SEA·TAC INTERNATIONAL AIRPORT

NOISE EXPOSURE UPDATE

PORT OF SEATTLE

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SEA-TAC INTERNATIONAL AIRPORT

NOISE EXPOSURE UPDATE

June, 1982

Port of Seattle

D/060/63E - 06/28/82

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CHAPTER 1

SUMMARY OF FINDINGS

CHAPTER 1

SUMMARY OF FINDINGS

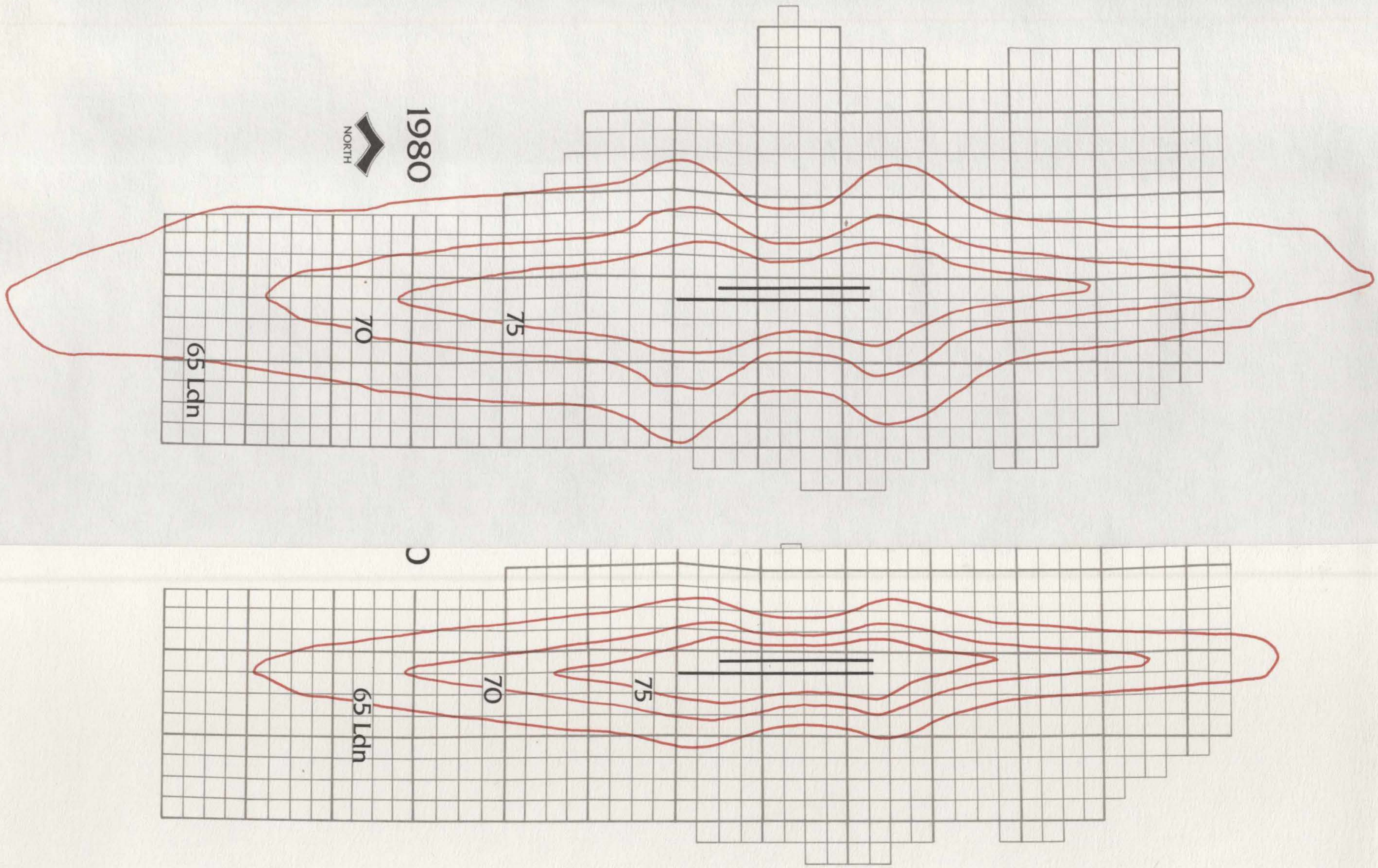
This study, The Sea-Tac International Airport Noise Exposure Update, represents an update of the noise analysis presented in the Sea-Tac/Communities Plan. The Update identifies existing levels of aircraft-generated noise exposure and forecasts future levels of aircraft-generated noise exposure for the years 1985, 1990, and 2000. Projected noise exposure levels are based on the most current data available and the most recent forecast of aviation demand.

Since completion of the Sea-Tac/Communities Plan in 1975, significant events have altered the level, composition, and structure of aircraft operations at Sea-Tac International Airport (Sea-Tac). Two of the most notable events have been airline deregulation and the growth of the commuter airline industry. Airline deregulation has, for example, resulted in an increase in major airlines operating at Sea-Tac--from twelve to over twenty-five. Operations by commuter airlines using small aircraft have about doubled. It was probable that these and other changes in operations altered the noise exposure levels predicted by the Plan. Considering that these noise levels provide the schedule and scope of Sea-Tac's noise remedy programs, two studies were deemed necessary: (1) an update of the projected noise exposure levels, and (2) a reevaluation of the noise remedy programs based on these updated projections. This update is the first of the two studies.

Findings concern two areas: future trends of noise exposure levels and changes in noise exposure levels since the Sea-Tac/Communities Plan. Through the year 2000, this study projects decreasing noise levels generated by aircraft. This decrease is attributed primarily to the changes in the types of aircraft serving Sea-Tac. Many of the existing types of aircraft have engines which will be retrofitted for quieter operations. Others will be retired and replaced by new technology aircraft which are quieter. Exhibit 1-1 illustrates the decrease in noise levels through the forecast years as the shifting of noise contours toward the Airport. Between 1980 and 1985, the area within each of the noise contours decreases by about 10%. An additional 14% to 15% decrease in area within contours is projected between 1985 and 1990. This is followed by a much more dramatic decrease in area within contours between 1990 and the year 2000--over a 45% reduction. In the year 2000, almost all areas projected to have significant noise exposure levels (i.e., levels over 75 annual average day-night level) will be within the existing Airport boundaries.

A comparison with the noise analysis in the Sea-Tac/Communities Plan shows that noise exposure levels have both decreased and increased in areas around the Airport. Generally, noise exposure levels have decreased north and south of the Airport and increased east and west of the the Airport. Not all of these changes were projected by the Sea-Tac/Communities Plan. For instance, noise exposure levels in areas northwest and southeast of the Airport actually decreased more than projected. At the same time, noise exposure levels in areas east and west of the Airport increased during a period in which a decrease had been projected.

These findings emphasize the timeliness of the study to follow, the reevaluation of the noise remedy programs recommended by the Sea-Tac/Communities Plan. The Port of Seattle will continue its commitment to base the schedule and scope of Sea-Tac's noise remedy programs on the most up-to-date forecasts of noise exposure levels.



SEA·TAC INTERNATIONAL AIRPORT

NOISE EXPOSURE UPDATE

PORT OF SEATTLE • SEATTLE, WASHINGTON

1980, 1985, 1990 & 2000

NOISE CONTOURS

FEET 0 2 4 8 12,000

Exhibit 1-1

CHAPTER 2

OVERVIEW

CHAPTER 2

OVERVIEW

2.1 STUDY SCOPE AND PURPOSE

In 1971, the Federal Aviation Administration (FAA) mapped noise contours for Sea-Tac International Airport. However, the first major noise analysis for the Airport was part of the Sea-Tac/Communities Plan. This noise analysis (Report Element 5.5), completed in September 1974, presented measured Noise Exposure Forecast (NEF) noise levels for 1973 operations as well as predicted Adjusted Noise Exposure (ANE) noise levels for 1978, 1983, and 1993. The forecasted years were based on 5-, 10-, and 20-year forecast periods. These noise exposure projections formed the basis for the development of Sea-Tac's noise remedy programs.

Since completion of the Sea-Tac/Communities Plan in 1975, significant events have altered the level, composition, and structure of aircraft operations at Sea-Tac. Two of the most notable events have been airline deregulation and the growth of the commuter airline industry. Airline deregulation, for example, has resulted in an increase in major airlines operating at Sea-Tac from twelve to over twenty-five. Operations by commuter airlines using small aircraft have about doubled. It was probable that these and other changes in operations altered the noise exposure levels predicted by the Plan. Considering that these noise levels provide the schedule and scope of Sea-Tac's noise remedy programs, two studies were deemed necessary: (1) an update of the projected noise exposure levels, and (2) a reevaluation of the noise remedy programs based on these updated projections.

This study fulfills the need to update projected noise exposure levels at Sea-Tac. Its methodology demonstrates the state of the art in noise prediction techniques. Its findings present the most current projections of noise exposure levels and establishes the difference between the noise exposure projections of the Sea-Tac/Communities Plan and this study.

2.2 ORGANIZATION

The study has been divided into four main parts:

- data collection
- forecast of aircraft operations
- Integrated Noise Model (INM) evaluation
- noise exposure projections

Collected data included noise measurements from the permanent Noise Monitoring System (NMS) stations and portable noise measuring equipment. Additional information was gathered on the level and composition of 1980 base year aircraft operations, aircraft flight procedures, status of aircraft Federal Aviation Regulation FAR Part 36 compliance, and meteorological records. The forecast of aircraft activity at Sea-Tac estimated the level of operations and composition of the fleet for the years 1985, 1990, and 2000. Based on a comparison of predicted and measured noise, the Integrated Noise Model (INM) was evaluated and calibrated to reflect the site specific characteristics of Sea-Tac. Noise exposure contours were generated by the validated model for existing and future levels of aircraft operations.

2.3 SPONSORS

This study has been sponsored by the Port of Seattle and prepared by the Port of Seattle Planning and Research Department for the Port of Seattle Aviation Department. Funding in part was provided by the Federal Aviation Administration through the Planning Grant Program of the Airport and Airway Development Act, Federal Grant No. A 53-0062-02.

2.4 CONSULTANT

The Parry Company assisted the Port of Seattle Planning and Research Department in the preparation of this study. Their role was to provide limited technical overview assistance and review of the methodology, data collection, and analysis done by the study staff.

2.5 PARTICIPANTS

Since the initiation of the Sea-Tac/Communities Plan, the Policy Advisory Committee (PAC), has been the main vehicle for public response regarding all Sea-Tac related policy issues. Members include representatives from citizen groups, public agencies, and private organizations.

In order to provide technical advise and a means for direct citizen participation in the development and preparation of the Sea-Tac Noise Exposure Update, PAC appointed a working subcommittee. Called the Technical Advisory Committee (TAC), this subcommittee was made up of representatives of a number of governmental agencies, aviation related companies and associations, and citizen groups which included:

Air Line Pilots Association (ALPA)
Air Transport Association (ATA)
The Boeing Airplane Company
City of Des Moines
Division of Aeronautics/Washington State Department of Transportation
Environmental Health Department/University of Washington
Environmental Protection Agency (EPA), Noise Program
Federal Aviation Administration (FAA), Airports Division, Planning Branch
Harbor Airlines
Highline School District
Northwest Airlines
Policy Advisory Committee (PAC) Citizen Representatives
Port of Seattle
Puget Sound Council of Governments
Riverton Heights Citizens
Washington Pilots Association
Zone III Citizens

TAC meetings were held regularly through the course of the study. Minutes or summaries of these meetings are available from the Port of Seattle Planning and Research Department.

Study status reports were made to PAC at PAC meetings during the course of the study.

In addition to the members of PAC and TAC, contacts were made throughout the study with various governmental agencies, aviation related companies and associations, and citizens groups. These included:

Alaska Airlines
Braniff Airways
Continental Airlines
Delta Airlines
Eastern Airlines
Federal Aviation Administration, Air Traffic Control Tower,
  Sea-Tac International Airport; Office of Energy and Environment
Flying Tiger Line
General Aviation Manufacturers Association (GAMA)
King County Department of Planning and Community Development
National Weather Service
Pan American World Airways
Port of Portland
Republic Airlines
Trans World Airlines
United Airlines
Western Airlines
Wien Air Alaska

CHAPTER 3

EXISTING CONDITIONS

CHAPTER 3

EXISTING CONDITIONS

3.1 INTRODUCTION

This inventory documents all pertinent information related to airport facilities, aircraft operations and the current noise environment at Sea-Tac and of the surrounding area. The information from this inventory will be used as the basis for projecting future aircraft noise exposure levels at Sea-Tac International Airport.

3.2 AIRPORT FACILITIES

Sea-Tac International Airport is located about 12 miles south of downtown Seattle and to the west of U.S. 99. Within its boundaries are 2,400 acres which accommodate a parallel runway and taxiway system, a passenger terminal complex of 56 aircraft gates and 1,915,000 square feet of building space, over 2 acres of general aviation transient aircraft parking apron, and over 500,000 square feet of air cargo building space.

3.2.1 Runway and Taxiway System

The Airport's runway system consists of a north/south set of parallel runways, 16R/34L and 16L/34R. Runway 16R/34L is the west of the two runways and is 9,425 feet long and 150 feet wide. It is equipped with High Intensity Runway Lights (HIRL), an instrument landing system-Category II on 16R (i.e. the north end of the runway) and a Visual Approach Slope Indicator (VASI) on 34L (i.e. the south end of the runway). Runway 16L/34R is the east of the two runways and is 11,900 feet long and 150 feet wide.[1/] It is equipped with HIRL, an instrument landing system - Category I[2/] on 34R (i.e. the south end of the runway) and a VASI on 16L (i.e. the north end of the runway). The main terminal area is located on the east side of the runways.

The Airport's taxiway system consists of a major taxiway thoroughfare and a number of access taxiways which connect the runways with the passenger terminal building and cargo areas. Taxiway A is the major taxiway thoroughfare. It runs parallel to runways between Runway 16L/34R and the terminal area. Taxiways A1, A2, A3, A4, A5, A7, A8, and A9 provide access between Runway 16L/34R and Taxiway A. Taxiways B, B2, B3, B5 and B6 provide access between the west side of the airfield and Runway 16R/34L. All taxiways have centerline lighting except the extreme south end of Taxiway A.

The airfield layout is illustrated in Exhibit 3-1.

3.2.2 Passenger Terminal Facilities

The passenger terminal complex includes a central terminal building (835,000 square feet) and two satellite buildings (540,000 square feet each) which are connected by an underground automated passenger transit system. The existing terminal buildings are configured for 56 aircraft gates and are designed to accommodate 12 to 15 million passengers a year.

3.2.3 General Aviation Facilities

A two acre general aviation transient aircraft parking apron is located south of the terminal area. Two Fixed Based Operators (FBO) manage parking and provide limited services for transient general aviation aircraft.

3.2.4 Air Cargo Facilities

Over 500,000 square feet of building space is used at Sea-Tac to handle air cargo and air mail. All of the cargo buildings are located in the northeast section of the airport with the exception of one cargo building south of the terminal buildings. All-cargo aircraft are accommodated on apron area adjacent to the cargo buildings and are on occasion accommodated near the general aviation transient aircraft parking area or the end of the main terminal's south concourse.

3.3 AIRCRAFT OPERATIONS

In 1980, there were 212,744 aircraft operations (i.e., an arrival or departure) at Sea-Tac. Scheduled and supplemental certificated air carriers accounted for 67.5% (143,646) of the year's operations[3/]; air taxi and commuter carriers for 19.1% (40,681); general aviation for 13.1% (27,876); and military for 0.3% (541).

3.3.1 Fleet Mix

Estimates of Sea-Tac operations by various aircraft categories are made using Civil Aeronautics Board Service Segment Data, the Official Airline Guide and sample counts at Sea-Tac. The 1980 fleet mix is estimated below:

Aircraft Category	Number of Operations	Percent of Total
Two-engine, narrow body (e.g., DC9, B737)	20,926	9.8%
Three-engine, narrow body (e.g., B727)	76,200	35.8%
Four-engine, narrow body (e.g., DC8, B707)	3,984	1.9%
Two- and three-engine, wide body (e.g., A300, DC10, L1011)	22,043	10.4%
Four-engine, wide body (e.g., B747)	9,563	4.5%
Single-engine piston (e.g., Beech Bonanza, Cessna Skylane)	9,923	4.7%
Twin-engine piston (e.g., Britten Norman Islander, Cessna 402)	38,494	18.1%
Turboprop (e.g., Beech 99, Swearingen Metro)	25,369	11.9%
Turbofan and Turbojet (e.g., Cessna Citation, Learjet)	4,962	2.3%
Other (e.g., helicopter, military)	1,280	0.6%
	212,744	100.0%

3.3.2 Runway and Flight Track Utilization

Runway utilization is a function of a combination of factors which include weather conditions, pilot preference, aircraft performance, navigational aids, FAA noise abatement procedures, and aircraft traffic requirements. The distribution of aircraft arrivals and departures by runway was based on observed frequency of use and was estimated for 1980 as follows:

	Air Carrier Arrivals (%)	Air Carrier Departures (%)
Runway 34R	30.4	6.4
Runway 34L	1.6	25.6
Runway 16R	55.9	3.4
Runway 16L	12.1	64.6
	100.0	100.0

	Commuter and General Aviation Arrivals (%)	Commuter and General Aviation Departures (%)
Runway 34R	26.0	21.5
Runway 34L	6.0	10.5
Runway 16R	55.9	13.6
Runway 16L	12.1	54.4
	100.0	100.0

Flight tracks are defined by the path of an aircraft projected on the ground as the aircraft either lands or takes off from the runway. The flight tracks utilized in this study are not intended to be inclusive of all paths available to aircraft on approach and departure. Many factors influence the individual flight path taken by an aircraft such as aircraft routing by the Federal Aviation Adminstration's Air Route Traffic Control Center and the Sea-Tac Air Traffic Control Tower, the origin and destination of the aircraft, the amount and location of other aircraft traffic in the area, performance characteristics of the aircraft, utilization of airport navigational aids, weather conditions, and pilot discretion. A limit to the number of flight tracks by the Integrated Noise Model (see Chapter 5 for a description of this noise prediction model) restricted flight track definition to only the center of the most frequently used "airspace corridors."[4/]

Propeller driven aircraft arrivals and departures are represented by the flight tracks closest to the airport and identified by a "C" (for conventional) on Exhibits 3-2 and 3-3. These aircraft are allowed by the FAA on departure to turn after takeoff upon reaching 1,000 feet mean sea level (MSL) and on approach position the aircraft on the base leg of the approach pattern no closer to the airport than outside the airport boundary. Turbojet aircraft arrivals and departures are represented by flight tracks identified by a "J" (for jet) on Exhibits 3-2 and 3-3. These aircraft are required to follow noise abatement procedures identified in FAA Order Sea TWR 7110.071 C (October 7, 1980).

In a south flow of traffic, aircraft generally follow the flight tracks shown in Exhibit 3-2. Weather and traffic permitting, turbojet arrivals are routed through Elliott Bay. Turbojet departures are not allowed to turn following takeoff until reaching 3,000 feet MSL and at least 3 nautical miles south of the airport for westbound aircraft and 3,000 feet MSL and at least 5 nautical miles south of the airport for eastbound aircraft.

In a north flow of traffic, aircraft generally follow the flight tracks shown in Exhibit 3-3. Turbojet arrivals are turned onto the final approach course 4 or more nautical miles south of the airport. Turbojet departures are routed westbound over Elliott Bay except depatures between the hours of 6 a.m. and 10 p.m. which are allowed to turn east 8 nautical miles north of the airport at or above 4,000 feet MSL.

A complete presentation of flight track utilization by origin and destination of air carrier and commuter/general aviation aircraft is found in Tables 6-2 and 6-3.

3.3.3 Aircraft Fleet Noise Compliance

The FAA's regulatory noise abatement program was initiated by the adoption of Part 36 of the Federal Aviation Regulations "Noise Standards: Aircraft Type and Airworthiness Certification" (14 CFR 36) which became effective December 1, 1969. Part 36 prescribed noise measurement, evaluation, and level requirements for the issuance of aircraft type and airworthiness certificates. These standards apply to subsonic transport category large airplanes and to subsonic turbojet engine powered airplanes regardless of category and weight. Subsequent amendments to Federal Aviation Regulations (FAR) have broadened the regulatory noise abatement program of the FAA.[5/] All civil subsonic turbojet powered aircraft with maximum certificated takeoff weight of 75,000 pounds or more, operating in the United States, regardless of the state of registry, are required to be in compliance with the established noise level limits of FAR Part 36 after specific dates.[6/]

U.S. certificated airlines have reported to the FAA that they expected 49% of their aircraft fleet to be in compliance with FAR Part 36 noise limits by January 1, 1981 and 87% in compliance by the start of 1985.[7/] At Sea-Tac, an estimated 62% of operations by FAR Part 36 affected aircraft were in compliance in 1980. This percentage represents a relatively high proportion of noise compliance in comparison with the U.S. aircraft fleet. It is primarily due to the large proportion of new technology wide-body aircraft (e.g. B747, DC10, LIO11, and A300) and the relatively small proportion of four-engine, narrow body aircraft (e.g. B707, B720, and DC8) in the Sea-Tac fleet mix. With the exception of a few B747-100 series aircraft, all wide-body aircraft currently comply with the noise level limits prescribed in FAR Part 36. None of the four-engine, narrow-body aircraft are reported as currently in compliance.

3.4 NOISE MONITORING SYSTEM

Noise measuring equipment which is used at Sea-Tac to monitor aircraft generated noise includes a permanent Airport Noise Monitoring System (NMS), designed and installed by EG&G, and a portable integrating noise meter (DA607P). This section describes the noise measuring equipment and gives a brief account of noise monitoring programs at other airports.

3.4.1 Permanent Airport Noise Monitoring System

Installation and operation of a permanent noise monitoring system was recommended in the Sea-Tac/Communities Plan. The Plan identified the need to continuously monitor "compliance with operational procedures and general trends in community (noise) exposure levels"[8/] by measuring aircraft generated noise. The Airport Noise Monitoring System (NMS) was installed at Sea-Tac in July 1979 and began official operation in September 1979.

The system is designed to measure and calculate hourly noise levels, single event levels and daily noise statistics in dBA at nine Remote Monitoring Stations (RMS). Exhibit 3-4 identifies the RMS sites. Noise picked up by each RMS is transmitted over telephone lines to a computer operated Central Processing System (CPS). The CPS accumulates the data and performs the necessary calculations for the various measures used to describe noise. Reports are automatically prepared by the computer.

3.4.2 Portable Noise Meter

The DA607P, developed by Digital Acoustics, Inc., is a portable noise monitor. The instrument is designed to measure and calculate hourly and daily noise levels, and single event levels. Reports are printed by the monitor in both alphanumeric and graphic forms.

3.4.3 Noise Monitoring Programs at Other Airports

Airport noise monitoring programs are individually tailored to the site and operational characteristics of the airport. Additionally, the goals and objectives of the airport operator affect the program. Consequently, noise programs will differ in complexity, commitment of labor and equipment resources and geographic area of concern. There are, however, three general types of programs: (1) airport-operated permanent noise monitoring systems for continuous measurements with fixed monitoring stations; (2) airport-operated portable noise monitoring systems for periodic measurements with a limited number of portable noise monitors; and (3) periodic noise monitoring contracted by the airport operator to an outside acoustician.

A number of airports maintain permanent noise monitoring systems. Although these systems are located at airports throughout the country, they are most common at California airports. The following list, compiled by the Federal Aviation Administration (FAA), identifies the airports with permanent noise monitoring systems.[9/]

Boston Logan International Airport, Massachusetts
Burbank Airport, California
Dulles International Airport, Virginia
Honolulu International Airport, Hawaii
JFK International Airport, New York
LaGuardia Airport, New York
Los Angeles International Airport, California
Newark International Airport, New Jersey
Ontario International Airport, California
Orange County Airport, California
San Diego International Airport, California
San Francisco International Airport, California
San Jose Municipal Airport, California
Santa Monica Municipal Airport, California
Sea-Tac International Airport, Washington
Torrance Airport, California
Washington National Airport, Virginia

The type and quantity of permanent noise monitoring equipment, the content of noise monitoring reports, and the application of the noise monitoring data for some of these airports are summarized in Appendix A.

3.5 NOISE ENVIRONMENT

Noise levels attributed to aircraft operations at Sea-Tac have been measured, analyzed, estimated and forecasted. This effort represents an on-going commitment by the Port of Seattle for a clear and comprehensive description of the present and anticipated airport noise environment. The following sections discuss the methods used to describe noise in the Sea-Tac/Communities Plan and this report. The sections also describe the measured and estimated noise exposure levels in and around the Airport.

3.5.1 Aircraft Noise Description Methodologies

This study describes cumulative noise exposure in terms of Day-Night Average Level (Ldn). Ldn is now the standard noise system in measuring cumulative noise at airports. The Ldn descriptor was not used in the Sea-Tac/Communities Plan, but it is comparable to the Noise Exposure Forecast (NEF) and Adjusted Noise Exposure (ANE) descriptors used in the Plan. Although the relationship between Ldn and NEF/ANE is not exact, NEF and ANE noise levels can be translated into Ldn by adding 35. The following comparison illustrates this approximate relationship.

NEF/ANE		Ldn
20	approximates	55
30	"	65
40	"	75

Noise Exposure Forecast (NEF) and Adjusted Noise Exposure (ANE)

Noise Exposure Forecast (NEF) was the "state of the art" noise descriptor used during the period of the Sea-Tac/Communities Plan. In order to adjust the computer derived NEF noise vs. distance curves to Sea-Tac specific aircraft operations as measured, a new set of noise vs. distance curves was defined. This adjustment to NEF was called Adjusted Noise Exposure (ANE).

Both NEF and ANE methodologies describe the total noise exposure produced by aircraft operations at a given point on the ground. For a more detailed discussion of NEF/ANE, see the Noise Exposure Analysis Element Report 5.5 of the Sea-Tac/Communities Plan.

Day-Night Average Level (Ldn)

The Ldn was developed in 1973-1974 for the U.S. Environmental Protection Agency (EPA). It has since become the standard noise system as prescribed by the Federal Aviation Administration (FAA). Section 102 of the Aviation Safety and Noise Abatement Act of 1979 (PL 93-193) recommends this system to be uniformly applied in measuring cumulative noise at airports and surrounding areas. Community reaction to noise and the impact of noise on the long-term nature of land uses has been determined to be appropriately reflected by Ldn.[10/]

Ldn is a cumulative noise descriptor which represents a summation of the noise energy averaged over a 24-hour period with a 10 decibel penalty applied to the noise levels from 10:00 p.m. to 7:00 a.m. Sound levels are expressed as A-weighted decibels, written dBA, which can be directly measured.

3.5.2 Aircraft Noise Levels

Aircraft noise levels are continually monitored at the nine Noise Monitoring System (NMS) Remote Monitoring Stations (RMS). The NMS distinguishes aircraft generated noise from ambient or other noise only if specific criteria are met. These criteria are met when threshold noise levels set at the RMS are exceeded and when stations are "triggered" in a sequence that indicates an aircraft operation. If an aircraft remains below the threshold or flies an unsequenced pattern, the NMS will not be able to identify this as aircraft-generated noise. Table 3-1 presents the annual average Ldn attributable to aircraft as calculated from NMS measurements for each RMS. (See Exhibit 3-4 for a map of RMS locations.)

TABLE 3-1

MEASURED 1980 ANNUAL AVERAGE LDN FOR
AIRCRAFT AT REMOTE MONITORING STATIONS

Remote Monitoring Station	Ldn in dBA	Location in Relation to Airport	Distance From Runway 16R/34L (along extended centerline)	Distance From Runway 16R/34L (at 90° extended centerline)
1	71.4	South	21,000' South	1,700' East
2	70.9	South	14,200' South	1,600' West
3	73.5	South	13,700' South	1,900' East
4	82.7	South	5,200 South	800' East
5	70.0	West	Mid-runway	2,300' West
6	80.7	North	3,100' North	400' East
7	73.4	North	11,600' North	1,400' West
8	68.7	North	16,500' North	1,500' West
9	69.7	North	9,800' North	1,900' East

Source: The Port of Seattle

3.5.3 Ambient Noise Levels

The community surrounding an airport is exposed to noise other than the noise attributed to airport operations. Major contributions to outdoor background or ambient noise levels come from transportation, industrial, construction, human and animal sources. Examples of outdoor Day-Night Average Levels (Ldn) in different areas are presented in Exhibit 3-5.

Surface vehicular traffic is a major contributor to ambient noise levels. There are correlations between volume of traffic and level of noise, and between distance from roadway and level of noise. Table 3-2 indicates how these relationships affect the noise levels at different distances from representative roadways near Sea-Tac accommodating varying volumes of traffic. Ldn values increase as the volume of surface traffic increases. Ldn values decrease as the distance from the roadway increases.

TABLE 3-2

TRAFFIC NOISE

Location	Average Daily Traffic Volume[2/] (1979)	% Bus and Truck Traffic Average Daily/Peak Hour		Ldn Values[3/]			Distance to Ldn Contour Value in Feet				Posted Speed Regulation
		Average Daily	Peak Hour	150'	300'	600'	60 Ldn	65 Ldn	70 Ldn	75 Ldn	
Jct. I-5 at S. 188th - South Leg[1/]	104,800	10%	5%	75.5	71.0	66.5	1630	757	351	163	60
Jct. I-5 at S. 188th - North Leg	111,000	10	5	75.8	71.3	66.8	1707	792	367	170	60
Jct. U.S. 99 at S. 216th - South Leg	23,000	4	2	67.1	62.6	58.1	449	208	96	44	60
Jct. U.S. 99 at S. 216th - North Leg	23,900	4	2	67.3	62.8	58.3	463	215	100	46	60
Jct. S.R. 509 at 7th Pl. S. - Southeast Leg	17,400	4	2	65.1	60.6	56.1	330	153	71	33	55
Jct. S.R. 509 at S. 128th - South Leg	28,100	4	2	67.1	62.6	58.1	449	208	96	44	55
Jct. Des Moines Way at S. 136th - South Leg	8,207	3	3	62.7	58.2	53.7	228	106	49	23	40
Jct. Des Moines Way at S. 156th - South Leg	8,616	3	3	62.7	58.2	53.7	228	106	49	23	40
Jct. Des Moines Way at S. 176th - South Leg	10,017	3	3	63.4	58.9	54.4	254	118	55	25	40
Jct. Des Moines Way at S. 200th - South Leg	5,813	3	3	61.1	56.6	52.1	178	83	38	18	40

1/ "Leg" is the segment of the roadway from the intersection in the direction specified.

2/ Sources of ADT from which peak hour traffic was computed: Washington State Department of Transportation, Public Transportation and Planning Division, 1979 Annual Traffic Report, and King County Department of Public Works, "King County - 1973 through 1979 Historical ADT Counts by Location."

3/ Ldn values were computed from the U.S. Highway Administration noise model assuming a flat, moderately absorbing ground plane with nominal highway speeds.

Source: The Parry Company

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Ambient noise levels are continually monitored at the nine Noise Monitoring System (NMS) Remote Monitoring Stations (RMS) on an hourly and daily basis. The NMS labels ambient noise as "community" noise and distinguishes it from noise attributed to most aircraft. Aircraft-generated noise is included if it does not exceed threshold noise levels set at the RMS and does not "trigger" the stations in a sequence that indicates an aircraft operation. Table 3-3 presents the annual average Ldn for "community" noise as calculated from NMS measurements for each RMS. (See Exhibit 3-4 for a map of RMS locations.)

TABLE 3-3

MEASURED 1980 ANNUAL AVERAGE LDN FOR
COMMUNITY NOISE AT REMOTE MONITORING STATIONS

Remote Monitoring Station	Ldn in dBA	Location in Relation to Airport	Distance From Runway 16R/34L (along extended centerline)	Distance From Runway 16R/34L (at 90° extended centerline)
1	63.1	South	21,000' South	1,700' East
2	62.3	South	14,200' South	1,600' West
3	65.1	South	13,700' South	1,900' East
4	63.8	South	5,200' South	800' East
5	62.5	West	Mid-runway	2,300' West
6	65.5	North	3,100' North	400' East
7	61.8	North	11,600' North	1,400' West
8	60.7	North	16,500' North	1,500' West
9	61.7	North	9,800' North	1,900' East

Source: The Port of Seattle

3.5.4 Maintenance Runup Noise Levels

Current practice at Sea-Tac restricts the location and time of engine maintenance "runups" or "trim checks" but allows airline discretion on frequency, duration, and aircraft types. Runups are allowed at the north and south ends of Taxiway A. During runups, aircraft are headed into the wind and thus are located at the north end of Taxiway A during a north wind and at the south end of Taxiway A during a south wind. Conditions for runups at the north end of Taxiway A occur approximately 32% of the year and at the south end of Taxiway A approximately 68% of the year. A runup curfew exists during the hours between 2300 and 0600. Since the summer of 1980, this curfew has been strictly enforced. Prior to that time, some runups of short duration or less than maximum takeoff power were permitted between 2300 and 0600 hours.

Frequency of engine maintenance runups and trim checks has significantly decreased at Sea-Tac over the past few years due primarily to new trim procedures that allow engine checks at the gates, the escalating cost of fuel, and the runup curfew. On the average, less than four runups take place per week. Based on this low rate, no measurement of runup noise was made at Sea-Tac for this study. However, Table 3-4 shows the approximate distances from runup aircraft to three Ldn contours:

TABLE 3-4

RUNUP NOISE LEVELS-
DISTANCE TO LDN CONTOURS

Ldn Contour	Distance (feet) from Aircraft
75	1,700
70	2,700
65	4,000

Source: The Parry Company

Noise levels and distances are based on the assumptions that: runups occur during the daytime; half occur at each runup location; four runups occur per week; engines are JT8D; duration of each runup averages 7.25 minutes; engines are at maximum thrust; and noise vs. distance curves presented in FAA Report FAA-Eq-73-7,1 are representative of runups at Sea-Tac.[11/]

3.5.5 Taxiing Noise Levels

Estimates of noise levels attributed to taxiing operations of aircraft along the main north/south taxiway (Taxiway A) were based on actual measurements and numerical estimation techniques. A complete discussion including methods and results is found at Section 5.4.1. of this study. Table 3-5 presents the estimate of taxiing noise levels for 1980. Location and identification of grid cells are based on the grid used in the Sea-Tac/Communities Plan. (See Exhibit 6-2 for a map of the Sea-Tac/ Communities Plan grid.) Each noise level represents the center of a 1/16 section (40 acres) or "cell."

3.5.6 Total Noise Environment

The Sea-Tac Noise Monitoring System (NMS) measures total noise at each of the nine Remote Monitoring Stations (RMS) on an hourly and daily basis. These noise levels were used to compute the 1980 annual average Ldn by RMS. Table 3-6 presents the annual average Ldn as calculated from NMS measurements. (See Exhibit 3-4 for a map of RMS locations.)

TABLE 3-6

MEASURED TOTAL 1980 ANNUAL AVERAGE DAY-NIGHT LEVELS
AT REMOTE MONITORING STATIONS

Remote Monitoring Station	Ldn in dBA	Location in Relation to Airport	Distance From Runway 16R/34L (along extended centerline)	(at 90° extended centerline)
1	72.1	South	21,000' South	1,700' East
2	71.3	South	14,200' South	1,600' West
3	74.2	South	13,700' South	1,900' East
4	82.8	South	5,200' South	800' East
5	70.9	West	Mid-runway	2,300' West
6	80.7	North	3,100' North	400' East
7	73.6	North	11,600' North	1,400' West
8	69.4	North	16,500' North	1,500' West
9	70.3	North	9,800' North	1,900' East

Source: The Port of Seattle

Note: Data from 361 days were included in all NMS averages except for RMS 8, for which 239 days of data were averaged. Data were omitted because of malfunctions either of the entire system or of a particular RMS.

TABLE 3-5

1980 ESTIMATED ANNUAL AVERAGE TAXIING LDN BY GRID CELL

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
	GRID COLUMNS												
12	53.1	53.8	54.5	55.1	55.6	56.0	56.2	56.3	56.2	55.9	55.4	54.9	54.2
13	53.9	54.7	55.5	56.2	56.9	57.4	57.7	57.8	57.6	57.2	56.7	56.0	55.2
14	54.7	55.6	56.5	57.4	58.3	59.0	59.4	59.6	59.3	58.7	58.0	57.1	56.2
15	55.5	56.5	57.6	58.7	59.8	60.8	61.6	61.8	61.3	60.5	59.4	58.3	57.2
16	56.2	57.3	58.6	59.9	61.4	62.9	64.3	64.8	63.9	62.4	60.9	59.5	58.2
17	56.8	58.1	59.5	61.1	62.9	65.1	68.2	70.6	67.0	64.3	62.2	60.5	59.0
18	57.3	58.7	60.2	62.0	64.2	67.0	71.7	79.9	69.6	65.9	63.4	61.4	59.7
19	57.6	59.1	60.8	62.7	65.0	68.1	72.8	80.4	70.8	66.9	64.2	62.0	60.2
20	57.8	59.3	61.0	63.0	65.4	68.5	73.2	80.7	71.2	67.3	64.6	62.3	60.5
21	57.9	59.4	61.1	63.1	65.5	68.5	73.2	80.6	71.2	67.4	64.6	62.4	60.5
22	57.7	59.2	60.9	62.8	65.2	68.2	72.8	80.4	71.0	67.1	64.4	62.2	60.4
23	57.5	58.9	60.5	62.3	64.5	67.3	71.8	86.7	70.4	66.5	63.9	61.8	60.0
24	57.1	58.4	59.9	61.6	63.6	66.1	69.8	86.4	69.3	65.5	63.1	61.1	59.5
25	56.5	57.9	59.1	60.6	62.3	64.4	67.6	85.9	67.3	64.1	62.0	60.3	58.8
26	55.9	57.0	58.2	59.5	60.9	62.4	64.2	65.3	64.0	62.2	60.6	59.2	57.9
27	55.2	56.2	57.2	58.3	59.4	60.4	61.3	61.7	61.3	60.3	59.2	58.1	57.0
28	54.5	55.3	56.2	57.1	57.9	58.7	59.2	59.4	59.1	58.6	57.8	56.9	56.0
29	53.7	54.4	55.2	55.9	56.6	57.1	57.5	57.6	57.4	57.0	56.4	55.8	55.0

NOTE: For reference, the runways are located between rows 18 and 26 and within Column O; and Taxiway A is located between rows 18 and 24 and within Column P. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

The annual average Ldn values calculated from the 1980 NMS measured data reflect the locations of each RMS relative to the location of the runways and the extended runway centerline. Annual average Ldn values decrease with an increase in the lateral and longitudinal distance from the runways and extended runway centerline.

In order to supplement the noise measurements at RMS, noise was monitored at five locations near Sea-Tac with a portable noise meter. The five locations were:

A. Northeast: Riverton Heights Community, intersection of S. 150th Street and 26th Avenue South.

B. Southeast: Mansion Hills area, intersection of S. 219th Street and 28th Avenue South.

C. Southwest: North Hill Residential Community, intersection of S. 208th Street and 6th Avenue South.

D. West Side: Ad hoc viewpoint, intersection of S. 170th Street and 14th Avenue South.

E. West Side: South of intersection of S. 160th Street and 12th Avenue South.

Exhibit 3-6 shows the locations of the mobile monitoring sites.

At each mobile monitoring site, noise levels were monitored for two consecutive hours with a portable Digital Acoustics DA607P noise meter. The meter was set up to record the following data: hourly Equivalent Noise Level (Leq), single event noise specified as Sound Exposure Level (SEL), single event noise maxima, and single event durations. Single events were defined as noise levels exceeding 70 dBA for 10 or more seconds. Leq's, single events, and single event maxima were averaged for each two hour period.

Table 3-7 compares noise levels as measured by a nearby RMS for the corresponding two hour period. The difference between the mobile monitoring and RMS levels is another example of how noise levels decrease with increases in the lateral and longitudinal distance from the runways and extended runway centerline.

