North East False Creek High Level Review
Entertainment & Transportation Noise Study

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Executive Summary

The proposed project will involve the construction of residential and commercial towers, Creekside Park and an outdoor performance venue in the North East False Creek (NEFC) area. There are existing and future residential land uses that may be impacted by noise from the project.

BKL Consultants has developed a 3D computer model of the study area, including residences in City Gate and South East False Creek (SEFC) for the purposes of predicting road and SkyTrain traffic noise levels and event noise levels from BC Place, GM Place and the new outdoor Performance Space for 3 scenarios. The software used is Cadna/A version 3.7, implementing internationally recognised calculation standards.

The criteria used in the evaluation were:

- the City's Zoning and Development By-law, Section 4.15 "Acoustics" which references Canadian Mortgage and Housing Corporation (CMHC) criteria;
- the City's Noise Control By-law No. 6555; and
- the World Health Organisation's (WHO) guideline to assess sleep disturbance.

One of the main findings was that standard acoustical design for new residential towers in the project area would be adequate if the entertainment noise sources meet the Noise Control By-law. If they are permitted to exceed the by-law limits, special consideration will need to be made in the design stage in order to meet the $L_{eq}24$ 35 dBA requirement for bedrooms. Single-loaded towers or enclosed balconies may be required for the nearest developments, but in all cases the 35 dBA criterion can be met with noise isolation design strategies that have been used in the past on other noise exposed projects.

It was predicted that the Noise Control By-law limits would be significantly exceeded at many residential suites if concert or sporting events are held with the proposed new BC Place roof in the open configuration. This situation would generally occur for suites elevated above and facing the roof within 300 m, but also likely at the closest Olympic Village towers because of the lower background noise levels. Closing the roof would reduce the subjective loudness of the noise by almost 50% at the loudest locations, but concert noise would still likely be above the daytime by-law limit for those suites within 300 m. A background noise measurement survey would better assist with estimating potential by-law exceedances. The Performance Space may exceed the daytime by-law limits at residential towers within 200 m and GM Place might only exceed the nighttime by-law limits at the nearest existing residential tower and proposed hotel to the south.

The Noise Control By-law could be revised to allow higher levels of noise for infrequent events throughout the City, relative to the background noise level at that location, based on similar by-laws and standards developed elsewhere (e.g. UK). This approach may be more appropriate than allowing an uncontrolled noise level for a certain number of events per year per venue.

Sleep disturbance can be avoided by limiting the hours of operation for BC Place and the Performance Space to daytime hours. Alternatively, closing the BC Place roof may mitigate its noise impact sufficiently for nighttime sporting events but not for concert events. It is our understanding that Deer Lake Park (Burnaby) concerts are not permitted to continue past 10:00 pm.

Detailed acoustical design work will be essential to provide an acceptable outdoor Performance Space. Without proper attention to the acoustical issues, there is a high chance for poor sound quality within the space and significant noise impacts in both the immediate neighbourhood and communities across False Creek such as Olympic Village and City Gate if pop/rock concerts are permitted. Design options that may mitigate some noise issues could exacerbate others unless proper details are developed.

All Performance Space location options presently have high ambient noise predictions. All locations have the potential to be reduced to acceptable levels but it is still assumed that all events will require an amplification system to obtain a suitable signal-to-noise ratio. There is no significant acoustical reason to choose one option over another at this point.

It should be noted that music "noise" is expected to be subjectively interpreted as more annoying than more neutral noises, such as road traffic, of the same decibel level because of the "message" contained within the music and tones that are harder for the brain to ignore. Therefore, it is difficult to assess the amount of annoyance that the open roof of BC Place and the new Performance Space could create, regardless of whether criteria are met.

For the new residential towers, it may be assumed that residents moving in would be aware that they are moving into a busy downtown area (activity zone) with nearby entertainment facilities, but a noise covenant would be more protective, as mentioned in the Brown Strachan report (Brown Strachan 2008), and is recommended.

This report has only addressed acoustical considerations. Also, while this is a high-level study, it should be noted that the model developed can be refined further in order to perform detailed analyses as more detailed design information comes available.

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1.0 Introduction

The proposed project will involve the construction of residential and commercial towers, Creekside Park and an outdoor performance venue in the North East False Creek (NEFC) area. There are existing and future residential land uses that may be impacted by the project.

The objectives of this high-level noise study undertaken by BKL Consultants Ltd. are to:

- develop a computer model of the study area, including residences in City Gate and South East False Creek (SEFC);
- predict road and SkyTrain traffic noise levels and event noise levels from BC Place, GM Place and the new outdoor Performance Space for 3 scenarios;
- determine which scenario is preferred from a noise perspective;
- assess whether compatible adjacent residential land uses are achievable using the City's Zoning and Development By-law and Noise Control By-law;
- recommend criteria that should be used if these by-laws are inadequate; and to
- comment on mitigation techniques that should be investigated to control the noise generation from the outdoor Performance Space.

Previous studies were performed recently to assess the viability of new residential near GM Place (BKL, 2006) and BC Place (Brown Strachan, 2008). A recent study on the Performance Space commented on a number of acoustical topics that will be important to consider (Eberle, 2008). The Vancouver Coastal Health Authority has documented complaints with pop/rock performances at the Plaza of Nations and BC Place at residences in SEFC. It is understood that the residents in the City Gate area to the east are also concerned with noise impacts.

A 3D noise model of the study area has been constructed using the outdoor sound propagation software Cadna/A. Existing and future noise levels were predicted at residences within the study area.

2.0 Acoustic Terminology and Criteria

The basic unit of measurement in acoustics is the decibel (dB) which represents a logarithmic ratio of the pressure variation in air relative to a reference pressure. Audible sound occurs over a wide frequency range from approximately 20 Hertz (Hz) to 20,000 Hz but the human ear is less sensitive to low and very high frequency sounds than to sounds in the mid frequency range (500-4000 Hz). "A-weighting" networks are commonly employed in sound level meters to simulate the frequency response of human hearing and A-weighted sound levels are often designated "dBA" rather than "dB". "C-weighting" networks are sometimes used in criteria dealing with loud low-frequency, or bass, noise levels.

An abrupt change in level of 3 dB will generally be noticed while the same change in level over an extended period of time will probably go unnoticed. A change of 6 dB is clearly noticeable subjectively and an increase of 10 dB is generally perceived as being twice as loud.

While the decibel or A-weighted decibel is the basic unit used for noise measurement, other indices are also used to describe environmental noise. The Equivalent Sound Level, abbreviated L_{eq}, is commonly used to indicate the average sound level over a period of time. L_{eq} represents the steady level of sound which would contain the same amount of sound energy as does the actual time-varying sound level. Since it is an energy average, it is strongly influenced by the loudest events occurring during the time period because these loudest events contain most of the sound energy. The L_{eq} can be measured over any period of time with an integrating sound level meter. Canadian Mortgage and Housing Corporation (CMHC) guidelines use the 24-hour L_{eq}, or $L_{eq}24$, for assessing interior noise levels. The City's by-laws have defined nighttime to extend from 10:00 pm to 7:00 am, so the L_{eq} over this period is referred to as the nighttime L_{eq} or the L_n.

Other metrics are also used sometimes. Percentile levels, such as the L_{10} or L_{90}, represent the sound level exceeded for a certain percentage of time, such as 10% or 90% of the time. The L_{90} is often referred to as the background noise level.

BKL has performed many 24-hour noise measurements near existing and proposed residences in Vancouver over the years. Typical $L_{eq}24$ values range from 55 dBA on non-arterial streets to 75 dBA near intersections of major arterial streets such as Kingsway and Knight Street. Measured downtown levels typically range from 65 dBA to 70 dBA.

Figure 1 shows a decibel "thermometer" scale with typical noise levels at specific setback distances. Noise levels will decrease as the distance is increased.

3.0 Methodology

The methodology used to complete the objectives of the study contained in Section 1.0 is described below.

3.1 Study Area

The study area, shown as the area within the yellow rectangle in Figure 2, roughly extends from Beatty Street and Cambie Bridge to the west of BC Place and Dunsmuir Viaduct to the north of GM Place to Main Street at the east and almost to 1st Avenue on the south. It includes existing residential towers at Expo Boulevard and Smithe Street, Expo Boulevard between Georgia and Dunsmuir

Viaducts, Pacific Boulevard near Cambie Bridge and Quebec Street between Georgia Viaduct and Terminal (City Gate). It also includes the closest new Olympic Village towers in SEFC (under construction) and the proposed residences in NEFC.

3.2 Modelling

Outdoor sound propagation between the source and receptor is affected by several sound attenuation mechanisms. For outdoor noise sources noise attenuation is affected by;

- ground cover such as grasses, shrubs and trees (sound is absorbed by the ground and ground cover that it passes over);
- sound spreads hemispherically with increasing distance from the source;
- sound is absorbed by the atmosphere it passes through and is affected by wind and temperature gradients;
- sound can be attenuated by physical barriers such as buildings, hills or mountains; and
- sound can be reflected by physical barriers such as buildings.

BKL has predicted residential noise exposures using the ISO 9613 (ISO, 1996) and NMPB-Routes-96 (NMPB, 1997) standards implemented in the outdoor sound propagation software Cadna/A, version 3.7. This software has been used to predict traffic noise impacts on such recent major projects as the Sea-to-Sky Highway improvements project and the Golden Ears Bridge project. The model calculations are performed in octave bands since outdoor sound propagation is frequency dependant. The noise sources were assigned octave spectrums, but the modelling results are presented in A-weighted decibels to allow comparison with evaluation criteria. Sound contour calculations were performed for assumed receptor heights of 1.5 m relative to the ground and noise contours were calculated on a 10 m by 10 m grid. Furthermore, point receivers were modelled on most of the residential towers. The height of the receivers were generally defined to assess the highest impacted floors of the facades. First order sound reflections were also taken into account using typical facade absorption coefficients.

The standards used assign a ground absorption factor from 0.0 to 1.0 to estimate sound attenuation due to ground effect. A ground absorption factor of 0.0 would be used for hard ground such as pavement or a lake. A ground absorption factor of 1.0 would be used for "soft" ground that would provide a higher level of sound attenuation, such as grass. A factor of 0.0 has been used throughout this model except for existing park areas and the proposed Creekside Park.

Atmospheric sound absorption varies slightly with different ambient temperature and relative humidity. The approximate annual average values of 10°C and 80% relative humidity were used in the model.

Since the terrain in the study area is basically flat except for the banks at the water, the Cadna/A model has not calculated any terrain shielding. However, there is potential for earth berming in Creekside Park and while that effect has not been taken into account, it could be incorporated into the model in the future.

