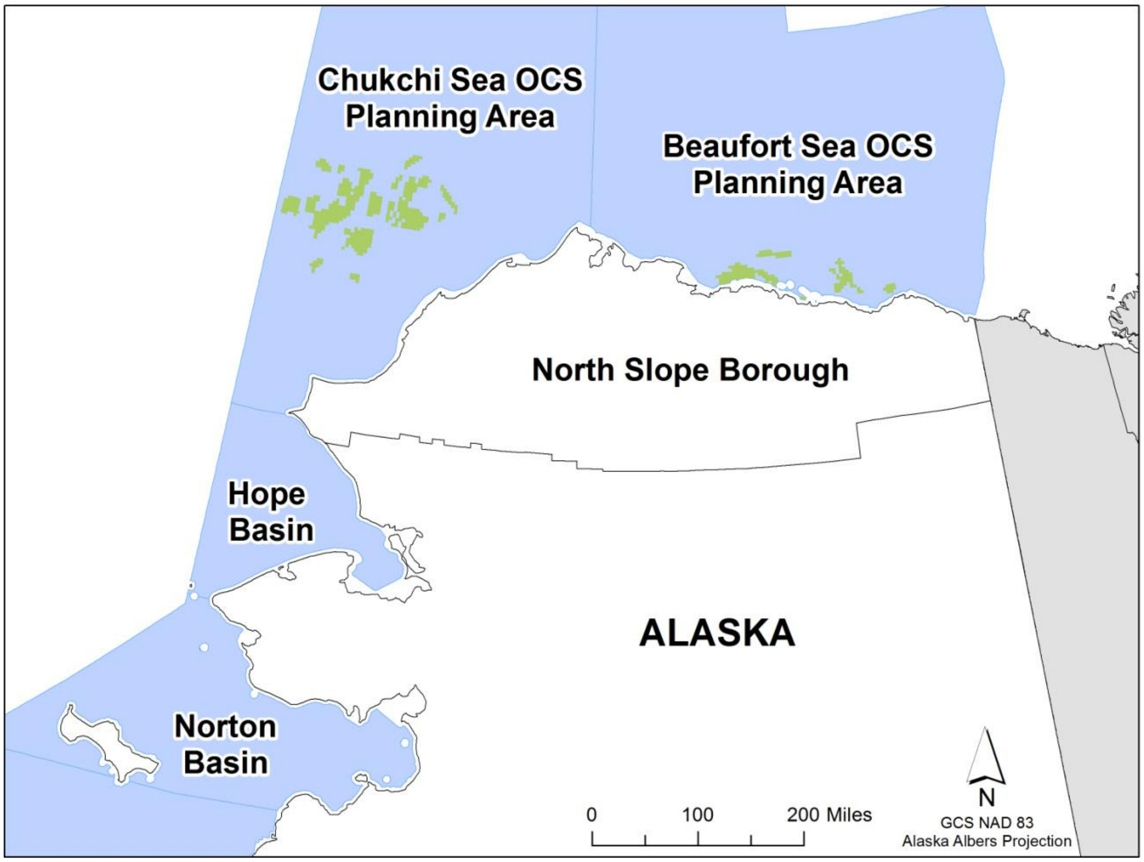
OCS Study
BOEM 2018-020

Arctic Air Quality Impact Assessment Modeling Study:

Final Project Report



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Disclaimer

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This report discusses a conservative "full build-out scenario" that describes air emissions sources associated with potential future oil and gas exploration, development, and production activities on the Beaufort Sea and Chukchi Sea Outer Continental Shelf. The elements of this scenario are included for the purpose of analysis and do not necessarily represent expected activities.

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Table of Contents

Section **Page**

List of Tables

List of Figures

Abbreviations and Acronyms

ADEC	Alaska Department of Environmental Conservation
ADM	atmospheric dispersion model(ing)
AERCOARE	meteorological pre-processor for AERMOD using the COARE over-water algorithm
AERMET	meteorological pre-processor for AERMOD
AERMOD	American Meteorological Society/United States Environmental Protection Agency regulatory model for dispersion
AMNWR	Alaska Maritime National Wildlife Refuge
ANWR	Alaska National Wildlife Refuge
AOCSR	Alaska Outer Continental Shelf Region
APCA	Anthropogenic Precursor Culpability Assessment
AQ	air quality
AQRP	Air Quality Regulatory Program
BC	boundary condition
BCF/yr	billion cubic feet per year
BOEM	Bureau of Ocean Energy Management
CALMET	meteorological pre-processor for CALPUFF
CALPUFF	California Puff regulatory air pollution dispersion model
CAMx	Comprehensive Air Quality Model with Extensions
CAP	criteria air pollutant(s)
CB05TUCL	Carbon Bond 2005 version with toluene and chlorine chemistry updates
CB6r2	Carbon Bond 6 revision 2 photochemical mechanism
CH_4	methane
CMAQ	Community Multi-scale Air Quality Model
CMV	commercial marine vessel
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COARE	Coupled Ocean-Atmosphere Response Experiment
DAT	deposition analysis threshold
$DEASCO_3$	Deterministic and Empirical Assessment of Smoke's Contribution to Ozone
DOI	U.S. Department of the Interior
DPP	development and production plan
dv	deciview
EDMS	Emissions and Dispersion Modeling System
EET	emission exemption threshold
EP	exploration plan
EPA	U.S. Environmental Protection Agency
ERG	Eastern Research Group, Inc.
FAA	Federal Aviation Administration
FBO	full build-out
FINN	NCAR Fire INventory
FPSO	Floating production storage and offloading
FY	future year

G&G	geological and geophysical
GBS	gravity-based structure(s)
GHG	greenhouse gas(es)
GHGRP	Greenhouse Gas Reporting Program
GIS	geographic information system
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation model
GSE	ground support equipment
GWP	global warming potential
HAP	hazardous air pollutant(s)
HFC	hydrofluorocarbon(s)
H1H	high first high
H_2S	hydrogen sulfide
kg/ha/yr	kilogram per hectare per year
km	kilometer
kW-hr	kilowatt-hour
LTO	landing and takeoff
MDA8	maximum daily running 8-hour average
MEGAN	Model of Emissions of Gases and Aerosols from Nature
MERP	Modeled Emission Rates for Precursors
METSTAT	Meteorological/Statistical program
MISR	Multi-angle Imaging SpectroRadiometer
MMbbl/yr	million barrels per year
MMIF	mesoscale model interface
MMM	Mesoscale Meteorological Modeling
MMS	Minerals Management Service
MODIS	Moderate Resolution Imaging Spectroradiometer
MOVES	Motor Vehicle Emission Simulator model
NAAQS	National Ambient Air Quality Standards
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NH_3	ammonia
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NO_2	nitrogen dioxide
NSB	North Slope Borough
NWS	National Weather Service
N_2O	nitrous oxide
O&G	oil and gas
OCD	Offshore and Coastal Dispersion model
OCS	Outer Continental Shelf
OCSLA	OCS Lands Act
OSAT	Ozone Source Apportionment Technology
PBL	planetary boundary layer
PFC	perfluorocarbon(s)

PGM	photochemical grid model(ing)
PM_{10}	particulate matter with an aerodynamic diameter of less than or equal to 10 micrometers
$PM_{2.5}$	particulate matter with an aerodynamic diameter of less than or equal to 2.5 micrometers
ppb	parts per billion
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PSAT	PM Source Apportionment Technology
PSD	Prevention of Significant Deterioration
Q-Q	Quantile-Quantile
QA	quality assurance
QC	quality control
RFD	reasonably foreseeable development
RHC	Robust Highest Concentration
SF_6	sulfur hexafluoride
SIL	significant impact level
SMOKE	Sparse Matrix Operator Kernel Emissions model
SO_2	sulfur dioxide
SRG	Science Review Group
SST	sea surface temperature
TAF	Terminal Area Forecast
TAPS	Trans-Alaska Pipeline System
UAF	University of Alaska, Fairbanks
ULSD	ultra-low sulfur diesel
VMT	vehicle miles traveled
VOC	volatile organic compound
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting model
$\mu g/m^3$	micrograms per cubic meter
µm	micrometer

I. INTRODUCTION

The Bureau of Ocean Energy Management (BOEM) Alaska Outer Continental Shelf Region (AKOCSR) has the delegated authority to regulate stationary sources of emissions from oil and gas activities proposed within the Chukchi Sea and Beaufort Sea Outer Continental Shelf (OCS) Planning Areas adjacent to the North Slope Borough (NSB) of Alaska. Proposed operators on the Alaska OCS are required to comply with the U.S. Department of the Interior (DOI)/BOEM Air Quality Regulatory Program (AQRP), established under 30 CFR part 550, subpart C, and BOEM has the obligation to implement the authority provided in OCS Lands Act (OCSLA) Section 5(a)(8). Figure I-1 shows the Alaska OCS area and NSB of Alaska.

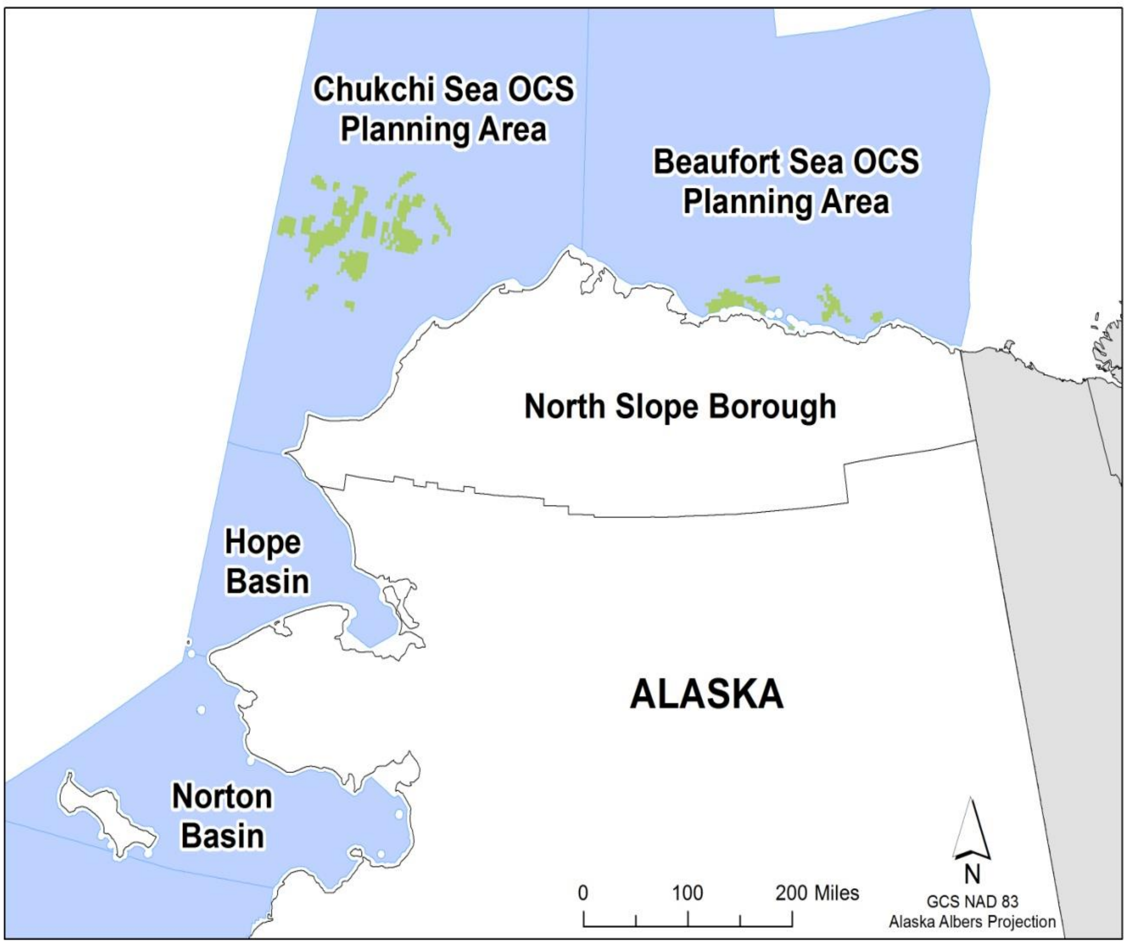

Figure I-1. Regional Map Depicting OCS Planning Areas Including Location of the Arctic AQ Modeling Study

(Select historical lease areas are indicated in green.) Source: BOEM, 2014

The overall objective of the BOEM Arctic Air Quality Impact Assessment Modeling Study (Arctic AQ Modeling Study or study) is to facilitate BOEM's assessment of potential air quality impacts from oil and gas exploration, development, and production on the Alaska OCS and related onshore activities. This study uses computerized atmospheric dispersion modeling and photochemical grid modeling to estimate increases in concentrations of emissions from existing and proposed anthropogenic activities. The air quality analysis is only as comprehensive and accurate as the emission inventory on which the analysis is based, and only as accurate as the meteorological dataset applied to disperse and transport the pollutants.

The Arctic AQ Modeling Study is organized into the following tasks:

- Task 1: Science Review Group
- Task 2: Conduct Meteorological Dataset Evaluation
- Task 3: Prepare Emission Inventories
- Task 4: Conduct Atmospheric Near-Field Dispersion Modeling
- Task 5: Conduct Photochemical/Dispersion Far-Field Pollutant Modeling
- Task 6: Prepare Emission Exemption Thresholds Evaluation
- Task 7: On-Call Statistical Support

Eastern Research Group, Inc. (ERG) and Ramboll conducted this study under BOEM Contract M13PC00014.

The study began in September 2013 and is scheduled to be completed in September 2018. During this 5-year period, the study team developed protocols and task-specific draft and final reports (for Tasks 2 through 6), which were reviewed and commented on by BOEM and the Science Review Group (SRG) prior to being finalized. Also, the study team developed numerous memos and two Interim Progress Reports (August 2015 and October 2016), which documented interim progress related to the main task reports.

This report contains the background, methods used, and results obtained for the main task activities covering the meteorological data set evaluation (Task 2), emissions inventory development (Task 3), near-field atmospheric dispersion modeling (Task 4), photochemical grid modeling (Task 5), and the emission exemption thresholds (EET) evaluation including the far-field dispersion modeling analysis (Task 6).

II. TASK 2: METEOROLOGICAL DATA EVALUATION

The goals of the Arctic AQ Modeling Study require a three-dimensional, physically-consistent meteorological dataset to drive the photochemical and dispersion models. Typically, this is supplied by running a prognostic (forecasting) model in “hindcast” mode, with sufficient observations to constrain the model. The current state-of-the-art prognostic meteorological model is the Weather Research and Forecasting (WRF) model.

Ramboll conducted an initial assessment of four existing WRF datasets under Task 2 and concluded that none of the datasets were sufficient to support the goals of the study. Ramboll performed a new WRF run specifically to support the study goals. The assessment methods for the initial evaluation and for the evaluation of the final dataset were very similar and are described below.

The final WRF output was used in a Model Justification Report (Ramboll Environ, 2017), where the performance of the WRF-based American Meteorological Society/United States Environmental Protection Agency regulatory model for dispersion (AERMOD) and California Puff regulatory air pollution dispersion model (CALPUFF) dispersion models were compared to the performance of the U.S. Environmental Protection Agency (EPA) regulatory-default model for offshore and coastal dispersion (OCD). This same final WRF dataset is also used in the near-field dispersion modeling (Task 4), photochemical grid modeling (Task 5), and the EET evaluation and far-field dispersion modeling (Task 6).

A. Meteorological Data Evaluation

i. Summary of Approach

Four potential WRF Arctic datasets existed as of the beginning of the study: Alpine Geophysics Chukchi WRF, Ohio State/National Center for Atmospheric Research (NCAR) WRF, University of Alaska, Fairbanks (UAF) Mesoscale Meteorological Modeling (MMM) WRF, and EPA/BOEM WRF for the WRF-AERCOARE project. The first two datasets were eliminated based on temporal coverage: the Alpine dataset covered only three summers, and the Ohio State dataset was saved at 3-hourly resolution (hourly data are required for the BOEM Arctic AQ Modeling Study).

