Noise Impact Analysis for a Proposed Bus Operating Base

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An evaluation was conducted of the potential noise impact for a proposed bus operating base in northern Seattle. In the analysis the impact of two alternative sites for the proposed base was examined. Both sites are located in residential areas. Thus, there was concern about the noise impact from bus traffic arriving and departing the base as well as daily operations at the base. Because of the need for buses to depart the base during early morning hours to travel to their assigned routes, of great concern was the potential impact of bus traffic on sleep disruption in neighborhoods near the base. A field noise-measurement program was undertaken to document the existing noise environment and to define typical bus passby noise levels. Based on these measurements, projections of the noise impact of buses relative to other noise sources were made. On the base noise-generating operations of particular interest include maintenance and repair activities and bus start-up and pull-out. Estimates of community noise levels for each operation were compared with noise-level limits in local ordinances to determine the extent of the potential impact of noise. For both off-base- and on-base-generated noise, mitigation measures were recommended, and estimates were made of the resulting noise-level reductions.

At the request of the municipality of Metropolitan Seattle, Bolt Beranek and Newman Inc. (BBN) conducted an evaluation of the potential impact of noise resulting from two alternative sites for a proposed bus operating base, called the North Operating Base. This evaluation was based on a review of the preliminary analysis contained in the draft environmental impact statement (EIS) for the North Operating Base (1) and its backup noise and vibration report (2).

The evaluation focused on the potential impact of buses leaving the base for their assigned routes and returning to the base, and the potential impact of maintenance and repair operations conducted at the base.

To better understand the effect of base-generated traffic on communities along the departure and arrival routes, a field noise-measurement program was undertaken. The impact assessment was then conducted based on the results of these measurements.

The paper is organized as follows. First, the measurements, impact analyses, and recommended mitigation measures are described. Second, the impact of base operations on surrounding communities, as reported in the draft EIS, is reviewed, and greater details about the mitigation measures are given. Finally, the major conclusions of the analyses are summarized.

IMPACT EVALUATION OF BASE-GENERATED TRAFFIC

Description of Proposed Operations

The draft EIS for the North Operating Base (1) indicated that there would be 616 bus trips leaving and returning to the base each day. The analysis presented in this paper is based on revised figures involving 583 bus trips in and out of the base. (Data from a June 15, 1982, memorandum from Linda Hender of Seattle Metro.)

For proposed site 1 [Aurora drive-in site (see Figure 1)], the major bus routes would be Aurora Avenue, North 145th Street, and North 130th Street. For proposed site 2 [Holyrood site (see Figure 2)], the major bus route would be North 205th Street.

Buses are scheduled to leave the base during early morning and early afternoon hours. Buses return to the base in the late morning and during the evening and night hours.

Note that the operating base is also expected to generate automobile traffic, amounting to approximately 50 percent more automobile trips per day than bus trips. However, because of the lower noise levels of automobiles compared with buses (even at the somewhat higher speeds of automobile travel), the analysis indicates that exposure to bus noise would exceed the exposure to automobile noise on all streets where the potential for noise impact might occur. Also, the base-generated automobile volume is a small fraction of existing traffic (see Figures 1 and 2). Accordingly, the analysis described in this paper focuses on the noise of bus traffic only.

Field Measurement Program

Traditionally, an analysis of the impact of traffic on a roadway is based on either the noise occurring during the peak traffic hour or during a complete 24-hr period. The proposed base-generated bus traffic will represent only a small percentage of the total daily volume of vehicles on the roadways near the proposed base sites. Further, the peak traffic hour for these roads usually occurs from either 7:00 to 8:00 a.m. or from 4:00 to 5:00 p.m., when proposed base-generated bus traffic is not expected to be high. Thus a conventional analysis would indicate that base-generated traffic will result in little or no impact on noise-sensitive land uses (residences) along the bus routes.

Nevertheless, because of the unusual distribution of base-generated traffic, and in particular the high number of buses expected to depart during early morning hours when other traffic is at a minimum, the potential for noise impact occurring during this period was a subject of concern. Although the projected number of bus operations during early morning hours is known, traffic volumes during this time of day are generally unavailable, which makes estimates of traffic noise levels inaccurate. Accordingly, a field noise-measurement program was undertaken to gather sufficient data to permit an assessment of the potential noise impact during early morning hours, as well as other times of the day.

The two major purposes of the field measurement program were to measure noise levels at selected locations to document existing conditions throughout the day and to measure noise levels of individual bus passbys because only limited data concerning bus noise levels were available.

The field noise-measurement program, as well as the subsequent analysis reported in this paper, concentrated on the noise environment along North 130th Street east of Aurora Avenue, south of proposed site 1. This street was chosen from among all the possible bus routes with residential dwellings because it had the lowest current traffic flow (which would indicate the lowest existing noise levels) and the highest ratio of proposed bus to existing traffic volumes (which would indicate the greatest potential for noise impact). Thus the analysis for this street should indicate worst-case conditions for the potential impact of bus noise on the residences along proposed bus routes for either site 1 or 2.

The first noise measurement was of the existing 24-hr noise environment. Two locations were selected for monitoring, as shown in Figure 3. At both locations the noise environment was measured with automatic noise-monitoring instrumentation for

Figure 1. Proposed site 1 showing 1980 average daily traffic volumes on the local street system.

