inter-noise 2009
innovations in practical noise control
2009 August 23-26
Ottawa, Canada

Soundscape design applications for industrial noise

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ABSTRACT

Four case studies are presented that demonstrate soundscape methods for assessing noise impacts and proposed mitigation strategies for industrial noise impacts. One is the expansion of a large cement plant located in a rural area. Year long monitoring of the soundscape was required by a local government agency. Effort to demonstrate that the cement plant sounds were below the existing ambient levels was required. Second is a case study of noise impacts and mitigation strategies for a rail car repair facility that adjoined a small residential neighborhood. Soundscape methods were used to advise the client of the necessity for specific noise mitigation interventions to meet local noise ordinance requirements. Third is a case study for a proposed residential neighborhood that would adjoin a plastics plant in land zoned for industrial uses. Soundscape analysis was used to illustrate how conventional noise mitigation and analysis techniques could not adequately reduce impact sounds associated with the facility. Fourth is the use of soundscape analysis to assist in evaluating noise mitigation designs for a series of generators used by a utility company.

1. INTRODUCTION

This paper presents a comparison among various soundscape studies conducted in the United States on the topic of industrial noise. The concept of *soundscape* or *acoustic landscap*e was

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presented in a series of studies at Simon Fraser University by *Murray Schafer*[1] in the 1960's. Since then, *Barry Truax*[2] amongst others have developed the concept further. However, there is little evidence of its application and adoption in the field of urban planning and noise mitigation design in North America. Schafer divides the soundscape into three categories: *keynote sounds*, *signals* and *soundmarks*. Keynotes are the sounds that are often referred to as the background or ambient sounds. They may be listened to sub-consciously, are often associated with sounds created by nature, such as animal and insect sounds, and weather related noise (rain, wind, snow, etc). Being referred to as climatic and geographic referents, keynote sounds of the *urbanscape* such as intensely layered vehicular and occupational noises associated with a condensed human population in a relatively small horizontal area are also included in this category. In a similar way, the sounds which characterize the *ruralscape*, such as of the plains and forest, and lastly, the *ex-urbanscape* or sub-urban sounds, such as slow to medium traffic flow on sprawling roads, landscaping machinery and air conditioning condensers on residential properties. Keynotes can be thought of as the ground, in a figure-ground relationship. Sound signals are distinctive sounds, which jump to the foreground, for example warning devices, such as screaming, whistles, or sirens. Soundmarks are sounds of cultural significance and are referential to a specific locale, they can be referred to as acoustic landmarks. An example might be a bell tower on a university campus, or a fog horn in a coastal community. There is some overlap among these categories, for example a bolt of lightning is a weather - related sound, but also warns of a thunderstorm, and may be a sound characteristic of places such as the Southern states of America holding some cultural significance in terms of place - making.

For the purposes of this paper, a specific acoustic event is the sound caused by a specific action in a point in space and time. It could be the wind blowing through the tree leaves, a motorbike or airplane passing by, children playing a game, a gun shot, a running compressor, the sound of a spoon clinking against cup etc. An important concept in evaluating the soundscape of a specific locale is that the ambient sounds are composed of a collage of specific acoustic events that must each be measured, evaluated and perceived. It is not a long term average of all the sounds, but rather the distinctive combination of all time variant sources of sounds much like the musical composition of a symphony played by a live orchestra.

2. CASE STUDIES

The following case studies are from industrial projects which demonstrate the specificity, in the nature of, and significance of, soundscape analysis and its place in design. The issues of acoustical adjacencies in terms of urban planning and the possibility of soundscape enactment, also play a significant role in the following examples.

A. Case Study One: The Expansion of a Large Cement Plant Located in a Rural Area

Case study one illustrates the concept of identifying the source of interest by carefully defining all that it is not. A large cement plant in a rural area was applying to a local government agency to expand its cement production by building a second cement plant next to an existing one. The cement plant was surrounded by over 1,600 acres of wooded buffer space between it and the nearest homes and adjoining property lines. The rural area surrounding the cement plant site was interspersed with small parcels of residential development, some of which could be found along the periphery of the plant's property line. A series of acoustical measurements were taken over a period of a year, in quarterly increments. These sound measurements were taken at six locations near residential neighborhoods and along the nearest property boundaries surrounding the plant site.