Ramboll collected several observational datasets, including the 31-year dataset from UAF; the DS-3505 Integrated Surface Global Hourly dataset from National Climatic Data Center (NCDC); upper-air data from National Oceanic and Atmospheric Administration (NOAA) radiosondes, Japan Agency for Marine-Earth Science and Technology research vessels, the Endeavor Island Vertical Profiler; and satellite-based cloud-cover retrievals. These observations were compared to WRF model output to assess the model’s ability to reproduce realistic atmospheric conditions.

Ramboll evaluated the surviving two WRF dataset candidates both quantitatively and qualitatively. The quantitative (statistical) portion used Ramboll’s Meteorological/Statistical (METSTAT) program that analyzes paired in-time and in-space statistics. Ramboll analyzed onshore and offshore datasets separately for wind speed, wind direction, temperature, and humidity (both absolute water vapor mixing ratio, and relative humidity) performance. Ramboll also analyzed offshore datasets for sea surface temperature (SST) performance.

The qualitative analysis involved plotting total monthly precipitation fields for each month of the year, for each WRF dataset. These were compared to the Parameter-elevation Regressions on Independent Slopes Model (PRISM) 30-year normals for each month. A further qualitative analysis involved plotting monthly averages of cloud cover fraction from each WRF simulation and comparing the results to the Multi-angle Imaging SpectroRadiometer (MISR) "first look" cloud cover product. Because this cloud cover retrieval is somewhat limited, due to its requirement of visible light, the innermost WRF domain over the North Slope was not well covered in the winter months.

ii. Final Findings

The METSTAT analysis results comparing both onshore and offshore observational datasets to each WRF dataset showed they were reasonably similar. The EPA/BOEM WRF dataset from the AERCOARE project (a BOEM/EPA project to develop a meteorological pre-processor for AERMOD using the Coupled Ocean-Atmosphere Response Experiment [COARE] over-water algorithm) showed slightly better performance than the UAF MMM WRF dataset.

While not a perfect comparison, the comparison to the PRISM 30-year normals showed that the UAF MMM WRF dataset substantially overpredicts precipitation. Comparison with the MISR satellite-based cloud cover product was inconclusive for the winter months, but did suggest a slight overprediction of cloudiness in the UAF MMM WRF dataset.

Ramboll found a more serious problem with the EPA/BOEM WRF dataset related to SST, a required input to WRF. The simulation used an SST dataset that did not represent the Mackenzie River outflow well, which can be up to 15 °C warmer than water in the Beaufort Sea during the summer. The warm, fresh water "floats" over the cold, salt water and creates a buoyant plume that can be seen far from shore (see Figure II-1). Due to a lack of local measurements and persistent clouds, this feature was not captured well in WRF, leading to reduced vertical stability and increased atmospheric convection. As a result, there were notable differences between modeled and measured meteorological parameters in the region.

The final recommendation of the Meteorological Dataset Evaluation document was to re-run WRF with an alternate SST dataset, after testing the accuracy of the various high-resolution SST products. This resulted in a new WRF dataset, called the BOEM Arctic WRF dataset (Brashers, et al., 2015).

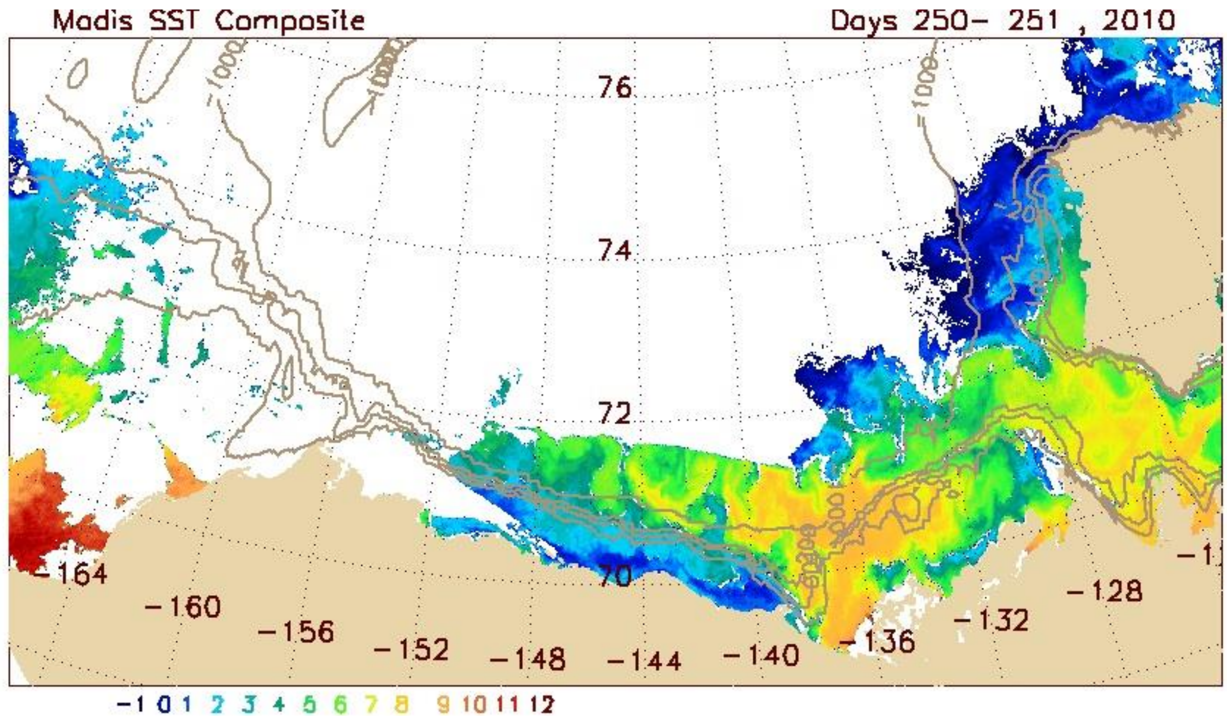

Figure II-1. Moderate Resolution Imaging Spectroradiometer (MODIS) SST Composite Image for September 7-8, 2010

B. Model Performance Evaluation

The BOEM Arctic WRF dataset, developed by Ramboll, spans 5 years (2009-2013), and was based on the previous EPA/BOEM WRF dataset with updates to improve performance in Northern Alaska. The Model Performance Evaluation document describes the WRF settings and input datasets, and presents an evaluation of how well WRF matched the observations (Brashers et al., 2016).

i. Summary of Approach

Ramboll subjected the BOEM Arctic WRF dataset to the same assessments as the candidate WRF datasets, described above: both quantitative and qualitative assessments. The quantitative assessment included separate onshore and offshore METSTAT analyses. The qualitative assessment examined vertical profiles taken at Point Barrow, from research vessels offshore, and from the Shell thermal profiler on Endeavor Island. Both PRISM precipitation and MISR cloud cover qualitative evaluations were also performed, though in this case the WRF precipitation was averaged by month over the full 5-year simulation, to better match the available PRISM 30-year normals. The UAF MMM WRF dataset was not subjected to the same 5-year average by month comparison with the PRISM 30-year normals, because the aim of the original comparison was to compare the single overlapping year between the two datasets (2009).

ii. Final Findings

The BOEM Arctic WRF meteorological model simulation, for January 2009 through December 2013, reproduced the observed surface meteorological variables reasonably well. The wind direction performance was improved over previous meteorological datasets for the same region. Sample METSTAT-based "soccer" plots for winds are shown in Figure II-2 (speed) and Figure II-3 (direction) for the onshore assessment. The model performance offshore seemed worse, due in part to lower spatial and temporal resolution of available measurements.

Vertical profiles also performed well, accurately reproducing observed conditions of coastal interactions in the planetary boundary layer. The 5-year average precipitation amounts for each month were consistent with the PRISM 30-year normal. Where and when valid satellite cloud retrievals were available, WRF-predicted cloud amount compared reasonably well. Based on Ramboll's experience, the BOEM Arctic WRF modeling's performance provides a sound basis for developing meteorological inputs for the study modeling.

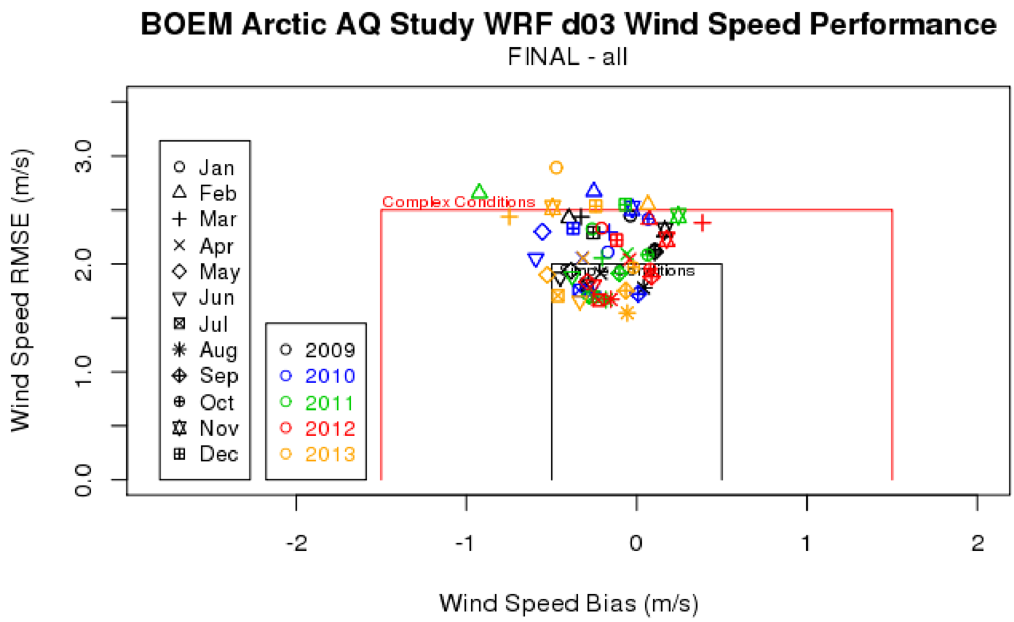

Figure II-2. BOEM Arctic WRF Onshore METSTAT 4 Kilometer Domain Wind Speed Performance

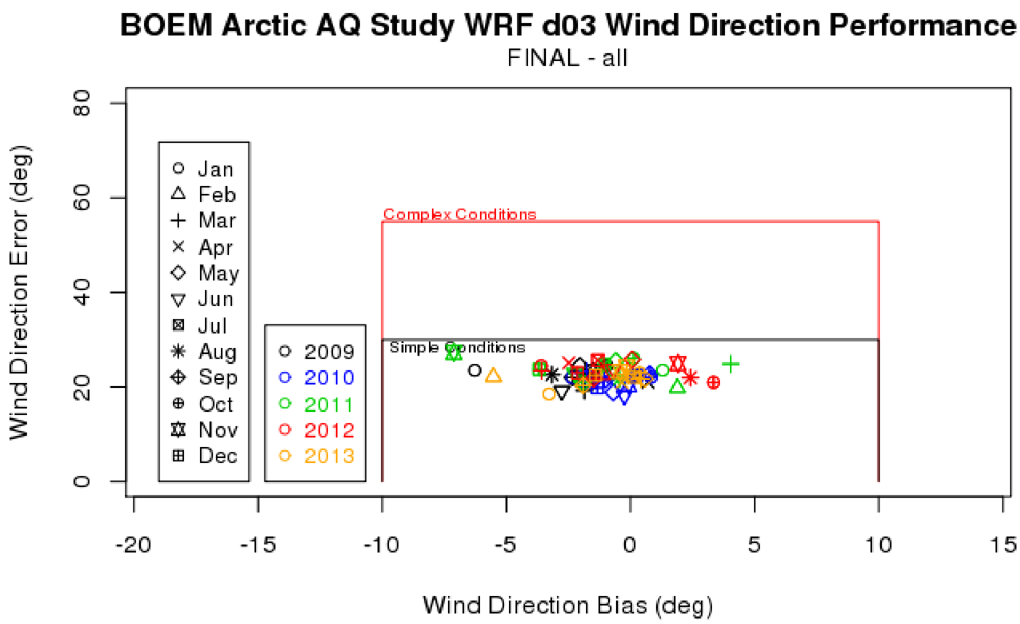

Figure II-3. BOEM Arctic WRF Onshore METSTAT 4 Kilometer Domain Wind Direction Performance

C. Model Justification Report

As stated in 30 CFR 550.218(e), air dispersion modeling of sources under BOEM jurisdiction must be conducted using a model that is approved by the BOEM Director and in accordance with the guidelines in Appendix W of 40 CFR part 51, often called the U.S. EPA Guideline on Air Quality Models (i.e., 2017 EPA Guideline) (U.S. EPA, 2017).

The OCD is the preferred dispersion model for overwater sources for short-range transport (source-to-receptor distances less than 50 kilometers [km]). The 2017 EPA Guideline does not currently list a preferred dispersion model for long-range (source-to-receptor distances greater than 50 km) transport over water, but the previous version (2005) listed CALPUFF as the preferred model for long-range transport over land (U.S. EPA, 2005). AERMOD is the preferred dispersion model for over-land short-range modeling. The last substantial change to the OCD model was in 1997, almost two decades ago (though there was a small bug fix released in 2000). AERMOD, unlike OCD, has undergone continuous updates to both its scientific algorithms and its input and output formats.

Section 8.4.5 of the 2017 EPA Guideline allows for the use of prognostic meteorological model output data where there is no National Weather Service (NWS) station near the emissions source, or where it is unfeasible or too expensive to measure site-specific meteorological data. In offshore situations, suitable meteorological datasets near a desired emission source are often unavailable or prohibitively expensive to obtain.

In the Model Justification Report (Ramboll Environ, 2017), Ramboll evaluated the preferred model for short-range transport of emissions from offshore sources, OCD, to two alternative models, AERMOD and CALPUFF, using prognostic WRF in place of observed meteorology.

i. Summary of Approach

There were two main components of the Model Justification Report: an evaluation using available offshore tracer studies; and, a “consequence” evaluation using the 5-year WRF dataset. Ramboll used WRF data to supply the meteorology to OCD, CALPUFF, and AERMOD simulations, for both components of the report.

For the tracer studies, Ramboll compared model results to observed concentrations of an inactive tracer. For the consequence evaluation, there were no observed concentrations available; CALPUFF and AERMOD results were compared to the regulatory-default model OCD. The release parameters and emission rates for the tracer studies were taken from the Minerals Management Service (MMS) project to enhance CALPUFF (Earth Tech, 2006). The release parameters and emission rates for the consequence analysis were taken from the BOEM/EPA WRF-AERCOARE project (ENVIRON, 2012a; ENVIRON, 2012b), and four synthetic sources were each placed 25 km from shore in the Beaufort Sea and 40 km from shore in the Chukchi Sea, with receptors placed both along the shoreline and along the state seaward boundary as shown in Figure II-4.

