MONITORING ENVIRONMENTAL PERFORMANCE COMMITMENTS IN CONSTRUCTION PROJECTS

U.S. Environmental Protection Agency

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Prepared for:
U.S. Environmental Protection Agency
Region 2
290 Broadway
New York, NY 10007-1866

Prepared by:
U.S. Department of Transportation
Research and Innovative Technology Administration
John A. Volpe National Transportation Systems Center
Environmental Measurement and Modeling Division, Acoustics Facility
Cambridge, MA 02142

ABBREVIATIONS

CEPP	Construction Environmental Protection Program
CO	Carbon monoxide
DOC	Diesel oxidation catalyst
DPF	Diesel particulate filter
DR	Deficiency report
EPA	Environmental Protection Agency
EPC	Environmental Performance Commitment
FHWA	Federal Highway Administration
HC	Hydrocarbon
HP	Horsepower
L_{10}	Fast A-weighted sound level exceeded 10 percent of the time, in dBA
L_{max}	Maximum A-weighted sound level at 50 ft., in dBA
MPT	Maintenance and Protection of Traffic
PE	Professional Engineer
PM2.5	2.5-micron particulate matter (diameter = 0.0000025 m)
PM10	10-micron particulate matter (diameter = 0.0000100 m)
POC	Point of Contact
PPM	Parts per million
ULSD	Ultra-low sulfur diesel

ENVIRONMENTAL PERFORMANCE COMMITMENTS (EPCs)

EPCs are measures implemented during project construction to reduce environmental impacts. These commitments are directed toward the Project's performance period only and focus primarily on reducing the impacts of construction equipment and trucks.

The following stakeholders stand to benefit greatly from successful implementation of EPCs:

- Most importantly, the Public, including residents, businesses, and associations such as the local chamber of commerce;

- At the overall management level, the involved Federal, state, and local agencies charged with planning, funding, managing, and maintaining the construction projects; and

- At the construction site level, all construction contractors involved in the Project.

Possible Environmental Performance Commitments
for air quality and dust control:

- *Use ultra-low sulfur diesel (ULSD) fuel in off-road construction equipment with an engine horsepower (HP) rating of 50 HP or above;*
- *Use diesel engine retrofit technology in off-road equipment to further reduce emissions. Such technology may include Diesel Oxidation Catalyst (DOC)/Diesel Particulate Filters (DPF), engine upgrades, engine replacements, or combinations of these strategies;*
- *Limit unnecessary idling times on diesel-powered engines to three minutes;*
- *Locate diesel-powered exhausts away from fresh air intakes; and*
- *Control dust related to the construction site through a Construction Environmental Protection Program (CEPP), including a Soil Erosion and Sediment Control Plan that includes, among other things, spraying of a suppressing agent (nonhazardous, biodegradable) on dust piles, containing fugitive dust, and adjusting construction activities to respond to meteorological conditions, as appropriate.*

for noise and vibration control:

- *Where practicable, schedule individual project construction activities to avoid or minimize adverse impacts;*
- *Coordinate construction activities with projects under construction in adjacent and nearby locations to avoid or minimize impacts;*
- *Consider condition of surrounding buildings, structures, infrastructure, and utilities, where appropriate; and*
- *Prepare contingency measures in the event established limits are exceeded.*

for traffic and circulation control:

- *Establish a project-specific pedestrian and vehicular maintenance and protection plan;*
- *Promote public awareness through such mechanisms as signage, telephone hotline and website updates;*

- *Ensure sufficient alternate street, building, and station access during the construction period; and*
- *Communicate regularly with the local DOT and participate in that agency's construction coordination efforts.*

CHECKLIST FOR PROJECT STAKEHOLDERS

All Project stakeholders should utilize the following checklist to ensure that implementation and verification of the EPCs are being performed and that the commitments are performing to the industry best practices in reducing construction activity impacts on **air quality and dust**, **noise and vibration**, and **traffic and circulation**.

AIR QUALITY AND DUST CONTROL

Meeting the requirements laid out in the following air quality and dust control checklist will help meet the suggested EPCs and mitigate air quality and dust impacts in the construction area.

Item No.	Responsible Parties	Frequency Checked	Currently Checked?	Checklist Item	Associated Worksheet(s)
1	Project Sponsors	Daily activity	☐	**Are Project sponsors, i.e., Federal, state, and local agencies, communicating with the Public about air quality and dust EPCs?** The benefits of reducing complaints about air quality and dust cannot be stressed enough: Any success toward this goal will save Project sponsors time, money, bad publicity, and Public frustration.	***1, 2***
2	Project Sponsors	Meetings at least quarterly	☐	**Has an Environmental Panel (EP) been formed?** In order to more quickly and efficiently evaluate growing air quality challenges, management stakeholders should form an EP including construction contractor management and management stakeholders. Before construction begins, the EP should draw up any air quality control specifications for the Project and determine the inspection and monitoring programs and their manpower requirements.	***1, 2***
3	Project Sponsors	Meetings at least quarterly	☐	**Has a Construction Air Quality Committee been formed?** The Project may also want to form a Construction Air Quality Committee (CAQC) and include the Project sponsors and other parties interested in monitoring the air quality stability of the area through the duration of the Project. The main initiatives for this CAQC committee would be to draw up two environmental plans: (1) a Construction Environmental Protection Program (CEPP), and (2) a Soil Erosion and Sediment Control Plan. The CAQC should be used to determine these plans and assign manpower requirements to them.	***1, 2***

4	EP, contractor	Establish once, with updates as required	☐	**Is an Air Quality and Dust Control Specification in place for the Project?** A contractually binding Air Quality and Dust Control Specification, or Dust Spec, can become a vital compliance tool used by both project managers and construction contractors to comply with a reasonable and universally accepted set of air quality and dust control requirements. A Dust Spec should outline the necessary measures and requirements for contractors to follow in order to control on- and off-site nuisance dust, and contractors should be made well aware of this Dust Spec once it is in place.	***16***
5	EP	Establish once; update as required; ***monitor every 2 weeks to 5 months***	☐	**Has a PM10 Monitoring Program been established?** A PM10 monitoring program should evaluate the effects of various utility relocation activities and measure baseline levels prior to mainline construction. Such programs include the use of portable Mini-VOL air samplers located at sidewalks for periods of time that range from two weeks to five months. The appropriate equipment and manpower may need to be contracted out, but it should not be necessary to hire a full-time air quality technician, since the PM10 sampling is infrequent compared to noise monitoring.	***14, 15, 16***
6	EP, contractor, Project Engineer	Establish once; update as required; ***monitor 3 times per week***	☐	**Is a dust control program in place?** A dust control program created by management stakeholders and sponsors will provide timely feedback to construction management such that additional dust control measures may be implemented as needed toward reducing construction-related sources of nuisance dust and PM10 emissions. As part of the program, construction areas and adjacent roadways in proximity to each PM10 sampling location should be inspected visually three times a week for observable on- and off-site nuisance dust, dirt tracking on public streets, and nuisance diesel emissions within the work area. All inspections should be catalogued in inspection reports. A full-time air quality technician need not be hired for these inspections since any Project staff member should be able to perform the visual inspection duties within his or her schedule. Using the information contained in the visual inspection report, the Project may notify construction field offices of problematic nuisance dust and diesel emissions and recommend solutions to rectify the condition. In the event of recurring nuisance conditions, contractors may be given deficiency reports (DR) via the site Project Engineer. A DR may allow the Project to withhold payment for repeated observable dust and diesel emission problems. In extreme cases, the information contained in the field inspection reports and DRs may be used to initiate further inspections and/or levy fines against the contractor for non-compliance with pollution control laws.	***5, 6, 14, 15, 16***

7	Project Sponsors, contractor, Project Engineer	Monitor weekly	☐	**If a dust control program is in place, are the following criteria included in the program?** • Use onsite wet suppression, alone or with binding agents, on a routine basis using a water truck. Calcium chloride may be used instead of wet suppression when freezing conditions exist. • Use wet-spray power-vacuum street sweepers on paved roadways. Power-vacuum street sweepers may be used throughout the project area to remove fine particulate dust from public roadways so that the dust will not be launched into the air by passing vehicles; the vacuum sweepers are able to collect dust particles smaller than 0.00001 m in diameter (PM10), which more traditional broom-powered street sweepers are incapable of removing. • Use windscreen fabric or wood barriers around the perimeter of construction sites. • Use crushed stone at construction ingress/egress areas. At every one of a worksite's egress gates, crushed stone and/or metal grates may be laid down for drivers to drive over, effectively removing as much mud, dirt, and dust as possible from truck wheels before it can be tracked out onto public streets. • Use wheel-wash stations at construction ingress / egress areas. Wheel-wash stations may be set up at egress gates of every worksite in order to remove as much mud, dirt, and dust as possible from truck wheels before it can be tracked out onto public streets. Removal methods include manual or automatic washing of wheels with high-pressure water hoses. • Cover active stockpiles with plastic tarps. • Use soil-binding agents on inactive stockpiles and open worksites. Various types of soil binding agents may be used in a construction area in order to keep dust down. These agents, such as calcium chloride, may be applied in a liquid state with a high-pressure water hose and allowed to dry and effectively glue the dust to the ground. • Cover dump trucks with windscreen fabric or tarps during material transport on public roadways. • Reduce the number of truck entrances and exits from a construction site.	***5, 6, 14, 16***

8	Project Sponsors, contractor, Project Manager	Establish once; update as required; monitor weekly	☐	**Is a diesel emissions retrofit program in place?** A retrofit program will retrofit diesel engines with diesel oxidation catalysts (DOC) and diesel particulate filters (DPF). A retrofit program can result in an approximately 20% reduction in PM10 and PM2.5 (0.0000025-m diameter particles) emissions for the retrofitted equipment. In addition, reductions in CO (40%) and HC emissions (50%) for the retrofitted equipment may result in the reduction of diesel odors and air toxics near residential communities and hospitals or other sensitive land-uses.	***3, 5, 6, 14, 15, 16***
9	Project Sponsors, contractor, Project Manager	Establish once; update as required; monitor weekly	☐	**If a diesel emissions retrofit program is in place, are the following criteria included in the program?** • Where possible, use ultra-low sulfur diesel (ULSD) fuel. The use of ultra-low sulfur diesel (ULSD) fuel in off-road construction equipment with an engine horsepower (HP) rating of 50 HP or above can reduce PM emissions by up to 14%. • Label retrofitted equipment. Equipment that has been retrofitted with a DPF, DOC, or other emissions reduction device, or is running on ULSD, should be labeled with a numbered, highly visible sticker. • Document retrofitted equipment in the construction equipment inventory. Equipment that has been retrofitted with a DPF, DOC, or other emissions reduction device, or is running on ULSD, should be documented as retrofitted and/or running on ULSD in the construction equipment inventory.	***3, 5, 6, 14, 15, 16***
10	Contractor, Project Engineer	Monitor weekly	☐	**Are engines off, when possible?** Turn off diesel construction equipment that is not in active use and dump trucks that are idling while waiting for five minutes or more to load or unload material. Turn off diesel construction equipment that is not in active use and dump trucks that are idling while waiting for five minutes or more to load or unload material.	***5, 6, 14, 16***
11	Contractor, Project Engineer	Monitor weekly	☐	**Has a safe staging zone been established?** Establish a staging zone for trucks that are waiting to load or unload material at the work zone in a location where diesel emissions from the trucks will not be noticeable to the public.	***5, 6, 14, 16***
12	Contractor, Project Engineer	Monitor weekly	☐	**Have fresh air intakes been avoided?** Locate construction equipment away from odor-sensitive locations such as fresh air intakes to buildings, air conditioners, and operable windows.	***5, 6, 14, 16***

13	Contractor, Project Engineer	Monitor weekly	☐	**Is electric-powered equipment replacing diesel / gasoline equipment, where possible?** If grid power is readily available on a worksite, electric-powered equipment may replace diesel-powered equipment in many cases, i.e., diesel generators. Electric-powered equipment should be physically labeled as such for inspectors and documented as such in the construction equipment inventory.	***3, 5, 6, 14, 16***

NOISE AND VIBRATION CONTROL

Meeting the requirements laid out in the following noise and vibration control checklist will help meet the suggested EPCs and mitigate noise and vibration impacts in the construction area.

Item No.	Responsible Parties	Frequency Checked	Currently Checked?	Checklist Item	Associated Worksheet(s)
14	Project Sponsors	Daily activity	☐	**Are Project sponsors, i.e., Federal, state, and local agencies, communicating with the Public about noise and vibration EPCs?** The benefits of reducing noise complaints cannot be stressed enough: Any success toward this goal will save the Project sponsors time, money, bad publicity, and Public frustration.	***1, 2***
15	Project Sponsors, Noise Technician / Acoustical Engineer	Meetings at least quarterly	☐	**Are Public / community meetings being held?** An essential component of any construction noise control program is to meet regularly with the affected Public and share plans for mitigating upcoming noisy events. The EP can organize these meetings periodically or as the ramping up of construction activity merits a meeting.	***1, 2***
16	Project Sponsors	Meetings at least quarterly	☐	**Has an Environmental Panel been formed?** In order to more quickly and efficiently evaluate growing noise and vibration challenges, management stakeholders should form an EP, internal to the Project, consisting of the main EPC Points of Contact (POC). These POCs should include Project sponsors and construction contractor management. Before construction begins, the EP should draw up any noise control specifications for the Project and determine the inspection and monitoring programs and their manpower requirements.	***1, 2***
17	EP, contractor	Establish once, with updates as required	☐	**Is a clear, concise Noise Control Specification in place for the Project?** A critical enforcement tool in a construction project's noise control program is the writing of a comprehensive noise control specification. As a contractually binding document, a Construction Noise Control Specification (Noise Spec) can become a vital compliance tool used by both project managers and construction contractors to comply with a reasonable and universally accepted set of noise control requirements. A Noise Spec should be drawn up at the beginning of a construction project by the EP.	***13***
18	Project Sponsors, Noise Technician / Acoustical Engineer	Monitor at least weekly	☐	**Is a compliance noise monitoring structure in place?** Construction noise levels must be monitored to ensure compliance with noise-sensitive lot-line and equipment emission noise limits contained in any Noise Spec. Long-term noise monitors should be deployed at noise-sensitive locations where noisy work is occurring, and a Noise Technician should be on staff to use a hand-held sound level meter to regularly patrol each construction area for quality control and compliance purposes.	***1, 3, 4, 5, 6, 7, 8 , 9, 10, 11, 12, 13***

19	Project Sponsors, Noise Technician / Acoustical Engineer	Daily activity	☐	**Has a telephone hotline been established?** A telephone hotline should be established by the Project so that the public may call 24 hours a day, 7 days a week, to lodge complaints in a carefully maintained Complaint Database about excessive noise or any other Project-related concern.	***1, 7***
20	Project Sponsors, Noise Technician / Acoustical Engineer, local DOT	Coordinate at least weekly	☐	**Is Project noise control staff coordinating fully with the local department of transportation (DOT)?** Project noise control staff should work closely and cooperatively in the field with the local DOT. An informal agreement between the Project and the DOT may allow the Project to police itself with respect to noise control, provided noise control mitigation is performed vigilantly and complaints are addressed.	***1, 2, 5, 6***
21	Project Sponsors, Noise Technician / Acoustical Engineer	Daily activity	☐	**Is a full-time Project Noise Technician on staff?** A Noise Technician / Acoustical Engineer should be employed throughout the peak construction phase to patrol the Project, particularly at night, in order to: (1) proactively anticipate and hopefully avoid noisy situations, and (2) respond immediately to any noise complaints received through the hotline. The Noise Technician is trained in sound level meter operation and in how to interpret and enforce the established Noise Spec.	***1, 2, 7, 13***
22	Project Sponsors, Noise Technician / Acoustical Engineer, Project Engineer, contractor	Update at least quarterly	☐	**Has a clear definition of reporting and responsibilities been established between contractors and the Project sponsors' engineer(s)?** Maintain a clear EPC Organizational Chart for the Project, with a flow of information (especially complaints) between each construction site's foremen, Project Engineer, management, local, state, and Federal agencies, Project Sponsors, and the Public clearly defined.	***2, 7***
23	Noise Technician / Acoustical Engineer, contractor	Monitor at least weekly	☐	**Are contractors and the Noise Technician aware of the noise limits of residential and commercial properties abutting work sites?** Noise criteria limits should be established in the Noise Spec at the property lines (lot-lines) of various sensitive locations defined by Project management stakeholders. The criteria should allow the contractor to produce up to 5 dBA more noise than existed prior to construction (defined through baseline L10 level measurements). Different noise limit allowances should apply for residential and commercial land-uses, and for daytime, evening, and nighttime periods. Limits written on maps of the construction area can serve the purpose of cataloguing this information.	***4, 8***

