On the Underestimation of NOx Emissions from Oil Well Drilling Activities in Kern County, CA

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A. INTRODUCTION AND SUMMARY

Kern County is a significant producer of oil and gas in California. As a result, significant numbers of oil and gas related projects request and receive approvals in Kern County annually. For example, in just 2013 and 2014 respectively, 2586 and 2207 permits were issued for well drilling by the State of California, Department of Conservation, Division of Oil, Gas and Geothermal Resources (hereafter "DOGGR") field office in District 4, with jurisdiction over Kern County. In addition, for 2013 and 2014 respectively, 1661 and 2257 permits were issued for rework of existing wells; and 1608 and 1363 permits were issued for well abandonment.[1] To illustrate the point relating to underestimation of NOx emissions from drilling activities, we will focus just on a few of the many new drilling projects proposed by various operators. We have every reason to believe that such underestimate is also occurring (and not just for NOx emissions but for other associated pollutants as well) for well rework and well abandonment activities as well as for emissions associated with related activities such as installation, rework or abandonment of Underground Injection wells, etc.

Well drilling activities for oil and gas[2] in Kern County involve fuel (mainly diesel) combustion in internal combustion engines of various sizes that are used for drilling activities. Sometimes such engines directly drive devices such as pumps; in other instances they provide power for generators and electrical energy from the generators is then used to drive motors. In any case, diesel combustion in engines results in emissions of NOx, among other pollutants such as carbon monoxide (CO), various sizes of particulate matter (PM), uncombusted fuels (including volatile and semi-volatile organic compounds), numerous toxic and hazardous air pollutants (HAPs) as well as greenhouse gases such as carbon dioxide (CO2). We focus on just NOx emissions in this analysis.

We reviewed several recent project submittals to DOGGR District 4 by various project operators – dealing with environmental impacts, including estimated air emissions for NOx and other pollutants. These include:

- the Rhythm Project Initial Study/Mitigated Negative Declaration (April 2015);
- the Terrebonne Project Initial Study/Mitigated Negative Declaration (April 2015);
- the Sherman 1-23 Initial Study/Mitigated Negative Declaration (July 2014);
- the Blackwells Corner Initial Study/Mitigated Negative Declaration (May 2014); and
- the Rio Viejo Initial Study/Mitigated Negative Declaration (May 2014).

In addition, we also reviewed summary information relating to estimated NOx emissions from drilling for the Jedessa, Tamarack 1, Patricia McKellar, and Rancho Grande 1 projects from 2012-2013.

Our review indicates the following: (a) that underlying activity assumptions made by various operators for developing emissions estimates are often either not supported or are inconsistent across projects; (b) to the extent activity assumptions to support emission estimates are provided, there is no mechanism to verify if subsequent actual activity levels in the field, are, in fact, consistent with the assumptions made in developing emission estimates in the pre-project planning and environmental analyses; (c) the DOGGR review of submitted documents lacks depth and critical analysis and rarely, if ever, challenges assumptions by project proponents; (d) there is no review of such emission estimates by the local air quality planning agency; (e) to the extent that the public is provided the opportunity to comment on such documents – they do not appear to have any impact on project approvals by DOGGR; (f) there appears to be no coordination between DOGGR approval of projects and the local air quality planning agency – thus, directly and adversely affecting air quality emissions inventories and air quality planning, including plans to bring the area into attainment for several National Ambient Air Quality Standards, including for ozone and fine particulate matter (PM2.5); and (g) NOx emission estimates associated with drilling activities (a subset of such emissions associated with oil and gas well drilling, development, completion, reworking, and abandonment) appear to be significantly lower than estimated emissions in other jurisdictions.

During the course of this study, it also became apparent that accessing relevant project documents at the local DOGGR office relating to past and current projects as a member of the public is not an easy task – further impeding the already opaque and inconsistent approval process for drilling projects by DOGGR.