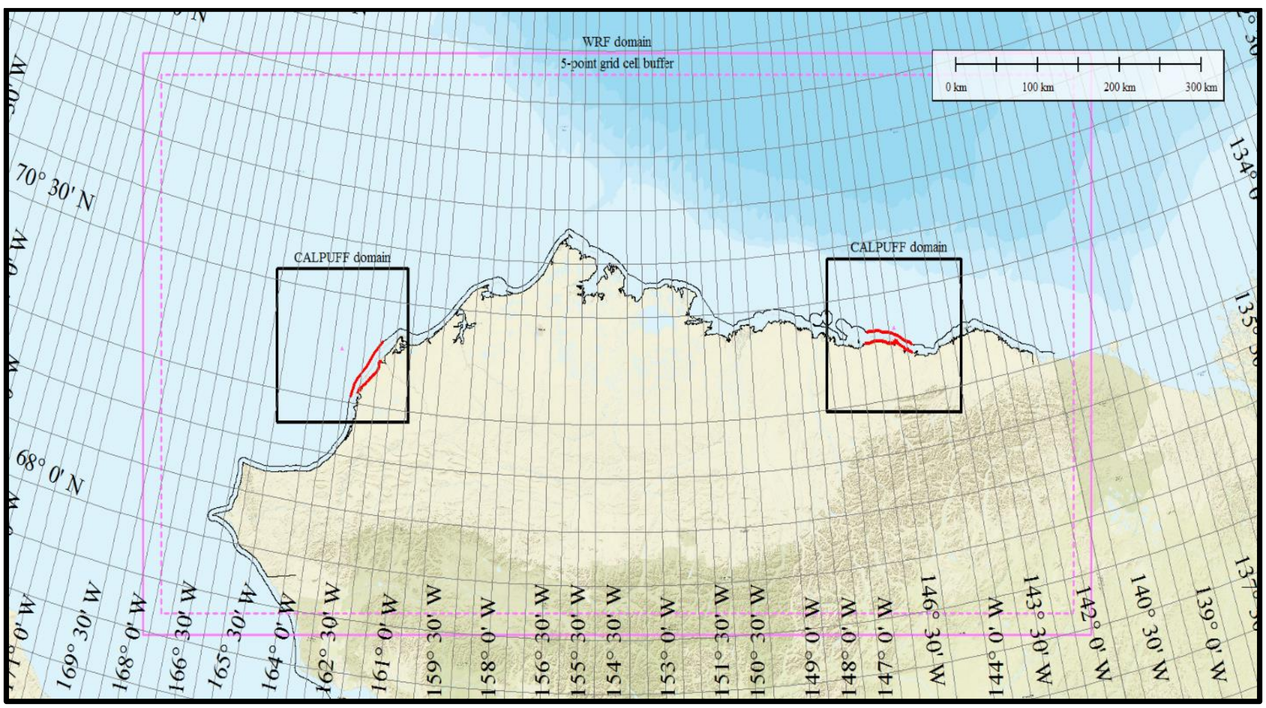

Figure II-4. Arctic WRF 4 Kilometer Modeling Domain

The tracer studies were performed in the 1980s and though they often had phases in multiple seasons, the total number of hours is limited. Half of the data were from periods before SST sensors were first deployed on satellites, which limited WRF’s ability to accurately reproduce the meteorology (due to very coarse SST inputs). The tracer studies were from Cameron, LA (July 1981 and February 1982); Carpinteria, CA (September 1985); Pismo Beach, CA (December 1981 and June 1982); and Ventura, CA (September 1980 and January 1981). These are the same tracer studies that were used for benchmark testing and development of OCD and CALPUFF.

Ramboll used the EPA mesoscale model interface (MMIF) program to convert the WRF output to the meteorological file formats required by each dispersion model. MMIF supports CALPUFF and AERMOD directly. The AERMOD modeling system has its own meteorological pre-processor named AERMET, and the CALPUFF modeling system has its own meteorological pre-processor named CALMET. MMIF replaced both AERMET and CALMET for this study. Although CALMET has reasonable support for overwater situations, AERMET has certain assumptions and simplifications that make it unsuitable for overwater use.

Ramboll wrote Fortran programs to convert MMIF output for AERCOARE to the overwater meteorological file format required by OCD, and to convert the AERMOD surface file (*.SFC) to the overland meteorological file format required by OCD.

Ramboll assessed model performance using a series of statistical measures, both following the EPA's Cox-Tikvart method, and using Quantile-Quantile (Q-Q) plots, Robust Highest Concentration (RHC), fractional factor of two, and geometric correlation coefficient, mean, and variance.

ii. Final Findings

For the tracer studies, the analysis showed that AERMOD, OCD, and CALPUFF perform differently at each individual tracer site, but that no model is an overall poor performer. When all the data are used or when the data are grouped by season, AERMOD and OCD model performance are comparable and AERMOD outperforms OCD in the winter, perhaps when the spatial gradients in stability and planetary boundary layer (PBL) heights are weakest. The results presented in the tracer study analysis suggest AERMOD is a comparable to, if not better than, the OCD model.

For the consequence analysis, there was better agreement between AERMOD and OCD concentrations than between CALPUFF and OCD, especially for the highest concentrations, which carry the most weight for regulatory purposes. From a model configuration perspective, this analysis revealed that area sources in OCD agree more closely with volume sources in AERMOD compared to area sources in AERMOD. At the high end of the concentrations, AERMOD tends to agree well (not underpredict) compared to OCD.

CALPUFF has a slight (for point sources) to larger (for area and volume sources) tendency to underpredict compared to OCD. It is also possible that OCD overpredicts compared to CALPUFF – because these are hypothetical sources with no corresponding observed concentrations, it is only possible to identify that there are differences. OCD is presumed to be the reference because it is the current regulatory-default dispersion model for overwater situations. At short source-receptor distances, CALPUFF's area and volume sources are similar to OCD's area source. At longer source-receptor distances, CALPUFF area and volume sources differ from OCD's area source, but it cannot be determined which is more correct. None of the tracer studies' releases could be characterized by volume or area sources, so it is not possible to compare any of the model's performance to observations for these source types. Given that OCD's area source algorithm appears to be very similar to a "pseudo point source" (a point source with a large stack diameter and a small stack exit velocity), it might be expected that the volume sources would agree, but there would be little expectation that the area source types would agree between models; the area source algorithms between the three models are just too different.

III. TASK 3: EMISSION INVENTORIES

One of the first steps in the Arctic AQ Modeling Study, and in support of subsequent air quality modeling analyses, was to develop a comprehensive air emissions inventory that accurately estimates emissions within the study area encompassing the North Slope region and adjacent waters of the Beaufort Sea and Chukchi Sea Planning Areas (see Figure I-1).

ERG developed the emissions inventory, which was completed in December 2014 and documented in the Final Task 3 Report (Fields Simms et al., 2014).

A. Summary of Approach

ERG first developed a detailed protocol in developing the emissions inventory for the study. The protocol provided details on the scope of the inventory, the procedures and data to be used for estimating emissions. The draft emissions inventory protocol was prepared, reviewed, and commented on by BOEM and the SRG. ERG incorporated responses to these comments into the final method used for the inventory, which is described below.

The scope of the inventory was defined as follows:

- Baseline – The year for which the most recent, credible, and reliable information was available. To the greatest extent possible, 2012 data were used, but these were sometimes augmented with data from other years (including 2011 and 2013).

- Future scenario – Future year sources and activities that are reasonably foreseeable and expected to continue for an extended period of time. Projected (future year) emissions were estimated for use in evaluating impacts anticipated from potential future oil and gas exploration, development, and production activities on the Arctic OCS. ERG projected future emissions based on information and guidance provided by BOEM for a year in the future when projected offshore operations are reasonably expected to be fully built out, or referred to hereafter as the full build-out (FBO) scenario (BOEM, 2014). ERG estimated annual emissions (i.e., baseline and future emissions), and developed temporal profiles for use in air quality modeling.

- Pollutants – The air pollutants that contribute to air quality and health and visibility concerns, including: criteria air pollutants (CAPs) and precursors; hazardous air pollutants (HAPs, as defined by the Clean Air Act, Title III); greenhouse gases (GHGs, including carbon dioxide [CO_2], methane [CH_4], nitrous oxide [N_2O], sulfur hexafluoride [SF_6], hydrofluorocarbons [HFCs], and perfluorocarbons [PFCs]); hydrogen sulfide (H_2S); and ammonia (NH_3).

- Sources – The sources operating within the inventory domain, including stationary sources located in North Slope communities and oil fields, on-road motor vehicles, nonroad equipment, marine vessels and other offshore (oil- and gas-related) sources (i.e., both OCS and near shore in state waters), the Trans-Alaska Pipeline System (TAPS) and airports. Also, emissions from other sources were estimated based on their potential influence on air quality concentrations, including dust from paved and unpaved portions of the Dalton Highway and other roads located in communities and the oil fields. Table III-1 lists the source groups and categories included in the Arctic AQ Modeling Study emissions inventory and the associated air pollutants. Note that emissions from biogenic sources (e.g., nitrogen oxides [NO_x] from soils, etc.) and geogenic sources (e.g., oil seeps, wildfires, etc.) will be estimated in a future stage in this study.

- Domain – The geographic area in which the emission sources are located. For the Arctic AQ Modeling Study emissions inventory, the domain encompasses the Arctic OCS, including the Chukchi and Beaufort Seas, near shore state waters (within 3 nautical miles of the coast), and the NSB.

i. Baseline Inventory

The baseline emissions inventory represents air emissions from the sources operating in the Arctic OCS, including the Chukchi and Beaufort Seas, near-shore state waters (within 3 nautical miles of the coast), and the NSB, over the course of a year. ERG generally developed the baseline emissions inventory using data from 2012, however, because it was necessary to use data from other years in order to compile a comprehensive inventory, the initial annual inventory is also referred to as the “baseline” emissions inventory.

a. Offshore Sources

Offshore activities during 2012 included oil and gas seismic surveys, exploratory drilling, and support helicopters visiting survey vessels and exploratory drilling rigs to deliver supplies and transfer personnel. Also, commercial marine and research vessels operated in the Beaufort and Chukchi Seas during this time, although these were not directly related to oil and gas exploration. To estimate vessel emissions, ERG applied activity data to appropriate Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model marine vessel emission factors (ANL, 2013) and HAP speciation profiles (U.S. EPA, 2013a). For estimating helicopter and aircraft landing and takeoff (LTO) emissions, ERG used the Federal Aviation Administration’s (FAA’s) Emissions and Dispersion Modeling System (EDMS) (FAA, 2013) where aircraft specific data were available, and EPA methods provided in the 2011 National Emissions Inventory (NEI) where only generic aircraft type (i.e., commercial carriers, air taxis, general aviation, and military aircraft) activity were available (U.S. EPA, 2013a).

Table III-1. Sources Included in the BOEM Arctic AQ Modeling Study Emissions Inventory

Group and Category		CAPs	HAPs	GHGs	H_2S	NH_3
Offshore Oil & Gas Activities	Seismic survey and supply vessels	✓	✓	✓		✓
	Seismic support helicopters	✓	✓	✓		
	On-ice seismic survey equipment	✓	✓	✓		✓
	Exploratory drilling – drill ships, jackups	✓	✓	✓		✓
	Exploratory drilling – fleet support vessels	✓	✓	✓		✓
	Platform construction and support vessels	✓	✓	✓		✓
	Island construction and support vessels	✓	✓	✓		✓
	Production platform operation	✓	✓	✓		✓
	Platform support – supply and support vessels	✓	✓	✓		✓
	Platform support – helicopters	✓	✓	✓		
	Pipelaying and support vessels	✓	✓	✓		✓
Offshore – Other	Commercial marine vessels	✓	✓	✓		✓
	Research vessels	✓	✓	✓		✓
Onshore Oil & Gas Fields	Seismic survey equipment	✓	✓	✓		✓
	Drilling/exploration	✓	✓	✓	✓	
	Well pads		✓		✓	
	Processing plants, gathering centers, etc.	✓	✓	✓	✓	
	Support (injection, seawater treatment)	✓	✓	✓	✓	
Airports	Aircraft and helicopters	✓	✓	✓		✓
	Ground support equipment	✓	✓	✓		✓
Trans-Alaska Pipeline System	Pump stations (1-4)	✓	✓	✓		✓
	On-road patrol vehicles	✓	✓	✓		✓
	Aerial surveillance aircraft	✓	✓	✓		✓
	TAPS fugitives	✓	✓	✓	✓	
	Natural gas supply line fugitives	✓	✓	✓	✓	
	Pigging operations	✓	✓	✓	✓	
	Pipeline replacement, repair	✓	✓	✓		✓
Onshore Non-Oil & Gas Activities	Power plants	✓	✓	✓		✓
	Industrial/commercial/institutional/residential fuel combustion	✓	✓	✓		✓
	On-road motor vehicles	✓	✓	✓		✓
	Nonroad mobile sources	✓	✓	✓		✓
	Road dust	✓				
	Waste burning	✓	✓	✓		✓
	Wastewater treatment	✓				
	Fuel dispensing	✓	✓	✓		
	Power plants	✓	✓	✓		✓
	Industrial/commercial/institutional/residential fuel combustion	✓	✓	✓		✓
Spills	OCS pipeline spills	✓	✓	✓		✓
	Platform spills	✓	✓	✓		✓

b. Onshore Sources

In addition to offshore sources, the emissions inventory includes estimates for onshore emission sources within the North Slope region and adjacent waters of the Beaufort Sea and Chukchi Sea Planning Areas. These sources include the North Slope oil and gas fields, as well as onshore sources located in eight nearby villages and elsewhere on the North Slope (e.g., airports, the TransAlaska Pipeline System, non-oil and gas related stationary and mobile sources, etc.).

Due to the wide variation in the types of onshore sources operating on the North Slope, their emissions inventory methods varied significantly. ERG used various methods and data to estimate baseline onshore source emissions, by source type, as follows:

- Seismic survey equipment – ERG estimated emissions based on estimated quantity of ultra-low sulfur diesel (ULSD) consumption, based on geological and geophysical (G&G) permit data (BOEM, 2012) and EPA WebFIRE emission factors (U.S. EPA, 2013b).

- Exploratory drilling – ERG estimated emissions based on estimated quantity of ULSD used in drilling rig engines, heaters, and boilers, based on permit data from the Alaska Department of Environmental Conservation (ADEC) and EPA WebFIRE emission factors (U.S. EPA, 2013b).

- Oil and gas production – ERG estimated emissions using data from the 2011 NEI (U.S. EPA, 2013a), data reported under subpart W of the Greenhouse Gas Reporting Program (GHGRP), ADEC permit data for sources that were too small to report to the NEI, and applying scaling factors to estimate emissions for some pollutants and sources that were not part of the permit data.

- Airports, aircraft, and ground support equipment – ERG estimated emissions for 11 airports using either aircraft-specific or air-carrier-specific data provided by the airports or the FAA’s Terminal Area Forecast (TAF) data (FAA, 2014), and the FAA’s EDMS. For the Deadhorse Airport, ERG discovered that the original baseline inventory had omitted commercial airline traffic (i.e., only general aviation had been accounted for). To correct this omission, ERG used aircraft-specific data from the FAA and reran the EDMS using the correct commercial data. This procedure and the associated results were documented in a memo (ERG, 2015a).

- TransAlaska Pipeline System – Pump Stations 1 through 4 are the only TAPS pump stations located in the NSB; ERG obtained emissions for Pump Stations 1, 3 and 4 from the 2011 NEI (Pump Station 2 was inactive). ERG estimated fugitive pipeline emissions using national production-based emission factors and a scaling factor (i.e., TAPS mileage within the North Slope vs. national pipeline mileages) (BTS, 2014). ERG estimated emissions from on-road motor vehicles and nonroad equipment used for pipeline operation and maintenance using the same methods as described below for on-road mobile sources nonroad sources, and assuming the levels of activity needed to operate and maintain the pipeline. Also, ERG estimated emissions for pipeline aerial surveillance by helicopters by assumed air time, and number of trips, and using the FAA’s EDMS (FAA, 2013).

- Non-oil and gas stationary, point, and area sources – In general, for the combustion sources, ERG estimated emissions by multiplying the relevant activity data by EPA WebFIRE emission factors (U.S. EPA, 2013b); ERG estimated HAP emissions using speciation fractions from the SPECIATE database (U.S. EPA, 2014a). For road dust, ERG estimated emissions by multiplying unpaved road vehicle miles traveled (VMT) by emission factors derived from empirical equations found in AP-42, Section 13.2.2 (U.S. EPA, 1995).

- On-road motor vehicles and nonroad mobile sources – For on-road motor vehicles, ERG estimated emissions using emission factors from EPA's Motor Vehicle Emission Simulator (MOVES) model (U.S. EPA, 2014b) with local meteorological and vehicle activity data for VMT and fuel consumption. For the nonroad mobile sources (i.e., snowmobiles and all-terrain vehicles), ERG used the EPA's NONROAD2008a model to derive emission factors based on fuel consumption (U.S. EPA, 2009).

ii. Projections Inventory

To help BOEM assess impacts on air quality from future oil and gas exploration, development and production on the Alaska OCS, as well as in near-shore state waters, ERG also developed future year emissions inventory projections. The future year emissions inventory projections covered sources and activities in Arctic OCS that are reasonably foreseeable, and expected to continue for an extended period of time. The projections reflect a future scenario as defined by BOEM and representative of a single future year when offshore operations are anticipated to be fully built out (i.e., FBO scenario) (BOEM, 2014). The sources and their respective levels of activity associated with the full build-out scenario are summarized in Table III-2.