24	Noise Technician / Acoustical Engineer, Project Engineer, contractor	Monitor at least weekly	☐	**Are contractors taking steps to avoid generating noise from cumulative operations that exceed noise limits established by the Noise Spec at the construction area lot-lines?** At least weekly, the Noise Technician should go out into the field and measure noise levels at lot-lines with a sound level meter. While nighttime measurements will ensure compliance during the most sensitive hours (10 PM – 7 AM), measurements should be taken at other times of day as well. Noise levels should not exceed the limits listed in the Noise Spec.	***1, 4, 5, 6, 7, 13***
25	Noise Technician / Acoustical Engineer, Project Engineer, contractor	Monitor daily	☐	**Are equipment use restrictions being enforced?** Whenever possible, the use of certain types of impact[2] equipment should be avoided or restricted during noise-sensitive hours. For example, the use of pile drivers, jackhammers, hoe rams, and other impact devices should be prohibited at night, i.e., during the hours of 10 PM to 7 AM. If a contractor's construction schedule allows it, construction work at night should be restricted in certain noise-sensitive areas. These restrictions can go a long way in avoiding complaints, fines, delays, and lawsuits.	***5, 6, 7, 8, 13***
26	Noise Technician / Acoustical Engineer, Project Engineer, contractor	Request at least monthly	☐	**Is management keeping a fairly up-to-date inventory of the construction equipment being used on a construction site?** This inventory should include the noise emission limit (L_{max}) for each piece of equipment being used and some indication that noise emission limits of individual pieces of equipment that come onto a construction site are being monitored by the contractor. Periodically request this inventory from a construction area's Project Engineer on short notice.	***3***
27	Noise Technician / Acoustical Engineer, Project Engineer, contractor	Monitor daily	☐	**Are contractors avoiding nuisance noise?** Unnecessary, nuisance noise conditions should be avoided and/or noted by the Noise Technician, as described in the contractor's Noise Monitoring Plan.	***1, 7, 13***
28	Noise Technician / Acoustical Engineer, contractor	As required	☐	**Are contractors aware of the acoustical performance requirements and details for construction, maintenance, and removal, and unit bid prices for noise barriers, curtain systems, and noise tent enclosures?** Keep on file drawings and plans for noise barriers and curtain systems stamped by a professional engineer (PE) licensed in that state.	***7, 13, Mitigation Materials***

29	Noise Technician / Acoustical Engineer, Project Engineer, contractor	As required	☐	**Are Noise Barriers being utilized?** A project may use an abundance of temporary and semi-permanent noise barriers to mitigate construction noise. In all cases, the performance requirement of the barriers should provide at least a 5-dBA insertion loss. Applicable construction worksite noise barriers include: • Temporary barriers, which do not require anchoring, use plywood attached to chain link fence posts mounted on top of jersey barriers; • Semi-permanent barriers, erected along worksite boundaries and intended to be in active use for many years, usually abut noise-sensitive buildings and are typically about 24 ft tall and made of inter-locked wooden timbers with posts anchored in drilled concrete caissons; • Noise curtain material is typically ¼-inch-thick heavy vinyl with a sound absorptive quilt attached to one side, very flexible, secured to structures and fenceposts by Velcro and wire strapping, and easily moveable and reusable; typical curtains provide a 5-dBA insertion loss; and • Noise tents, typically three-sides and a roof made of noise curtain material attached to steel frames, are used to cover stationary noise sources such as pumps and generators and/or dynamic noise sources such as a jackhammer operator performing work in a sensitive area.	***7, Mitigation Materials***
30	Noise Technician / Acoustical Engineer, Project Engineer, contractor	As required	☐	**Are contractors aware of any guidelines intended to assist them in fulfilling their LM Noise Spec obligations?** Any assistance materials should be kept on file with both the Noise Technician / Acoustical Engineer and the Project Engineer.	***13, Actual guidelines***
31	Contractor, Noise Technician / Acoustical Engineer, Project Engineer	As required	☐	**Are alternative construction methods being considered and utilized on the job?** Alternative construction methods can often be quieter than the original method. For example, hydraulic "push piles" can be much quieter than impact or vibratory pile driving; hydraulic jacks or splitters can be much quieter than hoe rams; slurry walls to support excavation can be constructed much more quietly than can more traditional sheet pile or soldier pile walls; and steel beam structures can be demolished more quietly with torch cutters and cranes as opposed to metal saws and shears.	***5, 6, 7, 8, 13***

32	Noise Technician / Acoustical Engineer, Project Engineer	As required	☐	**Are vibration mitigation measures being addressed?** Vibration criteria limits to protect historic buildings can be found in Swiss Standard SN 640312a. Longer-term human vibration annoyance, such as that caused by an elevated roadway shifted onto temporary supports that allow traffic-induced vibration to more easily propagate through the ground to the neighborhoods, will require vibration mitigation. Vibration studies based on human annoyance criteria found in American National Standards Institute (ANSI) standard S3.29 have concluded that contractors may be held responsible for unacceptable traffic vibration levels.	***5, 6, 7, Mitigation Materials***
33	Project Engineer	As required	☐	**Have historic buildings been equipped with vibration isolation options?** Provide vibration isolation options for caretakers of historic buildings to use in buffering any Project-related vibration. Management stakeholders should be ready to support this assistance when it is called for.	***1, 7,Mitigation Materials***
34	Contractor, Project Engineer	Daily activity	☐	**Are hauling trucks being lined with soil for sound absorption?** For any kind of hauling truck, lining the truck carrying case with ¾ cubic yard of soil can produce a 5-dBA reduction in noise from the movement of the truck over rough ground.	***5, 6, 7, 8***
35	Noise Technician / Acoustical Engineer, Project Engineer, contractor	Take inventory at least monthly	☐	**Is a quieter-type backup alarm being used?** Standard backup alarms create a loud and annoying noise to warn people that a vehicle is backing up. However, they are also a leading source of noise complaints. The Project may mandate that only quieter-type manually adjustable or automatically adjustable backup alarms can be used in construction areas, and contractors should be prepared to install them on all vehicles. These alarms are about 20 dB quieter than standard alarms yet can still be heard behind the vehicles. In some very noise-sensitive neighborhoods, the Project may prohibit the use of audible backup alarms of any kind at night: Doing so is acceptable to the Occupational Safety and Health Administration (OSHA) as long as an observer is present to direct the vehicle's rearward movements. ***Any deviation from standard backup alarms should take into account personal safety over noise mitigation.***	***3, 5, 6, 7, 8***

36	Noise Technician / Acoustical Engineer, Project Engineer, contractor	Take inventory at least monthly	☐	**Are auxiliary mufflers being utilized?** In order to better control exhaust noise, the Project may require the use of auxiliary mufflers or silencers on devices such as jackhammers. Larger silencers may also be fitted to equipment such as vacuum excavators to reduce low frequency noise from the Roots blower. Equipment that has been fitted with an auxiliary muffler should be labeled with a special sticker and documented in the construction equipment inventory. This will make it easier for monitors to see whether a given piece of equipment has been considered for noise reduction action.	***3, 5, 6, 7, 8***
37	Noise Technician / Acoustical Engineer	As required	☐	**Is an acoustical window treatment program in place?** An acoustical window treatment program implemented by the Project may prove to be one of the best noise mitigation measures in terms of providing cost-effective noise relief directly to the receptors that need it the most. When certain eligibility criteria are met, the Project should provide for new acoustical windows or internal window sashes for bedroom windows.	***7, Mitigation Materials***
38	Noise Technician / Acoustical Engineer	As required	☐	**Is temporary relocation of noise-sensitive receptors / people an option?** On rare occasions, the Project may provide for the temporary relocation of residents to hotels for a couple of days and nights so that particularly loud work can proceed.	***7, Mitigation Materials***

TRAFFIC AND CIRCULATION

Meeting the requirements laid out in the following traffic and circulation control checklist will help meet the suggested EPCs and mitigate traffic impacts in each construction.

Item No.	Responsible Parties	Frequency Checked	Currently Checked?	Checklist Item	Associated Worksheet(s)
39	Project Sponsors, local DOT	Daily activity	☐	**Are Project sponsors communicating with the Public about traffic and circulation EPCs?** The benefits of reducing complaints about traffic and circulation cannot be stressed enough: Any success toward this goal will save the Project sponsors and local DOT time, money, bad publicity, and Public frustration.	***1, 2***
40	Project Sponsors, Traffic Mitigation Manager, local DOT	As required	☐	**Is community notification and outreach being maintained?** Community liaisons working directly for the Project should notify area businesses and residents of upcoming potential construction impacts through the use of newspaper announcements, regularly scheduled (monthly) community meetings, and a Project webpage. The liaisons will, in many cases, be able to appease the public's concerns through some form of compromise solution. The telephone hotline already established for noise complaints and staffed 24 hours a day, 7 days a week by an operator, can also field questions and complaints from the Public about traffic congestion. A complaint database should be kept to aid in developing better plans to minimize traffic congestion.	***1, 2***
41	Project Sponsors, Traffic Mitigation Manager, local DOT	Meetings at least quarterly	☐	**Are neighborhood groups involved?** It is essential for traffic plans, detours, and mitigation options to be presented to the affected public. Public groups can be pre-existing associations, newly formed groups, or virtual groups reachable via email or webpage announcements.	***1, 2***
42	Project Sponsors, local DOT	Meetings at least quarterly	☐	**Has an Environmental Panel been formed?** In order to more quickly and efficiently evaluate growing traffic and circulation and safety challenges, management stakeholders should form an EP consisting of construction contractor management, management stakeholders such as the Project sponsors and the local DOT. Before construction begins, the EP should draw up any traffic and circulation control specifications for the Project and determine the inspection and monitoring programs and their manpower requirements.	***1, 2, 20***
43	Project Sponsors, Chamber of Commerce	Meetings at least quarterly	☐	**Has a Project Business Committee been established?** Under the auspices of the Project Sponsors and the local Chamber of Commerce, a Project Business Committee (PBC) may act as a watchdog group and facilitate contact between the Project and local businesses. The goal of the PBC should be to ensure that negative impacts on abutting businesses during construction be kept to a minimum.	***1, 2***
44	Traffic Mitigation Manager, local DOT	Daily activity	☐	**Is a Traffic Mitigation Manager on staff?** From the outset of the Project, a designated Traffic Mitigation Manager, speaking for the local DOT, should have approval authority over roadway occupation requests.	***1, 2, 20***

45	Traffic Mitigation Manager, local DOT	Daily activity		**Is adequate traffic surveillance in place?** Surveillance of traffic conditions from the Project operations center will aid monitoring and facilitate response to traffic incidents. The installation of controllable closed-circuit cameras at strategic points on buildings, bridges, and in tunnels to monitor traffic flow will serve this purpose.	***1, 17, 18, 19, 20***
46	Traffic Mitigation Manager, local DOT	As required	☐	**Are police details being used to control traffic?** Traffic police details may be used to control traffic at work site driveways, major pedestrian crosswalks, and locations where vehicular capacity has been temporarily reduced. However, traffic maintenance measures that rely solely on police details should be avoided. The local DOT should be consulted in the procurement and assignment of police officers.	***17, 18, 20***
47	Traffic Mitigation Manager, local DOT, Project Engineer	As required	☐	**Is a Maintenance and Protection of Traffic (MPT) Plan in place?** When a public way is to be occupied for construction work, the contractor should be required to prepare a plan stating the nature of the work, type and times of roadway occupation, and associated drawings stamped by a traffic engineer.	***17, 18, 20***

48	Traffic Mitigation Manager, local DOT, Project Engineer	As required	☐	**If a Maintenance and Protection of Traffic Plan is in place, are the following criteria included in the program?** • Account for alternative pedestrian access. Pedestrian detours must be detailed on engineered, stamped drawings. Continuous pedestrian access is required to buildings abutting work zones, and the Chamber of Commerce will be anxious to see that reasonable access is accounted for in any MPT Plan. • Post warning signs for pedestrians regarding changes in street vehicular traffic direction. Pedestrians must know to look for oncoming traffic in directions other than that which they were accustomed to, or they could walk into oncoming traffic. Local DOT should take the lead on this process and have the final say on any posting of signs. • Post signs directing pedestrians to public and private attractions whose normal entrances may have been disrupted. These should especially be placed along the more complicated pedestrian detour routes. • Post signs directing pedestrians to places of businesses whose normal entrances may have been disrupted. These should especially be placed where local deliveries and client access are called for on a 24-hour basis. • Lower speeds on the surrounding roadway. If necessary, slow down traffic by posting clear speed limit signs and restrict the number of driving lanes by laying clear, reflective roadway lines. The local DOT should take the lead on any area speed limit actions and enforcement. • Smooth the roadway surface. Smooth the roadway's surface to reduce noise and vibration. • Make special accommodations for handicapped pedestrian access, where necessary. Project sponsors and local DOT should all be involved in this highly visible and highly sensitive process.	***17, 18, 20***
49	Project Milestone Manager, Traffic Mitigation Manager, local DOT, Project Engineer	Daily activity	☐	**Is construction work being coordinated intelligently?** Scheduling multiple construction projects in restricted areas will require that the local DOT coordinate between the Project and other construction activity in the area. A Project milestone manager should communicate regularly with a DOT counterpart and coordinate among Project contractors to prioritize who will proceed and who will stand down in case of conflicts. This will prevent serious traffic congestion.	***17, 18, 20***

50	Traffic Mitigation Manager, local DOT, mass transit, Project Engineer	As required	☐	**Is everything possible being done to avoid interference with mass transit?** Elaborate construction methods should be developed to avoid restricting mass transit capacity, including buses, subways, and trains. Where construction is identified as affecting mass transit corridors, transit enhancements such as additional vehicles (buses) and new water transit routes may be provided. These measures should help to avoid vehicular traffic congestion. Consult with the local DOT and mass transit when considering alternative transit enhancements.	***17, 18, 20***
51	Traffic Mitigation Manager, local DOT, Project Engineer, contractor	As required	☐	**Have alternative truck routes been mapped out?** Truck routes for delivery of construction materials to work sites and removal of excavate from sites must be mandated by contract specification in order to minimize impacts to the public traffic flow. The local DOT should take the lead on this process and have the final say on any approved routes.	***17, 18, 20***

NOTE TO MANAGEMENT: This information is just the start of building a successful construction mitigation program. Many other challenges will confront Project management stakeholders before construction work even commences, including: (1) Writing comprehensive construction impact control specifications (noise, dust, and traffic control specs) for the contractors to follow; (2) Setting up a meaningful quality assurance and contractor compliance monitoring program; and (3) Explaining clearly and often to local authorities, contractors, news media, businesses, and, most importantly, the affected Public, the rationale for taking these sometimes burdensome steps toward construction impact mitigation. This Checklist is an evolving document and should be updated as necessary.

Worksheets

The 20 worksheets provided below (the Worksheets) are a companion to the above Checklists. The use of these worksheets in conjunction with the Checklists will allow the Project's management stakeholders and construction contractors to implement the Checklist items more efficiently and ultimately mitigate the noise, air quality, and traffic and circulation impacts caused by Project construction activities in any construction area. The worksheets are grouped into General, Noise, Air Quality, and Traffic and Circulation sections. In addition, two appendices provide background material on the worksheets: Appendix A gives definitions of technical terms used throughout the Checklist and Worksheets, and Appendix B offers construction noise and vibration impact mitigation material.

WORKSHEET #	WORKSHEET NAME
1	Complaint Database
2	Project EPC Organizational Chart
3	Construction Equipment Inventory
4	Lot-line Map Guidance
5	Inspection Report
6	Deficiency Report
7	Noise Monitoring Plan Worksheet
8	Noise Control Plan
9	Sound Level Meter Guidance
10	Noise Level Calculations Guidance
11	Noise Measurements Report Form
12	Application for Certificate of Equipment Noise Compliance
13	Construction Noise Control Specification
14	Air Quality Monitoring Plan Worksheet
15	PM10 Information Page
16	Construction Air Quality and Dust Control Specification
17	Maintenance and Protection of Traffic Plan
18	Traffic and Circulation Monitoring Plan Worksheet
19	New York City Department of Transportation Advanced Traveler Information System
20	Construction Traffic and Circulation Control Specification

GENERAL

Of the worksheets supplied below, several apply across several areas of construction impact, i.e., noise, air quality, and traffic and circulation.

The Complaint Database (Worksheet 1) is designed to track a variety of complaints to the Project Hotline from the time they are called in until the time when a solution to the complaint is found. If a Project Hotline has not already been established by Project management stakeholders, a partnership may be established for hotline calls to be placed with an existing 24-hour operator at the local DOT, or a separate telephone call-in line may be established by the Project with the help of a telephone company.

The Project EPC Organizational Chart (Worksheet 2) proposes a rough management structure for EPC progress review and management. The entities involved in this organizational chart would be tasked with keeping the Project noise and air quality specifications up to date and informing contractors, local agencies, local businesses, Federal sponsors, and the Public of all efforts being made to mitigate construction impacts in the construction area.

The Construction Equipment Inventory (Worksheet 3) is designed to keep track of what equipment is present in a construction area and monitor what steps are being taken to assure it meets all noise and air quality requirements.

The Lot-Line Map Guidance (Worksheet 4) offers a clear representation of the lot-lines of the various construction areas. Construction contractors and Project management stakeholders should be well aware of noise limits at these lot-lines of the various construction areas and regularly monitor these perimeters for excessive noise, particularly in the vicinity of sensitive noise receptors such as parks, office buildings, and residences. Tracking air quality at these lot-lines will also help avoid complaints on construction-related dust.

The Inspection Report (Worksheet 5) is a tool through which those closest to a construction area's daily business, i.e., Project Engineers and Project Foremen, can regularly document EPC progress, trouble spots, and requirements.

The Deficiency Report (Worksheet 6) is, in effect, an internal complaint mechanism through which engineers and inspectors can highlight, analyze, and mitigate potentially dangerous or annoying situations in a construction area before the deficiency has a chance to disturb the Public.

The technical terms used in these worksheets are defined in Appendix A, Definitions.

