorological Data

For this analysis, an ISC-PRIME compatible meteorological data set was generated using the SCREEN3 model's full array of screening meteorological data. Screening meteorological data are the meteorological categories listed in U.S. EPA's "SCREEN3 Model User's Guide" (EPA-454/B-95-004) and as shown in Table 6. A total of 72 wind directions, at 5-degree intervals, are used. Thus, the screening meteorological file contains all combinations of meteorological conditions and wind directions. This meteorological data considers theoretical worst-case conditions regardless if these conditions will actually occur at the project locations.

Table 6: Wind Speed and Stability Class Combinations Used For Screening Modeling

	Wind Speed (m/sec)												
Stability	1	1.5	2	2.5	3	3.5	4	4.5	5	8	10	15	20
A	*	*	*	*	*								
B	*	*	*	*	*	*	*	*	*				
C	*	*	*	*	*	*	*	*	*	*	*		
D	*	*	*	*	*	*	*	*	*	*	*	*	*
E	*	*	*	*	*	*	*	*	*				
F	*	*	*	*	*	*	*						

SCREEN3's default ambient temperature of 293 K was utilized. In addition, the guidance provided in the SCREEN3 Model User's Guide for mixing heights was utilized.

The mixing height used in SCREEN3 for neutral and unstable conditions (classes A-D) is based on an estimate of the mechanically driven mixing height. The mechanical mixing height for these conditions equals 320 times the wind speed. For stable conditions (classes E-F), the mixing height is set equal to 10,000 meters to represent unlimited mixing.

2.5 Background Concentrations

When comparing a project's impact to the ambient air quality standards, an ambient background concentration is needed. For the project, ADEC recommended ambient background concentrations from BP's Arctic North Slope Eastern Region (ANSER) monitoring program, which took place east of BP's Badami facility in 1999. The data is considered representative of the SOI project locations and has been reviewed and approved by ADEC. ADEC considers this data the best available regional data set for a North Slope project located 10 to 20 km or further offshore. Table 7 presents the background concentrations for use in the modeling analysis.

Table 7: Background Concentrations

Pollutant	Averaging Period	Background Concentration (μg/m^3)
NO_2	Annual	3.0
PM_{10}	24-hour	7.9
	Annual	1.8
SO_2	3-hour	9.8
	24-hour	7.2
	Annual	2.6

ADEC was also consulted regarding existing industrial sources in the vicinity of the project. Because of the remote offshore location of the project, impacts from other sources are anticipated to be insignificant and are not included in the modeling assessment.

2.6 Evaluation Methodology

When using screening meteorological data in ISC-PRIME, the model can only be used to predict maximum 1-hour concentrations from the modeled sources.

Conversion factors, also referred to as persistence factors, are needed to convert maximum 1-hour values to other averaging periods of concern. Table 8 presents the U.S. EPA's recommended conversion factors when using screening meteorological data.

Table 8: Conversion Factors for Modeling With Screening Meteorological Data

	Desired Averaging Period						
Model Output	1-hr	3-hr	8-hr	24-hr	Month	Quarter	Annual
Simple Terrain	1	0.9	0.7	0.4	0.18	0.13	0.08

For short-term averaging periods, no further adjustments are made to the modeled calculations since 24 hours per day operations are assumed for the project. On the other hand, annual impacts consider the totality of emissions over a 45-day project duration. Because emissions used in the analysis are based on a 45-day operating period, the annual emissions from the project are distributed over 45 days (rather than 365) and a factor of 0.1233 (45 days/365 days) is applied to annualize the subsequent impacts.

Flat terrain and rural dispersion coefficients and were used in the modeling analysis. For this modeling analysis, it was assumed that the ambient air boundary for the Frontier Discoverer is the side of the Frontier Discoverer (i.e., no exclusion zone). Receptors were spaced approximately every 10 meters around the Frontier Discoverer, at 25-meter resolution within one kilometer of the Frontier Discoverer, and at 50-meter resolution between 1 kilometer and 6 kilometers from the Frontier Discoverer, covering the nearby ice management activity.

2.7 Modeling Results

Table 9 summarizes the results of the ISC-PRIME modeling analysis. Based on the modeling analysis results in Table 9, the predicted impacts from the SOI project comply with the National Ambient Air Quality Standards. The maximum impacts are located adjacent to the Frontier Discoverer and are dominated by sources on the Frontier Discoverer and the Jim Kilabuk. For any pollutant, the primary and secondary icebreakers account for less than three percent of the maximum impact.