TABLE 3-7

REMOTE MONITORING STATIONS (RMS) AND DA607P MOBILE MONITORING SITE MEASUREMENTS

Mobile Monitoring Site	Date Time Period	RMS	Leq (dBA) Site	Leq (dBA) RMS	Number of Single Events Site	Number of Single Events RMS	Average SEL (dBA) Site	Average SEL (dBA) RMS	Average Single Event Maxima (dBA) Site	Average Single Event Maxima (dBA) RMS
A (departure)	07/16/81 1400-1530	6	71.4	84.0	21	22	92.8	104.6	83.9	97.2
B (departure)	07/09/81 1400-1600	3	72.5	74.0	24	25	93.5	95.1	84.0	85.7
C (departure)	07/08/81 1400-1600	4	64.3	82.0	17	26	87.6	105.6	77.9	97.7
D (departure)	07/07/81 1400-1600	5	71.1	65.5	18	19	95.1	89.2	86.3	79.8
E (arrivals)	07/07/81 1100-1300	6	64.4*	75.0	8	39	83.0	94.4	77.8	87.6
E (departure)	07/07/81 1100-1300	4	64.4*	82.0	5	31	88.9	89.2	79.1	89.2

*Leq for Site E includes arrivals and departures.

Source: The Port of Seattle

3.6 CLIMATE

The National Oceanic and Atmospheric Administration has provided the following climatological summary of the Seattle-Tacoma area which has been reprinted from the 1980 Sea-Tac Airport Annual Summary of Local Climatological Data.

The middle-latitude west coast climate of the Seattle-Tacoma area is modified by the imposing barrier of the Cascade Range on the east and to a lesser extent by the comparatively short Olympic Range to the west and northwest. It is characterized by equable temperatures, a pronounced though not defined rainy season, and considerable cloudiness, particularly during the winter months.

The Cascades are very effective in excluding continental influences from the Seattle-Tacoma area, particularly in keeping cold air from draining westward during the winter. Occasionally the pressure distribution will result in a southward flow of cold air from Canada west of the Cascades and it is only under these conditions that extremely cold weather strikes the southern Puget Sound area. The prevailing southwesterly circulation keeps the average winter daytime temperatures in the forties and the nighttime readings in the thirties. Summertime temperatures are predominately modified by the relative proximity of the ocean. During the summer months the nighttime readings are very consistently in the lower or middle fifties. On what may be called a typical summer afternoon the readings hover in the seventies or possibly lower eighties.

Occasionally during the warm season, even as early as April and as late as September, a weak elongated area of low barometric pressure develops along the immediate coast and rather dry, hot continental air moves toward the low pressure, spreading over the sections west of the Cascades. It is under these conditions that Seattle-Tacoma and vicinity gets its few hot days. These hot spells are only of a few days duration and almost invariably "break" or end with a sharp drop to temperatures of 70° or so, as it only takes a small change in the general pressure pattern to bring cool maritime air back in over the coastal lowlands.

The agreeable temperatures, along with the light precipitation characteristic of the warm season, gives the Seattle-Tacoma area a very pleasant summer climate. The dry season is centered around July and early August. July is the driest month of the year normally and December the wettest. However, the precipitation is rather evenly distributed through the winter and early spring months.

Better than 75 percent of the yearly average falls from October 1 through March. The rainfall of Seattle-Tacoma and vicinity comes almost entirely from the moving storms or areas of low barometric pressure common to the middle latitudes. These disturbances are most vigorous during the winter and through this season follow paths that bring them close to western Washington; whereas in the summer the storm tracks shift northward and the weaker individual storms are not the wind and rain producers that they are during the winter months. Local summer afternoon showers and a few thundershowers do occur in the Seattle-Tacoma area, but they are not sufficiently common to contribute materially to the average precipitation.

The occurrence of snow in the Seattle-Tacoma area is extremely variable and very often when it does fall it melts before accumulating measureable depth. There are winters on record with only a trace of snow and on the other extreme as much as 21.4 inches have fallen in a 24-hour period (January 1950). This is understandable in view of the fact that the air brought in over the area by the winter storms usually has had a long trajectory over the ocean. In fact, it is only when a storm is so oriented as to enable it to bring cold air out of Canada directly or over only a short water trajectory that deep snowfalls occur in the southern Puget Sound area.

Since the southern end of the Puget Sound trough is open to the southwest, winds generated by the storms moving in off the ocean, the prevalent wind for the eight months encompassing the storm season, is southwest. The Puget Sound trough is also open to the north. Hence, the occasionally severe winter storm that develops to the south or moves inland to the south of the Seattle-Tacoma area will result in strong winds from the northerly quarter.

Winds are relatively light during the summer months. During the course of a typical summer day the winds will be light and variable at night, becoming northerly and picking up to 8 to 15 m.p.h. during the afternoon, the proximity of the Sound resulting in a form of land-and-sea breeze.

Fog and stratus that forms over the Sound due to radiation and advection very seldom closes the field for more than a few hours in the morning. This also is true of fall, winter, and spring stratus with northeast winds from Lake Washington which is 6 miles east-northeast of the field. The steep bluffs along the Green River Valley tend to contain the fog until after sunrise when circulation increases and the fog drifts in, decreasing visibilities for a short time. Fall ground fogs frequently are deep enough to close the field during mornings; otherwise ground fogs are generally unimportant. Most of the summer stratus moves into the area from the southwest quadrant.

3.6.1 Meteorological Records

Surface weather observations are made at Sea-Tac by the U.S. National Weather Service. On an annual basis, meteorological conditions at Sea-Tac are presented in Table 3-8.

TABLE 3-8

ANNUAL SUMMARY OF METEOROLOGICAL DATA
SEA-TAC INTERNATIONAL AIRPORT

Normal maximum temperature of hottest month[1/]	74.4° F
Normal annual temperature[2/]	51.1° F
Percent of IFR weather[3/] (ceiling less than 1000 ft. and/or visibility less than 3 miles)	9.4%
Heavy fog[4/] (visibility 1/4 miles or less)	46 days per year
Winds[1/]	
0 - 3 m.p.h.	1.5%
3 - 12 m.p.h.	82.5%
Prevailing winds[5/]	south/southwest
Precipitation[2/]	38.79 inches
Relative humidity[6/]	
4 am	82%
10 am.	73%
4 pm	62%
10 pm.	75%

[1/]Period of Record: January 1970 - December 1974 (Sea-Tac Airport Layout Plan)

[2/]Period of Record: 1941 - 1970 (1980 Sea-Tac Annual Summary of Local Climatological Data - NOAA)

[3/]Period of Record: 1965 - 1974 (Sea-Tac Weather Service)

[4/]Period of Record: 1944 - 1980 (1980 Sea-Tac Annual Summary of Local Climatological Data - NOAA)

[5/]Period of Record: 1948 - 1963 (1980 Sea-Tac Annual Summary of Local Climatological Data - NOAA)

[6/]Period of Record: 1959 - 1980 (1980 Sea-Tac Annual Summary of Local Climatological Data - NOAA)

Sources: Port of Seattle and the National Oceanic and Atmospheric Administration

3.6.2 Weather and Noise

Weather conditions affect the noise levels generated by airport operations in three major areas: (1) the operating strategy of the airfield and airspace; (2) the performance of the aircraft; and (3) sound propagation.[12/]

The operating strategy of the airfield and airspace (i.e. the runway use combinations and flight track utilization) is governed to a large extent by considerations of ceiling (i.e., cloud height) and visibility, and prevailing wind direction. For example:

- during conditions of low ceiling and limited visibility, landing aircraft typically use only runways equipped with instrument landing systems

- during conditions of low ceiling and limited visibility, approaching aircraft may use different flight tracks than during better weather conditions

- runways are often closed during periods of heavy fog

- generally, aircraft approach the runways and takeoff from the runways into the wind. Direction of landings and takeoffs in crosswind conditions are determined by the FAA Air Traffic Control Tower

The performance of an aircraft on takeoff can be affected by certain weather conditions which lead to the reduction or increase in the distance between the aircraft and the ground. Noise measured on the ground varies with these changes in distance. For example:

- warmer air (higher temperatures) and conditions of high relative humidity require longer distances to take off and slower climb rates and therefore result in lower flyovers on departure

- high winds can increase rate of climb and reduce the distance needed for takeoff roll which results in higher flyovers on departure

Sound propagation (i.e. the movement of sound waves) through the air is altered by weather conditions. For example:

- noise upwind from a source is less at the same distance downwind from the same source

- low frequency (pitch) sound is not strongly attenuated and carries a long distance
- as frequency increases, sound energy more rapidly decreases with distance
- in warm weather, attenuation is strongest when humidity is low
- in cold weather, attenuation is generally less than in warm weather and sound carries farther
- in cold weather, sound may carry further when humidity is low than when the air is moist

Footnotes

1/Runway 16L has a 500 foot displaced runway threshold.

2/ILS on Runway 34R has a 2.75° glide slope.

3/Operations of Cascade Airlines were designated "air carrier" from April 1, 1980. Cascade operations were designated "commuter" prior to that date.

4/"Airspace corridors" were identified from overlayed plots of the paths of individual aircraft taken from the Sea-Tac Air Traffic Control Tower radar. The overlayed plots produced recognizable airspace corridors which were distinguished by frequency of use and differentiated between each other by aircraft utilization (jet vs. conventional piston/turboprop), weather conditions (IFR vs VFR), and origin and destination of the aircraft. The variance around the center of the airspace corridor (i.e. the flight track) increased with increased distance from the airport. For conventional piston/turboprop corridors, this spreading effect was particularly pronounced prior to entering final approach and upon entering the crosswind on departure. For jet corridors, this spreading effect was particularly pronounced prior to entering the glide slope outside the outer marker of the Instrument Landing System on approach and two to three nautical miles beyond the runway ends on departure. These overlayed plots are available for viewing at the Port of Seattle Planning and Research Department.

5/Amendment 91-136 added subpart E to FAR Part 91; Amendment 91-161 redefined "replacement airplanes" and required periodic submission to the FAA of fleet operator compliance plans. Amendment 91-170 brought subpart E of FAR Part 91 into conformance with Title III of the Aviation Safety and Noise Abatement Act of 1979 (P.L. 96-193).

6/All aircraft engaged in domestic or foreign commerce in the U.S. must be in compliance with the applicable noise levels of FAR Part 36 by January 1, 1985, unless scheduled for replacement under a FAA approved plan or covered by a "service to small communities exemption."

7/FAR Part 91.308 requires U.S. airlines to submit compliance schedules to the FAA on an annual basis. The first compliance plans were required as of April 1, 1980.

8/Sea-Tac/Communities Plan, Section 6.2.2.

9/FAA, "The Need for Airport Noise Monitoring Systems," Report No. FAA-EE-80-40 (September 1980).

10/American National Standard, 53.23-1980, "Sound Level Descriptors for Determination of Compatible Land Uses".

11/Runup Ldns were calculated from an algorithm combining the equation: Ldn = L Max + 10 log duration - 49.4 dB and the levels and distances from the noise vs. distance curves in FAA report, FAA-Eq-73-7,1.

12/A useful general reference for the effects of weather on noise is Noise and Vibration Control by Leo L. Beranek, ed. (1971) and published by McGraw-Hill.

CHAPTER 5

INTEGRATED NOISE MODEL

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INTEGRATED NOISE MODEL

5.1 INTRODUCTION

Noise exposure levels attributed to aircraft operations at Sea-Tac International Airport (Sea-Tac) were modeled for existing operations (1980) and forecast years (1985, 1990, and 2000). The Federal Aviation Administration (FAA) Integrated Noise Model (INM) was used with some modifications.1/ The INM was calibrated to match both monitored noise levels and Sea-Tac specific approach and departure procedures as controlled by the FAA and as reported by the airlines. In addition, INM output was subsequently adjusted to reflect an aircraft noise source (aircraft taxiing on taxiway) not modeled by the INM. The following sections describe the operation of the current version of the Integrated Noise Model, the model calibration process, and the analysis of aircraft noise sources not modeled by the INM.

5.2 INTEGRATED NOISE MODEL

The first version of the INM was released by the FAA in January 1978 as part of the agency's on-going efforts to provide the technical means to assess noise impact of aircraft operations and to analyze aircraft noise abatement. Since its introduction, the INM has become the recommended tool to generate Land Use Guidance Zones (LUG) and data for site analysis in land use compatibility planning2/. It meets the noise analysis requirements of FAA Order 5050.4 "Airport Environmental Handbook" (March 21, 1980) and is approved by the FAA for use in the noise exposure map requirements of Federal Aviation Regulations Part 150 (Airport Noise Compatibility Planning" (January 1981).

Continuous revisions and additions to the original model (Version 1) are made so that the INM is more flexible and better able to simulate local airport characteristics. Version 2.7 of the INM was used in the Sea-Tac Noise Exposure Update.

5.2.1 Capabilities and Constraints of the INM

The INM is capable of generating noise exposure levels in two forms of output; contour and grid. Contour analysis output is presented in the form of plots of contours and a table of the area impacted for any of the four cumulative measures of aircraft noise, which are: Noise Exposure Forecast (NEF), Equivalent Sound Level (Leq), Day-Night Average Sound Level (Ldn), and Community Noise Equivalent Level (CNEL). Grid analysis output includes calculations of the total noise exposure at any specified location, the contribution of each aircraft as categorized by their noise curves, and the contribution of each flight. The latter two are optional. Aircraft noise at specified locations can also be described by a Time Above (TA) measure. TA indicates the amount of time that a threshold sound level in A-weighted decibels (dBA) is exceeded during a given time period.

Specific program limits in the INM restrict the number of entries for each of the program input variables (e.g. runways, ground tracks, takeoff profiles, sets of noise curve data, etc.).3/ The model also has some limitations in the level of available output detail, such as the omission of Time Above calculations when new noise curves have been incorporated into the data base, and the rounding of grid point coordinates to the nearest 100 feet.

5.2.2 Standard Data Base

A standard data base of aircraft noise and performance for representative commercial, general aviation, and military aircraft are provided in the INM. Each aircraft type is associated with a set of departure profiles for each applicable trip length, approach parameters, Noise Exposure Level (NEL) vs. distance curves at several thrust settings, Effective Perceived Noise Level (EPNL) vs. distance curves at several thrust settings, and Time Above parameters. The contents of these data sets are available in the INM Data Base Report.

5.2.3 User-Provided Data

At least five types of data describing the airport and its associated activity must be provided by the user in order to run the model. These are:

- airport altitude and temperature
- runway configuration
- flight track definition
- approach profiles
- traffic mix

The airport altitude and temperature data consist of the airport altitude in feet above sea level and the average daily airport temperature in degrees Celsius for the period being modeled.

The runway definitions establish the airport geometry within a cartesian coordinate system or grid system. A runway is represented by the location from which departing aircraft begin their takeoff rolls and the far end of the physical structure of the runway. Where aircraft use only a portion of the actual concrete runway the model definition may be shorter than the physical structure. The touch-down location for approaching aircraft is defined in the approach profiles.

The flight track definition consists of all information needed to model a flight path's projection on the ground starting at the runway-end.

Approach profiles represent the approach procedures used for the airport. Each profile provides the model with a set of ground distances from the approach end of the runway, reference values of altitude and velocity at each of these distances, and an indication of the power and flap settings between them.

The traffic mix describes the aircraft types (57 aircraft types standard in the INM data base), numbers of operations, trip lengths for departures, and distribution of operations during the day, evening and night on each flight track.

5.2.4 Optional Parameters

The user of the INM may change some types of data that are normally provided by the INM. These changes are optional and include:

- takeoff profile modifications
- alternative aircraft types
- alternative takeoff profiles
- alternative noise curve data
- alternative approach parameters

5.3 INTEGRATED NOISE MODEL CALIBRATION

In order for the INM to more closely simulate local characteristics of Sea-Tac, four of the five optional parameters were used. The parameters calibrated were: takeoff profile modifications, alternative aircraft types, alternative takeoff profiles, and alternative noise curve data.[4/] These adjustments were made on the basis of airline interviews, observed operations, FAA noise abatement procedures, Noise Monitoring System (NMS) noise measurements, and fleet mix projections. (Use of NMS noise measurements in the calibration process is described in more detail in Appendix C.) The following sections provide brief explanations for the necessity of calibrating the INM.

5.3.1 Takeoff Profile Modifications

Commercial jet departure profiles of the standard INM data base conform to an FAA recommendation of January 18, 1974 (FAA AC 91-39). Takeoff profiles for all jet aircraft were modified in order to reflect the most recent FAA recommended noise abatement departure procedure (FAA AC 91-53), the Air Transport Association (ATA) standard departure procedure, and Sea-Tac departure procedures reported by interviewed airlines. Reduction in engine power from takeoff thrust to normal climb thrust was adjusted from an altitude of 1,500 feet to an altitude of 1,000 feet.

This modified departure procedure was applied to all departures with the exception of departures to the west in a south flow of traffic. Under Sea-Tac noise abatement procedures (FAA Sea Twr 7110.071C, October 7, 1980), jet aircraft departing in a south flow are allowed to turn west upon reaching a point at least three nautical miles south of the airport and after having reached 3,000 feet mean sea level (MSL). Therefore, in order for aircraft to reach this altitude at 3 miles distance, takeoff thrust was extended beyond an altitude of 1,000 feet along the west departure flight track.

5.3.2 Alternative Aircraft Types

A number of aircraft types that are forecasted as part of the future Sea-Tac fleet mix have not been incorporated at this time into the standard INM data base. Consequently, these aircraft have been added to the model: DC9-80, B767, B757, and DeHavilland Dash 7. Noise and performance statistics for the new DC9-80, B767, and B757 were acquired from the FAA Office of Noise Abatement in the Office of Environment and Energy. Noise and performance statistics for the Dash 7 were taken from the John Wayne Airport Environmental Impact Statement, Volume 2 (November 26, 1980).

5.3.3 Alternative Takeoff Profiles

A set of departure profiles for each aircraft type for each applicable trip length is provided in the standard INM data base. Takeoff profiles include altitude, velocity, and power setting data (i.e., engine thrust) for seven ground distances from the start of takeoff roll. Takeoff profiles also include the number of engines being used and the aircraft's gross takeoff weight.

The only takeoff profile data that were modified were those of the new Airbus 300 (A300). Interviews with the A300 operator at Sea-Tac led to the replacement of ground distance and altitude data for the A300 by the ground distance and altitude of the L1011. Comparisons of NMS measured Sound Exposure Level (SEL) and INM predicted SEL for the A300 confirmed the need for this change.

5.3.4 Alternative Noise Curves

The INM standard data base contains sets of noise vs. distance curves which are defined by EPNL and NEL noise levels at eight slant range[5/] distances (200, 400, 600, 1,000, 2,000, 4,000, 6,000, and 10,000 feet) for from two to six engine power settings (given in units of pounds of thrust per engine). The principle source of the data is the flight and noise certification testing conducted by the aircraft manufacturers and the FAA. In order to increase the accuracy of the INM in predicting aircraft noise exposure at Sea-Tac, these standard noise vs. distance curves were modified based on comparisons of measured Sound Exposure Levels (SEL)[6/] from Sea-Tac's permanent noise monitoring sites with INM simulated SELs.

Noise curves associated with eleven air carrier aircraft types (Airbus 300, Boeing 707, Boeing 727-100/200, Boeing 727 with Sound Absorption Material (SAM) engines, Boeing 737, Boeing 737 with SAM engines, Boeing 747-100/200, Lockheed L-1011, DC8, DC9, and DC10-10/30) were examined and subsequently modified. Air carrier aircraft are responsible for the greatest number of aircraft operations and dominate the aircraft generated noise environment around Sea-Tac.

5.4 ADDITIONAL INM CALIBRATION ELEMENTS

In the INM, aircraft operations other than approach and departure are not considered by the INM. This study, however, examined three additional aircraft noise sources; taxiing noise, engine runup, and low frequency noise and induced vibration. As a result of an evaluation of the contribution of these noise sources to the noise predicted by the INM, INM output was subsequently adjusted to reflect aircraft taxiing noise. No adjustments to INM output were made for either engine runup or low frequency noise and induced vibration.

5.4.1 Taxiing Noise

Estimates of noise levels attributed to taxiing aircraft along the main north/south taxiway (Taxiway A) were made for 1980 and all forecast years based on actual field measurements and numerical prediction techniques. Adjustments were made to the noise levels predicted by the Integrated Noise Model (INM) when taxiing noise levels (in Ldn) were within 10 dBA of the INM predicted noise level (in Ldn).

The method of estimating taxiing noise involved five steps. First, the taxi noise contribution of a single aircraft operation, specified as a Sound Exposure Level (SEL) was measured in the field for the five most common types of aircraft at Sea-Tac. Second, SELs of aircraft types not measured but identified in the existing or future fleet were estimated. Third, an Ldn was calculated for each direction of flow at a reference location. Fourth, the Ldns attributed to taxiing aircraft for each direction of flow and for combined flows were estimated for study grid cells in Columns I through U and in rows 1 through 50. (See Exhibit 6-2 for a map of study grid cells.) Tables 5-1 through 5-4 present the total annual average taxiing Ldns for 1980, 1985, 1990, and 2000 for rows 12 through 29. The noise levels predicted by the INM in these rows were most affected by taxi noise as per the criterion previously identified. Finally, INM levels were adjusted for noise from taxiing aircraft. (See Appendix D for a detailed description of the steps used to estimate taxiing noise.)

5.4.2 Engine Runup Noise Levels

As previously described in Section 3.5.4 "Runup Noise Levels," current practice at Sea-Tac restricts the location and time of day of engine maintenance "runups" or "trim checks" but allows airline discretion on number of runups, duration, and aircraft types. Engine maintenance runups are allowed at the north and south ends of Taxiway A (across from the reservoir at the north end and across from the fuel storage tanks at the south end) between the hours of 0600 and 2300.

In order to determine the contribution of engine runup noise, runup levels at distances approximating 75, 70, and 65 Ldn contours were compared to INM generated noise levels for 1980. Runup noise levels and distances were based on the assumptions that the runups occur during the daytime, half occur at each runup location, four runups occur on the average per week, engines are JT8D, duration of each runup averages 7.25 minutes, engines during runups are at maximum thrust, and noise vs. distance curves presented in FAA Report, FAA-Eq-73-71 are representative of runup noise levels.

At the 75 Ldn contours, the noise attributed to runup operations added less than 0.3 dBA to the INM generated noise levels for 1980. At the 70 and 65 runup Ldn contours, the additional noise attributed to runup operations added as much as 1.0 dBA to almost 3.0 dBA in some areas on the east side of the airport. The west side of the airport was less affected due to the location of the runup sites east of both runways.

No adjustments were made to the INM-generated noise levels, however, to reflect runup noise levels. The levels are typical of runup operations but are approximate due to their sensitivity to the assumptions used in the noise level calculations (e.g., duration, engine type, and thrust level) and to the uncertainty of the directivity effects of runups. In the use and interpretation of Sea-Tac noise contours the user should bear in mind the possible impact of runup noise levels on the total noise exposure.

5.4.3 Low Frequency Noise and Induced Vibration

Low frequency noise (below 20 hertz) and induced structural vibration produced by turbojet-powered aircraft are not directly included in the Ldn noise descriptor. Sounds below 20 hertz (Hz) become increasingly less audible with decreasing frequency and are therefore difficult to measure as an A-weighted sound pressure level. The A-weighting characteristic modifies the frequency response of the measuring instrument to account approximately for the frequency characteristics of the human ear.

TABLE 5-1

1980 ANNUAL AVERAGE TAXIING NOISE LEVELS IN LDN BY GRID CELL

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
	GRID COLUMNS												
12	53.1	53.8	54.5	55.1	55.6	56.0	56.2	56.3	56.2	55.9	55.4	54.9	54.2
13	53.9	54.7	55.5	56.2	56.9	57.4	57.7	57.8	57.6	57.2	56.7	56.0	55.2
14	54.7	55.6	56.5	57.4	58.3	59.0	59.4	59.6	59.3	58.7	58.0	57.1	56.2
15	55.5	56.5	57.6	58.7	59.8	60.8	61.6	61.8	61.3	60.5	59.4	58.3	57.2
16	56.2	57.3	58.6	59.9	61.4	62.9	64.3	64.8	63.9	62.4	60.9	59.5	58.2
17	56.8	58.1	59.5	61.1	62.9	65.1	68.2	70.6	67.0	64.3	62.2	60.5	59.0
18	57.3	58.7	60.2	62.0	64.2	67.0	71.7	79.9	69.6	65.9	63.4	61.4	59.7
19	57.6	59.1	60.8	62.7	65.0	68.1	72.8	80.4	70.8	66.9	64.2	62.0	60.2
20	57.8	59.3	61.0	63.0	65.4	68.5	73.2	80.7	71.2	67.3	64.6	62.3	60.5
21	57.9	59.4	61.1	63.1	65.5	68.5	73.2	80.6	71.2	67.4	64.6	62.4	60.5
22	57.7	59.2	60.9	62.8	65.2	68.2	72.8	80.4	71.0	67.1	64.4	62.2	60.4
23	57.5	58.9	60.5	62.3	64.5	67.3	71.8	86.7	70.4	66.5	63.9	61.8	60.0
24	57.1	58.4	59.9	61.6	63.6	66.1	69.8	86.4	69.3	65.5	63.1	61.1	59.5
25	56.5	57.9	59.1	60.6	62.3	64.4	67.6	85.9	67.3	64.1	62.0	60.3	58.8
26	55.9	57.0	58.2	59.5	60.9	62.4	64.2	65.3	64.0	62.2	60.6	59.2	57.9
27	55.2	56.2	57.2	58.3	59.4	60.4	61.3	61.7	61.3	60.3	59.2	58.1	57.0
28	54.5	55.3	56.2	57.1	57.9	58.7	59.2	59.4	59.1	58.6	57.8	56.9	56.0
29	53.7	54.4	55.2	55.9	56.6	57.1	57.5	57.6	57.4	57.0	56.4	55.8	55.0

NOTE: For reference, the runways are located between rows 18 and 26 and within Column O; and Taxiway A is located between rows 18 and 24 and within Column P. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

TABLE 5-2

1985 ANNUAL AVERAGE TAXIING LDN BY GRID CELL

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
						GRID	COLUMNS						
12	49.3	49.9	50.6	51.2	51.7	52.1	52.4	52.4	52.3	52.0	51.6	51.0	50.4
13	50.1	50.9	51.6	52.4	53.0	53.5	53.9	53.9	53.8	53.4	52.8	52.1	51.4
14	50.9	51.8	52.7	53.6	54.4	55.1	55.6	55.7	55.5	54.9	54.1	53.3	52.4
15	51.6	52.7	53.7	54.8	55.9	56.9	57.7	57.9	57.5	56.6	55.5	54.4	53.4
16	52.3	53.5	54.7	56.1	57.5	59.0	60.4	60.9	60.0	58.5	57.0	55.6	54.3
17	52.9	54.2	55.6	57.2	59.0	61.3	64.3	66.7	63.1	60.4	58.4	56.7	55.1
18	53.4	54.8	56.4	58.2	60.3	63.1	67.8	76.0	65.8	62.0	59.5	57.5	55.8
19	53.8	55.2	56.9	58.8	61.2	64.2	68.9	76.6	66.9	63.0	60.3	58.1	56.3
20	54.0	55.5	57.2	59.2	61.6	64.6	69.3	76.9	67.4	63.5	60.7	58.5	56.6
21	54.0	55.5	57.2	59.2	61.6	64.6	69.3	76.9	67.4	63.5	60.7	58.5	56.6
22	53.9	55.4	57.1	59.0	61.3	64.3	69.0	76.5	67.1	63.3	60.6	58.4	56.5
23	53.6	55.1	56.7	58.5	60.7	63.5	68.0	82.9	66.6	62.7	60.0	58.0	56.2
24	53.2	54.6	56.1	57.7	59.7	62.2	66.0	82.6	65.5	61.7	59.2	57.3	55.6
25	52.7	53.9	55.3	56.8	58.5	60.6	63.7	82.1	63.4	60.3	58.1	56.4	54.9
26	52.1	53.2	54.4	55.7	57.1	58.6	60.3	61.5	60.2	58.4	56.8	55.4	54.1
27	51.4	52.4	53.4	54.5	55.6	56.6	57.5	57.9	57.4	56.5	55.4	54.3	53.2
28	50.6	51.5	52.4	53.3	54.1	54.8	55.4	55.6	55.3	54.7	53.9	53.1	52.2
29	49.8	50.6	51.4	52.1	52.7	53.3	53.6	53.7	53.6	53.2	52.6	51.9	51.2

NOTE: For reference, the runways are located between rows 18 and 26 and within Column O; and Taxiway A is located between rows 18 and 24 and within Column P. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

TABLE 5-3

1990 ANNUAL AVERAGE TAXIING LDN BY GRID CELL

Grid Rows	GRID COLUMNS I	J	K	L	M	N	O	P	Q	R	S	T	U
12	47.6	48.2	48.9	49.5	50.0	50.4	50.7	50.7	50.6	50.3	49.8	49.3	48.7
13	48.4	49.1	49.9	50.6	51.3	51.8	52.1	52.2	52.1	51.7	51.1	50.4	49.7
14	49.2	50.1	51.0	51.9	52.7	53.4	53.9	54.0	53.7	53.2	52.4	51.6	50.7
15	49.9	50.9	52.0	53.1	54.2	55.2	56.0	56.2	55.8	54.9	53.8	52.7	51.6
16	50.6	51.8	53.0	54.4	55.8	57.3	58.7	59.2	58.3	56.8	55.3	53.9	52.6
17	51.2	52.5	53.9	55.5	57.3	59.6	62.6	65.0	61.4	58.7	56.7	54.9	53.4
18	51.7	53.1	54.7	56.5	58.6	61.4	66.1	74.3	64.1	60.3	57.8	55.8	54.1
19	52.1	53.5	55.2	57.1	59.4	62.5	67.2	74.8	65.2	61.3	58.6	56.4	54.6
20	52.3	53.8	55.5	57.5	59.9	62.9	67.6	75.1	65.7	61.8	59.0	56.8	54.9
21	52.3	53.8	55.5	57.5	59.9	63.0	67.6	75.0	65.7	61.8	59.1	56.9	55.0
22	52.2	53.7	55.4	57.3	59.6	62.6	67.2	74.8	65.4	61.6	58.9	56.7	54.8
23	51.9	53.4	55.0	56.8	59.0	61.8	66.3	81.3	64.9	61.0	58.4	56.3	54.5
24	51.5	52.9	54.4	56.0	58.0	60.6	64.3	81.0	63.8	60.0	57.6	55.6	54.0
25	51.0	52.2	53.6	55.1	56.8	58.9	62.1	80.4	61.8	58.6	56.5	54.7	53.2
26	50.4	51.5	52.7	54.0	55.4	56.9	58.7	59.8	58.5	56.7	55.1	53.7	52.4
27	49.7	50.7	51.7	52.8	53.9	54.9	55.8	56.2	55.8	54.8	53.7	52.6	51.5
28	48.9	49.8	50.7	51.6	52.4	53.2	53.7	53.9	53.6	53.1	52.3	51.4	50.5
29	48.1	48.9	49.7	50.4	51.0	51.6	52.0	52.1	51.9	51.5	50.9	50.2	49.5

NOTE: For reference, the runways are located between rows 18 and 26 and within Column O; and Taxiway A is located between rows 18 and 24 and within Column P. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

TABLE 5-4

2000 ANNUAL AVERAGE TAXIING LDN BY GRID CELL

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
	GRID COLUMNS												
12	47.7	48.4	49.0	49.6	50.1	50.5	50.8	50.8	50.7	50.4	50.0	49.4	48.8
13	48.5	49.3	50.0	50.8	51.4	51.9	52.3	52.4	52.2	51.8	51.2	50.5	49.8
14	49.3	50.2	51.1	52.0	52.8	53.5	54.0	54.1	53.9	53.3	52.5	51.7	50.8
15	50.0	51.1	52.1	53.2	54.3	55.3	56.1	56.3	55.9	55.0	54.0	52.9	51.8
16	50.7	51.9	53.1	54.5	55.9	57.4	58.8	59.4	58.4	56.9	55.4	54.0	52.7
17	51.3	52.6	54.0	55.6	57.5	59.7	62.7	65.1	61.5	58.8	56.8	55.1	53.6
18	51.8	53.2	54.8	56.6	58.7	61.5	66.2	74.4	64.2	60.4	57.9	55.9	54.2
19	52.2	53.7	55.3	57.2	59.6	62.6	67.3	75.0	65.4	61.4	58.7	56.6	54.7
20	52.4	53.9	55.6	57.6	60.0	63.1	67.7	75.3	65.8	61.9	59.1	56.9	55.0
21	52.4	54.0	55.7	57.6	60.0	63.1	67.7	75.2	65.8	62.0	59.2	57.0	55.1
22	52.3	53.8	55.5	57.4	59.7	62.7	67.4	74.9	65.5	61.7	59.0	56.8	55.0
23	52.1	53.5	55.1	56.9	59.1	61.9	66.4	81.4	65.0	61.1	58.5	56.4	54.6
24	51.6	53.0	54.5	56.2	58.2	60.7	64.4	81.1	63.9	60.2	57.7	55.7	54.1
25	51.1	52.4	53.7	55.2	56.9	59.0	62.2	80.6	61.9	58.7	56.6	54.9	53.4
26	50.5	51.6	52.8	54.1	55.5	57.1	58.8	60.0	58.7	56.9	55.3	53.8	52.5
27	49.8	50.8	51.8	52.9	54.0	55.1	56.0	56.3	55.9	54.9	53.8	52.7	51.6
28	49.0	49.9	50.8	51.7	52.5	53.3	53.8	54.0	53.8	53.2	52.4	51.5	50.6
29	48.3	49.0	49.8	50.5	51.2	51.7	52.1	52.2	52.0	51.6	51.1	50.4	49.6

NOTE: For reference, the runways are located between rows 18 and 26 and within Column O; and Taxiway A is located between rows 18 and 24 and within Column P. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

Complaints associated with high levels of low frequency noise commonly include annoyance due to building structure vibration and mild stress reactions and auditory sensations, such as pulsating and fluttering. It does not appear, however, that exposure to low frequency noise, at intensities below 130 db Sound Pressure Level (SPL), presents a serious health hazard.[7] Therefore, low frequency noise and induced vibration was not considered further in this study. These issues are addressed in more detail in Appendix E.

Footnotes

1/FAA Report FAA-EE-79-09 "Integrated Noise Model Version 2 User's Guide" (September 1979).

2/FAA Advisory Circular No. 150/5050-6 "Airport-Land Use Compatibility Planning" pages 11 and 17 (December 30, 1977).

3/"INM Version 2," pages 1-11.

4/The alternative approach parameter option was exercised only to define new aircraft types.

5/Slant range is the measurement of the distance between the aircraft and the point at which noise is predicted on the ground. This measurement is likened to the "hypotenuse" or longest side of a right-angled triangle in which the elevation of the aircraft represents the perpendicular side and the distance between the ground point directly below the aircraft and the prediction point equals the base.

6/Sound Exposure Level (SEL) is the A-weighted sound level integrated over the entire noise event and is the logarithmic product of sound intensity and duration.

7/EPA, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety" G-13, (March 1974).

CHAPTER 6

NOISE EXPOSURE LEVELS

CHAPTER 6

NOISE EXPOSURE LEVELS

6.1 INTRODUCTION

Noise exposure attributed to aircraft operations at Sea-Tac International Airport (Sea-Tac) will be presented in two forms in this study. Those are as contours of equal noise exposure and as noise exposure levels at specified points within a grid system for existing conditions (1980) and three forecast years (1985, 1990, and 2000). Input data are derived from the current data base (Chapter 3) and the forecast of aviation demand (Chapter 4). The calibrated Integrated Noise Model (Chapter 5) serves as the predictive tool to generate values of noise exposure. (See Appendix F for guidelines on the use and interpretation of noise contours.) This chapter describes the data and assumptions used as input for the INM and the resulting projections of noise exposure levels.

6.2 ANNUAL AVERAGE NOISE EXPOSURE LEVELS

Noise exposure levels for existing conditions (1980) and three forecast years (1985, 1990, and 2000) are described in this study as annual average day-night levels (Ldn). These levels are based on a number of variables which include: airport altitude and temperature, runway configuration and utilization, flight track identification and utilization, approach and takeoff profiles, aircraft noise and performance characteristics, and traffic mix (i.e., the number of operations and the distribution of operations by aircraft type, arrival vs. departure, time of day, and trip length of departures).

Data and assumptions applied to 1980 airport and aircraft operations were, for the most part, applied to the forecast years. These commonalities include:

- Airport Altitude and Temperature -- Airport altitude is 430 feet mean sea level and the 1980 average temperature was 10.8° C. (51.4° F.).[1/]

- Runway Configuration and Utilization -- The existing runway system consists of a set of parallel runways, Runway 16R/34L and Runway 16L/34R. The distribution of arrivals and departures by runway was based on observed frequency of use and was estimated for 1980 as follows:

	Air Carrier Arrivals (%)	Air Carrier Departures (%)
Runway 34R	30.4	6.4
Runway 34L	1.6	25.6
Runway 16R	55.9	3.4
Runway 16L	12.1	64.6
	100.0	100.0

	Commuter and General Aviation Arrivals (%)	Commuter and General Aviation Departures (%)
Runway 34R	26.0	21.5
Runway 34L	6.0	10.5
Runway 16R	55.9	13.6
Runway 16L	12.1	54.4
	100.0	100.0

For departures, runway use was further differentiated between runway end departures and intersection departures. Departures on Runway 34R take off from the intersection between the runway and Taxiway A-8, with the exception of heavy wide-body aircraft which use the full length of the runway. All jet aircraft and turboprop aircraft departures on Runways 16R and 16L use the full length of the runway. However, piston-powered aircraft take off mid-field.

- Flight Tracks Identification and Utilization -- Flight tracks are identified in Exhibit 6-1. Flight track use is presented in Tables 6-1 and 6-2. Both flight track utilization and flight track definitions were based on observations of operations from control tower radar. Flight track utilization was determined by matching origin and destination of operations to flight tracks. Flight tracks represented the center of the most frequently used "airspace corridors". (See Section 3.3.2 of Chapter 3 for further explanation of flight track identification.)

- Approach and Takeoff Profiles -- Approach profiles were defined as sets of ground distances from the approach end of the runway, reference values of altitude and velocity at each of these distances, and power and flap settings between them. A different approach profile was used for each of the following cases:

TABLE 6-1

AIR CARRIER FLIGHT TRACK UTILIZATION

North Flow Arrivals

Sector	Flight Track
North/Europe	JW
South/Hawaii	JS
Southeast/East	JE-60%/JS-20%/JSE-20%
Asia	JW-50%/JS-50%

North Flow Departures

Sector	Flight Track
North/South/Europe/Asia/Hawaii	Bay
Southeast/East	JE except on Bay during night operations

South Flow Arrivals

Sector	Flight Track
North/Southeast/East/Europe/Asia	Bay-80%/JN-20% except in IFR weather on JN
South/Hawaii	Bay

South Flow Departures

Sector	Flight Track
North	JW
South/Europe/Asia/Hawaii	JS
Southeast	JSE
East	JE-80%/JSE-20%

Note: See Exhibit 4-1 for identification and location of air carrier sectors.

Source: The Port of Seattle

TABLE 6-2

COMMUTER AND GENERAL AVIATION FLIGHT TRACK UTILIZATION

North Flow Arrivals -- Piston and Turboprop

Sector	Flight Track
North/West	CNW except on JNW in IFR weather
South	CSW except on JS in IFR weather
Southeast/East	CE except on JE in IFR weather

North Flow Departures -- Piston and Turboprop

Sector	Flight Track
North	CNW
West	CW
South	CSW
Southeast	CSE
East	CE

North Flow Arrivals -- Turbofan and Turbojet

Sector	Flight Track
North/West	JNW
South	JS
Southeast/East	JE-60%/JS-20%/JSE-20%

North Flow Departures -- Turbofan and Turbojet

Sector	Flight Track
North/West/South	Bay
Southeast	JE
East	CE

South Flow Arrivals -- Piston and Turboprop

Sector	Flight Track
North/West/South	CNW except on Bay in IFR weather
Southeast/East/Northeast	CE

South Flow Departures -- Piston and Turboprop

Sector	Flight Track
North	CNW-90%/CW-10%
West	CW
South	CSW
Southeast	CSE-80%/CE-20%
East	CE
Northeast	CNE

South Flow Arrivals -- Turbofan and Turbojet

Sector	Flight Track
North/West	Bay except on JN in IFR weather
South	Bay
Southeast/East/Northeast	CE

South Flow Departures -- Turbofan and Turbojet

Sector	Flight Track
North/West	JNW
South	JS
Southeast	JSE
East/Northeast	JE

Note: See Exhibit 4-2 for identification and location of general aviation sectors.