The effect of wind and temperature gradients on outdoor sound propagation can cause large variations in sound levels at large distances from the noise sources. When the receiver is upwind of the source, the wind will cause higher than normal attenuation that results in lower sound levels than would normally occur under calm conditions. Conversely, under downwind conditions, the opposite effect would occur, resulting in higher than normal sound levels. Crosswinds do not have these effects and result in sound levels that are essentially the same as those for calm conditions. Also, a temperature inversion can result in higher than normal sound levels, while a strong temperature lapse condition can result in lower than normal sound levels. The model assumes downwind conditions and no temperature gradient in order to provide a conservative (but not absolute worst case) estimate on potential noise levels.

3.3 Traffic Noise Sources

Traffic data was obtained from the City of Vancouver, including twenty-four hour traffic volumes for the major roads within the study area. They advised that the truck percentage is 3% for all roads and the day/night traffic percentage split is 85/15. Vehicles were assumed to travel 50 kph on all roads except 60 kph on Cambie Bridge and the viaducts. The NMPB-Routes-96 standard calculated sound power levels for road traffic based on this information.

SkyTrain noise was also modelled assuming 650 passbys during the day and 250 passbys during the night.

Marine noise was not modelled but is assumed to be insignificant relative to road and SkyTrain sources.

3.4 Entertainment Noise Sources

Three entertainment noise sources were modelled:

1. the roof of GM Place;
2. the roof of BC Place; and
3. loudspeakers for the new outdoor Performance Space.

The roof of GM Place was determined to be its only significant noise source and its sound power level was defined using the typical interior reverberant level of 95 dBA and transmission loss data that was previously estimated at a Bryan Adams concert (BKL, 2006) and shown in Table 1. The noise source was defined assuming a concert length extending from 7:30 to 11:00 pm, or 3.5 hours.

The roof of BC Place was also determined to be its only significant noise source. In order to model concert noise, the interior reverberant L_{10} level of 101 dBA was taken from data collected at a U2 concert in 1992 (Brown Strachan, 2008). The L_{10} level was reduced by 1 dB to approximate the typical L_{eq} level. The transmission loss of the roof was estimated based on previous measurements by BKL and is shown in Table 1. Since a time history was not available from the data previously collected, it was assumed that the duration of the concert noise level was 2.5 hours. Further to that, 0.5 hours of crowd noise was also added, also with a 101 dBA interior reverberant L_{10} level (but different frequency spectrum shape) based on Brown Strachan measurements. Pre-recorded music would also likely be playing between bands and before the show but these levels might be 20 dBA lower than the concert and crowd noise so they were not modelled. Measurements of pre-recorded background music at a recent Deer Lake Park (Burnaby) concert were 80 dBA at the mixing board location. These assumptions are consistent with the time history observed for the interior noise measurements conducted at the Bryan Adams concert at GM Place.

Table 1: Estimated Sound Transmission Loss of Existing GM Place and BC Place Roofs

Partition	Estimated Sound Transmission Loss per Octave Band (dB)						
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
BC Place Roof	3	4	8	13	17	23	24
GM Place Roof	9	17	23	22	29	28	29

In order to model sporting event noise, the crowd noise interior reverberant L_{10} level of 101 dBA from the U2 concert was used again. However, this level was reduced according to differences in attendance (estimated 40,000 at the U2 concert, 30,000 at a football game, 15,000 at a soccer game). Pre-recorded music would also likely be playing between plays and during intermissions but these levels might be 20 dBA lower than the crowd noise so they were not modelled.

Truck and tractor pull events would produce higher maximum noise levels, but only occur once per year and only during daytime hours so they have not been modelled.

There was a recent announcement that the BC Place roof would be replaced by a retractable roof after the 2010 Olympic Games. Since this study is trying to predict future noise impacts, the new BC Place roof was modelled using limited information (Brown Strachan, 2008). The Brown Strachan report indicated that a retractable roof with a 70 m by 85 m open area could be used and that the rest of the roof may be similar to the existing roof. The BC Pavilion Corporation (PavCo) has confirmed that the existing fabric roof construction should be assumed for now. Furthermore, the interior reverberant level for crowd noise was decreased by 0.5 dBA to account for the extra "sound absorption" provided by the roof opening. Most of the space's absorption is attributed to the crowd and non-retractable portion of the roof.

Figure 3 shows the BC Place and GM Place roof noise sources in blue as well as receptor locations on towers. The 70 m by 85 m open roof was modelled but the figure does not distinguish between the closed and open parts of the roof.

The outdoor Performance Space noise source was defined assuming that the dominant noise source would be "background" pre-recorded music for 3 hours during the daytime. The sound power level was based on the background music measured at Deer Lake Park before the first band started and in between bands. Two line arrays of loudspeakers were modelled using vertical line sources from 3.3 m to 7.8 m above the ground. The frequency-dependant directivity of the loudspeakers were defined using the published JBL AM6340/64 driver directivity data. The modelled stage was similar to the old Plaza of Nations stage with a 10 m distance between the two line arrays. A stage shell was not modelled for the default case but is presented later as a mitigation option.

Noise exposure levels were also modelled for a typical pop/rock concert based on measurements at Deer Lake Park on May 23, 2008 of the band REM. The equivalent sound level over the duration of the concert was approximately 95 dBA, measured at the mixing board 23 m from the stage.

The three location options investigated for the outdoor Performance Space were:

1. the existing Plaza of Nations site;
2. the foot of Georgia Street; or
3. adjacent to the west side of Creekside Park.

The loudspeakers were pointing away from the water in all cases: towards the northwest for Options 1 and 2 and north for Option 3. Figure 4 shows a 3D view from City Gate for Option 1, with view of the entertainment noise sources in blue.

3.5 Significance Criteria

The City's Zoning and Development By-law, Section 4.15 "Acoustics", and Noise Control By-law No. 6555 have been used to regulate noise in residential spaces in Vancouver to this point. However, there is some question as to whether these by-laws will be adequate to control noise ingress in this study area.

The Zoning and Development By-law has adopted the CMHC guideline and requires that the $L_{eq}24$ within new residential bedrooms that are adjacent to major roads, heavy rail or SkyTrain be designed to not exceed 35 dBA. Residences within the study area would fall under this category, but baseline noise measurements would likely not be taken during an event so event noise may not be captured in any acoustic study undertaken for a given project.

CMHC recommends that land use is normally unacceptable for residential use if the outdoor $L_{eq}24$ is 55-75 dBA unless special construction is used and that residential land use is not recommended if the $L_{eq}24$ is greater than 75 dBA. However, these guidelines were developed with respect to road and rail noise; concert music with a heavy bass component would result in upper limits of less than 75 dBA since facade constructions do not attenuate low frequency noise as effectively.

According the City's Noise Control By-law No. 6555, the residential areas within the study area are in Intermediate or Activity zones. This means that, according to Section 6, continuous noise cannot exceed 70 dBA during the day or 65 dBA during the night at the point of reception. The point of reception would be the closest residential balcony in this case.

Section 11 requires that commercial premises must not make continuous or non-continuous bass noise which has a 3 minute L_{eq} that exceeds 70 dBC during the daytime or 65 dBC during the nighttime at the point of reception. Since the dBC level is always greater than or equal to the dBA level, this requirement is more limiting than Section 6 requirements. Section 11B also requires that the 3 minute L_{eq} must not be more than 3 dBA above the background noise.

Further to the existing criteria, World Health Organisation (WHO) criteria have been used to estimate residents' susceptibility to sleep disturbance (Berglund et al., 1999). The document suggests that sleep disturbance can be expected when the nighttime L_{eq}, often referred to as the L_n, exceeds 30 dBA or when the fast-weighted maximum sound level, or L_{FMax}, exceeds 45 dBA, inside bedrooms.

If bedroom windows are left open, there will typically be a 15 dBA reduction from outdoor to indoor sound. If windows are closed, the amount of reduction will depend on the window, potentially the rest of the facade and the type of noise involved, but typically there is a 28 to 33 dBA reduction in the transfer of outdoor noise to indoors. Therefore, sleep disturbance could be expected for an outdoor L_n greater than 45 dBA or L_{FMax} greater than 60 dBA with open windows and an outdoor L_n greater than 58 dBA or L_{FMax} greater than 73 dBA with closed windows, unless special construction is used. However, it is important to note that closed windows are always assumed for new residential development projects and that maximum noise levels are often higher than 73 dBA due to loud vehicle passbys for new residential projects in Vancouver.

In order to rate the acceptability of daytime music noise from concerts, most existing standards look at the difference between the noise levels in question and the background noise levels. The acceptable limit depends on the type of noise and frequency of events. It is also important to note that larger noise impacts are sometimes permitted by these standards if the events are infrequent. For the purposes of this study, Section 11B of the Noise Control By-law was used, but it is difficult to predict the background noise at many of the study area locations since measurements have not been performed as part of this project.

4.0 Existing Noise

It is useful to review existing noise levels in order to better understand the significance of future noise level predictions. Figure 5 shows the $L_{eq}24$ due to road and SkyTrain traffic noise for the entire study area. The sound contours graphically show the noise level at 1.5 m above the ground, while the text boxes show the level at heights further above the ground on the residential towers or apartments. The level varies from 54 dBA at residential locations that aren't close to a road to approximately 70 dBA at residential locations close to the road.

5.0 Future Noise

Figures 6 to 8 show $L_{eq}24$ due to road and SkyTrain traffic plus entertainment noise for the entire study area. While it is unlikely that events would occur at all three venues on the same day, this has been modelled to show the worst case scenario. The dominant noise source at any particular location varies with proximity to each of the noise sources, although GM Place does not contribute significantly to any of the point receivers. BC Place is predicted to be the dominant source for residences looking down on the roof and residences not adjacent to major roads (such as the two Olympic Village towers). Most locations have more than one significant noise source, often a road plus BC Place. BC Place noise would have a smaller effect on the $L_{eq}24$ during a sporting event day since the duration of crowd noise would be shorter than 3 hours.

If a five hour outdoor pop/rock concert was held at the Performance Space, similar to the concert observed at Deer Lake Park, it would produce significant sound energy in the study area, especially if no special design considerations are made, whereas the impact shown is not very significant due to the much quieter sound source modelled.

While crowd noise from patrons arriving at or leaving concerts has not been modelled, this was previously addressed (BKL 2006) and is summarised as follows:

Since noise from voices is primarily in the mid frequency range, it is attenuated by windows to a greater extent than low frequency noise and therefore, any glazing system that would adequately attenuate traffic noise and concert sound should be very effective in attenuating loud voices. Assuming that windows are closed, the loudest of such events might be audible inside a unit, but noise from patrons is unlikely to cause any serious problems for normal pop/rock concerts. Occasionally however, there may be concerts that might attract a more raucous crowd.