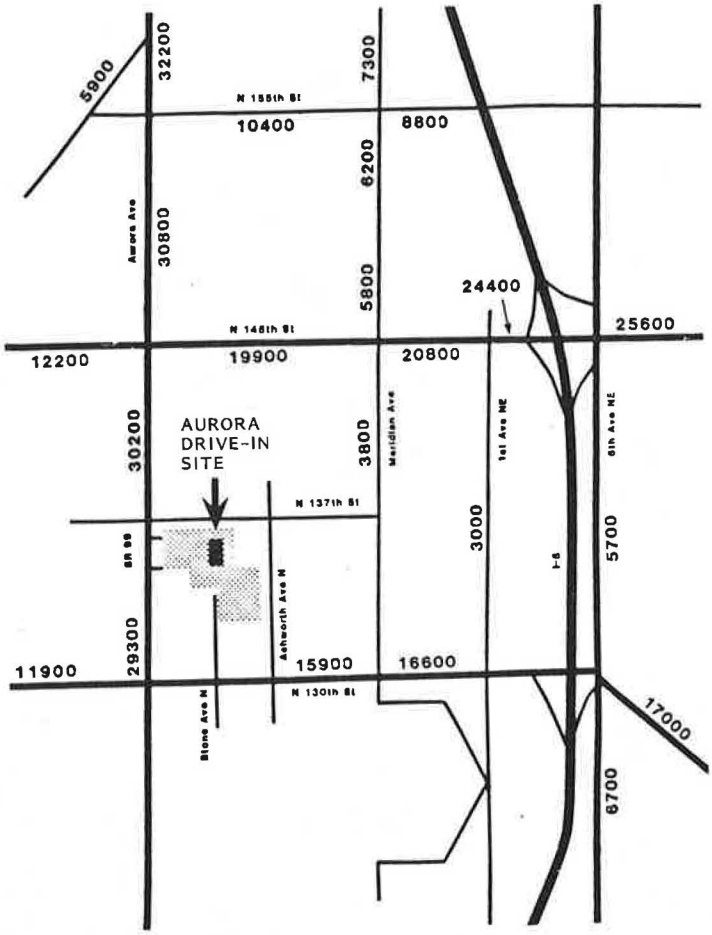


Figure 2. Proposed site 2 showing 1980 average daily traffic volumes on the local street system.

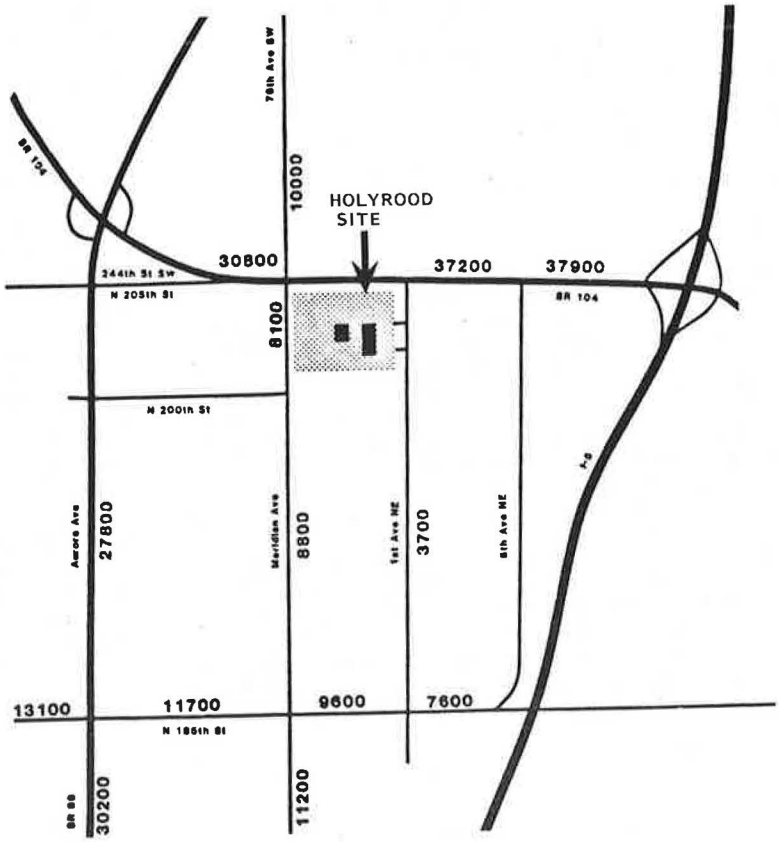


Figure 3. Noise measurement locations.

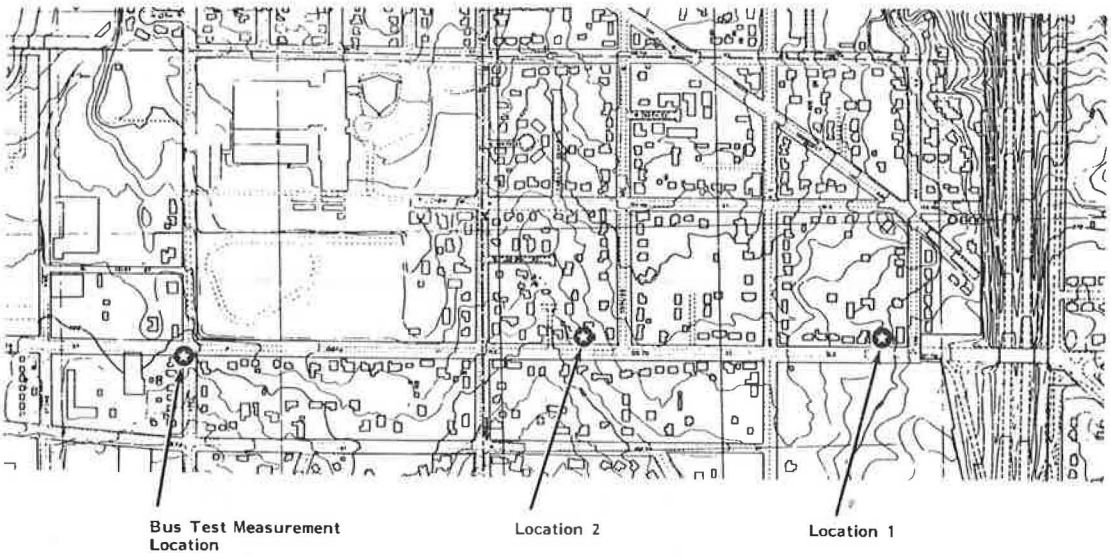


Table 1. Field measurement instrumentation.