WORKSHEET 1

Complaint Database

While the implementation of the EPCs in the Project has many goals, including safeguarding the environment, safeguarding the public, and minimizing the impact of construction on the economy of the construction area, a major goal for both Project management stakeholders and contractors is avoiding complaints. However, even successful implementation of the EPCs will not avoid some complaints, and an infrastructure must be in place to receive those complaints in an efficient and productive way.

If a Project Hotline has not already been established by Project management stakeholders to receive complaints, a partnership may be established for hotline calls to be placed with an existing 24-hour operator at the local DOT, or a separate telephone call-in line may be established by the Project with the help of a telephone company.

Once a hotline has been established to receive complaints, those complaints must be disseminated to Project management stakeholders for quick resolution. Worksheet 1 has been developed to allow management and contractors to track, resolve, and utilize complaints to improve relations with the Public and further advance the implementation of the EPCs. The technical terms used in this worksheet are defined in Appendix A, Definitions.

The Complaint Database worksheet follows a complaint from the moment it is called in to the Project hotline until its analysis and resolution. It includes entries for call information, annoyance information, complainant information, and management solution information. A detailed upkeep of this database will greatly improve the Project's relationship with the Public and eliminate annoyances from the vicinity of a construction area, avoiding the delay and expense of litigation.

A blank worksheet is attached below.

Complaint Database

HOTLINE NUMBER:	
Sheet Number:	
Date Sheet Created (MM/DD/YY):	
Created by:	

PAGE ___ OF ___

CALL INFORMATION					ANNOYANCE INFORMATION					COMPLAINANT INFORMATION		MANAGEMENT		
Entry No.	Date (MM/DD/YY)	Time (HH:MM, AM/PM)	Name of hotline operator	Type of call (CP = Complaint; CM = Comment; S = Suggestion; O = Other)	If Complaint, type of annoyance (N = Noise; V = Vibration; A = Air Quality; T = Traffic; O = Other)	Location of annoyance / comment	If complaint, date of annoyance (MM/DD/YY)	If complaint, time of annoyance (HH:MM, AM/PM)	Description of annoyance / comment	Name of complainant / commentor	Telephone number of complainant / commentor	If complaint, project policy addressing complaint	Description of annoyance mitigation / action	Management / Contractor personnel
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

WORKSHEET 2

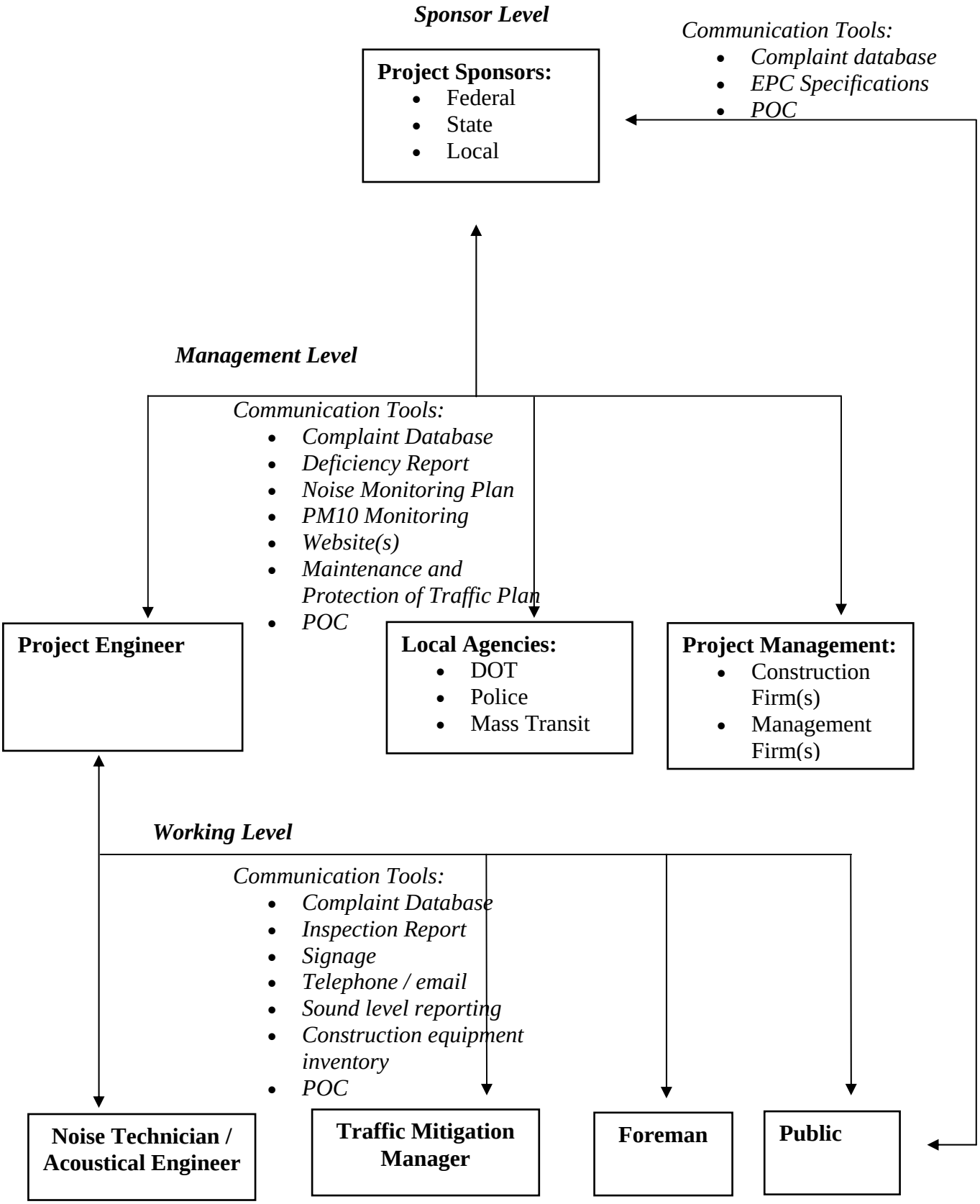
Project Environmental Performance Commitment Organizational Chart

This worksheet provides an organizational chart of EPC progress review and management. More detail may be included to identify the various EPC Points of Contact (POC) at every level on the chart. To the POC dedicated to mitigating the impacts of construction on the community, the Complaint Database is a very useful tool for gauging and improving upon EPC effectiveness.

At the **working level** within a construction project, the Noise Technician / Acoustical Engineer reports noise conditions in a construction work area to the Project Engineer through email and various noise measurement documents; the Traffic Mitigation Manager informs the Public of traffic congestion through signage; project foremen and inspectors report to the Project Engineer through Inspection Reports and the Construction Equipment Inventory; and the Public and/or local businesses complain to the Project Engineer through the Complaint Database and/or email.

At the **management level** within a construction project, the Project Engineer reports noise, dust, and traffic conditions in a construction area to the Federal sponsors through various Noise Monitoring Plan-related forms and reports; local agencies such as the local DOT review Maintenance and Protection of Traffic Plans (including signage proposals and police involvement), Deficiency Reports, PM10 monitoring, post information to Project websites, and, if necessary, respond to Complaint Database information and resolve issues with the approval of the Project sponsors; and local project management facilities monitor all of the above, especially any Complaint Database information, and report EPC progress to the Project sponsors.

At the **sponsor level** within a construction project, the Project sponsors monitor EPC progress, particularly progress made in minimizing complaints from the Public, and work to establish clear specifications for control of noise, dust, and traffic impacts, for use by Project Engineers, local agencies, project management stakeholders, and contractors.


Sponsor Level
Communication Tools:
Complaint database
EPC Specifications
POC
Project Sponsors:
Federal
State
Local
Management Level
Communication Tools:
Complaint Database
Deficiency Report
Noise Monitoring Plan
PM10 Monitoring
Website(s)
Maintenance and Protection of Traffic Plan
POC
Project Engineer
Local Agencies:
DOT
Police
Mass Transit
Project Management:
Construction Firm(s)
Management Firm(s)
Working Level
Communication Tools:
Complaint Database
Inspection Report
Signage
Telephone / email
Sound level reporting
Construction equipment inventory
POC
Noise Technician / Acoustical Engineer
Traffic Mitigation Manager
Foreman
Public

WORKSHEET 3

Construction Equipment Inventory

The Construction Equipment Inventory is designed to keep track of what equipment is present in a construction area and monitor what steps are being taken to assure it meets all noise and air quality impact mitigation requirements. For example, a particular piece of equipment's noise limit should be listed along with the actual measured noise of the piece of equipment; any noise limit exceedance by a given piece of equipment should result in a plan to replace that piece of equipment or a good explanation for not doing so. Also, any noise or air quality impact mitigation equipment, i.e., mufflers, diesel particulate filters, ultra-low sulfur diesel fuel, and/or quieter-type backup alarms, should be noted in the Construction Equipment Inventory. The technical terms used in this worksheet are defined in Appendix A, Definitions.

This inventory should be updated at least once a week by the contractor and turned in to the EPC POC at least monthly.

A blank inventory is attached below.

Construction Equipment Inventory

Work Site:

Date Inventory Created (MM/DD/YY):

Date Inventory Updated (MM/DD/YY):

Updated by:

PAGE ____ OF ____

								NOISE							AIR QUALITY			LABELING
Entry No.	Equipment	Model No.	Serial No.	Manufacturer	Date Manufactured (MM/DD/YY)	Date Arrived Onsite (MM/DD/YY)	Date Last Inspected (MM/DD/YY)	Impact Device?* (Y/N)	Usage Factor (% of Time in Use), in %	50-ft Lmax Noise Emission Limit (dBA)	Actual 50-ft Lmax Noise Emission (dBA)	Date Last Measured for Noise Emissions (MM/DD/YY)	Fitted with quieter-type backup alarm? (Y/N)	Fitted with auxiliary muffler? (Y/N)	Type of Fuel Used (Diesel, ULSD, gasoline, electricity)	Fitted with Diesel Particulate Filter? (Y/N; NA if not diesel fuel)	Fitted with Diesel Oxidation Catalyst? (Y/N; NA if not diesel fuel)	If the equipment has been retrofitted with DPF, DOC, quieter-type backup alarm, and/or auxiliary muffler, and/or is currently running on Ultra-Low Sulfur Diesel fuel, is it clearly labeled as such? (Y/N)
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		

* Impact equipment generates impulsive noise. Impulse noise is defined as noise produced by the periodic impact of a mass on a surface, of short duration (generally less than one second), high intensity, abrupt onset and rapid decay, and often rapidly changing spectral composition. By contrast, non-impact equipment generates a constant noise level while in operation.

WORKSHEET 4

Lot-line Map Guidance

Construction contractors and Project management stakeholders should be well aware of noise limits at the lot-lines of the various construction areas and regularly monitor these perimeters for excessive noise, particularly in the vicinity of sensitive noise receptors such as parks, office buildings, and residences, all of which can also be sensitive to construction-related noise. The technical terms used in this worksheet are defined in Appendix A, Definitions.

This worksheet functions best when fitted with a map of the construction site to be monitored, clearly labeled with lot-lines and recommended noise measurement locations. The worksheet also includes a noise level table designed to allow a construction area's Acoustics Engineer to list the noise limits at an area's lot lines and periodically conduct noise measurements to assure that area's noise emissions are not exceeding the lot-line limits. Space is provided for the Lmax, Leq, and L10 noise identifiers. A trained SLM operator can measure this noise data efficiently and inexpensively (see Worksheet 9, Sound Level Meter Guidance): Lmax is the maximum measured sound level at any instant in time; Leq is the equivalent sound level, or the continuous sound level that represents the same sound energy as the varying sound levels, over a specified monitoring period; and L10 is the sound level exceeded 10% of the time for a specified monitoring period. The duration of each measurement is required to be a minimum of 20 minutes, and a minimum of 10 measurements, arithmetically averaged together, are required. Meeting these requirements will define the background noise level at a given location prior to construction noise level measurement and the construction noise level at that same location during optimum construction activity. See Worksheet 10, Noise Level Calculations Guidance, below and in the EPC Tools Download, for guidance in arithmetically averaging sound levels and calculating actual sound level data for entry into Worksheet 11, Noise Measurements Report Form, Worksheet 8, Noise Control Plan, and Worksheet 12, Application for Certificate of Equipment Noise Compliance.

Each table also includes a column for PM10 level, a metric designed to describe the density of dust particles in the air. This metric is useful in gauging the impact of construction dust in an air quality sensitive area.

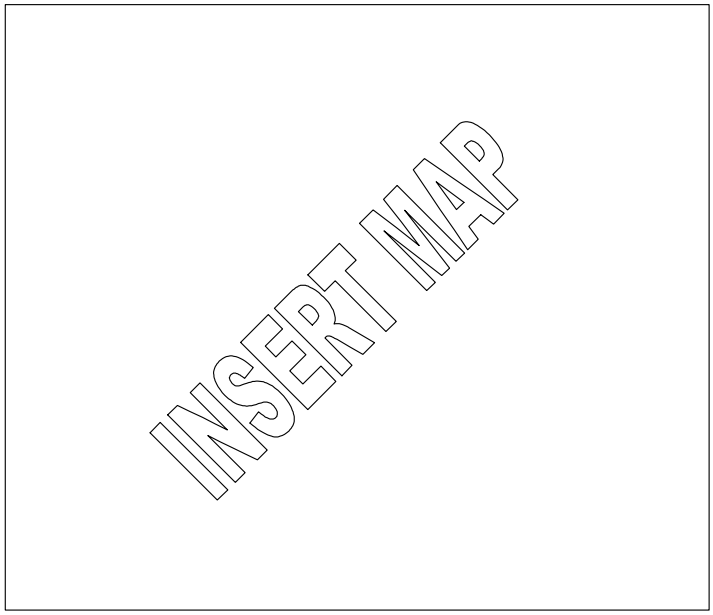
A blank map is attached below.

Construction Area Lot-Line Map

LEGEND

- **#** — **Noise Receptor Location**
- **A** — **Lot-Line Measurement Locations**
- **Category 1 Use**[1]
- **Category 2 Use**[2]
- **Category 3 Use**[3]

[1]Tracts of land where quiet is an essential element in the intended purpose.
[2]Residences and buildings where people normally sleep.
[3]Institutional land uses with primarily daytime and evening use.



Contractor:_____
Receptor Location:_____ **(circle on map above, if applicable)**
Location Sketch Type (circle one): Map Above Attached Sketch
Type of Measurement (circle one): Background Noise Construction Noise
Land Use (circle one): Residential Business/Recreational Industrial

				Noise Limit (if Construction Noise), in dBA			Measured Noise, in dBA			Measured Air Quality, in µg/m^3
Meas. No. (minimum 10)	**Meas. Date (MM/DD/YYYY)**	**Meas. Duration (HH:MM:SS)**	**Time of Day (HH:MM)**	**Lmax***	**Leq****	**L10*****	**Lmax**	**Leq**	**L10**	**PM10********
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
AVERAGE										

*Lmax = The maximum measured sound level at any instant in time.
**Leq = The equivalent sound level, or the continuous sound level that represents the same sound energy as the varying sound levels, over a specified monitoring period (minimum 20 minutes).
***L10 = The sound level exceeded 10% of the time for a specified monitoring period (minimum 20 minutes).
****PM10 = Dust particles smaller than 0.00001 meters in diameter.

WORKSHEET 5

Inspection Report

Those closest to a construction area's daily activities, i.e., Project Engineers and Foremen, should regularly document EPC progress, trouble spots, and outstanding requirements on a construction site in the Inspection Report. The technical terms used in this worksheet are defined in Appendix A, Definitions.

An inspection should be made of the construction area at least once a week, resulting in a weekly Inspection Report to the EPC POC.

A blank Inspection Report is attached below.

Field Engineer's Daily Report

Contract Name: _____ Shift: _____ Contract Day No.: _____
Contract No: _____ Job Area: _____ Day of Week: _____
Contractor: _____ Weather (°F): AM_____PM_____

Activity No. / Pay Item No.	Description of Work (Type of Work, Location, Quantities, Testing, Etc.)	Accep Y/N	Photo Y/N
Unusual Events:	☐ Accident (A) ☐ Delay (D) ☐ Instruction to Contractor (IC)	☐ Deficiency (DR) ☐ Visitor (V) ☐ Other: _____	

Reported By: _____ Date: _____
Page: ____ OF ____
Reviewed By: _____ Report No.: _____
Signature Report: _____

EPC WORKSHEET 5 printed: 6/22/2006

WORKSHEET 6

Deficiency Report

Those construction area personnel making weekly Inspection Reports, i.e., Project Engineers and Foremen, will regularly come across deficiencies in safety and construction noise, air quality, and traffic and circulation impact mitigation that may cause an adverse effect on the site or even the Public. Prompt action in the case of a deficiency is expected, but if a solution is not found for a deficiency, a Deficiency Report may be issued by the EPC POC. A Deficiency Report may result in punitive action or even litigation if not resolved in a timely manner. The technical terms used in this worksheet are defined in Appendix A, Definitions.

A blank Deficiency Report is attached below.