6.0 Effect of New BC Place Roof

All results presented for this study were made using the proposed future BC Place roof. Using the Cadna/A model, an analysis was performed to estimate the effect of the proposed BC Place roof system versus the existing roof. The assumptions made for the new roof system were discussed in Section 3.4. The modelling results show that adding a 70 m by 85 m open area in the roof would significantly increase almost all residential noise exposures. Music noise during a concert or crowd noise during a sporting event would increase by an average of 6-8 dBA compared with the existing condition, as summarised in Table 2. As mentioned previously, a change of 6 dB is clearly noticeable subjectively and an increase of 10 dB is generally perceived as being twice as loud. The predicted impact is significantly higher than the impact predicted by Brown Strachan in their report.

The GM Place roof attenuates approximately 10 dBA more noise compared to the existing BC Place roof. If the fixed part of the new BC Place roof used a similar construction, noise exposures would be significantly reduced while the operable part of the roof is closed. This is with the conservative assumption that the operable part of the roof would have a fabric construction similar to the existing BC Place roof. However, residential noise exposures would not benefit from a GM Place fixed roof construction while the roof is open because most of the noise impact is due to sound escaping through the opening and not through the fixed part of the roof. These effects are summarised in Table 2 for concert noise, but similar differences are expected for crowd noise.

Table 2 - BC Place Roof Options, Typical Concert Noise Level Differences

Residence Group	Typical Noise Level Difference (dB)			
	Existing / Closed Roof	Roof Open	Roof Open with "GM Place" Fixed Roof	Closed "GM Place" Roof[1]
Existing Towers Nearby	Reference	+8	+7	-7
City Gate	Reference	+6	+5	-8
Olympic Village	Reference	+8	+7	-7
New Towers Nearby	Reference	+6	+5	-8

[1] Existing BC Place roof construction used for 70 m x 85 m operable part of roof

7.0 Noise Control By-Law Exceedances

The Cadna/A results can be used to estimate the chance of by-law exceedances by the three entertainment facilities.

According to the model results, GM Place noise levels would typically be slightly below 70 dBC at the closest suites to the northwest and the proposed hotel to the south. In other words, there is a chance that the daytime criterion could be exceeded at a few suites during a concert. It is likely that the nighttime criterion (65 dBC) would be exceeded for most suites facing GM Place on the closest residential tower to the northwest and proposed hotel to the south. However, the 3 dBA above background criterion is unlikely to be exceeded because of the busy traffic arterials nearby. Figure 9 shows the typical C-weighted noise levels expected during a normal rock concert (e.g. Bryan Adams), excluding all other sources of noise such as road traffic.

As per Section 14A of the Noise Control By-law, BC Place is exempt from the requirements for concert or motor vehicle events provided that there are less than 10 such events per year. It is not exempt from sporting event noise.

Figure 10 shows the predicted typical C-weighted noise levels expected during a pop/rock concert. The point receivers that exceed the 70 dBC criterion are shown in red. If the event continues past 10:00 pm all of the receivers above 65 dBC would also be above the by-law. As can be seen from the point receiver results shown with text on the figure, noise levels are predicted to be much higher for the upper floors of the nearby towers than close to the ground (the sound contours show the predicted noise at 1.5 m above the ground). Noise levels are expected to exceed daytime and nighttime limits at most facades within 300 m that face BC Place by up to 17 dBC during the daytime. The daytime criterion may also be exceeded sometimes at the nearest Olympic Village suites. Based on the analysis, the same residences will also likely be more than 3 dBA above background noise. If the roof were closed, the by-law exceeding residential noise levels would be reduced significantly, but generally not below the by-law so the impacted area would remain roughly the same at a 300 m radius.

Figure 11 shows the predicted typical C-weighted crowd noise levels expected during a football game crowd cheering period. They are noticeably lower than the predicted concert noise because of the lack of low frequency sound in speech but also have a similar area that exceeds the daytime criterion, i.e. most facades that face BC Place within 300 m. Also, the text box point receiver results show that the dBA results (which generally better relates to perceived loudness) are similar for crowd or concert noise. If the roof were closed, the by-law exceeding area would be reduced to approximately 200 m.

If a soccer game has half the crowd of a football game (15,000 versus 30,000), noise levels would be reduced by 3 dB. This is assuming that the people in the crowd would be cheering at the same level. If this is true, the daytime criterion impacted area would be reduced to approximately 175 m when the roof is closed.

Pre-recorded music would often be played over the BC Place amplification system before the event or concert starts, in intermissions and between football plays but might be 20 dBA quieter than concert or crowd noise (80 dBA versus 100 dBA). Since none of the predicted concert noise levels are above 90 dBC, the pre-recorded music would likely not exceed the daytime criterion anywhere, even with the roof open.

Figures 12 to 14 show the predicted typical C-weighted concert noise levels from the Performance Space for the three location options. Since the modelled sound source levels are quite low at roughly 80 dBA in the audience area, community noise impacts are expected to be insignificant at most locations. The daytime by-law criterion may be exceeded at the residential facades facing the Performance Space within a 200 m radius. This type of event might not be expected to run past 10:00 pm, in which case the nighttime criterion would not be important to consider. However, the predicted results for a typical pop/rock concert at the Performance Space are approximately 15 dBC louder and noise levels would be expected to exceed daytime and nighttime limits at almost all facades within the study area that face the Performance Space.

8.0 Potential for Sleep Disturbance

Figures 9 to 14 show the C-weighted levels that would be expected during typical pop/rock concerts, football games or events with pre-recorded background music. The text boxes in the figures also show predicted A-weighted levels at selected point receivers. As mentioned in Section 3.5, A-weighted *indoor* noise levels are typically used to judge the potential for sleep disturbance.

Based on the analysis of a typical downtown tower 3 m by 3 m bedroom with floor to ceiling windows on one face (2.3 m tall), GM Place concert noise levels are unlikely to cause any sleep disturbance if windows are closed.

For BC Place concert or crowd noise, the maximum noise levels are estimated to be approximately 8 dBA louder than the typical noise levels shown in Figures 10 and 11. For concert noise, with high bass energy, sleep disturbance could be expected for maximum levels higher than 76 dBA with standard closed windows and 79 dBA with high performance windows. High performance windows would still result in a potential for sleep disturbance for residences above and facing BC Place within 300 m if the roof is open. If the roof is closed, the same type of residences within 200 m would have a potential for sleep disturbance with high performance windows.

Since crowd noise does not have much low frequency energy, it is easier for windows to attenuate the noise. Based on the analysis, closed windows would adequately attenuate maximum outdoor noise levels up to 85 dBA for standard construction and 87 dBA for double laminated construction. Other variables may alter the findings further. Nevertheless, sleep disturbance may be expected at residences elevated above and facing BC Place within 200 m if sporting events (with 30,000 people) were allowed to continue past 10:00 pm with an open roof. Closing the roof would mitigate this concern for crowd noise.

With the modelled sound source, the Performance Space has little potential to cause sleep disturbance if events are permitted past 10:00 pm except at the closest residential suites for Options 1 and 2. However, if pop/rock concerts were permitted past 10:00 pm, the potential for sleep disturbance would be significant. Based on the measurements conducted at Deer Lake Park, maximum noise levels would be approximately 13 dBA higher than the typical music levels shown in Figures 12 to 14.

9.0 Building Design Adequacy

If the Noise Control By-law limits are not exceeded, the City's Zoning and Development By-law requirement for an interior bedroom (L_{eq}24 not greater than 35 dBA) should be met for new residential in the area using standard acoustical evaluation, which considers traffic and other noise sources, but normally does not take entertainment noise into account. However, BC Place is expected to exceed the by-law by more than 15 dBC in some places with the roof is open.

Special acoustical consideration should be made for residential construction adjacent to BC Place and the Performance Space, taking event noise into account. Single-loaded towers or enclosed balconies may be required for the nearest developments, but in all cases the 35 dBA criterion can be met with noise isolation design that has been used in the past.

The existing developments in the study area would likely still meet the 35 dBA requirement for any of the options, although there would be significant increases in the noise exposure at the Olympic Village for Options 1 and 3 and at residential suites looking down onto the BC Place roof.

10.0 Effect of Ambient Noise on the Performance Space

An open space with special use, such as the proposed outdoor Performance Space, will likely be judged to have an unacceptable level of ambient noise if this noise is higher than 50 dBA (Mankovsky, 1971). This assumes that an amplified sound system will be used for all performances. Unamplified performances could be feasible if the ambient noise level was reduced further, but this may not be practical in the NEFC area.

Ambient noise levels due to road and SkyTrain traffic were predicted using the Cadna/A model. Each option was evaluated, taking the noise shielding and reflecting of the proposed buildings into account. The ground was assumed to be flat for each Performance Space, with no other noise shielding elements besides the new buildings. Table 3 shows the predicted ambient noise in the Performance Space area for the three location options. The time period differences were estimated using hourly noise data taken on Dunsmuir Viaduct over a 23 hour period in 2006 (BKL 2006).

Table 3: Estimated Performance Space Ambient Noise Levels

Option	Estimated Average Ambient Noise Level (dBA)		
	Midday	Afternoon	Evening
1	54-56	52-55	51-53
2	56-61	54-60	53-58
3	54-58	52-57	51-55

As can be seen from the table, the highest ambient noise levels will likely occur during midday. This is a result of high traffic volumes combined with higher average vehicle speeds. Traffic volumes are greater during peak hours but overall noise levels are reduced due to congestion which decreases average vehicle speeds.

The ambient noise level will also vary within each performance area, depending on proximity to buildings and gaps between buildings. Although the table shows that ambient noise levels would be unacceptable for all options, there should be opportunities during the detailed design to reduce these levels to acceptable limits using mitigation options such as noise barriers to close gaps between buildings or amphitheatre-style seating.

11.0 Other Considerations for the Performance Space

Sound from the loudspeakers will bounce off of the nearby buildings and be directed towards SEFC and/or City Gate, depending on the option. These reflections would also create slap echoes at certain locations within the Performance Space which would degrade the quality of sound received by the audience. In order to control this effect, the 1st storey of the immediately adjacent buildings may have to be sound absorptive or the Performance Space may require a more enclosed design, which could be provided by amphitheatre-style seating, for example.

An acoustic shell at the back of the stage would also reduce music spilling into the community. If reflections are reduced and a shell is introduced, noise levels at Olympic Village and City Gate could be reduced by 5 to 7 dBA for Option 1. Another consideration for a stage shell is that it may have to be temporary in order to permit viewing of sail pasts or other water activities.