Manufacturer	Model	Description
Noise Monitoring at Locations 1 and 2		
DAI	607P	Environmental noise analyzer
GR	9610	0.5-in. electret microphone
GR	9600	Preamplifier
B&K	UA0254	Windscreen
GR	1562A	Calibrator
Bus Measurement Recording		
Kudelski	Nagra III	Recorder
B&K	2203	Sound level meter
B&K	UA0254	Windscreen
B&K	4220	Pistonphone calibrator
B&K	4131	1-in. condenser microphone with random incidence adaptor
Bus Measurement Processing		
Kudelski	Nagra III	Recorder
DAI	607P	Environmental noise analyzer
B&K	2203	Sound level meter
B&K	2305	Graphic level recorder

a 1-day period from May 4 to May 5, 1982 (23 hr of data were acquired at each location). The two selected locations were thought to be representative of the noise environment along North 130th Street, although it is recognized that noise levels may vary from location to location, depending on proximity to other major roadways, presence of traffic signals, roadway gradients, and so forth. The locations selected were not intended to reflect the maximum or minimum exposure to noise along North 130th Street, but rather to generally be representative of conditions along the roadway.

Noise levels were monitored continuously at the selected locations with a DAI Model 607 noise monitor. (The instruments used to collect and process field data are given in Table 1.) These units sample the noise environment 8 times per second, store the measured noise levels internally, and generate a paper tape that lists hourly average sound levels as well as the statistics of the distribution of noise levels during the preceding hour. The monitors were also set up to measure and print out the noise levels of individual single events where the noise levels were greater than 75 dB(A). The units were calibrated at the beginning and conclusion of the measurement program.

Figure 4 shows the hourly average sound level measured at each location, as well as the day and night average sound level (L_{dn}), which is a measure of the 24-hr noise environment. The data in Figure 4 show that the pattern of hourly average sound levels is similar between the two locations, with the noise levels at location 1 typically 1 to 2 dB greater than those at location 2. The noise levels at both locations are fairly constant during daylight hours (8:00 a.m. to 8:00 p.m.), which indicates fairly constant traffic flow on North 130th Street during these hours. (Note that bus noise tests, to be described later, influenced the measured noise levels from 5:00 to 6:00 a.m. at both locations. Shown in Figure 4 are the measured noise levels, which include the bus passbys as well as the estimated noise levels with these bus passbys removed.)

The second set of measurements consisted of a series of planned bus passbys on North 130th Street between 5:00 and 6:00 a.m. on the morning of May 5, 1982. Noise levels were recorded at a measurement location on Ashworth Avenue, approximately 18 ft south of North 130th Street (see Figure 3). Eighteen different coaches of various types were used in the test, which involved each coach driving west past the measurement microphone, turning around, and driving back east past the measurement microphone. Nominal speed of travel was 25 to 30 mph. Because several coaches made 2 trips, a total of 25 passbys in each direction occurred during the test. The coaches selected for the test were representative of the typical mix of coaches expected to operate from the proposed operating base.

The measured bus passby noise levels were recorded on magnetic tape for later processing. The recorded noise levels were played back onto a graphic level recorder, from which the maximum noise level of each bus passby was determined. By correlating these measured noise levels with the observation log maintained in the field and the schedule of bus operations during the test, the maximum A-weighted noise level occurring during most of the passbys was determined. During the test there were occasional occurrences of multiple bus passbys; i.e., a bus heading east would pass by the measure-

Figure 4. Measured existing levels.

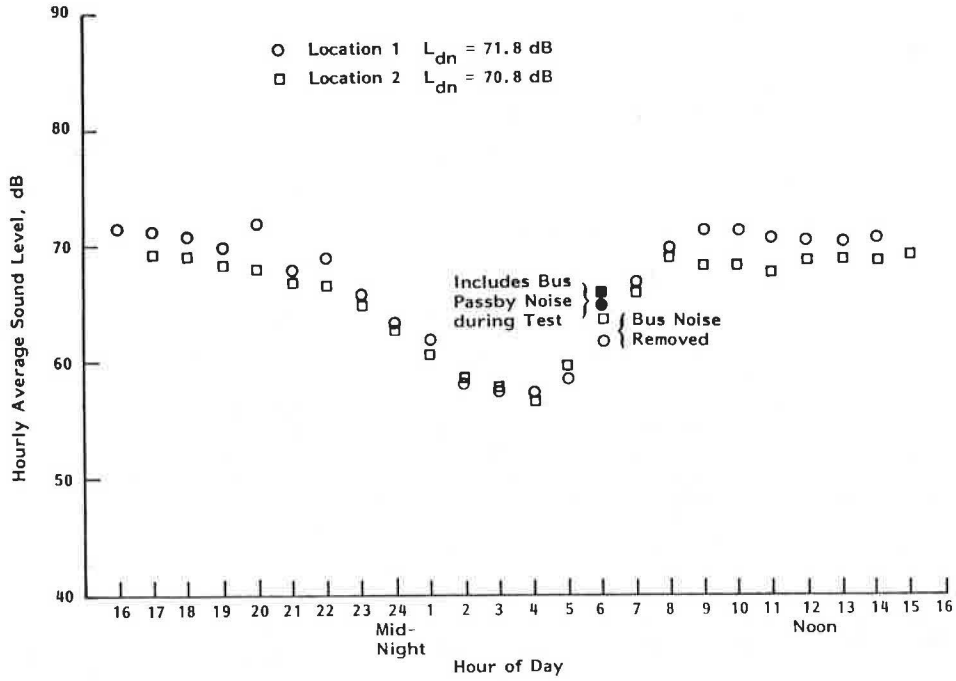


Table 2. Measured noise levels from bus passbys.