The methods used to estimate emissions for the baseline inventory were also used to estimate emissions for the projections inventory. For the sources that are the same in both inventories, only the activity data changed for the projections inventory. Also, there are additional sources in the projections inventory (i.e., pipelaying, gravel island, and offshore platform construction and operation) that are not present in the baseline inventory.

a. Offshore Sources

The offshore projection scenario developed by BOEM includes two sites in the Chukchi Sea, and four sites in the Beaufort Sea as noted in Figure III-1. The figure also shows the anticipated location of the Liberty (gravel) Island, discussed below. Because the projection scenario does not identify specific vessels and aircraft to be used, actual periods of activities, or actual vessel traffic patterns, ERG made several assumptions.

Table III-2. Full Build-Out Projections Scenario for Offshore Oil and Gas Activities

		Beaufort Sea	**Chukchi Sea**
Projected Production			
Production: Gas	BCF/yr	167	115
Production: Oil, Condensate	MMbbl/yr	132	204
Total Platform wells		215	260
Total Subsea Wells		34	90
Projected Activities and Duration: B1, B2, B3, and B4 = Development Areas in the Beaufort Sea; C1 and C2 = Development Areas in the Chukchi Sea			
Seismic Surveys	July – October	8-week run includes survey vessel, support, and scout vessels; support helicopters	4-week run includes survey vessel, support, and scout vessels; support helicopters
	December – May	1 on-ice operation lasting 4 weeks	None
Geohazard Surveys	July – October	8-week run includes survey and support vessels	8-week run includes survey and support vessels
Geotechnical Surveys		8-week run includes survey and support vessels	8-week run includes survey and support vessels
Exploratory Drilling	July – October	• 1 jackup at B3 and 1 jackup at B4 • Support vessels, icebreaker, spill response, helicopters	• 2 drill ships at C1 • Support vessels, icebreaker, spill response, helicopters
Offshore Pipeline Construction	July – October	• 44 miles of new construction • Pipelaying vessel, dredge ships, support vessels, helicopters	• 40 miles of new construction • Includes pipelaying vessel, dredge ships, support vessels, helicopters
Platform Construction	July – October (Gravel island construction December – May)	• 1 gravity-base system constructed at B1 • 1 gravity-base system constructed at B2 • 1 gravel island at Liberty location • Support vessels, icebreaker, helicopter support, gravel trucks	• 1 gravity- based system constructed at C1 • Support vessels, icebreaker, helicopters
		• Subsea well construction • 2 jackups at B2 and 1 jackup at B3 • Support vessels, helicopter support	• Subsea well construction • 1 jackup and 2 drill ships at C1 • Support vessels, helicopters
Production Platform Operation	Throughout the Year	• 1 platform at B1; 27 on platform wells • 2 platforms at B2; 81 on platform wells, 23 subsea wells • 1 platform at B3; 54 on platform wells, 11 subsea wells • 1 platform at B4; 54 on platform wells, providing a total of 215 on platform wells and 34 subsea wells • Platform equipment, support vessels, helicopter support	• 2 platforms at C1; 260 on platform wells and 90 subsea wells • Platform equipment, support vessels, helicopters
		• Production at Liberty Island; 32 wells • Platform equipment, support vessels	None

BCF/yr = billion cubic feet per year; MMbbl/yr = million barrels per year.
(Source: BOEM, 2014)

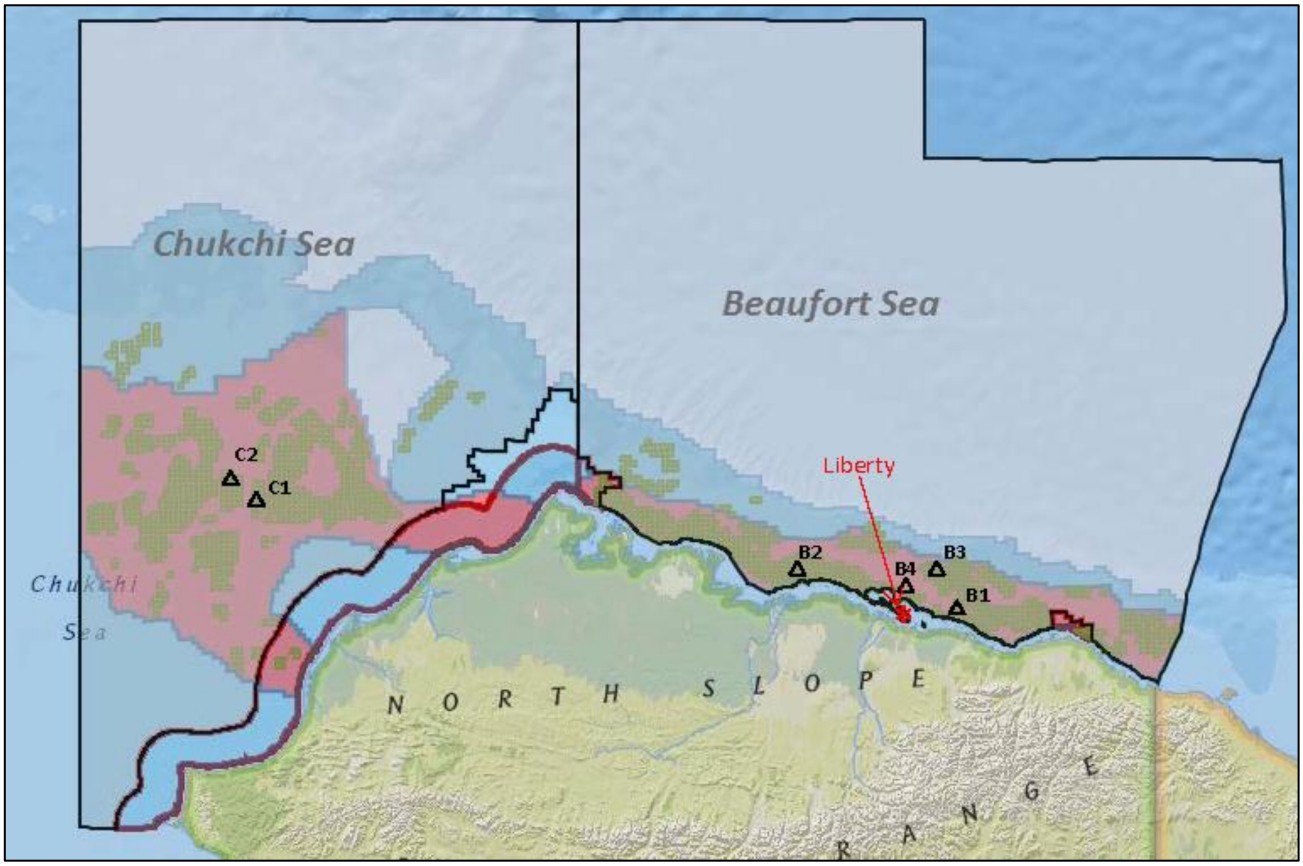

Figure III-1. Offshore Projected Development Areas

(Select historical lease areas are indicated in green.) Source: BOEM, 2014

ERG made the following assumptions regarding the methods and data to estimate projected offshore source emissions, by source type:

- Seismic survey vessels and support helicopters – ERG estimated emissions using the baseline inventory vessel method. Activity data (i.e., number of trips, distances) were based on assumptions shown in Table III-2 and locations shown in Figure III-1.
- Exploratory drilling – ERG estimated emissions using the same method as was used for the baseline inventory. Activity data were provided by BOEM (BOEM, 2014) and are summarized in Table III-3.
- Pipelaying and support vessels – ERG estimated support vessel emissions using the baseline inventory vessel method. Vessel characteristics were developed based on pipelaying vessels that operate in other areas of the Arctic. Each pipelaying vessel was assumed to require four support vessels and operate 24 hours/day laying pipe at a rate of 1 mile/day.

Table III-3. Projected Drilling Activity

Activity Type	Development Areas	Vessel Type	Number of Vessels	Wells per Vessel	Days per Well	Total Days
Exploratory	B3	Jackup	1	2	38	76
		Support Fleet	1	2	38	76
	B4	Jackup	1	1	38	38
		Support Fleet	1	1	38	38
	C1	Drillship	2	2	38	152
		Support Fleet	1	2	38	76
Subsea Well	B2	Jackup	2	3	38	228
		Support Fleet	1	3	38	114
	B3	Jackup	1	3	38	114
		Support Fleet	1	3	38	114
	C1	Drillship	2	3	38	228
		Jackup	1	3	38	114
		Support Fleet	1	3	38	114

(Source: BOEM, 2014)

- Platform construction – BOEM's full build-out scenario included construction of gravity-based structures (GBS) built to withstand winter ice flows. ERG estimated emissions for vessels involved in towing the GBS to the sites, positioning the platform, ballasting the base, as well as for support vessel and helicopter activities. ERG assumed levels of activity such as: platform towing at a rate of 2 mph; 40 hours each for tugs to put platforms in place; and support vessels operating during the remainder of the open water season (2.5 months).

- Platform operations – ERG derived emissions profiles from available data from some of the larger offshore platforms operating in Cook Inlet, Alaska, based on data compiled from the 2011 NEI and the EPA's GHGRP data. ERG applied the average Cook Inlet platform emissions per well to the projected number of production wells for each development area based on BOEM's scenario as shown in Table III-4.

- Spills – BOEM anticipates that there may be emissions associated with spills from future oil and gas exploration, development and production activities in the Chukchi and Beaufort Seas. BOEM's scenario included estimates of the potential spill quantities of diesel and crude; ERG estimated emissions based on evaporation curves (i.e., percentage of evaporation relative to time after spill). Also, ERG estimated emissions from associated spill response vessels by assuming days required to clean up spills of various quantities and hours/day of operation by each vessel (i.e., tug boats, larger vessels).

Table III-4. Projected Number of Wells

Location	Well Type	Development Areas	Number of Wells
Beaufort Sea	On-platform	B1	27
Beaufort Sea	On-platform	B2	81
Beaufort Sea	On-platform	B3	54
Beaufort Sea	On-platform	B4	54

Table III-4. Projected Number of Wells

Location	Well Type	Development Areas	Number of Wells
Beaufort Sea	Subsea	B2	23
Beaufort Sea	Subsea	B3	11
Chukchi Sea	On-platform	C1	260
Chukchi Sea	Subsea	C1	9
Liberty Island	-	-	32

(Source: BOEM, 2014)

b. Onshore Sources

ERG projected onshore emissions that represent anticipated future year emissions for sources that can reasonably be expected to be constructed and/or operated during a future year that is consistent with the offshore projection scenario. These sources, along with the methods and data used by ERG to estimate the projected emissions, are described below.

Several sources and activities are not addressed in this future year scenario because any prediction of future activities for these sources would be highly speculative at this time. These sources include existing onshore oil and gas production facility activities and several non-oil/gas related stationary point and mobile sources (i.e., these sources were included in the impacts modeling, as discussed below in Sections III.B and V.A). Also, no future (post-2012) regulations are anticipated to reduce future emissions from the existing onshore oil and gas production facilities and the existing non-oil/gas related stationary point and mobile sources, with one exception: Tier 4 diesel manufacturer emission standards that came into effect in 2014. Although these standards will serve to reduce emissions from affected engines after 2012 as older engines are replaced, the rate of turnover is difficult to predict. Therefore, ERG did not estimate these reductions, which will provide a conservatively high estimate of these emissions for modeling.

- New oil and gas production facilities – Four future production facilities are either currently under construction, are permitted for construction, or are reasonably expected to be built: Greater Moose's Tooth Unit 1 (AECOM, 2013), and Point Thomson Production Facility (ADEC, 2014), CD-5 Satellite at Alpine (ADEC, 2014). The method used to estimate projected emissions from each of these facilities was based on ADEC construction permits, BLM EIS, and actual emissions estimates for similar existing facilities.

- New pipeline construction and operations – Construction emissions for the two new onshore pipelines to be constructed and operated to transport new offshore production to the TAPS and the existing feeder pipelines were estimated based on construction emissions associated with Greater Moose's Tooth Unit 1 (AECOM, 2013).

- Liberty Island construction and drilling – Liberty Island will be planned as a self-contained offshore drilling/production facility located on a conventional gravel island with pipelines to shore. The island is planned to be built in Foggy Island Bay in the Beaufort Sea in approximately 21 feet of water. The future emissions projected to be emitted by Liberty Island will be due to its construction, followed by drilling and production operations. ERG estimated construction emissions for Liberty Island based upon construction emissions associated with Greater Moose's Tooth Unit 1 (AECOM, 2013). ERG derived the emissions estimates for the Liberty Island drilling operation from the Kuparuk River Transportable Drilling Rigs Renewal Application (ADEC, 2012), and the peak number of production wells to be drilled as provided in the BOEM scenario (BOEM, 2014).

- Airport and aircraft emissions – ERG projected the base year airport/aircraft emissions into future years using the FAA's Air Traffic Activity from the *FAA's Aerospace Forecast Fiscal Years 2012-2032* (FAA, 2014).

- New support facilities – In support of increased aircraft activities, a number of additional facilities would need to be built, including the following: an Exploration Base, an Air Support Base, and a Search and Rescue Base. Also, a new Supply Boat Terminal would be built to support offshore production in the Chukchi Sea. ERG based the construction emissions from these four facilities on construction emissions for Greater Moose's Tooth Unit 1 (AECOM, 2013), scaled based on the ratio of the proposed facility footprint divided by the Greater Moose's Tooth Unit 1 pad footprint. ERG used only emissions from the ice roads, gravel roads and pads, and facilities installation construction activities (both on-road motor vehicle and nonroad equipment) for this estimate.

- Trans-Alaska Pipeline System – The future year increased production would affect some of the existing emissions associated with the TAPS. According to Alyeska Pipeline Service Company statistics, the 2012 TAPS throughput was slightly over 200 million barrels (Alyeska, 2013), so the future year increased production would effectively double the TAPS throughput. A review of pump station inventories from ADEC's online Point Source Emissions Inventory indicated a general trend of decreased pump station emissions with decreasing throughput (ADEC, 2014). Conversely, increased throughput would result in increased emissions. ERG estimated future year emissions for pump stations, pipeline fugitives, and natural gas supply line fugitives by doubling the 2012 emissions. ERG assumed that future year emissions would not increase for on-road patrols, aerial surveillance, pigging operations, and pipeline replacement and repair.

- Non-oil and gas stationary point and area sources – Several point sources as well as commercial/institutional fuel combustion and residential fuel combustion used heating oil with a high sulfur content (i.e., not ULSD) in the baseline inventory. To account for the future use of ULSD in these sources, ERG reduced the baseline sulfur dioxide (SO_2) emissions by 99.4 percent (i.e., corresponding to a shift from 2,500 ppm sulfur content of heating oil to 15 ppm sulfur content of ULSD) to represent the projections inventory for these sources.

- Man-camp construction and operation – Subsequent to the submittal of the original emissions inventory as reported in the Final Task 3 Report (Fields Simms et al., 2014), BOEM requested the addition of a 100-person man-camp (both construction and operation) that would support the Chukchi Sea development. ERG added these emissions to the projection inventory only (i.e., and not the baseline inventory) and documented the emissions in the “new source” memo (ERG, 2015a). ERG based the operation emissions for the Chukchi Sea man-camp on similarly sized man-camp located near Nuiqsut in support of the Greater Moose’s Tooth Unit 1 development (AECOM, 2013). Assumed operating sources consisted of two continuously operating diesel-fired IC engines, each consuming 32 gallons of fuel per area. ERG estimated emissions using per gallon emission factors developed for Greater Moose’s Tooth Unit 1 (AECOM, 2013). ERG did not estimate man-camp construction emissions for Greater Moose’s Tooth Unit 1 (likely due to the modular nature of the man-camp structures); construction emissions were also not estimated for the Chukchi Sea man-camp.