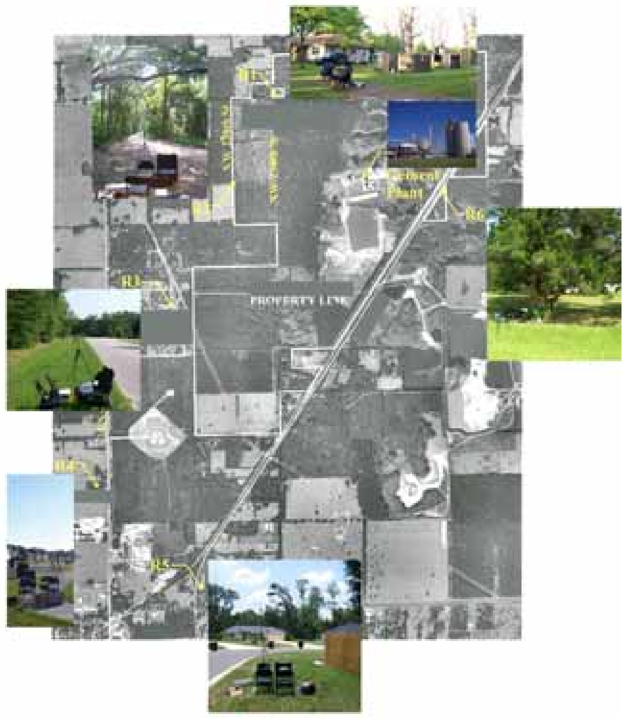

Figure 1: Map showing locations of measurement locations (R1-R6) in relation to the cement plant, and some photographic images of each site location.

Focus group discussions were held with cement plant staff, city officials and residents to identify acoustical issues and critical locations where monitoring should occur. These groups mentioned low frequency sounds propagating late at night especially under temperature inversion conditions. As a result of these discussions, the cement plant developed a comprehensive agenda for a noise management plan for both the new and existing facility and implemented major components of the plan on the existing facility.

Extremely concise and thorough notes were taken for each sound measurement by consultants attending the meters, noting the time and type of each specific acoustic event that occurred. An example of a specific acoustic event might be a vehicle passing on roads in the distance, birds chirping, wind blowing in the trees.