Bus Series	Bus No.	Maximum Passby A-Weighted Noise Level[a] (dB) Westbound (distance = 44 ft)	Eastbound (distance = 23 ft)	Eastbound (normalized[b])
1100	1103	79	-	-
1200	1261	-	86	80
	1268	76	75	69
	1209	78	80	74
	Avg	75	80	74
1300	1314	84	-	-
1400	1488	75	83	77
	1483	78	-	-
	1485	79	-	-
	1412	-	73	67
	1479	80	82	76
	1448	87	-	-
	1424	76	79	73
	1488	76	83	77
	1461	75	79	73
	1483	77	81	75
	1448	75	83	77
	1424	74	82	76
	Avg	77	81	75
1600	1666	79	82	76
	1668	75	81	75
	1690	-	77	71
	1668	73	78	72
	Avg	76	80	74
1700	1716	79	-	-
	1704	77	79	73
	1716	72	76	70
	1704	72	77	71
	Avg	75	77	71
Avg of all buses		77	80	74

[a]Measured with slow meter response.
[b]Normalized to 44-ft distance.

ment microphone simultaneously with a bus heading west. When this occurred, it was not possible to determine the maximum noise level of each individual vehicle.

The measured passby noise levels are given in Table 2. Note that westbound buses were approximately 44 ft from the measurement microphone, whereas eastbound buses were approximately 23 ft from the measurement microphone. In order to compare noise levels from buses traveling in both directions, the noise levels measured from eastbound buses were adjusted to reflect the noise level that would occur if these buses were traveling along the same lane at the same distance as the westbound buses, that is, at 44 ft (see the last column in Table 2). The data in Table 2 indicate that, on average, the westbound buses had noise levels that were 3 dB higher than the eastbound buses, which indicates that the driver's side is the noisier side of the bus.

The data in Table 2 also indicate that, although there may be considerable variability in the passby noise level for a given series of buses (the westbound passby levels for the series 1400 buses range from 74 to 87 dB), on average, no great variability exists among the various bus series. This may be due in part to the limited amount of data collected for some of the buses. Also note that at higher speeds greater differences between bus series may become apparent. For these tests, drivers were instructed to maintain a speed of 25 mph as they passed by the measurement location.

Note that during the passby test a variety of other vehicles traveling on North 130th Street passed by the measurement microphone. For example, during the tests a truck passed by with a maximum A-weighted sound level of 85 dB, which provided one of the highest readings during the measurement period.

The recorded bus noise levels were also played back into a DAI 607 noise-monitor unit, which provided the sound exposure level of individual events. This sound exposure level (SEL) is a useful measure of the total noise energy within each event; the summation of SELs occurring during a given time period may be used to derive the average sound level occurring during that time period. Unfortunately, because of the occurrence of simultaneous passbys (either of buses traveling in opposite directions or of several buses passing the measurement microphone in rapid sequence), it was not possible to determine the SEL of each bus passby. Nevertheless, the SEL determined by the monitor unit for a series of passbys (e.g., four buses passing by the microphone in a sequence) does have meaning and can be used as

a measure of the total energy in the four passbys. The measured SEL values for all of the bus events are given in Table 3. As indicated by the data in the table, some of the SEL values refer to individual passbys, whereas some are for multiple events. Also, when nonbus events occurred simultaneously with bus events (such as a car and bus driving by simultaneously), the SEL measured by the monitor unit had not been included.

Because SEL is a measure of total energy within each signal, the individual and multiple events can be combined together to derive an energy average for all events. As indicated by the data in Table 3, the energy-averaged SEL for all the events is 82.8 dB. This averaged SEL may then be used to predict the impact of a selected number of bus passbys.

Because of the multiple occurrences of bus passbys in both directions, it was not possible to segregate the eastbound and westbound SEL values. Nevertheless, the energy-averaged SEL value may be associated with an equivalent distance appropriate to all of the passbys; for estimation of average sound levels, this equivalent distance is 30 ft. For situations of greatest concern (early morning traffic when buses are traveling in the near lane), this approach may overestimate noise levels, because included in the average are the higher noise levels of buses traveling in the opposite direction when the driver's side faces the residence.

With the value of 82.8 dB for the average sound exposure level ($\overline{SEL}$) of a typical bus passby at 30 ft, the lower curve in Figure 5 has been developed by using the following relationship:

Hourly average sound level = $\overline{SEL}$ + 10 log (number of buses per hour) - 35.6 dB.

This lower curve represents the estimated hourly average sound level along North 130th Street from projected bus trips. The average sound levels shown in Figure 5 have been adjusted to an approximate distance of 41 ft, which corresponds to the approximate location of measurement microphones at locations 1 and 2 where 24-hr data were acquired. Shown beneath the curve of the estimated bus level is the number of bus trips expected by hour of day. The upper curve is presented for comparison purposes; this curve is the lower bound of the measured hourly average sound levels shown in Figure 4 at either locations 1 or 2.

Table 3. Measured SELs from bus passbys.