Source: The Port of Seattle

- Jet arrivals on Runways 16R and 16L in IFR and VFR weather.
- Jet arrivals on Runway 34R in IFR and VFR weather.
- Jet arrivals on Runway 34L in VFR weather.
- C130 arrivals on Runways 16R and 16L in IFR and VFR weather.
- C130 arrivals on Runway 34R in IFR and VFR weather.
- Piston-powered and turboprop arrivals on Runways 16R and 16L in IFR weather.
- Piston-powered and turboprop arrivals on Runways 16R and 16L in VFR weather.
- Piston-powered and turboprop arrivals on Runway 34R in IFR weather.
- Piston-powered and turboprop arrivals on Runway 34R in VFR weather.
- Piston-powered and turboprop arrivals on Runway 34L in VFR weather.

Takeoff profiles for each aircraft type and for each applicable trip length were derived from the standard INM data base. Ground distance and altitude data for the A300 was replaced by the ground distance and altitude data of the L1011. All jet departure profiles were modified to reflect a reduction in engine power from takeoff thrust to normal climb thrust at an altitude of 1,000 feet above ground. Takeoff thrust was extended beyond an altitude of 1,000 feet only along the westbound departure flight track south of the Airport.

- <u>Aircraft Noise and Performance Statistics</u> -- Noise vs. distance curves for eleven air carrier aircraft types were modified from the standard INM data base to reflect measurements from Sea-Tac's permanent noise monitoring system. Noise vs. distance curves for other aircraft types in the Sea-Tac fleet mix were used directly from the standard INM data base. Performance statistics of all aircraft types represented in the Sea-Tac fleet mix were used directly from the standard INM data base. Noise and performance statistics for the new DC9-80, B767, and B757 were acquired from the FAA Office of Noise Abatement. Noise and performance statistics for the DeHavilland Dash 7 were taken from the John Wayne Airport Environmental Impact Statement, Volume 2 (November 26, 1980).

- <u>Arrival and Departures</u> -- The number of aircraft arrivals are equal to the number of aircraft departures.

- <u>Time of Day</u> -- Ten percent of aircraft operations occur between 10 p.m. and 7 a.m. This distribution of operations was based on control tower data.

The number of aircraft operations and the distribution of operations by aircraft category[2/], however, were forecasted separately for each forecast year. (See Chapter 4, Forecast of Aviation Demand.) As input for the Integrated Noise Model, aircraft categories were further differentiated by aircraft type (i.e., manufacturers' models). For new technology aircraft types, the B767 and B757 were used to represented aircraft with similar noise and performance characteristics. The category of medium twin-engine turboprop aircraft (MTETP) was used to represent small turboprop and twin-engine piston aircraft. The DeHavilland Dash 7 was used to represent medium turboprop aircraft. The distribution of aircraft operations by aircraft type through the forecast period is presented in Table 6-3.[3/] (The impact of using the alternative forecasts of aircraft operations presented in Chapter 4 on projected noise levels is described in Appendix G.)

Noise levels are presented by the INM in two ways: as contours of equal noise exposure and as noise exposure levels at specified points within a grid system. Noise contours representing the Ldn values of 75, 70 and 65 are identified in this study. These noise levels approximate, respectively, the 40, 35 and 30 ANE levels identified in the Sea-Tac/Communities Plan. Noise exposure levels at specified points are identified for the grid system established in the Sea-Tac/Communities Plan. (See Exhibit 6-2 for a map of the grid used in the Plan.) Each noise value represents the center of a 1/16 section (40 acres) grid "cell." A grid cell measures 1,320 feet by 1,320 feet. Noise values are given in this study as an Ldn and as an approximate ANE (i.e., Ldn - 35 = approximate ANE) for those cells in rows 1 through 50 and columns I through U which have an ANE value counterpart in the Sea-Tac/Communities Plan.

6.2.1 1980 Annual Average Noise Exposure Levels

Noise contours for 1980 are illustrated in Exhibit 6-3. The 75 Ldn contour extends north to the Rainier Golf and Country Club and south to about South 240th Street, encompassing approximately 5.97 square miles. The 70 Ldn contour extends north to the Duwamish Waterway and south to about South 268th Street and encompasses approximately 13.07 square miles. The 65 Ldn contour extends north to the north end of King County International Airport (Boeing Field) and south to Federal Way, encompassing approximately 30.83 square miles.

TABLE 6-3

FLEET MIX

(Daily Operations by Aircraft Type)

INM #	Aircraft Type	1980	1985	1990	2000
1	DC9	26.3	29.0	0	0
4	B737	17.6	0	0	0
5	B727-2000	33.1	0	0	0
6	B727-100	44.3	0	0	0
8	B707	3.0	0	0	0
11	DC8	8.0	0	0	0
20	A300	2.2	3.8	4.9	10.1
21	DC10-10	26.9	26.2	14.4	4.6
22	L1011	9.2	13.1	14.4	18.5
23	DC10-30	22.1	26.1	43.0	69.5
25	B747-200	9.6	13.0	18.3	33.0
26	B747-100	16.6	12.9	9.9	1.7
28	DC9 SAM	0	0	33.5	22.1
29	B737 SAM	13.2	25.4	46.9	44.3
30	B727 SAM	131.8	152.3	104.7	0
32	DC8 SAM	0	8.5	0	0
35	LTJ	8.8	8.0	6.3	8.6
39	MTETP	69.7	41.2	43.2	56.9
43	MSEP6	27.8	34.8	37.9	40.1
44	MTEP10	106.6	95.6	94.1	105.2
46	LQTF	4.8	6.4	9.5	14.3
55	C130	2.1	1.5	1.5	1.5
147	DF9-80	0	10.9	26.8	66.4
148	B757	0	7.2	26.8	88.5
149	B767	0	34.1	43.6	90.6
150	DeHav-7		13.7	24.6	38.6
		583.7	563.7	604.3	714.5

Abbreviations:

B = Boeing
SAM = Sound Absorptive Material
LTJ = Light Turbojet
MTETP = Medium Twin-Engine Turboprop
MSEP6 = Medium Single-Engine Piston (6 Seat)
MTEP10 = Medium Twin-Engine Piston (10 Seat)
LQTP = Light Quiet Turbofan
DeHav-7 = DeHavilland Dash 7

Source: The Port of Seattle

Tables 6-4 and 6-5 present noise values at the grid cells for 1980. With the exception of cell N-26, southeast of Sea-Tac, all cells with noise levels over 80 Ldn (45 ANE) are within the existing Airport boundary. A number of cells experiencing noise levels over 75 Ldn (40 ANE) are identified outside the Airport boundary, particularly north and south of the Airport.

6.2.2 1985 Annual Average Noise Exposure Projections

Noise contours projected for 1985 are illustrated in Exhibit 6-4. The 75 Ldn contour extends north to about South 120th Street and south to about Kent-Des Moines Road, encompassing approximately 5.36 square miles. The 70 Ldn contour extends north to the Duwamish Waterway and south to about South 262nd Place and encompasses approximately 11.81 square miles. The 65 Ldn contour extends north to the north end of Boeing Field and south to Steel Lake, encompassing approximately 27.52 square miles.

Tables 6-6 and 6-7 present noise values at the grid cells for 1985. With the exception of cell N-26, southeast of Sea-Tac, the projections show that all cells experiencing noise levels over 80 Ldn (45 ANE) will be within the existing Airport boundary. As in 1980, there are cells experiencing noise levels over 75 Ldn (40 ANE) identified outside the Airport boundary.

6.2.3 1990 Annual Average Noise Exposure Projections

Noise contours projected for 1990 are illustrated in Exhibit 6-5. The 75 Ldn contour extends north to about South 124th Street and south Mt. Rainier Senior High School, encompassing approximately 4.58 square miles. The 70 Ldn contour extends north to about West Marginal Place South and south to about South 260th Street and encompasses approximately 10.20 square miles. The 65 Ldn contour extends north to Boeing Field and south to about South 298th Street, encompassing approximately 22.99 square miles.

TABLE 6-4
1980 ANNUAL AVERAGE LDN

(Ldn for each 1/16 section within study area)

Grid Columns

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
1			63.2	64.9	66.8	69.2	71.4	68.4	65.1	62.8			
2			63.1	64.8	66.9	69.6	72.0	68.8	65.4	63.1	61.1		
3	59.6	61.2	63.0	64.8	66.9	69.9	72.6	69.2	65.8	63.5	61.5		
4	59.8	61.2	62.9	64.7	66.9	70.2	73.3	69.7	66.1	63.8	61.8	60.0	
5	60.2	61.4	63.0	64.8	67.0	70.5	73.8	70.2	66.4	64.1	62.1	60.2	
6	59.9	61.6	63.3	64.9	67.1	70.8	74.4	70.7	66.7	64.4	62.4	60.5	59.3
7	59.8	61.4	63.4	65.2	67.4	71.2	75.0	71.2	67.1	64.6	62.7	60.8	59.7
8	60.2	61.4	63.3	65.3	67.8	71.6	75.7	71.6	67.4	64.9	62.9	61.0	60.0
9	60.5	61.5	63.4	65.4	68.2	72.2	76.4	72.2	67.8	65.2	63.2	61.9	60.5
10	60.8	62.2	63.7	65.7	68.5	72.8	77.2	72.8	68.3	65.5	63.6	62.3	61.0
11	61.3	62.7	64.0	65.9	68.9	73.4	78.1	73.3	68.8	65.9	64.5	63.0	61.6
12	61.8	63.3	64.6	66.5	69.6	74.2	79.1	74.1	69.5	66.6	65.3	63.7	62.3
13	62.5	64.1	65.8	67.4	70.7	75.5	80.4	75.3	70.7	67.7	66.4	64.7	63.2
14	63.5	65.2	66.7	68.8	72.2	77.1	81.9	76.8	72.2	69.3	67.9	66.0	64.3
15	64.4	66.3	67.9	70.2	73.8	78.8	83.6	78.7	74.0	70.8	69.2	67.2	65.2
16	64.8	66.8	68.6	71.0	74.9	80.5	86.1	81.9	76.7	72.5	70.1	68.0	65.8
17	64.5	66.7	69.2	71.3	75.9	82.3	90.1	87.9	79.7	73.8	70.4	68.0	65.7
18	63.0	65.2	67.6	70.5	75.1	82.0	92.3	89.7	79.1	72.7	69.1	66.8	64.5
19	61.3	63.2	65.6	68.5	73.2	80.7	94.2	88.0	77.4	71.3	67.7	65.4	63.3
20	60.9	62.6	64.7	67.0	71.2	78.9	96.4	87.0	76.2	70.5	67.2	65.0	62.9
21	60.7	62.6	64.6	66.9	70.9	77.8	95.5	86.2	75.8	70.3	67.1	64.8	62.8
22	60.8	62.6	64.7	67.0	71.0	78.1	94.8	87.4	76.5	70.3	67.1	64.8	62.7
23	61.2	63.2	65.5	68.4	73.1	80.1	96.3	90.7	79.3	72.6	68.4	65.5	63.1
24	62.8	65.1	67.8	70.7	75.1	82.4	98.1	90.5	81.2	74.8	70.5	67.7	65.0
25	64.5	66.8	69.5	71.8	76.1	82.9	90.2	89.6	81.4	75.1	71.9	69.4	66.5
26	65.3	67.4	69.5	71.9	75.4	81.0	85.9	85.9	80.7	75.1	71.7	69.3	67.2
27	65.2	66.8	69.2	71.4	74.4	79.5	84.4	84.5	79.6	74.4	71.3	69.0	67.0
28	64.4	65.9	68.1	70.3	73.0	78.0	82.9	83.1	78.3	73.1	70.1	68.0	66.1
29	63.7	65.1	67.2	69.3	72.0	76.9	81.6	81.8	77.1	72.0	69.2	67.0	65.1
30	63.1	64.8	66.8	68.8	71.4	76.0	80.6	80.7	76.2	71.4	68.7	66.5	64.4
31	63.0	64.6	66.5	68.5	71.0	75.4	79.7	79.8	75.5	71.0	68.4	66.3	64.1
32		64.4	66.4	68.4	70.8	74.9	79.0	79.2	75.0	70.8	68.3	66.2	64.0
33			66.1	68.2	70.5	74.3	78.4	78.5	74.5	70.6	68.2	66.1	64.0
34			65.9	68.0	70.3	73.9	77.9	77.9	74.0	70.4	68.1	66.0	63.9
35				67.9	70.1	73.4	77.0	77.1	73.5	70.2	67.9	65.8	63.8
36				67.7	69.8	72.9	76.3	76.4	73.0	69.9	67.8	65.7	63.6
37				67.5	69.5	72.3	75.6	75.7	72.5	69.6	67.5	65.5	63.4
38				67.3	69.3	71.9	75.0	75.1	72.0	69.4	67.4	65.3	63.3
39				67.0	69.0	71.4	74.3	74.4	71.5	69.0	67.1	65.0	63.1
40				66.9	68.8	71.0	73.7	73.8	71.1	68.9	66.9	64.9	62.9
41				66.1	68.1	70.2	72.9	73.0	70.5	68.4	66.6	64.7	62.8
42				66.1	67.9	69.8	72.2	72.3	69.7	67.8	66.0	64.0	62.2
43				66.1	67.8	69.6	71.8	71.8	69.4	67.6	65.8	63.8	62.0
44				66.1	67.7	69.4	71.3	71.3	69.0	67.3	65.5	63.6	61.9
45				66.0	67.5	68.9	70.0	69.9	68.4	66.9	65.1	63.3	61.6
46				66.0	67.4	68.6	69.6	69.5	68.1	66.6	64.9	63.1	61.4
47				65.9	67.2	68.2	69.2	69.1	67.8	66.3	64.7	62.9	61.3
48				65.7	66.8	67.8	68.8	68.7	67.5	66.1	64.5	62.8	61.2
49				65.4	66.5	67.5	68.4	68.4	67.2	65.9	64.4	62.7	61.2
50				64.9	66.0	67.1	68.1	68.1	67.0	65.8	64.3	62.7	61.2

Note: Underlined noise values (e.g. 66.4) include an adjustment for aircraft taxiing on Taxiway A.

For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

D/060/63D - 05/17/82

TABLE 6-5
1980 ANNUAL AVERAGE ANE

(Ldn - 35 = approximate ANE for each 1/16 section within study area)

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
	Grid Columns												
1			28.2	29.9	31.8	34.2	36.4	33.4	30.1	27.8			
2			28.1	29.8	31.9	34.6	37.0	33.8	30.4	28.1	26.1		
3	24.6	26.2	28.0	29.8	31.9	34.9	37.6	34.2	30.8	28.5	26.5		
4	24.8	26.2	27.9	29.7	31.9	35.2	38.3	34.7	31.1	28.8	26.8	25.0	
5	25.2	26.4	28.0	29.8	32.0	35.5	38.8	35.2	31.4	29.1	27.1	25.2	
6	24.9	26.6	28.3	29.9	32.1	35.8	39.4	35.7	31.7	29.4	27.4	25.5	24.3
7	24.8	26.4	28.4	30.2	32.4	36.2	40.0	36.2	32.1	29.6	27.7	25.8	24.7
8	25.2	26.4	28.3	30.3	32.8	36.6	40.7	36.6	32.4	29.9	27.9	26.0	25.0
9	25.5	26.5	28.4	30.4	33.2	37.2	41.4	37.2	32.8	30.2	28.2	26.9	25.5
10	25.8	27.2	28.7	30.7	33.5	37.8	42.2	37.8	33.3	30.5	28.6	27.3	26.0
11	26.3	27.7	29.0	30.9	33.9	38.4	43.1	38.3	33.8	30.9	29.5	28.0	26.6
12	26.8	28.3	29.6	31.5	34.6	39.2	44.1	39.1	34.5	31.6	30.3	28.7	27.3
13	27.5	29.1	30.8	32.4	35.7	40.5	45.4	40.3	35.7	32.7	31.4	29.7	28.2
14	28.5	30.2	31.7	33.8	37.2	42.1	46.9	41.8	37.2	34.3	32.9	31.0	29.3
15	29.4	31.3	32.9	35.2	38.8	43.8	48.6	43.7	39.0	35.8	34.2	32.2	30.2
16	29.8	31.8	33.6	36.0	39.9	45.5	51.1	46.9	41.7	37.5	35.1	33.0	30.8
17	29.5	31.7	34.2	36.3	40.9	47.3	55.1	52.9	44.7	38.8	35.4	33.0	30.7
18	28.0	30.2	32.6	35.5	40.1	47.0	57.3	54.7	44.1	37.7	34.1	31.8	29.5
19	26.3	28.2	30.6	33.5	38.2	45.7	59.2	53.0	42.4	36.3	32.7	30.4	28.3
20	25.9	27.6	29.7	32.0	36.2	43.9	61.4	52.0	41.2	35.5	32.2	30.0	27.9
21	25.7	27.6	29.6	31.9	35.9	42.8	60.5	51.2	40.8	35.3	32.1	29.8	27.8
22	25.8	27.6	29.7	32.0	36.0	43.1	59.8	52.4	41.5	35.3	32.1	29.8	27.7
23	26.2	28.2	30.5	33.4	38.1	45.1	61.3	55.7	44.3	37.6	33.4	30.5	28.1
24	27.8	30.1	32.8	35.7	40.1	47.4	63.1	55.5	46.2	39.8	35.5	32.7	30.0
25	29.5	31.8	34.5	36.8	41.1	47.9	55.2	54.6	46.4	40.1	36.9	34.4	31.5
26	30.3	32.4	34.5	36.9	40.4	46.0	50.9	50.9	45.7	40.1	36.7	34.3	32.2
27	30.2	31.8	34.2	36.4	39.4	44.5	49.4	49.5	44.6	39.4	36.3	34.0	32.0
28	29.4	30.9	33.1	35.3	38.0	43.0	47.9	48.1	43.3	38.1	35.1	33.0	31.1
29	28.7	30.1	32.2	34.3	37.0	41.9	46.6	46.8	42.1	37.0	34.2	32.0	30.1
30	28.1	29.8	31.8	33.8	36.4	41.0	45.6	45.7	41.2	36.4	33.7	31.5	29.4
31	28.0	29.6	31.5	33.5	36.0	40.4	44.7	44.8	40.5	36.0	33.4	31.3	29.1
32		29.4	31.4	33.4	35.8	39.9	44.0	44.2	40.0	35.8	33.3	31.2	29.0
33			31.1	33.2	35.5	39.3	43.4	43.5	39.5	35.6	33.2	31.1	29.0
34			30.9	33.0	35.3	38.9	42.9	42.9	39.0	35.4	33.1	31.0	28.9
35				32.9	35.1	38.4	42.0	42.1	38.5	35.2	32.9	30.8	28.8
36				32.7	34.8	37.9	41.3	41.4	38.0	34.9	32.8	30.7	28.6
37				32.5	34.5	37.3	40.6	40.7	37.5	34.6	32.5	30.5	28.4
38				32.3	34.3	36.9	40.0	40.1	37.0	34.4	32.4	30.3	28.3
39				32.0	34.0	36.4	39.3	39.4	36.5	34.0	32.1	30.0	28.1
40				31.9	33.8	36.0	38.7	38.8	36.1	33.9	31.9	29.9	27.9
41				31.1	33.1	35.2	37.9	38.0	35.5	33.4	31.6	29.7	27.8
42				31.1	32.9	34.8	37.2	37.3	34.7	32.8	31.0	29.0	27.2
43				31.1	32.8	34.6	36.8	36.8	34.4	32.6	30.8	28.8	27.0
44				31.1	32.7	34.4	36.3	36.3	34.0	32.3	30.5	28.6	26.9
45				31.0	32.5	33.9	35.0	34.9	33.4	31.9	30.1	28.3	26.6
46				31.0	32.4	33.6	34.6	34.5	33.1	31.6	29.9	28.1	26.4
47				30.9	32.2	33.2	34.2	34.1	32.8	31.3	29.7	27.9	26.3
48				30.7	31.8	32.8	33.8	33.7	32.5	31.1	29.5	27.8	26.2
49				30.4	31.5	32.5	33.4	33.4	32.2	30.9	29.4	27.7	26.2
50				29.9	31.0	32.1	33.1	33.1	32.0	30.8	29.3	27.7	26.2

Note: Underlined noise values (e.g. 31.7) include an adjustment for aircraft taxiing on Taxiway A.

For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

TABLE 6-6
1985 ANNUAL AVERAGE LDN

(Ldn for each 1/16 section within study area)

Grid Columns

	I	J	K	L	M	N	O	P	Q	R	S	T	U
1			62.9	64.7	66.6	68.7	70.3	67.9	64.9	62.7			
2			62.7	64.6	66.6	69.0	70.8	68.3	65.3	63.1	61.1		
3	59.1	60.8	62.6	64.5	66.7	69.3	71.4	68.8	65.7	63.5	61.5		
4	59.2	60.7	62.6	64.5	66.7	69.6	72.0	69.3	66.1	63.8	61.9	60.0	
5	59.5	60.9	62.6	64.5	66.8	69.9	72.6	69.8	66.4	64.1	62.2	60.3	
6	59.3	61.0	62.8	64.6	66.9	70.2	73.2	70.3	66.8	64.4	62.4	60.5	58.9
7	59.3	60.9	62.9	64.8	67.1	70.6	73.8	70.9	67.2	64.7	62.7	60.7	59.2
8	59.3	60.9	62.8	64.9	67.4	71.0	74.4	71.4	67.6	64.9	62.9	61.0	59.4
9	59.5	61.1	63.0	65.1	67.8	71.5	75.2	71.9	67.9	65.2	63.1	61.3	59.7
10	59.9	61.4	63.2	65.3	68.1	72.1	76.0	72.5	68.4	65.5	63.5	61.7	60.2
11	60.3	61.8	63.6	65.6	68.6	72.8	76.8	73.1	68.9	65.9	63.9	62.2	60.7
12	60.8	62.4	64.2	66.2	69.3	73.6	77.9	74.0	69.7	66.6	64.7	62.9	61.3
13	61.6	63.3	65.2	67.2	70.4	74.9	79.2	75.3	70.9	67.8	65.8	63.9	62.2
14	62.6	64.4	66.4	68.6	71.9	76.4	80.8	76.9	72.4	69.3	67.2	65.2	63.3
15	63.3	65.3	67.5	69.8	73.2	78.0	82.5	78.6	74.2	70.7	68.5	66.3	64.2
16	63.7	65.9	68.3	70.7	74.5	79.8	85.0	81.5	76.6	72.1	69.3	67.0	64.7
17	63.3	65.6	68.3	70.9	75.4	81.6	89.3	87.4	79.2	73.1	69.6	67.0	65.0
18	62.0	64.3	66.4	69.4	74.5	81.4	92.3	88.5	78.2	72.1	68.3	65.9	63.3
19	59.8	61.9	64.5	67.7	72.2	80.0	93.5	86.6	76.5	70.3	66.4	63.8	61.5
20	59.0	60.9	63.0	65.5	70.0	78.2	95.4	85.9	74.8	68.7	65.3	62.9	60.8
21	58.8	60.8	63.0	65.4	69.6	76.5	94.6	84.9	74.2	68.4	65.1	62.8	60.6
22	58.9	60.9	63.1	65.6	69.9	77.1	94.1	86.4	75.3	68.7	65.2	62.8	60.6
23	59.6	61.7	64.4	67.6	72.2	79.6	95.4	89.0	78.1	71.8	67.3	64.1	61.5
24	61.7	64.3	66.7	69.8	74.7	81.8	97.0	89.0	80.4	73.8	69.3	66.7	63.9
25	63.3	65.8	68.7	71.5	75.7	82.2	89.5	88.1	80.6	74.6	71.0	68.3	65.3
26	64.2	66.5	69.0	71.5	75.0	80.2	85.2	85.1	79.7	74.5	71.2	68.7	66.1
27	64.0	66.1	68.5	70.9	73.9	78.6	83.5	83.5	78.6	73.7	70.6	68.2	65.8
28	63.3	65.2	67.5	69.8	72.6	77.2	82.0	82.1	77.3	72.5	69.6	67.3	64.9
29	62.6	64.5	66.6	68.7	71.5	76.1	80.7	80.8	76.1	71.4	68.6	66.4	64.2
30	62.4	64.1	66.1	68.2	70.9	75.3	79.6	79.7	75.4	70.9	68.1	65.9	63.8
31	62.3	64.0	65.9	68.0	70.6	74.7	78.9	78.9	74.8	70.6	67.9	65.8	63.7
32		63.8	65.7	67.8	70.3	74.2	78.1	78.2	74.3	70.3	67.7	65.6	63.6
33			65.5	67.5	70.0	73.7	77.4	77.5	73.8	70.1	67.6	65.5	63.5
34			65.3	67.4	69.8	73.2	76.8	76.9	73.3	69.8	67.5	65.4	63.4
35				67.3	69.5	72.7	76.0	76.1	72.8	69.6	67.3	65.3	63.3
36				67.1	69.3	72.2	75.3	75.4	72.3	69.3	67.1	65.0	63.1
37				66.9	69.0	71.8	74.7	74.7	71.9	69.1	67.0	64.9	62.9
38				66.8	68.8	71.4	74.1	74.1	71.4	68.9	66.8	64.7	62.8
39				66.5	68.5	70.9	73.4	73.5	71.0	68.6	66.5	64.5	62.6
40				66.4	68.3	70.5	72.9	72.9	70.6	68.4	66.4	64.4	62.5
41				65.4	67.4	69.5	71.8	72.0	69.8	67.8	66.0	64.1	62.3
42				65.3	67.2	69.0	71.1	71.1	68.9	67.0	65.1	63.2	61.4
43				65.4	67.1	68.9	70.7	70.6	68.6	66.7	64.9	63.0	61.2
44				65.4	67.1	68.7	70.3	70.1	68.2	66.5	64.7	62.8	61.1
45				65.4	66.9	68.2	69.2	68.9	67.6	66.1	64.3	62.5	60.8
46				65.4	66.8	67.9	68.7	68.5	67.3	65.8	64.1	62.3	60.7
47				65.4	66.5	67.5	68.3	68.2	67.0	65.5	63.8	62.1	60.5
48				65.1	66.2	67.1	67.9	67.8	66.6	65.2	63.6	62.0	60.4
49				64.7	65.7	66.7	67.6	67.5	66.4	65.0	63.5	61.9	60.4
50				64.2	65.3	66.3	67.2	67.1	66.1	64.9	63.4	61.9	60.5

Note: Underlined noise values (e.g. 66.4) include an adjustment for aircraft taxiing on Taxiway A.

For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: Port of Seattle

D/060/63D - 05/20/82

TABLE 6-7
1985 ANNUAL AVERAGE ANE

(Ldn - 35 = approximate ANE for each 1/16 section within study area)

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
1			27.9	29.7	31.6	33.7	35.3	32.9	29.9	27.7			
2			27.7	29.6	31.6	34.0	35.8	33.3	30.3	28.1	26.1		
3	24.1	25.8	27.6	29.5	31.7	34.3	36.4	33.8	30.7	28.5	26.5		
4	24.2	25.7	27.6	29.5	31.7	34.6	37.0	34.3	31.1	28.8	26.9	25.0	
5	24.5	25.9	27.6	29.5	31.8	34.9	37.6	34.8	31.4	29.1	27.2	25.3	
6	24.3	26.0	27.8	29.6	31.9	35.2	38.2	35.3	31.8	29.4	27.4	25.5	23.9
7	24.3	25.9	27.9	29.8	32.1	35.6	38.8	35.9	32.2	29.7	27.7	25.7	24.2
8	24.3	25.9	27.8	29.9	32.4	36.0	39.4	36.4	32.6	29.9	27.9	26.0	24.4
9	24.5	26.1	28.0	30.1	32.8	36.5	40.2	36.9	32.9	30.2	28.1	26.3	24.7
10	24.9	26.4	28.2	30.3	33.1	37.1	41.0	37.5	33.4	30.5	28.5	26.7	25.2
11	25.3	26.8	28.6	30.6	33.6	37.8	41.8	38.1	33.9	30.9	28.9	27.2	25.7
12	25.8	27.4	29.2	31.2	34.3	38.6	42.9	39.0	34.7	31.6	29.7	27.9	26.3
13	26.6	28.3	30.2	32.2	35.4	39.9	44.2	40.3	35.9	32.8	30.8	28.9	27.2
14	27.6	29.4	31.4	33.6	36.9	41.4	45.8	41.9	37.4	34.3	32.2	30.2	28.3
15	28.3	30.3	32.5	34.8	38.2	43.0	47.5	43.6	39.2	35.7	33.5	31.3	29.2
16	28.7	30.9	33.3	35.7	39.5	44.8	50.0	46.5	41.6	37.1	34.3	32.0	29.7
17	28.3	30.6	33.3	35.9	40.4	46.6	54.3	52.4	44.2	38.1	34.6	32.0	30.0
18	27.0	29.3	31.4	34.4	39.5	46.4	57.3	53.5	43.2	37.1	33.3	30.9	28.3
19	24.8	26.9	29.5	32.7	37.2	45.0	58.5	51.6	41.5	35.3	31.4	28.8	26.5
20	24.0	25.9	28.0	30.5	35.0	43.2	60.4	50.9	39.8	33.7	30.3	27.9	25.8
21	23.8	25.8	28.0	30.4	34.6	41.5	59.6	49.9	39.2	33.4	30.1	27.8	25.6
22	23.9	25.9	28.1	30.6	34.9	42.1	59.1	51.4	40.3	33.7	30.2	27.8	25.6
23	24.6	26.7	29.4	32.6	37.2	44.6	60.4	54.0	43.1	36.8	32.3	29.1	26.5
24	26.7	29.3	31.7	34.8	39.7	46.8	62.0	54.0	45.4	38.8	34.3	31.7	28.9
25	28.3	30.8	33.7	36.5	40.7	47.2	54.5	53.1	45.6	39.6	36.0	33.3	30.3
26	29.2	31.5	34.0	36.5	40.0	45.2	50.2	50.1	44.7	39.5	36.2	33.7	31.1
27	29.0	31.1	33.5	35.9	38.9	43.6	48.5	48.5	43.6	38.7	35.6	33.2	30.8
28	28.3	30.2	32.5	34.8	37.6	42.2	47.0	47.1	42.3	37.5	34.6	32.3	29.9
29	27.6	29.5	31.6	33.7	36.5	41.1	45.7	45.8	41.1	36.4	33.6	31.4	29.2
30	27.4	29.1	31.1	33.2	35.9	40.3	44.6	44.7	40.4	35.9	33.1	30.9	28.8
31	27.3	29.0	30.9	33.0	35.6	39.7	43.9	43.9	39.8	35.6	32.9	30.8	28.7
32		28.8	30.7	32.8	35.3	39.2	43.1	43.2	39.3	35.3	32.7	30.6	28.6
33			30.5	32.5	35.0	38.7	42.4	42.5	38.8	35.1	32.6	30.5	28.5
34			30.3	32.4	34.8	38.2	41.8	41.9	38.3	34.8	32.5	30.4	28.4
35				32.3	34.5	37.7	41.0	41.1	37.8	34.6	32.3	30.3	28.3
36				32.1	34.3	37.2	40.3	40.4	37.3	34.3	32.1	30.0	28.1
37				31.9	34.0	36.8	39.7	39.7	36.9	34.1	32.0	29.9	27.9
38				31.8	33.8	36.4	39.1	39.1	36.4	33.9	31.8	29.7	27.8
39				31.5	33.5	35.9	38.4	38.5	36.0	33.6	31.5	29.5	27.6
40				31.4	33.3	35.5	37.9	37.9	35.6	33.4	31.4	29.4	27.5
41				30.4	32.4	34.5	36.8	37.0	34.8	32.8	31.0	29.1	27.3
42				30.3	32.2	34.0	36.1	36.1	33.9	32.0	30.1	28.2	26.4
43				30.4	32.1	33.9	35.7	35.6	33.6	31.7	29.9	28.0	26.2
44				30.4	32.1	33.7	35.3	35.1	33.2	31.5	29.7	27.8	26.1
45				30.4	31.9	33.2	34.2	33.9	32.6	31.1	29.3	27.5	25.8
46				30.4	31.8	32.9	33.7	33.5	32.3	30.8	29.1	27.3	25.7
47				30.4	31.5	32.5	33.3	33.2	32.0	30.5	28.8	27.1	25.5
48				30.1	31.2	32.1	32.9	32.8	31.6	30.2	28.6	27.0	25.4
49				29.7	30.7	31.7	32.6	32.5	31.4	30.0	28.5	26.9	25.4
50				29.2	30.3	31.3	32.2	32.1	31.1	29.9	28.4	26.9	25.5

Note: Underlined noise values (e.g. 31.7) include an adjustment for aircraft taxiing on Taxiway A.

For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1/320' by 1/320'.

Airport Boundary Outlined

Source: The Port of Seattle

Tables 6-8 and 6-9 present noise values at the grid cells for 1990. All cells experiencing noise levels over 80 Ldn (45 ANE) will be within the existing Airport boundary. Most of the cells with noise levels over 75 Ldn (40 ANE) will be within the Airport boundary.

6.2.4 2000 Annual Average Noise Exposure Projections

Noise contours projected for 2000 are illustrated in Exhibit 6-6. The 75 Ldn contour extends north to about South 132nd Street and south to about South 214th Street and encompasses 2.30 square miles. The 70 Ldn contour extends north to the Rainier Golf and Country Club and south to about South 240th Street, encompassing 5.45 square miles. The 65 Ldn contour extends north to the Boeing Plant on the westside of Boeing Field and south to about South 270th Street and encompasses 12.43 square miles.

Tables 6-10 and 6-11 present noise values at the grid cells for the year 2000. With the exception of cell 0-12, north of Sea-Tac, all cells experiencing noise levels over 75 Ldn (40 ANE) will be within the existing Airport boundary.

6.3 NOISE EXPOSURE TRENDS

Based on the methodology and data presented in this study, noise levels are projected to decrease through the year 2000. The magnitude of this abatement is demonstrated by the shifts of the noise contours toward the airport.

Table 6-12 illustrates the trend of shrinking noise contours. It presents a comparison of the area within the 75, 70, and 65 Ldn noise contours for each of the forecast years. Between 1980 and 1985, the area within each of the contours decreases by about 10%. An additional 14% to 15% decrease in area within contours is projected between 1985 and 1990. The decrease in area between 1990 and the year 2000 is much more dramatic--over a 45% reduction.

TABLE 6-8
1990 ANNUAL AVERAGE LDN

(Ldn for each 1/16 section within study area)

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
						Grid Columns							
1			61.9	63.9	65.9	68.1	69.8	67.2	64.1	61.7			
2			61.7	63.7	65.9	68.4	70.4	67.6	64.5	62.1	60.0		
3	58.0	59.7	61.6	63.6	65.9	68.7	71.0	68.1	64.9	62.5	60.4		
4	58.1	59.6	61.5	63.6	65.9	69.0	71.5	68.6	65.3	62.8	60.8	58.9	
5	58.4	59.8	61.6	63.6	66.0	69.3	72.1	69.1	65.6	63.2	61.1	59.1	
6	58.2	59.9	61.8	63.7	66.1	69.6	72.7	69.6	66.0	63.5	61.3	59.3	57.7
7	58.0	59.7	61.8	63.9	66.3	69.9	73.3	70.1	66.4	63.7	61.6	59.5	57.9
8	58.1	59.7	61.8	64.0	66.6	70.3	73.9	70.5	66.7	64.0	61.8	59.7	58.1
9	58.2	59.9	61.9	64.1	67.0	70.8	74.6	71.0	67.1	64.2	62.0	60.0	58.4
10	58.6	60.2	62.1	64.4	67.3	71.4	75.4	71.6	67.5	64.5	62.3	60.4	58.8
11	59.0	60.6	62.5	64.6	67.7	71.9	76.3	72.2	68.0	64.9	62.8	60.9	59.3
12	59.5	61.1	62.9	65.1	68.2	72.6	77.3	72.9	68.6	65.4	63.3	61.5	59.9
13	60.3	62.0	63.9	66.0	69.3	73.8	78.6	74.2	69.8	66.6	64.5	62.6	60.8
14	61.3	63.2	65.3	67.5	70.9	75.5	80.2	75.8	71.5	68.2	66.0	64.0	62.1
15	62.2	64.2	66.5	68.9	72.4	77.2	82.0	77.8	73.3	69.8	67.4	65.2	63.1
16	62.4	64.7	67.1	69.6	73.5	78.9	84.4	80.5	75.5	71.1	68.2	65.8	63.5
17	61.8	64.3	67.0	69.9	74.3	80.6	88.7	86.5	78.1	72.1	68.4	65.7	63.5
18	60.3	62.7	64.9	68.2	73.4	80.4	91.9	87.8	77.1	70.5	67.0	64.4	61.8
19	58.3	60.3	62.9	66.1	70.6	78.7	93.1	85.9	75.2	68.8	64.9	62.4	60.1
20	57.6	59.5	61.8	64.4	68.9	76.8	94.9	85.0	73.6	67.5	64.0	61.6	59.3
21	57.5	59.4	61.7	64.3	68.6	75.7	94.1	84.1	73.1	67.3	63.8	61.4	59.2
22	57.[illegible]	59.5	61.9	64.5	68.9	76.1	93.5	84.9	74.0	67.5	63.9	61.5	59.2
23	58.3	60.4	63.0	66.2	70.9	78.4	94.7	88.0	76.7	70.2	65.8	62.6	60.0
24	60.2	62.8	65.3	68.5	73.5	80.7	96.4	88.0	79.2	72.6	67.9	65.2	62.4
25	61.9	64.4	67.4	70.3	74.6	81.1	88.8	87.1	79.5	73.5	69.7	66.9	63.9
26	62.9	65.2	67.8	70.4	74.0	79.1	84.3	84.2	78.7	73.4	70.0	67.4	64.8
27	62.8	64.9	67.4	69.8	72.9	77.6	82.6	82.6	77.6	72.7	69.6	67.1	64.6
28	62.0	64.0	66.4	68.7	71.6	76.2	81.1	81.2	76.2	71.5	68.5	66.1	63.7
29	61.4	63.3	65.4	67.7	70.5	75.0	79.7	79.7	75.1	70.5	67.5	65.2	62.9
30	61.2	62.9	64.9	67.1	69.9	74.2	78.6	78.7	74.3	69.9	67.0	64.7	62.5
31	61.1	62.8	64.7	66.9	69.6	73.7	77.8	77.9	73.8	69.6	66.8	64.5	62.4
32		62.6	64.5	66.7	69.3	73.2	77.1	77.1	73.3	69.3	66.6	64.4	62.3
33			64.2	66.4	69.0	72.6	76.4	76.4	72.7	69.1	66.5	64.3	62.2
34			64.0	66.3	68.8	72.2	75.7	75.8	72.3	68.9	66.3	64.1	62.1
35				66.1	68.6	71.8	75.0	75.1	71.8	68.6	66.2	64.0	62.0
36				66.0	68.3	71.3	74.3	74.4	71.4	68.4	66.0	63.8	61.8
37				65.8	68.1	70.9	73.7	73.8	70.9	68.1	65.8	63.7	61.7
38				65.6	67.8	70.4	73.1	73.2	70.5	67.9	65.7	63.5	61.5
39				65.3	67.5	69.9	72.4	72.5	70.0	67.5	65.4	63.2	61.3
40				65.2	67.3	69.6	71.9	72.0	69.6	67.3	65.2	63.1	61.1
41				64.2	66.3	68.6	70.9	71.0	68.8	66.8	64.8	62.8	60.9
42				64.2	66.1	68.1	70.2	70.2	68.0	66.0	64.0	61.9	60.1
43				64.2	66.1	68.0	69.8	69.7	67.6	65.7	63.7	61.8	59.9
44				64.3	66.1	67.8	69.4	69.3	67.3	65.4	63.5	61.6	59.8
45				64.3	65.9	67.3	68.3	68.1	66.7	65.0	63.1	61.3	59.5
46				64.3	65.8	67.0	67.8	67.7	66.3	64.7	62.9	61.1	59.4
47				64.3	65.5	66.6	67.4	67.3	66.0	64.4	62.6	60.9	59.2
48				64.1	65.1	66.1	67.0	66.9	65.6	64.1	62.4	60.7	59.1
49				63.6	64.7	65.7	66.6	66.5	65.4	63.9	62.3	60.7	59.1
50				63.1	64.1	65.3	66.2	66.2	65.1	63.8	62.2	60.6	59.2

Note: Underlined noise values (e.g. 66.4) include an adjustment for aircraft taxiing on Taxiway A.