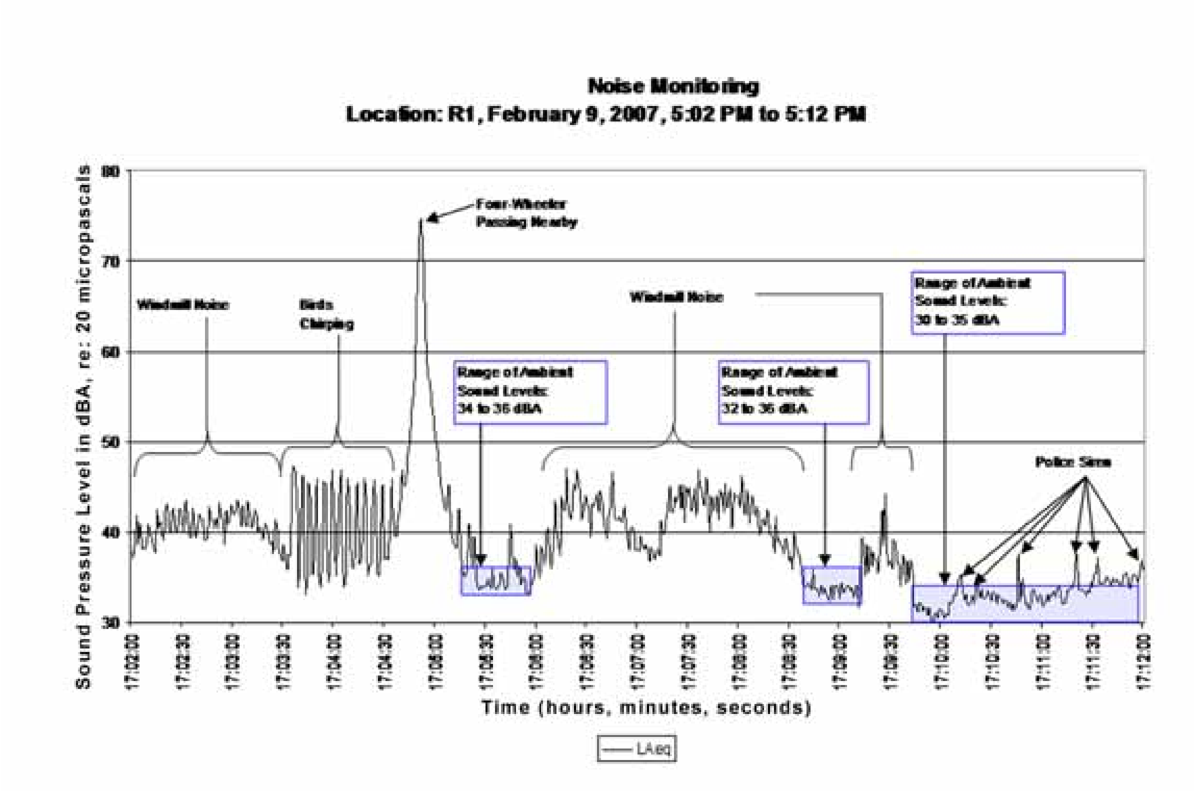

Figure 2: Graph showing the advantage of detailed note taking along with sound level measurements for clarity of presentation and analysis of specific acoustic events at location R1.

There was also a reference sound level meter located approximately 250 ft from the existing cement production line that showed a relatively constant noise level of approximately 78 to 80 dBA produced by the cement plant. Yet as the measurement locations moved further away from the source and into the residential neighborhoods, the graphs showed distinct acoustical events of 33 to 48 dBA with 1 loud event at 74 dBA, with a residential sound level of 30 to 33 dBA. If one were to try to interpret the graphs without having attended meters or listening to .wav files recorded of the data, one might think that the ambient noise consisted of “quiet” background noise of 30 dBA or less, and the spikes were evidence of noises related to the cement plant operations. The findings showed an opposite scenario. The residential noise level of approximately 30 to 33 dBA or less characterized the noise generated by the cement plant. The spikes indicating a series of specific acoustic events with sound levels of approximately 43 dBA to approximately 70 dBA were associated with sound sources usually considered to be ‘ambient noise’ including a 4 wheel ATV passing by, the turning of a small windmill in the garden of a house, birds chirping in trees, a police siren and cars on roads in the distance.

The development stipulation required sound levels produced by the addition of the second concrete plant to be less than 60 dBA at all points within the City limit. The County noise ordinance allowed up to 75 dBA noise transmitted to or from agriculturally-zoned land which most of the residential properties in the area were zoned and 61 dBA for daytime hours (7am until 10 pm) or 55 dBA for nighttime hours (10pm until 7am) transmitted to residentially-zoned property. The analysis of the data showed that the specific acoustic events typically called “ambient sounds” made up the foreground of the acoustic landscape at all locations. Coding of the data recorded over the year of monitoring showed that transportation noise including cars and trucks on near by roads, ATV’s and tractors near the monitoring equipment, planes flying overhead and trains varied from 48 to 75 dBA or higher; typical ambient sounds of cars on distant roads, trains in the distance, birds in the trees, wind blowing in the trees and residents air-conditioning units varied from 35 to 48 dBA. The only aural and physical measurement evidence of cement plant sounds only occurred when all of the typical ambient sounds were silent and levels of 30-33 dBA or less occurred when plant sounds were faintly audible at some times within the residual ambient of distant traffic, wind in the trees and other sounds of the rural soundscape.

B. Case Study Two: Noise Impacts and Mitigation Strategies for an Open Air Rail Car Repair Facility and Small Adjoining Residential Neighborhood

An open air rail car repair facility was a pre-existing business in an industrial zone. Single family residences were built on non-conforming land directly across a small street from the repair facility. The two building typologies had co-existed for a period of time because workers from the rail car repair facility lived in the houses. However, as new families moved into the street, they were less tolerant of the noise generated by the repair shop and eventually complained of the noise to County officials.