- Supply boat operation – BOEM also requested the addition of emissions from a supply boat traveling from Dutch Harbor to Chukchi Sea Development Areas C1 and C2. ERG based supply boat emissions upon operating parameters of an example vessel (*Harvey Champion*) (i.e., route distance, cruising speed, vessel rated power, and operating load factor) provided by BOEM (Crowley, 2015a; Crowley, 2015b). ERG based estimates of supply boat operation emissions for operations within the Chukchi Sea Planning Area upon shipping lane segments obtained from the U.S. Army Corps of Engineers (USACE, 2014).

B. Final Findings

This section presents the results of the Arctic AQ Modeling Study emissions inventory for the baseline emissions and the future projections. In addition to the results provided in the emissions inventory report published in December 2014, ERG provided a set of Emission Inventory Tables in Excel format for BOEM’s use in December 2015.

i. Baseline Inventory

Tables III-5 and III-6 summarize the baseline emissions inventory for CAPs, GHGs, and other pollutants (i.e., HAPs, H_2S, and NH_3). In the baseline emissions inventory, offshore sources include emissions from seismic survey vessels, drilling rigs, and survey/drilling support aircraft and vessels; commercial marine vessels (CMV); and research vessels. Onshore sources include oil and gas activities (i.e., seismic surveys, exploratory drilling, and oil and gas production); airports, aircraft, and ground support equipment (GSE); TAPS; and non-oil and gas related stationary and mobile sources. These tables show that emissions from onshore sources in the baseline inventory are much larger (i.e., by two orders of magnitude for most pollutants) than emissions from offshore sources. This result is not unexpected given that the offshore sources that operated during this time were limited to a very small number of sources as compared to the onshore sources.

Table III-5. Summary of Baseline Emissions – Criteria Air Pollutants (tons/yr)

Sector	Pollutant						
	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	Pb
Offshore	1,816.3	38.2	106.0	248.6	35.8	27.2	0.005
Onshore	45,811.7	1,243.1	2,918.4	14,073.4	35,647.2	4,774.5	0.244
Total	**47,628.0**	**1,281.3**	**3,024.4**	**14,322.0**	**35,683.0**	**4,801.7**	**0.250**

Table III-6. Summary of Baseline Emissions – Greenhouse Gases and Other Pollutants (tons/yr)

Sector	Greenhouse Gases				Other Pollutants		
	CO_2	CH_4	N_2O	CO_2e[a]	HAPs	H_2S	NH_3
Offshore	139,982.5	0.8	6.5	141,932.6	18.1	0.0	0.7
Onshore	13,570,837.3	8,792.4	29.1	13,799,316.2	398.5	16.4	4.4
Total	**13,710,819.8**	**8,793.2**	**35.6**	**13,941,248.8**	**416.6**	**16.4**	**5.2**

[a] Calculated using global warming potentials (GWPs) from IPCC, 2007.

Table III-7 shows the baseline emissions inventory for the onshore oil and gas sector, by source category. This table provides the total emissions (tons/yr) by pollutant and source category within the onshore oil and gas sector, as well as the percentage of the total pollutant emissions contributed by each source category. Production accounts for the majority of emissions generated within the sector.

Table III-7. Selected Baseline Emissions from Onshore Oil and Gas Sources

Pollutant		Exploratory Drilling	Oil and Gas Production	Seismic Survey Equipment	Total
NO_x	**Tons/yr**	**1,388.2**	**42,260.1**	**144.1**	**43,792.4**
	Percent of Total	3%	97%	<1%	100%
SO_2	**Tons/yr**	**42.1**	**1,049.0**	**9.5**	**1,100.6**
	Percent of Total	4%	95%	1%	100%
VOC	**Tons/yr**	**354.2**	**1,707.2**	**2.7**	**2,064.1**
	Percent of Total	17%	83%	<1%	100%
CO	**Tons/yr**	**318.0**	**8,967.5**	**31.0**	**9,316.5**
	Percent of Total	3%	96%	<1%	100%
PM_{10}	**Tons/yr**	**19.0**	**1,168.6**	**10.1**	**1,197.7**
	Percent of Total	2%	98%	<1%	100%
CO_2e	**Tons/yr**	**108,823.1**	**13,185,512.4**	**5,390.1**	**13,299,725.6**
	Percent of Total	<1%	99%	<1%	100%

ii. Projections Inventory

Tables III-8 and III-9 summarize the emissions inventory projections for the CAPs, GHGs, and other pollutants (i.e., HAPs, H_2S, and NH_3). These tables show projection emissions for the offshore sources based on BOEM's scenario (BOEM, 2014) and for the onshore sources reasonably expected to occur and that are affected by increased offshore production and exclusive use of ULSD fuel in selected onshore point and area sources.

Note that the projected emissions described in this section do not represent all future year projected emissions. The projected emissions include only those sources and activities that are expected to change (i.e., increase or decrease) in the future. Furthermore, the future year projected emissions should not simply be added to the 2012 emissions of the sources that are not expected to change to calculate total future year emissions because onshore oil and gas emissions from existing facilities, and emissions from construction and operation emissions from new facilities will likely not all occur during the same year. Work conducted by ERG and Ramboll during the modeling phase of the BOEM Arctic AQ study defined which specific emission sources were modeled to assess future air quality impacts, including emissions from existing facilities and from construction and operation of new facilities. See Section V.A below for more detail.

These tables show that the emissions projected for the offshore sources are distributed nearly equally across sources anticipated to be operating in the Beaufort and Chukchi Seas in the future.

Table III-8. Summary of Emissions Projections – Criteria Air Pollutants (tons/yr)

Sector	Pollutant						
	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	Pb
Offshore – Beaufort Sea	7,474.2	561.3	417.8	1,484.6	174.5	144.5	0.017
Offshore – Chukchi Sea	6,988.8	774.0	354.5	1,531.5	174.1	150.5	0.014
Onshore[a]	17,365.4	364.0	945.2	7,528.5	971.5	898.4	0.021
Total	**31,828.4**	**1,699.3**	**1,717.5**	**10,544.6**	**1,320.1**	**1,193.4**	**0.052**

[a] Includes only emissions from new sources and from sources expected to change under the projection scenario (i.e., future new oil and gas production facilities; new pipelines; Liberty (gravel) Island; airports, aircraft, and supply boat terminal; TAPS; and certain non-oil and gas stationary point and area sources).

Table III-9. Summary of Emissions Projections – Greenhouse Gases and Other Pollutants (tons/yr)

Sector	Greenhouse Gases				Other Pollutants		
	CO_2	CH_4	N_2O	CO_2e[a]	HAPs	H_2S	NH_3
Offshore – Beaufort Sea	1,293,500.1	52,375.3	181.9	2,657,097.2	68.3	0	2.3
Offshore – Chukchi Sea	1,534,029.2	73,618.2	242.5	3,446,759.1	56.2	0	1.8
Onshore[b]	18,371,080.1	26,602.2	76.9	19,059,046.5	80.7	0	0.002
Total	**21,198,609.3**	**152,595.7**	**501.4**	**25,162,902.8**	**205.1**	**0**	**4.1**

[a] Calculated using global warming potentials (GWPs) from IPCC, 2007.

[b] Includes only emissions from new sources and from sources expected to change under the projection scenario (i.e., future new oil and gas production facilities; new pipelines; Liberty (gravel) Island; airports, aircraft, and supply boat terminal; TAPS; and certain non-oil and gas stationary point and area sources).

Table III-10 shows the projected offshore emissions by source for the CAPs. The largest contributors to the projected offshore emissions are platform operation, resupply of drilling vessels, pipelaying activities, production support, and drilling vessels.

Table III-10. Emissions Projections from Offshore Sources (tons/yr)

Source	Criteria Air Pollutant						
	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	Pb
Survey Operations	553.8	0.5	28.3	62.9	8.6	6.3	0.001
Exploratory Drilling	6,550.8	12.3	442.1	1,043.2	138.3	102.2	0.021
Pipelaying and Support Vessels	1,705.1	1.0	87.0	191.4	26.3	19.3	0.004
Platform Construction	537.9	0.6	30.5	62.5	14.0	10.3	0.002
Platform Operations and Support Vessels	5,088.6	1,311.5	183.1	1,653.1	159.9	155.4	0.002
Spills	26.8	9.4	1.2	3.1	1.5	1.3	0.0002
Total	**14,463.0**	**1,335.3**	**772.3**	**3,016.1**	**348.6**	**295.0**	**0.031**

C. Emissions Inventory Uncertainty and Opportunities for Improvement

Two general areas of uncertainty in this study's inventory, and basically characteristic of any large-scale "bottom up" inventory of this type (i.e., based on the collection of data for each source in the domain) include:

- Use of emission factors combined with activity data (e.g., amount of fuel combusted, vessel activity kilowatt-hours [kW-hrs], aircraft travel distances, etc.) resulting in an approximate estimate of emissions, and not reflective of actual emissions with the same accuracy that direct source tests would yield.

- Limitations are due to the availability of source-specific data, such that surrogate data from similar sources is needed to ensure completeness of the inventory in terms of sources covered and pollutants included.

ERG identified specific areas of emissions inventory uncertainty, along with suggestions for ways to improve these specific estimates in future inventory versions, as provided below. These uncertainties and associated recommendations focus on the most significant sources (i.e., contributing the most emissions or combination of emissions) in the baseline and projections inventories.

- Baseline inventory:
    - **Oil and gas production** (greatest NO_x, volatile organic compound [VOC], SO_2, carbon monoxide [CO], carbon dioxide equivalent [CO_2e], and HAP emissions) – Uncertainty is associated with applying scaling factors to estimate emissions for some pollutants that were not available from ADEC permits (or 2011 NEI and GHGRP data) for smaller units. It is possible that ADEC now has permit data

collected in 2014 for these sources that could be used to update these estimates. Also, surveys of North Slope operations could provide better data and coverage of emissions as compared to what was last reported to the GHGRP, since these reporting requirements have recently changed.

- **Unpaved road dust re-entrainment** (greatest particulate matter with aerodynamic diameter of less than or equal to 10 micrometers [µm] [PM_{10}] and particulate matter with aerodynamic diameter of less than or equal to 2.5 µm [$PM_{2.5}$] emissions) – Uncertainty is associated with the lack of robust local silt and moisture content samples for the North Slope villages, which are used as inputs to the unpaved road dust algorithm to estimate emissions. Silt and moisture content sampling could be conducted in the North Slope villages following the sampling procedures detailed in Appendix C.1 and C.2 of U.S. EPA's AP-42 (U.S. EPA, 1995) to provide more accurate inputs to the equation, and thus more accurate emission estimates for these sources.

- Projections inventory:
  - **New oil and gas production facilities** (high NO_x, VOC, CO, PM_{10}, $PM_{2.5}$, and CO_2e emissions) – Uncertainty is associated with the emissions estimated for the planned Chukchi coast processing production base facility, and the lack of permit data on the sizes, unit types, or controls that may be put in place at the proposed facility. An initial construction permit application for this facility will be extremely beneficial to inform the projected emissions inventory.
  - **Offshore exploratory drilling, and platform operations and support vessels** (high NO_x, SO_2, and VOC emissions) – Uncertainty is associated with the following assumptions and surrogate data used to project emissions:
    - Assumptions of the number of support and scout vessels (for surveys, exploratory drilling, platform construction, production platforms, and pipelaying).
    - Surrogates used for vessel characteristics, and the number of helicopter trips (for surveys, exploratory drilling, platform construction, and production platforms).
    - Assumptions made for all vessel power rating and load factors, dredging vessel operating hours, and surrogate dredging vessels (for pipelaying).
    - Surrogate data used for gravity-based structures, then adjusted downward for Arctic conditions (for platform construction).
    - Surrogate data used from a platform in Cook Inlet (for platform production).

Uncertainty associated with these estimates can be addressed in the future when Beaufort/Chukchi platform operators apply for air quality permits. Studies to validate emissions such as testing and data logging of activity, throughput, and operating load will also be needed to more accurately assess emissions from the future Beaufort/Chukchi platforms.

D. Spatial and Temporal Allocation of Emissions

ERG developed two additional sets of emissions-related data needed for air quality modeling:

- Spatial surrogates used to spatially allocate the baseline and projected emissions inventories across the inventory domain.
- Temporal profiles used to distribute the annual baseline and projected emissions inventories over various timeframes.

In total, ERG developed over 550 unique point source latitude/longitude coordinates and nearly 40 sub-county boundary shapes from the nonpoint, on-road, and nonroad sectors for spatial allocation of the baseline and projections inventory within the modeling domain. Each allocation was converted to .kmz format, so that they could be visually inspected using *Google Earth*. The procedures followed and data used to develop the spatially allocated emissions were documented in a technical memorandum (ERG, 2015b).

ERG compiled the spatially allocated baseline and projections emissions inventory using geographic information system (GIS) software. Point source emissions were spatially allocated by the facility's latitude and longitude coordinates and then assigned to a unique 4-km grid cell within the modeling domain. For the nonpoint, on-road, and nonroad sectors, ERG developed unique boundary shapes for each source category within the North Slope and allocated the emissions evenly to 4-km grid cells using the spatial surrogates where there is overlap of a boundary area and a 4-km grid cell. Where there is partial overlap of a boundary area and a 4-km grid cell, the GIS software apportioned emissions based on area of the overlapping cell; therefore, the sum of the emissions of the unique source category within a boundary shape is equal to the sum of the emissions in the overlapping 4-km grids.

Also, ERG converted the annual emissions from the baseline and projections inventory to hourly emissions for inputs to the models. ERG implemented the EPA Sparse Matrix Operator Kernel Emissions (SMOKE) model (U.S. EPA, 2002) for developing hourly estimates, which includes a temporal crosswalk, monthly allocation factors, weekday allocation factors, and daily allocation factors. In some instances, default temporal allocation profiles from the SMOKE model were used, but if no existing SMOKE profile accurately characterized the temporal allocation of particular sources, custom profiles developed by ERG were applied, including to the extent feasible profiles reflecting seasonal and diurnal factors unique to the North Slope.

IV. TASK 4: ATMOSPHERIC DISPERSION MODELING

ERG conducted local scale, or near-field (within approximately 50 km of the source) atmospheric dispersion modeling (ADM) in support of two of the overarching project goals. First, the ADM supports the National Environmental Policy Act (NEPA) environmental impact air quality assessments, by estimating the impact from project oil and gas production on onshore pollution levels. Second, ADM supports the evaluation of the existing emissions exemption thresholds (see Task 6). The near-field ADM uses the meteorological dataset developed in Task 2 and the emissions inventory developed in Task 3.

A. Summary of Approach

As the first phase of the near-field ADM task, ERG prepared a detailed protocol (ERG, 2014). The protocol outlined the procedures to be used for the near-field ADM runs. BOEM and the SRG reviewed and commented on the draft ADM protocol. ERG incorporated responses to these comments into the final method that ERG used for the modeling in Task 4.

In summary, under Task 4, ERG modeled all near-shore sources (i.e., sources within 50 km of the shoreline) in separate modeling runs to assess the impact for each individual source. Each source was modeled using the baseline (base year) and FBO emissions scenarios, where applicable. For the FBO scenario, the different emissions levels for the construction and full production stages were modeled separately. This provides BOEM with an estimate of the impacts from individual sources for future comparison to submitted plans. Emission sources were categorized based on the release shape: point, area, and line. Point sources are facilities with distinct release sources (i.e., stacks) that have characteristics specified in the inventory (e.g., stack height, release temperature, exit velocity). For example, electric generating facilities (Figure IV-1) have a distinct location and release points, and were modeled as point sources. Area sources release emissions over an area. For this study, communities were modeled as area sources to capture the broad release area of the emissions. Line sources are sources whose emissions are released over a distance best represented by a line. For example, fugitive dust emissions from the Dalton Highway were modeled as lines.

