Drill Rig Technical Review Status

October 30, 2015

Simplified Overview of Technical Drill Rig Workgroup Timeline

1/23/14	• Industry presents North Slope industry monitored data for 1-hr NO_2 and $PM_{2.5}$
4/3/14	• DEC presents review of North Slope 1-hr NO_2 air quality (monitoring) data at a drill rig technical workgroup meeting
4/17/14	• Modeling to augment the monitoring, provide guardrails and drill rig activity categories are introduced
8/21/14	• Technical drill rig limits and modeling initially presented by AECOM at a drill rig technical workgroup meeting
12/19/14	• DEC presents to Drill Rig Technical Workgroup a technical review of modeling data after collaborating on modeling issues that still need to be resolved (background data, stack heights, etc.)
1/23/15	• Industry sends updated background NO_2 proposal for review
2/23/15	• Consensus reached not using background NO_2 proposal and adding NO_2 varying with wind speed
4/28/15	• AECOM is preparing final modeling files
7/8/15	• AECOM sends completed modeling files
8/10/15	• AECOM answers outstanding technical modeling questions on modeling files
8/27/15	• Internal DEC presentation to review of latest modeling results and the last outstanding issues (all pollutants (SO_2, NO_2, $PM_{2.5}$, CO, PM_{10}) ISRs, updated background approach)
9/23/15	• AECOM presents latest modeling results for SO_2 to DEC
9/25/15	•DEC presents review of latest review on revised model inputs (final ISRs, SO_2 fuel limits, outstanding CD 1 and CEMS review) internally to DEC
10/13/15	•DEC presents of final review of modeling methodology agreement including additional excursion modeling and summary nominal fuel use table, and discussion technical workgroup conclusions internally to DEC

North Slope Industry Monitored Data

Drill Rig Episode Description	Rig	Rig Hours-data	Power	1-hr NO_2 >0.08 ppm to 0.1 ppm	1-hr NO_2 >0.1 ppm	Max Fuel (gal/day)	Max NO_2 (ppb)	WS(mph)
CD1- Doyon19- Sidetrack 10/1/12-10/31/13 Sidetrack 1 11/1/12-1/25/13 Original 47,49 5/3/13-7/14/13 Original 49 (wells 1, 47,49)	1	1789	Ongrid	0	0	2436	68	1.8
CD3- Doyon 19, 141 Original 2/21/2011-4/16/2011 (wells 125,127,198)	2	1293	Ongrid	1	0	2856	87	3.34
DS1F- sidetrack, 1F-16 (11/4-11/14/01)	1	240	Ongrid	0	0	2850	33	1.3
Apad- 2006- Doyon14- workover 10/30/2006 -11/10/2006 Well 43	1	287	Off grid	0	0	2540	72	7.7
Apad 2006- Nabors 4ES 7/31/2006 through 8/27/2006 Well 2 workover	1	671	Off grid	8	3	2540	156	5.8
Apad-2007 Nabors 2ES sidetrack 1/1/2007 through 2/9/2007 Well 05i	1	957	Off grid	2	1	3444	111	6.2
Liberty SDI- Doyon 16 2/5-2/16/2007	1	263	Off grid	3	0	3375	84	11.8

DEC Conclusions Regarding the North Slope Industry Monitored Data

- There are no violations of the 1-hour NO_2 NAAQS in these data sets
- The data could be considered adequate for determining that drilling under similar North Slope conditions (i.e. similar number of rigs, fuels use, meteorological conditions, duration of activities, type of drill rigs, etc.) would not cause a violation of the 1-hour NO_2 NAAQS
- However, the data are not adequate to conclude that drill rig emissions under any scenario will not threaten the 1-hour NO_2 NAAQS

Monitoring to Modeling

- The technical workgroup agreed that modeling was best option for filling the data gaps
- Modeling was previously used to demonstrate compliance with the annual NO_2 NAAQS for Minor General Permit 1 (MG1) and the various source specific permits (minor and Title V)
- However, initial modeling runs showed that the commonly used approach of assuming continuous year-round operation did not demonstrate compliance with the 1-hour NO_2 NAAQS
  - The 1-hour NO_2 NAAQS went into effect April 12, 2010

Monitoring to Modeling (cont'd)

- The 1-hour NO_2 NAAQS is based on a complex calculation
  - 3-year average of the 98^{th}-percentile of the daily maximum 1-hour NO_2 concentration
- The technical workgroup therefore used a statistical approach for the 1-hour NO_2 demonstration
  - Conducted initial runs with the AERMOD dispersion model
  - Used a Monte Carlo statistical approach (using the TRANSVAP tool) to post process the AERMOD results
- The technical workgroup later decided to use the same approach for the 1-hour SO_2 NAAQS