As a result of our review and analysis which indicates significant underestimation of NOx emissions associated with oil and gas well drilling activities in Kern County, it is likely that such projects, which currently obtain approvals from the DOGGR for the California Environment Quality Act (CEQA) compliance via Mitigated Negative Declarations (MNDs), might need a full fledged Environmental Impact Reports (EIRs), as least as far as air quality impacts are concerned.

This analysis concludes with a set of recommendations to improve and strengthen the procedural and technical flaws identified with the current review (and approval) process for such projects by DOGGR.

B. ANALYSIS OF KERN COUNTY PROJECTS

Table 1 in Attachment B shows a summary of the NOx emissions as estimated by each of the projects analyzed in this study. Shown in Table 1 are NOx emissions from just the drilling activities alone. To the extent provided in the underlying project documents, Table 1 shows the equipment name (such as cranes, forklifts, drill motors, generators, etc.), the sizes of the combustion engines in hp, the assumed load factors for each of the equipment engines, and the activity levels (in hours per day and days per year) expected for each project. Collectively, the overall drilling activity is therefore an expected number of hp-hours for a given project. This is also calculated and provided in Table 1.

NOx emissions are usually estimated by multiplying the activity level (i.e., expected hp-hr) by an emission factor (typically in grams of NOx/hp-hr) to arrive at the mass emissions (grams, or converted to pounds or tons) of NOx for a given time period (such as hourly, daily, or for the project). The assumed NOx emission factors for each project, to the extent determinable from the underlying documents are also shown in Table 1.

To make comparisons meaningful, NOx emissions for projects are shown in Table 1 for not only a project as a whole (which may involve the drilling of multiple wells), but also on a per-well basis – since some of the project documents provide breakouts for just 1 well. In other words, in subsequent comparisons shortly, we will only compare 1-well NOx emissions from various projects in order to determine variability or consistency.

In addition to the activity level (in hp-hours) for the equipment engines and associated NOx emissions, Table 1 also provides an indicator of the well itself – typically the depth of the well. Obviously, the engine hp-hr activities at a given well pad ultimately should relate to the effort required to drill the well. Well depth (for vertical wells) is therefore used as the parameter of the underlying project goal. Thus, Table 1 shows, for each project where well depth is provided, the normalized engine activity level per 1000-ft of well depth (i.e., hp-hr/1000 ft). Finally, Table 1 also shows the estimated NOx emissions from the different projects in pounds/1000-ft well depth. These normalized parameters make it easier to compare across projects.

Next, we review specific findings from the data presented in Table 1.

First, it is clear that the level of reporting for NOx emissions development varies from project to project. While some of the recent 2014/2015 projects provide details of the equipment that will be used as well as line-by-line details of the equipment activity factors and associated NOx emissions (including emission factors), that is not always the case, especially for the older projects. Project documents for the older projects were not always transparent with regards to such details. They should be. Without such granular detail, it is not clear how DOGGR could have reviewed the underlying documents. Certainly, such lack of detail and transparency is not acceptable from a public review standpoint.

Second, as Table 1 shows, even for the projects with equipment detail, the level of detail varies. While some projects provide more detail for equipment types, others do not. There does not appear to be any standardization in such calculations. Clearly DOGGR could request information from applications on a more standard basis. That does not seem to be occurring.

Third, the load factors used for the various engines and activities are not supported in any of the documents. Thus, the basis for using 0.37 for the backhoe in a given project; or using 0.5 for the main drill rig motor in another project is not at all clear. It is important to note that these load factors directly affect the activity levels (i.e., hp-hr) that are then used in the emission calculations.

Fourth, the sizes (hp) of the equipment and the NOx emission factors used are typically not consistent across the projects. Table 2 shows the various types of equipment that are proposed to be used in the drilling phase for the projects analyzed, along with the engines sizes and the assumed NOx emission factors.