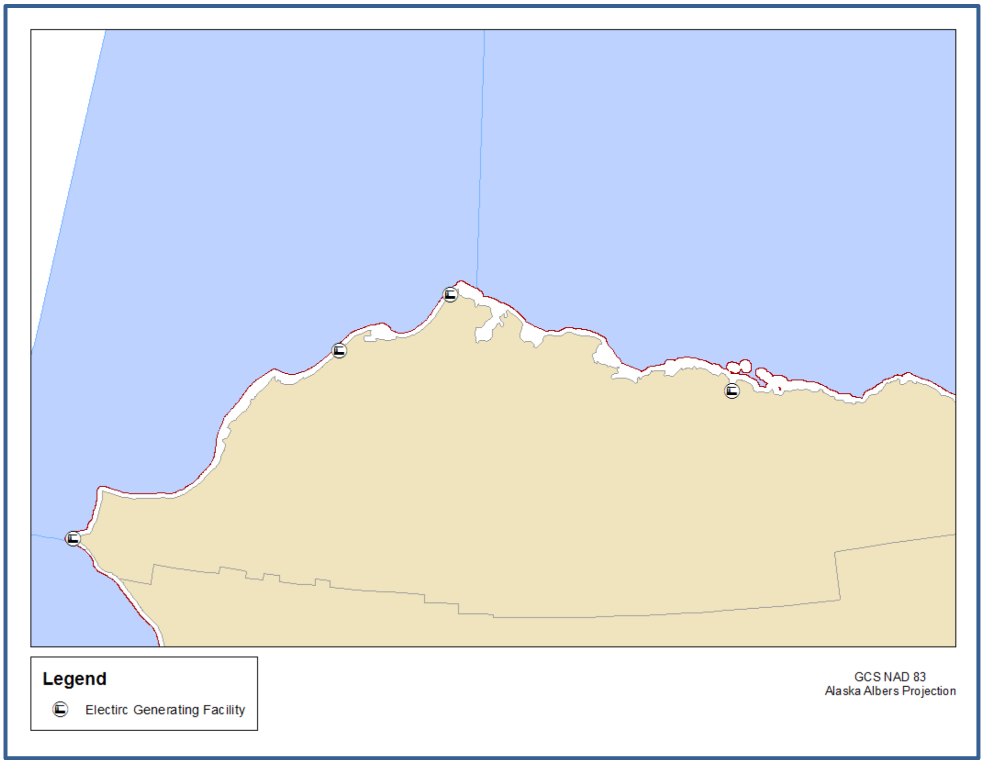

Figure IV-1. Location of Electricity Generating Facilities

ERG used the AERMOD model (version 16216r) with 5 years (2009-2013) of meteorology extracted from the Task 2 WRF simulation results. ERG used EPA-prescribed modeling options for regulatory assessment. For nitrogen dioxide (NO_2) modeling, ERG used a "Tier 1" approach, which assumes all NO_x is converted to NO_2 to provide a conservatively high estimate of NO_2 impacts.

ERG placed receptors at 500-meter intervals along the shoreline and state seaward boundary to assess the impact of each source at the jurisdictional interface of BOEM and onshore regulators. The shoreline receptors follow a generalized coastline definition, rather than a strict shoreline definition that would follow every coastal feature. This simplifies the receptor placement by not strictly following large coastal features such as bays, lagoons, and mouths of rivers. Figure IV-2 provides an example of the generalized shoreline receptors. ERG also placed receptors in the center of the North Slope communities (Figure IV-3) to quantify the onshore impacts in population areas.

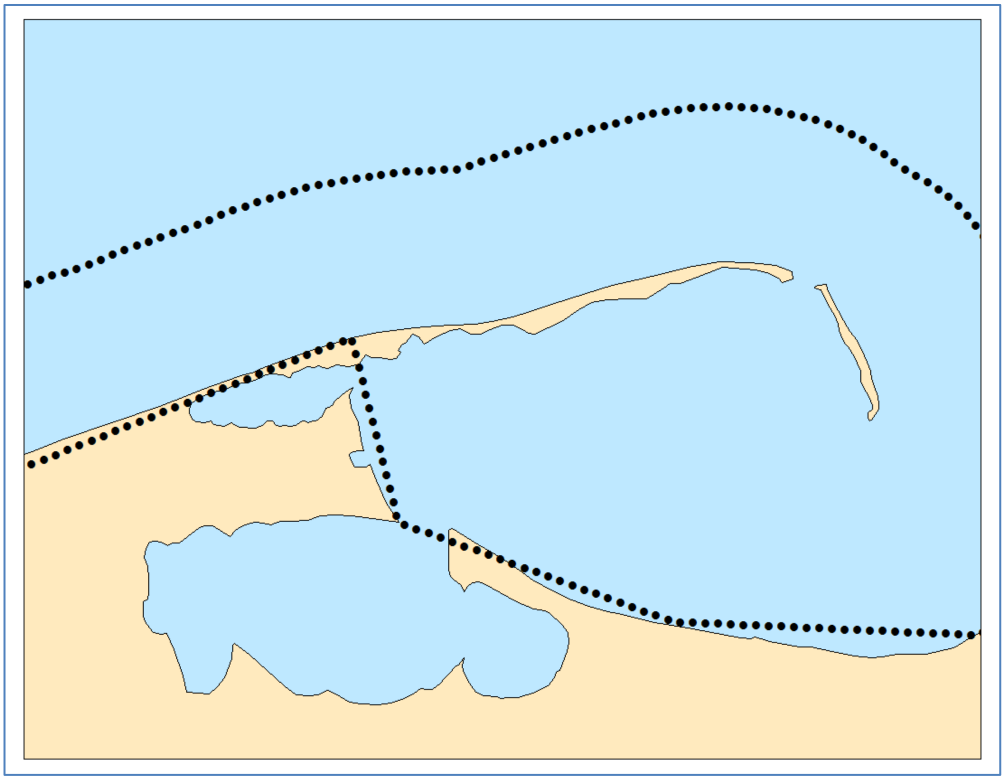

Figure IV-2. Example of Generalized Shoreline Receptors Along the North Slope

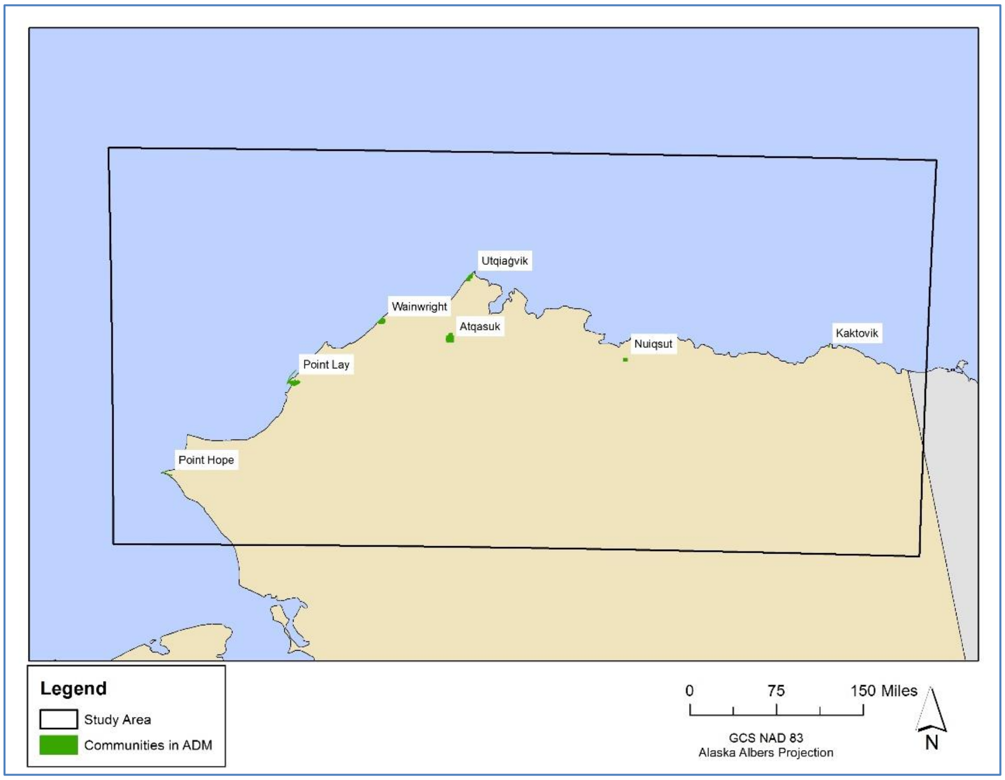

Figure IV-3. North Slope Communities Included in the Near-field Dispersion Modeling

B. Final Findings

The Task 4 ADB database produced by ERG provides impact and emissions information by source category and facility, where appropriate (Do et al., 2017a). All reported impacts are the maximum value of the highest reported concentration at each receptor, also known as the high first high (H1H) value. ERG made significance comparisons by comparing the H1H values to the EPA prescribed significant impact levels (SILs) and National Ambient Air Quality Standard (NAAQS). The database contains separate significance determinations for the shoreline receptors and for the state seaward boundary and community receptors. Tables IV-1, IV-2, and IV-3 show the range of impacts seen for each of the types of sources (i.e., point, area, line) used in the modeling.

Overall, the results of the ADM analysis show low estimated air quality impacts from the criteria air pollutants at the shoreline. This is largely due to low emissions from sources or large distances from the receptors. The modeling was designed for a conservatively high estimate of impact, in that the maximum hourly emission rate was used and comparison to both the NAAQS and SIL used the maximum, or H1H impact for assessment. In addition, NO_2 modeling runs assumed a full conversion of NO to NO_2, which provides a conservatively high estimate. Only estimates of these 1-hour NO_2 impacts showed any source over the SIL; however, these source impacts were ultimately a small percentage of the NAAQS and unlikely to cause a violation of the NAAQS at these conservatively high levels. Offshore sources had slightly higher impacts at the seaward boundary receptor locations, particularly for NO_2. However, the values were still comparable to shoreline values with respect to the percentage of the NAAQS. While direct $PM_{2.5}$ estimated impacts are conservatively high, the estimates are lower than what would be seen with photochemical modeling, as the estimates do not include the additional mass formed through the chemical reaction of SO_2 and NO_x emissions. The formation of secondary particulate matter species can be significant, depending on the meteorological conditions and other pollutant present.

These individual source modeling results can be combined to provide a conservatively high estimate of cumulative impact in an area. As new plans are submitted, BOEM can use the select similar sources from the modeling results and combine them to develop a rough estimate of the impacts of the proposed project. This could be used in project planning to suggest projects that might cause high impacts and warrant controls or other mitigation measures. The impact estimates could also be compared to submitted plan impact levels as a quality check. That is, the estimated impact can serve as a baseline level to compare the projects against to gauge whether plan impacts seem too high or low. For example, the modeled NO_2 estimates assume all NO_x is retained as NO_2, and as such are conservatively high. If a submitted project's estimates fall above an impact estimated from this modeling, even after accounting for any differences in emission levels and distances to the point of impact, it would suggest the proposed project modeling needs further review.

Table IV-1. Impact Ranges for Point Sources

Pollutant	Inventory	Range of Impact (µg/m³)				
		1 Hour	3-Hour	8-Hour	24-hour	Annual
CO	Baseline	[< 0.01 - 11.70]	--	[< 0.01 - 2.88]	--	--
	Full Build-Out	[< 0.01 - 631.60]	--	[< 0.01 - 155.41]	--	--
NO_2	Baseline	[< 0.01 - 3.47]	--	--	--	[< 0.01 - 0.07]
	Full Build-Out	[< 0.01 - 36.24]	--	--	--	[< 0.01 - 3.97]
PM_{10}	Baseline	--	--	--	[< 0.01 - 0.34]	--
	Full Build-Out	--	--	--	[< 0.01 - 0.38]	--
$PM_{2.5}$	Baseline	--	--	--	[< 0.01 - 0.25]	[< 0.01]
	Full Build-Out	--	--	--	[< 0.01 - 0.25]	[< 0.01]
SO_2	Baseline	[< 0.01 - 0.14]	[< 0.01 - 0.09]	--	[< 0.01 - 0.02]	[< 0.01]
	Full Build-Out	[< 0.01 - 7.43]	[< 0.01 - 4.61]	--	[< 0.01 - 1.15]	[< 0.01 - 0.03]

Table IV-2. Impact Ranges for Area Sources

Pollutant	Inventory	Range of Impact (µg/m³)				
		1 Hour	3-Hour	8-Hour	24-hour	Annual
CO	Baseline	[< 0.01 - 0.26]	--	[< 0.01 - 0.11]	--	--
	Full Build-Out	[< 0.01 - 0.26]	--	[< 0.01 - 0.10]	--	--
NO_2	Baseline	[< 0.01]	--	--	--	[< 0.01]
	Full Build-Out	[< 0.01]	--	--	--	[< 0.01]
PM_{10}	Baseline	--	--	--	[< 0.01 - 0.55]	--
	Full Build-Out	--	--	--	[< 0.01 - 0.55]	--
$PM_{2.5}$	Baseline	--	--	--	[< 0.01 - 0.06]	[≤ 0.01]
	Full Build-Out	--	--	--	[< 0.01 - 0.05]	[≤ 0.01]
SO_2	Baseline	[< 0.01 - 0.02]	[< 0.01 - 0.02]	--	[≤ 0.01]	[< 0.01]
	Full Build-Out	[< 0.01]	[< 0.01 - 0.02]	--	[≤ 0.01]	[< 0.01]

Table IV-3. Impact Ranges for Line Sources

Pollutant	Inventory	Range of Impact (µg/m³)				
		1 Hour	3-Hour	8-Hour	24-hour	Annual
CO	Baseline	[< 0.01 - 0.19]	--	[< 0.01 - 0.07]	--	--
	Full Build-Out	[< 0.01 - 3.90]	--	[< 0.01 - 1.79]	--	--
NO_2	Baseline	[< 0.01 - 1.73]	--	--	--	[< 0.01 - 0.02]
	Full Build-Out	[< 0.01 - 24.91]	--	--	--	[< 0.01 - 0.03]
PM_{10}	Baseline	--	--	--	[< 0.01 - 0.03]	--
	Full Build-Out	--	--	--	[< 0.01 - 0.18]	--
$PM_{2.5}$	Baseline	--	--	--	[< 0.01 - 0.01]	[< 0.01]
	Full Build-Out	--	--	--	[< 0.01 - 0.07]	[< 0.01]
SO_2	Baseline	[< 0.01 - 0.35]	[< 0.01 - 0.28]	--	[< 0.01 - 0.07]	[< 0.01]
	Full Build-Out	[< 0.01 - 0.35]	[< 0.01 - 0.28]	--	[< 0.01 - 0.07]	[< 0.01]

V. TASK 5: PHOTOCHEMICAL/DISPERSION FAR-FIELD POLLUTANT MODELING

Ramboll conducted regional air quality modeling with a photochemical grid model (PGM) to quantify air quality conditions associated with existing and potential future development in the OCS and the combined (cumulative) impact of OCS sources with other existing and other reasonably foreseeable future sources (i.e., reasonably foreseeable development or RFD).

In Task 5, Ramboll evaluated OCS and related source impacts on a regional scale, in this case a large area encompassing the North Slope and beyond. Regional scale impacts of interest are concentrations of ozone and $PM_{2.5}$, visibility degradation or regional haze associated with elevated levels of light absorbing and scattering particles and gasses, and acid deposition. Impacts of OCS sources and associated activities within the immediate vicinity (~50 km) of individual sources were modeled under Task 4.