Drill Rig Categories

- North Slope is initial modeling focus – Cook Inlet to follow
- The technical workgroup decided on categorizing the NS drilling operations into 4 scenarios

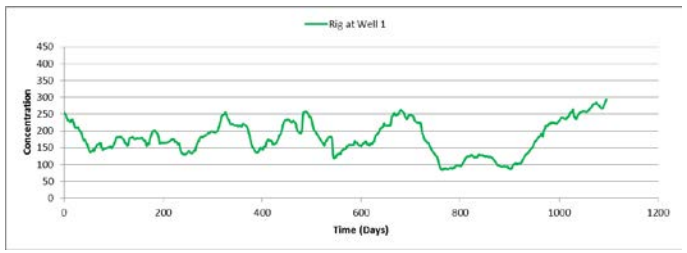
Drilling Category	Description
RDi (Routine Drilling Isolated)	Onshore routine infill drilling and sidetrack drilling at a detached pad, exploration, and delineation drilling.
RDc (Routine Drilling collocated)	Onshore routine infill drilling and sidetrack drilling at a collocated pad.*
DDi (Developmental Drilling Isolated)	Onshore developmental drilling at an isolated pad.
DDc (Developmental Drilling collocated)	Onshore developmental drilling at a collocated pad.*

*Collocated pad means a pad that is contiguous or adjacent to a major stationary source, under the same owner/operator, and under the same SIC code.

In August 2014

- Industry modeled 1-hr NO_2 impacts from a generic drill rig
  - Conducted separate run for each well head (modeled 5 wells per pad)
- Used TRANSVAP to assess impacts from 10,000 combinations of the modeled results
  - Varied when and how long rig operates at each well head
  - See following illustration

Illustration of How TRANSVAP Combines AERMOD Runs from a Rig Operating at 2 Well Heads



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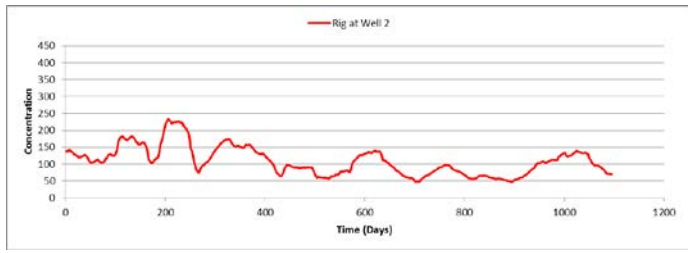

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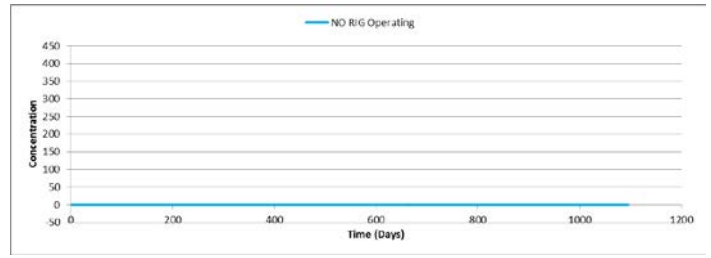