Deficiency Report

Contract No.: _____ **Contract Name:** _____
Date of Deficiency: _____ **Deficiency Report No.:** _____
Date Issued: _____ **Field Engineer:** _____

To:	**Discussed With:**	
Spec. Sections:	**Submittal No.:**	
Sched. Act. No.:	**Pay Item No.:**	
Requirement:		
Deficiency:		
Recommended Action:	**Response Due Date:**	
	RESIDENT ENGINEER	DATE
Corrective Action Taken:	**Forecast Complete Date:**	
CONTRACTOR QC MANAGER OR APPROPRIATE CONTRACTOR REPRESENTATIVE		DATE
DESIGN CHANGE: YES NO	PROJECT ENGINEER	DATE
Corrective Action Verified:	**Actual Complete Date:**	
	RESIDENT ENGINEER	DATE

EPC WORKSHEET 6 printed: 6/22/2006

NOISE

The following seven worksheets apply to the contractor's formal noise mitigation strategy, the Noise Monitoring Plan. This material is presented in three different sections: A Plan section, which offers the user tips on how to best prepare ahead of time for EPC implementation; the Guidance section, which offers tips on how to implement the EPCs in a timely and efficient manner; and the Specification section, which offers tips on how to assure that contractors, Project management stakeholders, and all other parties are following uniform protocols and aware of critical requirements that are subject to enforcement.

ADDITIONAL RESOURCES: Guidance on nearly every technical requirement of this Noise section, including receptor location selection, in-depth discussion of noise level metrics, and noise level measurements, is presented in the Federal Highway Administration (FHWA) Highway Construction Noise Handbook[1]. This document provides extensive information compiled on construction noise criteria and metrics, the effects, measurement, prediction, and mitigation of construction noise, and Public involvement in construction noise issues.

Noise Monitoring Plans

Each construction area should have a Noise Monitoring Plan in place, complete with each of the components described below, before work begins. The structure, requirements, and reporting mechanism of the Noise Monitoring Plan should be clear to the contractor and the management stakeholders at an early stage in the planning of construction activity, and the Noise Monitoring Plan should be updated every six months and forwarded to the EPC POC. In doing so, the contractor should address the following Noise Monitoring Plan components:

- Noise Monitoring Plan Worksheet (see Worksheet 7 below)
- Noise Control Plan (see Worksheet 8 below)

[1] "FHWA Highway Construction Noise Handbook". Federal Highway Administration. FHWA Report No. FHWA-HEP-06-015. Washington, DC. July 2006.

WORKSHEET 7

Noise Monitoring Plan Worksheet

The Noise Monitoring Plan Worksheet describes the noise monitoring and reporting procedure to be used during construction. This worksheet will be completed and signed by the construction area's Acoustical Engineer and will be submitted to the EPC POC prior to construction for review, and for acceptance and every six months after that. Noise generating equipment will not be operated prior to acceptance of all components of the Noise Monitoring Plan. The technical terms used in this worksheet are defined in Appendix A, Definitions.

All aspects of the Noise Monitoring Plan, particularly those items requiring contractor noise monitoring, reporting, and mitigation, should be documented in a Construction Noise Control Specification (Noise Spec), described below in Worksheet 13.

Again, guidance on nearly every technical requirement of the Noise Monitoring Plan, including receptor location selection, background noise, in-depth discussion of noise level metrics, and noise level measurements, is presented in the Federal Highway Administration (FHWA) Highway Construction Noise Handbook[1].

The Noise Monitoring Plan Worksheet requires completion of the following items, to be checked off as they are completed by the Acoustical Engineer:

Check Off

☐ Receptor locations where noise monitoring will be performed (see Worksheet 4 above, Lot-Line Map Guidance):

- Include all locations identified as appropriate to effectively monitor noise conditions during construction (receptor locations);
- Include sketches of all locations;
- Include the distance of the noise measurement location in relationship to the noise source, i.e., construction equipment;
- Include background noise readings at all the receptor locations identified;
- Background noise measurements, in dBA, slow, will be collected for at least 24 hours over two non-consecutive days Monday through Saturday and one Sunday at noise monitoring receptor locations prior to the start of construction[2];
- Background noise measurements should be performed in the absence of any contributing construction noise for each of the noise monitoring receptor locations;
- At least 10 background noise L10 levels will be arithmetically averaged into single L10 levels defining the background noise for daytime (7AM – 6PM), evening (6PM – 10PM), and nighttime (10PM – 7AM) time frames, respectively (see Worksheet 10, Noise Level Calculations Guidance, in Worksheet CD-ROM Tools directory); and
- At least 10 construction noise Lmax, Leq, and L10 levels will be arithmetically averaged into single Lmax, Leq, and L10 levels defining construction noise in the daytime (7AM – 6PM), evening (6PM – 10PM), and nighttime (10PM – 7AM) time

frames, respectively (see Worksheet 10, Noise Level Calculations Guidance, in Worksheet CD-ROM Tools directory,).

☐ The type of noise level measurement device that will be used (see Worksheet 9 below, Sound Level Meter Guidance):

- The SLM and the acoustic calibrator will be calibrated and certified annually by the manufacturer or other independent certified acoustical laboratory;
- The SLM will be field calibrated using an acoustic calibrator, according to the manufacturer's specifications, prior to and after each measurement;
- All measurements will be performed using the A-weighting network and the "slow" response of the SLM;
- The measurement microphone will be fitted with an appropriate windscreen, will be located 5 ft above the ground, and will be at least 5 ft away from the nearest hard surface; and
- Noise monitoring will not be performed during precipitation (rain) or when wind speeds are greater than 15 mph, unless the microphone is protected in such a manner as to negate the acoustic effects of rain and high winds.

☐ Background and construction noise data will be recorded in the Noise Measurements Report Form (see Worksheet 11, Noise Measurements Report Form, below):

- The type of measurement will be noted (background or construction noise);
- 24-hour noise measurements will be plotted graphically showing L10 and Lmax noise levels vs. time along with appropriate lot-line criteria limits for daytime, evening, and nighttime periods;
- Provide a sketch or diagram for the exact location of the noise measurements on the back of the Noise Measurements Report Form (attach Worksheet 4, Lot-Line Map Guidance). Include the location and distance of the noise measurement in relationship to the noise monitoring location;
- During construction and complaint response monitoring, all construction equipment operating during the monitoring period will be identified (use Worksheet 3, Construction Equipment Inventory) and the location sketched on the back of the Noise Measurements Report Form (attach Worksheet 4, Lot-Line Map Guidance). The sketch will include the distance between the noise measurement location and the construction equipment;
- All activities occurring while performing noise measurements will be noted in the "Field Notes" area of the Noise Measurements Report Form (Worksheet 11); and
- Any noise level of 85 dBA or greater requires an explanation.

☐ The noise monitoring methods and procedures to be used:

- Background noise will be collected as described above. A minimum of ten L10 measurements will be arithmetically averaged to determine a defining background noise level;
- Construction noise level measurements will be taken at each noise-sensitive receptor location during ongoing construction activities at least once each week during the applicable daytime, evening, and nighttime period; all other noise monitoring locations will be measured at least once each week during the daytime period. A

minimum of 10 Lmax, Leq, and L10 measurements will be arithmetically averaged to determine a defining construction noise level;

- The time period for each noise measurement will be 20 minutes;
- Construction noise measurements will coincide with daytime, evening, and nighttime periods of maximum noise-generating construction activity, and will be performed during the construction phase or activity that has the greatest potential to exceed noise level limitations;
- Daytime, evening, and nighttime construction noise levels at noise-sensitive locations and other noise monitoring locations will not exceed the lot-line noise limits;
- The lot-line criteria will apply to all points on a given lot-line of an affected receptor;
- Acceptable Lmax, Leq, and L10 values must be measured at a distance of 50 ft, and the percent of time in a day a noise condition exists must be accounted for. Since field measurement locations with an SLM may not always occur exactly 50 ft from a noise source, and not all noise sources are in use 100% of the time, calculations must be performed according to the steps in Worksheet 10, Noise Level Calculations Guidance, to take into account measurement distance and usage variations and predict lot-line construction noise during applicable daytime, evening, and nighttime periods.
- Equipment and associated equipment operating under full load will not exceed the Lmax noise limits;
- The 50-ft noise emission limits will apply to the entire operation in which the equipment is engaged;
- A distinction must be made whether a piece of equipment emits impact noise or continuous noise (impact equipment such as a pile driver generates impulse noise). Impulse noise is defined as noise produced by the periodic impact of a mass on a surface, of short duration (generally less than one second), high intensity, abrupt onset and rapid decay, and often rapidly changing spectral composition. By contrast, non-impact equipment generates a constant noise level while in operation (such as a diesel generator);
- The Contractor will update the Noise Monitoring Plan every six months;
- The Contractor will complete a new Noise Control Plan (see Worksheet 8 below, Noise Control Plan) with each updated Noise Monitoring Plan;
- The Contractor will complete an Application for Certificate of Equipment Noise Compliance (see Worksheet 12 below) for each piece of equipment on a site;
- Work performed by the Contractor in the absence of an approved Noise Monitoring Plan, Noise Measurements Report Form, Noise Control Plan, and completed Application(s) for Certificate of Equipment Noise Compliance, will be done solely at the discretion of the EPC POC. Any work stoppages ordered by the POC as a result of noise that violates specified conditions will not be grounds for compensation or claims from the Contractor;
- In the event that a lot-line or equipment noise level exceeds the established noise limits, the response procedure may include, but not be limited to, use of the following noise reduction materials and equipment:
    - New or used materials of a quality and condition to perform their designed function;
    - Shields, shrouds, or intake and exhaust mufflers;

- Noise-deadening material to line hoppers, conveyor transfer points, storage bins, or chutes;
- Temporary noise barriers (see Appendix B, Noise Barrier Photographs);
- Noise curtains (see Appendix B, Noise Barrier Photographs);
- All equipment with backup alarms operated by the Contractor, vendors, suppliers, and subcontractors on the construction site will be equipped with either audible self-adjusting ambient-sensitive backup alarms or manually-adjusting alarms;
- All equipment used on the constructions site, including jackhammers and pavement breakers, will have exhaust systems and mufflers that have been recommended by the manufacturer as having the lowest associated noise; and
- The local power grid will be used whenever feasible to limit generator noise.

☐ Adherence to the specified complaint procedure (see Worksheet 1, Complaint Database):

- Ensure that public and agency complaints are addressed and resolved consistently and expeditiously;
- If the Contractor receives a complaint regarding construction noise, the Contractor will immediately notify the EPC POC;
- Upon receipt or notification of a noise complaint from the EPC POC, the Contractor shall promptly perform noise measurements at the complainant's location during activities representative of the offending operation;
- The noise measurements will be performed using equipment and methods documented and approved in the Noise Monitoring Plan;
- The complaint noise response noise measurements will be immediately submitted to the EPC POC; and
- In the event the measured noise level exceeds allowable limits, or is resulting in nuisance conditions, the Contractor will immediately use noise reduction materials and methods such as those documented and approved in this Noise Monitoring Plan and described in Appendix B to reduce noise levels or to alleviate the nuisance conditions.

WORKSHEET 8

Noise Control Plan

The Noise Control Plan below documents expected noise levels versus noise level limits for a construction area. The Noise Control Plan requires the Acoustical Engineer to describe noise abatement measures in the event that expected noise levels exceed noise level limits. Each piece of equipment in a construction area will be documented in a Noise Control Plan, in close coordination with Worksheet 3, the Construction Equipment Inventory, and will be submitted by the construction area's Acoustical Engineer to the EPC POC prior to construction for review and acceptance and every six months after that. Noise generating equipment will not be operated prior to acceptance of the Noise Control Plan and the Noise Monitoring Plan. The technical terms used in this worksheet are defined in Appendix A, Definitions.

A blank Noise Control Plan is attached below.

NOISE CONTROL PLAN

resubmit every six months

(duplicate as needed)

PART A: EQUIPMENT INVENTORY

Contract No.: _____ Contract Name: _____

Contractor: _____

Site: _____ Date: _____

(ATTACH SITE SKETCH)

Code	Equipment				Noise Limit (dBA)	Estimated Noise at 50 ft (dBA)	Date Begin	Date End	Time Use
	Category	Model	ID #	HP					
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N
									D / E / N

D indicates "daytime" of 7 AM to 6 PM.

E indicates "evening" of 6 PM to 10 PM.

N indicates "nighttime" of 10 PM to 7 AM.

PART B: PREDICTED NOISE LEVELS

Date: _____ Land Use: _____

Time Period	Calculated Noise Levels		Lot-Line Noise Level Limit	
	Calculated L_{10} (dBA)	Calculated L_{max} (dBA)	L_{10} Limit (dBA)	L_{max} Limit (dBA)
Daytime (7AM - 6PM)				
Evening (6PM - 10PM)				
Nighttime (10PM - 7AM)				

NOISE ABATEMENT MEASURES _____

ANTICIPATED EFFECTS _____

CALCULATIONS - attach additional sheet(s) as needed

EPC WORKSHEET 8 printed: 6/26/2006

Guidance

The following tools and forms can help contractors and Project stakeholders acquire the data and information necessary to complete the Noise Monitoring Plan and the Noise Control Plan:

- Lot-Line Map Guidance (see Worksheet 4 above)
- Sound Level Meter Guidance (see Worksheet 9 below)
- Noise Level Calculations Guidance (see Worksheet 10 below and in EPC Tools Download)
- Noise Measurements Report Form (see Worksheet 11 below)
- Application for Certificate of Equipment Noise Compliance (see Worksheet 12 below)

WORKSHEET 9

Sound Level Meter Guidance

The sound level meter (SLM) is one of the Acoustical Engineer's most useful tools. This portable instrument can monitor and record a variety of sound level data anywhere on a construction site, including Lmax, Leq, and L10 data. It is an expensive instrument, and its operation requires training. However, frequent and adept use of this tool is the only way to maintain a useful Noise Monitoring Plan and Noise Control Plan and comply with a construction area's lot-line noise limits. The technical terms used in this worksheet are defined in Appendix A, Definitions.

The following guidance is provided to help the Acoustical Engineer make an informed decision about noise monitoring equipment purchases.

Type of Noise Measurement Equipment and Systems

A wide variety of noise measurement equipment is currently available for use in the measurement of construction noise levels[1]. Some examples of the range of such equipment include:

- Type I and Type II sound level meters with a variety of data output options and with the ability to report noise levels for a variety of noise level descriptors;

Type I SLMs

Type II SLM

- Permanent, continuous noise monitoring systems, with and without integrated video systems; and
- Automated, monitoring systems, with and without integrated video systems.

Permanent automated wireless noise monitoring system (note solar cell, antenna, transmitter, and microphone)

The need obviously exists to tailor the type of equipment utilized to the complexity of the project and its construction noise monitoring requirements. In performing valid construction noise measurements, the following factors should generally be considered:

- Meeting ANSI S1.4 Standard for Type I or Type II accuracy[2];
- Using an "integrating" sound level meter;
- Ability to measure and display Lmax, Leq, and L10;
- Ability to measure A-weighted decibels;
- Capable of measuring at slow and fast root-mean-square (RMS) response settings;
- Ability of monitor to be calibrated in the field;

[2] "Specification for Sound Level Meters". Acoustical Society of America. American National Standard Institute (ANSI) Standard No. ANSI S1.4. New York, NY. 1983.

- Use of a proper wind screen; and
- Proper measurement locations as related to adjacent buildings, structures, and activities.

There are many different makes and models of SLM on the market, available for different prices with many different capabilities per unit. It is not the purpose of this document to recommend one SLM over another, but several reputable SLM manufacturers may be mentioned:

Bruel & Kjaer (http://www.bksv.com/)
Larson Davis (http://www.larsondavis.com/)
Norsonics (http://www.scantekinc.com/)
Rion (http://www.rion.co.jp/english/)

Other Factors to Consider

In addition to the factors discussed above, other factors to consider in setting up a construction noise-monitoring program include[1]:

- Loss prevention techniques – protection and security issues related to noise measurement equipment, particularly if left unmanned;
- Processing of measured data;
- Manpower requirements;
- Power requirements – electric, solar, etc.; and
- Need to identify unique and unusual noise generating events.

WORKSHEET 10

Noise Level Calculations Guidance

Taking sound level readings with an SLM is only the first step in determining the actual sound level for a given construction site or individual piece of equipment. Acceptable Lmax, Leq, and L10 values must be measured at a distance of 50 ft, and the percent of time in a day a piece of equipment is operating, or a construction site noise condition exists, must be accounted for. Since field measurement locations with an SLM may not always occur exactly 50 ft from a noise source, and not all noise sources are in use or produce noise evenly 100% of the time (usage factor = 100%), calculations must be performed to account for measurement distance and noise level variations and predict lot-line construction noise during applicable daytime, evening, and nighttime periods. The Noise Level Calculations Guidance spreadsheet tool allows the user to follow the basic steps described below to enter measured field data and apply the required distance and usage factor corrections.

A blank, ready-to-use electronic version of the Noise Level Calculations Guidance spreadsheet, in Microsoft Excel format, is available through the EPC Tools Download on this website. The technical terms used in this worksheet are defined in Appendix A, Definitions.

Steps to be taken in Worksheet 10:

A. Download the WORKSHEET10_Noise_Level_Calculations_Guidance.xls spreadsheet from the EPC Tools Download link and open the spreadsheet;

B. Consulting Worksheet 4, Lot-Line Map Guidance, enter into the space provided in Section 1 of the spreadsheet the results from a minimum of 10 noise location readings, taken with an SLM over a duration of a minimum 20 minutes each. Readings will take place where noise emitted by all applicable equipment will cause the greatest noise level for each type of land use for a given time period. The Contractor will report field readings to the EPC POC via Worksheet 4, Lot-Line Map Guidance.

C. Calculate Lmax, Leq, and L10 values corrected for distance (reference = 50 ft) and usage (reference = 100%) in Sections 2, 3, 4, and 5. Double-click the spreadsheet to modify data and calculations. Enter data in the cells colored green, and updated calculations will appear in the cells colored gray.