12.0 Conclusions and Recommendations

Standard acoustical design for new residential towers in the project area would be adequate if the entertainment noise sources meet the Noise Control By-law. If they are permitted to exceed the by-law limits, special consideration will need to be made in the design stage in order to meet the $L_{eq}24$ 35 dBA requirement for bedrooms. Single-loaded towers or enclosed balconies may be required for the nearest developments, but in all cases the 35 dBA criterion can be met with noise isolation design strategies that have been used in the past on other noise exposed projects.

It was predicted that the Noise Control By-law limits would be significantly exceeded at many residential suites if concert or sporting events are held with the proposed new BC Place roof in the open configuration. This situation would generally occur for suites elevated above and facing the roof within 300 m, but also likely at the closest Olympic Village towers because of the lower background noise levels. Closing the roof would reduce the subjective loudness of the noise by almost 50% at the loudest locations, but concert noise would still likely be above the daytime by-law limit for those suites within 300 m. A background noise measurement survey would better assist with estimating potential by-law exceedances. The Performance Space may exceed the daytime by-law limits at residential towers within 200 m and GM Place might only exceed the nighttime by-law limits at the nearest existing residential tower and proposed hotel to the south.

The Noise Control By-law could be revised to allow higher levels of noise for infrequent events throughout the City, relative to the background noise level at that location, based on similar by-laws and standards developed elsewhere (e.g. UK). This approach may be more appropriate than allowing an uncontrolled noise level for a certain number of events per year per venue.

Sleep disturbance can be avoided by limiting the hours of operation for BC Place and the Performance Space to daytime hours. Alternatively, closing the BC Place roof may mitigate its noise impact sufficiently for nighttime sporting events but not for concert events. It is our understanding that Deer Lake Park (Burnaby) concerts are not permitted to continue past 10:00 pm.

A single-loaded design for the three proposed towers adjacent to BC Place would result in noise exposures similar to existing residential towers nearby for the facades not facing BC Place.

Detailed acoustical design work will be essential to provide an acceptable outdoor Performance Space. Without proper attention to the acoustical issues, there is a high chance for poor sound quality within the space and significant noise impacts in both the immediate neighbourhood and communities across False Creek such as Olympic Village and City Gate if pop/rock concerts are permitted. Design options that may mitigate some noise issues could exacerbate others unless proper details are developed.

All Performance Space location options presently have high ambient noise predictions. All locations have the potential to be reduced to acceptable levels but it is still assumed that all events will require an amplification system to obtain a suitable signal-to-noise ratio. There is no significant acoustical reason to choose one option over another at this point.

It should be noted that music "noise" is expected to be subjectively interpreted as more annoying than more neutral noises, such as road traffic, of the same decibel level because of the "message" contained within the music and tones that are harder for the brain to ignore. Therefore, it is difficult to assess the amount of annoyance that the open roof of BC Place and the new Performance Space could create, regardless of whether criteria are met.

For the new residential towers, it may be assumed that residents moving in would be aware that they are moving into a busy downtown area (activity zone) with nearby entertainment facilities, but a noise covenant would be more protective, as mentioned in the Brown Strachan report (Brown Strachan 2008), and is recommended.

This report has only addressed acoustical considerations. Also, while this is a high-level study, it should be noted that the model developed can be refined further in order to perform detailed analyses as more detailed design information comes available.

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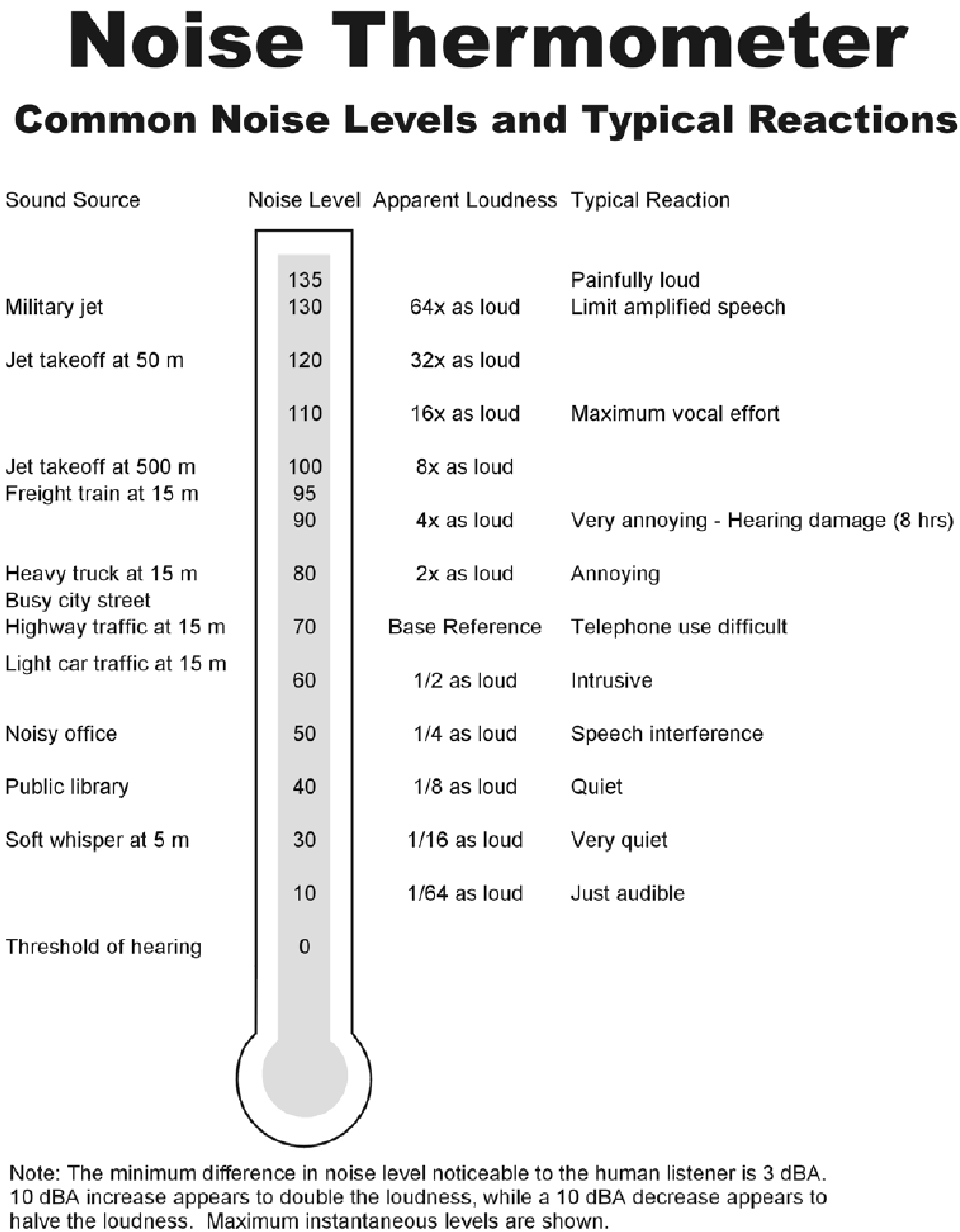

Figure 1: Noise Thermometer

BKL Consultants Ltd.

