KIRBY HILLS GAS STORAGE FACILITY
(SOLANO COUNTY, CALIFORNIA)

ACOUSTICAL ASSESSMENT OF AN EXPANSION PROJECT

AT THE EXISTING NATURAL GAS STORAGE FACILITY

H&K Report No. 2096

H&K Job No. 3927

Date of Report: May 4, 2007

Prepared for: **Lodi Gas Storage, L.L.C.**
1021 Main Street, Suite 1500
Houston, Texas 77002

Submitted by: Paul D. Kiteck, P.E. (Primary Author)
Hoover & Keith Inc.
11391 Meadowglen, Suite D
Houston, Texas 77082

Hoover & Keith Inc.
Consultants in Acoustics and Noise Control Engineering
11391 Meadowglen, Suite D, Houston, TX 77082 Phone: (281) 496-9876

REPORT SUMMARY

This report provides an acoustical assessment of an expansion project at the existing **Kirby Hill Gas Storage Facility,** located in Solano County, California. The project will entail an addition of two (2) new engine-driven compressor units (i.e., compression addition) to the natural gas compressor station (i.e., referred to as "Station") and new gas storage wells. The acoustical assessment includes an estimate of the potential noise impact due to the Station after installation of the compressor addition and an assessment of the noise due to drilling operations at the new well sites.

The following table summarizes the estimated sound level attributable to the new units at the closest noise-sensitive area (NSA), such as a residence, school, hospital or park, along with the estimated total sound contribution of the Station at the closest NSA (i.e., sound contribution of the existing Station compressor units and the new compressor units). The results presented in this table are defined as the "Noise Quality Analysis" for the expansion project (i.e., compressor addition) at the Station.

Noise Quality Analysis of the Expansion Project at the Kirby Hills Gas Storage Facility

Closest NSA to the Site Center (i.e., Compr. Enclosure)	Distance & Direction of NSA to the Site Center	Est'd Lden of the New Units (dBA)	Est'd Lden of Existing Units (dBA)	**Est'd Lden of New & Existing Units (dBA)**
Residence (R1 – NSA)	2,400 feet (NE)	45.0	44.0	**47.5**

The acoustical assessment indicates that if the recommended noise control measures and equipment noise specifications are successfully employed, the noise attributable to the Station at **Kirby Hill Gas Storage Facility** during operation of both the existing compressor units and the planned new compressor units should be lower than **50 dBA** CNEL (i.e., L_{den}) at the nearby NSAs surrounding the site, which is considered the noise policy (i.e., noise criterion) for the facility per the "Solano County General Plan". In addition, the noise assessment indicates that the noise generated by drilling operations at the planned new storage well sites or existing workover well sites should be lower than the noise guideline (i.e., criterion) of **50 dBA** (L_{den}) at the nearby NSAs.

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1.0 INTRODUCTION

In this report, we present an acoustical assessment of an expansion project at the existing **Kirby Hill Gas Storage Facility,** located in Solano County, California. The project will entail an addition of two (2) new engine-driven compressor units (i.e., compression addition) to the natural gas compressor station (i.e., referred to as "Station" in the report). In addition, the expansion project will also entail new gas storage well sites located within the property line for the facility that will require well drilling operations. The following summaries the purpose of the acoustical assessment:

- Estimate the sound level contribution of the Station at the nearby noise-sensitive areas (NSAs), such as residences, schools, hospitals or parks, which would result after the installation of the new compressor units.

- Estimate the noise contribution at the nearby NSAs resulting from the noise due to drilling operations at the planned new gas storage well site.

- Determine noise control measures and noise requirements for the Station equipment and other noise-generating activities to insure that the facility meets applicable sound criteria and noise guidelines.

2.0 TYPICAL METRICS, TERMINOLOGY AND SOUND CRITERIA/GUIDELINES

For the reader's information, a summary of applicable acoustical terminology and typical metrics used to measure and regulate environmental noise is provided at the end of the report (**Appendix D**, pp. 16-18). There are several metrics used for quantifying and regulating environmental noise level although the most common metric used by state and municipal agencies is the A-wt. sound level (i.e., dBA). There are also other metrics, such as L_{eq}, L_{dn} and/or Community Noise Equivalent Level (abbreviated CNEL or L_{den}) used to correlate human reaction to an intruding sound.

The "Health and Safety Element" of the "Solano County General Plan", dated May 1977, is specifically designed to provide the county or cities with a basis for controlling the actions of private individuals or firms and other public agencies who use or proposed to use planning area lands. This document provides specific policies/guidelines regarding the subject of noise-emitting industrial facilities (i.e., pp. 17-23 & pp. 61-69 of the "Element"), such as the proposed Kirby Gas Storage Facility. In summary, "Specific Policies" of the "Health and Safety Element", which are assumed to apply to this proposed facility, state the following:

> "The introduction of any fixed point, permanent, non-residential, noise-emitting land use (industrial, commercial, public utility, etc.) shall be prohibited if the projected noise emission level will exceed one or more of the following:

a. **50 dBA** CNEL (L_{den}), as measure at the boundary of a nearby residential zone.

b. **60 dBA** CNEL (L_{den}), as measured at the boundary of a nearby commercial zone, business zone (personal service, offices), or noise-sensitive industrial or manufacturing zone (research, communications, etc.)."

Consequently, we interpret this policy to require that the projected and resulting noise contribution of the Kirby Gas Storage Facility (i.e., noise generated by the Station and other associated intermittent activities) should be equal to or lower than **50 dBA** (L_{den}) at the nearby NSAs, such as a nearby residential property. If the facility can meet this noise criterion, the proposed land use for the facility should be acceptable and within the noise policy/guidelines of the General County Plan.

3.0 SITE/FACILITY DESCRIPTION

3.1 Site Description

Figure 1 (p. 8) provides an area layout around the facility that shows the location of the nearby NSAs, location of the Station and location of the planned new well sites. The Station is located in Solano County, California, approximately 10 miles southeast of Fairfield, CA. The closest NSA is a residence located approximately 2,400 feet northeast of the site center (i.e., location of the Compressor Enclosure for the Station), and there are other scattered residences and a church located within 1 mile of the site center. The locations of the surrounding NSAs were provided by personnel at Lodi Gas Storage. Consequently, H&K did not visit the site to conduct an ambient sound survey or verify the location of nearby NSAs, but we believe the information provided is accurate and reliable.