D. Calculated Lmax, Leq, and L10 results and other information will be reported to the EPC POC in the Noise Measurements Report Form (Worksheet 11), the Noise Control Plan (Worksheet 8), and the Application for Certificate of Equipment Noise Compliance (Worksheet 12).

ADDITIONAL RESOURCE: The FHWA's Roadway Construction Noise Model (RCNM) is a comprehensive construction noise prediction tool released in 2006[3]. This tool offers the ability

[3] "FHWA Roadway Construction Noise Model User's Guide". Federal Highway Administration. FHWA Report No. FHWA-HEP-05-054. Washington, DC. January 2006.

to gauge the noise impact of various pieces of construction equipment operating individually or in tandem at variable distances and with variable usage factors. This tool also allows the user to determine whether a construction area's noise levels exceed the lot-line noise limits of that construction area.

WORKSHEET 11

Noise Measurements Report Form

The Noise Measurements Report Form below describes the noise measurements taken as part of the completion of the Noise Monitoring Plan Worksheet (Worksheet 7) and Noise Control Plan (Worksheet 8). A form will be prepared for each measurement taken by the construction area's Acoustical Engineer and submitted to the EPC POC prior to construction for review and acceptance and every six months after that. Noise generating equipment will not be operated prior to acceptance of all Noise Measurements Report Forms. The technical terms used in this worksheet are defined in Appendix A, Definitions.

A blank Noise Measurements Report Form is attached below.

CONTRACT NO(S): _____
DATE: _____
TIME: _____

NOISE MEASUREMENTS REPORT FORM

MEASURED BY: _____ OF: _____
(COMPANY)

MONITORING ADDRESS: _____
(PROVIDE SKETCH ON BACK)

LOCATION NO: _____ WIND SPEED: _____ MPH DIRECTION: _____
LOCATION OF SOUND LEVEL METER: (NO CLOSER THAN 50 FEET FROM EQUIPMENT AND 5 FEET FROM REFLECTIVE SURFACE)

MONITORING WAS CONDUCTED: _____ FEET FROM EQUIPMENT

LAND USE (circle one): RESIDENTIAL/INSTITUTIONAL BUSINESS/RECREATIONAL INDUSTRIAL

SOUND LEVEL METER (MAKE AND MODEL): _____

DURATION OF MEASUREMENT: _____ minutes
CALIBRATION LEVEL: _____ dBA

	Noise Level (dBA)	Noise Limit (dBA)
Lmax*		
L1		
L10*		
L50		
L90		
Leq*		

(*) indicates required noise measurement data

FIELD NOTES
(e.g., 2200-2205 H, AIRPLANE, 90 dBA)

_____
_____
_____
_____
_____
_____
_____

CIRCLE ONE OF THE FOLLOWING:

ONGOING CONSTRUCTION **POST-CONSTRUCTION:** _____ **BASELINE CONDITIONS**
(CONTRACT)

(COMPLETE ALL THAT APPLY BELOW)

ACTIVE CONTRACT(S): _____
(LIST ALL CONTRACTS THAT CONTRIBUTE TO MEASURED NOISE)

COMPLAINT RESPONSE: _____
(DESCRIBE; IF NOT COMPLAINT RESPONSE, LIST NA)

ABATEMENT FOLLOW UP: _____
(DESCRIBE; IF NOT ABATEMENT FOLLOW UP, LIST NA)

EPC WORKSHEET 11 printed: 6/23/2006

WORKSHEET 12

Application for Certificate of Equipment Noise Compliance

The Application for Certificate of Equipment Noise Compliance below documents that a piece of construction equipment has been inspected for noise compliance before it was brought into a construction area. This form requires the Acoustical Engineer to describe noise abatement measures in the event that expected noise levels from a piece of equipment exceed noise level limits for that piece of equipment. An Application for Certificate of Equipment Noise Compliance will be prepared for each piece of equipment in a construction area, in close coordination with Worksheet 3, the Construction Equipment Inventory, and will be submitted by the construction area's Acoustical Engineer to the EPC POC prior to construction for review. Noise generating equipment will not be operated prior to an acceptance of its Application for Certificate of Equipment Noise Compliance. The technical terms used in this worksheet are defined in Appendix A, Definitions.

A blank Application for Certificate of Equipment Noise Compliance is attached below.

APPLICATION FOR CERTIFICATE OF EQUIPMENT NOISE COMPLIANCE

Contractor Name: _____

Contract Name & Number: _____

Equipment Type: _____

Manufacturer & Model: _____

Identification Number: _____

Rated Power & Capacity: _____

Operating Cond. During Test: _____

Measured Lmax Noise Levels and Distance:

Right Side: _____ dBA Lmax (slow) at _____ feet
Left Side: _____ dBA Lmax (slow) at _____ feet

Adjusted Lmax Noise Levels at 50 Feet:

Right Side: _____ dBA Lmax (slow) at 50 feet
Left Side: _____ dBA Lmax (slow) at 50 feet

Equipment Noise Emission Limit: _____ dBA Lmax (slow) at 50 feet

If equipment noise level exceeds maximum value allowed, indicate action taken to achieve compliance:

ACOUSTICAL ENGINEER
Name, Address & Phone No.

_____

ACOUSTICAL ENGINEER
Authorized Signature: _____ Date: _____

CONTRACTOR'S CONCURRENCE
Authorized Signature: _____ Date: _____

ENGINEER'S CONCURRENCE
Authorized Signature: _____ Date: _____

EPC WORKSHEET 12 printed: 6/22/2006

Construction Noise Control Specification

The requirements of the Noise Monitoring Plan, as well as a description of all acceptable noise mitigation strategies, should be documented in a Construction Noise Control Specification (Noise Spec), to be drawn up by the Project management stakeholders and approved by each contractor expected to abide by the requirements of the Noise Spec. See a template for a construction noise control specification in Worksheet 13 below.

WORKSHEET 13

Construction Noise Control Specification

In order to document exactly what is expected of contractors and Project management stakeholders in terms of a Noise Monitoring Plan, the Project's environmental panel should write up a Noise Spec before work begins, with the input of contractors, noise technicians, acoustical engineers, project engineers, government agencies, and local businesses. A Noise Spec can be drawn up for each construction area, tailored to inform each construction area's contractor personnel and Project stakeholder management how to most effectively implement the EPCs in that area. The technical terms used in this worksheet are defined in Appendix A, Definitions.

A Noise Spec should cover the following main topic areas:

1.0 Description
- 1.01 General
- 1.02 Terms Used
- 1.03 Submittals
- 1.04 Construction Limitations
  - A. Noise Levels
  - B. Lot-Line Guidance
  - C. Equipment Operations
  - D. Proactive Noise Barriers
- 1.05 Acoustical Engineer
- 1.06 Noise Monitoring Plan
- 1.07 Noise Control Plan
- 1.08 Equipment Noise Certification
  - A. Noise Measurements Report Form
  - B. Application for Certificate of Equipment Noise Compliance

2.0 Materials
- 2.01 General
- 2.02 Noise Monitoring Equipment
  - A. Sound Level Meter
  - B. Calibrator
- 2.03 Noise Reduction Materials and Equipment
- 2.04 Temporary Noise Barriers
- 2.05 Acoustical Barrier Enclosures
  - A. Materials
  - B. Construction Details
- 2.06 Noise Control Curtains
  - A. Materials
  - B. Construction Details

3.0 Construction Methods
- 3.01 Noise Monitoring Methods
  - A. General
  - B. Background Noise Monitoring

C. Construction Noise Monitoring
3.02 Reporting
3.03 Noise Reduction Methods
3.04 Temporary Noise Barriers
A. General
B. Installation, Maintenance and Removal
3.05 Equipment Noise Certification
3.06 Complaint Procedure
3.07 Acoustical Barrier Enclosures
A. General
B. Installation, Maintenance and Removal
3.08 Noise Control Curtains
A. General
B. Installation, Maintenance and Removal
4.0 Compensation
4.01 Method of Measurement
4.02 Basis of Payment
4.03 Payment of Terms

While some form of Noise Spec should be in place before work begins, the Noise Spec may be modified at any time in the life of a construction project.

AIR QUALITY

The following guidance and worksheets apply to the contractor's air quality impact mitigation strategy, in particular, the areas of construction dust control.

Air Quality Monitoring Plans

As with noise monitoring, air quality monitoring, particularly in the vicinity of a construction area's lot-lines, can avoid annoyance to and complaints by the Public. The Air Quality Monitoring Plan Worksheet (Worksheet 14), PM10 Monitoring Program (see Worksheet 15, PM10 Information Page), Dust Inspection Program, and Diesel Emissions Retrofit Program will reduce emissions and dust in a construction area.

WORKSHEET 14

Air Quality Monitoring Plan Worksheet

The following action items, discussed in the EPC Checklist and to be checked off here, will aid contractors and Project management stakeholders in improving air quality around a construction area. The technical terms used in this worksheet are defined in Appendix A, Definitions.

Check Off

- ❑ Use onsite wet suppression, alone or with binding agents, on a routine basis using a water truck
- ❑ Use wet-spray power-vacuum street sweepers on paved roadways
- ❑ Use windscreen fabric or wood barriers around the perimeter of construction sites
- ❑ Use crushed stone at construction ingress / egress areas
- ❑ Cover active stockpiles with plastic tarps
- ❑ Use soil-binding agents on inactive stockpiles and open worksites
- ❑ Cover dump trucks with windscreen fabric or tarps during material transport on public roadways
- ❑ Reduce the number of truck entrances and exits from a construction site (see Worksheet 4 above)
- ❑ Label and document retrofitted equipment in the Construction Equipment Inventory (document in Worksheet 3)
- ❑ Use ultra-low sulfur diesel (ULSD) fuel (document in Worksheet 3)
- ❑ Turn engines off, when possible
- ❑ Establish a safe staging zone (mark on Worksheet 4)
- ❑ Maintain safe fresh air intakes
- ❑ Replace diesel / gasoline equipment with electric-powered equipment, where possible (document in Worksheet 3)

PM10 Monitoring Program

For information on the PM10 (0.00001-m diameter particles) air quality metric, see Worksheet 15, PM10 Information Page. A PM10 monitoring program should evaluate the effects of various utility relocation activities and measure baseline levels prior to mainline construction. Such programs include the use of portable air samplers located at sidewalks for periods of time that range from two weeks to five months. To establish this type of PM10 monitoring program, the Project should consult with the local environmental protection agency and the Federal EPA. The appropriate equipment and manpower may need to be contracted out, but it should not be necessary to hire a full-time air quality technician, since the PM10 sampling is infrequent compared to noise monitoring.

Dust Inspection Program

A dust inspection program created by management stakeholders, i.e., EPA, will provide timely feedback to construction management such that additional dust control measures may be implemented as needed toward reducing construction-related sources of nuisance dust and PM10 emissions.

As part of the program, construction areas and adjacent roadways in proximity to each PM10 sampling location should be inspected visually three times a week for observable on- and off-site nuisance dust, dirt tracking on public streets, and nuisance diesel emissions within the work area. All inspections should be catalogued in inspection reports (see Worksheet 5 above). A full-time air quality technician need not be hired for these inspections since any local or Federal EPA staff member should be able to perform the visual inspection duties within his or her schedule.

Using the information contained in the visual inspection report, the Project may notify construction field offices of problematic nuisance dust and diesel emissions and recommend solutions to rectify the condition. In the event of recurring nuisance conditions, contractors may be given deficiency reports (DR) via the site Resident Engineer (see Worksheet 6 above). A DR may allow the Project to withhold payment for repeated observable dust and diesel emission problems. In extreme cases, the information contained in the field inspection reports and DRs may be used by local or Federal EPA to initiate further inspections and/or levy fines against the contractor for non-compliance with local pollution control laws.

Diesel Emissions Retrofit Program

A retrofit program will retrofit diesel engines with diesel oxidation catalysts (DOC) and diesel particulate filters (DPF). A retrofit program can result in an approximately 20% reduction in PM10 and PM2.5 (0.0000025-m diameter particles) emissions for the retrofitted equipment. In addition, reductions in carbon monoxide (40%) and hydrocarbon emissions (50%) for the retrofitted equipment may result in the reduction of diesel odors and air toxics near residential communities and hospitals or other sensitive land-uses.

Guidance

Monitoring air quality in a construction area to accepted industry and EPA standards will likely require the Project to set up a PM10 Monitoring Program (see Section 3.1.2 above). To establish this type of PM10 monitoring program, the Project should consult with the local and Federal EPA. The appropriate equipment and manpower may need to be contracted out, but it should not be necessary to hire a full-time air quality technician, since the PM10 sampling is infrequent compared to noise monitoring. The Project management stakeholders and contractor project engineers interested in gauging construction area air quality should be aware of the PM10 air quality metric and the portable air sampler (PAS) equipment, both discussed below.

PM10

Particulate matter (PM) is a major air pollutant consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, or mists. The size of the particles allows them to enter the air sacs deep in the lungs where they may be deposited to result in adverse health effects. PM10 also causes visibility reduction. PM10 data are typically reported as 24-hour average concentrations in $\mu g/m^3$ (weight of particles in micrograms per one cubic meter of air). PM10 is the industry standard gauge of air quality in a construction area. Worksheet 15 below, the PM10 Information Page, offers useful definitions and standards for the PM10 air quality metric[4].

[4] "PM10 Information Page". California Air Resources Board. http://www.arb.ca.gov/aqd/oldpm10/pminfo.htm. Sacramento, CA. 2006.

WORKSHEET 15

PM10 Information Page

This worksheet includes definitions for various technical terms and data related to PM10 monitoring, including tables of US, California, and New York State ambient air quality standards. The technical terms used in this worksheet are also defined in Appendix A, Definitions.

PARTICULATE MATTER (PM10): A major air pollutant consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, or mists. The size of the particles (10 microns or smaller, about 0.0004 inches or less) allows them to enter the air sacs deep in the lungs where they may be deposited to result in adverse health effects. PM10 also causes visibility reduction. The PM10 data listed in these web pages are reported as 24-hour average concentrations in $\mu g/m^3$ (weight of particles in micrograms per one cubic meter of air).

SAMPLING SCHEDULE: Only PM10 data collected using a high volume sampler with a size selective inlet (SSI) are presented in this page. The SSI is typically used to measure a 24-hour average concentration once every six days. Some monitoring sites measure PM10 more frequently throughout the year, others increase sampling frequency or sample only during high PM10 season. Special terminology, like the number of complete months (see below) and the percent of samples (see below) above the standard, was used in the tables to help illustrate the extent and severity of the PM10 problem.

MAX 24-HR**:** Highest Annual 24-hour concentration in $\mu g/m^3$.

AGM: Annual Geometric Mean of all 24-hour average concentrations at a monitoring site in $\mu g/m^3$.

MAX AGM: Highest Annual Geometric Mean at a monitoring site within the county, basin, or district.

AAM: Annual Arithmetic Mean of all 24-hour average concentrations at a monitoring site in $\mu g/m^3$.

MAX AAM: Highest Annual Arithmetic Mean at a monitoring site in $\mu g/m^3$.

EXPECTED PEAK DAY CONCENTRATION (EPDC): The PM10 concentration expected to recur once per year. The EPDC is calculated for each monitoring site based on data for 3 successive years and is listed by the last year of the three-year period. The EPDC can be higher than the highest concentration measured at a monitoring site.

MAX EPDC: Highest PM10 concentration expected to recur once per year within an area.

99TH PERCENTILE: PM10 24-hour concentration out of a year of monitoring data below which 99% of all values in the group fall. This is the current form of the federal 24-hour PM10 standard.

MAX 99TH PERCENTILE: Highest of the 99th percentiles of 24-hour PM10 concentrations taken from the monitoring sites within the county, basin, or district.

COMPLETE MONTHS: The number of complete months, quarters, and years represents completeness of the data. The data that meet each level of representativeness criteria (month, quarter, and year) are sufficiently complete to reliably characterize air quality during the representative period. The completeness criteria for PM10 are shown in the table below.

Criteria for Representativeness of PM10 Air Quality Data

Month	Four or more 24-hour samples
Quarter	Three representative months
Year	Four representative calendar quarters

PM10 AMBIENT AIR QUALITY STANDARDS: EPA and ARB have adopted air quality standards to protect the public and the environment from adverse effects of air pollution. The standards identify acceptable levels of pollutants that can be present in ambient air. The current PM10 air quality standards are shown in the table below. The 24-hour standards protect the public from the effects of short-term exposure to ambient PM10 concentrations and the annual standards protect the public and the environment from the effects of long term exposure. The State 24-hour standard is exceeded when the 24-hour PM10 concentration is greater than or equal to 50.5 $\mu g/m^3$. The federal 24-hour PM10 standard is exceeded when the 24-hour PM10 concentration is greater than or equal to 155 $\mu g/m^3$. The State annual standard is exceeded when the annual geometric mean of all 24-hour concentrations at a site is greater than or equal to 30.5 $\mu g/m^3$. The national annual standard is exceeded when the annual arithmetic mean of all 24-hour concentrations at a site is greater than or equal to 50.5 $\mu g/m^3$.

In 1997, EPA announced the new PM10 standards. EPA retained the annual PM10 standard of 50 $\mu g/m^3$ and adjusted the PM10 24-hour standard of 150 $\mu g/m^3$ by changing the form of the standard. The one-expected exceedance form was replaced by the 99th percentile of 24-hour concentrations at each monitor within an area averaged over 3 years.