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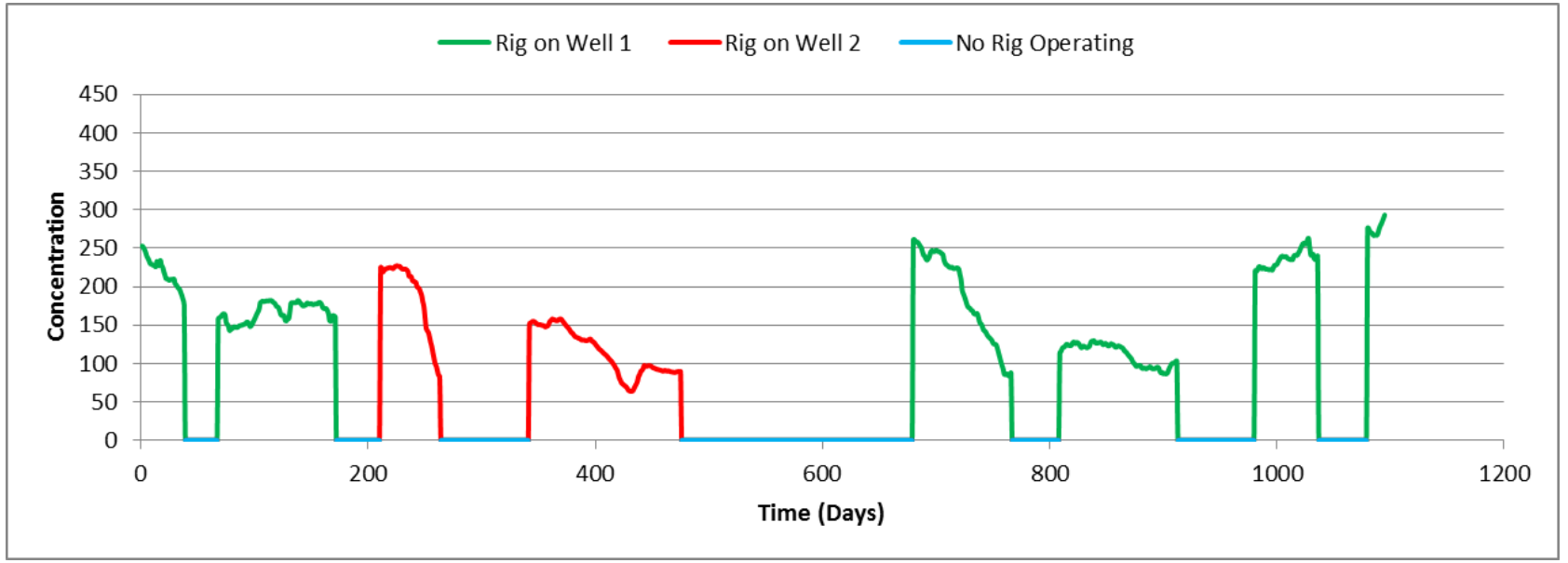


During This Past Year…

- Industry and DEC have worked through various aspects of the modeling analysis, background data and TRANSVAP runs
- Iterative process that included one or more of the following
  - Detailed technical discussions,
  - Review of EPA guidance,
  - Review of applicable data sets,
  - Changes in rig characterization/modeling assumptions, and/or
  - Revised modeling analysis/TRANSVAP runs
- Following table summarizes the various topics and resolutions

Issued Reviewed	Solution	Consensus Reached?	Outstanding Action Items
Drill Rig Activity Distribution Profiles for Routine Infill Drilling	Revised active drilling profile to a more conservative lognormal distribution and refitted inactive drilling profile	Yes	No
Convergence of the Statistical Aspects of the Modeling	Modeled to demonstrate the adequateness of the number of simulations and randomness of drill rig activity files generated for modeling	Yes	No
Stack and Associated Structure Heights	Shortened stack and structure heights to better represent typical drill rig	Yes	No
Stack Locations	Revised stack locations to more realistic configuration	Yes	No
TRANSVAP Results Determining Allowable Fuel Consumption	Used 99th percentile TRANSVAP results instead of 100th percentile to remove unrealistic drill rig activity scenarios	Yes	No
In-Stack Ratio (ISR)	Revised engine and heater/boiler in-stack ratios based on representative emissions units	Yes	No
Future Applicability of Modeling to Tier 4 Engine Impacts	Conducted modeling to demonstrate proposed drill rig modeling conservatively accounts for differences in Tier 4 engine emissions and ISR	Yes	No
Pad Size	Retained initially proposed smallest existing pad size	Yes	No
Other Pollutants and Averaging Periods	Modeled other criteria pollutants and averaging periods (except lead)	Yes	No
Background NO_2 Approach	Varied background concentration by wind-speed	Yes	CD 1 data under review
Impact of Intermittent Hourly Excursions in Fuel Consumption	Conducted modeling with randomly-occurring 25% increased fuel consumption, 20% of the time	Yes	Discussing the actual operational days for each category