While the size of the equipment is a choice made by the project proponent, NOx emission factors should typically be consistent for similar equipment. Currently, different engine emission standards (Tier 3 or Tier 4, for example) apply to engines in California depending on when the engines were manufactured. Clearly, when a specific project is being proposed, the project proponents know what engines will be used; and therefore there should be solid support for the emission factor – whether from actual test data or from manufacturers (via guarantees, supported, in turn, by test data). In Table 2, there appears to be considerable variation in the emission factors for the mid-range engines between 300-600 hp.

TABLE 2
EQUIPMENT SIZES AND NOX EMISSION FACTORS

EQUIPMENT-PROJECT	SIZE [HP]	NOX EF [G/HP-HR]
Welder-Blackwells Corner	20	2.247
Small Generator-Rhythm	45	3.592
Small Generator-Terrebone	45	3.592
Small Generator-Sherman 1-23	45	3.592
Generator-Rio Viejo	45	3.731
Generator-Sherman 1-23	75	3.731
Backhoe-Blackwells Corner	91	2.057
Drill Rig Motor #1-Sherman 1-23	200	2.043
Draw Works-Sherman 1-23	200	1.979
Crane-Rhythm	226	2.196
Crane-Terrebone	226	2.196
Crane-Sherman 1-23	226	2.196
Mud Pumps-Sherman 1-23	300	3.02
Crane-Rio Viejo	375	1.805
Backhoe-Rhythm	400	1.602
Backhoe-Terrebone	400	1.602
Backhoe-Sherman 1-23	400	1.602
Forklift-Blackwells Corner	400	1.277
Backhoe-Rio Viejo	400	1.654
Forklift-Rio Viejo	400	1.277
Crane-Blackwells Corner	485	1.805
Generator-Blackwells Corner	500	2.656
Draw Works-Blackwells Corner	540	1.607
Pump-Blackwells Corner	1000	3.851
Drill Rig Motor #1-Rhythm	1477	1.504
Drill Rig Motor #1 (Idle)-Rhythm	1477	1.504
Drill Rig Motor #2-Rhythm	1477	1.504
Drill Rig Motor #2 (Idle)-Rhythm	1477	1.504
Backup Drill Rig Motor #3-Rhythm	1477	1.504
Drill Rig Motor #1-Terrebone	1477	1.504
Drill Rig Motor #1 (Idle)-Terrebone	1477	1.504
Drill Rig Motor #2-Terrebone	1477	1.504
Drill Rig Motor #2 (Idle)-Terrebone	1477	1.504
Backup Drill Rig Motor #3-Terrebone	1477	1.504
Drill Rig Motor #1 (Idle)-Sherman 1-23	1477	1.504
Drill Rig Motor #2-Sherman 1-23	1477	1.504
Drill Rig Motor #2 (Idle)-Sherman 1-23	1477	1.504
Backup Drill Rig Motor #3-Sherman 1-23	1477	1.504
Drill Rig Motor-Rio Viejo	1600	1.491
Drill Rig Motor-Rio Viejo	1600	1.491
Idle Drill Rig Motor-Rio Viejo	1600	1.491

It is also worth comparing the NOx emission factors against the relevant CA emission standards. For example, for the largest engines, size 750 hp (560 kW) and greater, the NOx standard for engines manufactured after 2006-2010 is 3.5 grams/kW-hr or 2.61 grams/hp-hr.[3] Yet, the vast majority of the NOx emission factors used for these sized engines is significantly lower at around 1.5 grams/hp-hr. Why that is so or what makes these engines able to meet the lower (and unenforceable) assumed emission factor is not explained by DOGGR. We note that in one instance, the assumed emission factor of 3.851 grams/hp-hr for a 1000 hp engine was significantly higher than the standard for 2006 and later engines – likely because an older engine was proposed to be used. Why a 2014 project would be allowed to use a pre-2006 engine is also not explained by DOGGR.

