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A SNAPSHOT OF NOISE AND WORKER EXPOSURES IN SAND & GRAVEL OPERATIONS

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ABSTRACT

Previous studies and research efforts have shown that noise-induced hearing loss (NIHL) is a problem in the U.S. mining industry. This is especially true in surface and underground coal and stone mining where large, noisy equipment predominate. Workers in coal preparation and stone processing plants have also been found to be subject to high sound levels that could potentially cause NIHL over prolonged periods of exposure. National Institute for Occupational Safety and Health (NIOSH) researchers have been conducting a cross-sectional survey of equipment noise and worker noise exposures in the mining industry to estimate the potential for NIHL within the mining community. One commodity recently surveyed was the extraction of sand and gravel from surface pits and by river dredging. Little is known about the noise environment and worker exposures in these environments, where processing and mining equipment similar to coal and stone are employed. To address the potential for NIHL in the sand and gravel industry, sound levels on and around the dredges and processing equipment were recorded to identify areas of high noise levels. Full-shift worker dosimetry, in conjunction with task observations, was documented to determine the relationship between exposure and source. This paper presents research examining noise on dredges, in several surface mine sand and gravel operations and in the processing facilities. The locations where workers are likely to be overexposed and were found to be most susceptible to noise overexposures are reported. Results indicate that there are areas on the dredges (crane, suction pumps, and diesel engines) where sound levels greater than 90 dB(A) are present. In addition, crushers and screens used in the processing of the sand and gravel also generate sound levels greater than 90 dB(A). Although no surveyed worker exceeded the Mine Safety and Health Administration (MSHA) Permissible Exposure Level (PEL) of 90 dB(A) TWA_8, laborers, mechanics, oilers, helpers, pickers, and greasers are the workers likely to be exposed to hazardous sound levels and thus develop NIHL over time. Knowledge of the equipment noise, area sound levels, and worker dose levels is information that management and employees can use to reduce exposures. Exposures can be reduced in certain areas through administrative controls and through engineering controls applied to the noisiest equipment.

INTRODUCTION

Exposure to noise and noise-induced hearing loss (NIHL) continues to be problematic for the U.S. mining industry. The problem is particularly severe because large, noisy equipment is found throughout the industry. A NIOSH analysis of NIHL among miners illustrates the extent of NIHL in the mining industry (NIOSH 1996). This analysis of several thousand audiograms indicates the number of miners with hearing impairments (defined as an average hearing threshold level of 25 dB or greater for the frequencies 1000, 2000, 3000, and 4000 Hz) increased with age until age 50, at which time 49% of the metal/nonmetal and 90% of the coal miners had a hearing impairment (NIOSH 1996 and 1997).

Another NIOSH study looked specifically at noise exposure and hearing loss among sand and gravel miners (Landen et al 2004). These studies were conducted at 24 surface and 9 dredge operations. The results revealed that 69% of the miners' noise exposures exceeded the NIOSH Recommended Exposure Limit (REL) of (85 dB, A-weighted, as an 8-hr time-weighted average (TWA_8)). In addition, 41% exceeded MSHA's action level for enrollment in a hearing conservation program. In addition, Landen reported that hearing protection use was low, with 48% of the subjects reporting that they never used hearing protection.

To address NIHL issues in all mining, MSHA has published Health Standards for Occupational Noise Exposure (Federal Register 1999). Requirements of the new standard include:

- the adoption of an Occupational Safety and Health Administration (OSHA)-like Hearing Conservation Program (HCP);
- enrollment in the HCP for workers exposed above an Action Level of 85 dB(A) eight-hour time weighted average (TWA_8);
- reduction of worker exposures to or below a Permissible Exposure Level (PEL) of 90 dB(A) TWA_8 or equivalently a dose of 100%;
- no reduction in noise exposure being allowed due to the use of personal hearing protection; and
- a requirement that mine operators use all feasible engineering and administrative controls to reduce noise exposures.

NIOSH has responded to the problem of noise overexposure in the mining industry by conducting an extensive cross-sectional survey of noise sources and worker noise exposures. Initially these surveys were conducted in surface and underground (room & pillar and longwall) coal mines, coal preparation plants, and stone (aggregate) mines and crushing and processing facilities. Recently, these surveys have expanded to sand and gravel mines including dredging and their associated crushing, sizing and processing facilities. According to MSHA, in 2005 there were over 7,000 sand and gravel operations (approximately 6200 surface and 800 dredges) in the U.S., disbursed as seen in Figure 1. Employment in the sand and gravel industry exceeded 45,000 workers, with an average of 6 employees per mine. These surveys are designed to monitor worker noise dose, measure equipment sound levels, and understand the noise source/worker dose relationship. This is accomplished through full-shift dosimetry readings, equipment sound profiles, and worker task observations where possible.