3.2 Brief Description of the Facility and New Compressor Units

Figure 2 (p. 9) is a layout showing the existing enclosures/equipment and the planned location of the enclosures/equipment for the new compressor units. In summary, the Station serves a natural gas storage field, and there are generally two (2) operating modes of the Station: (a) gas injection mode, in which high pressure natural gas is injected into an underground caverns for storage using gas compression, and (b) gas withdrawal mode, in which high pressure gas flows out of the gas wells/caverns ("free flow conditions") or is pumped out at times of low gas pressures.

We understand, as part of the expansion project, that two (2) "high-speed" engine-driven compressor packages (i.e., units) will be installed at the Station. One of the new packages will consist of a Caterpillar (CAT) Model G3608 engine driving an Ariel Model JGC-4 reciprocating compressor, and the other new package will consist of a Caterpillar (CAT) Model G3612 engine driving an Ariel Model JGC-6 reciprocating compressor. The following describes auxiliary equipment and other items associated with the new gas compressor units:

- Engines/compressors installed inside a separate enclosure (i.e., Compressor Enclosure);
- Outdoor utility/gas cooler for each engine, shaft-driven by the engine;
- Exhaust engine system designed with a muffler system and emission-reduction system;
- Engine air intake filter assumed to be designed with an air filter/cleaner system;
- Added aboveground gas piping and piping system components;

The expansion project will include drilling operations at each new gas storage wells (i.e., referred to as "Storage Wells") and "workover" drilling operations at some older well (i.e., referred to as "Workover Wells"), and there is noise associated with drilling operations. Drilling operations at a new Storage Well typically operate 24 hours/day and last approximately 2 weeks. The drilling operations at a Workover Well also operate 24 hours/day but typically last only 1 week or less, and the equipment/operations associated with a Workover Well is substantially less than the equipment and drilling operations at a new Storage Well. The residence to the new Storage Wells is located approximately 2,850 feet from one of the new Storage Wells, and the closest residence to the Workover Wells is located approximately 2,300 feet from Workover Well L6.

4.0 ACOUSTICAL ASSESSMENT (COMPRESSOR ADDITION)

The following section discusses the results of the potential noise impact due to the compressor addition. The noise assessment was performed only for the closest NSA since the Station noise at more distant NSAs should be lower than the predicted noise level at the closest NSA.

4.1 Sound Contribution of the New Units & Station at the Closest NSA

The noise generated during operation of the compressor units (e.g., gas injection mode) is considered the operating condition that will generate the greatest amount of noise during Station operation. Consequently, the acoustical assessment assumes operation of the existing and/or new compressor units operating along with all auxiliary equipment that operates continuously. The following sound sources associated with the new units were considered significant:

- Noise generated by the new engines and compressors that penetrates the Compressor Enclosure;
- Noise associated with the engine exhaust system of the new units;
- Noise generated by the engine air intake system of the new units;
- Noise radiated from added outdoor aboveground gas piping;
- Noise of the outdoor utility/gas coolers for the new units.

Table A (p. 10) is a spreadsheet analysis of the estimated A-wt. sound level and unweighted O.B. SPLs at the closest NSA contributed by the noise sources of the new units for standard day propagating conditions (i.e., 50% R.H., 60 deg. F. & no wind). This analysis also includes the estimated "total" sound level of the Station at the closest NSA (i.e., sound contribution of the new units plus existing units). Note that the estimated ambient noise level was based on our experience and sound level information given in an ANSI Standard[1] since ambient noise levels were not measured. A description of the acoustical analysis methodology and source of sound data used for the analysis of the compressor addition are provided in **Appendix A** (pp. 13-14).

The following **Table 1** summarizes the calculated sound contribution (i.e., A-wt. sound level and calculated L_{den}) of the new compressor units, estimated sound contribution of the existing compressor units and the total sound contribution of the Station (i.e., sound contribution of the both new units and the existing units) at the closest NSA.

Operating Condition	Est'd A-Wt. Sound Level (i.e., Leq)	Calc'd Lden
Est'd sound contribution of the new compressor units at the Closest NSA	38.3 dBA	45.0 dBA
Est'd sound contribution of the existing units at the Closest NSA	37.3 dBA	44.0 dBA
Est'd "total" sound contribution (new and existing units) at the Closest NSA	40.8 dBA	47.5 dBA

Table 1: Summary of the Est'd Sound Contribution of New Units and Existing Units at the Closest NSA, and the "Total" Est'd Station Sound Contribution (i.e., Operation of New and Existing Units)

4.2 Sound Level Contribution of the New Units & Station at the Closest Station Property Line

Table B (p. 11) is a spreadsheet calculation of the estimated A-wt. level and unweighted O.B. SPLs at the north Station property line contributed by the significant noise sources for the new units. The predicted sound contribution at the property line was performed only at the property line closest to the Station equipment (i.e., north property line). The following **Table 2** summarizes the estimated "total" sound contribution (i.e., A-wt. sound level and calculated L_{den}) of the Station at the closest property line (i.e., sound contribution of both the new units and existing units).

Operating Condition	Est'd A-Wt. Sound Level (i.e., Leq)	Calc'd Lden
Est'd "total" sound contribution of the Station at north property line of station (i.e., operation of both new units and existing units)	45.2 dBA	51.9 dBA

Table 2: Est'd "Total" Sound Contribution of Station at the Closest Property Line of the Facility

[1] Typical Ldn, which is similar to the Lden, for a Quiet Residential Area given in Table 2 of Appendix D in the American National Standards Institute (ANSI) S12.9-1993/Part 3 entitled "Quantities and Procedures for Description and Measurement of Environmental Sound. Part 3: Short-Term Measurements with an Observer Present"

5.0 NOISE ASSESSMENT (DRILLING OPERATIONS AT WELL SITES)

The noise assessment of drilling operations at new storage well sites or workover well sites considers the noise produced by drill rig equipment during normal drilling activity that could impact the sound contribution at the nearby NSAs. To reduce computation, the estimated sound contribution of the drilling operations was performed only for the well site closest to the NSAs. The spreadsheet calculation of the estimated A-wt. sound level at the closest NSA to a new storage well site contributed by well drilling operations is provided in **Table C** (p. 12). **Table D** (p. 12) provides the spreadsheet calculation of the estimated A-wt. sound level at the closest NSA due to drilling operations at Workover Well L6.