Passby A-Weighted SEL at 30 ft (dB)	No. of Buses Measured	Passby A-Weighted SEL at 30 ft (dB)	No. of Buses Measured
79.7	1	84.3	1
86.4	2	81.8	1
84.9	1	78.0	1
85.3	3	84.5	1
91.4	6	85.6	2
91.9	8	80.8	1
91.5	5	84.7	4
76.4	1	89.7	4
80.8	1		

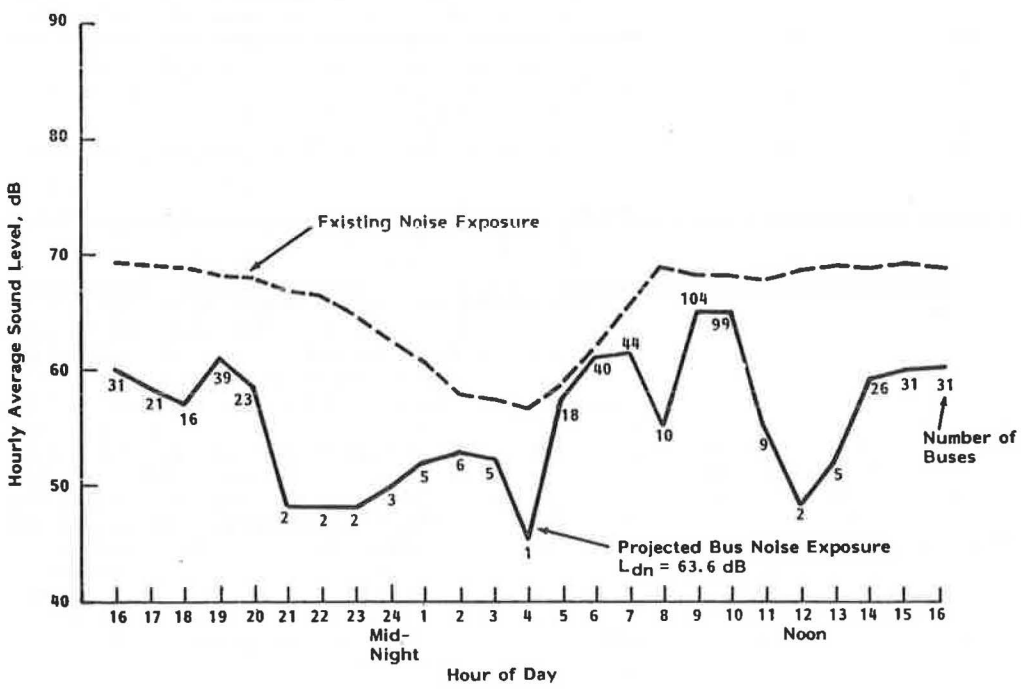
Note: The energy-average SEL of 43 bus passbys is 82.8 dB.

Analysis of Impact

Applicable regulations and criteria for judging the noise impact are described in detail in the draft EIS. For base-generated traffic, the assessment would involve comparison of projected bus levels with existing traffic levels, in light of federal compatibility guidelines related to absolute levels and U.S. Environmental Protection Agency (EPA) Region 10 guidelines about noise increases. The federal guidelines indicate that day and night levels in excess of 65 dB are unacceptable for residential land use. EPA Region 10 guidelines indicate that noise-level increases of up to 5 dB are considered slight, up to 10 dB are considered significant, and greater than 10 dB are considered serious.

On a daily basis the day and night sound level for locations along North 130th Street already places the location in an unacceptable noise envi-

Figure 5. Comparison of measured existing levels and projected bus levels.



ronment category. The projected L_{dn} value for proposed bus traffic is sufficiently low so as not to contribute to the total day and night level. On a 24-hr basis, therefore, the proposed bus operations would not affect residences along North 130th Street.

On an hourly basis, Figure 5 shows that between the hours of 4:00 and 6:00 a.m., projected hourly average sound levels of buses will be comparable to existing measured hourly average sound levels. Thus during these hours the total exposure to noise would be approximately 3 dB higher than at present. This would be categorized by the EPA guidelines as a slight impact.

Note however that there will be variations in both projected and existing noise levels from buses with locations along North 130th Street, and there may be some locations where future noise levels from buses may exceed existing levels by perhaps 2 to 3 dB. Under such conditions the increase in total noise level would likely still be less than 5 dB, and therefore would still be considered a slight impact.

One further consideration must be discussed, however. Even for those locations where future noise levels from buses will be less than existing levels, noise levels will likely be noticeable within the homes of residents. For some residents, the repeated passbys of buses may interfere with sleep. Unfortunately, the area of sleep disturbance from noise intrusions is not well understood, and there is little scientific data that provide clear guidelines concerning the impact of such noise sources, particularly when the average level is comparable to background levels. Thus even though EPA guidelines would indicate that only a slight impact might occur, and even though no specific criteria are available that can be cited as a basis on which to judge the potential for sleep disturbance, it should be recognized that during the hours of 4:00 to 6:00 a.m. such an impact on sleep might occur.

A final comparison might shed some light on this subject of sleep disturbance. The maximum sound levels and SELs measured at locations 1 and 2 during the hours of 10:00 p.m. to 7:00 a.m. are given in Table 4. The data in the table indicate those noise levels that may have been due to bus passbys as a result of the special bus noise tests conducted during that time period. Note that other sources of noise, such as other traffic vehicles normally traveling on North 130th Street, are already creating maximum levels and SELs that are comparable to and higher than noise levels that may be generated by bus passbys. Thus if these noise events are not now affecting sleep patterns, it is reasonable to expect that the projected bus passbys will not have an impact on sleep.