SCOPE OF WORK

Background

Noise surveys were conducted at nine sand and gravel operations that included three surface pits, five dredges and eight processing plants. Three dredges were mechanical navigation dredges (river-based, also known as hoist boats) that employ a crane and clam bucket to remove river bottom material, and two were electric hydraulic cutter head mining dredges (land-based) that employ a rotating cutter head and suction to remove the sand material from the pit. Table 1 (see Appendix) lists the specific characteristics of each operation. The operations were located in Arizona, New Jersey and Pennsylvania. In total, dosimetry for 75 workers (MSHA PELs) and 101 equipment noise profiles were completed. Noise dose was recorded for equipment operators, crushing plant operators, crusher operator, dredge/crane operators, boat pilots and deck hands, technicians, mechanics, and laborers. The equipment noise profiles included stationary and mobile mining equipment, control rooms, dredges, cranes, tow boats, and crushing and screening facilities. In addition, the mobile equipment was monitored for noise inside and outside the cabs to determine the effectiveness of the cabs at protecting the operators from engine and operational noise.

Figure 1. Distribution of sand and gravel operations in the U.S.

Instrumentation and Data Collection

The instrumentation used in the studies included personal dosimeters and sound level meters (SLM). Worker noise exposure was monitored using Quest[1] Q-400 Noise Dosimeters. The workers donned a dosimeter for their full work shifts. The microphone was located at the middle of the shoulder per MSHA recommendations (MSHA 2000). The dosimeter was set to monitor an MSHA PEL of 100% or a TWA_8 of 90 dB(A) (specific parameters of this setting include: A-weighting, 90-dB Threshold and Criterion Levels, 5-dB Exchange Rate, Slow Response, and a 140-dB Upper Limit).

Equipment and area sound levels were recorded using a Quest Model 2900 SLM and a Brüel & Kjær 2260 Investigator. The SLM and Investigator were mounted side-by-side on a tripod (Figure 2), with the microphone 1.5 m (5 ft) from the floor/ground (approximate ear height), angled at 70° from the source (per manufacturer recommendations), and facing the sound source. Measurements were made to delineate the near-field and far-field equipment sound levels. Near-field measurements were made on a 1- to 2-m (3- to 6-ft) grid, at a distance of approximately 1 to 2 m (3 to 6 ft) from the equipment. Far-field measurements were made up to 150 m (500 ft) from the equipment. An A-weighted Equivalent Sound Pressure Level (Leq) was recorded at each location. The parameter of interest for these studies was the average integrated sound level accumulated during a specified measurement period or Leq using a 3-dB exchange rate. The 3-dB exchange rate is the method most firmly supported by scientific evidence for assessing hearing impairment as a function of sound level and duration (NIOSH 1998). A slow response rate with an averaging time of 10 seconds was employed, with most readings being recorded over a 30-sec period.

Measurements made around the cranes (dredges) and processing facilities were used to generate sound profile plots. Although sound is a logarithmic quantity, the plots were generated linearly. It is believed that linear sound profile plots are adequate for describing the sound levels around mining equipment solely for the purpose of alerting mine workers of the areas to avoid and minimize their noise exposures.

RESULTS

Worker Noise Exposure

Workers at each site wore dosimeters for a full shift to provide noise exposure data (Figure 3). When two production shifts were used, workers on both shifts were surveyed. Table 2 (see Appendix) lists the worker dose levels that were measured, including the inside/outside cab dose levels for evaluation of cab effectiveness in preventing exposure from engine and equipment operation noise. A typical dosimeter location for outside cab measurements is shown in Figure 4.

Figure 2. Sound level meters used to measure equipment noise levels.

Figure 3. Noise exposure monitoring with a personal dosimeter.