Stack and Associated Structure Heights- Items to Note

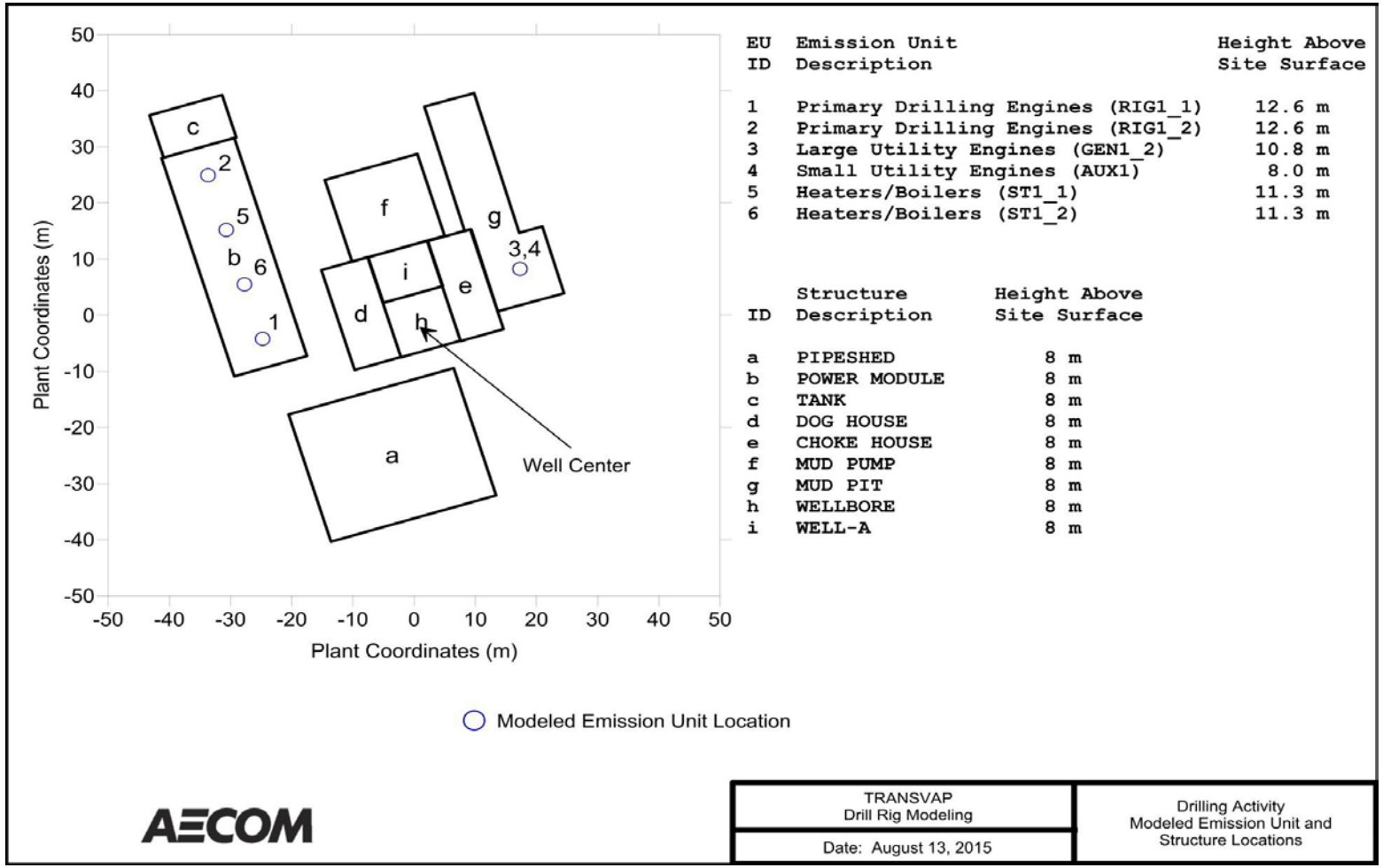
- Modeled stack and building heights now represent heights on a “typical” drill rig
  - Surveyed the building heights, stack heights, and stack-to-building height ratios from 7 North Slope drill rigs
  - Selected a relatively short building height (8 m)
  - Then used the average stack-to-building height ratio for each type of unit to calculate the stack height for that unit
- Drill rig characterized as having the units shown in following table
  - Units/ratings based on a survey of 22 North Slope drill rigs

Ratings and Stack Heights of Modeled Units

Unit Description	Cumulative Rating	Assumed Stack Height (m)*
Primary Drilling Engines	5,500 bhp	12.55
Large Utility Engine	800 bhp	10.84
Small Utility Engine	100 bhp	8.00
Heaters/Boilers	20 MMBtu/hr	11.32

* Height above site surface.