The impact of future bus traffic on streets other than North 130th Street will be lower than that indicated for North 130th Street. For example, projected bus operations on North 145th Street are about a third of those projected for North 130th Street, yet the traffic on North 145th Street is higher than on North 130th Street. This would tend to shift the curves shown on Figure 5 approximately 5 dB farther apart. With regard to the impact analysis for the proposed site 2, projected bus operations on North 205th Street are approximately twice that on North 130th Street; however, existing traffic flow on North 205th Street is more than twice that on North 130th Street. For North 205th Street, the two curves shown on Figure 5 would be shifted apart by approximately 1 dB.

Mitigation Measures

On the basis of the discussion in the preceding section, the only time period during which mitigation measures might be considered is the period from 4:00 to 6:00 a.m. A simple and effective way to reduce noise levels during this period would be to divert a portion of the traffic scheduled for North 130th Street to other east-west streets capable of handling the bus traffic, such as North 110th Street and North 85th Street. For example, removing half of the expected buses between 4:00 and 5:00 a.m. and between 5:00 and 6:00 a.m. would reduce hourly average sound levels by 3 dB on North 130th Street, and reducing expected buses by three-quarters would reduce hourly average sound levels by 6 dB. These changes in the pattern of hourly average sound levels are shown in Figure 6. Reducing noise levels on North 130th Street by 3 to 6 dB could well ensure that sleep disturbance is minimized.

Note that the addition of bus traffic on North 110th Street or North 85th Street will likely have little effect on nearby residents because of the low level of bus traffic diverted to these streets. Also, these streets have higher traffic volumes than North 130th Street, and therefore presumably higher noise levels during the hours of 4:00 to 6:00 a.m.

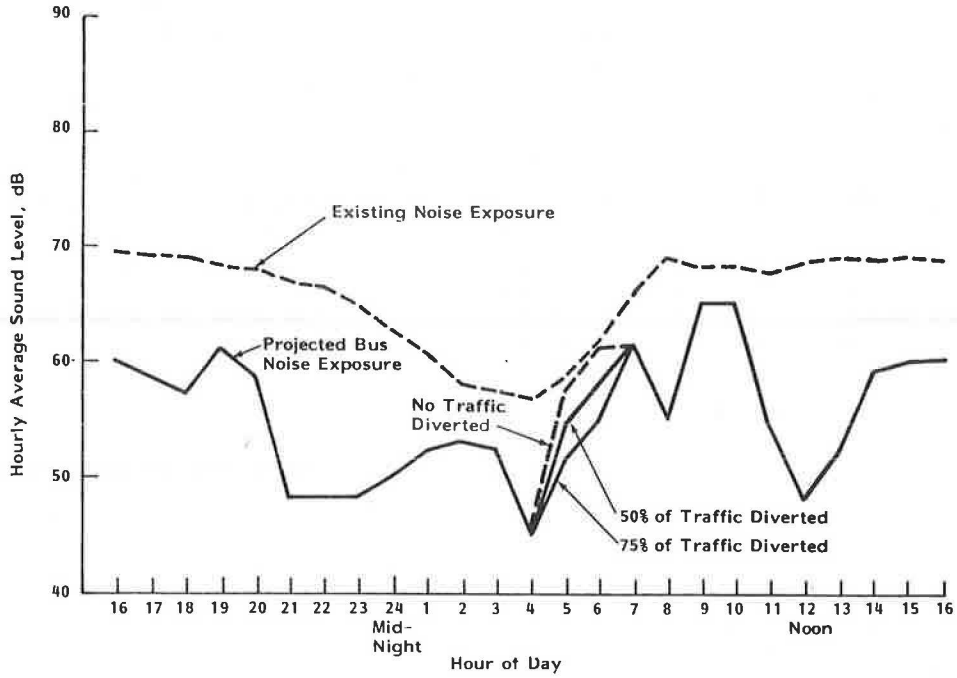
Table 4. Measured night noise levels at locations 1 and 2.

Hour	SEL (dB)	Maximum A-Level (dB)
Location 1		
10:00-11:00 p.m.	83.9	81.2
	83.8	80.3
	85.3	81.4
11:00 p.m.-12:00 midnight	84.4	80.0
12:00-1:00 a.m.	89.7	86.2
3:00-4:00 a.m.	86.3	80.7
	82.8	78.7
4:00-5:00 a.m.	88.0	84.0
5:00-6:00 a.m.[a]	83.4	78.4
	82.3	77.2
	84.0	79.5
	81.6	77.2
6:00-7:00 a.m.	83.8	81.2
Location 2		
10:00-11:00 p.m.	82.4	78.8
11:00 p.m.-12:00 midnight	84.8	81.5
	82.0	78.7
	83.1	79.4
12:00-1:00 a.m.	86.2	83.0
Location 2 (continued)		
1:00-2:00 a.m.	83.4	80.1
2:00-3:00 a.m.	87.4	83.4
3:00-4:00 a.m.	84.5	79.7
4:00-5:00 a.m.	81.3	77.5
	90.8	85.1
	84.3	79.8
5:00-6:00 a.m.[a]	89.6	84.8
	83.5	80.1
	81.9	77.9
	85.9	78.2
	85.2	82.0
	83.4	79.5
	83.3	78.8
	83.7	80.2
	94.7	86.3
6:00-7:00 a.m.	82.1	78.7
	85.2	81.1
	87.0	82.5
	81.2	77.2

Note: Only noise signals with levels greater than 75 dB are listed.

[a]Period of bus passby test.

Figure 6. Change in projected bus levels for traffic diversion from 4:00 to 6:00 a.m.