Table 9: Modeling Analysis Results

Pollutant	Averaging Period	Max. Modeled 1-Hour Impact (µg/m³)	Persistence Factor	Emissions Adjustment [B]	Background Concentration (µg/m³)	Total Impact [C] (µg/m³)	NAAQS (µg/m³)	Comply?
NO_2 [A]	Annual	3070.2	0.08	0.1233	3.0	25.7	100	Yes
PM_{10}	24-hour	210.6	0.4	1	7.9	92.1	150	Yes
	Annual	210.6	0.08	0.1233	1.8	3.9	50	Yes
SO_2	3-hour	244.1	0.9	1	9.8	229.5	1,300	Yes
	24-hour	244.1	0.4	1	7.2	104.8	365	Yes
	Annual	244.1	0.08	0.1233	2.6	5.8	80	Yes

[A] Assume that all NO_2 = NOx * 0.75

[B] Annual emissions adjustment to modeled hourly emissions to account for duration at each drill site (i.e., 45 days per site/365 days = 0.1233). Short-term emissions are not adjusted since 24 hours per day operations are considered.

[C] Total modeled impact is the product of the maximum modeled 1-hour impacts, meteorological persistence, and emissions adjustments plus background concentrations.

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APPENDIX A

Incinerator Stack Parameters

AIR SCIENCES INC. DENVER • PORTLAND	Air Sciences Inc. CALCULATIONS	PROJECT TITLE: Shell Frontier Discoverer	BY: T. Martin
		PROJECT NO: 180-15	PAGE 1 OF 1 SHEET 0
		SUBJECT: Drill Rig Incineration	DATE: 2/19/2007

Emissions

Incinerator Rating: 125 kg/hr, 275 lb/hr, 0.14 ton/hr

Operating Schedule: 24 hrs/day, 45 days/yr

Pollutant	# Stacks	Emission Factor (lb/ton) [1]	Emissions Max. 1-Hour (lb/hr)	Max. 1-Hour (g/sec)	Max. 24-Hour (lb/day)	Max. 24-Hour (g/sec) *	Annual Average (tons/yr)	Annual Average (g/sec) *
NOx	1	3.0	0.41	5.20E-02	9.9	5.20E-02	0.22	6.41E-03
PM_{10}	1	7.0	0.96	1.21E-01	23.1	1.21E-01	0.52	1.50E-02
SO_2	1	2.5	0.34	4.33E-02	8.3	4.33E-02	0.19	5.34E-03

[1] Emission factor from AP-42, Table 2.1-12; industrial/commercial, multiple chamber combustors.
* Emission rate (in g/s) for annual periods is adjusted to account for a maximum of 45 days at each drill site

Stack Parameters For Modeling

Frontier Discoverer

Source Description	Model ID	Source Type	Vertical or Horizontal?	Release Ht. [1] (ft)	Release Ht. (m)	Stack Dia. (ft)	Stack Dia. (m)	Exit Temp. (deg F)	Exit Temp. (deg K)	Exit Vel. (m/s)
Stack #7: 1 Incinerator [2]	INCIN_D	POINT	Vertical	42.1	12.83	1.5	0.46	662	623	10

[1] Above main deck which is approximately 4.57 meters (15 feet) above the water surface.
[2] Assume stack is located near main engine stack on rig and is affected by same building downwash as main engine stack.

Input values are denoted in blue.

Shell Kulluk - Beaufort Sea, Alaska
ISC Prime Loads Analysis - Shell Kulluk Main Engines
03/07/07

Model Run	Emission Rate (g/s)	Exhaust Airflow	Max. Modeled 1-Hour Impact ($\mu g/m^3$) *	Comments
#1	1.0	100%	116.5	Base case - 100% emissions and 100% airflow from main engines on Shell Kulluk.
#2	0.78	75%	96.1	75% load case - Assume emissions are nearly linear with load.
#3	0.55	50%	73.1	50% load case - Assume emissions are nearly linear with load; emissions at 50% load are around 55%.

* From ISCPRIME modeling of the Shell Kulluk main engines.

Frontier Discoverer - Beaufort Sea, Alaska
ISC Prime Loads Analysis - Frontier Discoverer (FD) Main Engines
03/07/07

Model Run	Emission Rate (g/s)	Exhaust Airflow	Max. Modeled 1-Hour Impact (mg/m^3) *	Comments
#1	1.0	100%	56.0	Base case - 100% emissions and 100% airflow from main engines on FD.
#2	0.78	75%	55.6	75% load case - Assume emissions are nearly linear with load.
#3	0.55	50%	54.4	50% load case - Assume emissions are nearly linear with load; emissions at 50% load are around 55%.

* From ISCPRIME modeling of the FD main engines.