For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1.320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

D/060/63D - 05/20/82

TABLE 6-9
1990 ANNUAL AVERAGE ANE

(Ldn - 35 = approximate ANE for each 1/16 section within study area)

Grid Columns

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
1			26.9	28.9	30.9	33.1	34.8	32.2	29.1	26.7			
2			26.7	28.7	30.9	33.4	35.4	32.6	29.5	27.1	25.0		
3	23.0	24.7	26.6	28.6	30.9	33.7	36.0	33.1	29.9	27.5	25.4		
4	23.1	24.6	26.5	28.6	30.9	34.0	36.5	33.6	30.3	27.8	25.8	23.9	
5	23.4	24.8	26.6	28.6	31.0	34.3	37.1	34.1	30.6	28.2	26.1	24.1	
6	23.2	24.9	26.8	28.7	31.1	34.6	37.7	34.6	31.0	28.5	26.3	24.3	22.7
7	23.0	24.7	26.8	28.9	31.3	34.9	38.3	35.1	31.4	28.7	26.6	24.5	22.9
8	23.1	24.7	26.8	29.0	31.6	35.3	38.9	35.5	31.7	29.0	26.8	24.7	23.1
9	23.2	24.9	26.9	29.1	32.0	35.8	39.6	36.0	32.1	29.2	27.0	25.0	23.4
10	23.6	25.2	27.1	29.4	32.3	36.4	40.4	36.6	32.5	29.5	27.3	25.4	23.8
11	24.0	25.6	27.5	29.6	32.7	36.9	41.3	37.2	33.0	29.9	27.8	25.9	24.3
12	24.5	26.1	27.9	30.1	33.2	37.6	42.3	37.9	33.6	30.4	28.3	26.5	24.9
13	25.3	27.0	28.9	31.0	34.3	38.8	43.6	39.2	34.8	31.6	29.5	27.6	25.8
14	26.3	28.2	30.3	32.5	35.9	40.5	45.2	40.8	36.5	33.2	31.0	29.0	27.1
15	27.2	29.2	31.5	33.9	37.4	42.2	47.0	42.8	38.3	34.8	32.4	30.2	28.1
16	27.4	29.7	32.1	34.6	38.5	43.9	49.4	45.5	40.5	36.1	33.2	30.8	28.5
17	26.8	29.3	32.0	34.9	39.3	45.6	53.7	51.5	43.1	37.1	33.4	30.7	28.5
18	25.3	27.7	29.9	33.2	38.4	45.4	56.9	52.8	42.1	35.5	32.0	29.4	26.8
19	23.3	25.3	27.9	31.1	35.6	43.7	58.1	50.9	40.2	33.8	29.9	27.4	25.1
20	22.6	24.5	26.8	29.4	33.9	41.8	59.9	50.0	38.6	32.5	29.0	26.6	24.3
21	22.5	24.4	26.7	29.3	33.6	40.7	59.1	49.1	38.1	32.3	28.8	26.4	24.2
22	22.6	24.5	26.9	29.5	33.9	41.1	58.5	49.9	39.0	32.5	28.9	26.5	24.2
23	23.3	25.4	28.0	31.2	35.9	43.4	59.7	53.0	41.7	35.2	30.8	27.6	25.0
24	25.2	27.8	30.3	33.5	38.5	45.7	61.4	53.0	44.2	37.6	32.9	30.2	27.4
25	26.9	29.4	32.4	35.3	39.6	46.1	53.8	52.1	44.5	38.5	34.7	31.9	28.9
26	27.9	30.2	32.8	35.4	39.0	44.1	49.3	49.2	43.7	38.4	35.0	32.4	29.8
27	27.8	29.9	32.4	34.8	37.9	42.6	47.6	47.6	42.6	37.7	34.6	32.1	29.6
28	27.0	29.0	31.4	33.7	36.6	41.2	46.1	46.2	41.2	36.5	33.5	31.1	28.7
29	26.4	28.3	30.4	32.7	35.5	40.0	44.7	44.7	40.1	35.5	32.5	30.2	27.9
30	26.2	27.9	29.9	32.1	34.9	39.2	43.6	43.7	39.3	34.9	32.0	29.7	27.5
31	26.1	27.8	29.7	31.9	34.6	38.7	42.8	42.9	38.8	34.6	31.8	29.5	27.4
32		27.6	29.5	31.7	34.3	38.2	42.1	42.1	38.3	34.3	31.6	29.4	27.3
33			29.2	31.4	34.0	37.6	41.4	41.4	37.7	34.1	31.5	29.3	27.2
34			29.0	31.3	33.8	37.2	40.7	40.8	37.3	33.9	31.3	29.1	27.1
35				31.1	33.6	36.8	40.0	40.1	36.8	33.6	31.2	29.0	27.0
36				31.0	33.3	36.3	39.3	39.4	36.4	33.4	31.0	28.8	26.8
37				30.8	33.1	35.9	38.7	38.8	35.9	33.1	30.8	28.7	26.7
38				30.6	32.8	35.4	38.1	38.2	35.5	32.9	30.7	28.5	26.5
39				30.3	32.5	34.9	37.4	37.5	35.0	32.5	30.4	28.2	26.3
40				30.2	32.3	34.6	36.9	37.0	34.6	32.3	30.2	28.1	26.1
41				29.2	31.3	33.6	35.9	36.0	33.8	31.8	29.8	27.8	25.9
42				29.2	31.1	33.1	35.2	35.2	33.0	31.0	29.0	26.9	25.1
43				29.2	31.1	33.0	34.8	34.7	32.6	30.7	28.7	26.8	24.9
44				29.3	31.1	32.8	34.4	34.3	32.3	30.4	28.5	26.6	24.8
45				29.3	30.9	32.3	33.3	33.1	31.7	30.0	28.1	26.3	24.5
46				29.3	30.8	32.0	32.8	32.7	31.3	29.7	27.9	26.1	24.4
47				29.3	30.5	31.6	32.4	32.3	31.0	29.4	27.6	25.9	24.2
48				29.1	30.1	31.1	32.0	31.9	30.6	29.1	27.4	25.7	24.1
49				28.6	29.7	30.7	31.6	31.5	30.4	28.9	27.3	25.7	24.1
50				28.1	29.1	30.3	31.2	31.2	30.1	28.8	27.2	25.6	24.2

Note: Underlined noise values (e.g. 31.7) include an adjustment for aircraft taxiing on Taxiway A.

For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

TABLE 6-10
2000 ANNUAL AVERAGE LDN

(Ldn for each 1/16 section within study area)

Grid Rows	Grid Columns: I	J	K	L	M	N	O	P	Q	R	S	T	U
1			57.7	60.1	62.6	65.6	68.1	65.1	60.9	57.9			
2			57.5	60.0	62.6	65.9	68.6	65.5	61.3	58.3	55.9		
3	53.8	55.4	57.4	59.8	62.6	66.1	69.1	65.8	61.7	58.7	56.3		
4	54.5	55.6	57.4	59.8	62.6	66.3	69.7	66.2	62.1	59.1	56.7	54.8	
5	55.6	56.3	57.6	59.8	62.7	66.5	70.2	66.6	62.5	59.4	57.0	54.9	
6	54.8	56.7	58.3	60.0	62.8	66.8	70.7	67.0	62.8	59.7	57.1	54.9	53.6
7	54.1	55.9	58.3	60.5	63.0	67.0	71.3	67.4	63.1	59.9	57.3	55.0	53.7
8	54.3	55.5	57.8	60.6	63.4	67.3	71.9	67.7	63.3	60.1	57.4	55.5	53.9
9	54.3	55.8	57.6	60.5	63.7	67.7	72.6	68.1	63.6	60.3	57.5	55.8	54.2
10	54.6	56.1	57.7	60.5	63.8	68.1	73.4	68.4	63.9	60.5	58.1	56.2	54.7
11	55.1	56.6	58.1	60.7	64.1	68.6	74.2	68.9	64.4	61.0	58.7	56.8	55.3
12	55.7	57.1	59.0	61.0	64.4	68.9	75.2	69.5	64.9	61.4	59.2	57.4	55.9
13	56.5	58.1	60.0	62.1	65.6	70.2	76.6	70.8	66.1	62.6	60.5	58.5	56.9
14	56.9	58.6	60.6	62.7	66.3	71.3	78.0	72.0	67.1	63.6	61.5	59.5	57.7
15	57.2	59.2	61.4	63.6	67.3	72.7	79.8	73.6	68.5	65.2	62.5	60.4	58.3
16	57.3	59.4	61.8	64.7	68.3	74.2	81.9	76.0	70.5	66.6	63.4	60.9	58.7
17	57.0	59.1	61.6	64.8	68.9	75.6	85.9	82.5	72.8	67.4	63.8	61.0	58.7
18	55.9	57.9	60.4	63.4	68.0	75.1	89.0	84.5	72.4	66.5	62.7	60.0	57.8
19	55.1	56.9	59.2	62.0	66.5	73.4	90.0	83.0	71.0	65.4	61.8	59.3	57.1
20	55.0	56.7	58.9	61.6	65.7	73.0	91.7	82.2	70.3	65.0	61.6	59.1	57.0
21	55.1	56.8	58.9	61.6	65.8	72.9	92.2	81.5	70.4	65.0	61.6	59.1	57.1
22	55.2	56.9	59.1	61.8	65.9	72.8	90.1	82.2	70.8	65.3	61.8	59.2	57.1
23	55.3	57.1	59.5	62.5	67.0	73.7	91.3	85.4	72.7	66.6	62.4	59.5	57.2
24	55.9	58.0	60.6	63.9	68.3	75.5	93.0	85.2	74.2	67.7	63.7	60.5	57.8
25	57.1	59.4	62.1	65.3	69.3	75.9	84.8	84.4	74.1	68.8	64.9	61.8	59.0
26	58.0	60.1	62.5	65.0	68.8	73.9	79.9	80.0	73.5	68.4	65.1	62.3	59.8
27	58.2	60.0	61.9	64.6	68.1	72.6	78.2	78.3	72.6	67.9	64.4	62.0	59.7
28	57.9	59.5	61.3	64.0	67.2	71.4	76.6	76.7	71.4	67.1	63.8	61.5	59.2
29	57.8	59.2	60.8	63.4	66.5	70.5	75.3	75.4	70.5	66.4	63.1	60.4	58.7
30	57.5	58.8	60.6	63.0	66.1	69.9	74.3	74.5	59.9	66.0	62.8	60.2	58.5
31	57.6	58.9	60.7	63.0	65.9	69.5	73.6	73.8	69.5	65.8	62.7	60.1	58.0
32		58.6	60.4	62.5	65.4	68.8	72.8	73.0	68.9	65.4	62.4	60.0	58.0
33			59.8	62.1	64.9	68.3	72.1	72.3	68.4	65.0	62.2	59.9	58.0
34			59.4	61.8	64.6	67.8	71.6	71.7	67.9	64.7	61.9	59.6	57.7
35				61.5	64.3	67.4	71.0	71.1	67.5	64.4	61.6	59.4	57.5
36				61.3	64.0	67.0	70.5	70.6	67.1	64.1	61.4	59.1	57.2
37				61.0	63.7	66.6	69.9	70.0	66.7	63.8	61.1	58.8	56.8
38				60.8	63.4	66.2	69.4	69.5	66.3	63.4	60.8	58.5	56.6
39				60.4	63.0	65.7	68.8	68.9	65.8	63.0	60.5	58.2	56.2
40				60.2	62.7	65.4	68.4	68.5	65.5	62.8	60.2	58.0	56.0
41				59.7	62.1	64.8	67.7	67.9	64.9	62.3	59.9	57.7	55.8
42				59.7	62.0	64.5	67.3	67.4	64.4	61.9	59.5	57.4	55.4
43				59.8	62.0	64.3	67.0	67.0	64.1	61.6	59.3	57.2	55.3
44				59.9	61.9	64.1	66.6	66.6	63.7	61.3	59.0	57.0	55.1
45				59.8	61.6	63.5	65.1	65.0	62.9	60.6	58.5	56.6	54.8
46				59.9	61.5	63.2	64.8	64.6	62.6	60.3	58.3	56.3	54.6
47				59.9	61.2	62.8	64.4	64.2	62.2	60.0	58.0	56.1	54.4
48				59.6	60.8	62.3	64.0	63.9	61.9	59.7	57.8	56.0	54.3
49				59.1	60.3	61.9	63.6	63.6	61.6	59.6	57.7	56.0	54.4
50				58.5	59.8	61.6	63.2	63.2	61.4	59.4	57.7	56.0	54.4

Note: Underlined noise values (e.g. 66.4) include an adjustment for aircraft taxiing on Taxiway A.

For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

TABLE 6-11
2000 ANNUAL AVERAGE ANE

(Ldn - 35 = approximate ANE for each 1/16 section within study area)

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
1			22.7	25.1	27.6	30.6	33.1	30.1	25.9	22.9			
2			22.5	25.0	27.6	30.9	33.6	30.5	26.3	23.3	20.9		
3	18.8	20.4	22.4	24.8	27.6	31.1	34.1	30.8	26.7	23.7	21.3		
4	19.5	20.6	22.4	24.8	27.6	31.3	34.7	31.2	27.1	24.1	21.7	19.8	
5	20.6	21.3	22.6	24.8	27.7	31.5	35.2	31.6	27.5	24.4	22.0	19.9	
6	19.8	21.7	23.3	25.0	27.8	31.8	35.7	32.0	27.8	24.7	22.1	19.9	18.6
7	19.1	20.9	23.3	25.5	28.0	32.0	36.3	32.4	28.1	24.9	22.3	20.0	18.7
8	19.3	20.5	22.8	25.6	28.4	32.3	36.9	32.7	28.3	25.1	22.4	20.5	18.9
9	19.3	20.8	22.6	25.5	28.7	32.7	37.6	33.1	28.6	25.3	22.5	20.8	19.2
10	19.6	21.1	22.7	25.5	28.8	33.1	38.4	33.4	28.9	25.5	23.1	21.2	19.7
11	20.1	21.6	23.1	25.7	29.1	33.6	39.2	33.9	29.4	26.0	23.7	21.8	20.3
12	20.7	22.1	24.0	26.0	29.4	33.9	40.2	34.5	29.9	26.4	24.2	22.4	20.9
13	21.5	23.1	25.0	27.1	30.6	35.2	41.6	35.8	31.1	27.6	25.5	23.5	21.9
14	21.9	23.6	25.6	27.7	31.3	36.3	43.0	37.0	32.1	28.6	26.5	24.5	22.7
15	22.2	24.2	26.4	28.6	32.3	37.7	44.8	38.6	33.5	30.2	27.5	25.4	23.3
16	22.3	24.4	26.8	29.7	33.3	39.2	46.9	41.0	35.5	31.6	28.4	25.9	23.7
17	22.0	24.1	26.6	29.8	33.9	40.6	50.9	47.5	37.8	32.4	28.8	26.0	23.7
18	20.9	22.9	25.4	28.4	33.0	40.1	54.0	49.5	37.4	31.5	27.7	25.0	22.8
19	20.1	21.9	24.2	27.0	31.5	38.4	55.0	48.0	36.0	30.4	26.8	24.3	22.1
20	20.0	21.7	23.9	26.6	30.7	38.0	56.7	47.2	35.3	30.0	26.6	24.1	22.0
21	20.1	21.8	23.9	26.6	30.8	37.9	57.2	46.5	35.4	30.0	26.6	24.1	22.1
22	20.2	21.9	24.1	26.8	30.9	37.8	55.1	47.2	35.8	30.3	26.8	24.2	22.1
23	20.3	22.1	24.5	27.5	32.0	38.7	56.3	50.4	37.7	31.6	27.4	24.5	22.2
24	20.9	23.0	25.6	28.9	33.3	40.5	58.0	50.2	39.2	32.7	28.7	25.5	22.8
25	22.1	24.4	27.1	30.3	34.3	40.9	49.8	49.4	39.1	33.8	29.9	26.8	24.0
26	23.0	25.1	27.5	30.0	33.8	38.9	44.9	45.0	38.5	33.4	30.1	27.3	24.8
27	23.2	25.0	26.9	29.6	33.1	37.6	43.2	43.3	37.6	32.9	29.4	27.0	24.7
28	22.9	24.5	26.3	29.0	32.2	36.4	41.6	41.7	36.4	32.1	28.8	26.5	24.2
29	22.8	24.2	25.8	28.4	31.5	35.5	40.3	40.4	35.5	31.4	28.1	25.4	23.7
30	22.5	23.8	25.6	28.0	31.1	34.9	39.3	39.5	34.9	31.0	27.8	25.2	23.5
31	22.6	23.9	25.7	28.0	30.9	34.5	38.6	38.8	34.5	30.8	27.7	25.1	23.0
32		23.6	25.4	27.5	30.4	33.8	37.8	38.0	33.9	30.4	27.4	25.0	23.0
33			24.8	27.1	29.9	33.3	37.1	37.3	33.4	30.0	27.2	24.9	23.0
34			24.4	26.8	29.6	32.8	36.6	36.7	32.9	29.7	26.9	24.6	22.7
35				26.5	29.3	32.4	36.0	36.1	32.5	29.4	26.6	24.4	22.5
36				26.3	29.0	32.0	35.5	35.6	32.1	29.1	26.4	24.1	22.2
37				26.0	28.7	31.6	34.9	35.0	31.7	28.8	26.1	23.8	21.8
38				25.8	28.4	31.2	34.4	34.5	31.3	28.4	25.8	23.5	21.6
39				25.4	28.0	30.7	33.8	33.9	30.8	28.0	25.5	23.2	21.2
40				25.2	27.7	30.4	33.4	33.5	30.5	27.8	25.2	23.0	21.0
41				24.7	27.1	29.8	32.7	32.9	29.9	27.3	24.9	22.7	20.8
42				24.7	27.0	29.5	32.3	32.4	29.4	26.9	24.5	22.4	20.4
43				24.8	27.0	29.3	32.0	32.0	29.1	26.6	24.3	22.2	20.3
44				24.9	26.9	29.1	31.6	31.6	28.7	26.3	24.0	22.0	20.1
45				24.8	26.6	28.5	30.1	30.0	27.9	25.6	23.5	21.6	19.8
46				24.9	26.5	28.2	29.8	29.6	27.6	25.3	23.3	21.3	19.6
47				24.9	26.2	27.8	29.4	29.2	27.2	25.0	23.0	21.1	19.4
48				24.6	25.8	27.3	29.0	28.9	26.9	24.7	22.8	21.0	19.3
49				24.1	25.3	26.9	28.6	28.6	26.6	24.6	22.7	21.0	19.4
50				23.5	24.8	26.6	28.2	28.2	26.4	24.4	22.7	21.0	19.4

Note: Underlined noise values (e.g. 31.7) include an adjustment for aircraft taxiing on Taxiway A.

For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measur 1,320' by 1,320'.

Airport Boundary Outlined

Source: The Port of Seattle

TABLE 6-12

COMPARISON OF AREA WITHIN PROJECTED NOISE CONTOURS

(in square miles)

	1980	1985	1990	2000
75 Ldn	5.97	5.36	4.58	2.30
70 Ldn	13.07	11.81	10.20	5.45
65 Ldn	30.83	27.52	22.99	12.43

(by percentage change from previous forecast year)

	1980	1985	1990	2000
75 Ldn	-	-10.2%	-14.6%	-49.8%
70 Ldn	-	-9.6%	-13.6%	-46.6%
65 Ldn	-	-10.7%	-16.5%	-45.9%

Source: The Port of Seattle

Table 6-13 presents a comparison of projected noise levels at the Noise Monitoring System (NMS) Remote Monitoring Stations in order to illustrate the trend toward lower noise levels at specific locations. All stations are projected to experience decreases in noise levels through the forecast period, with the most significant decreases between 1990 and the year 2000.

The major factor responsible for this trend is the gradual shift in aircraft type from low bypass ratio-engined aircraft (e.g., DC8 and Boeing 707) to high bypass ratio-engined aircraft (e.g., Boeing 747, L1011, and DC10). The higher the engine bypass ratio, the lower the noise level generated by the engine. Airlines are purchasing aircraft which meet FAR Part 36 noise standards and also achieve higher fuel efficiency. New technology aircraft (e.g., B757, B767, DC9-80) will meet the strict Stage III FAR Part 36 requirements and will also achieve more seat-miles per gallon of fuel than their currently operating counterparts. The benefit of this change in fleet mix is reflected in the reductions of noise through the forecast period.

TABLE 6-13

PROJECTED NOISE LEVELS (in Ldn) AT
REMOTE MONITORING STATIONS (RMS)

RMS	INM Predicted 1980	1985	1990	2000
1	73.0	72.2	71.3	67.6
2	72.1	71.6	70.6	66.4
3	75.9	75.1	74.0	69.7
4	84.7	83.3	82.4	79.7
6	82.1	81.5	80.8	77.8
7	71.3	70.8	70.0	66.6
8	69.6	69.2	68.5	65.6
9	71.1	70.9	70.0	66.9

(change in dBA from previous forecast year)

RMS	1980	1985	1990	2000
1	-	-0.8	-0.9	-3.7
2	-	-0.5	-1.0	-4.2
3	-	-0.8	-1.1	-4.3
4	-	-1.4	-0.9	-2.7
6	-	-0.6	-0.7	-3.0
7	-	-0.5	-0.8	-3.4
8	-	-0.4	-0.7	-2.9
9	-	-0.2	-0.9	-3.1

Source: The Port of Seattle

Footnotes

[1]/1980 Sea-Tac Annual Summary of Local Climatological Data - NOAA.

[2]/Aircraft "categories" are identified by the following: number of engines and width of the fuselage (e.g., wide vs. narrow body) for air carrier aircraft; method of propulsion (e.g., piston, turboprop, turbojet, or turbofan); number of piston engines, if applicable; seating capacity, if applicable; and general weight (e.g., light, medium, or heavy) for general aviation aircraft. Aircraft "types" refer to manufacturer's models (e.g., Boeing 727-100, L1011, etc.).

[3]/In order to test the significance of the distribution of specific aircraft types within categories, a test case was run for 1985 in which Ldn values were calculated for a fleet mix of only the loudest aircraft type within the category. Ldn values were higher in this test case than the values calculated by using the applied fleet mix by 0.1 to 0.6 dBA. With the exception of two grid cells, the largest increases (0.5 and 0.6 dBA) were within the Airport boundaries. Outside the Airport boundaries, the size of the increase dropped off quickly with increasing distance from the Airport in all directions. Based on these findings, the forecast of aircraft types presented in Table 6-3 was used in the forecast of noise levels at Sea-Tac.

APPENDICES

Appendix A

Application of Airport Noise Monitoring Data

A. APPLICATION OF AIRPORT NOISE MONITORING DATA

Although noise monitoring itself does not decrease the impact of noise on people, its use provides data helpful in dealing with the environmental impacts of noise exposure. Monitoring systems enable airport operators to assess noise exposure levels around airports and evaluate achievement of noise reduction goals. They serve as a planning and research tool for issues such as the differentiation between aircraft and non-aircraft noise sources, the calibration of predictive noise exposure models, and the assessment of alternative aircraft and airfield operating procedures. Systems can also be set up to monitor compliance with noise abatement procedures and detect deviations from noise standards. Further, noise monitoring systems can provide the airport operator with the capability to investigate specific public inquiries and evaluate noise complaints. This appendix will describe the format and application of the output from the Sea-Tac Airport Noise Monitoring System (NMS), the format and application of the output from other representative airport noise monitoring systems, and the constraints and opportunities of the application of the output from the Sea-Tac Airport NMS in uses identified at other airports.

A.1 SEA-TAC INTERNATIONAL AIRPORT NOISE MONITORING SYSTEM

Noise measuring equipment which is used at Sea-Tac to monitor aircraft generated noise includes a permanent Airport Noise Monitoring System (NMS), designed and installed by EG&G, and a portable integrating noise meter (DA607P).

Installation and operation of a permanent noise monitoring system was recommended in the Sea-Tac/Communities Plan. The Plan identified the need to continuously monitor "compliance with operational procedures and general trends in community (noise) exposure levels" by measuring aircraft generated noise. The Airport Noise Monitoring System (NMS) was installed at Sea-Tac in July 1979 and began official operation in September 1979.

The system is designed to measure and calculate hourly noise levels, single event levels and daily noise statistics at nine Remote Monitoring Stations (RMS). Noise picked up by each RMS is transmitted over telephone lines to a computer operated Central Processing System (CPS). The CPS accumulates the date and performs the necessary calculations for the various measures used to describe noise. Hourly and daily reports are automatically prepared by the computer.

The DA607P, developed by Digital Acoustics, Inc., is a portable noise monitor. The instrument is designed to measure and calculate hourly and daily noise levels, and single event levels. Reports are printed by the monitor in both alphanumeric and graphic forms.

The data collected by the permanent airport noise monitoring system has been used primarily as a planning and research tool and as a means to regularly assess the general trends in noise exposure levels around the airport. Examples of its use include the following:

* A monthly report presenting average monthly Ldn values for the 9 Remote Monitoring Stations which is distributed to persons and agencies upon request.

* Calibration of the Federal Aviation Administration's Integrated Noise Model (INM) for the Sea-Tac Noise Exposure Update Study. Measured noise exposure levels were used to adjust INM standard noise vs. distance tables for individual aircraft types. Measured cumulative noise levels were used to verify approach and departure procedures and flight track definitions.

* A program conducted by the Federal Aviation Administration (FAA) to continue the validation process for the FAA's INM which involved simultaneous acquisition of radar tracking data and acoustical data.

* Confirmation of the occurrence of "loud" aircraft operations in response to public inquiries. However, information regarding aircraft identification by airline or aircraft type is available only through the FAA.

A.2 NOISE MONITORING SYSTEMS AT OTHER AIRPORTS

Many airports throughout the country operate permanent noise monitoring systems which provide continuous measurements with fixed monitoring stations. They are most common, however, at California airports due to legal requirements of noise monitoring at airports with a "noise problem".[1/] The following list identifies the airports with permanent noise monitoring systems.

Boston Logan International Airport, Massachusetts
Burbank Airport, California
Dulles International Airport, Virginia
Honolulu International Airport, Hawaii
JKF International Airport, New York
LaGuardia Airport, New York
Los Angeles International Airport, California
Newark International Airport, New Jersey
Ontario International Airport, California
Orange County Airport, California
San Diego International Airport, California
San Francisco International Airport, California
San Jose Municipal Airport, California
Santa Monica Municipal Airport, California
Sea-Tac International Airport, Washington
Torrance Airport, California
Washington National Airport, Virginia

The type and quantity of noise monitoring equipment, and the content of noise monitoring reports for some of these airports are presented in Table A-1. Noise monitoring data is used by these different operators in a variety of ways for reasons which are affected by factors such as the goals and objectives of the airport operator, legal requirements, and enforcement of noise standards. Examples of the uses of noise monitoring system data at the airports identified in Table A-1 include the following:

Boston Logan International Airport

* Inform public of noise environment

* Verification of Integrated Noise Model output

* Assessment of alternative departure headings from Runway 22R

Honolulu International Airport

* Input for predictive noise model

Los Angeles International Airport/Ontario International Airport

* Quarterly reports required under State of California Administrative Code, Title 21

La Guardia Airport/J.F. Kennedy International Airport/Newark International Airport

* Inform public of noise environment

* Background information for lobbying effort for aircraft engine retrofit program

* Monitor compliance with "permission to operate requirement"

* Basis for admonition letters to violators of "permission to operate requirement"

San Jose International Airport

* Quarterly reports required under State of California Adminstrative Code, Title 21

* Input for predictive noise model

* Monitor new aircraft introduced into San Jose fleet mix for future planning efforts

Orange County Airport (John Wayne Airport)

* Quarterly reports required under State of California Administrative Code, Title 21

* Input for predictive noise model

* Monitor compliance with standard instrument departure procedure and noise limits at noise monitoring stations

* Basis for admonition letters to violators of noise limits

* Future possibility of monitoring "noise budget" program proposed in the Airport's Airport Noise Control and Land Use Compatibility (ANCLUC) Program (October 1980)

Dulles International Airport/Washington National Airport

* Inform public of noise environment

* Validation process for the FAA's INM which involved simultaneous acquisition of radar tracking data and acoustical data

* Response to public inquiries concerning individual aircraft events

A.3 CONSTRAINTS AND OPPORTUNITIES OF THE USE OF SEA-TAC NOISE MONITORING SYSTEM DATA

As indicated by the list of uses of noise monitoring system data at other airports in the previous section, the Port of Seattle has used its NMS data for many of the same reasons as other airport operators. Planning and Research and Public Information have been the principal uses at Sea-Tac.

The application of the NMS data at Sea-Tac has not gone beyond those uses identified in section A.1 due primarily to the limitations of staff resources, the constraints of the Airport Noise Monitoring System itself, and the current operating conditions at Sea-Tac. Staff is currently available to assure that the automatic reporting functions of the system operate properly, to prepare monthly reports, and to participate in noise planning projects on a project specific basis. Beyond these functions, however, staff resources have not been budgeted. The Airport NMS does not have the capability to identify individual aircraft events by operator or aircraft type and therefore does not have the ability to assess the contribution of aircraft operators or aircraft types to the total noise environment. This capability is available through the acquisition and processing of FAA radar tracking disc recordings from the Sea-Tac advanced radar terminal system (ARTS) or through the manual matching of noise events with aircraft identification. A need for the investment of the high costs of both of these alternatives to implement an individual aircraft identification program has not as yet been determined. Under current operating conditions at Sea-Tac, there are no noise abatement procedures or noise standards to which aircraft operators are required to comply or legal requirements for reporting (e.g. State of California Administrative Code, Title 21) that the airport operator is mandated to satisfy. Therefore, use of NMS data for enforcement purposes has not been needed.

An opportunity to reassess the present scope of Sea-Tac's noise monitoring capabilities and usages will present itself as a result of the planning and preparation of the study which will update the noise remedy programs recommended in the Sea-Tac/Communities Plan. Recommendations of that study could cover not only the physical expansion of the noise monitoring system itself, (e.g. addition of new remote monitoring stations) but changes in the management and staffing capabilities of the system (e.g. centralized noise monitoring and abatement function as at Boston Logan) and increases in the uses of the NMS data for monitoring noise abatement procedures which may be proposed and adopted in the future.

TABLE A-1

AIRPORT NOISE MONITORING SYSTEMS

Airport	Type and Quantity Mobile Monitoring Equipment	Type and Quantity Data Analysis Equipment	Type and Specification of Permanent Monitoring System	Items Reported in Quarterly and Yearly Monitoring Reports	Individual to Contact for Information
Boston Logan International Airport	Bolt, Baranek and Newman - Portable noise computer (2), Sound Level Meter		Bolt, Baranek and Newman PDP8 -- two monitor modes: (a) data for every noise event recorded and printed; (b) information printed for noise levels above a specified threshold. Airport is developing a NMIS (Noise Management Information System) which will add flight ID and runway use information from ARTS II air traffic control system, and weather data. 18 sites	Single-event fly-overs max dBA, duration, SENEL, hourly noise levels (Leq), 24-hr levels (Ldn), manually derived monthly and annual average Ldn.	Charles C. Snyder, Jr. 617-482-2930
Honolulu International Airport	Hydrospace Portable Monitor (1)		EG&G Hydrospace 15 sites	Ldn, LDNA, LDNC, LEQ, MNT, 75 SENEL Exceedance Daily, HNL, HNLA, HNLC, SENEL RMS Status	Dean S. Nakagawa 808-836-6526

Airport	Type and Quantity Mobile Monitoring Equipment	Type and Quantity Data Analysis Equipment	Type and Specification of Permanent Monitoring System	Items Reported in Quarterly and Yearly Monitoring Reports	Individual to Contact for Information
Los Angeles International Airport and Ontario International Airport	Bolt, Baranek and Newman Model 614.(4), EG&G portable noise monitor mounted in mobile van with 6800 microprocessor	Varian Model 71 mini-computer, Diablo single-head disk, EG&G patch panel Tektronix Model #4631 hard-copy unit and Model #4010-1 CRT terminal, Pertec 9-channel mag tape unit, Tex Instr Model #700 electronic data terminal (2), Magnasync/Moviola tape unit	EG&G Hydrospace	Quarterly: CNEL for each RMS and cumulative usage for past 4 quarters. Monthly: CNEL averages for each month of quarter. Annual: Graphic plot of monthly CNEL averages for each RMS for past 12 months. Map of 75 CNEL contours for past 4 quarters with RMS identified. Daily: Reports for every day of quarter.	Walter V. Collins 213-646-9410
Port Authority of New York & New Jersey La Guardia, Kennedy and Newark Airports) (Equipment for each airport)	Bolt, Baranek and Newman Mod. 613 B&K 2203 Sound Level Meter, B&K 2225 Integrating Sound Level Meter Kudelski Nagra III recorder	B&K Type 1613 octave filter set, B&K Type 1616 1/3 octave filter set, Type 2307 level recorder	BB&N Model 702 Kennedy - 6 sites, LGA - 2 sites, Newark - 3 sites. Preset threshold; 105 PndB.	Airport summary of jet activity by airline, aircraft runway use and mileage. Airline summary which identifies those airlines that have exceeded a preset violation rate.	J. P. Muldoon 212-466-7474
San Jose International Airport	B&K 2218 Sound Level Meter (1)	None	Tracor Calculate 5 dBA max HNLC, HNLA, CNELC, CNELa, and daily summary of each. SENEL violations. 15 sites	Quarterly: HNL for each month	Marvin Ellis 408-277-4705

Airport	Type and Quantity Mobile Monitoring Equipment	Type and Quantity Data Analysis Equipment	Type and Specification of Permanent Monitoring System	Items Reported in Quarterly and Yearly Monitoring Reports	Individual to Contact for Information
Orange County Airport (John Wayne Airport) Santa Ana, CA	BB&N Model 614	BB&N Mod. 614	Tracor 9 sites	Daily Reports: CNELa, CNELc, CNELt, LDNc, LDNa, LDNt, LEQc, LEQa, LEQt, L1, L5, L10, L50, L90, L99, SENEL. Also in quarterly and monthly reports. Aircraft activity summary.	W. J. Martin 714-834-6634
Seattle-Tacoma International Airport	Quest. #215 Type II meter, DA 607P (1)	Dedicated micro-processor generating 24-hour data summaries. Texas Instr TI-59 programmable calculator.	EG&G 9 sites	Monthly reports only. Ldn	Joe Sims 206-382-3331
Dulles International Airport and Washington National Airport (Wash., DC)	B&K Mod. 2204 Sound Level Meter (2), GenRad 1988 Sound Level Meter (2), GenRad 1981B Sound Level Meter (1), GenRad 1933 Sound Level Meter (1), GenRad 1954 Dosimeter (2)	GenRad 1945 Community Noise Analyser (6), IVIE 1E30 Spectrum Analyser (1), Kudelski Nagra IV tape recorders (3), Uher 4200 tape recorders (13), Metrasonics Graphic level recorders (10), Metrasonics DB 602 Sound Level Analyser (1)	EG&G 23 sites	Average single-event data for air carrier aircraft type. Max averages, duration average, slant range average, average height above monitor L1, L10, L50, L90, L99, Leq, Ldn, LeqA, LeqC. Density plots showing percent of flyovers.	Steven Newman 202-426-3396 Sal Cicchelli 703-471-4225 Neal Phillips 703-471-4225

Footnotes

1/State of California Administrative Code, Title 21, Chapter 2.5, Subchapter 6, "California Airport Noise Standards", 1970.

Appendix B

Fleet Mix Forecast

FLEET MIX FORECAST
(annual operations)

Years	1980	1985	1990	2000
1. Sector: Hawaii				
4 EW	1,547	1,487	1,624	2,045
3 EW	212	579	634	798
Subtotal	1,759	2,066	2,258	2,843
2.-A. Sector: Canada & Alaska/500 MI				
3EN	1,338	613	420	0
2EN	4,819	3,185	3,683	4,867
2EW	0	61	67	234
Medium Prop	-0-	115	234	358
Subtotal	6,157	3,974	4,404	5,459
2.-B. Sector: Canada & Alaska/1,000 MI				
2EW	0	88	97	313
3EN	1,049	738	506	0
2EN	3,139	3,224	3,806	5,076
Subtotal	4,188	4,050	4,409	5,389
2.-C. Sector: Canada & Alaska/1,500 MI				
4EN	11	6	0	0
4EW	10	12	13	17
3EW	2,555	2,631	2,883	3,629
3EN	7,410	6,539	4,480	0
2EN	1,258	2,733	5,414	9,353
2EW	0	1,362	1,499	3,578
Freight - 4EW	784	804	824	845
Subtotal	12,028	14,087	15,113	17,422

Years	1980	1985	1990	2000
3-A. Sector: West-S.B. Coast/500 MI				
4EN	3	18	0	0
4EW	11	1	1	1
3EW	3,019	2,283	2,515	3,211
3EN	17,292	9,501	6,542	0
2EW	403	1,304	1,452	4,211
2EN	2,889	3,425	6,717	12,109
Small Prop	9,170	4,763	4,332	4,124
Medium Prop	-0-	2,130	4,125	5,933
Freight - 2EW	-0-	257	527	540
Freight - 4EN	502	257	0	0
Subtotal	33,289	23,939	26,211	30,129
3-B. Sector: Puget Sound/ North & West Bound				
Small Prop	24,224	10,833	10,747	12,178
Medium Prop	-0-	774	1,185	1,897
Subtotal	24,224	11,607	11,932	14,075
3.-C. Sector: West Coast/ Southbound 1,000 MI				
4EW	188	192	211	263
3EW	2,571	2,203	2,414	3,039
2EW	0	2,721	3,001	8,574
3EN	25,241	18,536	12,696	0
2EN	4,152	7,605	15,188	26,313
4EN	44	23	0	0
Freight - 4EW	15	15	16	16
Freight - 4EN	3	2	0	0
Freight - 2EW	0	1	3	3
Subtotal	32,214	31,298	33,529	38,208
3.-D. Sector: West Coast/ Southbound 1,500 MI				
3EN	1,110	490	336	0
2EW	0	59	64	195
2EN	0	88	338	560
Subtotal	1,110	637	738	755

Years	1980	1985	1990	2000
4-A. Sector: Southeast/500 MI				
2EW	0	21	23	83
3EN	748	219	151	0
2EN	4,466	1,862	2,116	2,752
Small Prop	1,817	502	454	471
Medium Prop	-0-	77	135	202
Freight - J.P.	516	529	542	556
Subtotal	7,547	3,210	3,421	4,064
4-B. Sector: Southeast/1,000 MI				
4EW	2	1	1	1
3EW	1,488	1,386	1,519	1,912
4EN	1,262	1,411	0	0
3EN	7,417	5,925	4,058	0
2EW	0	1,014	2,317	4,449
2EN	203	1,293	3,606	6,838
Subtotal	10,372	11,030	11,501	13,200
4-C. Sector: Southeast/1,500 MI				
3EW	2	1	1	1
3EN	5,533	4,293	2,941	0
2EW	0	515	565	1,821
2EN	0	773	2,435	4,732
Subtotal	5,535	5,582	5,942	6,554
4-D. Sector: Southeast/over 1,500 MI				
3EN	1,486	1,462	1,001	0
3EW	1,688	1,938	2,123	2,673
2EW	414	1,167	1,279	1,988
2EN	0	263	829	1,611
Subtotal	3,588	4,830	5,232	6,272

Years	1980	1985	1990	2000
5-A. Sector: East/500 MI				
2EW	0	1,329	1,475	3,483
3EN	3,206	4,651	3,223	0
3EW	2,302	3,896	4,320	6,209
4EW	9	10	11	15
2EN	0	699	2,224	2,371
Small Prop	10,884	14,926	13,569	15,978
Medium Prop	-0-	1,939	3,324	5,687
Subtotal	16,401	27,450	28,146	33,743
5-B. Sector: East/1,000 MI				
3EN	293	219	150	0
2EW	0	19	20	26
2EN	0	39	124	240
3EW	2	27	30	90
Subtotal	295	304	324	356
5-C. Sector: East/1,500 MI				
4EW	31	41	45	56
3EW	5,731	6,332	6,940	8,737
3EN	3,890	2,210	1,514	0
2EW	0	2,972	4,033	5,648
2EN	0	1,327	2,272	3,716
4EN	1,375	910	0	0
Freight - 4EW	504	517	530	543
Freight - 4EN	538	276	0	0
Freight - 2EW	0	275	564	578
Subtotal	12,069	14,860	15,898	19,278
5-D. Sector: East/Over 1,500 MI				
4EW	549	785	861	1,084
3EW	1,658	1,987	2,177	2,740
3EN	187	191	132	0
2EW	0	585	788	1,042
2EN	0	35	109	211
4EN	232	172	0	0
Freight - 4EW	70	72	74	76
Freight - 4EN	2	1	0	0
Freight - 2EW	0	1	2	2
Subtotal	2,698	3,829	4,143	5,155

Years			1980	1985	1990	2000
6.	Sector: Far East					
		4EW	3,460	3,352	3,673	4,624
	Subtotal		3,460	3,352	3,673	4,624
7.	Sector: Europe					
		4EW	2,393	2,206	2,418	3,045
		3EW	0	615	673	847
	Subtotal		2,393	2,821	3,091	3,892
Total Annual Operations			179,327	168,926	179,965	211,418

Appendix C

Calibration of the Integrated Noise Model

C. CALIBRATION OF THE INTEGRATED NOISE MODEL

During this study, adjustments were made to the basic FAA Integrated Noise Model (INM) with the purpose of minimizing differences between noise levels predicted by the INM and those actually measured in the field for aircraft operations at Sea-Tac International Airport (Sea-Tac). Because the goal of the study has been to update the noise levels projected in the original Sea-Tac/Communities Plan, these INM refinements have been aimed at providing the best fit between measured and predicted values of Day-Night Levels (Ldn). Ldn was selected as the most appropriate noise metric for comparison with Actual Noise Exposure (ANE) values used in the Sea-Tac/Communities Plan and for future use in noise remedy program planning.