One mitigation measure suggested early in the study was the modification of homes along North 130th Street. As discussed previously, reducing the noise level by 3 dB can be achieved by diverting approximately half of the traffic to alternate routes. Reducing the noise level by 6 dB can be accomplished by diverting three-quarters of the traffic. For the same type of reduction to be achieved by building modification, fairly significant changes to the building structure would be required. A study (3) of the costs of building modifications for noise abatement indicated that (in 1973 dollars) modifications to a single-family dwelling would cost approximately $6,000 to achieve a 5-dB reduction in noise. In 1982 dollars, this would be more than $10,000, which is clearly not a cost-effective measure in the light of the reduction in noise obtainable by simply diverting traffic. Of course, the reduction achievable through building modification does apply throughout the entire day, whereas the route-diversion mitigation measure only applies to those hours in which it is implemented.

Reduction of the noise levels of buses through source control would include replacing noisy buses with quieter models or retrofiting buses to produce lower noise levels. Consideration of this mitigation measure was beyond the scope of this study.

IMPACT EVALUATION OF BASE OPERATIONS

Proposed Operations and Their Potential Impact

The draft EIS (1) and the noise and vibration technical backup report (2) describe future base activities and provide noise-level estimates for these activities. These documents categorize activities in terms of maintenance operations, fuel and wash operations, and bus start-up operations. Although all of the assumptions and input information used to develop the noise-exposure estimates were not completely available, the projected noise-exposure levels from these various operations appear quite reasonable based on a review and analysis of the data presented in the report by Michael R. Yantis Associates (2).

The impact analysis indicates that for both proposed site 1 and proposed site 2 the noise of maintenance operations will provide the greatest impact in terms of the amount by which the Seattle and King County noise ordinance will be exceeded. For selected residential locations, the noise-level estimates are projected to exceed ordinance limits by as much as 27 to 29 dB. Bus start-up noise is the second greatest cause of concern, providing future noise levels that will exceed the ordinance by as much as 12 to 14 dB at selected locations. Fuel and wash operations will have the least potential impact at most residential locations.

Mitigation Measures

For purposes of describing measures to reduce or eliminate the potential noise impact, it is useful to categorize sources of the potential noise impact as follows: maintenance operations that occur indoors, maintenance operations that occur outside, and bus start-up operations. Indoor maintenance operations would include stalled coach tests, fast idle tests, and the use of pneumatic tools. Maintenance operations that occur outside would include the use of eductor trucks, cyclone cleaners, yard sweepers, and fuel and wash operations.

Such a breakdown is useful because the most cost-effective measure of noise control for indoor activities is clearly the closing of maintenance building doors during the times when these operations occur. Note that several of these operations occur rather infrequently, such as stalled coach tests, which are expected to occur approximately 3 times per day at less than 5 min per time. Closing doors during these intervals should not create any adverse impact on maintenance personnel inside the building.

For outside maintenance operations, including fuel and wash operations, care should be taken to schedule such activities during daytime hours. For example, one report (2) indicates that the yard sweepers will typically operate between 6:30 and 7:30 a.m. If this activity can be shifted to slightly later in the morning, the noise impact would not be as severe.

One of the major sources of noise is the eductor truck, which is used to pump out selected storage sumps on the base. This activity will occur fairly infrequently; however, when the activity does occur, the resulting noise levels will be high enough to exceed noise ordinance limits. A recommended mitigation measure will be the use of noise barrier walls to provide shielding to nearby residents. Because the exact locations of the eductor trucks have not yet been determined, it is difficult to assess the precise benefits of such walls relative to the noise produced by these trucks. It is likely, however, that the noise reduction provided by the walls for the eductor truck noise will not be sufficient to eliminate the potential noise impact. A supplementary measure would be the use of portable noise barriers, such as those used in construction work, located in the immediate vicinity of the truck to provide an extra measure of noise control. Because of the infrequency of eductor truck operations, use of such portable barriers should not have a major impact on base operations.

Even if the noise of maintenance operations were entirely controlled by closing the maintenance doors, scheduling of operations to occur during daytime periods, and using portable noise barriers, the noise of bus start-up and pull-out operations would result in noise levels in excess of ordinance limits, and at selected locations the noise of fuel and wash operations would also exceed ordinance limits. Because bus start-up operations occur throughout the base, and because these activities will occur throughout the entire 24-hr period, the use of noise barrier walls along the perimeter of the base will be an effective mitigation measure. The barriers may be contructed of wood or masonry block at an approximate height of 13 ft aboveground.

Recommended locations for such walls are shown in Figures 7 and 8. These locations have been selected primarily to minimize the impact of base activity on residential areas that surround the base. The length of wall indicated for each site in Figures 7 and 8 is greater than indicated in the draft EIS; the additional length was deemed necessary to avoid the potential for sound paths to the community around the sides of the walls.

After the operating base site is selected, and grading plans and the layout of the base are completed (for building placement, bus parking, entrance and exit locations, and so on), it would be desirable to develop more detailed and specific plans for such walls. It is quite possible that the height of the walls can be reduced, at least in selected locations, from the estimated 13 ft. The 13-ft height has been chosen as a height that, for all prediction locations used in the draft EIS, will eliminate the impact of bus start-up noise.

With implementation of the mitigation measures just described, placement of buildings on the site will not have a significant effect on the reduction of community noise levels.

CONCLUSIONS

The major conclusions resulting from the analysis described in this paper are as follows.

1. Base-generated bus traffic along North 130th Street will not affect nearby residences throughout most of the day. From 4:00 to 6:00 a.m., base-generated bus traffic will have a slight impact. During this time period the noise of bus passbys may cause sleep disturbance for some residents, although the area is already exposed to noise of comparable levels from other vehicles on North 130th Street.
2. The potential noise impact of base-generated traffic on other streets in the vicinity of proposed sites 1 or 2 will be lower than that described for North 130th Street.
3. The potential noise impact of base-generated traffic from 4:00 to 6:00 a.m. may be mitigated by diverting a portion of the bus trips to other east-west streets. For those streets selected, there should be no noise impact.