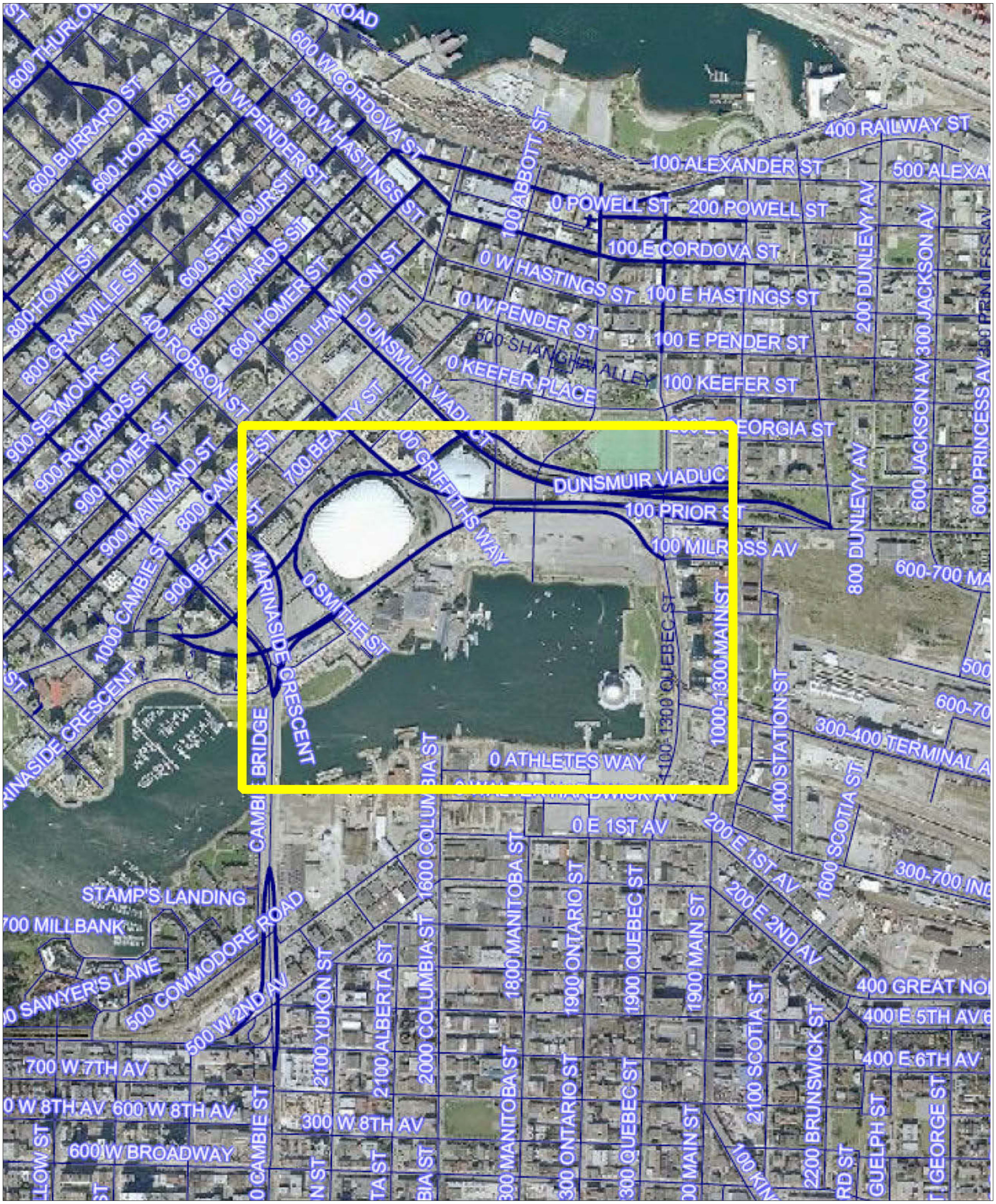

Figure 2: Study Area

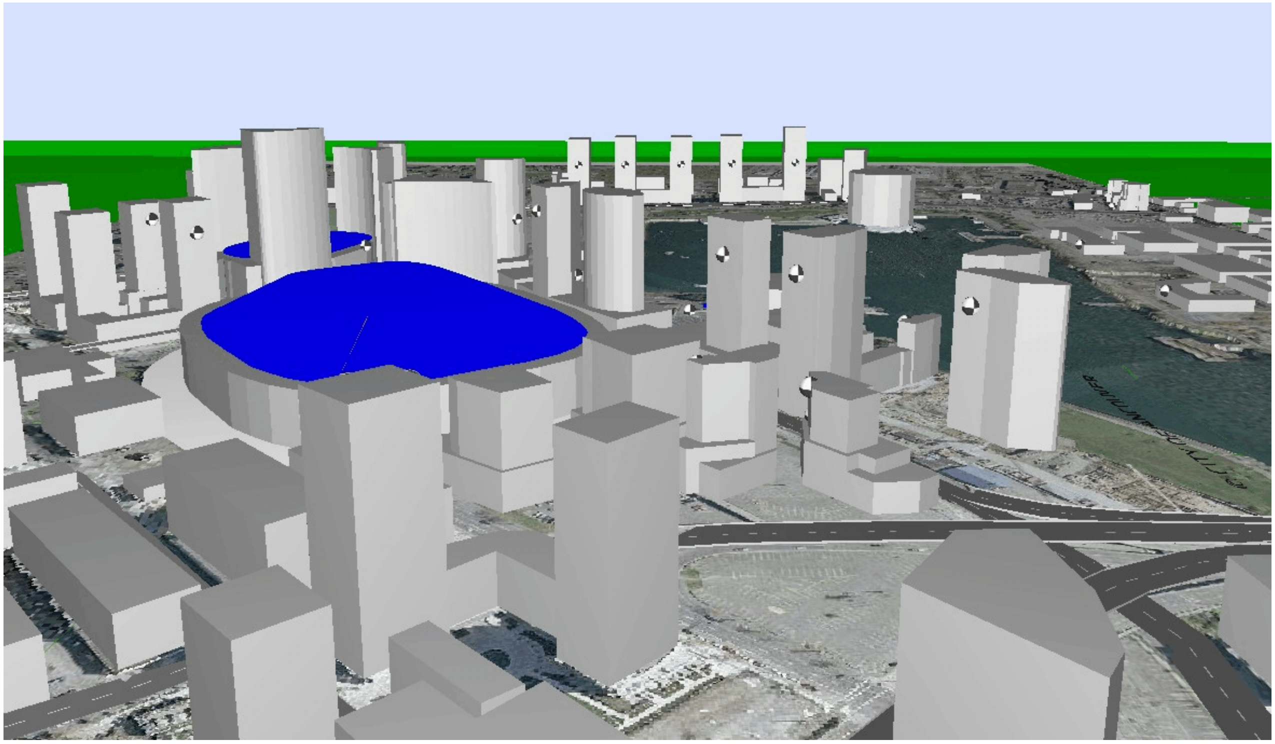

Figure 3: 3D View of the Study Area from the West

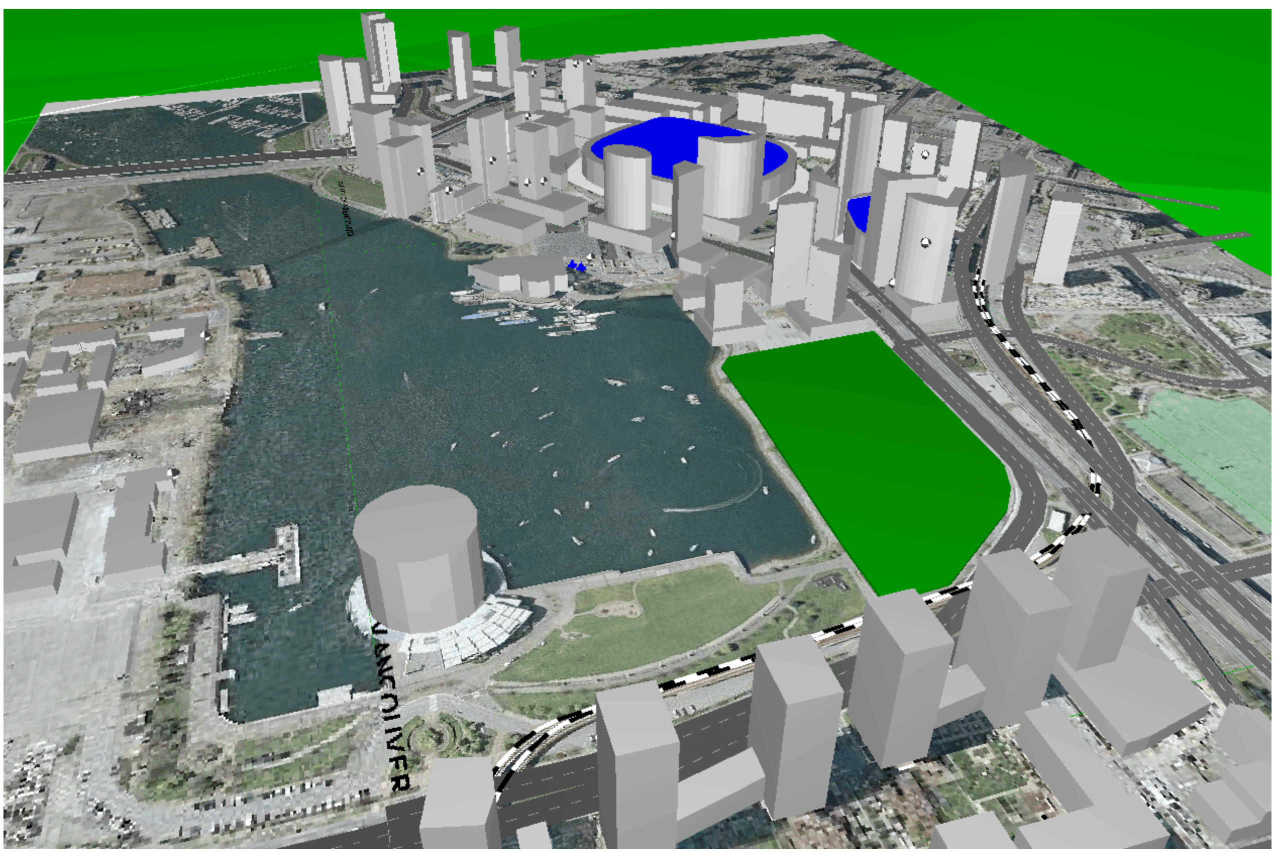

Figure 4: 3D View of the Study Area from the East

File: 177-08AII | **Figure 5: Predicted Existing Leq24** | Date: June 2008

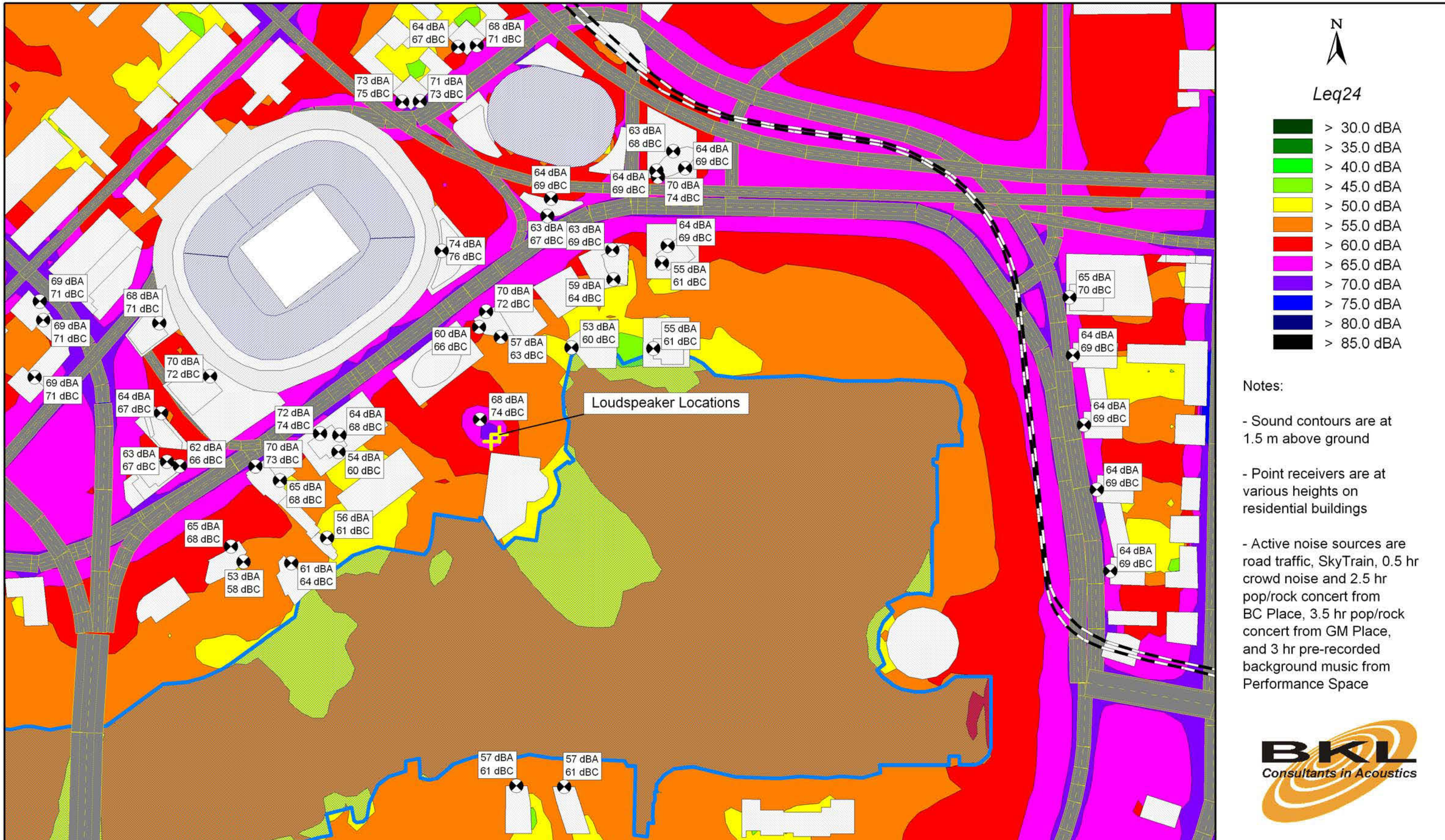

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Figure 6: Predicted Future Leq24, Option 1