C.1 DATA BASE

The INM comparison and INM modification process was carried out in several stages and with several data sets. Two test days were selected; November 18, 1980, representing south flow aircraft operations and December 18, 1980, representing north flow. Operations on these two days were entered in the INM and the resulting model-generated Ldn values were compared to those actually measured by the Sea-Tac Noise Monitoring System (NMS). To examine longer-term averages and to accommodate seasonal differences, the NMS-measured Ldn values over all of 1980 were averaged and compared with INM output calculated from the average operations over that year. In order to compare the single-event noise exposure levels of specific aircraft types, a detailed survey of operations was conducted from February 16 to February 21, 1981, during which noise levels of individual flights were measured with the NMS. Equivalent levels were then calculated with the INM by using single north and south flow landings and takeoffs for each aircraft type and the detailed output options of the model. Additional field measurements of aircraft noise were made by Port of Seattle staff and The Parry Company.[1/] These measurements were used to supplement the NMS data by recording noise levels from taxi operations and by collecting additional sideline noise levels near the airport.

C.2 COMPARISON SEQUENCE

The initial comparisons between the INM and the NMS-measured data were for the unmodified INM and for the north flow and south flow test days. These provided an initial estimate of the range of differences between the modeled and the measured data. Because an objective was to include the aircraft operating procedures that are specific to Sea-Tac, the first suite of modifications to the INM consisted of changes to approach and takeoff profiles, to flap and thrust settings, and to the initial flight track definitions. All changes were made solely on the basis of information corroborated by the airlines and the Federal Aviation Administration (FAA). These changes were not made on the basis of the initial INM-RMS differences but on the basis of actual Sea-Tac procedures.

The INM was run after incorporating the revised operating procedures. Model predictions were compared to measured Ldn values for the north and south flow test days. A pattern of differences was found to be that the INM consistently underpredicted the measured Ldn values. Therefore, the modification process proceeded to the next level of detail within the model: a comparison between the measured and computed noise levels of single flights by each aircraft type. No further changes to operating procedures were made because such changes would not represent actual conditions.

In order to calibrate the INM by a comparison between measured and INM predicted noise levels of single aircraft events, changes to the INM's noise-distance-thrust tables were made. These changes were based on data collected during the February, 1981 detailed operation and noise measurement survey. The procedures for carrying out the noise table modifications were developed with The Parry Company. For each aircraft operation, the measured single-event noise level, specified as Sound Exposure Levels, (SEL), was tabled against estimated values of slant range and thrust. The SELs predicted by the INM for equivalent operations were generated and the averaged differences used to modify the original INM noise tables for certain aircraft. The SELs were then recalculated using the INM with the revised noise tables and these revised model SELs were recompared to the measured SELs. Since there were still consistent differences for some aircraft operations, a second set of changes was incorporated. The INM was rerun with the second set of noise table changes to produce another set of SELs. Because these model SELs compared well with the measured values, with residual differences within acceptable limits, no further noise table changes were made and the modifications were incorporated into the INM data base.2/

New aircraft types not included in the existing INM data base, such as the Boeing 757 and 767 and the Douglas DC9-80, were defined using operating parameters and noise levels obtained from the FAA and The Parry Company.

Ldn levels predicted by this final version of the INM were checked against measured Ldn values for both the north and south flow test days and for the 1980 annual average. This comparison demonstrated an acceptable fit and verified that the revised model would calculate noise levels with sufficient accuracy. Tables of the values used in the SEL and Ldn comparisons and of the INM noise table change increments are available upon request from the Port of Seattle Planning and Research Department. A more detailed discussion of the INM modification and verification process follows.

C.3 OPERATING PROCEDURE MODEL CHANGES

Four types of flight operation modifications to the INM were considered in fitting the model to Sea-Tac's specific conditions: topography, aircraft thrust and flap settings, flight profiles and flight tracks. Noise table changes are discussed in section C.4.

The INM does not contain any provision for alteration of the assumptions that the airport is located on a large, level, undeveloped plain. Hills and valleys, trees, buildings, and streets all affect the propagation of noise by increasing or decreasing reflections or absorption. While some correction of the model is possible where there is a uniform topographic slope, the land contours and surface structures around Sea-Tac are too randomly distributed for correction. To evaluate the magnitude of the topographic effect, the actual slant ranges from each aircraft flight profile to appropriate NMS stations were calculated with corrections for ground elevation. By calculating the ratio of these corrected ranges to the ranges used by the INM, it was concluded that topographic differences were important only at RMS 4, where predicted noise levels would be 1 to 3 dBA higher than measured data, depending on aircraft flight profile. Because this site is on airport property and is already within a high noise zone (1980 average LdnA = 82.7), no attempt was made to recalculate the comparison levels for that station. It was recognized, however, that predicted levels for station RMS 4 could exceed measured ones by several decibels even after other corrections were made.

A survey of airline chief pilots was made to obtain details of flight procedures to include in the INM. Three possible flight modifications were considered as a result of this survey which addressed aircraft thrust and flap settings and flight profiles: (1) altitude of takeoff thrust reduction, (2) A300 takeoff profile, and (3) approach thrust and speed for fuel conservation.

The change that affected the most aircraft was the reduction in the altitude at which takeoff thrust is reduced to climb thrust from 1,500 feet to 1,000 feet. With the exception of the Airbus A300, all commercial jet aircraft in Version 2 of the INM are programmed for the thrust cutback at 1,500 ft. Airlines now use a 1,000 ft. cutback altitude as a fuel economy measure. This results in lower noise levels for the takeoff zone. This change was made for all aircraft using the Takeoff Profile Modification section of the INM, with two exceptions. Because of minimum turning altitudes set by the FAA for Sea-Tac traffic, aircraft departing in a south flow for destinations to the northwest (Track JW, primarily to Alaska) were programmed to maintain takeoff thrust to an altitude of 3,000 feet. The second exception was to maintain the 1,500 ft. cutback altitude for Boeing 747 aircraft departing for maximum distance routes. These longer flights represent greater takeoff weights which in turn requires a longer period of takeoff thrust. These two exceptions were also implemented by using the Takeoff Profile Modification section.

Visual observations and the results of the pilot survey showed that the standard INM departure profile for the Airbus A300 did not reflect actual operations. The climb rate was not as high as identified in the INM data base but essentially similar to other wide-bodied aircraft of similar passenger capacity. The A300 takeoff profiles were therefore redefined to match the altitudes of the Lockheed L-1011 while maintaining the speed and thrust settings of the A300.

An additional operating procedure, stemming from the objective of fuel savings, was identified during the pilot survey. When airplane traffic on approach to Sea-Tac is light, aircraft spacing is well beyond minimums, and VFR (Visual Flight Rules) conditions apply, pilots will delay lowering flaps and landing gear. They will approach the airport with minimum thrust and high speed for as long as is practicable. This operating procedure was not incorporated into the INM for two reasons. The combination of light traffic and VFR weather conditions does not occur on a regular basis. Secondly, this procedure affects noise levels only at a considerable distance from the airport and would affect areas of lower noise levels areas outside the area covered by the noise remedy programs. This modification cannot be included in the INM as an intermittent operation.

Based on observations of aircraft flight tracks, as shown by the FAA radar, one change was made in the initial track definitions. It was noted that during a north traffic flow, departing aircraft routed to turn out over Elliott Bay commonly initiated their west turn sooner than originally identified (approximately two nautical miles from the north end of the runway). This change was incorporated in the INM.

The Ldn values calculated by the INM after incorporating these revised operating procedures showed a consistant pattern of underprediction by the INM for both the north and south flow test days and for the 1980 annual average. Based on these differences, the decision was made to revise the noise-distance curves of individual aircraft in the INM.

C.4 NOISE CURVE REVISIONS

To alter the individual aircraft noise curves, it was necessary to collect data on noise levels of individual aircraft operations at Sea-Tac. These data were collected as part of a detailed survey combining direct observation and logging of aircraft by Port of Seattle staff and noise level measurements made by the NMS. Trip stage length was determined from the airline schedules. Direct observation recorded the runway used and the exact time of arrival or departure to enable correlation with NMS records. In order to accurately identify the exact aircraft type for each operation logged, aircraft series and presence of sound suppressing engine nacelles were obtained from airline operations departments.

For each aircraft type used by the INM, tables were made of the measured single event noise levels as specified by Sound Exposure Levels (SEL) vs. the slant ranges to the NMS monitor stations and the thrust levels appropriate to landing or takeoff. The SEL noise metric was chosen because it combines both noise loudness and duration to give a measure of the total noise energy of each aircraft operation. The slant ranges were calculated from the approach and departure profiles contained in the INM data base, and the revised operating procedures described in section C.3, not from direct measurements. The thrust values were assumed to be those specified in the INM data base.

While SEL measurements were made for both north and south flow operations, the majority of flights during the survey period occurred in south flow. Therefore, the SELs used in modifying the INM noise tables were primarily from south flow. SELs were calculated from the INM by running the model for single north and south flow flights for each appropriate landing and departure profile for each aircraft type. By using the detailed output options of the INM, the total noise produced by each aircraft type was generated as a 24-hour average level (24-hour Leq). This was converted to a one-second Leq value, equivalent for purposes of this study to the SEL produced by the NMS. The equation used in this calculation was as follows: 1-second Leq (SEL) = 24-hour Leq + 49.365, where 49.365 = 10 $\log_{10}$ of the number of seconds in 24 hours.

A range of values in the INM table were changed to correct for the differences between measured and predicted SELs. Because the slant ranges for the measured values did not correspond exactly to the distances tabled in the INM, interpolation was necessary. In addition, since the INM requires that noise levels always increase with higher thrust and shorter distance, this sometimes forced an increase in table values for distance-thrust combinations that were not directly a part of the SEL comparisons in order to maintain a consistent trend of increase. As a result, there was not a simple, fixed formula to determine the exact amount by which to raise or lower a particular INM noise table value. The effect of a set of modifications could only be checked by rerunning the INM and generating a new series of SELs. For this study, two sets of noise table changes were made in order to produce a reasonable level of accuracy.

Once the table of measured SELs vs. thrust and slant range was prepared for each aircraft type, standard INM noise tables were modified. The procedure used was based on methodology provided by The Parry Company. Their procedure was adjusted by the study staff to utilize the SEL data collected during the detailed survey at Sea-Tac. Measured data were grouped according to the slant range intervals in the INM noise table. For each thrust and altitude group, the average difference between the measured and INM-calculated SELs was calculated to the nearest whole decibel. Based on these differences, the INM table values were twice adjusted. The first adjustment to the INM table values was made following the incorporation of the operating procedure changes. The second adjustment was made to the first set of adjusted noise table values.

Since all field data were measured in units of dBA, not in EPNdB, only the NEL noise tables were changed in the INM. The EPNL tables were not altered. In order not to over-specify the precision of the resulting noise tables, all values were rounded to the nearest whole decibel except where interpolation or the need to maintain a constant trend of increase required the addition of 0.1 or 0.5 decibel.

The noise curves for all large, jet-powered, commercial aircraft were modified (except for new types such as the B757, B767, etc.) based on the results of the detailed flight survey. However, some combinations of aircraft type, stage length and type of operation (i.e. arrival or departure) for which only one or two flights were observed during the flight survey were recorded but not used to adjust noise tables.

Observed differences between measured and calculated SELs varied among the types of operations, represented by each noise curve. Since each noise curve was used for both arrivals and all stage lengths of departures for a given aircraft type, and in some instances for several aircraft types, noise vs. distance table changes became a compromise. While in theory, an aircraft could be redefined into several individual subtypes to minimize compromise, the limits on total numbers of aircraft types and other data sets that could be used in running the INM render extensive redefinition impractical. Therefore, the redefinition process was used only once to give the DC10-10 and the DC10-30 separate noise vs. distance tables. These two aircraft showed the greatest differences between aircraft sharing noise curves in the comparison process.

C.5. RESULTS AND CONCLUSIONS

The changes to the noise vs. distance tables led to a very close fit between the measured and predicted SELs for aircraft approaches. There was much greater variability for the takeoff comparisons. When landing, the flight track and altitude of large aircraft are tightly constrained to the approach glide path. Their descent rate is relatively independent of weight, thereby resulting in the individual operation of an aircraft type producing very similar noise levels. For takeoff, on the other hand, the flight track of large aircraft are less tightly constrained. Aircraft are initially assigned runway heading by the Sea-Tac Air Traffic Control Tower but the path of the aircraft over the ground is neither guided by airport navigational aids (as with an approach glide slope) nor controllable under certain weather conditions. Altitude varies greatly depending on the passenger, cargo, and fuel load (i.e., takeoff weight) and on local weather conditions.

While the differences in takeoff weight due to fuel load are largely accounted for by the different stage length categories in the INM, other load and weather variables are not. Therefore, the residual variability between the model and actual operations is greater for departures than for approaches.

In both the overall averages and the SEL comparisons, the modified operating procedures did not increase the accuracy of the model predictions. As previously noted, the operational changes were made to best describe the flight procedures in use at Sea-Tac. The intention was not to directly improve the fit between predicted and measured noise levels. The net effect of the operational changes was to increase the magnitude of the modifications needed to be made to the noise vs. distance tables.

The inclusion of the noise table changes greatly improved the accuracy of the landing event SELs. The net accuracy for departures was not as great, for reasons previously noted, but there were improvements over the unaltered INM. The differences produced by the operational changes were generally corrected. The net results of the INM modifications were reviewed by The Parry Company.

In addition to SEL prediction, the magnitude and the pattern of the differences between the measured values of LdnA and the INM-predicted values of Ldn were important in evaluating the accuracy of the revised INM. The LdnA from the NMS includes all large jet transport aircraft, most small private jets, and some turboprop operations. For the purposes of this study, NMS values of LdnA and INM-predicted values of Ldn are the most directly comparable noise metrics.

Table C-1 presents a comparison between measured values of the 1980 annual average LdnA and INM-predicted values of the 1980 annual average Ldn. Comparison sites are the 9 NMS Remote Monitor Stations. The two INM values shown are (1) "Revised Procedures", including the operational changes and the original noise tables; and (2) "Revised Procedures + Revised Noise Curves", which is the final, modified INM version used in this study. Means and standard deviations of the comparison differences are given. All values are in dBA.

The final fit of the model was within acceptable tolerances. Two of the nine predicted Ldn values were within 1 dBA of the measured levels, five were within 2 dBA, and the remaining two differed by 2.1 dBA and 2.4 dBA. On average, the model overpredicted by +1.5 dBA. This was consistent with our intent to place any net bias towards overprediction. The model, as revised, provides forecasts, well within reasonable tolerance limits, of cumulative noise levels based on Sea-Tac specific flight procedures and measured noise data.

TABLE C-1

COMPARISON OF MEASURED AIRCRAFT NOISE (LdnA) AND INM PREDICTED NOISE LEVELS AT REMOTE MONITORING STATIONS

(1980 Annual Average)

Station	NMS LdnA	INM Ldn (Revised Procedures)	Difference	INM Ldn (Revised Procedures & Revised (Noise Curves)	Difference
1	71.4	69.9	-1.5	73.0	+1.6
2	70.9	69.2	-1.7	72.1	+1.2
3	73.5	72.0	-1.5	75.9	+2.4
4	82.7	81.4	-1.3	84.7	+2.0
5	70.0	66.7	-3.3	70.6	+0.6
6	80.7	78.6	-2.1	82.1	+1.4
7	73.4	68.2	-5.2	71.3	-2.1
8	68.7	67.0	-1.7	69.6	+0.9
9	69.7	67.8	-1.9	71.1	+1.4
Mean Change	-	-	-2.4	-	+1.5
+/- Standard Deviation	-	-	1.3	-	0.6

Source: The Port of Seattle

D/060/63J - 06/28/82

Footnotes

[1]/In order to verify that the portable equipment would provide data that would be equivalent to that generated by the NMS, the DA607P was calibrated with RMS 6. The DA607P was configured to emulate the RMS with respect to threshold and duration levels so that metrics would be calculated in equivalent ways. A series of measurements of both cumulative noise and individual aircraft flight noise were made and the results from the two monitor systems were compared. Values of 1-hour Leq and of single-event noise levels (expressed as an SEL) all matched at the 0.1 dBA level. L max and event durations for the SELs also matched.

[2]/Noise table changes were not made if the comparison difference was less than +/- 1 dBA. Values within +/- 3 dBA were considered acceptable if there was not a consistant bias toward either overprediction or underprediction at all distances.

Appendix D

Estimation of Noise from Taxiing Aircraft

D. ESTIMATION OF NOISE FROM TAXIING AIRCRAFT

The method of estimating taxiing noise involved five steps. First, the noise energy contribution of a single taxiing operation was measured in the field as a Sound Exposure Level (SEL) for each of the five most common aircraft types at Sea-Tac. Second, SELs of other aircraft types identified in the existing or future fleet were estimated. Third, an Ldn was calculated for each direction of flow at a reference location. Fourth, the Ldns attributed to taxiing aircraft for each direction of flow and for combined flows were estimated for study grid cells in Columns I through U and in rows 1 through 50 (See Exhibit 6-2.). Finally, INM levels were adjusted for noise from taxiing aircraft.

D.1 FIELD MEASUREMENTS

Source measurements of taxiing noise levels from the five most common air carrier aircraft types were made at a reference distance of 130 feet from the centerline of the main north/south taxiway (Taxiway A). These events were recorded as SELs for aircraft taxiing past the reference location. An average SEL was calculated for each aircraft type from multiple measurements. The average SELs are listed in Table D-1. The aircraft types measured are estimated to generate over 85% of the taxiing noise energy through the year 2000.

TABLE D-1

MEASURED AVERAGE SEL OF TAXIING AIRCRAFT
(130 feet from centerline of taxiway)

Aircraft Type	Number of Measurements	SEL (dBA)
DC10	5	106.7
DC9	4	110.5
B747	4	109.4
B737	3	103.2
B727	19	108.9

D.2 ESTIMATES OF TAXIING SELs

Taxiing SELs (at the reference locations) of aircraft types not measured but identified in the existing or future fleet mixes were estimated from the relationship between the measured SELs of aircraft in Table D-1 to that aircraft's noise vs. distance curve in the INM. Based on this relationship, taxiing SELs were derived from the noise vs. distance curves in the INM for the aircraft listed in Table D-2.

TABLE D-2

ESTIMATED SEL OF TAXIING AIRCRAFT
(130 feet from centerline of taxiway)

Aircraft Type	SEL (dBA)
DC8	115.0
DC8 with SAM	108.0
DC9 with SAM/DC9-80	92.0
B707	115.0
B727 with SAM	102.0
B737 with SAM	98.0
B757	94.0
B767	94.0
L1011	104.5
A300	97.0

D.3 NORTH AND SOUTH FLOW TAXIING Ldn at 130 FEET

Based on the taxiing SELs presented in the preceeding two steps and the composition of aircraft operations described in Chapter 4--Forecast of Aviation Demand--an annual average taxiing Ldn for a reference distance of 130 feet from the taxiway was estimated for each flow of traffic along Taxiway A and for the years 1980, 1985, 1990 and 2000. Table D-3 presents the annual average taxiing Ldns at 130 feet from the taxiway for both south flow (i.e., traffic moving from north to south), and north flow (i.e., traffic moving from south to north) and for the years 1980, 1985, 1990 and 2000.

TABLE D-3

ESTIMATED ANNUAL AVERAGE TAXIING LDN
(130 feet from taxiway for each direction of flow and year)

Year	Ldn at 130 Feet	
	South Flow	North Flow
1980	83.2	79.8
1985	79.4	76.0
1990	77.7	74.4
2000	77.8	74.5

D.4 TOTAL TAXIING Ldn at GRID CELLS

For grid cells in Columns K through U and in rows 10 through 27, the Ldn attributed to taxiing aircraft was estimated separately for north flow taxiing and south flow taxiing. These grid cell estimates were based on an equation for noise generated by a finite line source adjusted for divergence and atmospheric absorption. The critical assumption in this equation is that over a year's time, the noise generated by aircraft moving along a taxiway can be treated as an infinite number of equal sources fixed along the taxiway. This equation was published by E. J. Rathe in the Journal of Sound and Vibration, Volume 10, No. 3, 1969. The estimates of taxiing noise levels at distances greater than 130 feet from the taxiway include only the attenuation or lessening of noise due to divergence or spreading and atmospheric absorption. An atmospheric absorption factor of 1 dBA per 5,200 feet was used.[1/] Other types of attenuation, including the effects of barriers, and ground effects, have been ignored because of the complexity of estimating them. They would, if included, result in lower taxiing noise estimates for the locations of interest. The actual levels could be as much as 10 dBA less than our estimates. The estimation of taxiing noise was completed with the combination of north and south flow taxiing Ldns at each grid cell, which gave the total annual average taxiing Ldn.

D.5 TAXIING ADDITION TO INM NOISE LEVELS

Adjustments were made to the noise levels predicted by the Integrated Noise Model in order to account for taxiing noise along Taxiway A. For the grid cells, the INM Ldn was adjusted if the taxiing Ldn was within 10 dBA of the

INM Ldn. Because of the logarithmic nature of the decibel scale, the addition of one Ldn value to another Ldn value that is 10 dBA larger results in a combined Ldn value of about 0.40 more than the larger value (e.g., 60 dBA + 70 dBA = 70.4139 dBA).

For noise contours, the criterion for adjustment was that a noise level of 75, 70, or 65 Ldn fell either between or beside a grid cell adjusted for taxiing noise. An interpolation procedure was developed to adjust the locations of the 75, 70, and 65 Ldn contours accordingly. Because the rate of change of Ldn along a line is a function of the distance to the source, a linear interpolation cannot be used. Instead, an equation was developed to interpolate between grid points using the concept of an "apparent source." From the rate of change observed between two grid points, the distance to an apparent source was calculated. Then using the location of the apparent source and one grid point, the location of the contour was calculated. INM-produced noise contours were adjusted accordingly. This interpolation procedure was tested on unadjusted INM outputs and is accurate to approximately 50 feet at distances between 1,000 feet and 3,500 feet from the runways.

Footnote

[1]/The atmospheric absorption factor was taken from Figure 7.6 of Noise and Vibration Control and represents "Reddish" noise and 70% humidity. Of the three noise types plotted (White, Pink, and Reddish), Reddish is least affected by air absorption. Use of this factor is therefore conservative. The actual condition is affected by the mix of frequency spectra of the aircraft in use.

Appendix E

Low Frequency Noise and Vibration Effects of Commercial Jet Transport Aircraft in the Airport Community

"Low Frequency Noise and Vibration Effects Of Commercial Jet Transport Aircraft In The Airport Community - A Working Paper"

Prepared By

The Parry Company

for

The Port of Seattle

May, 1981

CONTENTS

"Low Frequency Noise and Vibration Effects
Of Commercial Jet Transport Aircraft
In The Airport Community

INTRODUCTION

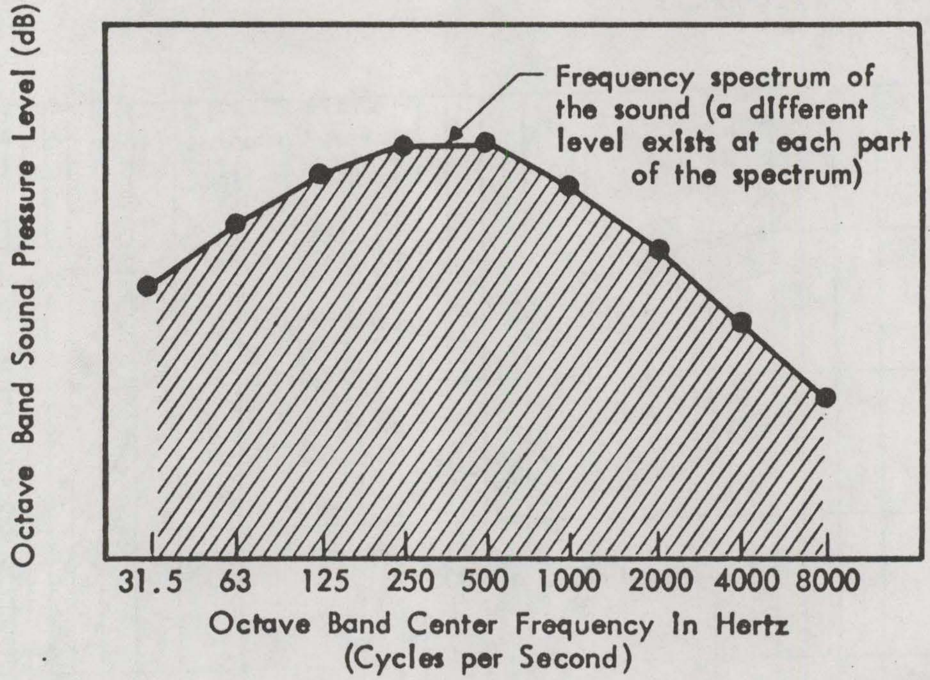
Although the main acoustical effects of jet aircraft are well described by the day-night sound level (LDN) measure, low-frequency noises (below 20 hertz) and structural vibrations are not directly included. This paper describes these two ancillary aspects of airport community exposure to aircraft noise and explains some of their possible effects.

DISCUSSION

The noises produced by turbojet-powered aircraft cover a wide spectral range. Figure 1 (from Reference 1), for example, shows a somewhat idealized, but typical noise spectrum for the exhaust of a jet. From that figure it can be seen that the sound pressure levels increase in energy from the low frequencies (around 30 Hz) up to maximum levels in the mid-frequencies (around 500 Hz) and then decrease steadily with increase in frequency above 500 Hz. In addition to the wide frequency band of noise of this jet exhaust, practical engines produce discrete frequency noises from their rotating compressor and turbine machinery. The composite spectrum of a typical jet-powered aircraft then looks something like that of Figure 2 (from Reference 2). Note that the jet noise peak in Figure 2 is at a lower frequency than that of Figure 1. A general increase in energy below 500 Hz is typical of the change in the jet noise spectrum resulting from increased sizes of the newer high-bypass ratio engines. However, note also that there is still a rapid decrease in energy at the lower frequencies. In fact, the octave-band sound levels at a distance of 1,000 ft. from the aircraft shown in Figure 2 are all below 110 dB.

The National Research Council (NRC) has assembled the most concise set of criteria for evaluating low frequency noise and vibration resulting from airborne sound (Reference 3). These are displayed in Figure 3. That figure shows both physiological and structural criteria. Note that the range of frequencies covered is from 0.1 Hz to 20 Hz. Also that Curve A and B1 are both above 120 dB sound pressure level. Curves B2 and C indicate that sounds below 20 Hz become increasingly less audible with decreasing frequency. Thus, for the spectrum in Figure 2, there would be little or no expected effects. However, the criteria do not imply that these effects are not detectable, but that the effects are generally not annoying or otherwise adverse.

On the other hand, citizens living around airports are known



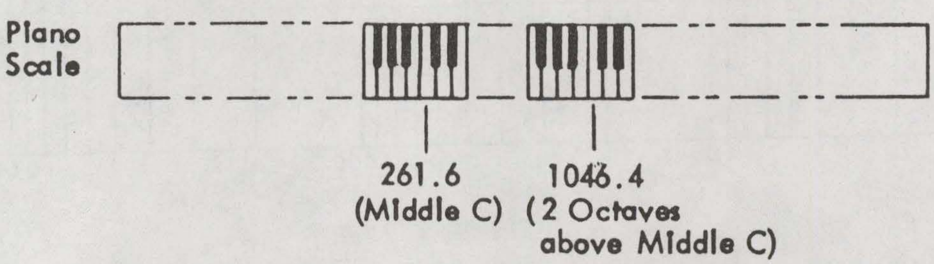


FIGURE 1. TYPICAL FREQUENCY SPECTRUM OF A JET EXHAUST

SOURCE: Reference 1.

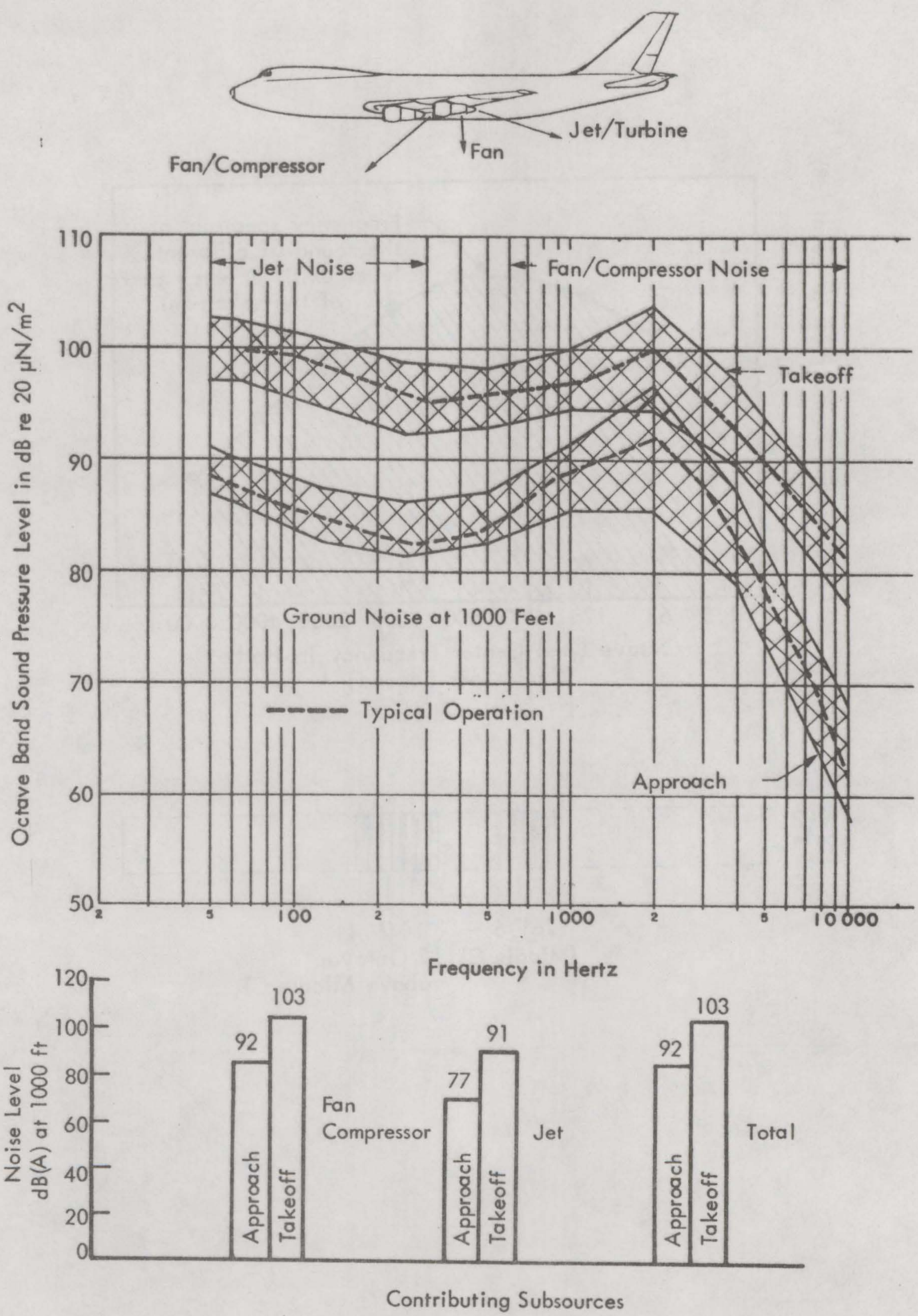


Figure 2 – Noise Levels and Spectra of 4-Engine High Bypass Ratio Turbofan Aircraft

SOURCE: Reference 2.

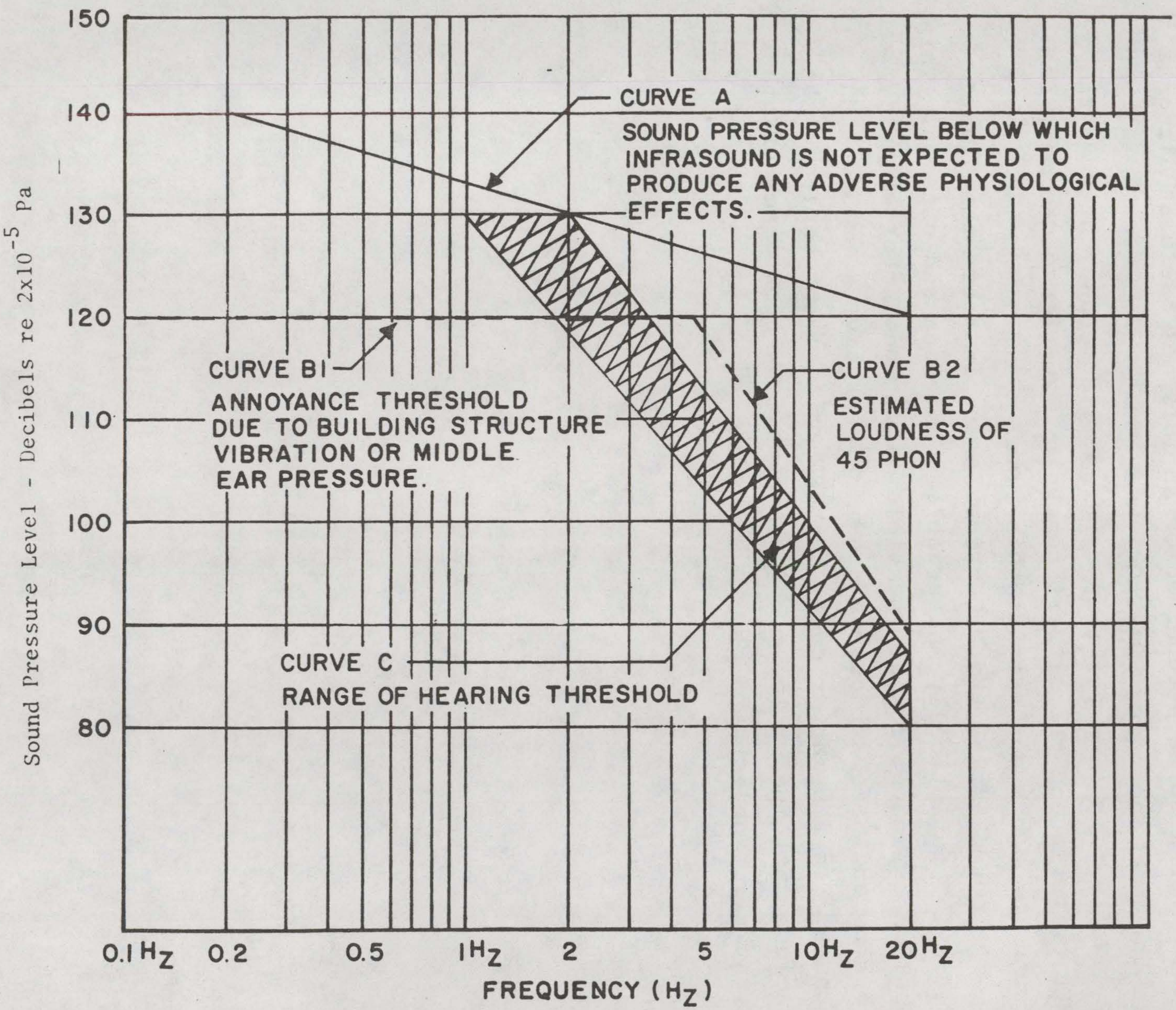


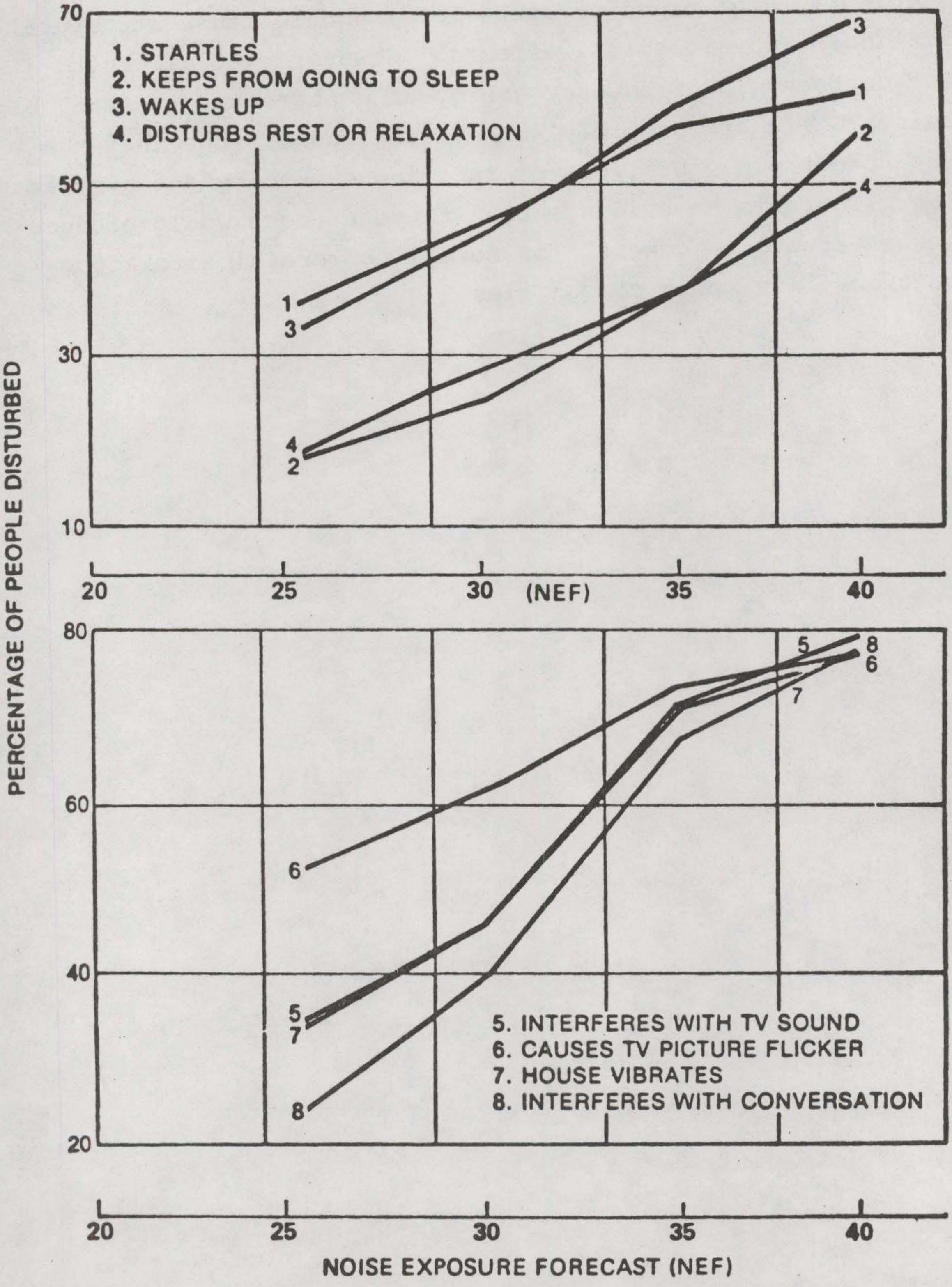
FIGURE 3 - INFRASOUND CRITERIA

SOURCE: Reference 3

to comment on vibration effects in their homes from jet aircraft operations. The "Wilson Committee" in England (Reference 4) found house vibration to be highly correlated with other reported complaints around London's Heathrow Airport (Figure 4). This effect has also been reported on an informal basis at airports in the U.S. including SEA-TAC.