Two general conclusions can be made from these data. First, all worker doses were below the MSHA PEL of 100% (0.19 to 90.02%, see Table 2). There were two workers, a plant man and a belt picker, who accumulated dose levels around 90%. The plant man was responsible for cleaning around the processing equipment, including while the plant was operating. As seen in the "Equipment/Area Noise Measurement" section of the report, much of the equipment generates sound levels greater than 90 dB(A), thus this worker's noise dose was not unexpected. The belt picker worked on the dredge that utilized on-board processing. The worker was located in a crudely built shanty located next to the belt carrying material from the grizzly to the processing facility. This worker's job was to pick wood and other debris from the belt. Because the shanty had little if any noise controls in place, the picker was subject to the sound levels generated by the nearby processing equipment. Again, his measured dose was not unexpected. Secondly, a comparison of the interior and exterior mobile equipment dose levels indicates that the equipment cabs provided sufficient protection from noise for the operators. The front end loader (FEL), crane and haul truck operators all had MSHA PEL noise dose levels below 52%, yet the outside dose levels were as high

[1]Reference to brand names does not imply endorsement by NIOSH.

as 245%. This illustrates that the cabs were protecting the operators from engine and equipment operational noise.

Figure 4. Example of dosimeter outside mobile equipment.

Equipment/Area Noise Measurements

Sound level measurements were taken around all stationary equipment such as conveyor belts and conveyor belt drives, crushers, screens, cranes, tow boats, and mobile equipment including front-end loaders and trucks. Table 3 (see Appendix) lists the results of the sound level measurements for both the processing equipment and dredges. For convenience, equipment such as screens, crushers, and belt drives are lumped together by category even though they varied widely in size and product throughput. The sound levels varied widely because of the size and throughput just mentioned, because of equipment age and condition, and because the ranges include measurements taken at varying distances from the stationary equipment.

Dredges

To illustrate the sound levels measured on the dredges, several examples are included. Figures 5 and 6 include a photograph and sound profile plot of the sound levels on a mechanical navigation dredge with on-board processing. Figure 6 illustrates that outside the diesel engine room is the noisiest, but also that the barge areas containing the processing equipment have sound levels above 90 dB(A).

Figures 7 and 8 include a photograph and sound profile plot of the sound levels on a navigational dredge that dumps material directly into barges. Figure 8 illustrates that in general the noise levels are below 90 dB(A). Noise levels above 90 dB(A) were recorded in the crane engine room and diesel engine room (located in belly of the barge).

Figure 5. Navigational dredge with on-board processing.

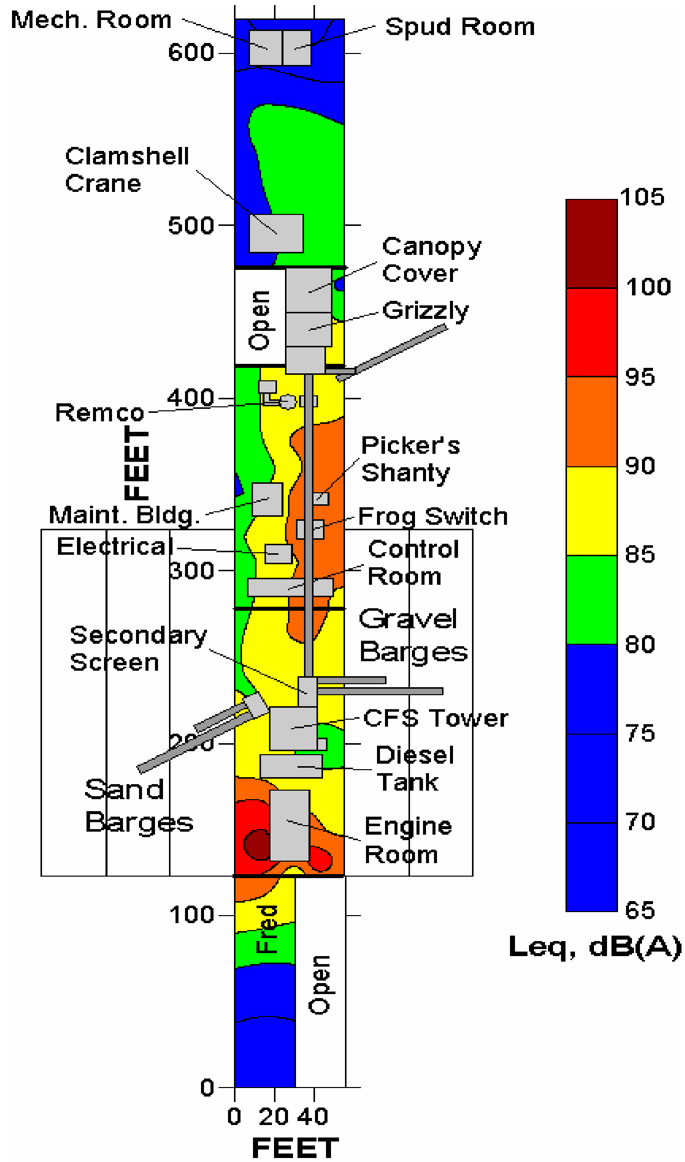

Figure 6. Sound profile plot for navigational dredge with on-board processing.