Date: June 2008

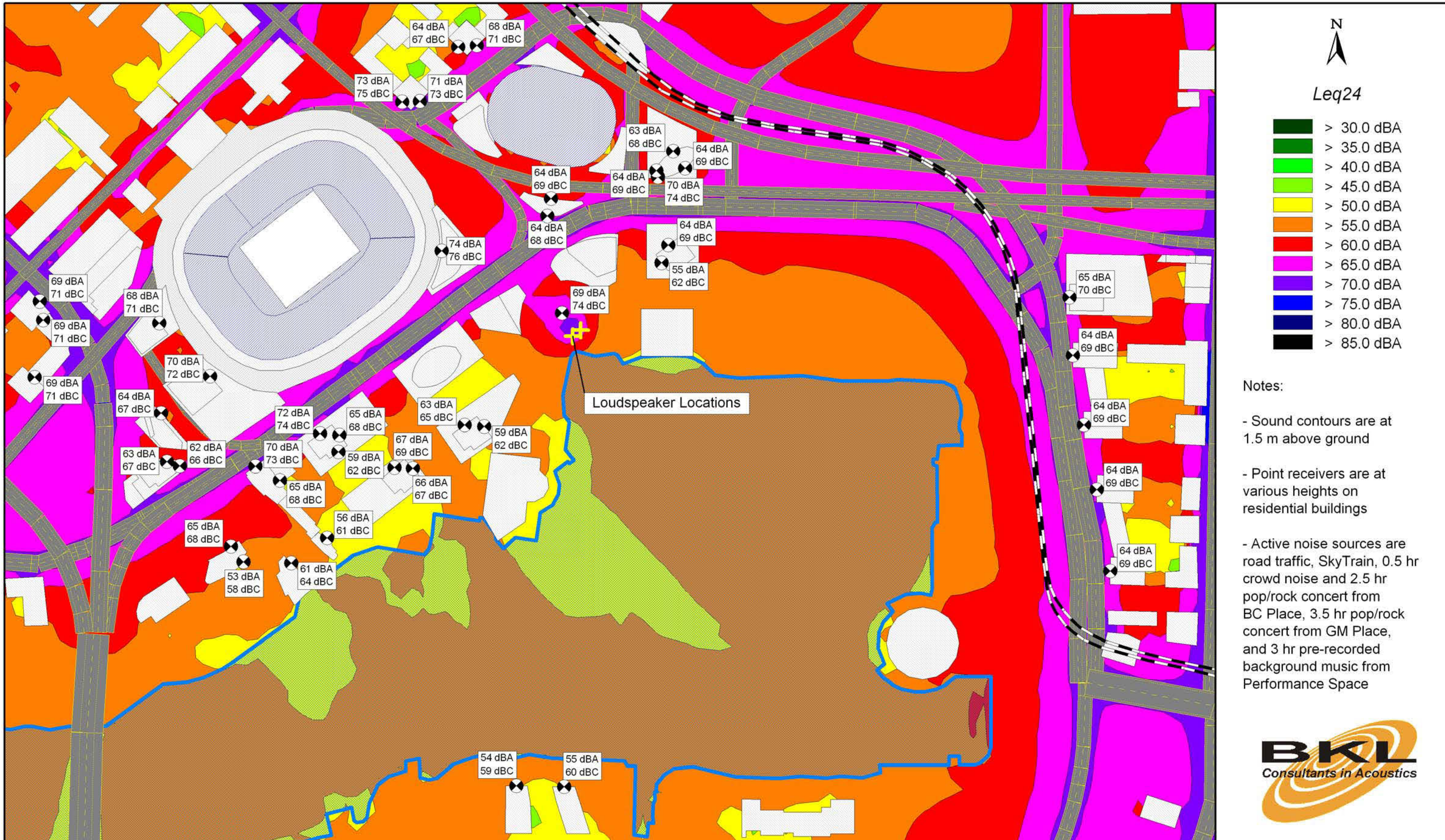

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Figure 7: Predicted Future Leq24, Option 2

Date: June 2008

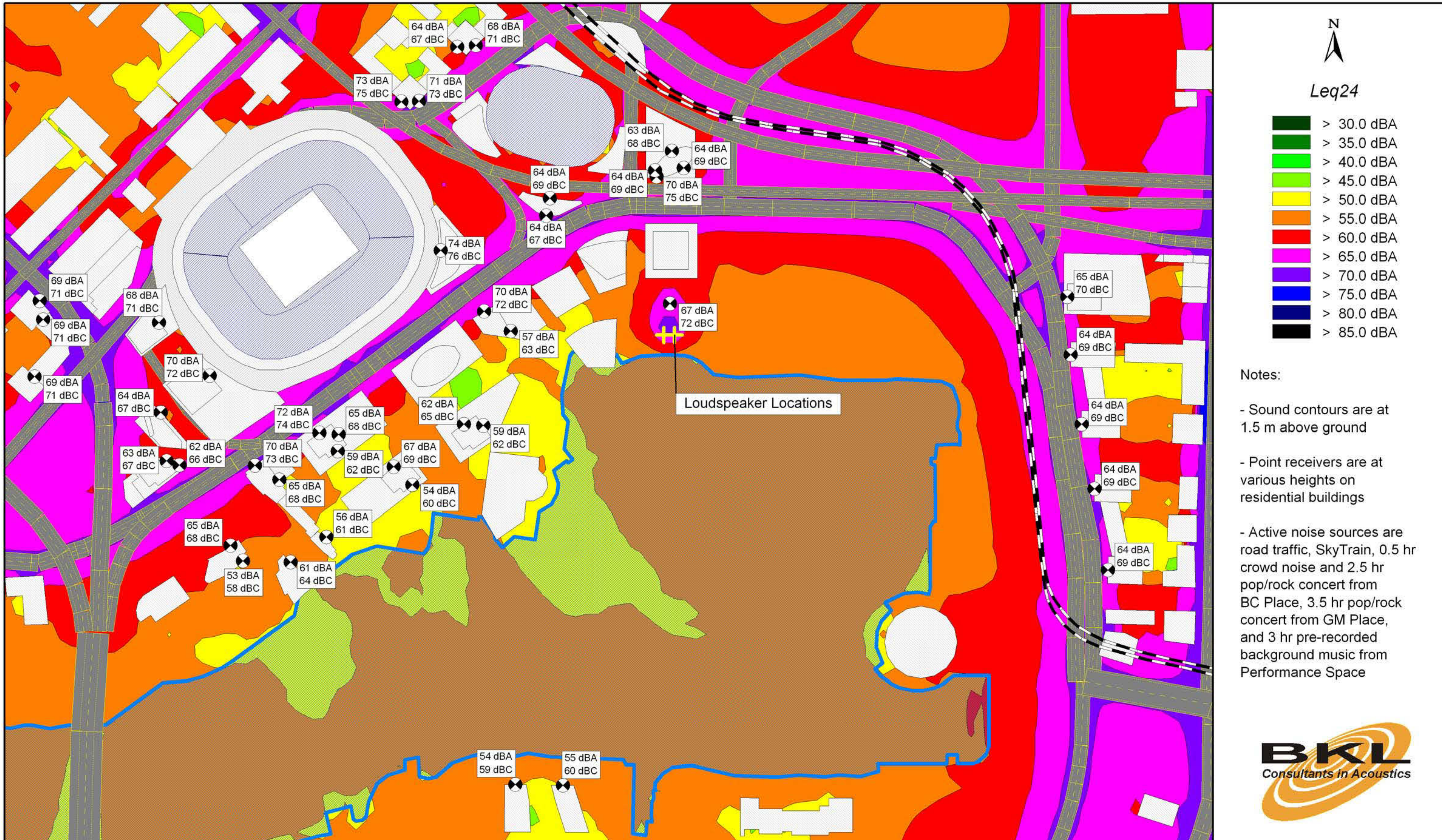

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Figure 8: Predicted Future Leq24, Option 3

Date: June 2008

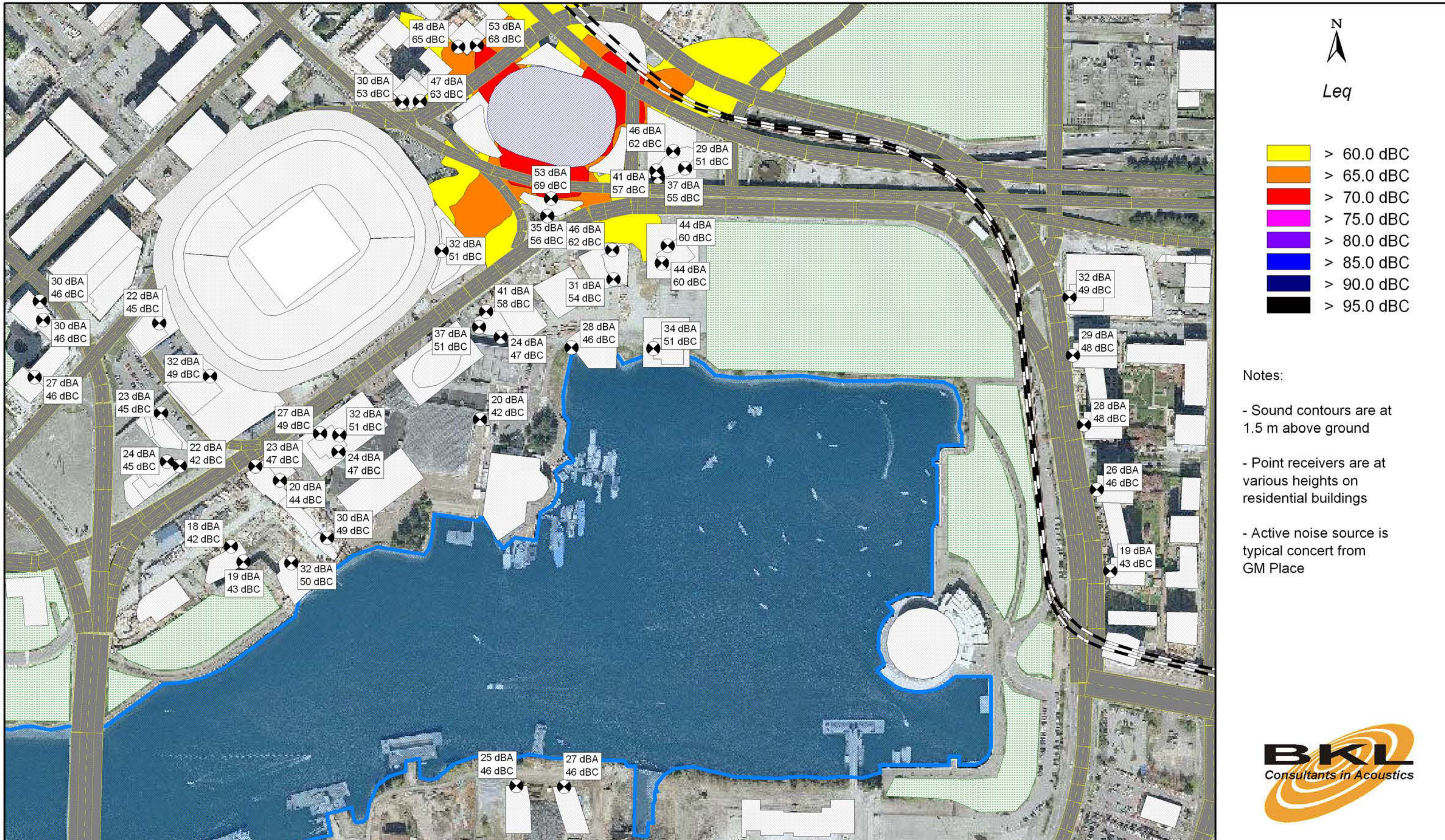

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Figure 9: Predicted Concert Noise from GM Place, Option 1