Stack and Associated Structure Heights- Assumed Drill Rig Stack/Building Locations



EU ID	Emission Unit Description	Height Above Site Surface
1	Primary Drilling Engines (RIG1_1)	12.6 m
2	Primary Drilling Engines (RIG1_2)	12.6 m
3	Large Utility Engines (GEN1_2)	10.8 m
4	Small Utility Engines (AUX1)	8.0 m
5	Heaters/Boilers (ST1_1)	11.3 m
6	Heaters/Boilers (ST1_2)	11.3 m

ID	Structure Description	Height Above Site Surface
a	PIPESHED	8 m
b	POWER MODULE	8 m
c	TANK	8 m
d	DOG HOUSE	8 m
e	CHOKE HOUSE	8 m
f	MUD PUMP	8 m
g	MUD PIT	8 m
h	WELLBORE	8 m
i	WELL-A	8 m

Important Aspects of the Modeling Analysis

- Continued to assume vertical, uncapped stacks
- Used two different fuels for 1-hr SO_2 demonstration, but kept total fuel consumption constant
    - Ultra-Low Sulfur Diesel (ULSD) for engines (0.0015% sulfur)
    - Low End Point Diesel (LEPD) for heaters/boilers (0.15% sulfur)
    - Varied the fuel allocation of each by season
- Used current AERMOD/AERMET (version 15181) for NO_2 and 24-hr PM-2.5 but previous version (14134) for other pollutants
    - AECOM provided 1-hr SO_2 and 24-hr PM-2.5 sensitivity runs to show results do not change

Important Aspects(cont'd)

- Used Plume Volume Molar Ratio Method (PVMRM) to estimate NO_2
  - Non-Guideline (alternative) modeling technique that requires Department and R10 approval
    - R10 has previously granted similar requests – DEC expects that they will continue to do so
  - Alternative modeling techniques are subject to public comment (per EPA and State rule)
  - EPA proposed revised version (PVMRM2) as Guideline approach in July 2015
    - Proposal does <u>not</u> require revisions to work in progress

Items to Note re TRANSVAP Results

- Industry provided results in terms of “nominal” fuel consumption (gallons/day)
  - Provided value for each pollutant/averaging period and drilling scenario
  - The term “nominal” is undefined but generally represents the quantity that could be burned without violating the given NAAQS

Current Nominal Fuel Limits (gal/day)

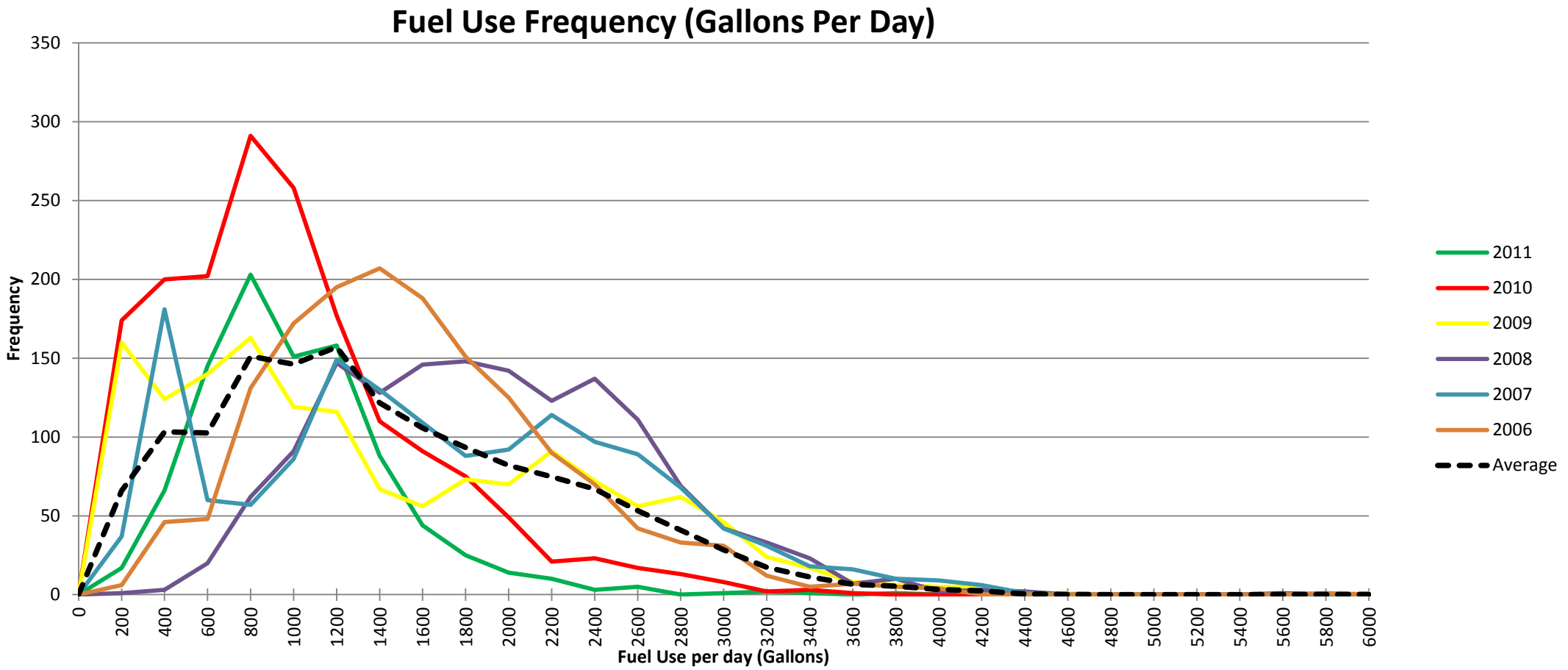
Pollutant	Averaging Period	Drill Rig Scenario			
		RDi	RDc	DDi	DDc
CO	1-Hour	1,540,600			
	8-Hour	708,600			
NO_2	1-Hour	14,700	11,400	14,700	10,700
	Annual	113,400			
$PM_{2.5}$	24-Hour	47,700			
	Annual	83,100			
PM_{10}	24-Hour	118,800			
SO_2	1-Hour	21,000	21,000	17,900	17,900
	3-Hour	103,900			
	24-Hour	39,800			
	Annual	129,300			
Smallest Limit per Scenario		**14,700**	**11,400**	**14,700**	**10,700**