The factors for the Terrebonne and Rhythm projects are consistent because both projects are proposed by the same operator; however, that is generally not the case. While most project proponents purport to use computer programs as a basis for the NOx emission factor, it is not clear what options are used in such programs (such as engine descriptions, controls, if any on such engines, the age and type of the engines, etc.) to derive the resultant emission factors. As we will discuss later, as a general matter, the emission factors appear to be significantly lower than factors used in other jurisdictions. While engines used for such activities may, indeed, have lower emission factors, since there is no verification of the NOx emission factors assumed by the project proponents, there is simply no reliable means to verify that actual engines used in the field are comparable to those used in the analyses put forth by the operators. This is a significant shortcoming.

Fifth, we compare the calculated activity levels (in hp-hr/1000 ft of well drilled) for the various projects (where the data was available to make this comparison), in Table 3.

The projects are listed, in order to increasing well depth. While there is some reason to believe that the activity level might increase as the well depth increases, there does not seem to be any consistency whatsoever. For example, for the two relatively shallow wells at Blackwells Corner and Sherman 1-23, the difference (and directionality) of the activity levels is striking. The shallower well at Blackwells Corner is estimated to use almost 5 times the hp-hr as the deeper well as Sherman 1-23. Similarly, there appears to be directionality (i.e., increase in activity levels with depth), the large differences in the calculated activity levels are not clear or supported. For example, why there should be an almost 50% increase in activity level at Terrebonne as compared to Rhythm (both proposed by the same project proponent) is not clear. Nor it is clear why either of these two projects should be so much smaller in activity as compared to the slightly deeper well at Rio Viejo. It is this type of comparison, during review, that DOGGR should be conducting – so that the basis of the differences, to the extent there are any, can be fleshed out and understood. Whether these large differences and inconsistencies can be explained by underlying geological differences or not should be

TABLE 3
NORMALIZED ACTIVITY LEVELS AND WELL DEPTHS COMPARISON

PROJECT	WELL DEPTH	ACTIVITY LEVEL (HP-HR/1000-FT)
Blackwells Corner	1,300	63,309
Sherman 1-23	2,150	13,842
Rhythm	12,500	25,409
Terrebonne	13,500	37,198
Rio Viejo	14,000	64,743

TABLE 4
COMPARISON OF NOX EMISSIONS ON A PER WELL AND PER 1000-FT DRILLED BASIS

PROJECT	WELL DEPTH [FT]	NOX [TONS/ WELL]	NOX [LB/1000 FT]
Blackwells Corner	1,300	0.27	415.4
Sherman 1-23	2,150	0.08	74.4
Rhythm	12,500	0.54	86.8
Terrebone	13,500	0.86	127.1
Rio Viejo	14,000	1.50	214.3
Tamarack #1	14000	2.43	[1]
Jedessa		0.82	[1]
Patricia McKellar		5.5	[1]
Rancho Grande 1		1.1	[1]

[1] Not enough detail to calculate

explored. To the extent formation differences cannot explain such differences, it is clear that there are likely to be fault assumptions in activity factors.

Sixth, and finally, we compare the NOx emissions levels on a per well as well as per 1000-ft drilled basis in Table 4.

Not surprisingly, given the significant unexplained variations in the NOx emission factors as well as the activity factors, we have significant reported variations in the NOx emissions on both per well and per 1000 ft basis – even for similar depth wells.

For example, note the wide difference in the NOx emissions per well between Blackwells Corner and Sherman 1-23. There is no explanation for why the Sherman 1-23 well drilling emissions are as low as estimated. Similarly, note the wide range in the NOx emissions for the 4 deeper wells – ranging from 0.54 to 2.43 pounds on a per well basis (a factor of 4+) and also on a per 1000 ft depth basis – ranging from 86.8 pounds to 214.3 pounds – a factor of almost 3, for the three projects for which this parameter could be computed.