Discussions were held with City staff, train repair staff and counsel and residents to determine appropriate measurement locations, identify acoustical concerns and develop possible mitigation strategies. A series of acoustical experiments were designed to simulate each of the activities undertaken in the facility during typical days. Sound levels for each activity were measured at key locations to determine specific operations that caused the greatest number and magnitude of violations.

Figure 3: Photographic images of the open air rail car repair facility.

Much of the work at the rail car repair facility consisted of loud impacts of workers “banging out” dented rail cars with 20 pound sledge hammers, the use of large impact tools, riveting machines, etc. Peak sound levels of 102 dBA from large numbers of impacts were recorded at the residential property line with relatively steady noise levels of 60 to 76 dBA. The characteristic sound of the somewhat intermittent yet repetitive hammering of metal, and the operation of light industrial machinery reverberating through the metal roofed open air “sheds” and into the adjacent residential area. A computer model was built to estimate sound levels after completely closing in the existing structure, constructing a noise barrier wall along the property line, and providing noise mitigation upgrades to the residences.

Table 1. Summary of Sound Propagation Model calibration measurements

Source	Source Location	Receiver Location	Measured Sound Level	Modeled Sound Level	Difference: Model - Measured
10 lb Hammer	S5	R3	82 dBA	83 dBA	+1
10 lb Hammer	S5	R2	72 dBA	73 dBA	+1
Hog Grinder	S4	R3	65 dBA	67 dBA	+2
Hog Grinder	S4	R2	70 dBA	70 dBA	0
Needle Scaler	S2	R1	73 dBA	75 dBA	+2
Hog Grinder	S3	R1	71 dBA	72 dBA	+1

Thus, the recommendations made focused on noise mitigation either by blocking the sound paths between the noise source and the houses by building a superstructure around the metal building to enclose the building which would reduce the sound levels by 40 to 45dB, with a resulting estimated sound level of <55 dB at the property line. The purchase of the residential properties across the road from the facility and relocation of residents was also investigated as a possible method to solve the problem.

C. Case Study Three: A Proposed Residential Neighborhood Adjoining a Plastics Plant in Land Zoned for Industrial Use

An existing plastics plant was located on industrially–zoned property. The building was fully closed on all sides except for large doors at the loading dock for the facility was located near the property line.

Figure 4: Photographic image of the plastics plant showing the adjacency from the truck loading docks to the property line fence of the proposed new residences.

A developer was seeking to purchase the neighboring land to change its zoned use from industrial to residential, so a large number of single family detached homes could be built on the site. According to local ordinances, the sound level limit was an instantaneous Lmax of 60 dBA during the day, and 55 dBA at night for residential properties. Whereas, sounds propagated from industrial property to industrial property could be 75 dBA with a relatively low probability of noise related complaints from an industrial neighbor.

The noise issues of concern to the plastics plant were not so much due to the internal processes and machinery of the plastics plant, but rather the maneuvering, and unloading of semi-trucks at the loading bays on the exterior of the building. Sound levels recorded at the shared property line dividing the proposed residential development and the industrial plant were measured at 95 dBA.