The explanation for this apparent discrepancy between the NRC criteria and the airport community experience can only be found through hypothesis at this time.

As noted above, the NRC criteria are in terms that imply definite statistically measureable conditions and effects. This would not account for all possible situations. For example, some persons and some structures are more sensitive to sound than others. In the latter case, the NRC criteria probably do not include rattling of loose objects such as window panes or other lightweight objects.



COMMUNITY RESPONSE TO AIRCRAFT OPERATIONS - LONDON HEATHROW AIRPORT

FIGURE 4

SOURCE: Reference 4.

CONCLUSION

There is some evidence that low frequency noise at sufficiently high sound pressure levels could cause structural vibration or physiological effects. However, jet aircraft noise contains low frequency energy at measureable, but not high, levels. There are possibly some unusual conditions that can cause detectable vibrations or rattling caused by jet aircraft noise. There is no evidence that these effects would produce adverse effects in general for normal commercial aircraft operations in airport communities.

REFERENCES

1. "Community Noise Exposure Resulting From Aircraft Operations: Application Guide For Predictive Procedure," Aerospace Medical Research Laboratory, AMRL-TR-73-105, November 1974.

2. "Transportation Noise And Noise From Equipment Powered By Internal Combustion Engines," U.S. EPA; NTID 300.13, December 31, 1971.

3. "Guidelines For Preparing Environmental Impact Statements On Noise," Committee on Hearing, Bioacoustics, and Biomechanics, National Research Council, National Academy of Sciences, 1977.

4. "NOISE", Final Report, Committee on the Problem of Noise, London, July 1963.

Appendix F

Guidelines on Use and Interpretation of Noise Contours

F. GUIDELINES ON USE AND INTERPRETATION OF NOISE CONTOURS

Before applying computer-developed noise contours to noise reduction or land use planning programs, some guidelines on use and interpretation are necessary. Modeled noise contours are, by design, sensitive to the magnitude and character of the input data (e.g. noise and performance data of aircraft types, level, and composition of aircraft operations, flight procedures, flight track variations, etc.). Additionally, these noise contours reflect site-specific characteristics of the study area (e.g., topography, atmospheric conditions, etc.). Because of the sharp line appearance, noise contours are often misinterpreted as geographically precise representations of noise exposure levels. Recognizing the influence of site characteristics on the actual dimensions and accuracy of noise contours will assist in drawing valid conclusions. The precision of modeled noise contours remains a function of both user-controlled factors and technical limitations of the predictive program.

F.1 USER-CONTROLLED FACTORS

The principal types of data that affect noise contour dimensions are provided by the user or are standard (and usually subject to user modification) in the predictive program. They include:

- Airport operational characteristics
  - Runway configuration
  - Flight track definition
  - Flight profiles
- Aircraft operations
  - Fleet mix
  - Time of day
  - Runway and flight track utilization
- Aircraft performance
  - Noise vs. distance curves
  - Approach parameters
  - Takeoff profiles

(Sections 5.2.3 "User Provided Data" and sections 5.3.1 "Takeoff Profile Modifications, 5.3.2 "Alternative Aircraft Types", 5.3.3 "Alternative Takeoff Profiles," and 5.3.4 "Alternative Noise Curves" describe the use of these elements in the Integrated Noise Model.)

The accuracy of resulting noise contours (and of calculated noise levels in general), of course, depends on the accuracy of the data provided by the user.

F.2 PREDICTIVE PROGRAM TECHNICAL LIMITATIONS

The noise prediction program uses fixed values for a number of conditions which may actually vary in specific instances. These variations may lead to differences between measured and modeled noise levels and can include:

- Aircraft noise vs. distance data for various thrust levels at various slant-range distances -- These data generally cover thrust variations from maximum takeoff to near idle and slant range distances of 200 feet to 10,000 feet. Noise levels for thrust levels and slant-range distances between programmed values are derived using interpolation and extrapolation techniques.

- Non-reference atmospheric conditions -- Predicted noise levels are intended to approximate average conditions for the study area and the observation period. On any particular day, actual barometric pressure, temperature, and humidity may differ from the average reference conditions in the model data base. The influence of prevailing wind conditions on noise propagation has yet to be quantified in the prediction program.

- Reference aircraft performance -- Aircraft performance is generally based on standard day, sea level, zero wind conditions with limited adjustments for non-reference conditions. Even when these performance data are adjusted to reflect airport specific characteristics, there is a potential for variation during periods when temperature, wind, and field altitude differ from those used in the derivation of the aircraft performance data base.

- Terrain -- Predicted noise levels are generated for a ground surface which is flat and free of obstacles. Although some adjustments can be made to the data base in order to accommodate topographic changes and surface features, such effects may give rise to substantial variations within any particular airport community.

Appendix G

Noise Levels for Forecast Range

G. NOISE LEVELS FOR FORECAST RANGE

Aside from the forecast of annual aircraft operations used in the projections of noise levels presented in Chapter 6, two additional forecasts were generated for air carrier operations. These forecasts are presented in Table G-1 as Alternative I and Alternative II. The methodology used to derive all the forecasts are identical with the exception of the following differences: (a) the selected forecast uses a multiplier or "add factor" to account for possible variations in projected load factors, passenger forecasts, and average seats per aircraft type assumptions, (b) Alternative I does not use the "add factor" and (c) Alternative II represents the mid-point between the selected forecast and Alternative I. Both Alternative I and Alternative II represent lower forecasts of annual operations than the selected forecast.

The impact of using the Alternative I forecast or the Alternative II forecast on noise level projections can be estimated by assuming the same distribution of operations by aircraft type, flight track, time of day, stage length of departure, approach and departure profiles, and arrivals and departures as for the selected forecast. Commuter, general aviation/air taxi and military operations do not change between the selected forecast, Alternative I forecast, and Alternative II forecast. Therefore, only the change in the level of air carrier operations is used to compute differences in the projected noise levels.

For each of the three forecast years, the number of air carrier operations projected in the Alternative I forecast is approximately 16% less than the selected forecast. This represents an estimated 0.7 dBA decrease in Ldn noise levels from the Ldn noise levels projected by the selected forecast. For each of the three forecast years, the number of air carrier operations projected in the Alternative II forecast is approximately 8% less than the selected forecast. This represents an estimated 0.3 dBA decrease in Ldn noise levels projected for the selected forecast.

In order to illustrate the impact of these differences on the area within noise contours, a comparison is made between the noise levels projected by the forecasts with the greatest difference between them, the selected forecast and Alternative I forecast. The noise contours of Alternative I are superimposed on the noise contours of the selected forecast for 1985, 1990 and the year 2000 and are presented in Exhibits G-1, G-2, and G-3 respectively. The differences in the area within the 75, 70, and 65 Ldn noise contours are presented in Table G-2.

For each of the forecast years, the area within each of the noise contours is less for Alternative I forecast than for the selected forecast. In addition, the reduction in area is greater north and south of the airport than east and west. The reduction in area is also greater within the 65 Ldn noise contour than the 75 Ldn noise contour.

TABLE G-1

RANGE OF FORECASTS
(Annual Operations)

Categories	Actual 1980	Forecast 1985 Selected	1985 Alt. I	1985 Alt. II	1990 Selected	1990 Alt. I	1990 Alt. II	2000 Selected	2000 Alt. I	2000 Alt. II
Air Carrier	132,716	132,340	111,040	121,690	141,320	118,530	129,920	164,040	137,570	150,800
Commuter	46,611	36,590	36,590	36,590	38,650	38,650	38,650	47,380	47,380	47,380
General Aviation/ Air Taxi	32,876	36,300	36,300	36,300	40,080	40,080	40,080	48,850	48,850	48,850
Military	541	540	540	540	540	540	540	540	540	540
Total	212,744	205,770	184,470	195,120	220,590	197,800	209,190	260,810	234,340	247,570

Source: Port of Seattle

TABLE G-2

COMPARISON OF AREA WITHIN PROJECTED NOISE CONTOURS
FOR THE SELECTED FORECAST AND ALTERNATIVE I FORECAST
(in square miles)

	1980	Forecast 1985		1990		2000	
		Selected	Alt I.	Selected	Alt. I	Selected	Alt. I
75 Ldn	5.97	5.36	4.81	4.58	4.10	2.30	2.06
70 Ldn	13.07	11.81	10.56	10.20	9.10	5.45	4.83
65 Ldn	30.83	27.52	24.42	22.99	20.42	12.43	11.21

(in difference in square miles of area
within projected noise contours for the
selected forecast less the Alternative I forecast)

	Forecast 1985	1990	2000
75 Ldn	0.55	0.48	0.24
70 Ldn	1.25	1.10	0.62
65 Ldn	3.10	2.57	1.22

Source: The Port of Seattle

CHAPTER 7

NOISE EXPOSURE UPDATE COMPARISON WITH THE SEA-TAC/COMMUNITIES PLAN

CHAPTER 7

NOISE EXPOSURE UPDATE COMPARISON WITH THE SEA-TAC/COMMUNITIES PLAN

7.1 INTRODUCTION

A comparison between the noise exposure levels of the Sea-Tac/Communities Plan and the noise exposure levels of this study is presented here to demonstrate (1) the changes in noise exposure levels since the Sea-Tac/Communities Plan, (2) the degree of accuracy of the Sea-Tac/Communities Plan projected noise exposure levels, and (3) the reasons for changes and/or differences between the noise exposure levels of the two studies.

7.2 NOISE EXPOSURE LEVELS SINCE THE SEA-TAC/COMMUNITIES PLAN

Between 1973 (i.e., the base year for the Sea-Tac/Communities Plan) and 1980 (i.e., the base year for this study), noise exposure levels have generally decreased north and south of the Airport and increased east and west of the Airport. The change in terms of the difference in ANE levels is presented by grid cell in Table 7-1. For geographical reference, the relative significance of these changes is illustrated on a map of Sea-Tac in Exhibit 7-1.

7.3 SEA-TAC/COMMUNITIES PLAN PROJECTIONS OF NOISE EXPOSURE LEVELS

The Sea-Tac/Communities Plan projected a decrease in noise levels between 1973, 1978, and 1983. Tables 7-2, 7-3, and 7-4 present the noise levels (in ANE by grid cell) for those respective years from the Plan.

However, a comparison between the 1978 and 1983 projections of the Sea-Tac/Communities Plan and the 1980 base year noise levels of this study shows that noise levels have not decreased in all areas as originally projected.

TABLE 7-1
ANE CHANGE BETWEEN 1980 UPDATE AND 1973 COMMUNITIES PLAN
(1980 ANE[1/] - 1973 ANE = Change +/-)
(ANE change +/- for each 1/16 section within study area)

Grid Rows	Grid Columns I	J	K	L	M	N	O	P	Q	R	S	T	U
1			-4	-4	-4	-3	-3	-2	-1	+1			
2			-5	-4	-4	-3	-3	-1	-1	0	+1		
3	-3	-5	-4	-4	-4	-3	-2	-2	0	+1	+2		
4	-3	-4	-2	-4	-4	-3	-3	-1	-1	+1	+2	+1	
5	-2	-4	-4	-4	-4	-3	-3	-1	-1	0	+1	+1	
6	-2	-3	-4	-4	-4	-3	-4	-1	0	0	+1	+2	+1
7	-1	-3	-4	-4	-4	-3	-3	-1	-1	+1	+1	+1	+2
8	-1	-3	-3	-4	-3	-3	-3	0	-1	0	+1	+1	+1
9	0	-1	-3	-4	-3	-3	-4	0	0	0	+1	+2	+2
10	0	-1	-2	-3	-2	-2	-4	0	-1	+1	+1	+1	+1
11	0	0	-2	-3	-3	-1	-3	0	0	0	+2	+1	+1
12	+1	0	0	-2	-2	-2	-5	+1	0	+1	+1	+2	+1
13	+1	+1	0	-2	-1	0	-5	+1	+1	+1	+1	+2	+2
14	+2	+1	+1	0	0	0	-4	+3	+2	+1	+3	+2	+2
15	+2	+2	+2	+1	+1	+2	-4	+4	+3	+2	+3	+3	+2
16	+3	+3	+3	+2	+2	+3	-3	+4	+4	+3	+3	+3	+3
17	+3	+3	+3	+2	+3	+3	-1	+3	+5	+3	+2	+3	+3
18	+5	+5	+6	+6	+6	+5	+2	+7	+8	+7	+6	+6	+7
19	+3	+3	+4	+4	+4	+4	+4	+5	+6	+5	+5	+5	+5
20	+4	+4	+4	+3	+3	+3	+4	+4	+6	+6	+5	+5	+5
21	+4	+4	+4	+3	+4	+3	+4	+3	+6	+5	+5	+5	+5
22	+4	+4	+3	+3	+3	+3	+2	+3	+5	+3	+4	+4	+4
23	+3	+3	+4	+3	+4	+4	+4	+7	+6	+6	+4	+4	+4
24	+5	+5	+5	+6	+6	+6	+6	+7	+8	+7	+6	+6	+5
25	+4	+4	+4	+4	+4	+3	0	+7	+6	+5	+5	+5	+5
26	+4	+4	+4	+4	+4	+5	+3	+4	+6	+5	+5	+5	+5
27	+4	+4	+4	+3	+3	+5	+2	+4	+5	+4	+4	+4	+5
28	+3	+3	+3	+3	+2	+3	+2	+3	+3	+3	+3	+3	+4
29	+3	+2	+2	+2	+1	+3	+2	+2	+3	+2	+2	+2	+3
30	+2	+3	+3	+2	0	+2	+2	+2	+1	0	+2	+2	+2
31	+3	+3	+3	+2	0	+1	+1	+1	+2	0	+1	+2	+2
32		+2	+2	+1	0	+2	0	0	+2	0	+1	+2	+2
33			+2	+1	0	+1	0	+1	+2	0	+1	+2	+2
34			+2	+1	-1	+1	0	0	+1	-1	0	+2	+2
35				0	0	0	0	0	+1	0	0	+1	+2
36				0	0	0	-1	-1	0	0	0	+1	+2
37				+1	0	0	0	0	+1	0	+1	+2	+1
38				0	-1	0	-1	-1	0	-1	0	0	+1
39				0	-1	-1	-1	0	0	-1	0	0	+1
40				0	-1	-1	-1	-1	-1	0	0	0	+1
41				-1	-1	-1	-1	-2	-1	-1	0	0	+1
42				-1	-1	-1	-2	-2	-1	-1	-1	-1	-1
43				-1	-1	-1	-2	-2	-2	-1	-2	-1	-1
44				-1	-1	-1	-2	-2	-2	-2	-2	-2	-1
45				-1	-1	-2	-3	-3	-3	-2	-3	-3	-2
46				-1	-1	-1	-3	-3	-3	-2	-3	-3	-4
47				0	-1	-2	-3	-3	-3	-3	-2	-3	-4
48				0	-1	-2	-3	-3	-2	-3	-2	-4	-5
49				-2	-1	-2	-3	-3	-3	-3	-4	-4	-5
50				-2	-2	-3	-3	-3	-3	-3	-4	-4	-6

Note: For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

1/ ANE for 1980 = Ldn - 35; 1980 ANE rounded to whole number for this table

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Souce: The Port of Seattle

D/060/63D - 06/11/82

TABLE 7-2
1973 ANE FROM SEA-TAC/COMMUNITIES PLAN

(ANE for each 1/16 section within study area)

Grid Columns

Grid Rows	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1											32	34	36	37	39	35	31	27						
2											33	34	36	38	40	35	31	28	25					
3			17	19	20	22	23	25	28	31	32	34	36	38	40	36	31	28	25					
4			17	19	20	22	23	25	28	30	30	34	36	38	41	36	32	28	25	24				
5			17	19	20	21	23	25	27	30	32	34	36	39	42	36	32	29	26	24				
6			18	19	20	21	23	25	27	30	32	34	36	39	43	37	32	29	26	24	23			
7			18	19	20	21	23	24	26	29	32	34	36	39	43	37	33	29	27	25	23	22		
8			18	19	20	21	23	24	26	29	31	34	36	40	44	37	33	30	27	25	24	22		
9				19	20	21	23	24	26	28	31	34	36	40	45	37	33	30	27	25	24	23	21	
10				19	20	21	23	24	26	28	31	34	36	40	46	38	34	30	28	26	25	23	22	
11					20	22	23	24	26	28	31	34	37	40	47	38	34	31	28	27	25	24	23	
12					21	22	23	25	26	28	30	34	37	41	49	38	35	31	29	27	26	24		
13					21	22	23	25	27	28	31	34	37	41	50	39	35	32	30	28	26	25		
14					21	22	24	25	27	29	31	34	37	42	51	39	35	33	30	29	27	26		
15				20	21	22	24	26	27	29	31	34	38	42	53	40	36	34	31	29	28	26	25	
16				20	21	23	24	26	27	29	31	34	38	43	54	43	38	35	32	30	28	26	25	
17				20	21	23	24	26	27	29	31	34	38	44	56	50	40	36	33	30	28	26	25	23
18				15	17	18	20	21	23	25	27	30	34	42	55	48	36	31	28	26	23	22	20	19
19			14	15	16	18	19	21	23	25	27	30	34	42	56	48	36	31	28	25	23	21	20	18
20			14	15	16	17	19	21	22	24	26	29	33	41	57	48	35	30	27	25	23	21	20	18
21	11	12	13	15	16	17	19	20	22	24	26	29	32	40	57	48	35	30	27	25	23	21	20	
22			14	15	16	18	19	21	22	24	27	29	33	40	58	49	37	32	28	26	24	22	20	
23						18	20	21	23	25	27	30	34	41	47	49	38	32	29	27	24	22	21	
24							20	22	23	25	28	30	34	41	57	49	38	33	30	27	25	23	21	
25							23	25	26	28	31	33	37	45	55	48	40	35	32	29	27	25	24	
26							23	25	26	28	31	33	36	41	48	47	40	35	32	29	27	25		
27								25	26	28	30	33	36	40	47	46	40	35	32	30	27	26		
28								25	26	28	30	32	36	40	46	45	40	35	32	30	27	26		
29								24	26	28	30	32	36	39	45	45	39	35	32	30	27	25		
30								24	26	27	29	32	36	39	44	44	40	36	32	30	27	25		
31									25	27	29	32	36	39	44	44	39	36	32	29	27	25		
32										27	29	32	36	38	44	44	38	36	32	29	27	25		
33											29	32	36	38	43	43	38	36	32	29	27	25		
34											29	32	36	38	43	43	38	36	33	29	27	25		
35												33	35	38	42	42	38	35	33	30	27	25		
36												33	35	38	42	42	38	35	33	30	27	25		
37												32	35	37	41	41	37	35	32	29	27	25		
38												32	35	37	41	41	37	35	32	30	27	25		
39												32	35	37	40	40	37	35	32	30	27	25		
40												32	35	37	40	40	37	34	32	30	27	25		
41												32	34	36	39	40	37	34	32	30	27	25		
42												32	34	36	39	39	36	34	32	30	28	26		
43												32	34	36	39	39	36	34	33	30	28	26		
44												32	34	36	38	38	36	34	33	31	28	27		
45												32	34	36	38	38	36	34	33	31	29	27		
46												32	33	35	38	38	36	34	33	31	30	29		
47												31	33	35	37	37	36	34	32	31	30	30		
48												31	33	35	37	37	35	34	32	32	31	30		
49												32	33	35	36	36	35	34	33	32	31	31		
50												32	33	35	36	36	35	34	33	32	32	31		

Note: For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: Sea-Tac/Communities Plan

TABLE 7-3
1978 ANE PROJECTION FROM SEA-TAC/COMMUNITIES PLAN

(ANE for each 1/16 section within study area)

Grid Rows	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
													Grid Columns											
1											31	33	35	36	38	34	30	26						
2											31	33	35	37	39	34	30	26	23					
3			16	17	18	20	22	24	27	29	31	33	35	37	39	35	30	27	24					
4			16	17	18	20	22	24	26	29	31	33	35	37	40	35	30	27	24	22				
5			16	17	18	20	21	23	26	29	31	33	35	38	41	35	31	27	24	22				
6			16	17	18	20	21	23	25	28	31	33	35	38	42	36	31	28	25	23	21			
7			16	17	18	20	21	23	25	28	31	33	35	39	43	36	31	28	25	23	21	20		
8			16	17	18	20	21	23	25	27	30	33	35	39	43	36	32	27	25	23	22	21		
9				17	18	20	21	23	24	27	30	33	35	39	44	36	32	28	26	24	22	21	20	
10				17	18	20	21	23	24	27	29	33	35	39	46	37	32	29	26	24	23	22	20	
11					19	20	21	23	24	27	29	33	35	39	47	37	33	29	27	25	24	22	21	
12					19	20	22	23	25	27	29	33	36	40	48	37	33	30	27	26	24	23		
13					19	20	22	23	25	27	29	33	36	40	49	38	33	30	28	26	25	23		
14					19	21	22	24	25	27	29	32	36	40	51	38	34	31	29	27	25	24		
15					19	21	22	24	26	27	30	33	36	41	52	39	35	32	30	28	26	24		
16				18	20	21	22	24	26	28	30	33	36	42	54	41	37	34	31	29	26	25	23	
17				18	20	21	22	24	26	28	30	33	36	43	55	48	39	35	31	29	27	25	23	
18				14	15	16	18	20	21	24	26	29	33	41	55	46	35	30	27	24	22	20	19	
19			12	13	15	16	18	20	21	23	26	29	33	40	55	46	34	30	26	24	22	20	18	17
20			12	13	14	16	17	19	21	23	25	28	32	40	56	46	34	29	26	24	21	20	18	16
21	10	11	12	13	14	16	17	19	20	22	25	27	31	38	56	46	34	29	26	24	21	20	18	
22			12	13	15	16	18	19	21	23	25	28	32	39	56	47	35	30	27	24	22	20	19	
23						16	18	20	21	23	26	29	32	39	56	48	36	31	28	25	23	21	19	
24							18	20	22	24	26	29	33	40	56	47	37	32	28	26	23	21	20	
25							22	23	25	27	29	32	36	43	54	47	39	34	30	28	26	24	22	
26							22	23	25	27	29	32	35	40	47	46	39	34	31	28	26	24		
27								23	25	27	29	31	35	39	46	45	39	34	31	28	26	24		
28								23	25	26	29	31	34	39	45	44	38	34	31	28	26	24		
29								23	24	26	28	31	34	38	44	44	38	34	31	28	26	24		
30								23	24	26	28	31	35	38	43	43	38	34	31	28	26	24		
31									24	26	28	31	35	38	43	43	38	34	31	28	26	24		
32										26	28	31	35	37	43	43	37	35	31	28	25	24		
33											28	31	35	37	42	42	37	34	31	28	25	23		
34											28	31	34	37	42	42	37	34	31	28	25	23		
35												31	34	37	41	41	37	34	31	28	25	23		
36												31	34	36	41	41	36	34	31	28	26	24		
37												31	34	36	40	40	36	34	31	28	25	23		
38												31	34	36	40	40	36	34	31	28	25	23		
39												31	33	36	39	39	36	33	31	28	25	23		
40												31	33	35	39	39	36	33	31	28	26	23		
41												31	33	35	38	38	35	33	31	29	26	24		
42												31	33	35	38	38	35	33	31	29	26	24		
43												31	33	35	38	38	35	33	31	29	27	25		
44												31	32	35	37	37	35	33	31	29	27	25		
45												30	32	35	37	37	35	33	32	30	27	26		
46												30	32	34	37	37	35	33	32	30	28	27		
47												30	32	34	36	36	34	33	31	30	29	28		
48												30	32	34	36	36	34	32	31	30	29	29		
49												30	32	34	35	35	34	32	31	30	30	29		
50												31	32	34	35	35	34	32	31	30	30	30		

Note: For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: Sea-Tac/Communities Plan

TABLE 7-4
1983 ANE PROJECTION FROM SEA-TAC/COMMUNITIES PLAN

(ANE for each 1/16 section within study area)

Grid Rows	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
											Grid Columns													
1											30	33	34	33	33	31	29	25						
2											31	32	34	34	34	31	29	26	23					
3			15	17	18	20	21	24	27	29	31	32	34	34	34	32	30	26	23					
4			15	17	18	20	21	23	26	29	30	32	34	35	35	32	30	27	24	22				
5			16	17	18	19	21	23	26	28	30	32	34	35	36	33	30	27	24	22				
6			16	17	18	19	21	23	25	28	30	32	34	36	37	33	30	27	24	22	21			
7			16	17	18	19	21	23	25	28	30	32	34	36	37	33	31	28	25	23	21	20		
8			16	17	18	19	21	22	24	27	30	32	34	36	38	34	31	28	25	23	22	20		
9				17	18	19	21	22	24	27	29	32	34	37	39	34	31	28	26	24	22	21	20	
10				17	18	19	21	22	24	26	29	32	34	37	40	34	32	28	26	24	23	21	20	
11					18	20	21	22	24	26	29	32	34	37	41	35	32	29	27	25	23	22	21	
12					19	20	21	23	24	27	29	32	35	38	42	35	32	29	27	25	24	23		
13					19	20	22	23	25	27	29	32	35	38	43	36	33	30	28	26	25	23		
14					19	20	22	23	25	27	29	32	35	39	44	37	33	31	29	27	25	24		
15				18	19	21	22	24	25	27	29	32	35	39	45	38	34	32	30	28	26	24	23	
16				18	19	21	22	24	25	27	30	32	36	40	47	40	36	33	31	29	26	25	23	
17				18	19	21	22	24	25	27	30	32	36	41	50	46	38	34	31	29	27	25	23	22
18				13	15	16	18	19	21	23	26	28	32	39	49	43	33	29	26	24	22	20	18	17
19			12	13	14	16	17	19	21	23	25	28	32	38	50	43	33	29	26	24	22	20	18	16
20			12	13	14	15	17	19	20	23	25	27	31	38	51	43	33	28	26	24	21	19	18	16
21		11	12	13	14	15	17	19	20	22	25	27	30	37	51	44	33	29	26	24	21	19	18	
22			12	13	14	16	17	19	21	23	25	27	31	37	51	45	34	30	27	24	22	20	18	
23						16	18	20	21	23	26	28	32	38	51	45	35	31	27	25	23	21	19	
24							18	20	22	24	26	29	32	38	51	44	36	31	28	26	23	21	19	
25							21	23	25	27	29	32	35	41	51	45	38	33	30	28	25	24	22	
26							21	23	25	27	29	31	34	39	47	43	38	33	30	28	26	24		
27								23	25	27	29	31	34	38	43	43	38	33	30	28	26	24		
28								23	24	26	29	31	34	38	42	42	37	33	30	28	26	24		
29								23	24	26	28	30	34	37	41	41	37	34	30	28	25	24		
30								22	24	26	28	30	34	37	41	41	37	34	30	28	25	23		
31									24	25	28	30	34	37	40	40	37	34	30	28	25	23		
32										25	28	30	34	36	40	40	36	34	30	28	25	23		
33											28	31	34	36	39	39	36	34	31	28	25	23		
34											28	31	34	36	39	39	36	34	31	28	25	23		
35												31	34	36	38	38	36	34	31	28	25	23		
36												31	33	35	38	38	35	33	31	28	25	23		
37												31	33	35	38	38	35	33	31	28	25	23		
38												31	33	35	37	37	35	33	31	28	25	23		
39												31	33	35	37	37	35	33	31	28	25	23		
40												31	33	35	36	36	35	33	31	28	25	23		
41												31	33	34	36	36	34	33	31	28	26	23		
42												31	32	34	36	36	34	33	31	29	26	24		
43												31	32	34	35	35	34	33	31	29	27	24		
44												30	32	34	35	35	34	33	31	29	27	25		
45												30	32	33	35	35	34	33	31	30	27	26		
46												30	32	33	34	34	34	32	31	29	28	27		
47												30	31	33	34	34	33	32	31	30	29	28		
48												30	31	32	33	33	33	32	31	30	29	28		
49												30	31	32	33	33	33	32	31	30	29	29		
50												30	31	32	33	33	32	31	31	30	29	29		

Note: For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

Source: Sea-Tac/Communities Plan

Noise levels have decreased more than originally projected south and northwest of the Airport but have also increased more than originally projected east, west, and northeast of the Airport. The differences in ANE levels between the 1978 and 1983 projections of the Sea-Tac/Communities Plan and the 1980 base year noise levels of this study are presented by grid cell in Tables 7-5 and 7-6, respectively.

7.4 INTERPRETATION OF CHANGES/DIFFERENCES IN NOISE EXPOSURE LEVELS

Both the Sea-Tac/Communities Plan and this study used computer programs to predict noise levels and construct noise contours; the Sea-Tac/Communities Plan with the Noise Exposure Forecast (NEF) procedure and this study with the Integrated Noise Model (INM). Both programs require data pertaining to the noise and performance characteristics of aircraft and the operating characteristics of aircraft and the airport. However, their application has resulted in the changes and differences in noise exposure levels identified in the preceding two sections. These differing results are primarily attributable to the methodology used to estimate noise exposure, forecast assumptions that had not materialized by 1980, operational assumptions that had changed by 1980, and the scope and structure of aircraft noise and performance characteristics. In the sections that follow, the input variables and the assumptions of both studies will be briefly discussed and compared.

7.4.1 Noise Descriptors

The Sea-Tac/Communities Plan and this study use different noise descriptors to discuss cumulative noise exposure. This study describes noise exposure as Day-Night Average Sound Level (Ldn). The Sea-Tac/Communities Plan used the Noise Exposure Forecast (NEF) and Adjusted Noise Exposure (ANE) descriptors. Although there is no fixed relationship between Ldn and NEF/ANE, noise levels calculated in NEF or ANE can be translated into Ldn by adding 35. The following table illustrates this approximate relationship:

TABLE 7-5

ANE CHANGE BETWEEN 1980 UPDATE AND 1978 COMMUNITIES PLAN PROJECTION

(1980 ANE[1/] - 1978 ANE = Change +/-)

(ANE change +/- for each 1/16 section within study area)

Grid Rows	Grid Columns: I	J	K	L	M	N	O	P	Q	R	S	T	U
1			-3	-3	-3	-2	-2	-1	0	+2			
2			-3	-3	-3	-2	-2	0	0	+2	+3		
3	-2	-3	-3	-3	-3	-2	-1	-1	+1	+2	+3		
4	-1	-3	-3	-3	-3	-2	-2	0	+1	+2	+3	+3	
5	-1	-3	-3	-3	-3	-2	-2	0	0	+2	+3	+3	
6	0	-1	-3	-3	-3	-2	-3	0	+1	+1	+2	+3	+3
7	0	-2	-3	-3	-3	-3	-3	0	+1	+2	+3	+3	+4
8	0	-1	-2	-3	-2	-2	-2	+1	+1	+3	+3	+3	+3
9	+2	0	-2	-3	-2	-2	-3	+1	+1	+2	+2	+5	+4
10	+2	0	0	-2	-1	-1	-4	+1	+1	+2	+3	+3	+3
11	+2	+1	0	-2	-1	-1	-4	+1	+1	+2	+3	+3	+3
12	+2	+1	+1	-1	-1	-1	-4	+2	+2	+2	+3	+3	+3
13	+3	+2	+2	-1	0	+1	-4	+2	+3	+3	+3	+4	+3
14	+4	+3	+3	+2	+1	+2	-4	+4	+3	+3	+4	+4	+4
15	+3	+4	+3	+2	+3	+3	-3	+5	+4	+4	+4	+4	+4
16	+4	+4	+4	+3	+4	+4	-3	+6	+5	+4	+4	+4	+5
17	+4	+4	+4	+3	+5	+4	0	+5	+6	+4	+4	+4	+4
18	+7	+6	+7	+7	+7	+6	+2	+9	+9	+8	+7	+8	+8
19	+5	+5	+5	+5	+5	+6	+4	+7	+8	+6	+7	+6	+6
20	+5	+5	+5	+4	+4	+3	+5	+6	+7	+7	+6	+6	+7
21	+6	+6	+5	+5	+5	+5	+5	+5	+7	+6	+6	+6	+7
22	+5	+5	+5	+4	+4	+4	+4	+5	+7	+5	+5	+6	+6
23	+5	+5	+5	+5	+6	+6	+5	+8	+8	+7	+5	+6	+5
24	+6	+6	+7	+7	+7	+7	+7	+9	+9	+8	+8	+7	+7
25	+5	+5	+6	+5	+5	+5	+1	+8	+7	+6	+7	+6	+6
26	+5	+5	+6	+5	+5	+6	+4	+5	+7	+6	+6	+6	+6
27	+5	+5	+5	+5	+4	+6	+3	+5	+6	+5	+5	+6	+6
28	+4	+5	+4	+4	+4	+4	+3	+4	+5	+4	+4	+5	+5
29	+5	+4	+4	+3	+3	+4	+3	+3	+4	+3	+3	+4	+4
30	+4	+4	+4	+3	+1	+3	+3	+3	+3	+2	+3	+4	+3
31	+4	+4	+4	+3	+1	+2	+2	+2	+3	+2	+2	+3	+3
32		+3	+3	+2	+1	+3	+1	+1	+3	+1	+2	+3	+4
33			+3	+2	+1	+2	+1	+2	+3	+2	+2	+3	+4
34			+3	+2	+1	+2	+1	+1	+2	+1	+2	+3	+4
35				+2	+1	+1	+1	+1	+2	+1	+2	+3	+4
36				+2	+1	+2	0	0	+2	+1	+2	+3	+3
37				+2	+1	+1	+1	+1	+2	+1	+2	+3	+3
38				+1	0	+1	0	0	+1	0	+1	+2	+3
39				+1	+1	0	0	0	+1	+1	+1	+2	+3
40				+1	+1	+1	0	0	0	+1	+1	+2	+2
41				0	0	0	0	0	+1	0	+1	+1	+2
42				0	0	0	-1	-1	0	0	0	0	+1
43				0	0	0	-1	-1	-1	0	0	0	0
44				0	+1	-1	-1	-1	-1	-1	0	0	0
45				+1	+1	-1	-2	-2	-1	-1	-2	-2	0
46				+1	0	0	-2	-2	-2	-1	-2	-2	-2
47				+1	0	-1	-2	-2	-1	-2	-1	-2	-3
48				+1	0	-1	-2	-2	-1	-1	-1	-2	-3
49				0	0	-1	-2	-2	-2	-1	-2	-2	-4
50				-1	-1	-2	-2	-2	-2	-1	-2	-2	-4

Note: For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

1/ ANE for 1980 = Ldn - 35; 1980 ANE rounded to whole number for this table

Source: The Port of Seattle

TABLE 7-6
ANE CHANGE BETWEEN 1980 UPDATE AND 1983 COMMUNITIES PLAN PROJECTION
(1980 ANE[1/] - 1983 ANE = Change +/-)
(ANE change +/- for each 1/16 section within study area)

Grid Rows	I	J	K	L	M	N	O	P	Q	R	S	T	U
1			-2	-3	-2	+1	+3	+2	+1	+3			
2			-3	-2	-2	+1	+3	+3	+1	+2	+3		
3	-2	-3	-3	-2	-2	+1	+4	+2	+1	+3	+4		
4	-1	-3	-2	-2	-2	0	+3	+3	+1	+2	+3	+3	
5	-1	-2	-2	-2	-2	+1	+3	+2	+1	+2	+3	+3	
6	0	-1	-2	-2	-2	0	+2	+3	+2	+2	+3	+4	+3
7	0	-2	-2	-2	-2	0	+3	+3	+1	+2	+3	+3	+4
8	+1	-1	-2	-2	-1	+1	+3	+3	+1	+2	+3	+3	+3
9	+2	0	-1	-2	-1	0	+2	+3	+2	+2	+2	+3	+4
10	+2	+1	0	-1	0	-1	+2	+4	+1	+3	+3	+3	+3
11	+2	+3	0	-1	0	+1	+2	+3	+2	+2	+3	+3	+4
12	+3	+1	+1	0	0	+1	+2	+4	+3	+3	+3	+4	+3
13	+3	+2	+2	0	+1	+3	+2	+4	+3	+3	+3	+4	+3
14	+4	+3	+3	+2	+2	+3	+3	+5	+4	+3	+4	+4	+4
15	+4	+4	+4	+3	+4	+5	+4	+6	+5	+4	+4	+4	+4
16	+5	+5	+4	+4	+4	+6	+4	+7	+6	+5	+4	+4	+5
17	+5	+5	+4	+4	+5	+6	+5	+7	+7	+5	+4	+4	+6
18	+7	+7	+7	+8	+8	+8	+8	+12	+11	+9	+8	+8	+8
19	+5	+5	+6	+6	+6	+8	+9	+10	+9	+7	+7	+6	+6
20	+6	+5	+5	+5	+5	+6	+10	+9	+8	+8	+6	+6	+7
21	+6	+6	+5	+5	+6	+6	+10	+7	+8	+6	+6	+6	+7
22	+5	+5	+5	+5	+5	+6	+9	+7	+8	+5	+5	+6	+6
23	+5	+5	+5	+6	+6	+7	+10	+11	+9	+7	+6	+6	+5
24	+6	+6	+7	+7	+8	+9	+12	+12	+10	+9	+8	+7	+7
25	+5	+5	+6	+5	+6	+7	+4	+10	+8	+7	+7	+6	+7
26	+5	+5	+6	+6	+6	+7	+4	+8	+8	+7	+7	+6	+6
27	+5	+5	+5	+5	+5	+7	+6	+7	+7	+6	+6	+6	+6
28	+6	+5	+4	+4	+4	+5	+6	+6	+6	+5	+5	+5	+5
29	+5	+4	+4	+4	+3	+5	+6	+6	+5	+3	+4	+4	+5
30	+4	+4	+4	+4	+2	+4	+5	+5	+4	+2	+4	+4	+4
31	+4	+5	+4	+4	+2	+3	+5	+5	+4	+2	+3	+3	+4
32		+4	+3	+3	+2	+4	+4	+4	+4	+2	+3	+3	+4
33			+3	+2	+2	+3	+5	+5	+4	+2	+2	+3	+4
34			+3	+2	+1	+3	+4	+4	+3	+1	+2	+3	+4
35				+2	+1	+2	+4	+4	+3	+1	+2	+3	+4
36				+2	+2	+3	+3	+3	+3	+2	+2	+3	+4
37				+2	+2	+2	+3	+3	+3	+2	+2	+3	+3
38				+1	+1	+2	+3	+3	+2	+1	+1	+3	+3
39				+1	+1	+1	+2	+2	+2	+1	+1	+2	+3
40				+1	+1	+1	+2	+3	+1	+1	+1	+2	+3
41				0	0	+1	+2	+2	+2	0	+1	+2	+2
42				0	+1	+1	+1	+1	+1	0	0	0	+1
43				0	+1	+1	+2	+2	0	0	0	0	0
44				+1	+1	0	+1	+1	0	-1	0	0	0
45				+1	+1	+1	0	0	-1	-1	-1	-2	0
46				+1	0	+1	+1	+1	-1	0	-1	-1	-2
47				+1	+1	0	0	0	0	-1	-1	-2	-3
48				+1	+1	+1	+1	+1	0	-1	-1	-2	-3
49				0	+1	+1	0	0	-1	-1	-2	-2	-3
50				0	0	0	0	0	0	0	-2	-2	-3

Note: For reference, the runways are located between rows 18 and 26 within column O. Each grid cell measures 1,320' by 1,320'.