C. COMPARISONS TO OTHER JURISDICTIONS

In the previous section, we have shown the significant and unexplained variations in activity levels, emission factors, and resultant NOx emissions from the various projects, on normalized (i.e., per well, and per 1000-ft drilling) basis.

We have also shown that NOx emission factors, particularly for the larger engines, appear to be too low in most instances.

Since oil and gas drilling is not limited to just Kern County, we reviewed NOx emissions analyses or studies conducted by others. Below we report on some of our findings.

In 2009 and later in 2014, Texas undertook a fairly extensive analysis of drill rig emissions associated with oil and gas exploration in parts of Texas. Actual activity data were solicited via phone and e-mail and collected from numerous rig operators and companies. Based on this, and using emission factors consistent with EPA's standards and models, NOx (and other pollutant emissions) inventories were developed. Distinct differences were noted in rig types for three sets of wells: vertical wells less than 7000 feet; vertical wells greater than 7000 feet; and horizontal/directional wells. Table 5 below shows the summary of rig and activity parameters.

Most useful for our comparison, the Texas study also developed emission factors for various pollutants, including NOx for the vertical (less than 7000 ft and greater than 7000 ft) and horizontal/directional wells. The study reported that the estimated NOx emissions in 2013-2015 per 1000 ft were around 0.36 tons or

TABLE 5
SUMMARY OF RIG AND ACTIVITY PARAMETERS FROM TEXAS (2009)[4]

MODEL RIG CATEGORY	RIG TYPE	ENGINE TYPE	# OF ENGINES	AVERAGE AGE (YRS)	ENGINE SIZE (HP)	HOURS/1,000 FT DRILLED	AVERAGE LOAD (%)
Vertical <= 7,000 ft	Mechanical	Draw Works	1.60	7	442	30.8	51.8
		Mud Pumps	1.69	6	428	29.4	45.9
		Generator	0.97	4	330	28.3	70.4
Vertical > 7,000 ft	Mechanical	Draw Works	2.01	25	455	35.9	47.4
		Mud Pumps	1.62	18	761	33.2	46.0
	Electrical		2.15	2	1,381	62.6	48.5
Horizontal/Directional	Mechanical	Draw Works	2.00	15	483	50.1	41.1
		Mud Pumps	2.00	6	1,075	36.4	42.6
		Generator	2.00	10	390	26.8	69.0
	Electrical		2.03	2	1,346	47.3	52.5
All	All	Completion	1.00	Default	350	10.0	43.0

720 pounds per 1000 ft for the vertical wells less than 7000 feet. For vertical wells greater than 7000 feet the study estimated the NOx emissions to be 0.0876 tons (or 175 pounds in 2013), 0.0828 tons (or 166 pounds in 2014) and 0.0746 tons (or 149 pounds in 2015) – all per 1000 feet.[5]

Comparing the calculated NOx emissions per 1000 ft as provided in Table 4 (and Table 1, Attachment B) for the various Kern County projects, we see that the emission for the two shallow well projects - Blackwells Corner (415.4 pounds) and Sherman 1-23 (74.4 pounds) are significantly lower than the 720 pounds per 1000 ft as estimated by the Texas study – the value for Sherman 1-23 at almost 10 times smaller.

While the comparisons for the deeper well projects are a little better, the factors calculated for the Rhythm (86.8 pounds) or Terrebonne (127.1 pounds) are also significantly smaller than the values estimated by Texas.

A different Texas study discussed the NOx emission factors for various drilling operations. For example, hydraulic pump (or mud pump) engine emission factors were determined to be 5.081 grams/hp-hr in 2013 and 4.775 grams/hp-hr in 2014.[6] While newer engines may be in used in Kern County which may explain the much lower emission factors used, as shown in Table 2 above, one cannot be certain given the lack of verification – that actual factors are not, in fact, much higher as indicated in the Texas study.