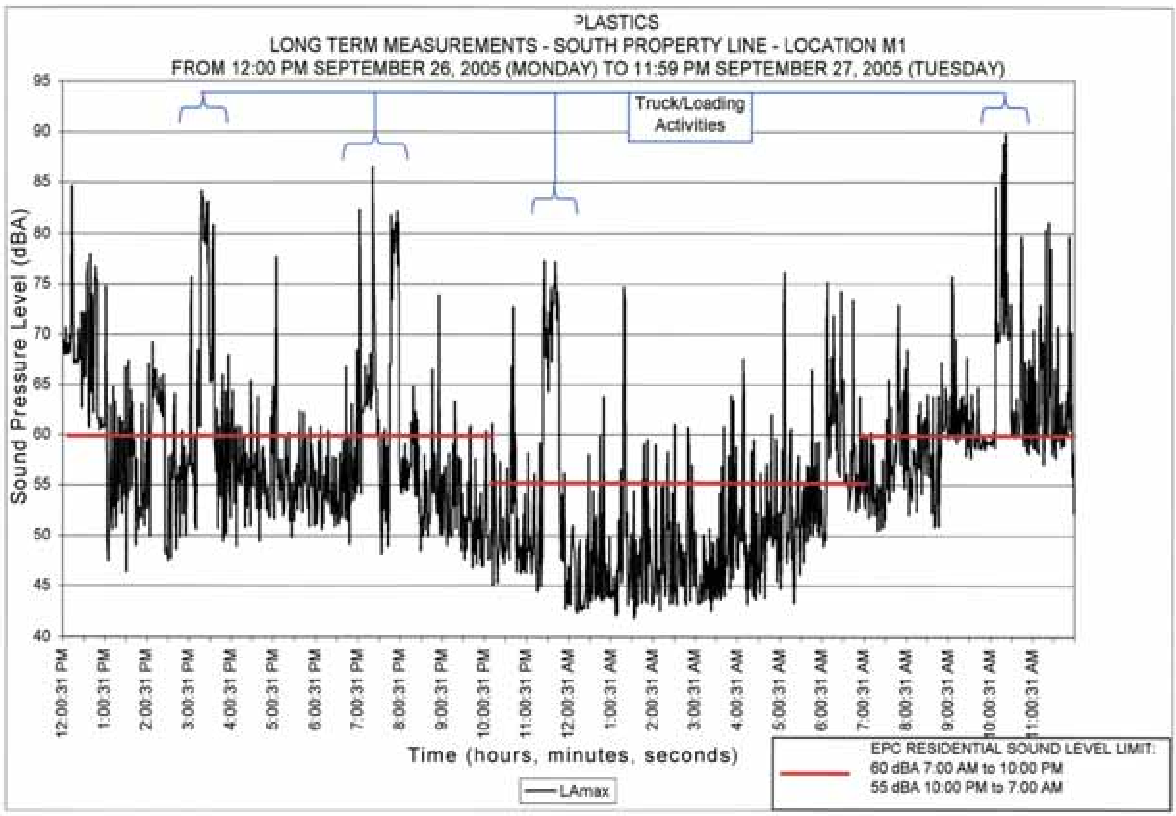

Figure 5: Graph showing the sound levels of specific truck related noises and loading activities as compared with the EPC residential sound limit (Control of Noise at Construction Sites).

Even a 20 foot plus tall noise barrier wall along the property line would be insufficient to reduce the characteristic impact sounds associated with such vehicles, which include sharp bursts of air brakes, impacts of fork lifts driving over metal ramps, impact sounds of pallets of piping being dropped in place, a piercing rhythmic mid to high frequency beeping sound as the truck is placed into reverse gear, and the low frequency rumble of the engine as it idles or revs up. It was recommended that the application to change the zoning classification be denied because there would be significant noise disturbances from a series of specific acoustic events that occurred at the loading dock that could not be reduced to reasonable or required residential sound level limits. Severe restrictions on normal industrial operations would be required to achieve a soundscape compatible with normal residential living.

D. Case Study Four: Role of Ambient Sound Levels in Establishing a Design Criteria in Evaluating Noise Mitigation Designs for a Series of Generators Used By a Utility Company

Noise from the testing of an emergency generator at a utility company located along a busy road in a predominantly commercial area was compatible with adjacent land uses until an apartment building was constructed across the street from the generator room. After a hurricane event forced the emergency generators to operate continuously for several weeks, complaints were made by the apartment building residences and the utility company was cited by local code enforcement officers. The utility company was required to reduce the emergency generator noise to comply with the local noise ordinance sound level limits for residential adjacencies of 55 dBA during the day and 50 dBA at night at the receiver property line.


Figure 6: Some photographic images of the emergency generation plant building in proximity to the multi-level condominium building.

Acoustical measurements made at the site prior to developing noise mitigation strategies included short term measurements of specific acoustical events and long term measurements of sound levels over a one week period. The data showed that ambient sound levels on grade at the site were generally in the 53 to 57 dBA range during the daytime and in the 52 to 54 dBA range during the nighttime, with only very brief excursions below 50 dBA. Ambient sound levels actually increased to as high as 65 dBA as one moved up the face of the apartment building to the upper balconies, due to a more direct line of site exposure to a wider range of sounds from the surrounding streets and buildings as well as a direct line of site to a cooling tower on the roof of the utility company building.