The results of this analysis indicates that the maximum A-wt. noise level of drilling operations at the new storage wells will be equal to or less than **38.9 dBA** (i.e., L_{den} of **45.6 dBA**) at the closest NSA. In addition, the maximum A-wt. noise level of drilling operations at the workover wells will be equal to or less than **37.1 dBA** (i.e., L_{den} of **43.8 dBA**) at the closest NSA. Consequently, the noise of the drilling operations at the new storage well sites or workover well sites may be potentially audible the closest NSAs (i.e., residences) but should have minimum noise impact on the surrounding environment. A description of the analysis methodology and source of sound data for well drilling operations is provided in the **Appendix B** (p. 15) along with a summary of the primary rig equipment.

6.0 NOISE CONTROL MEASURES AND EQUIPMENT NOISE SPECIFICATIONS

The following section provides recommended noise control measures and noise specifications for Station equipment and auxiliary components.

6.1 Enclosure for the New Engines-Compressors

Noise control measures will be applied to the enclosure that covers the new engines-compressors rather than to the equipment themselves. The following describes specific requirements and other items related to the components of the enclosure.

- As a minimum, walls/roof of the enclosure should be constructed with exterior steel of 22 gauge and interior layer of 6-inch thick unfaced mineral wool (e.g., 6.0-8.0 pcf density) covered with 26-gauge perforated liner. No louvers should be installed in the walls, and a minimum number of skylights could be installed in the roof to provide natural light.

- It is assumed that the enclosure forced-air ventilation system will employ wall-mounted and/or rooftop air-supply fans and exhaust air would be vented through roof openings (e.g., via a gravity-type roof ridge vent and/or via rooftop exhaust fans). The noise associated with each fan associated with the ventilation system should not exceed **60 dBA** at 50 feet.

6.2 Engine Exhaust System

The exhaust system for each new engine should include a muffler system that provides the following dynamic sound insertion loss (DIL) values at the rated operating conditions (i.e., DIL values if a single muffler system is employed):

DIL Values in dB per Octave-Band Center Frequency (Hz) for Exhaust Muffler System

31.5	63	125	250	500	1000	2000	4000	8000
18 dB	22 dB	32 dB	38 dB	40 dB	40 dB	38 dB	35 dB	25 dB

The following describes other items related to the exhaust system that should be addressed:

- Exhaust piping located outside between the enclosure and outdoor muffler should be completely covered with an acoustical lagging material. This pipe lagging could consist of a 3-inch thick inner layer of high-density insulation (e.g., mineral wool or ceramic fiber material, 3.0-6.0 pcf density) covered with a heavy-gauge steel jacketing (e.g., minimum 20-ga.). As an alternative, the exhaust piping could be covered with a removable/reusable acoustical blanket material, which is described in more detail below.

- Exhaust pipe expansion joint (if located in the exhaust piping outside the enclosure) should be covered with a removable/reusable acoustical blanket material. The blanket material should consist of a core of 2.0-in thick needled fiber mat (6.0-8.0 pcf), a liner material of mass-loaded vinyl (surface weight of 1.0-1.25 psf) covered with a coated fiberglass cloth, and the inner layer of insulation (i.e., insulation facing the expansion joint) should be covered with a stainless steel mesh instead of coated fiberglass cloth.

6.3 Added Aboveground Gas Piping and Components

The noise assessment indicates that the additional aboveground gas piping and other piping components for the new units should not have to be covered with any type of acoustical insulation and/or acoustical material to meet the noise criteria, although it is recommended that the aboveground outdoor discharge and suction piping should be inserted underground soon after exiting the Compressor Enclosure.

6.4 Engine Air Intake System

It is recommended that the air intake system of each new engine should include a CAT “heavy-duty” air filter/cleaner system (i.e., type of air filter system with a “pre-cleaner”). This “heavy-duty” type of air filter system provides significant reduction the engine air intake noise although the station noise requirement could probably be achieved if a “standard” CAT filter is employed.

6.5 Utility/Gas Cooler

The utility/gas cooler associated with each new compressor unit should not exceed **65 dBA** at **50 feet** from the cooler perimeter with all fans/motors operating at the maximum tip speeds (i.e., equivalent to a PWL of approximately **97–98 dBA**).

7.0 SUMMARY AND FINAL COMMENT

The following **Table 3** summarizes the estimated sound level attributable to the new units at the closest noise-sensitive area (NSA), such as a residence, school, hospital or park, along with the estimated total sound contribution of the Station at the closest NSA (i.e., sound contribution of the existing Station compressor units and the new compressor units). The results presented in this table are defined as the "Noise Quality Analysis" for the expansion project (i.e., compressor addition) at the Station.

Closest NSA to the Site Center (i.e., Compr. Enclosure)	Distance & Direction of NSA to the Site Center	Est'd Lden of the New Units (dBA)	Est'd Lden of Existing Units (dBA)	**Est'd Lden of New & Existing Units (dBA)**
Residence (R1 – NSA)	2,400 feet (NE)	45.0	44.0	**47.5**

Table 3: Noise Quality Analysis for the Expansion Project at the Kirby Hills Gas Storage Facility

The acoustical assessment indicates that if the recommended noise control measures and equipment noise specifications are successfully employed, the noise attributable to the Station at **Kirby Hill Gas Storage Facility** during operation of both the existing compressor units and the planned new compressor units should be lower than **50 dBA** CNEL (i.e., L_{den}) at the nearby NSAs surrounding the site, which is considered the noise policy (i.e., noise criterion) for the facility per the "Solano County General Plan". In addition, the noise assessment indicates that the noise generated by drilling operations at the planned new storage well sites or existing workover well sites should be lower than the noise guideline (i.e., criterion) of **50 dBA** (L_{den}) at the nearby NSAs.