PM10 Ambient Air Quality Standards: California, New York State, and Federal

California Standards

Averaging Time	**California Standards Concentration**
24-hour	50 $\mu g/m^3$
Annual Mean	30 $\mu g/m^3$ (Geometric Mean)

New York State and Federal Standards

		New York State Standards			Corresponding Federal Standards					
					Primary Standard			Secondary Standard		
Pollutant [1]	**Avg. Period**	**Conc.**	**Units**	**Statistic [2]**	**Conc.**	**Units [3]**	**Statistic**	**Conc.**	**Units**	**Statistic**
Sulfur Dioxide	12 consecutive months	0.03	PPM	Arithmetic Mean (A.M)	80	µg/m³	A.M.			
	24-hour	0.14	PPM	Maximum	365	µg/m³	Maximum			
	3-hour	0.50	PPM	Maximum				1300	µg/m³	Maximum
Carbon Monoxide	8-hour	9	PPM	Maximum	10	µg/m³	Maximum	10	µg/m³	Maximum
	1-hour	35	PPM	Maximum	40	µg/m³	Maximum	40	µg/m³	Maximum
Ozone [4]	1-hour	0.12	PPM	Maximum	235	µg/m³	Maximum	235	µg/m³	Maximum
	8-hour	0.08	PPM	Maximum	157	µg/m³	Maximum	157	µg/m³	Maximum
Hydrocarbons (non-methane)	3-hour (6-9 am)	0.24	PPM	Maximum						
Nitrogen Dioxide	12 consecutive months	0.05	PPM	Maximum	100	µg/m³	A.M	100	µg/m³	A.M.
Lead [5]	3 consecutive months				1.5	µg/m³	Maximum			
Fine Particulate Matter ($PM_{2.5}$)	12 consecutive months				15	µg/m³	A.M.	15	µg/m³	A.M.
	24-hours				65	µg/m³	Maximum	65	µg/m³	Maximum
Inhalable Particulates (PM_{10}) [6]	12 consecutive months				50	µg/m³	A.M.	50	µg/m³	A.M.
	24-hours				150	µg/m³	Maximum	150	µg/m³	Maximum
Total Suspended Particulates (TSP) [7]	12 consecutive months	75	µg/m³	Geometric Mean (G.M.)						
	24-hours	250	µg/m³	Maximum	260	µg/m³	Maximum	150	µg/m³	Maximum

[1] New York State (NYS) also has standards for beryllium, fluorides, hydrogen sulfide, and settleable particulates (dustfall). Ambient monitoring for these pollutants is not currently conducted.

[2] All maximum values are concentrations not to be exceeded more than once per calendar year. (Federal Ozone Standard not to be exceeded more than three days in three calendar years).

[3] Gaseous concentrations for Federal standards are corrected to a reference temperature of 25°C and to a reference pressure of 760 millimeters of mercury.

[4] Former NYS Standard for ozone of 0.08 parts per million (PPM) was not officially revised via regulatory process to coincide with the Federal standard of 0.12 PPM which is currently being applied by NYS to determine compliance status.

[5] Federal standard for lead not yet officially adopted by NYS, but is currently being applied to determine compliance status.

[6] Federal standard for PM_{10} not yet officially adopted by NYS, but is currently being applied to determine compliance status.

[7] NYS also has 30, 60, and 90-day standards as well as geometric mean standards of 45, 55, and 65 µg/m³ in Part 257 of New York Environmental Conservation Rules and Regulations (NYCRR). While these Total Suspended Particulates (TSP) standards have been superseded by the above PM_{10} standards, TSP measurements may still serve as surrogates to PM_{10} measurements in the determination of compliance status.

% OF SAMPLES ABOVE THE STANDARD: The % of samples above the standard is calculated based on the total number of samples and the number of samples with concentrations that exceeded the standard. The percents are first calculated for calendar quarters. Only quarters

with 12 or more samples are included in the calculation. The percents for all complete quarters are then averaged. For a basin, county, or district, samples or exceedances measured at multiple monitoring sites on the same day are counted as one.

HIGHLY IRREGULAR OR INFREQUENT EVENTS: The ambient air quality data are used in determining an area's designation status with respect to the State standards. The designation criteria provide for excluding exceedances affected by highly irregular or infrequent events because it is not reasonable to mitigate these exceedances through the regulatory process.

Three types of highly irregular or infrequent events may be identified:

- Exceptional Event - specific, identifiable event beyond reasonable regulatory control which causes an exceedance of a state standard. An exceptional event may be caused by an act of nature (for example, a severe wind storm or a forest fire) or it may be of human origin (for example, a chemical spill or industrial accident).
- Extreme Concentration Event - an event that may not have a specific, identifiable cause, but is identified by a statistical procedure which calculates the concentration (Expected Peak Day Concentration) that is not expected to recur more frequently than once per year. One potential cause of an extreme concentration event is adverse meteorology. Measured concentrations that are higher than the Expected Peak Day Concentration are identified as extreme concentrations and are excluded from the area designation process. The highest concentration remaining after excluding extreme concentrations is referred to as the designation value.
- Unusual Concentration Event - an event that causes an anomalous exceedance of a State standard. To identify an exceedance as affected by an unusual concentration event, it must be found (based on the relevant information) that the impact of the affected exceedance is limited to the local area, the exceedance is not expected to recur, and the data do not support a nonattainment designation.

NATURE AND SOURCES OF THE POLLUTANT: Particulate matter can be directly emitted or can be formed in the atmosphere when gaseous pollutants such as SO_2 and NO_2 undergo chemical reaction in the atmosphere.

Major sources of PM10 include:

- motor vehicles
- wood burning stoves and fireplaces
- dust from construction, landfills, and agriculture
- wildfires and brush/waste burning
- industrial sources
- windblown dust from open lands

MEASUREMENTS METHODS: PM10 samples are collected over a 24-hour period on an 8-inch x 10-inch quartz fiber filter by using a high volume sampler equipped with a size selective inlet (SSI), and operated at 36 to 44 cubic feet per minute. Each filter is weighed before and after sampling to determine the net weight gain (micrograms) of the sample. Samples are usually

collected from midnight to midnight every sixth day. PM10 data collected using other measurements methods, including the dichotomous sampler, Tapered Element Oscillating Microbalance (TEOM), or Beta Attenuation Monitor, are not presented in this document.

ELEMENTAL ANALYSES: Some PM10 filters are analyzed for chemical composition, including some or all of the following: five ionic species (nitrate, sulfate, ammonium, chloride, potassium) and total carbon. This information is useful in identifying sources of particulate matter. The chemical composition data are reported as a 24-hour average concentration in $\mu g/m^3$.

Portable Air Sampler

The PAS is the industry standard equipment for collecting PM10 readings, in units of $\mu g/m^3$.

Portable air sampler in the field

There are many different makes and models of PAS on the market, available for different prices with many different capabilities per unit. It is not the purpose of this document to recommend one PAS over another, but several reputable PAS manufacturers may be mentioned:

Airmetrics (http://www.airmetrics.com/products/minivol/index.html)
SKC (http://skcinc.com/prod/100-3901.asp)

Air Quality Monitoring Specifications

Each construction area should have a Construction Dust Control Specification (Dust Spec) in place. As with the Noise Spec, the Dust Spec should be very clear about what is expected of contractors and Project management stakeholders in terms of air quality monitoring, air quality impact mitigation, and complaint management through the entire life of a construction project. The Project's environmental panel should write up a Dust Spec before work begins, with the input of contractors, air quality technicians, project engineers, government agencies, and local businesses. A Dust Spec can be drawn up for each construction area, tailored to inform each area's contractor personnel and Project stakeholder management how to most effectively implement the EPCs in that area.

Worksheet 16 discusses the main topics a Dust Spec should cover.

WORKSHEET 16

Construction Air Quality and Dust Control Specification

In order to document exactly what is expected of contractors and Project management stakeholders in terms of air quality monitoring and impact mitigation, the Project's environmental panel should write up a Construction Air Quality and Dust Control Specification (Dust Spec) before work begins, with the input of contractors, air quality technicians, project engineers, government agencies, and local businesses. A Dust Spec can be drawn up for each contruction area, tailored to inform each construction area's contractor personnel and Project stakeholder management how to most effectively implement the EPCs in that area. The technical terms used in this worksheet are defined in Appendix A, Definitions.

A Dust Spec should touch the following main topic areas:

1.0 Description
- 1.01 General
- 1.02 PM10 Monitoring Program
- 1.03 Dust Inspection Program
- 1.04 Regulatory Requirements
- 1.05 Submittals

2.0 Materials
- 2.01 Dust Suppression Agents
- 2.02 Barriers, Screens, and Covers
- 2.03 Seeding

3.0 Construction Methods
- 3.01 Construction Site Dust Control - General
- 3.02 Public Roadway Dust Control
- 3.03 Control of Earthwork Dust
- 3.04 Control of Stockpile Dust
- 3.05 Demolition Dust Control Measures

4.0 Compensation
- 4.01 Method of Measurement
- 4.02 Basis of Payment
- 4.03 Payment Items

While some form of Dust Spec should be in place before work begins, the Dust Spec may be modified at any time in the life of a construction project.

TRAFFIC AND CIRCULATION

The following guidance and worksheets apply to the contractor's traffic and circulation impact mitigation strategy, in particular, the areas of safety and communication.

Traffic and Circulation Monitoring Plans

As with noise and air quality monitoring, traffic and circulation monitoring – performed under the auspices of the local DOT – can avoid annoyance and complaints by the Public. Worksheet 17 presents a proposed Maintenance and Protection of Traffic (MPT) Plan, and Worksheet 18 provides a Traffic and Circulation Monitoring Plan Worksheet.

Maintenance and Protection of Traffic Plan

When a public way is to be occupied for construction work, the contractor should be required to prepare an MPT Plan stating the nature of the work, type and times of roadway occupation, and associated drawings stamped by a traffic engineer. Pedestrian detours must be detailed on engineered, stamped drawings. Continuous pedestrian access is required to buildings abutting work zones, and the local Chamber of Commerce will be anxious to see that reasonable access is accounted for in any MPT Plan.

Worksheet 17 below presents a proposed MPT Plan.

WORKSHEET 17

Maintenance and Protection of Traffic Plan

Project engineers should strive to identify a Maintenance and Protection of Traffic Plan (MPT Plan) that allows for an efficiency of operations, while still maintaining traffic through the project limits and responding to the contractor's work and staging plan. It is critical that the MPT Plan establishes, from the onset, an environmentally responsive approach to protecting on-site staff and the Public.

An MPT Plan should be in place before construction work begins in the relevant traffic areas. Any MPT Plan should include as its priorities safety and the preservation of mass transit and vehicular and pedestrian traffic during construction. Such a plan should have the approval of the local DOT and be filed with the DOT as official project documentation with the potential for distribution to the Public. Since MPT Plans will change from action to action and be dynamic throughout the Project construction process, it is difficult to present an MPT Plan template. However, the following MPT Plan worksheet presents a listing of the key items that should be included. The MPT Plan is not to be confused with the Traffic and Circulation Monitoring Plan Worksheet (Worksheet 18), which is meant to be an internal document. The technical terms used in this worksheet are defined in Appendix A, Definitions.

Check Off

- ❑ Notify local DOT of all potential impacts to traffic by project construction.
- ❑ Preserve safety of drivers, passengers, pedestrians, and construction staff at all times.
- ❑ Preserve mass transit.
- ❑ Preserve vehicular traffic.
- ❑ Preserve pedestrian traffic.
- ❑ File MPT Plan with local DOT.

WORKSHEET 18

Traffic and Circulation Monitoring Plan Worksheet

The following action items, discussed in the EPC Checklist and to be checked off here, will aid contractors and Project management stakeholders in improving traffic and circulation around a construction area. The technical terms used in this worksheet are defined in Appendix A, Definitions.

Check Off

- ❑ Maintain community notification and outreach through newspaper announcements, regularly scheduled community meetings, and a Project webpage
- ❑ Bring a Traffic Mitigation Manager on staff to speak to contractors, the Public, and Project sponsors on behalf of the local DOT
- ❑ Place adequate traffic surveillance in the vicinity of the construction area(s)
- ❑ Consider using police details to control some traffic situations, after consulting with the local DOT
- ❑ Post warning signs for pedestrians regarding changes in street vehicular traffic direction, after consulting with the local DOT
- ❑ Post signs directing pedestrians to public and private attractions whose normal entrances may have been disrupted, after consulting with the local DOT
- ❑ Where necessary, make special accommodations for handicapped pedestrian access
- ❑ Avoid interference with mass transit
- ❑ Map out alternative truck routes

Guidance

The local DOT may already have a traffic camera surveillance system in place. As an example, the New York City Department of Transportation (NYCDOT) maintains the Advanced Traveler Information System. This system is described in detail in Worksheet 19 below.

Project management stakeholders might consider utilizing parts of the existing Advanced Traveler Information System in building a useful traffic camera surveillance system in the vicinity of construction sites to be monitored.

WORKSHEET 19

New York City Department of Transportation Advanced Traveler Information System

The NYCDOT's Traffic Management Center, located in Long Island City, Queens, NYC, contains closed circuit television cameras trained on major arteries, which allow operations staff to track traffic conditions at key locations in the city.

Twenty-two of NYCDOT's traffic cameras, showing live traffic conditions at major locations, now can be seen on City Drive Live on NYC TV, the television network of NYC, on Channel 93 (72 for Cablevision Subscribers) all day, every day.

Visitors to the NYCDOT web pages can access these cameras to view real-time traffic movements through the Advanced Traveler Information System (ATIS) web site, http://nyctmc.org/. ATIS provides both streaming video and frequently updated still images from locations in the five boroughs.

To access streaming video and stills, we recommend a minimum of 56K modem capability. In addition, the Real Player plug-in must be used for streaming video. If a user does not have Real Player, he/she may download it free from the ATIS introduction page at http://nyctmc.org/.

At times when demand is high, video streaming may not be available to each visitor. If a user cannot receive a video stream, he/she will be redirected to a still photo of the location, which is updated every few minutes. Please try again at a later time to access the video stream. To manage the demand, the user will be able to access each video stream for a maximum of three minutes, for a total of 20 minutes of every hour. After that time, the user will be able to access only still web cam images.

The cameras are being used by NYCDOT staff to monitor traffic conditions, and may be repositioned to view traffic from varying directions. The user may see different views if visiting a camera location at different times. To see the list of available camera locations, visit the ATIS website at http://nyctmc.org/.

From time to time, cameras may be out of service because of construction, weather conditions, or mechanical or electrical failure. These cameras will be restored to service as soon as possible. We apologize for any inconvenience.

Links are also provided to other web sites that provide cameras at additional locations in NYC. In addition, the Metropolitan Transportation Authority (MTA), which operates many of the bridges and tunnels in NYC, provides several cameras on its web site, http://webcam.mta.info/mta3/index.jsp.

Traffic and Circulation Control Specification

Each construction area should have a Traffic and Circulation Control Specification (Traffic Spec) in place. As with the Noise Spec, the Traffic Spec should be very clear about what is expected of contractors and Project management stakeholders in terms of traffic and circulation monitoring, traffic and circulation impact mitigation, and complaint management through the entire life of a construction project. The Project's environmental panel should write up a Traffic Spec before work begins, with the input of contractors, a Traffic Mitigation Manager, project engineers, government agencies, and local businesses. A Traffic Spec can be drawn up for each construction area, tailored to inform each construction area's contractor personnel and Project stakeholder management how to most effectively implement the EPCs in that area.

Worksheet 20 below discusses the main topics a Traffic Spec should cover.

WORKSHEET 20

Construction Traffic and Circulation Control Specification

In order to get down in writing exactly what is expected of contractors and Project management stakeholders in terms of traffic and circulation monitoring and impact mitigation, the Project's environmental panel should write up a Construction Traffic and Circulation Control Specification (Traffic Spec) before work begins, with the input of contractors, a Traffic Mitigation Manager, project engineers, government agencies, and local businesses. A Traffic Spec can be drawn up for each construction area, tailored to inform each area's contractor personnel and Project stakeholder management how to most effectively implement the EPCs in that area. The technical terms used in this worksheet are defined in Appendix A, Definitions.

A Traffic Spec should cover the following main topic areas:

1.0 Description
- 1.01 General
- 1.02 Traffic Mitigation Manager
- 1.03 Maintenance and Protection of Traffic Plan
- 1.04 Police Detail
- 1.05 Traffic Surveillance
- 1.06 Regulatory Requirements
- 1.07 Submittals

2.0 Materials
- 2.01 Pedestrian Warning Signage
- 2.02 Traffic Warning Signage

3.0 Construction Methods
- 3.01 Alternative Truck Routes
- 3.02 Alternative Resident Parking
- 3.03 Alternative Business Parking
- 3.04 Handicapped Access

4.0 Compensation
- 4.01 Method of Measurement
- 4.02 Basis of Payment
- 4.03 Payment Items

While some form of Traffic Spec should be in place before work begins, the Traffic Spec may be modified at any time in the life of a construction project.

APPENDIX A: DEFINITIONS

This appendix defines pertinent terminology used throughout the Checklist, Worksheets, and standard discussions of noise, air quality, and traffic and circulation impact mitigation.

% OF SAMPLES ABOVE THE STANDARD: The % of samples above the standard is calculated based on the total number of samples and the number of samples with concentrations that exceeded the standard. The percents are first calculated for calendar quarters. Only quarters with 12 or more samples are included in the calculation. The percents for all complete quarters are then averaged. For a basin, county, or district, samples or exceedances measured at multiple monitoring sites on the same day are counted as one.