Figure 7. Navigational dredge without on-board processing.

Figures 9 and 10 include a photograph and sound profile plot of the sound levels on an electric hydraulic cutter head mining dredge, with an underwater suction pump and a cutter basket that extracts sand from the bottom of the pit, then pumps the sand/water mix back to the processing facilities. Figure 10 illustrates that the sound levels are generally below 90 dB(A) except near the fresh water pumps and the DC electric motor driving the underwater suction pumps at the rear of the dredge. The sound level measurements on all the dredges indicate the areas where exposure to noise should be limited (near the diesel engines of the barge and crane, and on-board processing facilities) and where overexposures could be minimized (control room, offices, and crane operators cab).

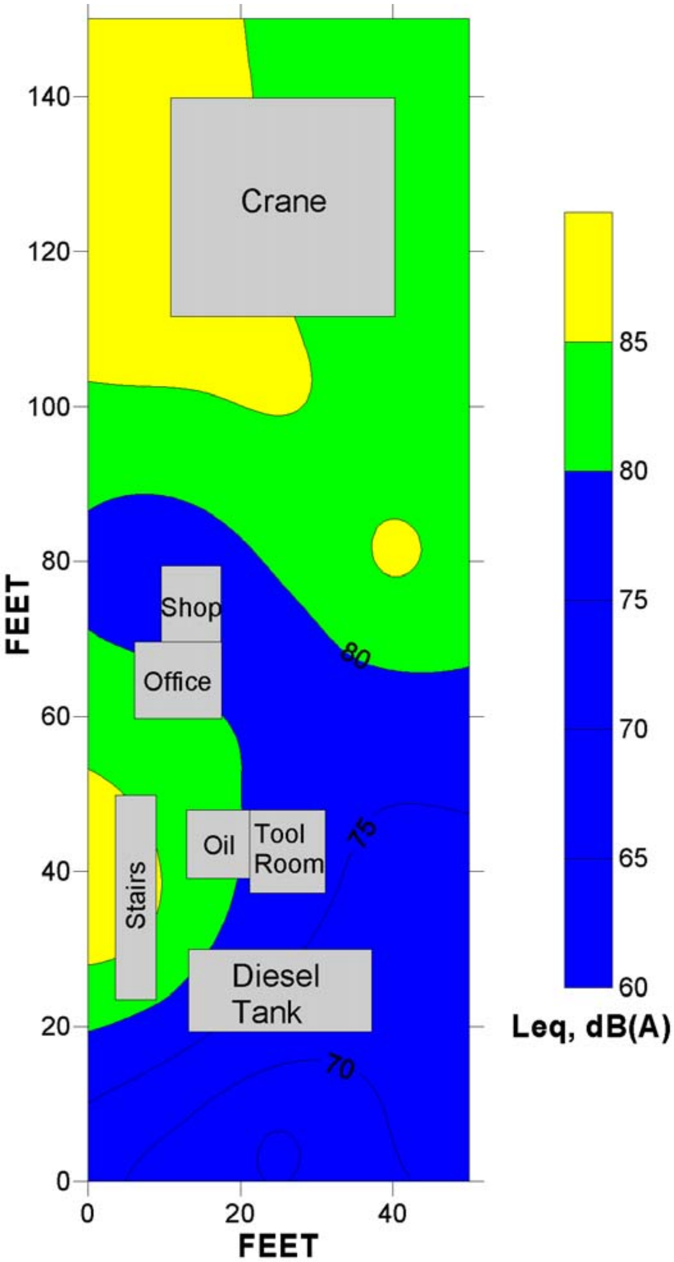

Figure 8. Sound profile plot for a navigational dredge without on-board processing.

Figure 9. Electric hydraulic cutter head mining dredge.