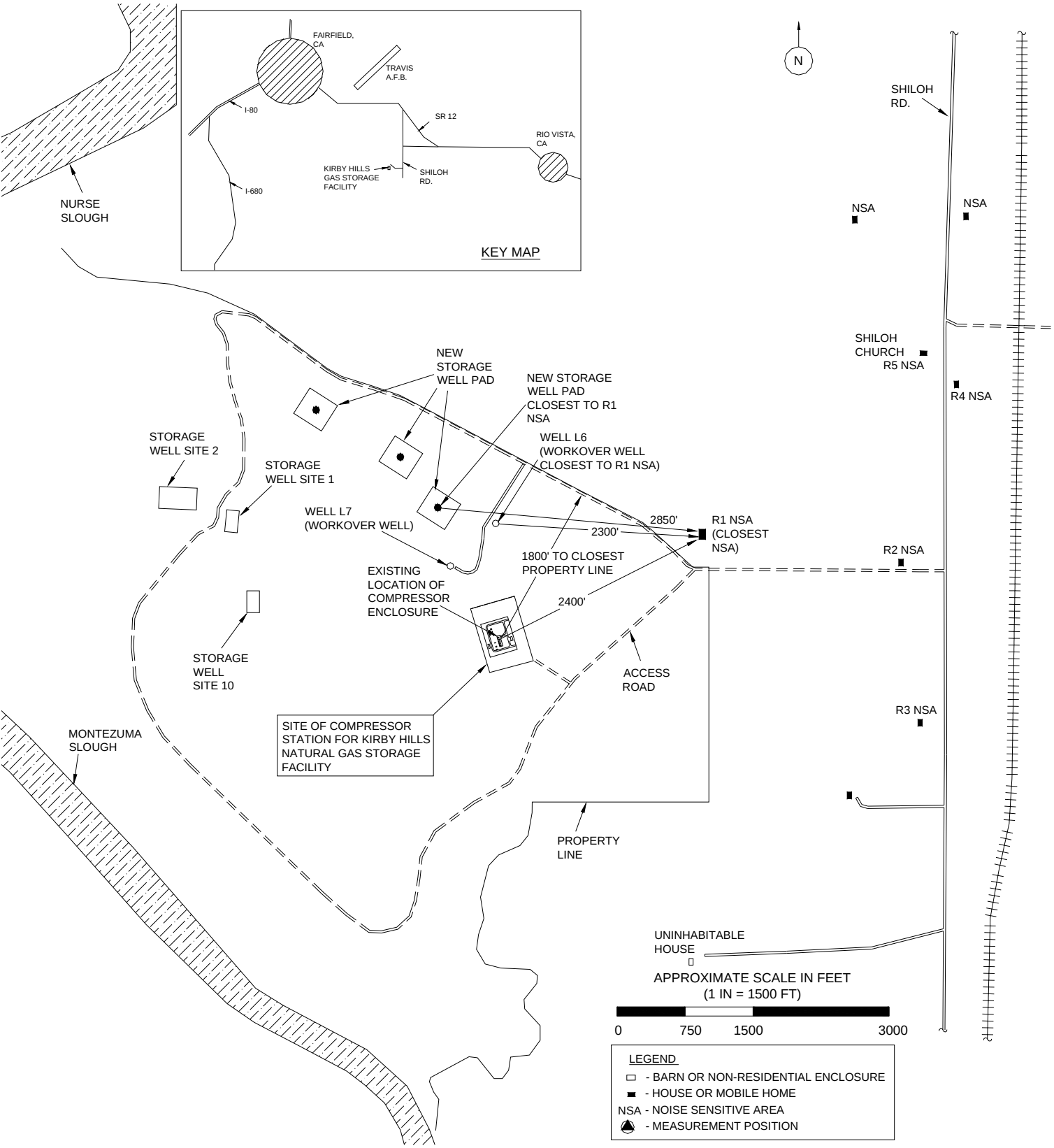


Figure 1: Kirby Hill Gas Storage Facility: General Area Layout Showing the Location of the Nearby NSAs, Location of the Station and other Areas of Interest.

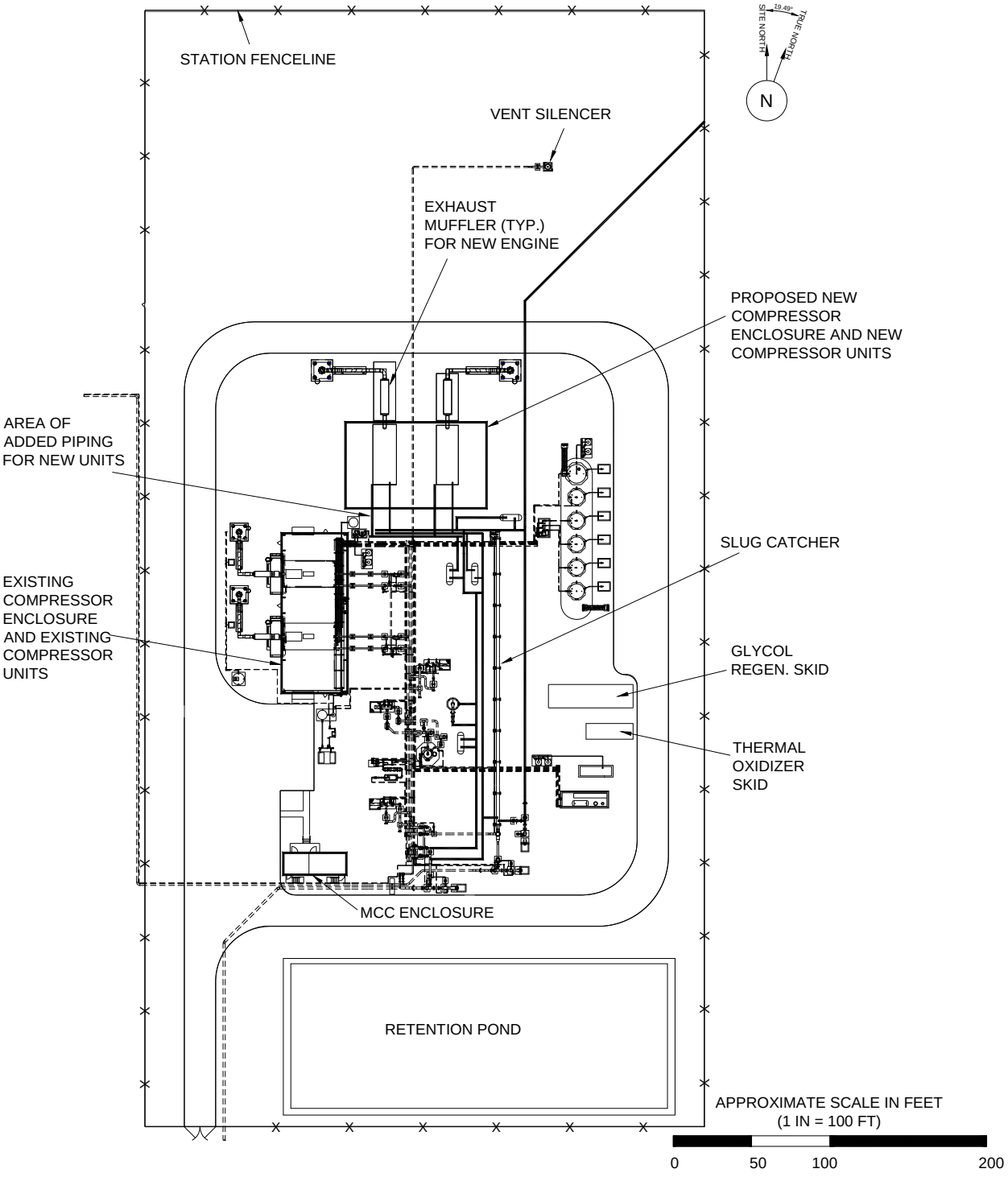


Figure 2: Kirby Hill Gas Storage Facility: Layout of Enclosures/Equipment associated the Station and Conceptual Layout of New Equipment for Expansion Project.