Airport Boundary Outlined

1/ ANE for 1980 = Ldn - 35; 1980 ANE rounded to whole number for this table

Source: The Port of Seattle

D/060/63D - 05/20/82

NEF/ANE		Ldn
20	approximates	55
30	approximates	65
40	approximates	75

In 1973, NEF was the "state-of-the-art" noise descriptor. Adjusted Noise Exposure (ANE) was developed specifically for the Sea-Tac/Communities Plan in order to adjust the computer-derived NEF curves to actual operations as measured at Sea-Tac. This adjustment was based on over 4,300 measurements at 66 different locations around the Airport. Slant distances were calculated, aircraft noise was measured in one-third octave bands and an EPNL analysis was completed for each event.

Ldn has become the standard noise system, as prescribed by the FAA and recommended by Section 102 of the Aviation Safety and Noise Abatement Act of 1979 (PL 93-193), to be uniformly applied in measuring cumulative noise at airports. Ldn is also the descriptor for which the Noise Monitoring System (NMS) installed at Sea-Tac is programmed. Measurements from the NMS (expressed as A-weighted decibels) were used to modify the standard noise vs. distance curves of the INM in this study in order to more closely match actual Sea-Tac aircraft operations.

7.4.2 Aircraft Departures and Fleet Mix

The number of average daily departures identified in this update for 1980 is higher than the projections made for either 1978 or 1983 in the Sea-Tac/Communities Plan. This update identifies 291 average daily departures for 1980. The Sea-Tac/ Communities Plan forecasted 183 average daily departures in 1978 and 214 in 1983. The difference is primarily attributable to the omission of departures of aircraft under 12,500 pounds from the projections made in the Sea-Tac/Communities Plan.

The distribution of departures among aircraft categories differs between the two studies. Not only did the Plan not identify aircraft under 12,500 pounds in either the 1978 or 1983 projected fleet mix but significantly overpredicted the number of large 4-engine turbofan aircraft and underpredicted the number of 3-engine turbofan aircraft. Table 7-7 presents a breakdown of the fleet mix components of this update and of the Sea-Tac/Communities Plan.

TABLE 7-7

FLEET MIX COMPARISON BETWEEN THE
SEA-TAC/COMMUNITIES PLAN AND NOISE EXPOSURE UPDATE
(Average Daily Departures)

Aircraft Categories [1]	Update 1980	Plan Projections 1978	Plan Projections 1983
1. Large 4-engine turbojet (B707-120)	1	3	-
2. Large 4-engine turbofan (DC8-60)	4	47	33
3. 3-engine turbofan (B727)	104	72	81
4. 2-engine turbofan (B737, DC9)	29	17	16
5. Large, "new" generation, 4-engine turbofan (B747)	13	10	11
6. Large, "new" generation, 3-engine turbofan (DC10, L1011)	29	27	47
7. 2-engine piston/turboprop over 12,500 lbs.	4	5	5
8. New technology (A300)	1	2	21
9. 2-engine piston/turboprop under 12,500 lbs.	91	-	-
10. Other general aviation and military	15	-	-
TOTAL	291	183	214

[1]Aircraft categories are based on those used in the Sea-Tac/Communities Plan.

Inherent in the fleet mix projections of both studies are assumptions concerning the proportion of aircraft operations in compliance with FAR Part 36 noise standards. This study identified 63% of air carrier operations in compliance in 1980 and assumes 92% in 1985. The Sea-Tac/Communities Plan assumed 50% in compliance in 1978 and 100% in compliance in 1983. Although the level of compliance in 1980 is less than was projected by the Sea-Tac/Communities Plan, the proportion of complying aircraft operations is much higher than expected given current U.S. airline projections. U.S. airlines have reported to the FAA that they expected 49% of their aircraft fleet to be in compliance with noise standards by Jaunary 1, 1981[1].

7.4.3 Runway Utilization

Both studies allocated air carrier aircraft arrivals and departures between runways in similar proportions. However, the Sea-Tac/Communities Plan allocated more aircraft to the west runway (i.e., Runway 16R/34L) and more aircraft to the runways during a north flow of traffic (i.e., Runways 34R and 34L) than this update.

Table 7-8 presents a comparison of runway utilization between the two studies.

TABLE 7-8

RUNWAY UTILIZATION COMPARISON BETWEEN
THE SEA-TAC/COMMUNITIES PLAN AND NOISE EXPOSURE UPDATE
(Percentage of Air Carrier Aircraft Operations)

Air Carrier Arrivals	Update	Sea-Tac/ Communities Plan
Runway 34R	30.4%	34.5%
Runway 34L	1.6%	1.8%
Runway 16R	55.9%	60.5%
Runway 16L	12.1%	3.2%
	100.0%	100.0%
Air Carrier Departures		
Runway 34R	6.4%	2.0%
Runway 34L	25.6%	34.1%
Runway 16R	3.4%	3.0%
Runway 16L	64.6%	60.9%
	100.0%	100.0%

7.4.4 Flight Track Identification and Utilization

Flight tracks identified in both studies were defined to represent the center of the most densely used airspace corridors. However, this study identified a larger number of tracks, primarily flight tracks used by general aviation aircraft in Visual Flight Rule (VFR) weather conditions.

(See Exhibit 6-1 for Noise Exposure Update flight tracks.) This study also defined flight tracks which represented noise abatement procedures which were not defined as flight tracks in the Sea-Tac/Communities Plan (e.g., Visual Bay Approach). These additional flight tracks were identified by the observation of flights on control tower radar.

7.4.5 Aircraft Approach and Departure Procedures

On approach, the two studies assumed the same basic approach procedures and profiles. However, the Sea-Tac/Communities Plan did assume the use of a two-segment approach procedure in 1983 and 1993. This procedure was the intersection of the Instrument Landing System (ILS) 3° glide slope from a 6° approach slope at about three miles from touchdown. This study assumes the continued use of the 3° glide slope north of the Airport and 2.75° glide slope south of the Airport through the forecast years.

On takeoff, the altitude at which aircraft cutback from takeoff power to climb power was not the same. This study uses a 1,000 foot thrust cutback for departures. The 1,000 foot thrust cutback reflects the most recent FAA-recommended noise abatement departure procedure, the ATA standard departure procedure, and the Sea-Tac departure procedures reported by the airlines. The Sea-Tac/Communities Plan used a 1,500 foot thrust cutback.

The 1,000 foot thrust cutback was applied to all jet departures in this study with two exceptions. Under Sea-Tac noise abatement procedures (FAA Sea Twr 7110.071C, October 7, 1980), jet aircraft departing in a south flow are allowed to turn west upon reaching a point at least three nautical miles south of the airport and after having reached 3,000 mean sea level (MSL). Therefore, takeoff thrust was extended beyond an altitude of 1,000 feet along the west departure flight track. A 1,500 foot cutback altitude was maintained for Boeing 747 departing on long distance flights. These long stage lengths represented greater takeoff weight which in turn required a longer period of takeoff thrust before cutting back to climb power.

7.4.6 Aircraft Takeoff Profiles

Takeoff profiles were identified for different groups of aircraft corresponding to different lengths in the two studies. The Sea-Tac/Communities Plan used takeoff profiles for 6 aircraft classes with a maximum of 3 different stage lengths for each class. Table 7-9 shows the aircraft classes and stage lengths for which takeoff profiles were used in the Plan.

TABLE 7-9

TAKEOFF PROFILES BY AIRCRAFT CLASS AND STAGE LENGTH
SEA-TAC COMMUNITIES PLAN

Aircraft Class	Stage Length of Departure (nautical miles)					
	0-500	500-1500	Over 1500	1500-2000	2000-3000	Over 4000
1. Large 4-engine turbojet (e.g., B707-120)	X	X	X	--	--	--
2. Large 4-engine turbofan (e.g., DC8-60)	X	X	X	--	--	--
3. 3-engine turbofan (e.g., B727)	X	X	X	--	--	--
4. 2-engine turbofan (e.g., B737, DC9)	X	X	--	--	--	--
5. Large, "new" generation, 4-engine turbofan (e.g., B747)	--	--	--	X	X	X
6. Large, "new" generation, 3-engine turbofan (e.g., DC10, L1011)	X	X	X	--	--	--

Note: X = takeoff profile defined; -- no takeoff profile defined

This update uses the takeoff profiles included in the standard INM data base with the exceptions of modifications to the takeoff profiles for the Airbus 300 and the addition of new takeoff profiles for the Boeing 757, Boeing 767, DC9-80 and the DeHavilland Dash 7. Unlike the Sea-Tac/Communities Plan, which groups takeoff profiles by aircraft class, the INM assigns one of 104 takeoff profiles to each of 57 aircraft types for each of 6 applicable stage lengths included in the standard data base (or any modified or newly defined takeoff profile or aircraft type). Even so, in some instances, several aircraft share the same takeoff profile, or a particular takeoff profile is applicable for more than one stage length.

7.4.7 Noise vs. Distance Curves

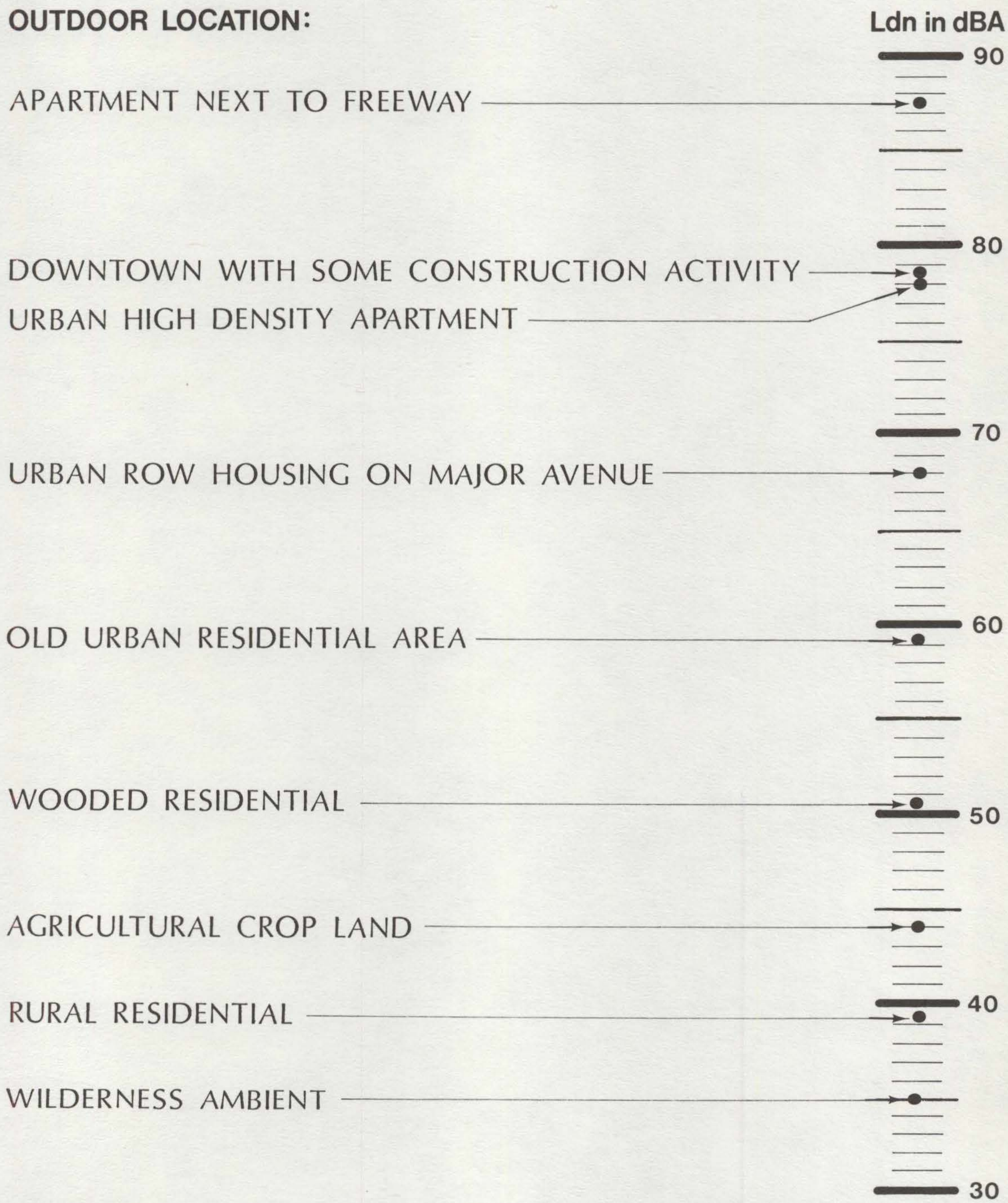
This study calibrated noise vs. distance curves for some types of air carrier aircraft that had been introduced into the Sea-Tac fleet since the Sea-Tac/Communities Plan (e.g., Boeing 727 with Sound Absorptive Material and Boeing 737 with Sound Absorptive Material). The noise curves for these aircraft had been estimated in the Sea-Tac/Communities Plan and were now based on actual measurements.

In this study, 23 sets of noise vs. distance curves were used to describe the noise levels generated by the operation of the aircraft in the Sea-Tac fleet through the forecast years. Five sets of noise distance curves were identified for five categories of general aviation aircraft, 17 curves for 20 air carrier aircraft types, and one curve for one military aircraft type. On the other hand, the Sea-Tac/Communities Plan used 11 sets of noise vs. distance curves to describe the noise levels generated by the operation of the aircraft in the Sea-Tac fleet through its forecast years (1973 through 1993). One set of noise vs. distance curves was identified for general aviation aircraft over 12,500 lbs., and 10 sets of curves for air carrier aircraft categories.

Footnotes

1/ FAR Part 91.308 requires U.S. airlines to submit compliance schedules to the FAA on an annual basis. The first compliance plans were required as of April 1, 1980.

Comparative Ldn Values at Various Locations



SOURCE: ENVIRONMENTAL PROTECTION AGENCY, "PROTECTIVE NOISE LEVELS: CONDENSED VERSION OF EPA LEVELS DOCUMENT", (NOVEMBER 1978).

Exhibit 3-5

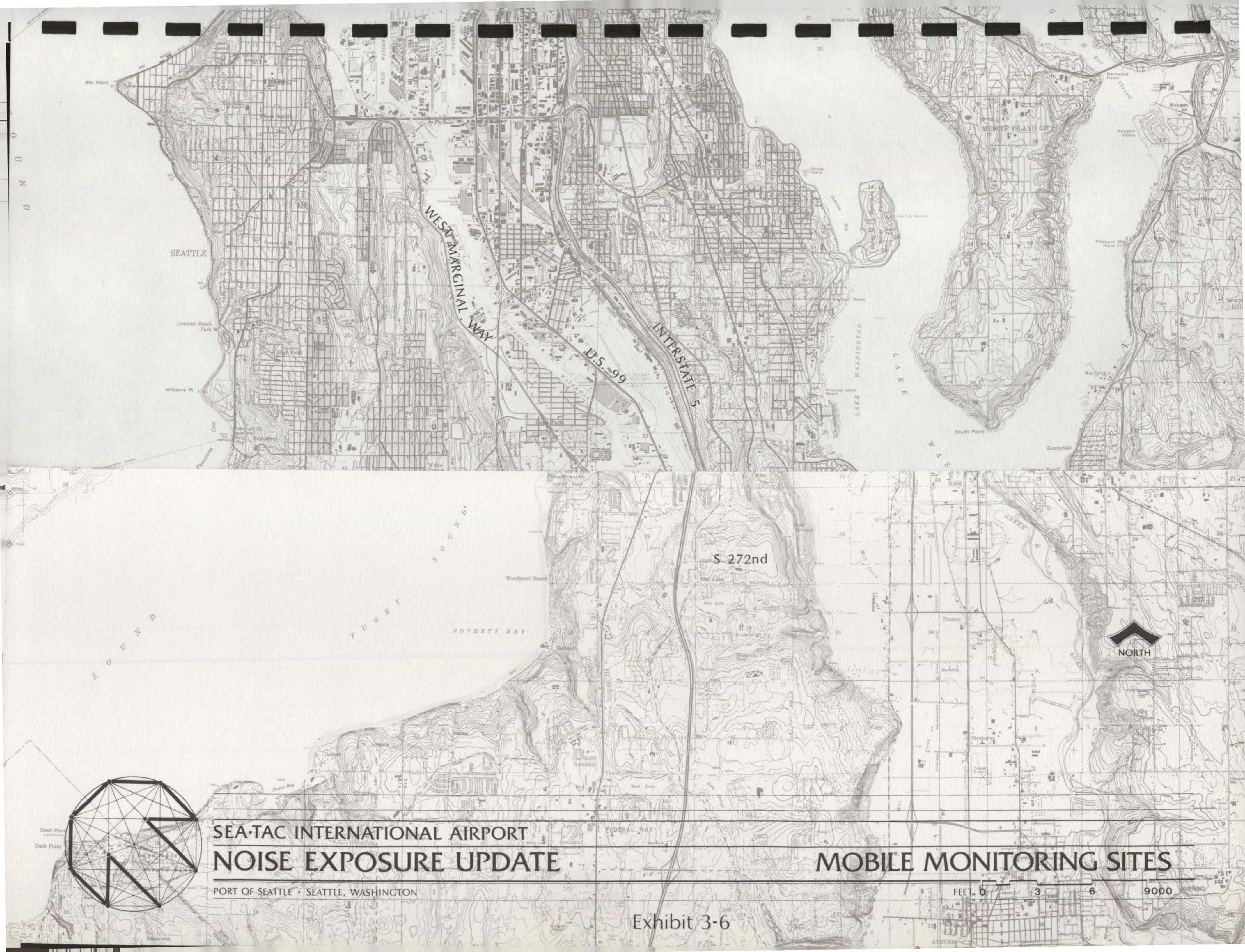

SEA·TAC INTERNATIONAL AIRPORT
NOISE EXPOSURE UPDATE
PORT OF SEATTLE · SEATTLE, WASHINGTON
MOBILE MONITORING SITES
FEET 0 3 6 9000
NORTH
WEST MARGINAL WAY
U.S. 99
INTERSTATE 5
S 272nd
SEATTLE
Alki Point
Lowman Beach Park
Williams Pt
MERCER ISLAND CITY
South Point
Kennydale
Woodmont Beach
POVERTY BAY
Dash Point

Exhibit 3-6

CHAPTER 4

FORECAST OF AVIATION DEMAND

CHAPTER 4

FORECAST OF AVIATION DEMAND

4.1 INTRODUCTION

A forecast of aircraft operations is required in order to predict future aircraft-generated noise exposure levels. Based on the operations forecast, future noise exposure levels will reflect changes in the number of operations and types of aircraft in the fleet, and the sector in which the aircraft are traveling. A summary of the forecast used in this study is presented in Table 4-1. Projections represent demand unconstrained by airport facilities or airspace use.

TABLE 4-1

SUMMARY OF AVIATION FORECAST
SEA-TAC INTERNATIONAL AIRPORT

	Actual	Forecast		
Forecast	1980	1985	1990	2000
1. Passengers	9,156,800	10,083,700	11,687,600	15,247,400
% change from previous period	--	10.1%	15.9%	30.5%
2. Operations				
Air Carrier	132,720	132,340	141,320	164,040
Commuter Aviation	46,610	36,590	38,650	47,380
General Aviation/ Air Taxi	32,880	36,300	40,080	48,850
Military	540	540	540	540
TOTAL	212,750	205,770	220,590	260,810
% change from previous period	--	-3.0%	7.0%	18.0%

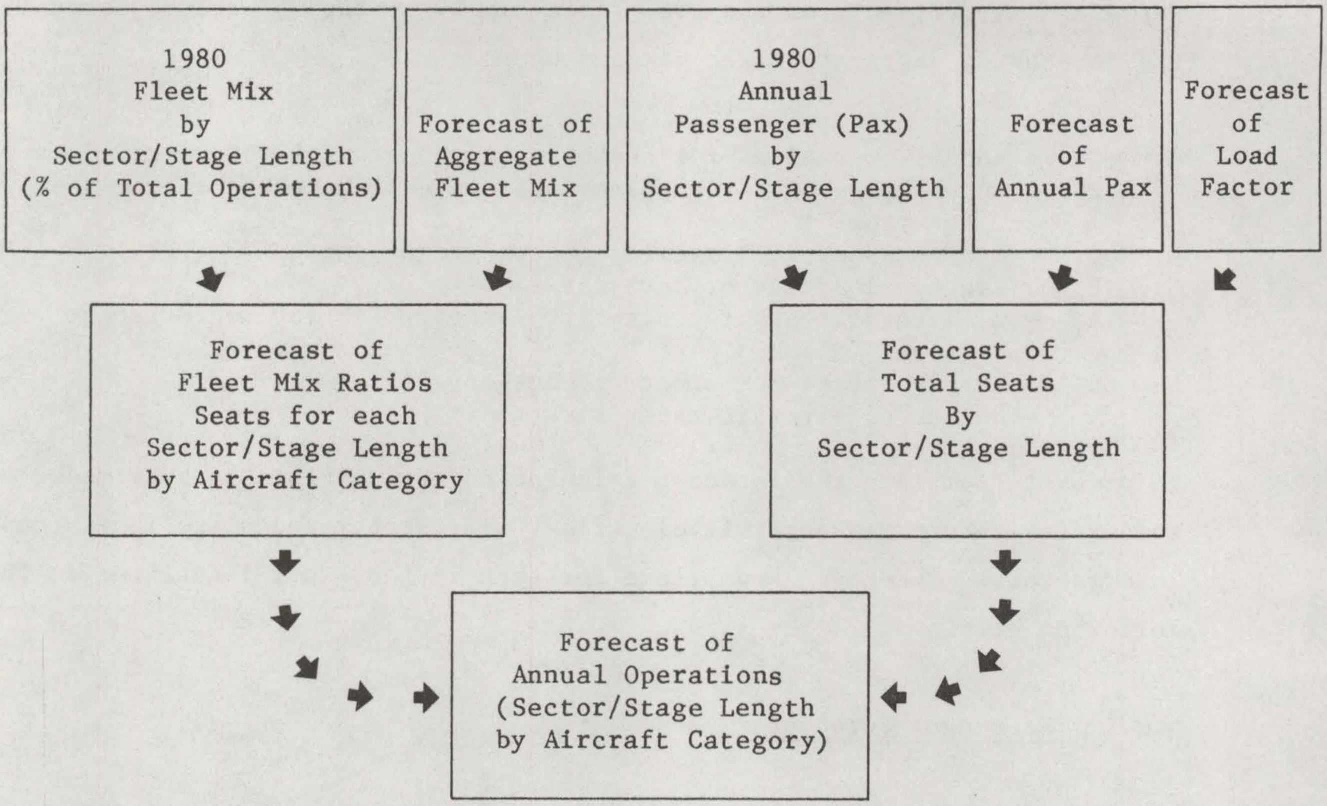
Source: The Port of Seattle

Separate projections are made for commercial passenger, general aviation, all-cargo, and military operations. Commercial passenger aviation operations include the operations of air carrier and commuter airlines and are derived from projected passenger levels. Trends of general aviation, all-cargo, and military operations are based on historical growth patterns.

In the following sections, forecast methodology is described, forecast assumptions are identified, and traffic projections are presented. The format of this forecast is designed for use in the Federal Aviation Administration (FAA) Integrated Noise Model (INM). As input for the INM, each aircraft operation must be identified by a representative aircraft type, flight track, and stage length of departure. Therefore, the forecast addresses each. The type of aircraft is differentiated in order to account for variance in aircraft performance and noise levels. The forecast, however, projects "categories" of aircraft which are later distinguished by representative "types" (i.e., manufacturers' models) as presented in Table 6-3. Flight track usage is identified from projections of the geographic origin and destination of an aircraft. Origins (the last stop of a flight before arriving at Sea-Tac) and destinations (the first stop of a flight leaving Sea-Tac) are grouped into geographic sectors which radiate from Sea-Tac. Stage length of departure is the distance in nautical miles to the first stop of a flight leaving Sea-Tac. Stage lengths are projected by distance intervals of 0-500, 500-1,000, 1,000-1,500, and over 1,500 nautical miles. This measure is used as a surrogate for takeoff weight. Thus, the longer the stage length, the heavier the aircraft.

4.2 COMMERCIAL PASSENGER AVIATION FORECASTS

Commercial passenger aviation forecasts include the operations of the certificated air carriers and commuter airlines. The procedure for developing the commercial passenger aviation forecast for operations is illustrated in the following diagram:



The forecast is a function of the demand for total aircraft seats by sector/stage length and the mix of aircraft serving each sector. It is represented by the following operations forecast equation which was developed by the Port of Seattle:

$$_tO_j = \sum_{i=1}^{N} \frac{\dfrac{P_t \times S_j \times A_{ij}}{L_t}}{B_i} \qquad t = 1985,\ 1990,\ 2000$$

Where A_{ij} is derived from the 1980 fleet mix by sector "j" and adjusted by the forecasted aggregate fleet mix and where

- O_j = annual operations for sector/stage length "j" for year "t"
- P_t = annual passengers (enplanements and deplanements) forecast for year "t"
- S_j = % of passengers traveling sector/stage length "j" (1980)
- L_t = average load factor for year t
- A_{ij} = % of total seats for aircraft category "i" for sector/stage length "j"
- B_i = average seats for aircraft category "i"
- N = number of aircraft categories

In order to complete the forecast calculation, projections must be made concerning future passenger levels, fleet mix, sector and stage length, and load factors. Forecast assumptions for each variable are identified in the following sections.

4.2.1 Passenger Forecast

The passenger forecast methodology was adapted from the Puget Sound Council of Governments' Air Carrier Demand Forecasts: Central Puget Sound Region (October 1980), adjusted for 1979 and 1980 actual data.

Projections of passenger originations are based on the historical relationship between passenger originations, regional personal income per capita, and average revenue per passenger mile. The historical data are presented in Table 4-2. The multiple regression equation derived from this historical data is as follows:

$$\text{Orig} = -15.8 + 1.35\ (I) - 1.54\ (R)$$

where Orig = natural logarithm of annual adjusted originations per capita
I = natural logarithm of regional personal income per capita in 1967 dollars
R = natural logarithm of average revenue per passenger miles in 1967 dollars

TABLE 4-2
HISTORICAL DATA
PASSENGER FORECAST

Year	Origina-tions (000)	Origination Adjustments (000) Deduction	Addition	Adjusted Origina-tions Per Capita	Regional Population (000)1/	Regional Personal Income (1967$ Mill) 2/	Personal Income Per Capita (1967$)	Average Passenger Revenue Per Revenue Passenger Mile (Current 3/)	(1967$)
1954	501.8	---	---	0.38	1330.2	3534.0	2656	.0566	.0720
1955	573.1	---	---	0.42	1361.9	3763.2	2763	.0560	.0709
1956	618.8	---	---	0.44	1393.7	3943.1	2823	.0558	.0698
1957	683.8	---	---	0.48	1425.3	4079.8	2862	.0554	.0664
1958	695.5	---	---	0.48	1457.1	4204.3	2885	.0580	.0681
1959	771.3	---	---	0.52	1488.1	4426.9	2974	.0596	.0687
1960	686.3	---	---	0.45	1513.0	4451.5	2942	.0614	.0699
1961	721.4	---	---	0.47	1546.8	4677.6	3024	.0624	.0699
1962	911.4	150.1	---	0.48	1584.0	5070.3	3201	.0631	.0696
1963	765.9	---	---	0.48	1609.8	5076.0	3153	.0609	.0661
1964	898.2	---	---	0.55	1640.5	5207.2	3175	.0595	.0637
1965	1079.7	---	---	0.64	1685.1	5561.4	3301	.0587	.0621
1966	1291.6	80.0	110.0	0.76	1730.0	6291.9	3636	.5067	.0584
1967	1659.1	200.0	---	0.81	1810.8	6820.0	3766	.0549	.0549
1968	1932.7	220.0	---	0.90	1893.3	7347.9	3881	.0546	.0524
1969	2095.7	200.0	---	0.98	1943.0	7428.5	3823	.0568	.0520
1970	2014.9	140.0	50.0	0.99	1938.7	7288.9	3760	.0579	.0508
1971	1980.5	90.0	---	0.98	1936.4	7282.7	3761	.0606	.0521
1972	1908.0	---	55.0	1.02	1916.4	7528.0	3927	.0608	.0508
1973	2082.3	---	---	1.09	1915.1	7855.2	4102	.0634	.0497
1974	2303.3	---	---	1.19	1935.5	7995.1	4131	.0729	.0515
1975	2359.4	---	---	1.21	1955.1	8285.8	4238	.0759	.0515
1976	2609.9	---	---	1.32	1974.4	8720.1	4416	.0797	.0484
1977	2817.2	---	---	1.41	2001.2	8981.6	4488	.0842	.0474
1978	3221.9	---	150.0	1.64	2051.2	9585.3	4673	.0830	.0427
1979	3663.0	---	150.0	1.74	2187.8	10433.0	4600	.0101	.0404
1980	3296.5	---	---	1.47	2247.0	11280.8	4800	.1163	.0465

1/ State of Washington Office of Financial Management, revised 1976, 1979; includes King, Pierce, Snohomish, Kitsap Counties.
2/ U.S. Dept. of Commerce, Bureau of Economic Analysis, 1979, adjusted to 1967 dollars by Consumer Price Index (Seattle-Everett), U.S. Dept. of Labor, Bureau of Labor Statistics.
3/ CAB, Handbook of Airline Statistics, 1973, supp. 1975, CAB, Air Carrier Traffic Statistics, monthly; Air Carrier Financial Statistics, quarterly; adjusted by CPI (Seattle-Everett).

The primary assumptions underlying the forecast of originations include:

- The relationship between air passenger demand and local population growth, local per capita income, and average revenue per passenger mile will remain the same throughout the forecast period.
- Unforeseen technological changes will not significantly change the characteristics for air travel or materially affect the inflation-adjusted costs of flying.
- Terminal capacity, as well as the supporting infrastructure, will continue to be sufficient to accommodate air travel demands.

Table 4-3 indicates the projections of population, regional income, and average revenue per passenger mile used in the calculation for passenger originations.

TABLE 4-3

PROJECTIONS OF INDEPENDENT VARIABLES FOR PASSENGER FORECAST

Year	Regional Population 1/	Regional Personal income (1967) 1/	Average Passenger Revenue Per Revenue Passenger Mile (1967 $) 2/
1985	2,424,700	$5,640,000,000	.054
1990	2,633,700	6,304,000,000	.057
2000	3,077,600	7,713,000,000	.063

1/ Puget Sound Council of Governments, revised January 1981.
2/ Port of Seattle forecast, March 1981. These projections are based on a Boeing forecast of fuel costs rising at 3% annually.

Connecting passengers were forecast at a constant 26% of originating passengers based on conclusions from the previously cited Air Carrier Demand Forecast study.1/ The sum of connecting passengers and originations represents enplanements. Enplanements are assumed to equal deplanements. Therefore, a doubling of enplanements represents total passengers. The forecast of total passengers at Sea-Tac is presented in Table 4-4 and is used as data for the variable "P_t" in the operations forecast equation.

TABLE 4-4

TOTAL PASSENGER FORECAST
SEA-TAC INTERNATIONAL AIRPORT

Year	Total	Annual Growth
1980 Actual	9,156,800	--
1985	10,083,700	2.3%
1990	11,687,600	3.0%
2000	15,247,400	2.7%

Source: The Port of Seattle

4.2.2 Passengers By Sector/Stage Length

Passengers are further distinguished by geographic sector for the forecast years based on 1980 passenger numbers reported in Civil Aeronautics Board Service Segment Data. Service Segment Data identifies passengers on an annual basis by non-stop segments. Sectors were identified by seven "directions" (southbound/West Coast, southeast, east, Alaska/Canada, Hawaii, Far East, and Europe) and four stage lengths (0-500 nautical miles, 500-1,000 nautical miles, 1,000-1,500 nautical miles, and over 1,500 nautical miles) and are illustrated in Exhibit 4-1. The distribution of passengers among sectors in 1980 is presented in Table 4-5 and this distribution is used for the variable "S_j" in the operations forecast equation. This distribution is assumed to remain constant throughout the forecast period.

4.2.3 Load Factor

Load factor represents the percent of available seats on an aircraft occupied by passengers. Load factors of 52% in 1985, 55% in 1990, and 57% in 2000 are used as data for variable "L_t" in the operations forecast equation. Two assumptions underlying the load factors are (1) average load factors will increase on average over the forecast horizon and (2) "thru" passengers account for an additional 6% of the available seats.

In order to calculate the demand for total aircraft seats at Sea-Tac for each sector/stage length, the forecast of passengers by sector/stage length(P_t x S_j) was divided by the load factor (L_t). This forecast is represented by the first term in the numerator of the operations forecast equation.

TABLE 4-5

1980
PASSENGER DISTRIBUTION
BY SECTOR
SEA-TAC INTERNATIONAL AIRPORT

	Hawaii	Far East	Alaska/ Canada	West Coast	South East	East	Europe	Total
Less than 500 miles	-	-	2%	13%*	1%	10%	-	26%
500-1,000 miles	-	-	3%	21%	8%	**	-	32%
1,000-1,500 miles	-	-	10%	**	3%	12%	-	25%
Over 1,500 miles	4%	3%	-%	-	4%	4%	2%	17%
Total	4%	3%	15%	34%	16%	26%	2%	100%

* 6% of this 13% is NW Puget Sound commuter traffic.
** less than .5%.

Source: Civil Aeronautics Board Service Segment Data (1980).

4.2.4 Seats Distributed By Aircraft Type and Sector/Stage Length

The distribution of seats by aircraft type and by sector/stage length is accomplished by first forecasting the fleet mix, and second by applying the forecast to the distribution of seats for 1980. These steps are described in the following two sections.

Forecast of Fleet Mix

Commercial passenger aviation fleet mix projections are developed for both the aircraft fleet at Sea-Tac and for each sector/stage length. In both cases, aircraft are categorized by the number of engines and the width of the fuselage.

The aggregate commercial passenger aviation fleet mix forecast for Sea-Tac is expressed as percentages of total air carrier/commuter operations and is presented in Table 4-6. Assumptions incorporated into the forecast include:

- All categories of aircraft comply with FAR Part 36 noise level limits by 1985 unless covered by the "service to small communities exemption" of Title III of the Aviation Safety and Noise Abatement Act of 1979. At Sea-Tac, this exemption applies only to DC9s.
- New technology aircraft now under production (e.g., B757, B767, and DC9-80) will be introduced into the Sea-Tac fleet mix by 1985.
- Fuel efficient operation of aircraft will remain a high priority for airlines.
- Although commuter-type operations will capture an increasing share of short-haul markets, the markets (or routes) served by airlines at Sea-Tac will remain relatively stable.

Four-engine, wide-body aircraft, like the Boeing 747, represent 5% of Sea-Tac's operations and should retain about this share through year 2000. Long, overwater routes from Sea-Tac to Europe and Asia will continue to require four- and three-engine aircraft. The only four-engine, wide-body jets identified in aircraft manufacturers' plans are the Boeing 747 and the TA11, an Airbus Industrie derivative of the A300.

The category of four-engine, narrow-body aircraft (e.g., DC-8 and Boeing 707) accounted for approximately 2% of 1980 operations at Sea-Tac. This percentage should decrease given the age of the aircraft, the relatively high rate of fuel consumption, and the relatively high levels of noise generation. These aircraft are projected to be absent in the 1990 fleet mix.

TABLE 4-6

SEA-TAC AIR CARRIER/COMMUTER FLEET MIX FORECAST
(Percentage of Operations)

Aircraft Category	Actual 1980	Forecast 1985	1990	2000	Forecast of Average Seats Per Aircraft
Four-engine, wide-body (e.g., B747)	5%	6%	6%	6%	(375)
Four-engine, narrow-body (e.g., DC8, B707)	2%	2%	0%	0%	(175)
Three-engine, wide-body (e.g., L1011, DC10)	12%	14%	15%	16%	(245)
Two-engine, wide-body (e.g., A300, B767)	1%	8%	10%	17%	(225)
Three-engine, narrow-body (e.g., B727)	42%	32%	21%	0%	(135)
Two-engine, narrow-body (e.g., DC9, B737, B757)	12%	15%	27%	38%	(150)
Medium Turboprop (e.g., DeHavilland-7, Short 330)	0%	3%	5%	7%	(40)
Small Turboprop and Twin-Engine Piston (e.g., Beech 99, Britton Norman Islander)	26%	20%	16%	16%	(12)
TOTAL	100%	100%	100%	100%	

NOTE: No prop aircraft in sectors over 500 miles.

Sources: Civil Aeronautics Board Service Segment Data, International Edition of the Official Airline Guide, and the Port of Seattle.

The category of three-engine, wide-body jets is predicted to remain a significant proportion of the operations at Sea-Tac through the forecast period. As of December 31, 1980, 73 orders were reported for existing three-engine, wide-body aircraft types (e.g., L1011 and DC-10), with options for an additional 79.2/ Three-engine aircraft are projected to continue dominating two-engine aircraft on long-distance overwater routes. Consequently, this aircraft category is forecast to increase slightly.

Two-engine, wide-body aircraft, such as the Boeing 767, will be one of the most popular categories of aircraft in the next decade according to major aircraft manufacturers. The forecast projects an increase in shares from 1% to 17% in the year 2000. Increasing demand for fuel economy, and the retirement of some of the two- and three-engine, narrow-body aircraft, should contribute to the growing use of the two-engine, wide-body aircraft.

Although the Boeing 727 is the only three-engine, narrow-body aircraft now in commercial operation, the aircraft accounted for about 42% of Sea-Tac's 1980 operations. This type aircraft is forecast to be replaced eventually by two-engine, narrow- and two-engine, wide-body aircraft. Nonetheless, recent deliveries and continued sales of the Boeing 727 predict a 32% share of 1985 Sea-Tac operations. This share should drop to 21% in 1990 and to 0% in 2000 in anticipation of increasing operations of new technology, two-engine aircraft, and the possibility of reengining the Boeing 727 from three to two engines.

The category of two-engine, narrow-body aircraft accounted for 12% of 1980 operations at Sea-Tac. This category will include many of the fuel efficient new technology aircraft (e.g., B757 and DC-9-80). With the introduction of the DC9-80 and the Boeing 757 into the Sea-Tac fleet by 1985, operations are forecast to more than double in 1985 to 27% and more than triple to 38% in the year 2000.

The category of medium turboprop includes aircraft with 30-50 passenger capacity. In 1980, there were no airlines operating this size of aircraft at Sea-Tac. However, they have been subsequently introduced into Sea-Tac markets. Continued growth of medium turboprop commuter operations in shorthaul markets is anticipated within 500 nautical miles. Growth reflects a shift from large jet operations on the shorthaul markets and some redistribution of small turboprop and twin-engine piston commuter aircraft to larger commuter sized aircraft. The forecast projects an increase in shares from 3% in 1985 to 5% in 1990, and to 7% in 2000.