A design criterion of 50 to 55 dBA was established with the understanding that it may not be possible to actually measure sounds as low as 50 dBA due to the elevated ambient sound levels. Sound levels along the face of the apartment building prior to renovations were in the 69 to 73 dBA range due to the operation of the generator. After the acoustical renovation, sound levels were measured as low as 52 dBA on grade, controlled primarily by the ambient sound levels. The specific contribution of the emergency generator could not be precisely determined due to the presence of the ambient sounds.

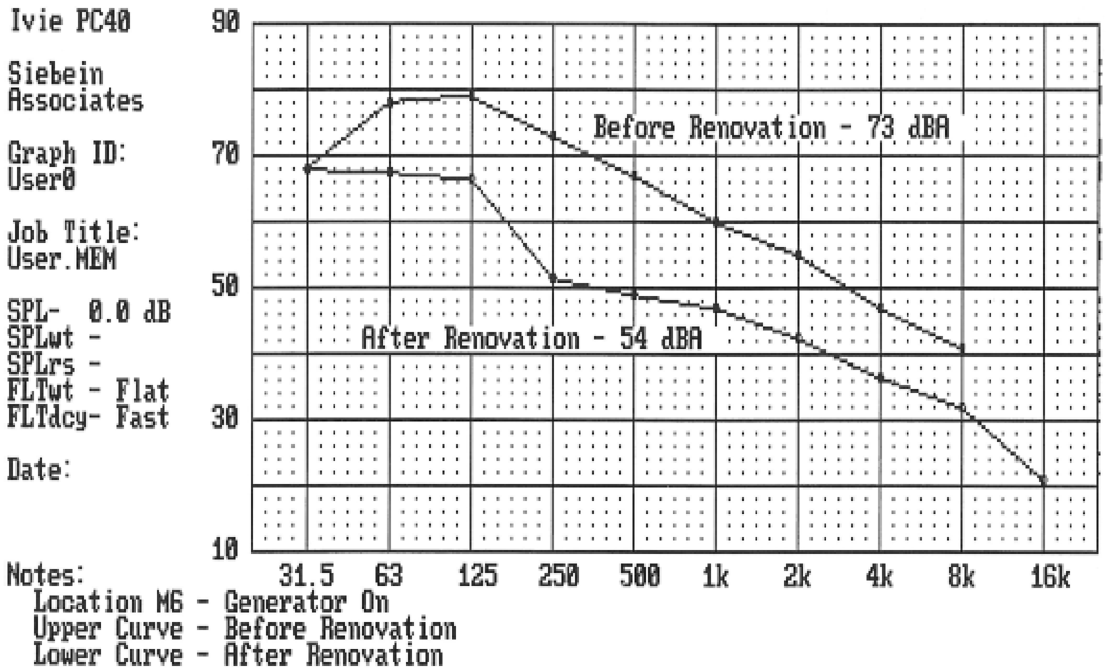

Figure 7: Graph showing sound levels recorded at the ground level of the property line of the residential apartment building, before and after the renovation of the power generation plant building.

3. CONCLUSIONS

The issues associated with industrial noise mitigation are multifarious and problematic when zoned in close proximity to residential areas. Each community has a unique acoustical landscape, or soundscape, which must be assessed in a qualitative and a quantitative method. From this soundscape analysis, practical data can be acquired and analyzed, and an intervention to address the noise issue can be designed specifically for the acoustical criteria of the area. The concept of evaluating both the ambient sound or keynotes and the industrial noise sources as specific acoustic events coupled with the perceptual identification of individual sounds composing the combined ambient plus industrial soundscape were key elements in measuring, evaluating predicting and simulating practicable noise management options and ultimately the design of effective noise mitigation systems to maintain or improve the acoustical quality of each soundscape were essential elements of each case study.

4. ACKNOWLEDGMENTS

We gratefully acknowledge all past and present staff members of Siebein Associates Inc, who contributed to the work showcased in this paper, including Gary Siebein Jr., Lana Cheshire, and Reece Skelton.

5. REFERENCES

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[2]Barry Truax, "Acoustic Communication" (Greenwood Publishing Group, CT 2001).