Key

Red = Pollutant/averaging period with smallest fuel consumption

Yellow Highlight = Smallest nominal fuel limit

Nominal Values Are Above Historic Drill Rig Fuel Use within Prudhoe Bay



Note re Possible Variances (Excursions)

- Industry noted that drilling efforts sometimes require temporary "spikes" in fuel consumption

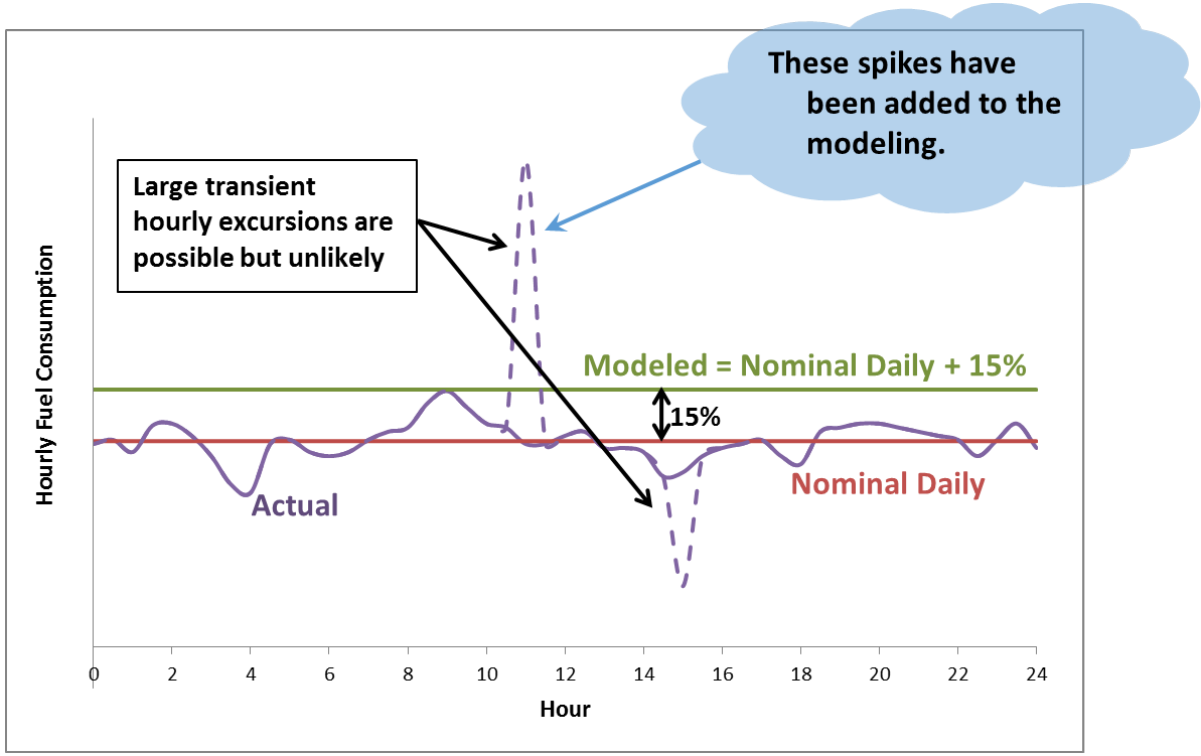


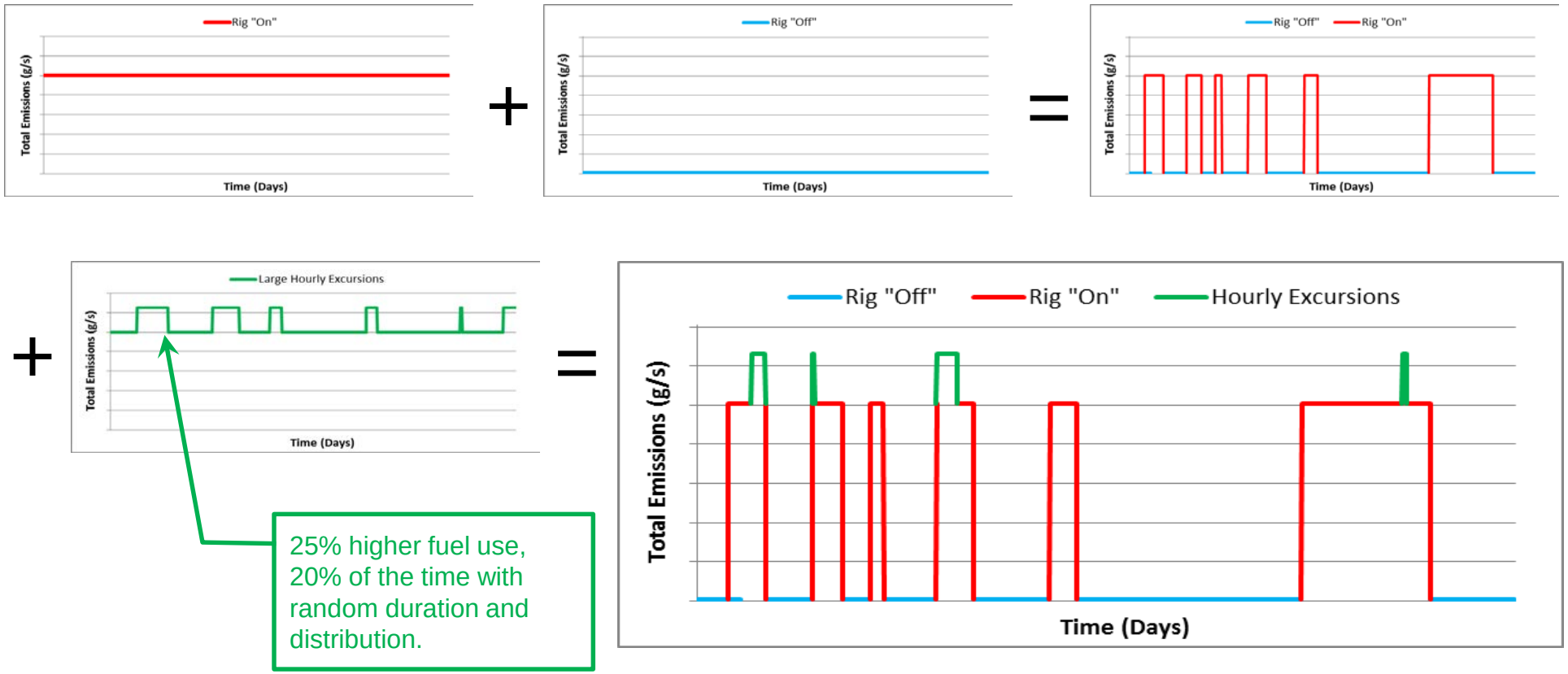
Figure is courtesy of AECOM

Variances(cont'd)