Source No. & Dist (Ft)	Noise Sources and Other Conditions/Factors associated with Acoustical Analysis	PWL or SPL in dB Per Octave-Band Center Frequency (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	A-Wt. Level	
1)	PWL of New Engines/Compressors inside Bldg.	115	118	122	122	118	116	118	116	112	124	
	Attenuation of the Building	-6	-10	-16	-22	-28	-32	-35	-38	-38		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
2400	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65		
2400	Atm. Absorption (50% R.H., 60 deg F)	0	0	0	-1	-2	-4	-7	-18	-33		
2400	Source Sound Level Contribution	44	42	40	34	23	15	10	0	0	29	
2)	PWL of Unsilenced Engine Exhaust (2 New Units)	126	132	138	134	129	130	128	115	105	134	
	Atten. of Noise Control (Muffler & SCR System)	-18	-22	-28	-35	-40	-40	-35	-25	-20		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
2400	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65		
2400	Atm. Absorption (50% R.H., 60 deg F)	0	0	0	-1	-2	-4	-7	-18	-33		
2400	Source Sound Level Contribution	43	44	44	33	22	21	20	6	0	31	
3)	PWL of Engine Air Intake with Filter (2 New Units)	80	78	75	75	75	78	80	90	80	92	
	NR of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
2400	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65		
2400	Atm. Absorption (50% R.H., 60 deg F)	0	0	0	-1	-2	-4	-7	-18	-33		
2400	Source Sound Level Contribution	15	12	9	9	8	9	7	6	0	14	
4)	PWL of Added Aboveground Piping (Unlagged)	108	105	105	102	100	100	98	95	92	105	
	Atten. of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
2400	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65		
2400	Atm. Absorption (50% R.H., 60 deg F)	0	0	0	-2	-2	-4	-7	-18	-33		
2400	Source Sound Level Contribution	43	39	39	35	33	31	25	11	0	35	
5)	PWL of Engine Utility/Gas Cooler (2 New Units)	112	110	105	98	95	92	90	88	85	99	
	NR of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
2400	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65		
2400	Atm. Absorption (50% R.H., 60 deg F)	0	0	0	-1	-2	-4	-7	-18	-33		
2400	Source Sound Level Contribution	47	44	39	32	28	23	17	4	0	30	
6)	PWL of Misc. Equipment assoc. with New Units	100	98	95	92	90	85	82	80	75	92	
	NR of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
2400	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65		
2400	Atm. Absorption (50% R.H., 60 deg F)	0	0	0	-1	-2	-4	-7	-18	-33		Calc'd
2400	Source Sound Level Contribution	35	32	29	26	23	16	9	0	0	24	Lden
Est'd Sound Contribution of New Units at Closest NSA		**50**	**49**	**47**	**40**	**35**	**32**	**27**	**14**	**0**	**38.3**	**45.0**
Est'd Sound Contribution of Existing Units at Closest NSA		**52**	**48**	**45**	**42**	**33**	**30**	**25**	**10**	**5**	**37.3**	**44.0**
Est'd Sound Contribution of Existing Units plus New Unit		**54**	**52**	**49**	**44**	**37**	**34**	**29**	**16**	**5**	**40.8**	**47.5**

Table A: Compressor Station for the Kirby Hills Gas Storage Facility: Est'd Sound Contribution of 2 New Engine-Driven Compressor Units at the Closest NSA (i.e., Residence, located approx. 2,400 Ft. NE of the Station Site Center), and Est'd Total Sound Level Contribution of the Station (i.e., Sound Contribution of Existing Station Units plus New Units).

Note (1): Est'd (typical) ambient sound level at the residences located around the natural gas storage facility.

NOTE: Muffler DIL & Equipment PWL values on this spreadsheet should <u>not</u> be used as the specified values. Refer to "Noise Control Measures" section in report or other company specifications for actual specified values.

Source No. & Dist (Ft)	Noise Sources and Other Conditions/Factors associated with Acoustical Analysis	PWL or SPL in dB Per Octave-Band Center Frequency (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	A-Wt. Level	
1)	PWL of New Engines/Compressors inside Bldg.	115	118	122	122	118	116	118	116	112	124	
	Attenuation of the Building	-6	-10	-16	-22	-28	-32	-35	-38	-38		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
1800	Hemispherical Radiation	-63	-63	-63	-63	-63	-63	-63	-63	-63		
1800	Atm. Absorption (30% R.H., 60 deg F)	0	0	0	-1	-1	-3	-5	-14	-25		
1800	Source Sound Level Contribution	46	45	43	36	26	18	15	2	0	32	
2)	PWL of Unsilenced Engine Exhaust (2 New Units)	126	132	138	134	129	130	128	115	105	134	
	Atten. of Noise Control (Muffler & SCR System)	-18	-22	-28	-35	-40	-40	-35	-25	-20		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
1800	Hemispherical Radiation	-63	-63	-63	-63	-63	-63	-63	-63	-63		
1800	Atm. Absorption (30% R.H., 60 deg F)	0	0	0	-1	-1	-3	-5	-14	-25		
1800	Source Sound Level Contribution	45	47	47	35	25	24	25	14	0	34	
3)	PWL of Engine Air Intake with Filter (2 New Units)	80	78	75	75	75	78	80	90	80	92	
	NR of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
1800	Hemispherical Radiation	-63	-63	-63	-63	-63	-63	-63	-63	-63		
1800	Atm. Absorption (30% R.H., 60 deg F)	0	0	0	-1	-1	-3	-5	-14	-25		
1800	Source Sound Level Contribution	17	15	12	11	11	12	12	14	0	19	
4)	PWL of Added Aboveground Piping (Unlagged)	108	105	105	102	100	100	98	95	92	105	
	Atten. of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
1800	Hemispherical Radiation	-63	-63	-63	-63	-63	-63	-63	-63	-63		
1800	Atm. Absorption (30% R.H., 60 deg F)	0	0	0	-2	-1	-3	-5	-14	-25		
1800	Source Sound Level Contribution	45	42	42	37	36	34	30	19	5	39	
5)	PWL of Engine Utility/Gas Cooler (2 New Units)	112	110	105	98	95	92	90	88	85	99	
	NR of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
1800	Hemispherical Radiation	-63	-63	-63	-63	-63	-63	-63	-63	-63		
1800	Atm. Absorption (30% R.H., 60 deg F)	0	0	0	-1	-1	-3	-5	-14	-25		
1800	Source Sound Level Contribution	49	47	42	34	31	26	22	12	0	33	
6)	PWL of Misc. Equipment assoc. with New Units	100	98	95	92	90	85	82	80	75	92	
	NR of Noise Control	0	0	0	0	0	0	0	0	0		
	Misc. Atten. (Shielding and/or Land Contour)	0	0	0	0	0	0	0	0	0		
1800	Hemispherical Radiation	-63	-63	-63	-63	-63	-63	-63	-63	-63		
1800	Atm. Absorption (30% R.H., 60 deg F)	0	0	0	-1	-1	-3	-5	-14	-25		Calc'd
1800	Source Sound Level Contribution	37	35	32	28	26	19	14	4	0	27	Lden
Est'd Contribution of Facility at the North Property Line		**53**	**52**	**50**	**42**	**38**	**36**	**32**	**21**	**3**	**41.4**	**48.1**
Est'd Sound Contribution of Existing Units at Closest NSA		**55**	**52**	**48**	**45**	**42**	**35**	**32**	**12**	**8**	**42.8**	**49.5**
Est'd Total Sound Contribution (Existing Units plus New Units)		**57**	**55**	**52**	**47**	**43**	**38**	**35**	**22**	**8**	**45.2**	**51.9**