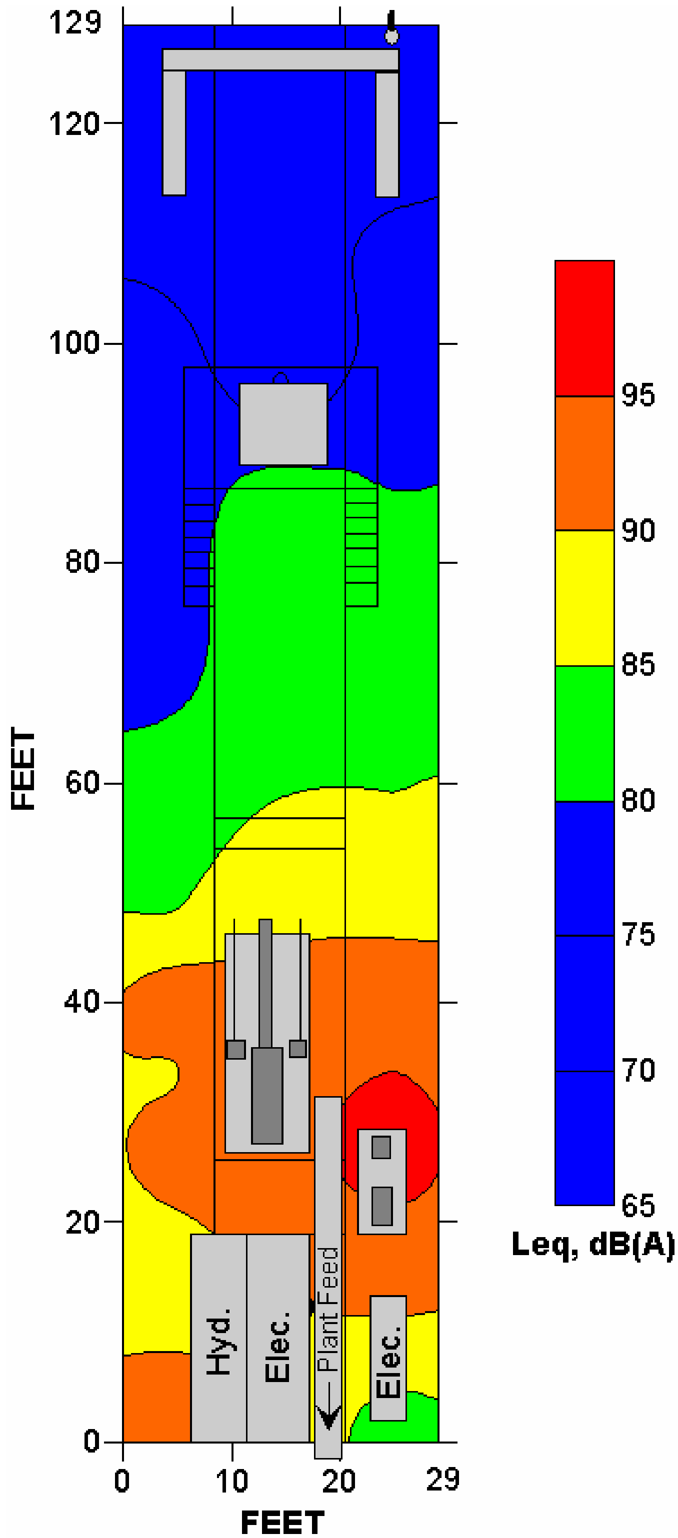

Figure 10. Sound profile plot for an electric hydraulic cutter head mining dredge.

Tow Boats

At the three river-based dredges tow boats were used to move the loaded and empty barges between the dredge and processing plants/storage yard. Figures 11 and 12 are two of the three tow boats used to move barges. Because these tow boats generally push only one barge at a time they are small by comparison to the tow boats that normally ply the rivers around Pittsburgh. Table 3 includes the range of sound levels measured on the tow boats. The measurements revealed that the pilot houses were quiet (< 74 dB(A)), the diesel engine rooms were noisy (110 dB(A)), and the deck area was quiet (<

80 dB(A)) except near the engine rooms and exhaust mufflers (100 dB(A)).

Figure 11. Tow boat pushing an empty barge.

Figure 12. Tow boat pushing a loaded barge.

Processing Plants

The processing plant equipment consisted of screens, crushers, conveyor belts, cyclones, sand classifiers and screws, miscellaneous buildings (shops, electrical, compressor, etc), cranes, and control rooms. In addition, front end loaders and haul trucks were used at the surface sand and gravel operations and in the processing facilities. Table 3 contains a summary of the sound levels measured in all the processing facilities. The cranes that removed material from the barges and deposited the material into a hopper had similar sound levels as the cranes on the dredges. Sound levels measured in the cabs were slightly higher (82 to 88 dB(A)) while the engine room sound levels were nearly identical (up to 107 dB(A)). Based on these results, it is recommended that as little work as possible should be done in the crane engine rooms while operating.