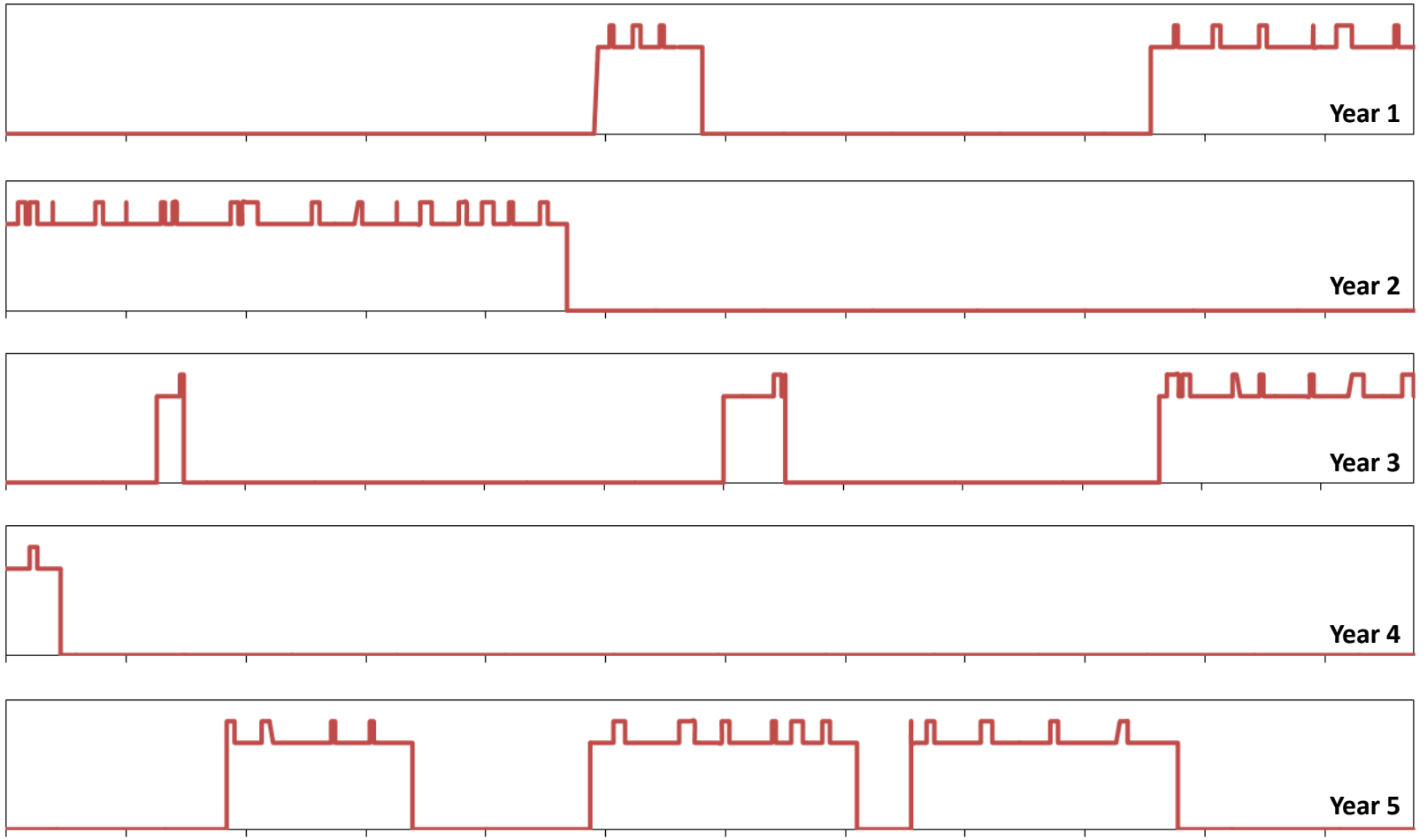
- Industry incorporated excursions by assuming:
  - They lead to a 25% increase in fuel consumption, and
  - Randomly occur 20% of the operational time
- See following figure

How to Turn Activity Profiles into Simulations with Hourly Excursions

- Use the TRANSVAP postprocessor to combine impacts from each profile created with AERMOD output:



Example 5-Year Drill Rig Activity Profile with Excursions



Industry Proposed “Excursion” Limits vs. “Nominal” Limits

Allowable Fuel Consumption Based on 1-hour NO_2 Demonstration

Fuel consumption (gal/day) for each scenario	**RDi**	**RDc**	**DDi**	**DDc**
Proposed Nominal Fuel Limit	14,700	11,400	14,700	10,700
Proposed Excursion Limit (allowed 25% higher fuel use 20% of the time)	18,375	14,250	18,375	13,375

- Note: See DEC comments on next page

DEC Comments on Proposed Excursion Limits

- The “20%” concept would need to be translated to an allowed operating period
  - For example 6 days within each 30 day operating period
- The excursion analysis assumed the fuel spikes occurred from the modeled drill rig (see *Stack and Associated Structure Heights-Modeled Units* slide)
  - Potential allowances for concurrent well servicing activities (including well fracking) would need additional consideration

Tickler Regarding a Mundane but Important Program Requirement

- Any program based on this modeling will need to require vertical, uncapped stacks during drill rig activities.
  - Critical modeling assumption
  - Capped/horizontal stacks would
    - Likely cause increased modeled impacts and
    - Lead to more restrictive fuel limits

Technical conclusions

- Drill rig fuel use limits are only for North Slope drill rigs represented by the modeled drill rig
  - May not represent operations that include additional significant sources

“Monte Carlo” Modeling with TRANSVAP