Date: June 2008

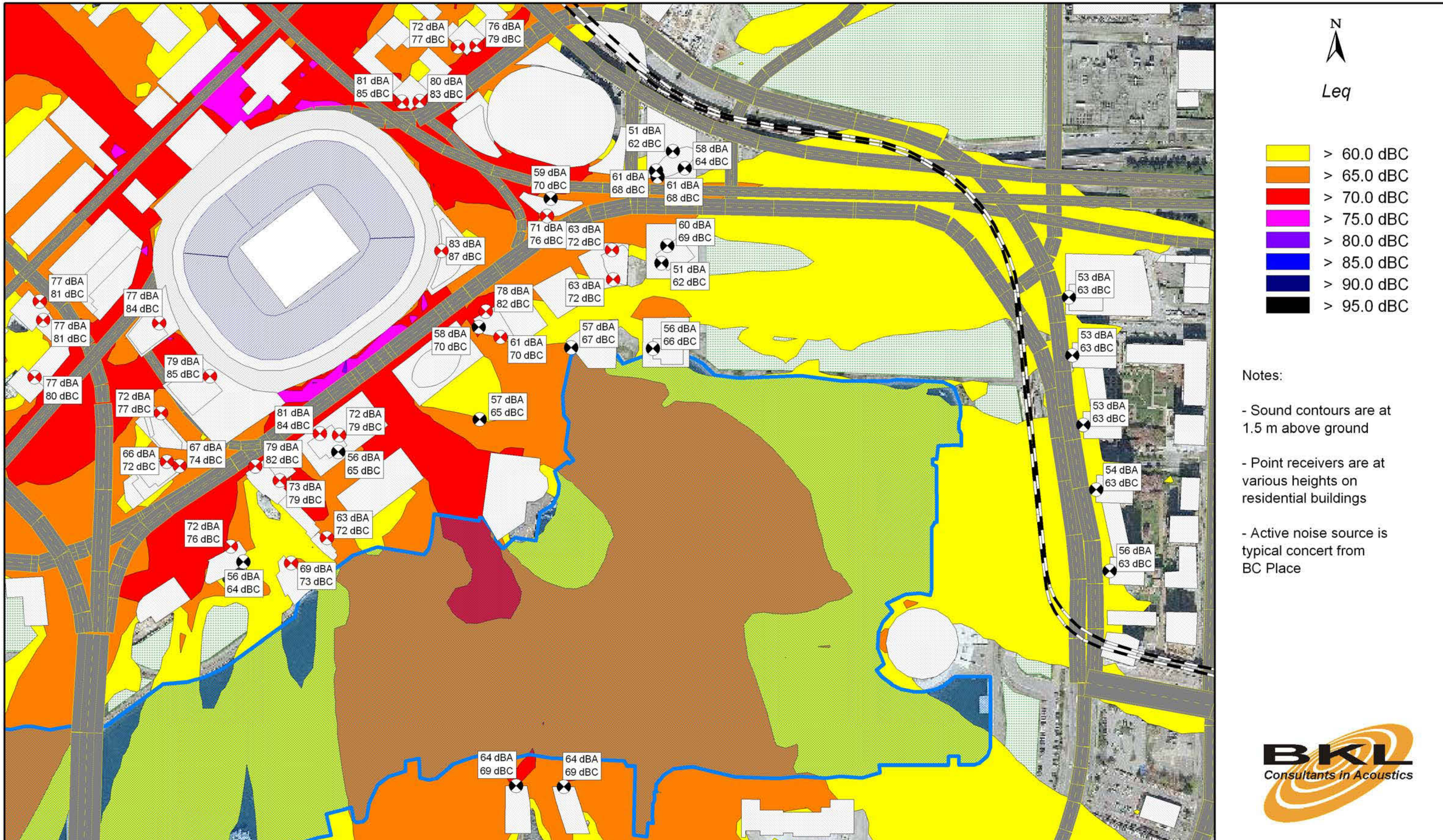

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Figure 10: Predicted Concert Noise from BC Place, Option 1

Date: June 2008

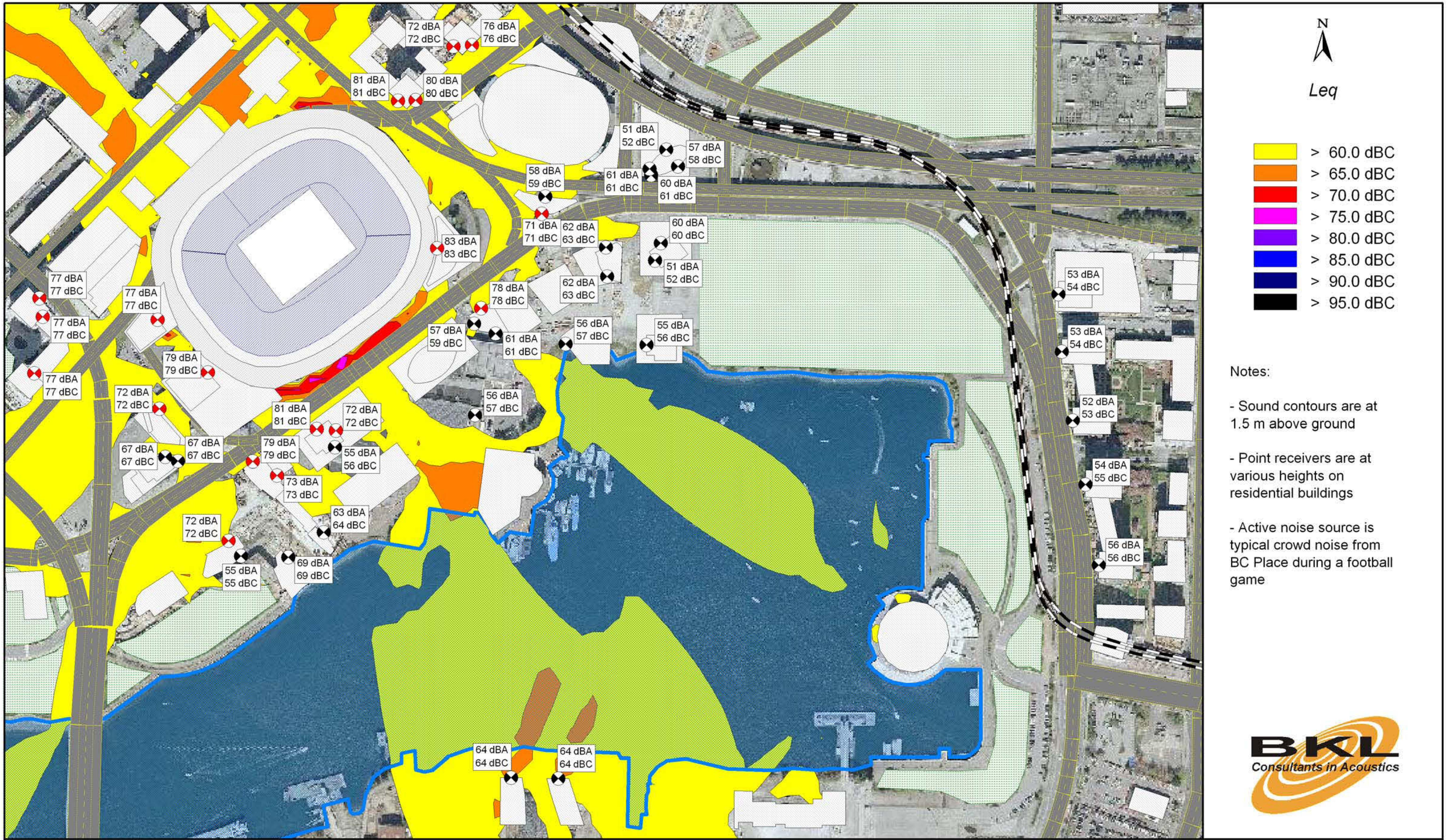

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Figure 11: Predicted Crowd Noise from BC Place during Football Game, Option 1