An AllisChalmers (AC51), 6-ft diameter cone crusher is illustrated in Figure 13. The sound profile plot for this crusher is shown in Figure 14 and reveals that sound levels approaching 100 dB(A) were present. An example of a screen that is processing river dredged sand and gravel is illustrated in Figure 15. The sound profile plot for the primary triple-deck screen is shown in Figure 16 and reveals that sound levels between 105 and 110 dB(A) were present. Two screens, processing primarily sand, are shown in Figure 17. The fact that they are processing sand and small gravel, and are using urethane screen cloth to control noise, keeps the sound levels generally below 90 dB(A) (Figure 18). Finally, Figure 19 illustrates the sound levels for an entire plant. In general, the sound levels are below 90 dB(A) except in the area around the No. 1 primary screen and 60-in crusher.

DISCUSSION

Considering the high noise levels that the mining, dredging and processing equipment generate, and the large number of sand and gravel operations in the U.S. and the 45,000+ employees, the concern for preventing NIHL is significant. Sound levels as high as 112 dB(A) were recorded near crushers, 108 dB(A) near screens, 107 dB(A) in the engine rooms of the cranes, and up to 97 dB(A) in the plant areas. Over time, exposure to these noise levels for even short durations could result in permanent hearing loss. Fortunately, the results of this research effort indicate that workers are avoiding high noise areas as revealed by the relatively low dose levels recorded. In general, all but three of the doses recorded were less than 60% with only two approaching the MSHA PEL of 100% (89.96% and 90.2%) as shown in Table 2.

Figure 13. AllisChalmers AC51 cone crusher.

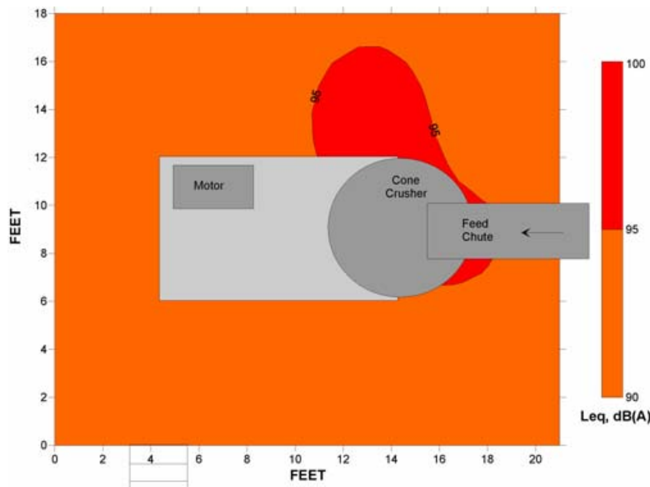

Figure 14. Sound profile plot for AC51 cone crusher.

Figure 15. Primary triple-deck screen.

Because most employees are in cabs or control rooms, they are protected from noise overexposure as illustrated by the results of the dose measurements. For those workers who must spend time in the processing plants and engine rooms, it would be prudent to restrict time spent in and around the screens and crushers in the plants and the pumps and motors on the dredges, and to require mobile equipment operators to keep all doors and windows closed while the equipment is in operation. All workers should be made aware of the sound levels around all equipment and in the plants and dredges, and be instructed to use hearing protection based on NIOSH's recommended exposure limit (REL) of 85 dB, A-weighted, as an 8-hr time-weighted average (TWA_8) (NIOSH 1998). Exposures at or above this REL are hazardous, creating an excess risk of developing occupational NIHL. For workers whose noise exposures equal or exceed 85 dB(A), NIOSH recommends proper use of hearing protection, among other assessment, training, and prevention approaches. Any area that has a sound level of 85 dB(A) or higher has the potential to exceed the NIOSH REL depending on the exposure time. Since the length of exposure can vary and/or is not known prior to entering a high sound area, the potential adverse effects on a worker's hearing are also not known, thus it makes sense to use hearing protection when in areas where the sound levels are 85 dB(A) or greater.