In yet another study conducted in 2012 by the Ozone Transport Commission, relying on work done in the Western US by WRAP, the overall drilling emissions from oil and gas wells were reported to be in the range of 2.26 tons/well to 9.78 tons/well.[7] This is a significantly bigger range compared to the calculated values for NOx emissions per well in Table 4. Except for the Tamarack #1 and Patricia McKellar projects, estimated Kern County project NOx emissions are significantly smaller.

The comparisons to studies done by other jurisdictions above indicates that, in most cases, NOx emissions estimated by project proponents in Kern County are significantly lower on a comparable basis. Without appropriate actual field data and strong verification of claims made by project proponents (and accepted by DOGGR), it is not possible to simply rely on the claims of the proposed NOx emissions from oils and gas drilling activities in Kern County.

D. RECOMMENDATIONS

In view of the significant uncertainties and likely significant underestimation of NOx emissions from oils and gas drilling activities, we recommend the following:

i. improve the transparency and usefulness of the documents submitted to DOGGR by requiring a minimum of set of project related details such as:
   - well depth and direction;
   - specific lists of equipment;
   - specific details for each engine including manufacturers data and test results;
   - support for assumed load factors for each engine;
   - support for the assumed activity levels, particularly on a per-well basis (i.e., the hp-hr/well) consistent with well depth and formation details;
   - support for each NOx emission factor used, including test data;

ii. improve the DOGGR website so that the public can access details on actual activity levels post-project – such as actual numbers of days of drilling; actual equipment used, etc.; and

iii. improve verification of actual field equipment used and activity levels as compared to those in the submitted documents pre-project; and document actions taken to resolve uncertainties between pre-project and post-project data.

TABLE 1 — COMPARISON OF ACTIVITY LEVELS AND NOX EMISSIONS FROM VARIOUS PROJECTS

Project: Rhythm | Apr-15

Drilling Phase Only Equipment	Qty	Size [hp]	Hrs/Day	Duration [days/proj]	Total Hrs [hrs/proj]	Load Factor	hp-hr/project [hp-hr]	# Wells	Depth/ well [ft]	hp-hr/1000 ft	NOx EF [g/hp-hr]	Nox [lb/hr]	Nox [lb/day]	Nox [tons/ proj]	Nox [lb/ 1000ft]
Backhoe	1	400	4	25	100	0.37	14800				1.602	0.523	2.091	0.026	
Crane	1	226	8	2	16	0.29	1049				2.196	0.317	2.538	0.003	
Drill Rig Motor #1	1	1477	24	25	600	0.5	443100				1.504	2.449	58.767	0.735	
Drill Rig Motor #1 (Idle)	1	1477	24	8	192	0.05	14179				1.504	0.245	5.877	0.024	
Drill Rig Motor #2	1	1477	24	25	600	0.5	443100				1.504	2.449	58.767	0.735	
Drill Rig Motor #2 (Idle)	1	1477	24	8	192	0.05	14179				1.504	0.245	5.877	0.024	
Backup Drill Rig Motor #3	1	1477	1	33	33	0.05	2437				1.504	0.245	0.245	0.004	
Small Generator	2	45	12	25	300	0.74	19980				3.592	0.527	6.329	0.079	
All-Project							952824	3	12500	25409		6.999	140.49	1.63	86.8
All-1-Well ONLY								1						0.54	