Table B: Kirby Hill Gas Storage Facility: Est'd Sound Contribution of the Facility at the Closest Property Line of the Facility (i.e., North Property Line, located approx. 1,800 Feet from the Compr. Bldg.)

NOTE: Muffler DIL & Equipment PWL values on this spreadsheet should <u>not</u> be used as the specified values. Refer to "Noise Control Measures" section in report or other company specifications for actual specified values.

Dist (Ft) or Calculation	Noise Sources and Other Conditions/Factors associated with Acoustical Analysis	SPL or PWL in dB Per Octave-Band Center Freq. (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	A-Wt. Level	
	PWL of Drill Rig during Drilling Operation: Note (1)	125	122	118	108	110	112	112	105	100	117	
	Misc. Atten. (e.g., Shielding and/or Land Contour)	0	-1	-2	-3	-4	-5	-6	-8	-8		
2850	Hemispherical Radiation	-67	-67	-67	-67	-67	-67	-67	-67	-67		Calc'd
2850	Atm. Absorption (50% R.H., 60 deg F)	0	0	-1	-2	-4	-6	-11	-23	-34		Lden
Est'd Sound Contribution of Well Drilling Operation		**58**	**54**	**48**	**36**	**35**	**34**	**28**	**7**	**0**	**38.9**	**45.6**

Table C: Kirby Hills Gas Storage Facility: Est'd Sound Contribution of the Temporary Drilling Rig Operation at a New Storage Well that is Nearest to the Closest NSA (i.e., Residence located Approximately 2,850 Feet from the New Storage Well Site).

Note (1): Est'd maximum unweighted octave band sound power levels (PWLs) and A-wt. PWL of a well drilling operation based on field sound tests by H&K on a similar type of drill rig expected to be utilized at these storage well drilling sites.

Dist (Ft) or Calculation	Noise Sources and Other Conditions/Factors associated with Acoustical Analysis	SPL or PWL in dB Per Octave-Band Center Freq. (Hz) 31.5	63	125	250	500	1000	2000	4000	8000	A-Wt. Level	
	PWL of Workover Drill Rig during Operation: Note (2)	120	116	112	102	104	105	105	97	91	110	
	Misc. Atten. (e.g., Shielding and/or Land Contour)	0	0	0	-1	-2	-3	-4	-5	-5		
2300	Hemispherical Radiation	-65	-65	-65	-65	-65	-65	-65	-65	-65		Calc'd
2300	Atm. Absorption (50% R.H., 60 deg F)	0	0	-1	-2	-3	-5	-9	-18	-28		Lden
Est'd Sound Contribution of Well Drilling Operation		**55**	**51**	**46**	**34**	**34**	**32**	**27**	**9**	**0**	**37.1**	**43.8**

Table D: Kirby Hills Gas Storage Facility: Est'd Sound Contribution of the Temporary Workover Drilling Rig Operation at an Existing Workover Well that is Nearest to the Closest NSA (i.e., Residence located Approximately 2,300 Feet from Workover Well L6).

Note (2): Est'd maximum unweighted octave band PWLs and A-wt. PWL of drilling operations at a workover well based on field sound tests by H&K on a similar type of drilling operations at these storage well drilling sites, noting that the drilling operations and equipment at a workover well are significantly less than drilling operations for a cavern well site.

APPENDIX A: DESCRIPTION OF THE ANALYSIS METHODOLOGY AND THE SOURCE OF SOUND DATA FOR THE COMPRESSOR ADDITION

ANALYSIS METHODOLOGY (COMPRESSOR ADDITION)

In general, the predicted sound level contributed at the closest NSA by the equipment associated with the compressor addition was calculated as a function of frequency from estimated octave-band (O.B.) sound power levels (PWLs) for each significant sound source. The following summarizes the analysis procedure:

- Initially, unweighted O.B. PWLs of the significant noise sources associated with the compressor station were determined from actual sound level measurements performed by H&K at similar type of gas compressor facilities.

- Then, expected noise reduction (NR) or attenuation in dB per O.B. frequency due to any noise control measures, sound propagation (hemispherical radiation), atmospheric sound absorption and/or sound shielding were subtracted from the unweighted O.B. PWLs to obtain the unweighted O.B. sound pressure levels (SPLs) of each noise source.

  Since sound shielding by buildings can influence the sound level contributed at the NSAs, we also included the sound shielding due to buildings, if appropriate. The sound attenuation effect due to vegetation or land contour were typically not considered in the analyses since there appears to be limited amount of vegetation (e.g., trees) or hills between the site and the nearby NSAs.

- Finally, the resulting estimated unweighted O.B. SPLs for all noise sources associated with the compressor station (with noise control and other sound attenuation effects) were logarithmically summed, and the total unweighted O.B. SPLs were corrected for A-weighting to provide the estimated overall A-wt. sound level contributed by the new units at the closest NSA.