A. Summary of Approach

Ramboll performed modeling for both a Base Case and a Future Year (FY) scenario. Both full annual scenarios used the 2012 WRF model meteorological fields developed in Task 2. WRF results for 2012 were selected from the 2009 – 2013 WRF model output developed in Task 2. Year 2012 WRF result were found to be reasonably representative of "typical" meteorological conditions in northern Alaska and provided the best opportunity for collecting the wide range of activity data needed for estimating emissions from most of the air pollution sources operating on the North Slope. Base Case modeling used the Base Case emission inventory and FY modeling used the FY emission inventory for the North Slope Borough and adjacent state and federal waters developed by ERG under Task 3. In both scenarios, Ramboll combined the Task 3 inventory with emissions from anthropogenic sources in the remaining portions of the modeling domain (primarily Alaska, but also including small portions of northwestern Canada and Siberia). Ramboll estimated anthropogenic emissions outside of the NSB and adjacent state and federal waters and biogenic, lightning, and wildfire emissions for the entire modeling domain for the 2012 Base Case and used without modification for the FY modeling. Ramboll then spatially and temporally allocated and merged emissions together in preparation for modeling. Ramboll performed modeling over a set of nested domains as shown in Figure V-1 with the inner domains having the highest spatial resolution. Ramboll selected the 4 km domain to encompass all of the onshore NSB emission sources and to include offshore sources out to a distance of roughly 200 km or more from shore. For Comprehensive Air Quality Model with Extensions (CAMx), Ramboll extracted boundary conditions (BCs) for the 12 km domain from the 36 km simulation results and the 12 and 4 km grids were modeled using 2-way nesting (allowing interactions between the two grids in both inbound and outbound directions).

Ramboll based specification of the PGM vertical layer structure on the definition of the WRF vertical layers structure. Ramboll ran the WRF simulation with 34 vertical layer interfaces (thus making 33 vertical layers) from the surface up to 100 mbar (approximately 16 km above mean sea level). The WRF model employs a terrain-following coordinate system based on the eta (η) coordinate, which is defined by relative pressure differences between layers. WRF levels are more finely stratified near the surface in an attempt to improve simulation of the atmospheric boundary layer structure and processes: Instead of the common practice of specifying a surface layer depth of approximately 40 m, two 12 m layers overlaid by a 16 m layer were used to better capture the very stable conditions often observed in the Arctic. Ramboll adopted a layer collapsing scheme for the PGM simulations, whereby pairs of upper level WRF layers are combined into single PGM layers to improve the PGM computational efficiency while maintaining the fine layer structure used in WRF in the lower layers (up to approximately 1.2 km). This provides for a better simulation of the stable thermal stratification of the boundary layer and avoids errors potentially introduced by layer collapsing.

Day-specific BCs for the outermost (36 km horizontal resolution) domain were obtained from a 2012 simulation of the GEOS-Chem (v10-01) global chemical model (ACMG, 2017). The use of an alternative global model (MOZART-4/GEOS5) as a source for the BCs was also explored via a test simulation on the 36 km domain with BCs derived from MOZART (NCAR, 2017a). Comparisons of Community Multi-scale Air Quality Model (CMAQ) simulations based on MOZART BCs with CMAQ simulations based on GEOS-Chem BCs showed generally similar results for ozone and PM over northern Alaska. Based on these results and the fact that, in contrast to GEOS-Chem, MOZART does not use day-specific values for dust emissions, BCs based on the GEOS-Chem model were selected for use in the final model simulations.

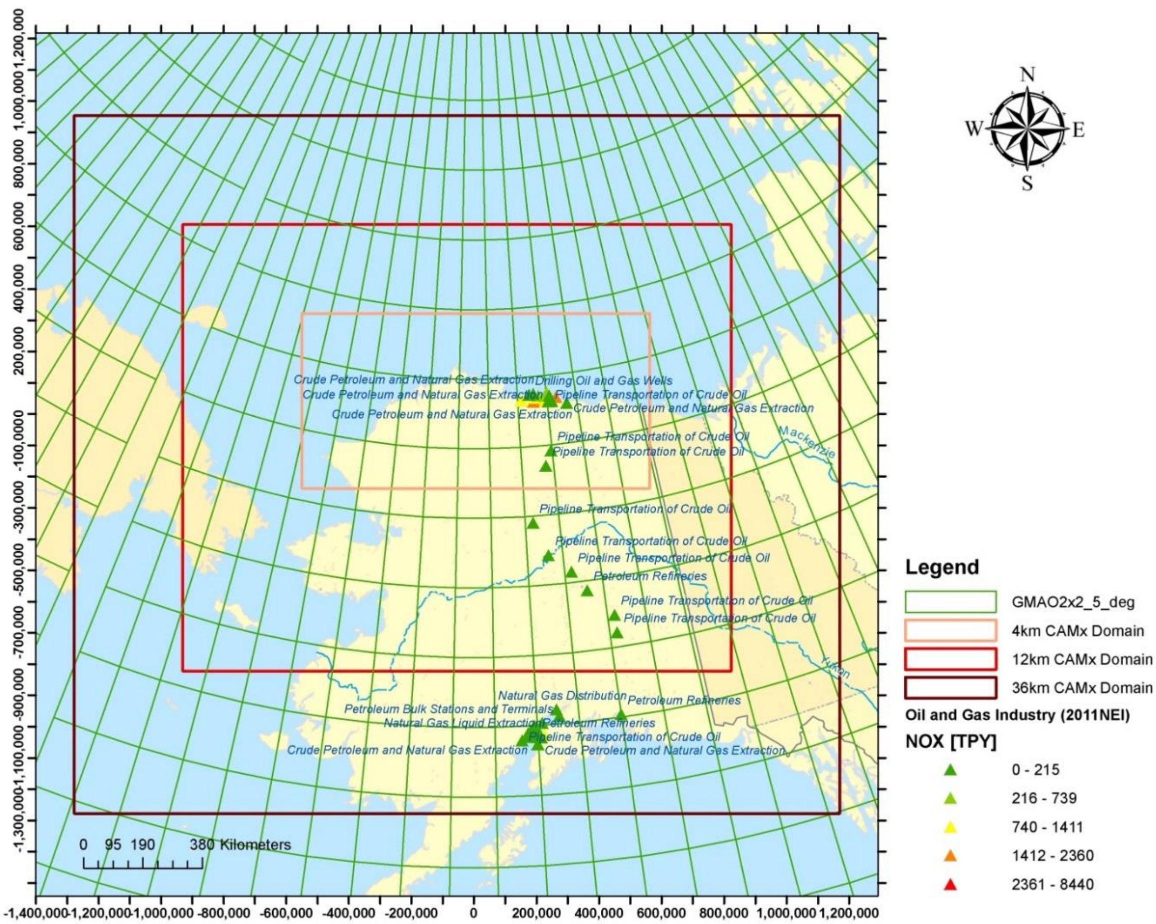

Figure V-1. CAMx Nested Modeling Domains at Horizontal Resolutions of 36 km, 12 km, and 4 km

Green Grid Lines Represent the GEOS-Chem 2 x 2.5 Degree Global Modeling Grid.

Ramboll based the modeling procedures on the U.S. EPA's current and revised draft modeling guidance procedures (U.S. EPA, 2007; U.S. EPA, 2014c). Emissions processing procedures and photochemical model configuration are described in a detailed modeling protocol (ENVIRON, 2014a). BOEM and the SRG reviewed and commented on the Task 5 Modeling Protocol and their recommendations were incorporated into the final modeling procedures documented in the Task 5 Final Report (Stoeckenius et al., 2017).

In this study, BOEM and the SRG applied two PGMs commonly used for ozone and PM modeling in the U.S: CAMx version 6.20 with the Carbon Bond 6 revision 2 (CB6r2) photochemical mechanism including active excess methane emissions (ENVIRON, 2014b) and CMAQ version 5.0.2 (Byun and Ching, 1999) with the Carbon Bond 2005 version with toluene and chlorine chemistry updates (CB05TUCL) (CMAQ, 2017). Ramboll performed initial Base Case simulations using both CAMx and CMAQ. Both models were found to produce mostly similar results aside from differences related to sea salt emission estimates. Ramboll then performed Refined Base Case and FY simulations using CAMx in order to take advantage of the source apportionment technology available in CAMx as described below.

Biogenic emissions were generated using the Model of Emissions of Gasses and Aerosols in Nature (MEGAN) version 2.03, developed at the National Center for Atmospheric Research (Sakulyanontvittaya et al., 2008). Ramboll obtained meteorological data needed by MEGAN from the 2012 WRF output. Ramboll obtained NO_X emissions generated by lightning from the in-line lightning emissions module contained in the CMAQ PGM. Ramboll obtained sea salt emissions from the CAMx sea salt emissions preprocessor.

Ramboll based wildfire emissions on 2012 calendar year estimates of fire emissions from the NCAR, which were derived from analysis of fire locations determined by satellite borne detectors. Ramboll Environ processed the day-specific Fire INventory from NCAR (FINN) (NCAR, 2017b) to develop "point sources" of fire emissions using plume rise estimates as a function of fire size from the Western Regional Air Partnership's (WRAP) Joint Fire Science Program's Deterministic and Empirical Assessment of Smoke's Contribution to Ozone ($DEASCO_3$) project. A description of the WRAP 2002 fire plume rise approach can be found in Mavko and Morris (2013).

Ramboll used the SMOKE system to prepare emissions from Task 3 for use in the PGM (CEMPD, 2017). SMOKE consists of a set of programs that convert annual, daily, or hourly estimates of emissions at the state or county level to hourly emissions fluxes on a uniform spatial grid formatted for input to either the CMAQ or CAMx PGMs. SMOKE integrates emissions inventories with source-based temporal, spatial, and chemical allocation profiles to create hourly emissions fluxes on a predefined model grid. For elevated sources that require allocation of the emissions to the vertical model layers, SMOKE integrates meteorological data to derive dynamic vertical profiles.

Ramboll processed emissions by major source category in several different processing "streams" to simplify the emissions modeling process and facilitate the quality assurance/quality control (QA/QC) of results. SMOKE includes QA and reporting features to keep track of the adjustments at each step of emissions processing and to ensure that data integrity is not compromised. Ramboll Environ reviewed the SMOKE log files for noteworthy error messages and ensured that appropriate source profiles are being used. In addition, Ramboll reviewed and compared SMOKE output summary reports with input emission totals.

Ramboll evaluated results from the Base Case modeling against contemporaneous ambient monitoring data to confirm that the model was performing reasonably well in reproducing observed air quality conditions. Ramboll then compared results from the Base Case and FY model runs to quantify expected changes in air quality under the FY scenario as compared to the Base Case. In addition, the FY scenario model output included estimates of the contributions of the specified source groups listed in Table V-1 to predicted ozone and $PM_{2.5}$ concentrations. Ramboll calculated the contributions of emissions from each source group to predicted ozone and $PM_{2.5}$ concentrations using the Ozone Source Apportionment Technology (OSAT) and PM Source Apportionment Technology (PSAT) probing tools available in CAMx. The Anthropogenic Precursor Culpability Assessment (APCA) version of OSAT was used in the future year scenario modeling. APCA differs from OSAT in that it distinguishes between natural and anthropogenic emissions; when ozone is formed due to the interaction of biogenic VOC and anthropogenic NO_x under VOC-limited conditions, a case OSAT would assign the ozone formed to the biogenic VOC, APCA recognizes that biogenic VOC is uncontrollable and re-directs the ozone formed to the anthropogenic NO_x. Thus, APCA assigns ozone formed to natural emissions only when it is due to natural VOC interacting with natural NO_x emissions.

A detailed description of procedures used to prepare the model-ready emissions inventories and run the photochemical grid model are presented together with a detailed description of results in a final PGM modeling report (Stoeckenius et al., 2017).

Table V-1. Source Groups for CAMx Source Apportionment

Source Group[a]	Name	Source Categories
A	Natural[b]	Biogenic, Lightning NO_x
B	Baseline Oil and Gas (O&G)	Existing O&G sources included in Base Year scenario of the Arctic AQ Study Emissions Inventory
C	Baseline Other Anthropogenic	Existing anthropogenic sources other than O&G included in Base Year scenario of the Arctic AQ Study Emissions Inventory
D	New O&G	New O&G sources included in the Future Year scenario
E	Outside of NSB Anthropogenic	Anthropogenic sources outside of the NSB and adjacent state and federal waters
F	Fires	All wildfires and prescribed burns
G	Baseline All	Source Groups B and C
H	NSB All	Source Groups B, C and D
FY	Future Year	All sources in Future Year scenario
BY	2012 Base Year	2012 Base Year run results

[a] Results for groups A – H are from the Future Year scenario source apportionment outputs; results for group FY are from the Future Year scenario “host model” (all sources combined) outputs; results for group BY are from the “host model” (all sources combined) outputs from the Base Year scenario outputs.

[b] Although sea salt represents a “natural” source of emissions, a tracer for sea salt is not included in PSAT so sea salt contributions are not included in Source Group A.

B. Final Findings

Analysis of the photochemical modeling results focused on evaluating the impacts of new oil and gas sources under the FBO scenario on regional concentrations of ozone and $PM_{2.5}$ and on acid deposition and visibility impacts to Class I and specified Class II areas. Detailed findings are described in the final PGM modeling report (Stoeckenius et al., 2017). Highlights of the results include:

- Only limited ambient data were available for use in evaluating model performance for the Base Case simulation. The simulated seasonal pattern of ozone concentrations over the North Slope qualitatively matched the observed pattern although the model consistently overpredicts by roughly 10 parts per billion (ppb) during November through February and is unable to reproduce the periods of zero or near zero ozone observed during March through April. Model performance is much better during June through October. Overall performance statistics exhibit low bias and normalized mean error within generally accepted regulatory modeling performance criteria. Evaluation of model performance for $PM_{2.5}$ is confounded by highly uncertain sea salt emission values and a complete lack of contemporaneous speciated $PM_{2.5}$ data.

- Predicted 4th highest maximum daily running 8-hour average (MDA8) ozone concentrations along the North Slope under the FBO scenario are generally in the upper 30s to lower 40s ppb, well below the 70 ppb NAAQS. Ozone source apportionment results indicate that anthropogenic sources in the NSB contribute up to 11.4 ppb to these predicted ozone design values with nearly all this amount attributable to existing (baseline) oil and gas sources. New oil and gas sources contribute a maximum of 3.3 ppb. Predicted ozone increases between the Base Case and the FY scenario are limited to a maximum of 1.2 ppb along the North Slope.

- 8th Highest daily average $PM_{2.5}$ concentrations under the FBO scenario are generally less than 5 micrograms per cubic meter ($\mu g/m^3$) higher than in the Base Case scenario at the same location except near Wainwright, where increased support vessel activity and a new petroleum processing facility with an assumed 200 MMbbl/yr throughput under the FBO scenario results in a projected increase of 13.8 $\mu g/m^3$ which is 40 percent of the 35 $\mu g/m^3$ NAAQS. Annual average $PM_{2.5}$ concentrations are predicted to increase by more than 0.5 $\mu g/m^3$ in the immediate vicinity of new sources, with a maximum increase of 8.5 $\mu g/m^3$ near Wainwright. The predicted annual average $PM_{2.5}$ concentration at this location (but not elsewhere) exceeds the level of the NAAQS (12 $\mu g/m^3$) even after subtracting the approximate mass attributable to sea salt based on predicted sodium and particulate chloride content (see discussion of sea salt sensitivity below).

- For Class I and specified Class II areas, maximum Prevention of Significant Deterioration (PSD) pollutant concentration increments (annual average NO_2, PM_{10}, and SO_2; 24-hour average PM_{10}, $PM_{2.5}$, SO_2; and 3-hour average SO_2) from new oil and gas sources are all below the corresponding Class I and Class II area allowable increments.

- Incremental visibility impacts at several specified Class II areas from new oil and gas sources relative to natural background conditions are modeled to exceed 1.0 deciviews on multiple days during the year. Visibility impacts at Denali National Park are modeled to exceed 0.5 deciviews on one day out of the year.

- Comparison of annual nitrogen and sulfur deposition attributable to new oil and gas sources with western (0.005 kilogram per hectare per year [kg/ha/yr]) and eastern (0.01 kg/ha/yr) deposition analysis thresholds (DATs) developed by the Federal Land Managers for the lower 48 states indicates nitrogen deposition above the 0.01 kg/ha/yr DAT in all areas within the NSB and in some areas outside the NSB. Sulfur deposition is lower but the maximum sulfur deposition from new oil and gas sources exceeds 0.01 kg/ha/yr in the Alaska Maritime National Wildlife Refuge (AMNWR) and in the Arctic National Wildlife Refuge (ANWR).