Figure 7. Recommended noise barriers, north base, site 1.

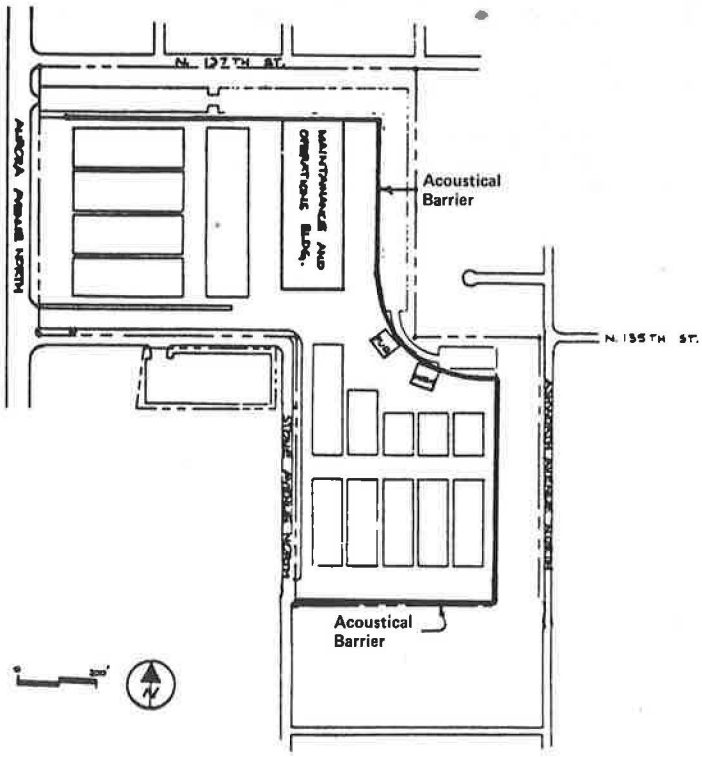
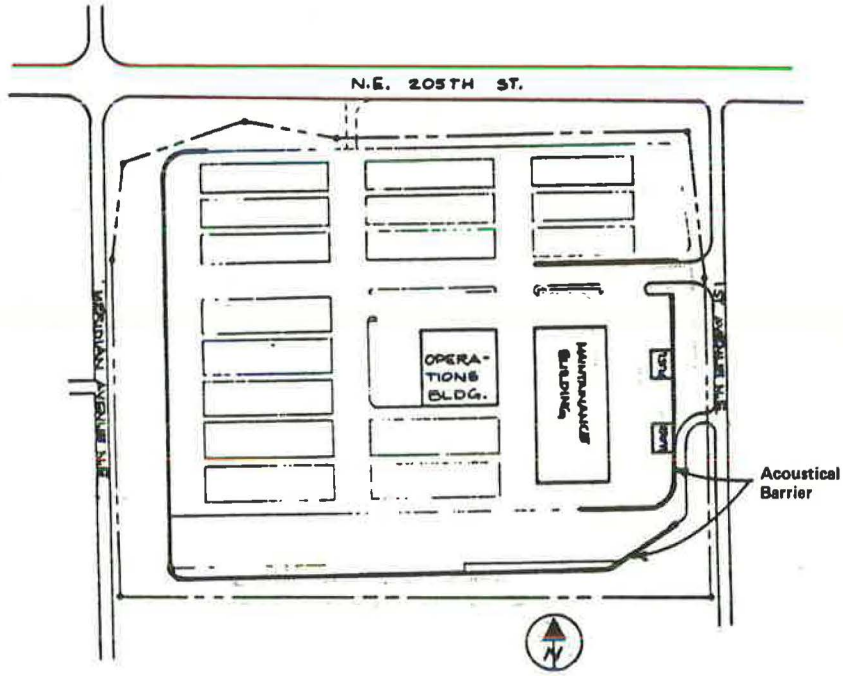


Figure 8. Recommended noise barriers, north base, site 2.



4. Modification of residences along roads on which buses are scheduled to operate is not a cost-effective method of noise control.

5. The major source of noise impact resulting from on-base operations is maintenance activity, and in particular the use of eductor trucks. Bus start-up and pull-out noise is also a significant contributor to the noise impact in community areas surrounding the proposed base.

6. The potential noise impact of maintenance activities that occur inside the maintenance building can be completely mitigated by closing the building doors when these operations are under way.

7. Whenever possible, outside maintenance activities should be scheduled to occur during daytime hours.

8. When eductor trucks are used, portable noise barriers should be used to reduce the potential noise impact.

9. As an overall mitigation measure for on-base sources, and particularly for bus start-up and pull-out noise, construction of noise barrier walls along the perimeter of the operating base is recommended. A masonry block or wooden wall 13 ft high will eliminate the impact of bus start-up and pull-out noise.

10. After detailed plans for the operating base are prepared, a detailed design of the recommended noise barrier walls should be undertaken. This design would specify exact dimensions and locations to provide maximum noise reduction at the greatest cost-effectiveness.

REFERENCES

1. SEPA Draft Environmental Impact Statement/NEPA Environmental Assessment--North Operating Base. Municipality of Metropolitan Seattle, March 1982.
2. Environmental Impact Statement--Noise and Vibration Portion for the Proposed Metro North Operating Base. Michael R. Yantis Associates, Seattle, Dec. 1981.
3. Bolt Beranek and Newman, Inc. Highway Noise: Generation and Control. NCHRP, Rept. 173, 1976, 174 pp.