Project: Terrebone | Apr-15

Drilling Phase Only Equipment	Qty	Size [hp]	Hrs/Day	Duration [days/ proj]	Total Hrs [hrs/proj]	Load Factor	hp-hr/project [hp-hr]	# Wells	Depth/ well [ft]	hp-hr/1000 ft	NOx EF [g/hp-hr]	Nox [lb/hr]	Nox [lb/day]	Nox [tons/ proj]	Nox [lb/ 1000ft]
Backhoe	1	400	4	40	160	0.37	23680				1.602	0.523	2.091	0.042	
Crane	1	226	8	2	16	0.29	1049				2.196	0.317	2.538	0.003	
Drill Rig Motor #1	1	1477	24	40	960	0.5	708960				1.504	2.449	58.767	1.175	
Drill Rig Motor #1 (Idle)	1	1477	24	8	192	0.05	14179				1.504	0.245	5.877	0.024	
Drill Rig Motor #2	1	1477	24	40	960	0.5	708960				1.504	2.449	58.767	1.175	
Drill Rig Motor #2 (Idle)	1	1477	24	8	192	0.05	14179				1.504	0.245	5.877	0.024	
Backup Drill Rig Motor #3	1	1477	1	48	48	0.05	3545				1.504	0.245	0.245	0.006	
Small Generator	2	45	12	40	480	0.74	31968				3.592	0.527	6.329	0.127	
All-Project							1506520	3	13500	37198		6.999	140.49	2.57	127.1
All-1-Well ONLY								1						0.86	

TABLE 1 - COMPARISON OF ACTIVITY LEVELS AND NOX EMISSIONS FROM VARIOUS PROJECTS (CONT.)

Project: Sherman 1-23 | July 14

Drilling Phase Only Equipment	Qty	Size [hp]	Hrs/Day	Duration [days/proj]	Total Hrs [hrs/proj]	Load Factor	hp-hr/project [hp-hr]	# Wells	Depth/well [ft]	hp-hr/1000 ft	NOx EF [g/hp-hr]	Nox [lb/hr]	Nox [lb/day]	Nox [tons/proj]	Nox [lb/1000ft]
Backhoe	0	400	4	40	160	0.37	0				1.602	0.000	0.000	0.000	
Crane	0	226	8	2	16	0.29	0				2.196	0.000	0.000	0.000	
Drill Rig Motor #1	1	200	24	4	96	0.5	9600				2.043	0.450	10.810	0.022	
Drill Rig Motor #1 (Idle)	0	1477	24	8	192	0.05	0				1.504	0.000	0.000	0.000	
Drill Rig Motor #2	0	1477	24	40	960	0.5	0				1.504	0.000	0.000	0.000	
Drill Rig Motor #2 (Idle)	0	1477	24	8	192	0.05	0				1.504	0.000	0.000	0.000	
Backup Drill Rig Motor #3	0	1477	1	48	48	0.05	0				1.504	0.000	0.000	0.000	
Generator	1	75	24	4	96	0.42	3024				3.731	0.259	6.218	0.012	
Mud Pumps	1	300	24	3	72	0.42	9072				3.02	0.839	20.133	0.030	
Draw Works	1	200	24	4	96	0.42	8064				1.979	0.366	8.796	0.018	
Small Generator	0	45	12	40	480	0.74	0				3.592	0.000	0.000	0.000	
All-Project							29760	1	2150	13842		1.915	45.96	0.08	76.1

Project: Blackwells Corner | May-14

Drilling Phase Only Equipment	Qty	Size [hp]	Hrs/Day	Duration [days/proj]	Total Hrs [hrs/proj]	Load Factor	hp-hr/project [hp-hr]	# Wells	Depth/well [ft]	hp-hr/1000 ft	NOx EF [g/hp-hr]	Nox [lb/hr]	Nox [lb/day]	Nox [tons/proj]	Nox [lb/1000ft]
Crane	1	485	6	2	12	0.29	1688				1.805	0.560	3.358	0.003	
Backhoe	1	91	2	1	2	0.37	67				2.057	0.153	0.305	0.000	
Forklift	1	400	2	4	8	0.2	640				1.277	0.225	0.450	0.001	
Generator	2	500	24	2	48	0.74	35520				2.656	4.333	103.992	0.104	
Pump	1	1000	24	2	48	0.74	35520				3.851	6.282	150.780	0.151	
Draw Works	1	540	24	2	48	0.34	8813				1.607	0.650	15.611	0.016	
Welder	1	20	4	2	8	0.34	54				2.247	0.034	0.135	0.000	
							82302	1	1300	63309		12.237	274.63	0.27	423.0

[1] CALCULATIONS FOR 1S/1W. PROJECT WILL BE 1S/2W OR 2S/1W-SEE IS.