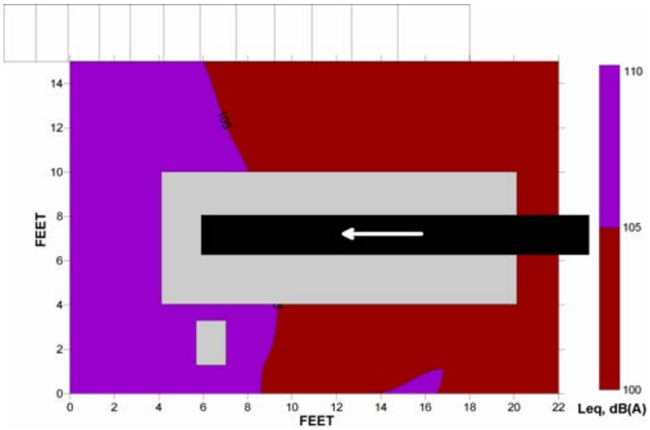

Figure 16. Sound profile plot for primary triple-deck screen.

Figure 17. Diester 6- x 20-ft shaker screens.

The sound level measurements on all the dredges indicate that workers should limit their exposure near the diesel engines of the barge and crane, and on-board processing facilities. Similarly on the tow boats, the diesel engines are noisy and should be avoided when possible. When it is necessary to be near the engines, workers should wear appropriate hearing protection. In addition, based on the measured sound levels, it is recommended that as little work as possible should be done in the crane engine rooms while they are operating.

It is also important that hearing protection devices (HPDs) are used in high noise areas even though workers are limiting their exposures as evidenced by the lack of MSHA PEL doses over 100%. Finally, HPDs are only a temporary substitute for effective engineering and administrative noise controls. Noise-induced hearing loss will be eliminated only through a coordinated effort of applying noise controls, training, and HPD use for exposure reduction.

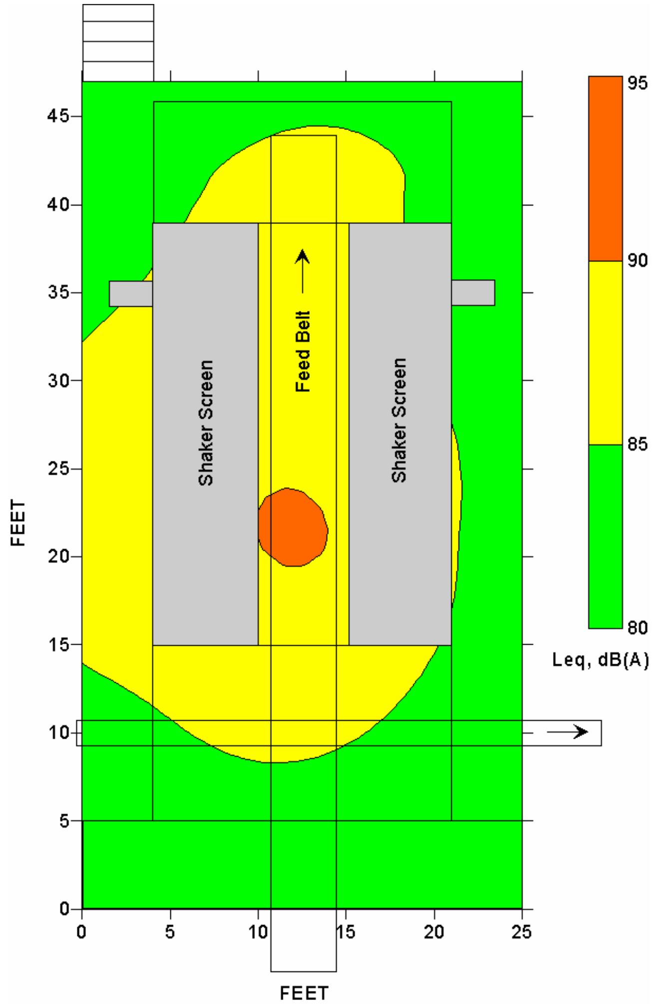

Figure 18. Sound profile plot for Diester 6- x 20-ft shaker screen.

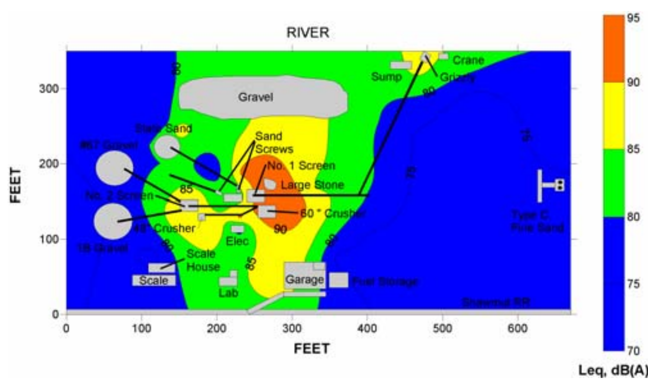

Figure 19. Sound profile plot for entire plant.