99TH PERCENTILE: PM10 24-hour concentration out of a year of monitoring data below which 99% of all values in the group fall. This is the current form of the federal 24-hour PM10 standard.

A-WEIGHTING: The weighting network used to account for changes in level sensitivity as a function of frequency. The A-weighting network de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 kHz and 6.3 kHz in an effort to simulate the relative response of the human ear. See also frequency weighting.

ACOUSTIC ENERGY: Commonly referred to as the mean-square sound-pressure ratio, sound energy, or energy, acoustic energy is the square of the ratio of the mean-square sound pressure (often referred to as frequency weighted) and the reference mean-square sound pressure of 20 μPa, the threshold of human hearing. It is arithmetically equivalent to $10^{(SPL/10)}$, where SPL is the sound pressure level, expressed in decibels

AMBIENT NOISE: All-encompassing sound that is associated with a given environment, usually a composite of sounds from many sources near and far.

AMPLITUDE: The maximum value of a sinusoidal quantity measured from peak to peak.

ANNUAL ARITHMETIC MEAN: Mathematical average over the course of one year of all 24-hour average concentrations at a monitoring site in $\mu g/m^3$.

AGM: Annual Geometric Mean of all 24-hour average concentrations at a monitoring site in $\mu g/m^3$.

BACKGROUND NOISE: All-encompassing sound of a given environment without the sound source of interest.

COMPLETE MONTHS: The number of complete months, quarters, and years represents completeness of PM10 data. The data that meet each level of representativeness criteria (month, quarter, and year) are sufficiently complete to reliably characterize air quality during the representative period.

DECIBEL (dB): A unit of measure of sound level. The number of decibels is calculated as ten times the base-10 logarithm of the square of the ratio of the mean-square sound pressure (often referred to as frequency weighted) and the reference mean-square sound pressure of 20 μPa, the threshold of human hearing.

ELEMENTAL ANALYSES: Some PM10 filters are analyzed for chemical composition, including some or all of the following: five ionic species (nitrate, sulfate, ammonium, chloride, potassium) and total carbon. This information is useful in identifying sources of particulate matter. The chemical composition data are reported as a 24-hour average concentration, in $\mu g/m^3$.

ENVIRONMENTAL PROTECTION COMMITMENT (EPC): A detailed set of mitigation goals agreed to by contractors assigned to a construction project. The EPCs commit the contractors to implementing strategies to mitigate construction noise, air quality, and traffic and circulation impacts on the Public. These EPCs are directed primarily toward the construction equipment and trucks for the life of the Project.

EXCEPTIONAL EVENT: A specific, identifiable event beyond reasonable regulatory control which causes an exceedance of a state standard. In air quality PM10 control, an exceptional event may be caused by an act of nature (for example, a severe wind storm or a forest fire) or it may be of human origin (for example, a chemical spill or industrial accident).

EXISTING LEVEL: The measured or calculated existing noise level at a given location.

EXPECTED PEAK DAY CONCENTRATION (EPDC): The PM10 concentration expected to recur once per year. The EPDC is calculated for each monitoring site based on data for 3 successive years and is listed by the last year of the three-year period. The EPDC can be higher than the highest concentration measured at a monitoring site.

EXTREME CONCENTRATION EVENT: An event that may not have a specific, identifiable cause, but is identified by a statistical procedure which calculates the concentration Expected Peak Day Concentration that is not expected to recur more frequently than once per year. One potential cause of an extreme concentration event is adverse meteorology. Measured concentrations that are higher than the Expected Peak Day Concentration are identified as extreme concentrations and are excluded from the area designation process. The highest concentration remaining after excluding extreme concentrations is referred to as the designation value.

FREQUENCY: The number of cycles of repetition per second or the number of wavelengths that have passed by a stationary point in one second.

FREQUENCY WEIGHTING: A method used to account for changes in sensitivity as a function of frequency. Three standard weighting networks, A, B, and C, are used to account for different responses to sound pressure levels. Note: The absence of frequency weighting is referred to as "flat" response. See also A-weighting.

GROUND EFFECT: The change in sound level, either positive or negative, due to intervening ground between source and receiver. Ground effect is a relatively complex acoustic phenomenon, which is a function of ground characteristics, source-to-receiver geometry, and the spectral characteristics of the source. A commonly used rule-of-thumb for propagation over soft ground (e.g., grass) is that ground effects will account for about 1.5 dB per doubling of distance. However, this relationship is empirical and tends to break down for distances greater than about 30.5 to 61 m (100 to 200 ft).

HARD GROUND: Any highly reflective surface in which the phase of the sound energy is essentially preserved upon reflection; examples include water, asphalt, and concrete.

HIGHLY IRREGULAR EVENTS: Ambient air quality data are used in determining an area's designation status with respect to State PM10 standards. The designation criteria provide for excluding exceedances affected by highly irregular or infrequent events because it is not reasonable to mitigate these exceedances through the regulatory process.

IMPULSIVE NOISE: Impulsive noise is defined as noise produced by the periodic impact of a mass on a surface, of short duration (generally less than one second), high intensity, abrupt onset and rapid decay, and often rapidly changing spectral composition. Impact equipment such as a pile driver or jackhammer generates impulsive noise. By contrast, non-impact equipment generates a constant noise level while in operation, such as a diesel generator.

INSERTION LOSS: The sound level at a given receiver before the construction of a barrier minus the sound level at the same receiver after the construction of the barrier. The construction of a noise barrier usually results in a partial loss of soft-ground attenuation. This is due to the barrier forcing the sound to take a higher path relative to the ground plane. Therefore, barrier insertion loss is the net effect of barrier diffraction, combined with this partial loss of soft-ground attenuation.

L10: The sound level exceeded 10 percent of a specific time period, usually at least 20 minutes. For example, from a 20-sample measurement period, the second highest sound level (10% of 20 samples) is the 10-percentile exceeded sound level. Other similar descriptors include L50 (the sound level exceeded 50% of a specific time period), L90 (the sound level exceeded 90% of a specific time period), etc.

Leq: The equivalent sound level, or the continuous sound level that represents the same sound energy as the varying sound levels, over a specified monitoring period, usually at least 20 minutes.

LINE-OF-SIGHT: Refers to the direct path from the source to receiver without any intervening objects or topography.

LINE SOURCE: Multiple point sources moving in one direction, e.g., a continuous stream of roadway traffic, radiating sound cylindrically. Note: Sound levels measured from a line source decrease at a rate of 3 dB per doubling of distance.

Lmax: The maximum measured sound level at any instant in time.

LOT-LINE: The boundary of a construction area and the location at which construction noise, air quality, and traffic and circulation impacts begin to affect the Public. Noise limits tend to be established at the lot-line of a construction area.

MAXIMUM 24-HOUR: Highest Annual 24-hour concentration of PM10 in $\mu g/m^3$.

MAXIMUM 99TH PERCENTILE: Highest of the 99th percentiles of 24-hour PM10 concentrations taken from the monitoring sites within the county, basin, or district.

MAXIMUM AAM: Highest Annual Arithmetic Mean PM10 level at a monitoring site, in $\mu g/m^3$.

MAXIMUM AGM: Highest Annual Geometric Mean PM10 level at a monitoring site within the county, basin, or district.

MAXIMUM EXPECTED PEAK DAY CONCENTRATION: Highest PM10 concentration expected to recur once per year within an area.

MEASUREMENTS METHODS: PM10 samples are collected over a 24-hour period on an 8-inch x 10-inch quartz fiber filter by using a high volume sampler equipped with a size selective inlet (SSI), and operated at 36 to 44 cubic feet per minute. Each filter is weighed before and after sampling to determine the net weight gain (micrograms) of the sample. Samples are usually collected from midnight to midnight every sixth day. PM10 data collected using other measurements methods, including the dichotomous sampler, Tapered Element Oscillating Microbalance (TEOM), or Beta Attenuation Monitor, are not presented in this document.

MICROPHONE: An electronic instrument that transforms sound-pressure variations into electrical signals, that are in turn measured by instruments such as a sound level meter (SLM) or a one-third octave-band analyzer, and/or recorded by a tape recorder. The microphone in most conventional acoustic measurement systems is capable of measuring sound levels down to about 15 or 20 dBA.

MITIGATION: Any activity, whether proactive (planning and monitoring) or reactive (complaint response), that tends to lessen the effect on the Public of construction noise, air quality, and traffic and circulation impacts.

NOISE: Any unwanted sound. "Noise" and "Sound" are often used interchangeably.

NOISE BARRIER: The structure, or structure together with other material, that potentially alters the noise at a site from a BEFORE condition to an AFTER condition.

NOISE LIMIT: A standard acceptable noise level set by a local environmental agency, usually set at a construction area lot-line or at a distance of 50-ft from a single piece of construction equipment. There tends to be a different noise limit for daytime, evening, and nighttime periods.

PARTICULATE MATTER (PM10): A major air pollutant consisting of tiny solid or liquid particles of soot, dust, smoke, fumes, or mists. The size of the particles (10 microns or smaller, about 0.0004 inches or less) allows them to enter the air sacs deep in the lungs where they may be deposited to result in adverse health effects. PM10 also causes visibility reduction. The PM10 data listed in these web pages are reported as 24-hour average concentrations in mg/m^3 (weight of particles in micrograms per one cubic meter of air).

PM10 AMBIENT AIR QUALITY STANDARDS: EPA and ARB have adopted air quality standards to protect the public and the environment from adverse effects of air pollution. The standards identify acceptable levels of pollutants that can be present in ambient air. The 24-hour standards protect the public from the effects of short-term exposure to ambient PM10 concentrations and the annual standards protect the public and the environment from the effects of long term exposure. The State 24-hour standard is exceeded when the 24-hour PM10 concentration is greater than or equal to 50.5 $\mu g/m^3$. The federal 24-hour PM10 standard is exceeded when the 24-hour PM10 concentration is greater than or equal to 155 $\mu g/m^3$. The State annual standard is exceeded when the annual geometric mean of all 24-hour concentrations at a site is greater than or equal to 30.5 $\mu g/m^3$. The national annual standard is exceeded when the annual arithmetic mean of all 24-hour concentrations at a site is greater than or equal to 50.5 $\mu g/m^3$.

PM10 SOURCES: Particulate matter can be directly emitted or can be formed in the atmosphere when gaseous pollutants such as SO_2 and NO_2 undergo chemical reaction in the atmosphere.

PILE: A relatively slender, deep foundation unit, wholly or partly embedded in the ground, installed by driving, drilling, auguring, jetting, or otherwise, and which derives its capacity from the surrounding soil and/or from the soil or rock strata below its tip.

POINT SOURCE: Source that radiates sound spherically. Note: Sound levels measured from a point source decrease at a rate of 6 dB per doubling of distance.

RECEPTOR: A location particularly sensitive to noise or air quality impacts from construction, usually equipped with a noise monitor or air quality monitor or both. A

receptor can be an office, residential structure, park, hospital, church, or any number of location types.

SAMPLING SCHEDULE: PM10 data collected using a high volume sampler with a size selective inlet (SSI) are preferred. The SSI is typically used to measure a 24-hour average concentration once every six days. Some monitoring sites measure PM10 more frequently throughout the year, others increase sampling frequency or sample only during high PM10 season. Special terminology, like the number of complete months and the percent of samples above the standard, was used in the tables to help illustrate the extent and severity of the PM10 problem.

SOFT GROUND: Any highly absorptive surface in which the phase of the sound energy is changed upon reflection; examples include terrain covered with dense vegetation or freshly fallen snow. Note: at grazing angles greater than 20 degrees, which can commonly occur at short ranges, or in the case of elevated sources, soft ground becomes a good reflector and can be considered acoustically hard ground.

SOUND LEVEL METER: A device equipped with a microphone that is used to electronically measure and store sound level information for a local area.

STRUCTURES: Includes retaining walls, bridges, culverts, and concrete drainage channels.

UNUSUAL CONCENTRATION EVENT: An event that causes an anomalous exceedance of a State standard. To identify an exceedance as affected by an unusual concentration event, it must be found (based on the relevant information) that the impact of the affected exceedance is limited to the local area, the exceedance is not expected to recur, and the data do not support a nonattainment designation.

UTILITIES: Transmission and distribution lines, pipes, cables and other associated equipment used for public services including, but not limited to, electric transmission and distribution, lighting, heating, gas, oil, water, sewage, cablevision, data communications, and telephone.

WAVELENGTH: The perpendicular distance between two wave fronts in which the displacements have a difference in phase of one complete period.

WINDSCREEN: A conventional windscreen is a porous sphere [usually made of foam and about 3.5 inches (9 cm) in diameter] placed atop a microphone to reduce the effects of wind-generated noise on the microphone diaphragm. By reducing the wind-generated noise on the microphone diaphragm, the signal-to-noise (S/N) ratio of a sound measurement is effectively improved.

APPENDIX B: CONSTRUCTION NOISE AND VIBRATION IMPACT MITIGATION MATERIALS

1 Noise Barrier Photographs

Temporary Noise Barrier

Temporary noise barriers, which do not require anchoring, use plywood attached to chain link fence posts mounted on top of jersey barriers. A temporary noise barrier is pictured below joined with noise curtain material.

Semi-Permanent Noise Barrier

Semi-permanent barriers are erected along worksite boundaries and intended to be in active use for many years. They usually abut noise-sensitive buildings and are typically about 24 ft tall and made of inter-locked wooden timbers with posts anchored in drilled concrete caissons.

Noise Curtain Material Barrier

Noise curtain material is typically ¼-inch-thick heavy vinyl with a sound absorptive quilt attached to one side, very flexible, secured to structures and fence posts by Velcro and wire strapping, and easily moveable and reusable.

Noise Tent

Noise tents, typically three-sides and a roof made of noise curtain material attached to steel frames, are used to cover stationary noise sources such as pumps and generators and/or dynamic noise sources such as a jackhammer operator performing work in a sensitive area.

2 Proposed Offsite Residential Window Noise Mitigation Policy

The Project management stakeholders will determine by vote the eligibility of an individual resident to receive project-funded noise mitigation measures, specifically, residential window noise mitigation measures. The process will be initiated by a written request from a resident and evaluated against the Source and Receptor Criteria described below. To be eligible, all of the Criteria specified must be met unless otherwise agreed upon by the stakeholders.

SOURCE CRITERIA

1. Project construction activities are required to be performed during nighttime hours (10 PM - 7 AM) per contract schedule or permits.

2. The contractor has implemented all appropriate and reasonable noise abatement methods on-site, as specified in the Project's Noise Spec, the contractor's Noise Control Plan, or otherwise, and yet a demonstrable noise issue remains.

3. Project construction activities are performed within close proximity of the residential receptor. An attached lot-line map should detail the areas of potential noise impact.

RECEPTOR CRITERIA

1. The resident is the legal occupant of a legal residential unit as evidenced by zoning or an occupancy permit.

2. Noise levels associated with Project construction, measured at the lot-line outside the resident's unit, consistently are (or are predicted to be) greater than 5 dBA over the background L10 levels during nighttime hours (10 PM - 7 AM); or severe, repeated, and consistent nuisance conditions associated with Project construction exist (or will exist) at the residence during nighttime hours.

3. Elevated noise levels from Project construction are anticipated to exist consistently for a period in excess of two consecutive months.

4. The building has no structural or maintenance defect that facilitates or enhances transmission of external noise into the residential unit.

5. The circumstances involve either:

    A) a resident with a health condition aggravated by consistent exposure to Project construction noise that is substantiated fully in writing by a physician,

B) a fully demonstrated hardship situation associated with consistent exposure to Project construction noise, and this may involve an infant, a house-bound person, or like circumstance, or

C) a situation where Project Noise Engineers have determined using standard assessment methods involving field measurements, computer modeling, and alternative analysis that window treatment is or will be necessary as part of the noise mitigation strategy for the particular location.

MITIGATION MEASURES

1. Mitigation is limited to bedroom windows, unless a relevant health condition is documented by a physician, a specific hardship condition exists, or the residence is configured in such a way that other windows that face Project construction must be considered to protect the bedroom environment.

2. The mitigation measures approved by the stakeholders will be based on site-specific noise conditions, the type and performance of existing windows, and historic building requirements. Possible measures include:

- Fixed or operable interior glazed storm sash (primary consideration; possibly combined with window or glass replacement);
- Fixed or operable replacement window with double pane glass;
- Replacement of single pane glass with double pane glass (considered for historic windows); and/or
- Sliding glass storm door

Performance Goal: The performance goal for window sound-proofing will be to provide an incremental noise reduction improvement of at least 10 dBA and an overall noise reduction of at least 35 dBA through the treated window system.

3. The Project stakeholders will track and document the reasons for the recommended mitigation measures and the associated costs, along with the eventual decision of the stakeholders.

4. A right-of-entry and written acceptance of the mitigation measures must be received from the resident, building owner, and authorized managing agent (if any) prior to installation of window treatments.

5. All approved mitigation measures are to be provided by the Project. Reimbursement of outside expenses incurred by residents is hereby declared to be contrary to this Policy and is prohibited.

6. The cost of any window treatment mitigation measure performed under this Policy shall be consistent with industry standards involving union labor and the

furnishing of all supplies and materials to complete the necessary window treatment. This is expected not to exceed $800 per interior storm sash, $2,500 per window replacement, and $5,000 per residence.

3 Swiss Standard SN 640312a

This vibration standard, issued by the Swiss Association of Road and Traffic Experts (VSS), offers insight into how contractors have approached the problem of vibration in highly sensitive physical structures such as historic buildings. Another useful document on this subject, and one frequently utilized to address the effects of construction vibration on humans, is the Acoustical Society of America's "Guide to the Evaluation of Human Exposure to Vibration in Buildings"[5].