TABLE 1 - COMPARISON OF ACTIVITY LEVELS AND NOX EMISSIONS FROM VARIOUS PROJECTS (CONT.)

Project: Rio Viejo | May-14

Drilling Phase Only Equipment	Qty	Size [hp]	Hrs/Day	Duration [days/ proj]	Total Hrs [hrs/proj]	Load Factor	hp-hr/ project [hp-hr]	# Wells	Depth/ well [ft]	hp-hr/1000 ft	NOx EF [g/hp-hr]	Nox [lb/hr]	Nox [lb/day]	Nox [tons/ proj]	Nox [lb/ 1000ft]
Backhoe	1	400	4	30	120	0.37	17760				1.654	0.540	2.159	0.032	
Crane	1	375	8	2	16	0.29	1740				1.805	0.433	3.462	0.003	
Forklift	1	400	4	40	160	0.2	12800				1.277	0.225	0.901	0.018	
Drill Rig Motor	1	1600	24	30	720	0.5	576000				1.491	2.630	63.111	0.947	
Drill Rig Motor	1	1600	12	30	360	0.5	288000				1.491	2.630	31.556	0.473	
Idle Drill Rig Motor	1	1600	24	10	240	0.02	7680				1.491	0.105	2.524	0.013	
Generator	2	45	4	16	64	0.42	2419				3.731	0.311	1.244	0.010	
							906399	1	14000	64743		6.873	104.96	1.50	213.8

[1] CALCULATIONS FOR 1S/1W. PROJECT WILL BE 2S/6W-SEE IS.

Project: Older/Other

	# Wells	Depth/well [ft]	hp-hr/1000 ft	NOx EF [g/hp-hr]	Nox [lb/hr]	Nox [lb/day]	Nox [tons/proj]	Nox [lb/1000 ft]
Project: Jedessa Apr-14	1	Unknown					0.82	
Project: Tamarack #1	1	14000					2.43	
Project: Patricia McKellar	1	Unknown					5.5	
Project: Rancho Grande 1	1	Unknown					1.1	

ENDNOTES

1 See Weekly Activity Report issued by DOGGR dated December 27, 2014 available at ftp://ftp.consrv.ca.gov/pub/oil/weekly_summary/2014.

2 We note that drilling activities with attendant emissions of various pollutants, including NOx, are not just limited to drilling for oil and gas. For example, numerous wells are also drilled in the area for water as well. We have not included emissions from non-oil related well drilling activities.

3 http://www.arb.ca.gov/regact/offrdcie/frooal.pdf

4 Table 6.6, Drilling Rig Emission Inventory for the State of Texas, Final Report Prepared for: Texas Commission on Environmental Quality, Eastern Research Group, Inc., July 15, 2009 (revised August 20, 2014). For more details, see Table D.2 and D.3 in this report. Available at http://www.tceq.state.tx.us/assets/public/implementation/air/am/contracts/reports/ei/5820783985FY0901-20090715-ergi-Drilling_Rig_EI.pdf

5 Ibid., see Tables F.1 and F.2.

6 Table 3-5, Specified Oil and Gas Well Activities Emissions Inventory Update, Final Report, prepared for: Texas Commission on Environmental Quality, Air Quality Division, by Eastern Research Group, Inc., August 1, 2014. Available at https://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/5821199776FY1426-20140801-erg-oil_gas_ei_update.pdf

7 p. 10. Technical Information, Oil and Gas Sector, Significant Stationary Sources of NOx Emissions, October 17, 2012. Available at http://www.otcair.org/upload/Documents/Meeting%20Materials/Final%20Oil%20%20Gas%20Sector%20TSD%2010-17-12.pdf

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