- Predicted $PM_{2.5}$ concentrations are sensitive to large uncertainties in estimated emissions of road dust in some populated areas such as Barrow and to sea salt emissions throughout the coastal zone. While uncertainties in road dust emissions do not play a significant role in evaluating the impacts of new oil and gas sources, a potential overestimation of sea salt emissions can result in an overestimation of the impact of NO_X emissions on particulate nitrate formation, thus adding to the predicted total $PM_{2.5}$ mass burden, as well as to acid deposition and visibility impacts. A sensitivity analysis was conducted using a new experimental sea salt emissions preprocessor (Stoeckenius et al., 2017) to help evaluate the sensitivity of predicted impacts to uncertainties in sea salt emissions. CAMx sensitivity runs were prepared for two different 10-day periods: one in April and one in August. Each 10-day simulation consisted of a 3-day spin-up period and seven analysis days. Results from these runs were compared with results for the same periods from the original CAMx run. Highlights of the sensitivity analysis results include:

    - The revised sea salt emission estimates averaged 96 percent less than in the original simulation. While no contemporaneous sodium observations were available with which to evaluate the revised sea salt estimates, the much lower sea salt emissions generated by the new preprocessor provided a convenient benchmark for the sensitivity analysis. Comparisons of the revised sodium predictions with historical (1997 – 2009) monthly average sodium measured at Barrow and with predictions for the corresponding 7-day periods during April and August from the original CAMx simulation show a large reduction in overprediction bias towards levels more in line with observed values in August but a large underprediction in April.

    - Reduced sea salt emissions result in large reductions in particulate nitrate due to reduced sodium nitrate formation. This has a corresponding impact on total predicted $PM_{2.5}$ in coastal areas where a large fraction of the predicted $PM_{2.5}$ is associated with nitrate. Sensitivity to reduced sea salt emissions are much smaller away from the coast.

    - Reductions in particulate nitrate resulting from reduced sea salt emissions result in lower estimates of visibility impacts in the Alaska National Wildlife Refuge where large impacts were predicted from the original model run. However, even with lower sea salt emissions, the new oil and gas sources (Source Group D in Table V-1) are predicted to result in peak day visibility impacts exceeding the 1 deciview (dv) threshold at coastal locations in the ANWR on at least a few days during the year. The impact of reduced sea salt emissions on predicted visibility impacts in other Class I and selected Class II areas is less clear given the limited temporal coverage of the sensitivity analysis.

- Impacts of sea salt emission reductions on ozone were minimal; averaging an increase of 0.74 ppb during the August period.

VI. TASK 6: EMISSION EXEMPTION THRESHOLD EVALUATION

A key objective of the Arctic AQ Modeling Study is to evaluate the current regulatory equations in 30 CFR 550.303(d) used to estimate exemption thresholds for offshore source emission rates of selected pollutants for the study domain. If this examination shows that the equations can be improved relative to the source emission rates of selected pollutants in the study domain, then ERG will develop options for revisions of the equations for consideration by BOEM.

Task 6 builds on the modeling analyses conducted by the ERG/Ramboll in Tasks 4 and 5, combined with additional modeling to rigorously test the existing emission exemption threshold (EET) formulas.

A. Summary of Approach

In general, the EET evaluation approach involves modeling "synthetic" offshore sources in the Chukchi and Beaufort Seas. The reason for using hypothetical, but representative, sources is twofold:

- Using synthetic sources avoids the perception that BOEM is calling into question previous exemption analysis for existing sources. It is not the intent of this study to review previous plans and test the validity of the analysis already conducted for current exploration or production operations.
- Developing synthetic sources allows the flexibility to pair various emission levels with various distances to shore to ensure the formula is tested with the full range of possible values. By capturing the full range of possibilities, the existing EET formulas will be thoroughly tested for any limitations, including combinations of emissions and distance to shore not currently leased.

For the synthetic source emissions levels, ERG developed emission rates for the following emissions scenarios that represent:

- Drilling exploration plan (EP) with well testing.
- Development and production plan (DPP).
- DPP with well testing.
- Production-only DPP.
- Floating production storage and offloading (FPSO) platforms.

ERG developed all five scenarios for small-, medium-, and large-scale operations using calculation methods consistent with submitted EPs and DPPs.

ERG reviewed publicly available EPs and DPPs from BOEM's website for typical platform configurations and emissions levels submitted to BOEM for approval (BOEM, 2017). ERG then used the platform configurations and support vessels from the available plans to construct synthetic sources for each of the five scenarios and each operational scale. Table VI-1 summarizes the scenarios and indicates equipment required under each scenario. For example, all production operations (Scenarios 2, 3, and 4) include at least one vent or flare (with volumes that include upsets).

Table VI-1. Summary of Mandatory Equipment Under Each Scenario

Scenario	Description	Includes (At Least One)
1	Drilling EP well testing	Diesel engines
2	Production and drilling DPP	Diesel engine, flare or vent, and fugitives (default of 11,420 components with light oil stream type)
3	Production and drilling DPP with well testing	Diesel engine, flare or vent, and fugitives (default of 11,420 components with light oil stream type); and well testing
4	Production **only**	Diesel engine, flare or vent, and fugitives (default of 11,420 components with light oil stream type)
5	FPSOs	Diesel engine, flare or vent, and fugitives (default of 11,420 components with light oil stream type)

After adding all the representative equipment for each scenario, ERG made additional modifications to operational hours and activity levels to ensure an adequate variation in the annual and hourly emission level to be modeled. Hourly emission rates are consistent with the supporting maximum hourly emission rate calculations in the EP and DPP air quality spreadsheets (i.e., the total hourly emission rate if all equipment was operated at the same time). The emission values were rounded to the nearest hundred to flag that the modeled emissions are synthetic sources (e.g., 15,897 would be rounded to 15,900). Table VI-2 presents the initial hour emission levels of PM_{10}, $PM_{2.5}$, SO_2, NO_x, NH_3, VOC, and CO used in modeling.

Table VI-2. Hourly Emission Levels for Synthetic Sources

Scenario	Description	Size	Emissions (lb/hr)						
			PM_{10}	$PM_{2.5}$	SO_2	NO_x	NH_3	VOC	CO
1	Drilling EP with well testing	L	66	65	631	1,487	0.77	56	356
		M	42	41	459	948	0.63	34	224
		S	31	31	176	587	0.25	34	142
2	Production and drilling DPP	L	114	113	669	3,824	0.77	126	600
		M	41	40	460	1,076	1.10	138	263
		S	32	31	176	600	0.25	139	144
3	Production and drilling DPP well testing	L	77	77	506	2,780	0.63	88	346
		M	44	44	461	1,001	0.84	140	238
		S	32	31	176	600	0.25	139	144
4	Production only DPP	L	14	14	1.7	925	0.05	119	305
		M	2.7	2.7	1.7	289	0.05	105	161
		S	1.0	1.0	0.9	28	0.01	106	6.6
5	FPSOs	L	15	14	112	676	0.22	125	182
		M	17	17	115	671	0.14	135	178
		S	13	12	113	517	0.22	21	142

Each emission scenario was modeled for a variety of distances to shore that are representative of the active lease blocks in the Chukchi Sea and Beaufort Sea. ERG calculated the distance to shore for all the active lease blocks in the Arctic OCS. The active lease blocks were determined using the Active Lease Polygons shapefile published on the BOEM "Geographic Mapping Data in Digital Format" website (BOEM, 2015) and the ArcGIS proximity toolset to calculate the closest distance to shore for each active lease block. Because of barrier islands off the Alaska coast, the overall lease block minimum distance to shore of 3 statute miles (4.8 km) determined by the analysis periodically fell outside the BOEM Planning Area boundary (i.e., within state waters). Therefore, the distances were adjusted to be parallel to the state seaward boundary instead of the shoreline. This will ensure all locations selected will be placed just outside state waters. Table VI-3 summarizes the distances used for synthetic source placement in modeling.

Table VI-3. Summary Statistics for Distance to Shore

Distance to Shore (statute miles [km])	Distance from Seaward Boundary (statute miles [km])	Represents
3 [4.8]	1 [1.6]	Minimum distance of all lease blocks
16 [25.7]	13 [20.9]	Average distance for Beaufort Sea
22 [35.4]	19 [30.6]	75th percentile distance for the Beaufort Sea
39 [62.8]	36 [57.9]	Maximum distance for the Beaufort Sea
60 [96.6]	57 [91.9]	25th percentile distance for all lease blocks
83 [133.6]	80 [128.7]	25th percentile distance for Chukchi Sea
91 [146.5]	89 [143.2]	Median distance of all lease blocks
106 [170.6]	103 [165.8]	Average/median distance for Chukchi Sea
120 [193.1]	117 [188.3]	75th percentile distance for all lease blocks
163 [262.3]	160 [257.5]	Maximum distance for all lease blocks

The proposed synthetic source locations were selected at random from the modeling grid cell that fell along the distance lines. All locations are within federal waters in the 4 km WRF domain, and coincide with the center of a modeling grid cell. Figure VI-1 shows the proposed synthetic source locations in the study area.

ERG modeled the synthetic sources at 50 km or less from the state seaward boundary using AERMOD following similar modeling procedures to the ADM modeling in Task 4 (i.e., same modeling set and options) in multiple locations in the Chukchi and Beaufort Seas, at multiple distances to shore. Synthetic sources at a distance greater than 50 km from the state seaward boundary were modeled with CALPUFF. Along the 57-mile contour from the state seaward boundary, a subset of sources was modeled with both AERMOD and CALPUFF to determine the difference in impact predicted by both models.

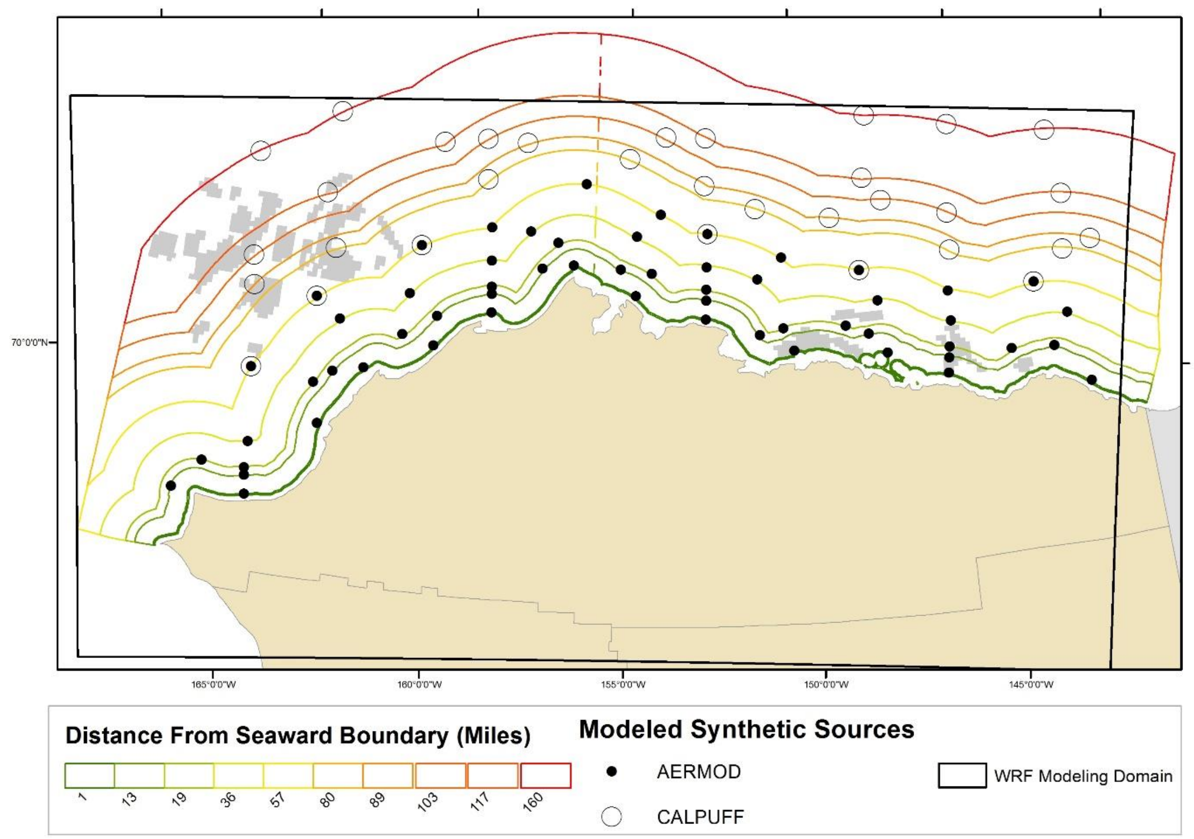

Figure VI-1. Synthetic Source Placement

Each of the modeled synthetic sources was subjected to the existing EET formulas to determine the level of impact at the receptors compared to the established SILs for each NAAQS. The results of the exemption formulas were compared to the over/under SILs conclusions from the modeling. This produced three outcomes with respect to the EET:

- "Pass"
  - A correct evaluation.
  - Emissions from the scenario were above the EET threshold, which indicated modeling was needed and the modeling impacts were above the SIL, or emissions from the scenario were below the EET threshold, which indicated modeling was not needed and the modeled impacts were below the SIL.
- False positive (Type I error)
  - Emissions from the scenario were above the EET threshold, which indicated modeling was needed, however the modeled impact was below the SIL.
- "Miss" (Type II error)
  - Emissions from the scenario were below the EET threshold, which indicated modeling was not necessary, however the modeled impact was over the SIL.

B. Final Findings

The existing EET formulas are overly conservative for most annual standards. Specifically, the existing formulas suggest modeling is needed more often than is necessary. In addition, for the short-term standards, the formulas have a higher "miss" rate. However, the miss rate generally does not exceed 15 percent for most of the NAAQS. The 1-hour SO_2 and 24-hour NAAQS $PM_{2.5}$ and PM_{10} have a miss rate higher than 15 percent.

Although the emission exemption thresholds generally show they are still protective, BOEM may want to consider alternative approaches to reduce the false positive rate to reduce the burden on the operator. An alternative approach to the EET formulas would be to utilize the modeling information from this task to estimate impacts based on comparable modeled sources. For example, an operator could identify a synthetic source modeling run at a comparable emission rate and distance to shore as the proposed source to evaluate the likelihood of a significant impact. If the comparable synthetic source impacts are below SIL values, then the proposed source should be as well. Because not all possible iterations of emissions levels and distances to shore were modeled, there would have to be concessions in matching to ensure a protective estimate (i.e., conservatively high estimate of impact). For example, a comparable source should select a synthetic source with higher emission rates in the absence of an exact match. The results from any modeling submitted to BOEM could also be added to the database to provide additional sources for comparison. Additionally, the synthetic source database does include a unit emission rate source (i.e., 1 gs^{-1}) impact run for three source types: 1) elevated hot stack, 2) short cold stack, and 3) vessel characterized as a volume. These results could be scaled and combined to estimate a more comparable emissions rate.

For secondary formation, ERG developed conservatively low modeled emission rates for precursors (MERPs) (Table VI-4) for use in the Arctic based on three synthetic sources placed in both the dispersion and photochemical grid future year modeling (Do et al., 2017). The MERP guidance from EPA is still in draft form and the EPA is continuing to add to the MERP modeling database. As such BOEM will want to continue to coordinate with the EPA on the best methods for estimating source contributions to secondary formation in Alaska's unique climate and evaluate EPA modeling results for Alaska. BOEM could coordinate with the ADEC on any additional modeling efforts to support MERP development specific to Alaska.

Table VI-4. MERPs Based on Hypothetical Sources

NAAQS	SIL	Emission Rate (tpy)	Estimated Impact	MERP (tpy)
Daily $PM_{2.5}$	1.2	100	1.18	102
Annual $PM_{2.5}$	0.2	100	0.22	91
8-hr O_3	1.0	100	0.04	2,500

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