VIBRATIONS

The effects of vibrations on buildings

A. General

1. Scope

This standard applies to vibrations that have an effect on buildings and are caused by:
-explosions;
-all types of machines and construction equipment; and/or
-road vehicles and trams

It does not apply to vibrations caused by:
-people (disturbance);
-any machines, apparatus, installations, or other particularly sensitive components and stored goods contained within the buildings; or
-the ground (subsidence, ground liquefaction etc.).

It does not apply to vibrations with a frequency below 8 Hz, such as are found during earthquakes. Vibrations below 8 Hz must be given special attention.

2. Object

This standard contains:
-Criteria for evaluating the effects of vibrations on buildings;
-Reference values which, when adhered to, generally mean that there will be no structural damage;
-Recommendations for the execution and analysis of vibration measurements; and
-Recommendations for crack surveillance and the evaluation thereof.

3. Aim

[5] "Guide to the Evaluation of Human Exposure to Vibration in Buildings". Acoustical Society of America. American National Standard Institute (ANSI) Standard No. ANSI S3.29-1983. New York, NY. April 1983.

Adhering to the reference values will normally avoid damage to buildings as a result of vibrations.
Damage to buildings can also arise from subsidence and other distortions. Their effects cannot be ascertained through vibration measurements and are consequently not the object of this standard.

4. Evaluation criteria

The decisive factor in evaluating the damaging effects of vibrations is the maximum value of the velocity vector V_R [mm s^1], allowing for the vibration frequency [Hz] and the frequency of the occurrence.

5. Subjective evaluation

People can judge vibrations to be strong or a disturbance, even if they cause no structural damage. With the simultaneous perception of noise (explosions, digging, traffic noise etc.), the strength of vibrations is often overestimated.

Consequently, the subjective evaluation of vibrations is not a reliable measure for evaluating the effect of vibrations on buildings.

6. The effect of vibrations

The vibration of buildings.
The vibrations transmitted through a building cause those elements of the building sensitive to vibration to vibrate (pillars, columns, beams, girders, floors, walls etc.) If the resonance frequencies (fundamental frequency and overtones) fall into the vibration wave band due to weakly damped building components, the resonance effects can result in significant vibration amplitude. The resonance frequency of building components lies predominantly between 10 and 60 Hz. Consequently, vibrations with a dominant frequency of around less than 60 can pose a threat to buildings, and in particular a frequency of less than 30 can cause problems.

Dynamic tensions.
Vibrations generate dynamic tensions. Damage occurs when the dynamic tensions, together with the existing tensions, exceed the resistance and the endurance strength of the material.

Frequency of occurrence.
The likelihood of damage increases with each exposure to strain.

Transmission of vibrations through the ground.
As a rule, the ground has an absorbent effect on the transmission of vibrations. Soft ground predominantly carries low frequency vibrations; hard ground carries high frequencies.

The measurement of building vibrations includes the influence that the building foundation has on the vibration.

B. Reference values

7. Gradation of the reference values

As shown in Table 3, the reference values depend on how sensitive the building is to vibrations, the frequency of exposure and the determining frequency of the vibrations. The reference values for averagely sensitive buildings (class 3) are provided in the table. For the other sensitivity ranges (classes 1, 2 and 4), a margin is given within which the reference values should take into account the condition of the building.

8. Sensitivity ranges of buildings

There are four distinct sensitivity classes:
(1) a little sensitive;
(2) somewhat sensitive;
(3) averagely sensitive; and
(4) particularly sensitive.

The deciding factor is the sensitivity of the building components. It is determined by the means of construction, the building materials used, as well as by the structural condition of the building.
Building components with plaster and cement cladding, along with weakly attached secondary building materials and fittings are considerably more sensitive to vibrations than unplastered brick and reinforced concrete components.

Contact zones between different construction materials are particularly sensitive.

9. Frequency of exposure

Vibrations are divided into three classes according to how often a building is exposed to vibrations during the assessment period:
(1) occasionally: Rate of exposure is considerably less than 1,000;
(2) frequently; and
(3) permanently: Rate of exposure is considerably more than 100,000.
A single exposure is termed as each time the maximum value of the velocity vector exceeds the reference value by 0.7. The assessment period is understood to be the time during which the building is subjected to studied vibrations.

10. Frequency range

Within this standard, there are three frequency ranges:
(1) 8 to 30 Hz;
(2) 30 to 60 Hz; and

(3) 60 to 150 Hz.
The determining frequency is calculated using the strongest vibration component, within a margin of +/- 10%.

11. Tables

Table 1. Sensitivity ranges.

Sensitivity ranges	Building construction	Civil engineering
(1) a little sensitive		-Bridges in steel or reinforced concrete -Steel, concrete or compact brickwork supporting structures -Lugs, tunnels, caverns, shafts in solid rock or well-reinforced soil -Crane and machine foundations
(2) somewhat sensitive	-Industrial and trade buildings in reinforced concrete or steel structure, generally without plaster -Silos, towers, factory chimneys without plaster or a steel structure -Lattice towers -Condition: The buildings are built and maintained according to the general building regulations	-Underground caverns, tunnels, shafts, piping -Subterranean parking areas -Underground piping (gas, water, sewage system, cable) -Dry stone walls
(3) averagely sensitive	-Housing in concrete, reinforced concrete or brick -Office buildings, schools, hospitals, churches with natural stone or roughcast brickwork with plaster -Condition: The buildings are built and maintained according to the general building regulations	-Spring tapping -Reservoirs -Cast-iron piping -Caverns, intermediate ceilings and carriageway ceilings in tunnels -Sensitive cables
(4) particularly sensitive	-Houses with plaster or roughcast plaster ceilings -Half-timbered buildings -Newly-built and recently renovated buildings in class (3) -Historic and protected buildings	-Old lead cables -Old cast-iron piping

Table 2. Frequency of exposure and vibration sources

Frequency range	Rate of exposure	Typical vibration sources
Occasionally	Considerably less than 1000	-Vibrations -Compression machines and vibratory pile drivers, if the significant vibrations only occur during the start-up or shutdown of the machine
Frequently		-Frequent vibrations -Pile hammers and vibratory pile drivers -Compression machines -Pneumatic drills, if only used occasionally -Emergency power groups that are frequently put into operation
Permanently	Considerably greater than 100 000	-Traffic -Fixed machines -Pneumatic drills, when used for long periods

Table 3. Reference values

Sensitivity range	Frequency range	Maximum value of the velocity vector V_R [mm · s ^{1}] Determining frequency <30 Hz* 30-60 Hz >60 Hz**
(1) a little sensitive	Occasionally Frequently Permanently	Reference values: Up to 3 times the values corresponding to sensitivity class (3)
(2) somewhat sensitive	Occasionally Frequently Permanently	Reference values: Up to twice the values corresponding to sensitivity class (3)
(3) averagely sensitive	 Occasionally Frequently Permanently	**<30 Hz 30-60 Hz >60 Hz** 15 20 30 [mm · s ^{1}] 6 8 12 [mm · s ^{1}] 3 4 6 [mm · s ^{1}]
(4) particularly sensitive	Occasionally Frequently Permanently	Reference values: Between the reference values of class (3) and the half of those values

* For frequencies below 8 Hz, lower reference values must be applied.
** For frequencies above 150 Hz, higher reference values can be applied.

12. Application of the reference values

The value of the velocity vector is to be determined through measurements.

- For values below the reference values, a small amount of damage is unlikely. Isolated instances of exceeding the reference values by up to 30% only marginally increase the probability of damage.
- Values that are up to double the reference value mean that damage is likely.
- Continuous cracks are only to be expected where values are several times the reference values.
- In special circumstances, an expert should be consulted. He/she can, in particular cases, set higher or lower reference values.

C. Carrying out the vibration measurements

13. Principles

Since the vibrations can vary greatly in different areas of the building, the initial measurements ought to be taken simultaneously in several places.

The subsequent permanent surveillance can then be reduced to the most critical areas. In order to determine the maximum value of the velocity vector, the three perpendicular components must be measured at each measuring point

14. Measuring position and attaching the sensors

Choosing an appropriate measuring position and connecting the sensor to the load-bearing structure correctly are critical conditions for obtaining usable measurement results.

Position:

-Measuring positions should be chosen from the rigid, load-bearing parts of the structure, where the determining effects of the vibrations are expected.

-For ceiling panels, however, measurements should be taken at the peripheral rim.

-For vibrations with determining frequencies higher than 60Hz, the measuring points should be chosen primarily on the foundation walls.

Attachment:

-For an acceleration of more than 3 $m \cdot s^2$, the sensors must be fixed securely to the building components. For an acceleration of less than 3 $m \cdot s^2$, it is acceptable to position the sensor unsecured. Accelerations of 3 $m \cdot s^2$ are reached by the following (sinusoidal) oscillation speeds and frequencies:

- 25 $mm \cdot s^{1}$ at 20 Hz
- 12 $mm \cdot s^{1}$ at 40 Hz
- 8 $mm \cdot s^{1}$ at 60 Hz

- Unsuitable measuring positions are: Exposed, peeling coatings or wall plaster, rickety windowsills, floating screed, carpets etc.

15. Demands on the measuring equipment

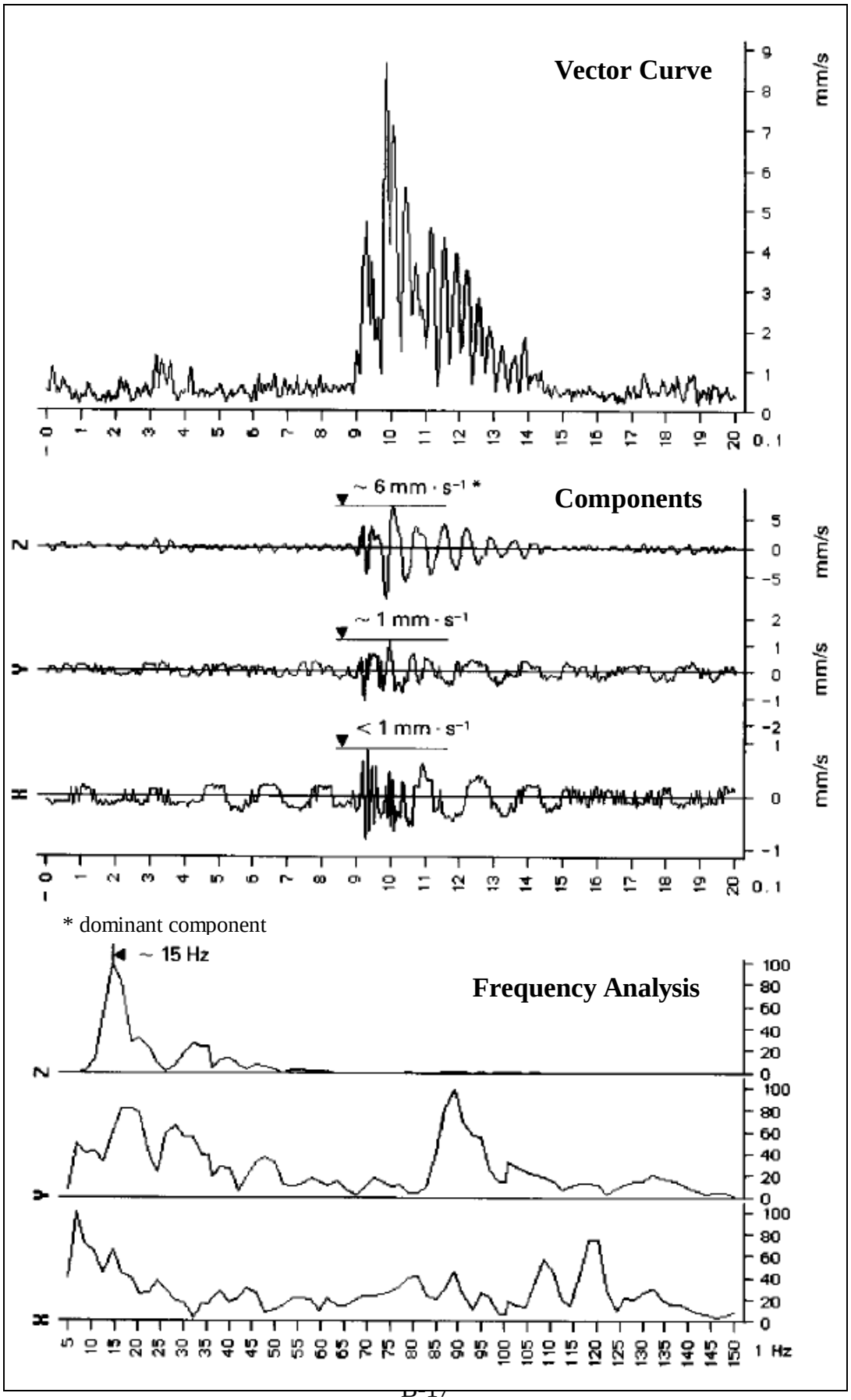
Within buildings with a determining frequency range of 5 to 150 Hz, the measuring equipment (sensors und measurement amplifiers) must ensure the following:
-Storage or a graphic recording of the oscillation speed values of the vector and its three components during the operation time.
-Establishment of the determining frequency.
The efficient working order of the measuring equipment should be checked periodically. The equipment calibration must be clearly displayed in a test report. In certain cases, the entire measurement chain must be mechanically or electrically calibrated in situ before and after each measurement operation.

16. Analysis

The reference values in Table 3 correspond to the maximum value of the velocity vector. The determining factor is the critical combination of the maximum value of the velocity vector V_R and the frequency of the dominating components at a given time. In this way, the entire vibration process can be considered.

Example:
Duration of vibration (displayed as vector V_R, components Z, Y, X; determining: V_R max. = 8,5 mm s^1, Z-component has the lowest frequency, around 15 Hz)

Auwil, vibration as a result of road works
20.11.1991, 8:36
Measuring point: 1st floor ceiling


Vector Curve
mm/s
Components
~ 6 mm · s⁻¹ *
~ 1 mm · s⁻¹
< 1 mm · s⁻¹
Z
N
H
mm/s
0.1
* dominant component
~ 15 Hz
Frequency Analysis
1 Hz

17. Presentation of results (protocol)

The measurement protocol must contain all of the metrological information: particularly the time and date of the measuring; a description of the place and nature of the vibration source; the measuring equipment; the position of the measuring points; the direction of the components and a description of the building.

D. Cracks and the protocol for cracks

18. Describing cracks

Buildings constructed from non-metallic materials are almost never without cracks. The following information refers only to cracks that are visible to the naked eye from a distance of 1m. These will have a minimum width of 0.05mm.

Regarding the penetration depth of cracks, the following distinctions are made:

-Surface cracks
They cover a marginal part of the building's cross-sectional area; at worst they affect the aesthetic of the building, but they are not generally a threat to a building's serviceability, durability or stability.

-Continuous cracks
They can affect the serviceability of the building.

Cracks can be described as follows:

Description	Width
Fine cracks	<_ 0.2 mm
Medium cracks	0.2mm … 1mm
Wide cracks	1mm … 3mm
Gaping cracks	>_ 3mm
Continuous cracks	

19. Crack development

Construction period:
During the building process and during the period when building materials bond, cracks can appear (contraction, shrinkage, creepage, expansion due to temperature changes or hydration warmth etc).
External temperature changes (such as frost) also cause every building to exhibit cracks some time after its construction or reparation. The absolute number of cracks increases with time.
In general, the following crack widths are deemed admissible in terms of aesthetics and durability:

-raised aesthetic demands 0.1 mm
-external building components affected by environmental factors 0.2mm
-external building components unaffected by environment factors 0.3mm
-internal building components 0.4 mm

Deterioration:

Over the course of time, the following causes of cracks have an effect on buildings:
-Temperature changes;
-Shrinkage;
-Chemical transformations;
-Physical and biological attacks;
-Abrasion, attrition;
-Load-dependent deformations;
-Ground subsidence; and
-Rebuilding, etc.

In general, the yearly growth rate of cracks decreases as the building ages, where the bearing capacity of the building components has not been weakened.

20. An increase in cracks during vibrations

The stresses to which a building is subjected during vibrations with velocity values not significantly exceeding the appropriate reference value are low. In these cases, new cracks can appear where the existing tensions (including shrinkage and static pressure etc.) are so great that the additional weak dynamic tension is sufficient to create or increase cracks. Cracks that have appeared as a result of low-level vibration effects would most likely have appeared eventually (after months or years). Thus, crack formation as a result of vibrations can be seen partially as an acceleration of a pre-existing crack formation process. This is a relevant point to consider during the damage assessment process. Cracks appearing during vibrations only differ in exceptional cases from standard tension cracks; “typical” vibration cracks do not exist.

21. Protocol for cracks

Recording and carrying out careful crack surveillance can help to monitor the quantity, length and width of pre-existing cracks and cracks that have appeared within a given time frame (surface and continuous cracks). It is advisable for the protocol for cracks to be assimilated in a contradictory manner.
In highly urbanised areas, it may be sensible to abandon crack surveillance if vibrations are subject to ongoing monitoring through sufficient measuring; and also if the approved vibration levels are significantly less than those attributed to the corresponding building material as stated in this standard (see Table 3).

Editor:
Swiss Association of Road and Traffic Experts (VSS)

Seefeldstrasse 9, 8008 Zürich Seefeldstrasse 9, 8008 Zurich
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