SOURCE OF SOUND DATA (COMPRESSOR ADDITION)

The following describes the source of sound data used for estimating the source sound levels and/or the source PWLs for the new units (e.g., engines/compressors, associated equipment and components).

(1) Engine exhaust PWL were calculated from sound data measured in the field by H&K on a similar type of engines to be utilized at this facility. The DIL values for the exhaust muffler used in the analysis are generally lower than the recommended values in order that the noise design analysis incorporates an acoustical "margin of safety."

(2) The estimated PWL of equipment inside the enclosure (i.e., engines & compressors and/or other equipment inside the enclosure) was calculated from sound data measured by H&K on similar compressor installations.

(3) The noise radiated from aboveground gas piping is primarily a result the noise generated by the gas compressors. Measurement of both near field and far field sound data on gas piping is presumed to be an accurate method of quantifying the noise associated with the gas piping, and consequently, the estimated PWL values for gas piping used in the analysis were determined from near field and far field sound data by H&K on gas piping configurations similar to the anticipated gas piping design of the proposed compressor units.

(4) The estimated PWL for jacket-water (JW) coolers and gas coolers were designated to meet the design noise goal. Note that the estimated PWL for the JW coolers utilized in the acoustical analysis assumes some noise associated with jacket-water piping.

The noise level for the coolers used in the acoustical analysis is generally higher than the sound level requirement in order that the noise design analysis incorporates an acoustical "margin of safety." In addition, there can be other noise associated with the coolers that is not directly related to the operation of the cooler fans (e.g., noise of the JW piping and/or compressor noise radiated from the tubes of the gas coolers).

(5) The estimated PWL values for the engine air intake were calculated from measured sound data in the field tests by H&K on similar engine that will be employed.

APPENDIX B: ANALYSIS METHODOLOGY AND SOURCE OF SOUND DATA (DRILLING OPERATIONS AT NEW STORAGE WELL OR WORKOVER WELL)

In general, the predicted sound level contributed by drilling operations at a gas storage well site or a workover well site was calculated as a function of frequency from estimated unweighted octave-band (O.B.) sound power levels (PWLs) and A-wt. PWL of the similar type of well drilling operations. The following summarizes the acoustical analysis procedure:

- Initially, unweighted O.B. PWLs of the specific type of drilling operations were determined from actual sound level measurements on a similar type of drilling operations/equipment expected to be utilized at this facility.

- Then, expected attenuation in dB per O.B. frequency due to sound propagation (hemispherical radiation), atmospheric sound absorption and sound shielding (e.g., attenuation due to forest/trees and land contour, if appropriate) were subtracted from the unweighted O.B. PWLs to obtain the unweighted O.B. sound pressure levels (SPLs) of the drilling operations.

- Finally, the resulting estimated total unweighted O.B. SPLs for the drilling operations, including sound attenuation effects, were logarithmically summed and corrected for A-weighting to provide the estimated overall A-wt. sound level contributed by the drilling operations at the specified distance(s).

The estimated sound level contribution of the drilling operations/rig at a new storage well site is based primarily on measured sound data by H&K at drilling rigs with similar type of equipment expected to be used at the site. For reference, the following describes the primary equipment and other items (e.g., potential noise sources) associated with a typical drilling rig at a new storage well site.

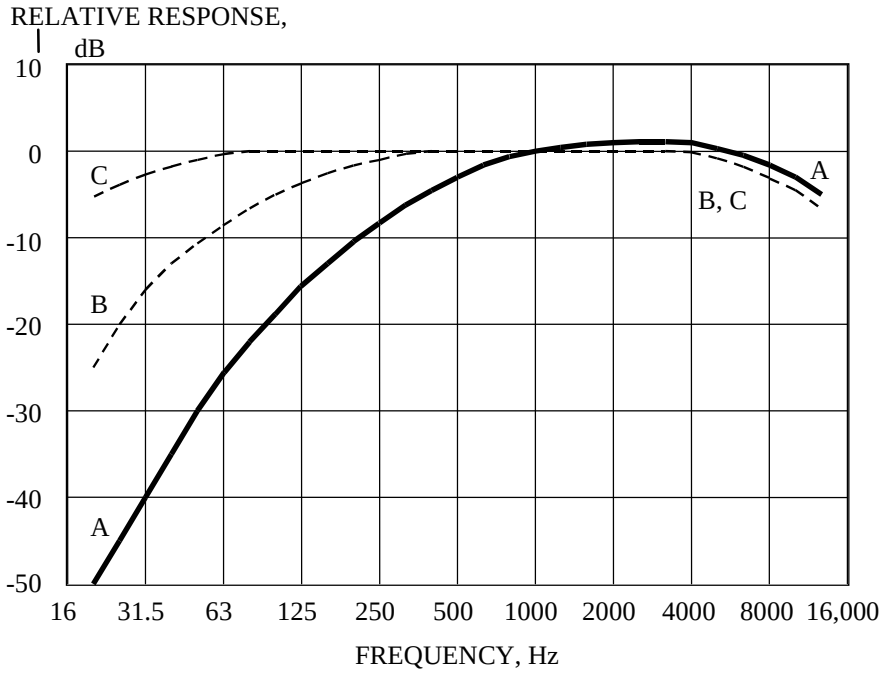
- Drawworks: engine-driven hydraulic power unit (e.g., 300 HP CAT 3406 engine)
- Derrick: 118’ x 365,000 lb. capacity
- Triplex centrifugal mud pumps (e.g., 1,000 HP CAT engine and/or 300-500 HP CAT engine)
- Engine-driven electric generator sets (e.g., CAT 300 HP & 430 HP gen sets)
- Air compressors (i.e., Ingersol Rand 1250/350, driven by 500 HP CAT 3412 engine)
- Booster pumps (single stage pump driven by a 200-300 HP CAT 3406E engine)
- Mud mixing/cleaning equipment (e.g., 50 HP centrifugal pumps) and water pump
- Fluid systems shale shakers (associated with the mud mixing/cleaning equipment)
- Crane(s), dozer (CAT D7G), loader(s), backhoe and/or forklift

APPENDIX C: SUMMARY OF TYPICAL METRICS FOR REGULATION ENVIRONMENT NOISE AND ACOUSTICAL TERMINOLOGY

(1) Decibel (dB): A unit for expressing the relative power level difference between acoustical or electrical signals. It is ten times the common logarithm of the ratio of two related quantities that are proportional to power. When adding dB or dBA values, the values must be added logarithmically. For example, the logarithmic addition of **35 dB** plus **35 dB** is **38 dB**.