Date: June 2008

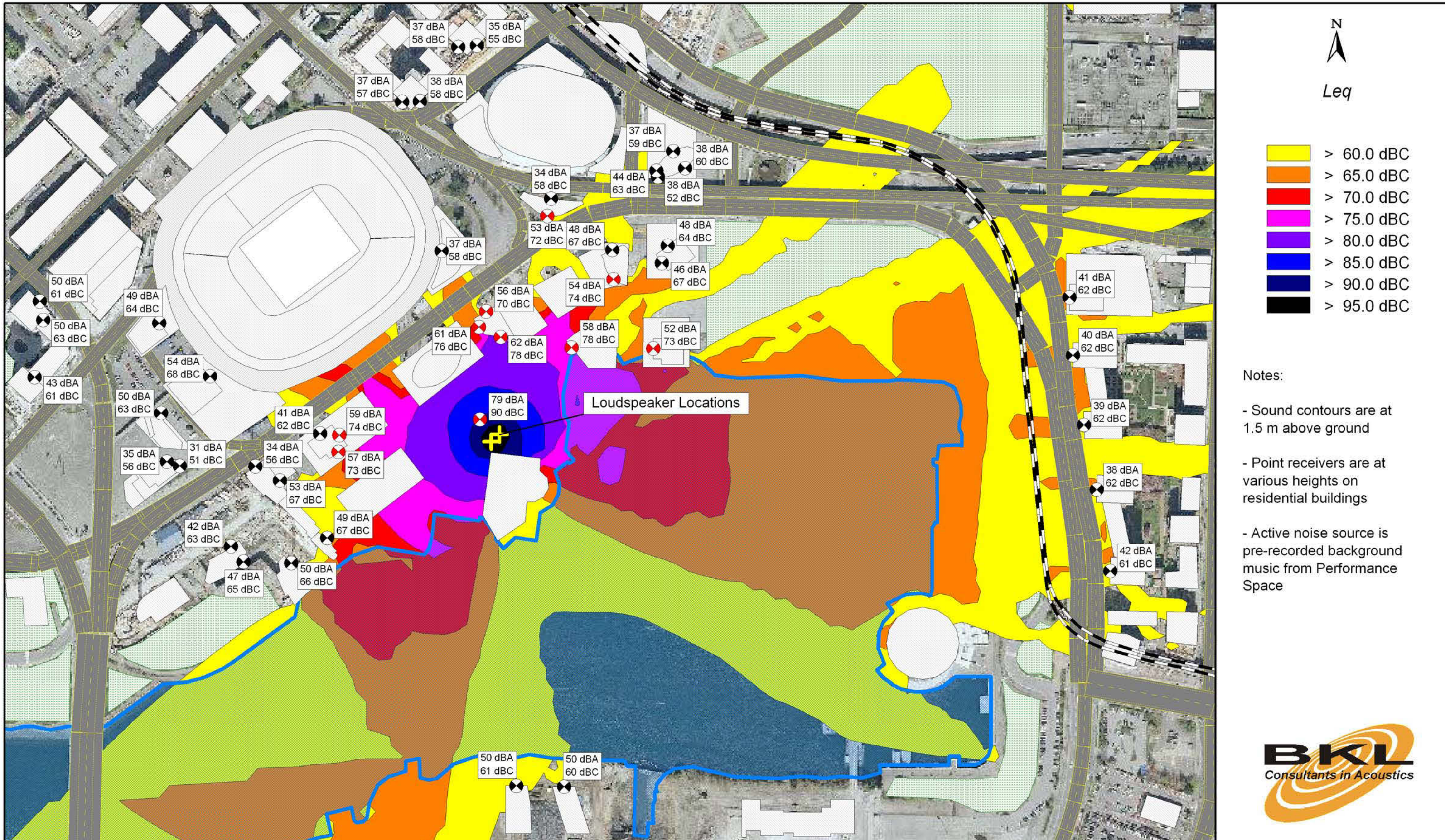

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Figure 12: Predicted Background Music from Performance Space, Option 1

Date: June 2008

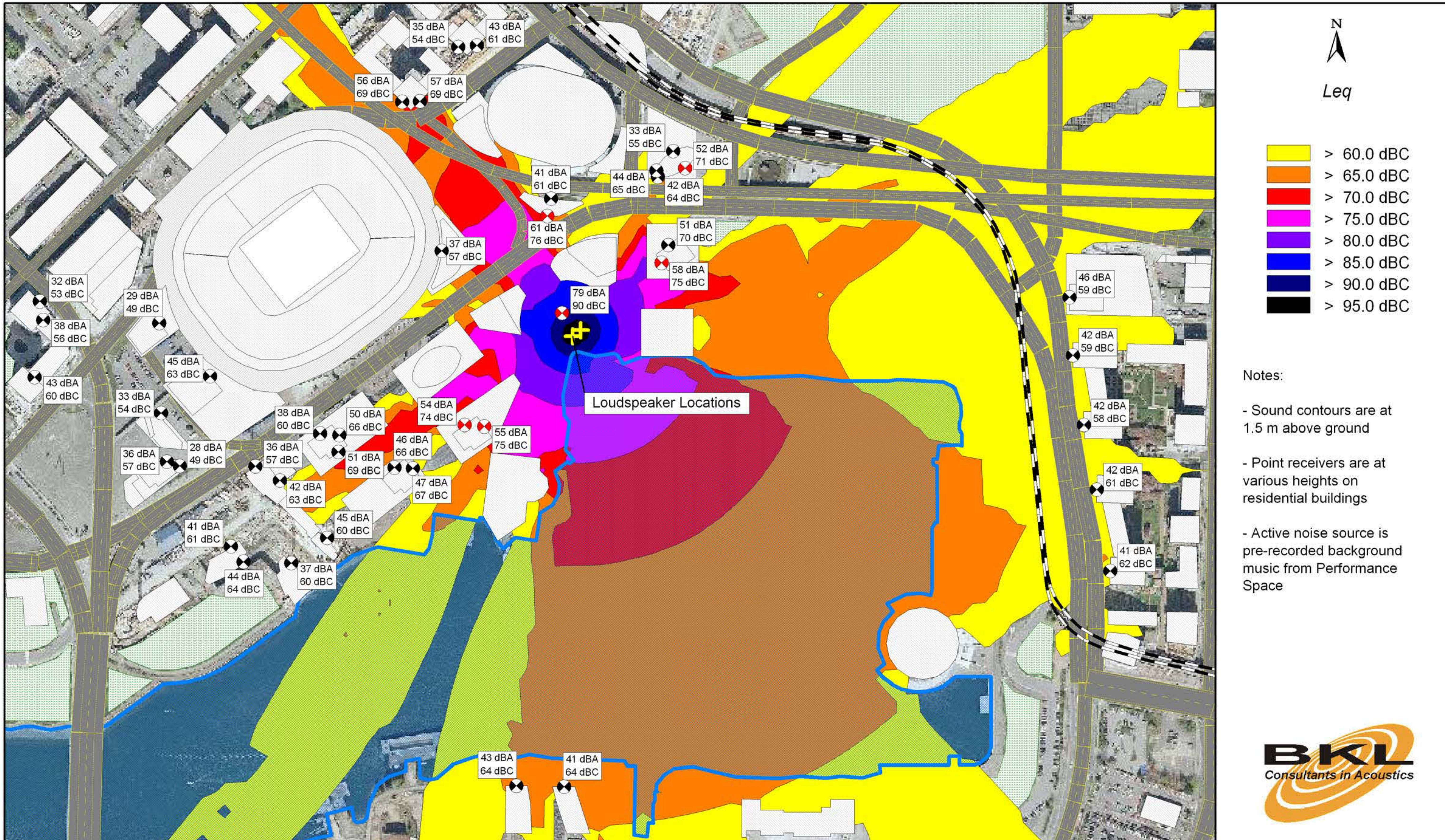

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Figure 13: Predicted Background Music from Performance Space, Option 2

Date: June 2008

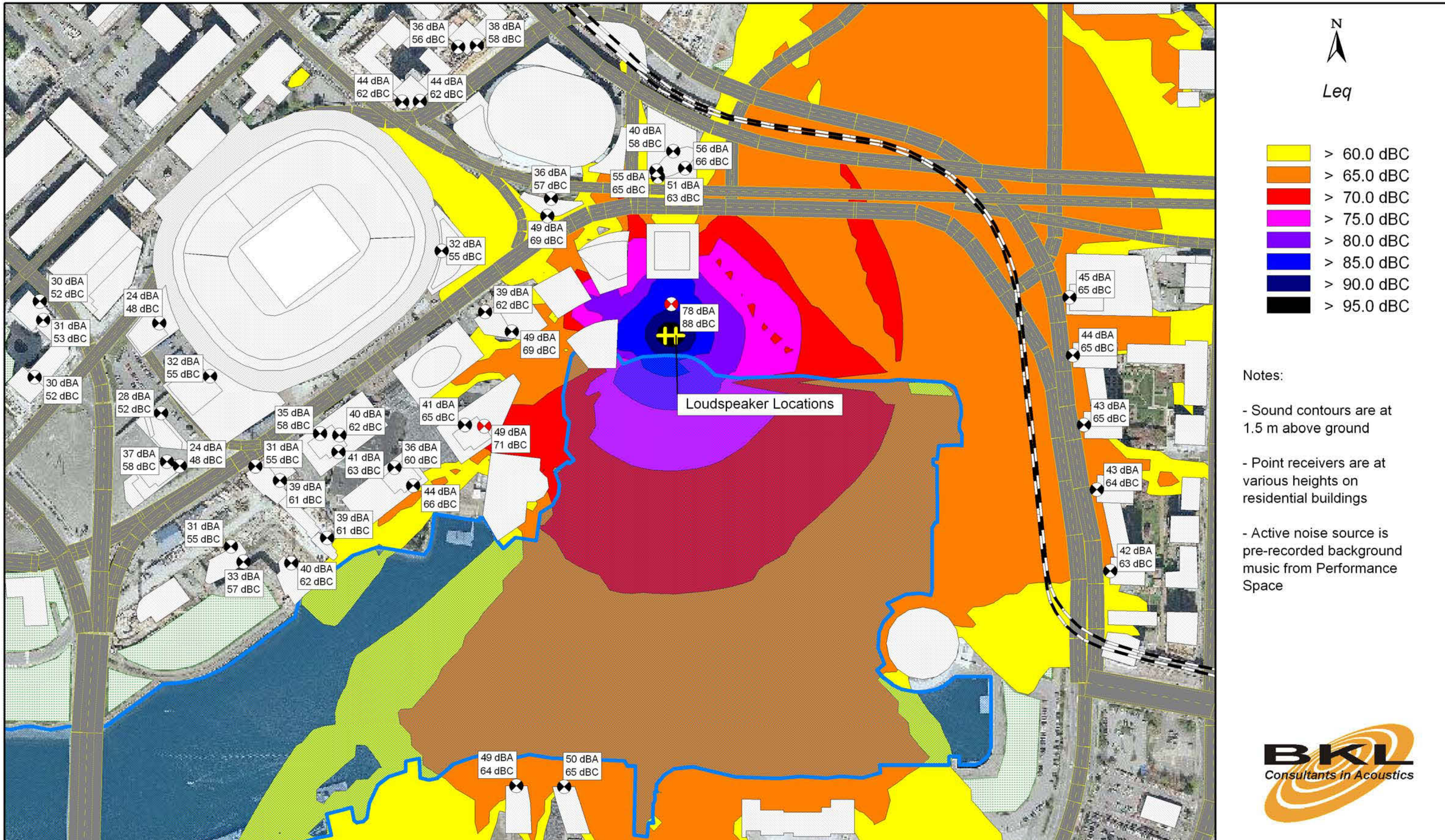

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Figure 14: Predicted Background Music from Performance Space, Option 3

Date: June 2008