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Appendix

Table 1. Characteristics of sand and gravel operations surveyed

Dredge	Location	Type	Product	Processing Facilities	Approximate Production, st/yr	No. of Employees
S&G1	Land	Pit	Sand & Gravel	Land, Both[2]	1,000,000	25-30
S&G2	Land	None[1]	Sand & Gravel	Land, Wet	400,000	7
S&G3	River	Dredge, Crane	Sand & Gravel	OnBoard, Wet	350,000	14
S&G4	Land	Pit	Sand & Gravel	Land, Dry	120,000	7
S&G5	Land	Dredge, Suction	Primarily Sand	Land, Wet	1,200,000	11
S&G6	Land	Dredge, Suction	Primarily Sand	Land, Wet	400,000	10
S&G7	Land	Pit	Sand & Gravel	Land, Wet	180,000	7
S&G8	River	Dredge, Crane	Sand & Gravel	Land, Wet[3]	200,000	25
S&G9	River	Dredge, Crane	Sand & Gravel	Land, Wet	140,000	9

[1]None – No mining occurred at this site. Material for processing is trucked from two off-site pits.
[2]Both – Material processed both dry and wet.
[3]Land-based processing facilities were not surveyed at this site.

Table 2. MSHA PEL noise dose for sand and gravel workers

Occupation	No. of Recorded Doses	Worker Range of MSHA PEL Dose, %	Outside Cab Range of MSHA PEL Dose, %
FEL Operator	17	0.19 – 51.83	27.21 – 244.31
Laborer/Utility Man	7	16.81 – 63.05	ND[1]
Dredge Operator/Trainee (CR[2])	7	2.32 – 10.74	ND
Plant Operator (CR)	6	1.72 – 10.45	ND
Plant Man	6	28.79 – 90.02	ND
Crane Operator	6	3.06 – 26.36	48.20 – 109.81
Haul Truck Operator	5	10.32 – 50.27	63.12 – 121.99
Boat Pilot	4	8.58 – 43.58	ND
Crusher Operator	3	3.66 – 41.20	ND
Technician	3	0.83 – 15.39	ND
Shopman/Maintenance Man	3	5.95 – 38.56	ND
Belt Picker	2	23.71 – 89.96	ND
Dredge Oiler	2	8.67 – 11.27	ND
Water Truck Operator	2	14.61 – 59.13	ND
Deck Hand	1	4.74	ND
Scale Man	1	1.67	ND

[1]ND – Not determined.
[2]CR – Control Room.

Appendix (cont'd)

Table 3. Sound level measurements at sand and gravel sites surveyed

Area	Equipment	Location	Leq Range, dB(A)[1]
Dredge	Crane, Operators Cab	Inside	76 – 85
	Crane, Engine Room	Inside	102 – 107
	Office, Tool Room, Misc. Rooms	Inside	64 – 89
	Diesel Motor	Inside	103
	Barge Area	Outside	64 – 102
	Control Room	Inside	66 – 76
	Control Room	Outside	69 – 84
	Suction Pump Drive Motors	Outside	83 – 96
	Hydraulic Pump Room	Inside	98
	Electrical Room	Inside	92
Tow Boat	Pilot House	Inside	67 – 74
	Deck	Outside	75 – 100
	Auxiliary Rooms	Inside	76 – 83
	Engine Room	Inside	110
Plant	Crane, Operators Cab	Inside	82 – 88
	Crane, Engine Room	Inside	92 – 107
	Crushers	Area	81 – 112
	Control Rooms	Inside	56 – 79
	Control Rooms	Outside	73 – 83
	Screens	Area	77 – 108
	Cyclones	Area	81 – 88
	Belts, Drives, Transfers	Area	62 – 95
	Sand Classifiers	Area	76 – 89
	Misc. Buildings, Trailers	Inside	51 – 89
	Scale House	Inside	51 – 72
	Sand Screws	Area	81 – 88
	Plant Area Noise	Ground Level	61 – 97

[1]Measured with a 3-dB Exchange Rate.