(2) A-Weighted Sound Level (dBA): The A-wt. sound level is a single-figure sound rating, expressed in decibels (Re 20 μPa), which correlates to the human perception of the loudness of sound. The dBA level is commonly used to measure industrial and environmental noise since it is easy to measure and provides a reasonable indication of the human annoyance value of the noise. The dBA measurement is not a good descriptor of a noise consisting of strong low-frequency components or for a noise with tonal components. The A-weighted curve approximates the response of the average ear at sound levels of 20 to 50 decibels. The following are the relative response of A-weighted filter per octave band frequency, and a graph/curve is provided that shows a graphical representation of the A-wt. filter response per frequency (in Hz).

31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz	8,000 Hz	16,000 Hz
-39.4 dB	-26.2 dB	-16.1 dB	-8.6 dB	-3.2 dB	0 dB	+1.2 dB	+1.0 dB	-1.1 dB	-6.6 dB



(3) Background or Ambient Noise: The total noise produced by all other sources of a given environment in the vicinity of a specific source of interest, and includes any Residual Noise.

(4) Human Perception of Change in Sound Level

- A **3 dB** change of sound level is barely perceivable by the human ear
- A **5 or 6 dB** change of sound level is noticeable
- If sound level increases by **10 dB**, it appears as if the sound intensity has doubled.

(5) Sound Pressure Level (L_p or SPL): Ten times the common logarithm to the base 10 of the ratio of the mean square sound pressure to the square of a reference pressure. Therefore, the sound pressure level is equal to 20 times the common logarithm of the ratio of the sound pressure to a reference pressure (20 micropascals or 0.0002 microbar).

(6) Octave Band (O.B.) Sound Pressure Level (SPL): Sound is typically measured in frequency ranges (e.g., high-pitched sound, low-pitched sound, etc.) that provides more meaningful sound data regarding the sound character of the noise. When measuring two noise sources for comparison, it is better to measure the spectrum of each noise, such as in octave band SPL frequency ranges. Then, the relative loudness of two sounds can be compared frequency range by frequency range. As an illustration, 2 noise sources can have the same dBA rating and yet sound completely different. For example, a high-pitched sound at a frequency of 2000 Hz could have the same dBA rating as a much louder low-frequency sound at 50 Hz.

(7) Daytime Sound Level (L_d) & Nighttime Sound Level (L_n): L_d is the equivalent A-weighted sound level, in decibels, for a 15 hour time period, between 07:00 to 22:00 Hours (7:00 a.m. to 10:00 p.m.). L_n is the equivalent A-weighted sound level, in decibels, for a 9 hour time period, between 22:00 to 07:00 Hours (10:00 p.m. to 7:00 a.m.).

(8) Equivalent Sound Level (L_{eq}): The equivalent sound level (L_{eq}) can be considered an average sound level measured during a period of time, including any fluctuating sound levels during that period. In this report, the L_{eq} is equal to the level of a steady (in time) A-weighted sound level that would be equivalent to the sampled A-weighted sound level on an energy basis for a specified measurement interval. The concept of the measuring L_{eq} has been used broadly to relate individual and community reaction to aircraft and other environmental noises.

(9) Day-Night Sound Level (L_{dn}): The L_{dn} is an energy average of the measured daytime L_{eq} (L_d) and the measured nighttime L_{eq} (L_n) plus **10 dB**. The **10-dB** adjustment to the L_n is intended to compensate for nighttime sensitivity. As such, the L_{dn} is not a true measure of the sound level but represents a skewed average that correlates generally with past sound surveys which attempted to relate environmental sound levels with physiological reaction and physiological effects. For a steady sound source that operates continuously over a 24-hour period and controls the environmental sound level, an L_{dn} is approximately **6.4 dB** above the measured L_{eq}. If both the L_d and L_n are measured, then the L_{dn} is calculated using the following formula:

$$L_{\text{dn}} = 10\log_{10}\left(\frac{15}{24}10^{L_{\text{d}}/10} + \frac{9}{24}10^{(L_{\text{n}}+10)/10}\right)$$

(10) Community Noise Equivalent Level (CNEL or L_{den}): A metric similar to the L_{dn}, except that a **5 dB** adjustment is added to the equivalent continuous sound exposure level for evening hours (i.e., L_e) between 19:00 to 22:00 hours (7:00 p.m. to 10:00 p.m.) in addition to the **10 dB** nighttime adjustment used in the L_{dn}. For a steady sound source that operates continuously over a 24-hour period and controls the environmental sound level, the CNEL is approximately **6.7 dB** above the measured L_{eq}. If the L_d, L_e (i.e., evening L_{eq}) and L_n are measured, then the CNEL is calculated using the following formula:

$$L_{\text{den}}(CNEL) = 10\log_{10}\left(\frac{12}{24}10^{L_{\text{d}}/10} + \frac{3}{24}10^{(L_{\text{e}}+5)/10} + \frac{9}{24}10^{(L_{\text{n}}+10)/10}\right)$$

(11) L-Percent Sound Levels: The L percent levels (e.g., L_{50}, L_{90} & L_{10}) refer to the A-weighted sound levels that are exceeded for 90, 50 and 10 percent of the time, respectively, during a sound measurement period. For example, the 50-percentile exceeded sound level is designated to as L_{50} and is sometimes described as the median sound level. The range between the L_{10} and L_{90} values usually provides a good indication of the variability of the sound levels during the period of measurement.

(12) Sound Level Meter (SLM): An instrument used to measure sound pressure level, sound level, octave-band SPL, or peak sound pressure level, separately or in any combinations thereof. The measured weighted SPL (i.e., A-Wt. Sound Level or dBA) is obtained by the use of a SLM having a standard frequency-filter for attenuating part of the sound spectrum.

(13) Sound Power Level (L_W or PWL): Ten times the common logarithm of the ratio of the total acoustic power radiated by a sound source to a reference power. A reference power of a picowatt or 10^{-12} watt is conventionally used.

(14) Tone: A tone is a sound sensation-having pitch, which is a listener's perception of the frequency (for example, the higher the frequency, the higher the pitch). For a measured sound spectrum, a tone is represented as a "peak" in the spectrum curve. Noise that contains significant tones is considered a tonal type of noise.

(15) Broadband Noise: Noise comprised of a wide frequency range and not characterized by any tonal components.

End of Report