The category of small turboprop and twin-engine piston aircraft includes all commuter aircraft serving Sea-Tac in 1980. These aircraft typically accommodate from 5 to 20 passengers. The share of operations are forecast to decrease through the forecast years. However, the small seating capacity of these aircraft results in a relatively large proportion of the total aircraft operations.

The following assumptions were used in the application of the aggregate fleet mix projections discussed above to the individual sector/stage lengths:

- Between 1980 and 1985 -
    1. decrease in share of four-engine, narrow-body operations allocated to two-engine, wide-body
    2. decrease in share of three-engine, wide-body operations allocated to two-engine, wide-body
    3. decrease in share of three-engine, narrow-body operations allocated to two-engine, wide-body and two-engine narrow-body and medium prop
    4. decrease in share of small prop operations allocated to medium prop

- Between 1985 and 1990 -
    1. decrease in share of two-engine, narrow-body operations allocated to two-engine, wide-body
    2. decrease in share of three-engine, narrow-body operations allocated to two-engine, narrow-body and medium prop
    3. decrease in share of small prop operations allocated to medium prop
    4. decrease in share of four-engine, narrow-body operations allocated to two-engine, wide-body

- Between 1990 and 2000 -
  1. decrease in share of three-engine, narrow-body operations allocated to two-engine, narrow-body and two-engine, wide-body and medium prop
  2. decrease in share of small prop operations allocated to medium prop

Application of Fleet Mix Forecast

The distribution of seats by aircraft type and by sector/stage length is accomplished by the following steps:

(1) Calculate 1980 aircraft category "i" operations in sector/stage length "j" as a percent of total operations in sector/stage length "j" using data from Table 4-7.

(2) Multiply this result by the average number of seats for each aircraft category "i" using data from Table 4-6. Steps (1) and (2) give the distribution of seats for 1980.

(3) Use the forecast of fleet mix to adjust the 1980 seat distribution for 1985, 1990 and 1995. This forecast is discussed in the next section.

(4) Calculate the forecast seat distribution for each aircraft category in sector/stage length "j" as a percent of total seats in the sector/stage length "j".

These steps provide data for variable "A_{ij}" in the operations forecast equation.

TABLE 4-7

1980 AIR CARRIER/COMMUTER FLEET MIX - ALL SECTORS
(Annual Operations)

Stage Length	Sectors: FAR EAST	HAWAII	ALASKA	WEST	SOUTHEAST	EAST	EUROPE
0-500 nautical miles			B737 - 4,819 B727 - 1,338	B737 - 657 B727 - 17,292 DC9 - 2,232 DC8 - 505 DC10 - 1,338 B747 - 11 A300 - 403 L1011 - 1,681 BET - 1,213 BNI - 5,593 SWM - 2,364 Puget Sound (N&W) BNI - 16,297 CNA - 7,927	B737 - 2 B727 - 748 DC9 - 4,464 BET - 1,619 EMB - 308 SWM - 179 NDC - 227	B727 - 3,206 B747 - 9 DC10 - 2,302 BET - 9,766 EMB - 730 SWM - 388	
500-1000 nautical miles			B737 - 3,139 B727 - 1,049	B737 - 1,290 B727 - 25,241 B707 - 16 B747 - 191 DC8 - 43 DC9 - 2,862 DC10 - 2,571	B737 - 121 B727 - 7,417 B707 - 2 B747 - 2 DC9 - 82 DC8 - 1,260 DC10 - 1,488	N727 - 293 DC10 - 2	
1000-1500 nautical miles			B737 - 1,258 B727 - 7,410 B707 - 11 B747 - 794 DC10 - 2,555	B727 - 1,110	B727 - 5,533 DC10 - 2	B727 - 3,890 B707 - 1,087 B747 - 535 DC8 - 826 DC10 - 5,731	
Over 1500 nautical miles	B747 - 3,460	B747 - 1,547 DC10 - 212			B727 - 1,486 L1011 - 1,688 A300 - 414	B727 - 187 B747 - 619 DC8 - 234 DC10 - 1,658	B747 - 2,393
Subtotal	3,460	1,759	22,373	90,837	27,042	31,463	2,393

Total = 179,327

Abbreviations:

B = Boeing
BET = Beech 99;
BNI = Britten Norman Islander
CNA = Cessna 402
EMB = Embraer Bandeirante
NDC = Corvette
SWM = Swearingen Metro

Sources: Civil Aeronautics Board Service Segment Data and International Edition of the Official Airline Guide.

4.2.5 Operations Forecast

Applying the data described thusfar to the operations forecast equation and dividing by the average number of seats for each aircraft type (B_i in the forecast equation, data from Table 4-6), the forecast of commercial operations for each sector/stage length is derived. An add factor of .836 was then divided into the commercial operations for each sector/stage length. The purpose of the add factor is to adjust for variations in projected load factors, passenger forecasts and average seat per aircraft category assumptions. Finally, adjustments to operations in several sector/stage length categories were made to the four-engine, wide-body aircraft type to constrain the forecasts to conform more closely to prior experience. The forecasts are summarized in Table 4-8 for each year and for each sector/stage length. Appendix B presents the same data in more detail, by aircraft category.

4.3 ALL-CARGO AVIATION FORECAST

Growth of air cargo at Sea-Tac has been essentially static since 1976. Because of the 20-year span of this forecast, however, some estimate of increased all-cargo operations must be planned in order to accommodate expanded population and associated commercial trade. Therefore, a token 0.5% per year was used to forecast all-cargo operations. The forecast is shown by sector/stage length in Appendix B.

4.4 GENERAL AVIATION AND AIR TAXI FORECAST

In 1980, general aviation operations totaled 27,876. An estimated 5,000 air taxi operations took place. Combined, this represented approximately 15% of the airport's total operations. With no facilities for permanently based general aviation aircraft, very few operations are pleasure- or recreation-oriented. Trip purposes are primarily attributed to: executive flying (i.e., corporate-owned aircraft used for business); business flying (i.e., aircraft owned by businessmen and used for business); and Customs clearance. Air taxi operators at Sea-Tac are primarily small airplane cargo couriers. The following sections describe the forecast of operations, the fleet mix projections, and the distribution of operations by sector/stage length for general aviation and air taxis.

TABLE 4-8

SUMMARY OF AIR CARRIER AND COMMUTER AIRCRAFT OPERATIONS FORECAST
BY SECTOR/STAGE LENGTH
(Annual Operations)

Sector/Stage Length	Year 1980	1985	1990	2000
Hawaii	1,760	2,070	2,260	2,840
Canada and Alaska				
0-500 nautical miles	6,160	3,970	4,400	5,460
500-1000 nautical miles	4,190	4,050	4,410	5,390
1000-1500 nautical miles	12,030	14,090	15,120	17,420
Southbound/West Coast				
0-500 nautical miles	57,510	35,550	38,140	44,200
500-1000 nautical miles	32,210	31,300	33,530	38,210
1000-15000 nautical miles	1,110	640	740	760
Southeast				
0-500 nautical miles	7,550	3,210	3,420	4,060
500-1000 nautical miles	10,370	11,030	11,500	13,200
1000-1500 nautical miles	5,540	5,580	5,940	6,560
1500-2500 nautical miles	3,590	4,830	5,230	6,270
East				
0-500 nautical miles	16,400	27,450	28,150	33,740
500-1000 nautical miles	290	300	330	360
1000-1500 nautical miles	12,070	14,860	15,900	19,280
1500-2500 nautical miles	2,700	3,830	4,140	5,160
Asia	3,460	3,350	3,670	4,620
Europe	2,390	2,820	3,090	3,890
Total	179,330	168,930	179,970	211,420

Source: The Port of Seattle

4.4.1 General Aviation Operations

General aviation operations for Sea-Tac are projected to increase at 2% per year over the forecast period. Despite an annual growth rate of over 11% between 1975 and 1979, general aviation operations declined by 22% between 1979 and 1980. The FAA report Aviation Forecasts: FY 1981-1992 (September 1980) has forecast a 3.1% growth rate nationally between 1980 and 1992 for general aviation operations at towered airports. The less optimistic forecast of 2% per year used in this study is based on the recent downturn in the economy, the decreasing purchases of general aviation aircraft and the decreasing growth rates of student pilot enrollments. The general aviation operations forecast at Sea-Tac is as follows:

Year	General Aviation Annual Operations
1980 reported	27,876
1985	30,800
1990	34,000
2000	41,400

4.4.2 Air Taxi Operations

Like general aviation operations, air taxi operations are projected to increase at 2% per year over the forecast period. This modest rate of growth reflects the general growth in the economy. The air taxi operations forecast at Sea-Tac are as follows:

Year	Air Taxi Annual Operations
1980 estimated	5,000
1985	5,500
1990	6,080
2000	7,450

4.4.3 General Aviation and Air Taxi Fleet Mix

The forecast of general aviation/air taxi fleet mix is based on a sample of Sea-Tac control tower operations data and the projected changes in fleet mix for the United States active general aviation aircraft fleet.3/ Table 4-9 illustrates the exceptionally high proportion of twin-engine piston and turbine aircraft at Sea-Tac as compared to the U.S. general aviation aircraft fleet. Sales reports support the historical trend toward the increasing number and proportion of multi-engine, turbine aircraft in the general aviation/air taxi fleet. This trend is reflected in the number of general aviation/air taxi operations forecasted for Sea-Tac. (See Table 4-10.)

4.4.4 General Aviation and Air Taxi Sector/Stage Length

Geographic origin and destination sectors for general aviation/air taxi are generally defined by the location of Victor Airways. (See Exhibit 4-2). Proportions of aircraft types within sectors and between sectors are assumed to remain constant through the forecast period. Distribution of operations between sectors is based on a sample of control tower operations data and is estimated to be as follows:

North	25%
West	25%
South/Southwest	10%
Southeast	15%
Northeast/East	25%
Total	100%

The stage length of general aviation/air taxi aircraft departures is not addressed in this forecast. No distinction is necessary as input into the noise exposure projections.

TABLE 4-9

GENERAL AVIATION AND AIR TAXI FLEET MIX FORECAST
SEA-TAC INTERNATIONAL AIRPORT
(Percentage of Operations)

Aircraft Type	1980 Est.	1980 U.S. 1/	1985	1990	2000
Single-engine piston	33%	80.3%	32.0%	31.5%	27.0%
Twin-engine piston	41%	11.8%	40.5%	40.0%	39.0%
Turboprop	11%	1.6%	11.5%	12.5%	15.0%
Turbojet and Turbofan	12%	1.5%	13.0%	13.0%	16.0%
Helicopter	3%	2.8%	3.0%	3.0%	3.0%
Other (balloons, dirigibles, gliders)	0%	2.0%	0	0	0
TOTAL	100%	100.0%	100.0%	100.0%	100.0%

1/GAMA, General Aviation Statistical Data: 1980 Edition. Percentages are based on U.S. active general aviation aircraft.

Source: The Port of Seattle

TABLE 4-10

GENERAL AVIATION AND AIR TAXI FLEET MIX FORECAST
SEA-TAC INTERNATIONAL AIRPORT
(Annual Operations)

Aircraft Type	1980 Est.	1985	1990	2000
Single-engine piston	10,849	11,615	12,624	13,190
Twin-engine piston	13,479	14,701	16,030	19,052
Turboprop	3,617	4,174	5,010	7,328
Turbojet and Turbofan	3,945	4,719	5,210	7,816
Helicopter	986	1,089	1,202	1,466
TOTAL	32,876	36,298	40,076	48,852

Source: The Port of Seattle

4.5 MILITARY AVIATION FORECAST

Military operations have been steadily decreasing at Sea-Tac since 1973. In 1980, 541 military aircraft operations were reported. Annual operations are forecast to remain at approximately 540. Sector/stage lengths are projected through the forecast period to be 75% south and 25% north, each within the 0-500 nautical mile stage length.

4.6 FORECAST RANGE

Aside from the forecast presented in this chapter, two other forecasts were generated for air carrier operations. The results of those forecasts are presented in Table 4-11 as Alternative I and Alternative II. The methodology used to derive these forecasts are identical to that used to derive the forecast presented in this chapter with the following differences: (a) in Alternative I the add factor is omitted and (b) Alternative II represents the midpoint between the selected forecast and Alternative I. Both Alternative I and Alternative II represent lower forecasts of annual operations than the selected forecast.

In comparison with the three most recently prepared forecasts of annual operations at Sea-Tac by other governmental agencies, the selected forecast falls within a broad range of projected operations. This range of projections is presented in Exhibit 4-3. The Washington State Department of Transportation (WSDOT) forecast was prepared for the Washington State Airport System Plan (October 1980). The Federal Aviation Administration (FAA) forecast was prepared for the FAA Aviation Forecast--Seattle-Tacoma (December 1979). Both the WSDOT and FAA forecasts were prepared prior to airline deregulation and were not able to predict the new competitiveness which arose from the open-market environment of deregulation or to predict the current general downturn in the economy. Even though increases in commercial airline operations following deregulation exceeded the projections of both the WSDOT and FAA, growth rates forecasted by WSDOT and FAA are probably overly optimistic when viewed against the current general downturn in the economy, the air traffic controllers' strike, increasing aircraft operating costs, and the continuation of post-deregulation market

TABLE 4-11

RANGE OF FORECASTS
SEA-TAC INTERNATIONAL AIRPORT
(Annual Operations)

Categories	Selected Forecast	Alternative I	Alternative II
		1985	
Air Carrier	132,340	111,040	121,690
Commuter	36,590	36,590	36,590
GA/Air Taxi	36,300	36,300	36,300
Military	540	540	540
Total	205,770	184,470	195,120
		1990	
Air Carrier	141,320	118,530	129,920
Commuter	38,650	38,650	38,650
GA/Air Taxi	40,080	40,080	40,080
Military	540	540	540
Total	220,590	197,800	209,190
		2000	
Air Carrier	164,040	137,570	150,800
Commuter	47,380	47,380	47,380
GA/Air Taxi	48,850	48,850	48,850
Military	540	540	540
Total	260,810	234,340	247,570

Source: Port of Seattle

establishment (e.g., decrease in new market airline entrants, airline mergers, development of more profitable and energy-efficient airline route systems, introduction of large commuter-size aircraft into the Sea-Tac market, etc.). In contrast, the "high" and "low" forecasts prepared by the Puget Sound Council of Governments in the Air Carrier Demand Forecasts: Central Puget Sound Region (October 1980), project future levels of operations lower than the selected forecast through the year 1985 and through the year 2000 for the "low" PSCOG forecast.[4/] The lower projections of aircraft operations of both the PSCOG forecast and this study's selected forecast reflect such factors as lower projections of airline passengers, higher average seats per air carrier aircraft operation, a shift in the composition of the commuter airline fleet mix to larger commuter-sized aircraft, and lower forecasts of general aviation operations.

Footnotes

1/Puget Sound Council of Governments, Air Carrier Demand Forecasts: Central Puget Sound Region (October 1980).

2/Boeing, "Dimensions of Airline Growth", (March 1980).

3/General Aviation Manufacturers Association, General Aviation Statistical Data: 1980 Edition.

4/The PSCOG forecast includes operations of passenger air carrier, all-cargo, commuter and air taxi operations. Operations of military and general aviation from the selected forecast were added for purposes of comparison.

CHAPTER 4

FORECAST OF AVIATION DEMAND

4.1 INTRODUCTION

A forecast of aircraft operations is required in order to predict future aircraft-generated noise exposure levels. Based on the operations forecast, future noise exposure levels will reflect changes in the number of operations and types of aircraft in the fleet, and the sector in which the aircraft are traveling. A summary of the forecast used in this study is presented in Table 4-1. Projections represent demand unconstrained by airport facilities or airspace use.

TABLE 4-1

SUMMARY OF AVIATION FORECAST
SEA-TAC INTERNATIONAL AIRPORT

Forecast	Actual 1980	Forecast 1985	1990	2000
1. Passengers	9,156,800	10,083,700	11,687,600	15,247,400
% change from previous period	--	10.1%	15.9%	30.5%
2. Operations				
Air Carrier	132,720	132,340	141,320	164,040
Commuter Aviation	46,610	36,590	38,650	47,380
General Aviation/ Air Taxi	32,880	36,300	40,080	48,850
Military	540	540	540	540
TOTAL	212,750	205,770	220,590	260,810
% change from previous period	--	-3.0%	7.0%	18.0%

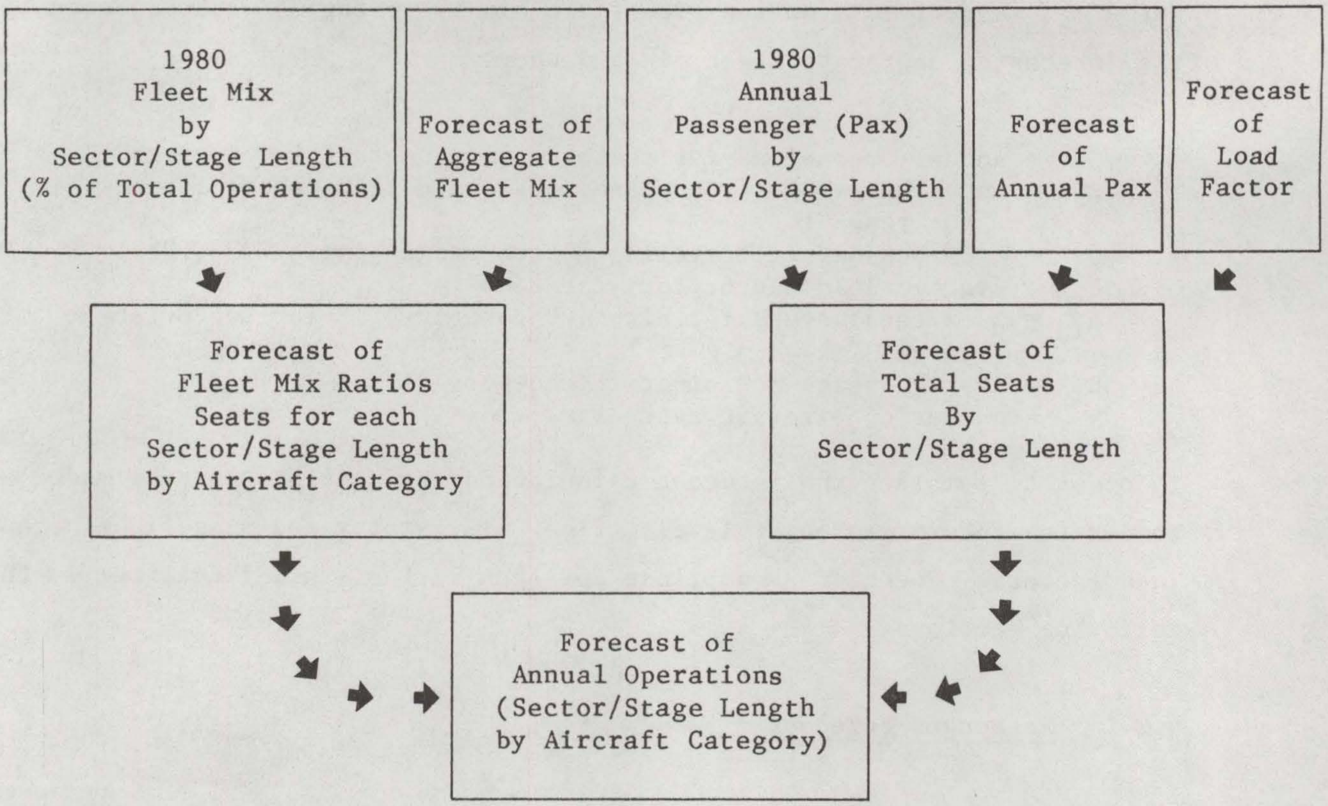
Source: The Port of Seattle

Separate projections are made for commercial passenger, general aviation, all-cargo, and military operations. Commercial passenger aviation operations include the operations of air carrier and commuter airlines and are derived from projected passenger levels. Trends of general aviation, all-cargo, and military operations are based on historical growth patterns.

In the following sections, forecast methodology is described, forecast assumptions are identified, and traffic projections are presented. The format of this forecast is designed for use in the Federal Aviation Administration (FAA) Integrated Noise Model (INM). As input for the INM, each aircraft operation must be identified by a representative aircraft type, flight track, and stage length of departure. Therefore, the forecast addresses each. The type of aircraft is differentiated in order to account for variance in aircraft performance and noise levels. The forecast, however, projects "categories" of aircraft which are later distinguished by representative "types" (i.e., manufacturers' models) as presented in Table 6-3. Flight track usage is identified from projections of the geographic origin and destination of an aircraft. Origins (the last stop of a flight before arriving at Sea-Tac) and destinations (the first stop of a flight leaving Sea-Tac) are grouped into geographic sectors which radiate from Sea-Tac. Stage length of departure is the distance in nautical miles to the first stop of a flight leaving Sea-Tac. Stage lengths are projected by distance intervals of 0-500, 500-1,000, 1,000-1,500, and over 1,500 nautical miles. This measure is used as a surrogate for takeoff weight. Thus, the longer the stage length, the heavier the aircraft.

4.2 COMMERCIAL PASSENGER AVIATION FORECASTS

Commercial passenger aviation forecasts include the operations of the certificated air carriers and commuter airlines. The procedure for developing the commercial passenger aviation forecast for operations is illustrated in the following diagram:



The forecast is a function of the demand for total aircraft seats by sector/stage length and the mix of aircraft serving each sector. It is represented by the following operations forecast equation which was developed by the Port of Seattle:

$$ {}_tO_j = \sum_{i=1}^{N} \frac{\dfrac{P_t \times S_j \times A_{ij}}{L_t}}{B_i} \qquad t = 1985,\ 1990,\ 2000 $$

Where A_{ij} is derived from the 1980 fleet mix by sector "j" and adjusted by the forecasted aggregate fleet mix and where

O_j = annual operations for sector/stage length "j" for year "t"
P_t = annual passengers (enplanements and deplanements) forecast for year "t"
S_j = % of passengers traveling sector/stage length "j" (1980)
L_t = average load factor for year t
A_{ij} = % of total seats for aircraft category "i" for sector/stage length "j"
B_i = average seats for aircraft category "i"
N = number of aircraft categories

In order to complete the forecast calculation, projections must be made concerning future passenger levels, fleet mix, sector and stage length, and load factors. Forecast assumptions for each variable are identified in the following sections.

4.2.1 Passenger Forecast

The passenger forecast methodology was adapted from the Puget Sound Council of Governments' Air Carrier Demand Forecasts: Central Puget Sound Region (October 1980), adjusted for 1979 and 1980 actual data.

Projections of passenger originations are based on the historical relationship between passenger originations, regional personal income per capita, and average revenue per passenger mile. The historical data are presented in Table 4-2. The multiple regression equation derived from this historical data is as follows:

$$Orig = -15.8 + 1.35 (I) - 1.54 (R)$$

where Orig = natural logarithm of annual adjusted originations per capita
I = natural logarithm of regional personal income per capita in 1967 dollars
R = natural logarithm of average revenue per passenger miles in 1967 dollars

TABLE 4-2
HISTORICAL DATA
PASSENGER FORECAST

Year	Originations (000)	Origination Adjustments (000) Deduction	Origination Adjustments (000) Addition	Adjusted Originations Per Capita	Regional Population (000)1/	Regional Personal Income (1967$ Mill) 2/	Personal Income Per Capita (1967$)	Average Passenger Revenue Per Revenue Passenger Mile (Current 3/)	Average Passenger Revenue Per Revenue Passenger Mile (1967$)
1954	501.8	---	---	0.38	1330.2	3534.0	2656	.0566	.0720
1955	573.1	---	---	0.42	1361.9	3763.2	2763	.0560	.0709
1956	618.8	---	---	0.44	1393.7	3943.1	2823	.0558	.0698
1957	683.8	---	---	0.48	1425.3	4079.8	2862	.0554	.0664
1958	695.5	---	---	0.48	1457.1	4204.3	2885	.0580	.0681
1959	771.3	---	---	0.52	1488.1	4426.9	2974	.0596	.0687
1960	686.3	---	---	0.45	1513.0	4451.5	2942	.0614	.0699
1961	721.4	---	---	0.47	1546.8	4677.6	3024	.0624	.0699
1962	911.4	150.1	---	0.48	1584.0	5070.3	3201	.0631	.0696
1963	765.9	---	---	0.48	1609.8	5076.0	3153	.0609	.0661
1964	898.2	---	---	0.55	1640.5	5207.2	3175	.0595	.0637
1965	1079.7	---	---	0.64	1685.1	5561.4	3301	.0587	.0621
1966	1291.6	80.0	110.0	0.76	1730.0	6291.9	3636	.5067	.0584
1967	1659.1	200.0	---	0.81	1810.8	6820.0	3766	.0549	.0549
1968	1932.7	220.0	---	0.90	1893.3	7347.9	3881	.0546	.0524
1969	2095.7	200.0	---	0.98	1943.0	7428.5	3823	.0568	.0520
1970	2014.9	140.0	50.0	0.99	1938.7	7288.9	3760	.0579	.0508
1971	1980.5	90.0	---	0.98	1936.4	7282.7	3761	.0606	.0521
1972	1908.0	---	55.0	1.02	1916.4	7528.0	3927	.0608	.0508
1973	2082.3	---	---	1.09	1915.1	7855.2	4102	.0634	.0497
1974	2303.3	---	---	1.19	1935.5	7995.1	4131	.0729	.0515
1975	2359.4	---	---	1.21	1955.1	8285.8	4238	.0759	.0515
1976	2609.9	---	---	1.32	1974.4	8720.1	4416	.0797	.0484
1977	2817.2	---	---	1.41	2001.2	8981.6	4488	.0842	.0474
1978	3221.9	---	150.0	1.64	2051.2	9585.3	4673	.0830	.0427
1979	3663.0	---	150.0	1.74	2187.8	10433.0	4600	.0101	.0404
1980	3296.5	---	---	1.47	2247.0	11280.8	4800	.1163	.0465

1/ State of Washington Office of Financial Management, revised 1976, 1979; includes King, Pierce, Snohomish, Kitsap Counties.
2/ U.S. Dept. of Commerce, Bureau of Economic Analysis, 1979, adjusted to 1967 dollars by Consumer Price Index (Seattle-Everett), U.S. Dept. of Labor, Bureau of Labor Statistics.
3/ CAB, Handbook of Airline Statistics, 1973, supp. 1975, CAB, Air Carrier Traffic Statistics, monthly; Air Carrier Financial Statistics, quarterly; adjusted by CPI (Seattle-Everett).

The primary assumptions underlying the forecast of originations include:

- The relationship between air passenger demand and local population growth, local per capita income, and average revenue per passenger mile will remain the same throughout the forecast period.
- Unforeseen technological changes will not significantly change the characteristics for air travel or materially affect the inflation-adjusted costs of flying.
- Terminal capacity, as well as the supporting infrastructure, will continue to be sufficient to accommodate air travel demands.

Table 4-3 indicates the projections of population, regional income, and average revenue per passenger mile used in the calculation for passenger originations.

TABLE 4-3

PROJECTIONS OF INDEPENDENT VARIABLES
FOR PASSENGER FORECAST

Year	Regional Population 1/	Regional Personal income (1967) 1/	Average Passenger Revenue Per Revenue Passenger Mile (1967 $) 2/
1985	2,424,700	$5,640,000,000	.054
1990	2,633,700	6,304,000,000	.057
2000	3,077,600	7,713,000,000	.063

1/ Puget Sound Council of Governments, revised January 1981.
2/ Port of Seattle forecast, March 1981. These projections are based on a Boeing forecast of fuel costs rising at 3% annually.

Connecting passengers were forecast at a constant 26% of originating passengers based on conclusions from the previously cited Air Carrier Demand Forecast study. 1/ The sum of connecting passengers and originations represents enplanements. Enplanements are assumed to equal deplanements. Therefore, a doubling of enplanements represents total passengers. The forecast of total passengers at Sea-Tac is presented in Table 4-4 and is used as data for the variable "P_t" in the operations forecast equation.

TABLE 4-4

TOTAL PASSENGER FORECAST
SEA-TAC INTERNATIONAL AIRPORT

Year	Total	Annual Growth
1980 Actual	9,156,800	--
1985	10,083,700	2.3%
1990	11,687,600	3.0%
2000	15,247,400	2.7%

Source: The Port of Seattle

4.2.2 Passengers By Sector/Stage Length

Passengers are further distinguished by geographic sector for the forecast years based on 1980 passenger numbers reported in Civil Aeronautics Board Service Segment Data. Service Segment Data identifies passengers on an annual basis by non-stop segments. Sectors were identified by seven "directions" (southbound/West Coast, southeast, east, Alaska/Canada, Hawaii, Far East, and Europe) and four stage lengths (0-500 nautical miles, 500-1,000 nautical miles, 1,000-1,500 nautical miles, and over 1,500 nautical miles) and are illustrated in Exhibit 4-1. The distribution of passengers among sectors in 1980 is presented in Table 4-5 and this distribution is used for the variable "S_j" in the operations forecast equation. This distribution is assumed to remain constant throughout the forecast period.

4.2.3 Load Factor

Load factor represents the percent of available seats on an aircraft occupied by passengers. Load factors of 52% in 1985, 55% in 1990, and 57% in 2000 are used as data for variable "L_t" in the operations forecast equation. Two assumptions underlying the load factors are (1) average load factors will increase on average over the forecast horizon and (2) "thru" passengers account for an additional 6% of the available seats.

In order to calculate the demand for total aircraft seats at Sea-Tac for each sector/stage length, the forecast of passengers by sector/stage length(P_t x S_j) was divided by the load factor (L_t). This forecast is represented by the first term in the numerator of the operations forecast equation.

TABLE 4-5

1980
PASSENGER DISTRIBUTION
BY SECTOR
SEA-TAC INTERNATIONAL AIRPORT

	Hawaii	Far East	Alaska/ Canada	West Coast	South East	East	Europe	Total
Less than 500 miles	-	-	2%	13%*	1%	10%	-	26%
500-1,000 miles	-	-	3%	21%	8%	**	-	32%
1,000-1,500 miles	-	-	10%	**	3%	12%	-	25%
Over 1,500 miles	4%	3%	-%	-	4%	4%	2%	17%
Total	4%	3%	15%	34%	16%	26%	2%	100%

* 6% of this 13% is NW Puget Sound commuter traffic.
** less than .5%.

Source: Civil Aeronautics Board Service Segment Data (1980).

4.2.4 Seats Distributed By Aircraft Type and Sector/Stage Length

The distribution of seats by aircraft type and by sector/stage length is accomplished by first forecasting the fleet mix, and second by applying the forecast to the distribution of seats for 1980. These steps are described in the following two sections.

Forecast of Fleet Mix

Commercial passenger aviation fleet mix projections are developed for both the aircraft fleet at Sea-Tac and for each sector/stage length. In both cases, aircraft are categorized by the number of engines and the width of the fuselage.

The aggregate commercial passenger aviation fleet mix forecast for Sea-Tac is expressed as percentages of total air carrier/commuter operations and is presented in Table 4-6. Assumptions incorporated into the forecast include:

- All categories of aircraft comply with FAR Part 36 noise level limits by 1985 unless covered by the "service to small communities exemption" of Title III of the Aviation Safety and Noise Abatement Act of 1979. At Sea-Tac, this exemption applies only to DC9s.
- New technology aircraft now under production (e.g., B757, B767, and DC9-80) will be introduced into the Sea-Tac fleet mix by 1985.
- Fuel efficient operation of aircraft will remain a high priority for airlines.
- Although commuter-type operations will capture an increasing share of short-haul markets, the markets (or routes) served by airlines at Sea-Tac will remain relatively stable.

Four-engine, wide-body aircraft, like the Boeing 747, represent 5% of Sea-Tac's operations and should retain about this share through year 2000. Long, overwater routes from Sea-Tac to Europe and Asia will continue to require four- and three-engine aircraft. The only four-engine, wide-body jets identified in aircraft manufacturers' plans are the Boeing 747 and the TA11, an Airbus Industrie derivative of the A300.

The category of four-engine, narrow-body aircraft (e.g., DC-8 and Boeing 707) accounted for approximately 2% of 1980 operations at Sea-Tac. This percentage should decrease given the age of the aircraft, the relatively high rate of fuel consumption, and the relatively high levels of noise generation. These aircraft are projected to be absent in the 1990 fleet mix.

TABLE 4-6

SEA-TAC AIR CARRIER/COMMUTER FLEET MIX FORECAST
(Percentage of Operations)

Aircraft Category	Actual 1980	Forecast 1985	1990	2000	Forecast of Average Seats Per Aircraft
Four-engine, wide-body (e.g., B747)	5%	6%	6%	6%	(375)
Four-engine, narrow-body (e.g., DC8, B707)	2%	2%	0%	0%	(175)
Three-engine, wide-body (e.g., L1011, DC10)	12%	14%	15%	16%	(245)
Two-engine, wide-body (e.g., A300, B767)	1%	8%	10%	17%	(225)
Three-engine, narrow-body (e.g., B727)	42%	32%	21%	0%	(135)
Two-engine, narrow-body (e.g., DC9, B737, B757)	12%	15%	27%	38%	(150)
Medium Turboprop (e.g., DeHavilland-7, Short 330)	0%	3%	5%	7%	(40)
Small Turboprop and Twin-Engine Piston (e.g., Beech 99, Britton Norman Islander)	26%	20%	16%	16%	(12)
TOTAL	100%	100%	100%	100%	

NOTE: No prop aircraft in sectors over 500 miles.

Sources: Civil Aeronautics Board Service Segment Data, International Edition of the Official Airline Guide, and the Port of Seattle.

The category of three-engine, wide-body jets is predicted to remain a significant proportion of the operations at Sea-Tac through the forecast period. As of December 31, 1980, 73 orders were reported for existing three-engine, wide-body aircraft types (e.g., L1011 and DC-10), with options for an additional 79.[2/] Three-engine aircraft are projected to continue dominating two-engine aircraft on long-distance overwater routes. Consequently, this aircraft category is forecast to increase slightly.

Two-engine, wide-body aircraft, such as the Boeing 767, will be one of the most popular categories of aircraft in the next decade according to major aircraft manufacturers. The forecast projects an increase in shares from 1% to 17% in the year 2000. Increasing demand for fuel economy, and the retirement of some of the two- and three-engine, narrow-body aircraft, should contribute to the growing use of the two-engine, wide-body aircraft.

Although the Boeing 727 is the only three-engine, narrow-body aircraft now in commercial operation, the aircraft accounted for about 42% of Sea-Tac's 1980 operations. This type aircraft is forecast to be replaced eventually by two-engine, narrow- and two-engine, wide-body aircraft. Nonetheless, recent deliveries and continued sales of the Boeing 727 predict a 32% share of 1985 Sea-Tac operations. This share should drop to 21% in 1990 and to 0% in 2000 in anticipation of increasing operations of new technology, two-engine aircraft, and the possibility of reengining the Boeing 727 from three to two engines.

The category of two-engine, narrow-body aircraft accounted for 12% of 1980 operations at Sea-Tac. This category will include many of the fuel efficient new technology aircraft (e.g., B757 and DC-9-80). With the introduction of the DC9-80 and the Boeing 757 into the Sea-Tac fleet by 1985, operations are forecast to more than double in 1985 to 27% and more than triple to 38% in the year 2000.

The category of medium turboprop includes aircraft with 30-50 passenger capacity. In 1980, there were no airlines operating this size of aircraft at Sea-Tac. However, they have been subsequently introduced into Sea-Tac markets. Continued growth of medium turboprop commuter operations in shorthaul markets is anticipated within 500 nautical miles. Growth reflects a shift from large jet operations on the shorthaul markets and some redistribution of small turboprop and twin-engine piston commuter aircraft to larger commuter sized aircraft. The forecast projects an increase in shares from 3% in 1985 to 5% in 1990, and to 7% in 2000.

The category of small turboprop and twin-engine piston aircraft includes all commuter aircraft serving Sea-Tac in 1980. These aircraft typically accommodate from 5 to 20 passengers. The share of operations are forecast to decrease through the forecast years. However, the small seating capacity of these aircraft results in a relatively large proportion of the total aircraft operations.

The following assumptions were used in the application of the aggregate fleet mix projections discussed above to the individual sector/stage lengths:

- Between 1980 and 1985 -
  1. decrease in share of four-engine, narrow-body operations allocated to two-engine, wide-body
  2. decrease in share of three-engine, wide-body operations allocated to two-engine, wide-body
  3. decrease in share of three-engine, narrow-body operations allocated to two-engine, wide-body and two-engine narrow-body and medium prop
  4. decrease in share of small prop operations allocated to medium prop

- Between 1985 and 1990 -
  1. decrease in share of two-engine, narrow-body operations allocated to two-engine, wide-body
  2. decrease in share of three-engine, narrow-body operations allocated to two-engine, narrow-body and medium prop
  3. decrease in share of small prop operations allocated to medium prop
  4. decrease in share of four-engine, narrow-body operations allocated to two-engine, wide-body

- Between 1990 and 2000 -
  1. decrease in share of three-engine, narrow-body operations allocated to two-engine, narrow-body and two-engine, wide-body and medium prop
  2. decrease in share of small prop operations allocated to medium prop

Application of Fleet Mix Forecast

The distribution of seats by aircraft type and by sector/stage length is accomplished by the following steps:

(1) Calculate 1980 aircraft category "i" operations in sector/stage length "j" as a percent of total operations in sector/stage length "j" using data from Table 4-7.

(2) Multiply this result by the average number of seats for each aircraft category "i" using data from Table 4-6. Steps (1) and (2) give the distribution of seats for 1980.

(3) Use the forecast of fleet mix to adjust the 1980 seat distribution for 1985, 1990 and 1995. This forecast is discussed in the next section.

(4) Calculate the forecast seat distribution for each aircraft category in sector/stage length "j" as a percent of total seats in the sector/stage length "j".

These steps provide data for variable "A_{ij}" in the operations forecast equation.

TABLE 4-7

1980 AIR CARRIER/COMMUTER FLEET MIX - ALL SECTORS
(Annual Operations)

Stage Length	Sectors: FAR EAST	HAWAII	ALASKA	WEST	SOUTHEAST	EAST	EUROPE
0-500 nautical miles			B737 - 4,819 B727 - 1,338	B737 - 657 B727 - 17,292 DC9 - 2,232 DC8 - 505 DC10 - 1,338 B747 - 11 A300 - 403 L1011 - 1,681 BET - 1,213 BNI - 5,593 SWM - 2,364 Puget Sound (N&W) BNI - 16,297 CNA - 7,927	B737 - 2 B727 - 748 DC9 - 4,464 BET - 1,619 EMB - 308 SWM - 179 NDC - 227	B727 - 3,206 B747 - 9 DC10 - 2,302 BET - 9,766 EMB - 730 SWM - 388	
500-1000 nautical miles			B737 - 3,139 B727 - 1,049	B737 - 1,290 B727 - 25,241 B707 - 16 B747 - 191 DC8 - 43 DC9 - 2,862 DC10 - 2,571	B737 - 121 B727 - 7,417 B707 - 2 B747 - 2 DC9 - 82 DC8 - 1,260 DC10 - 1,488	N727 - 293 DC10 - 2	
1000-1500 nautical miles			B737 - 1,258 B727 - 7,410 B707 - 11 B747 - 794 DC10 - 2,555	B727 - 1,110	B727 - 5,533 DC10 - 2	B727 - 3,890 B707 - 1,087 B747 - 535 DC8 - 826 DC10 - 5,731	
Over 1500 nautical miles	B747 - 3,460	B747 - 1,547 DC10 - 212			B727 - 1,486 L1011 - 1,688 A300 - 414	B727 - 187 B747 - 619 DC8 - 234 DC10 - 1,658	B747 - 2,393
Subtotal	3,460	1,759	22,373	90,837	27,042	31,463	2,393

Total = 179,327

Abbreviations:

B = Boeing
BET = Beech 99;
BNI = Britten Norman Islander
CNA = Cessna 402
EMB = Embraer Bandeirante
NDC = Corvette
SWM = Swearingen Metro

Sources: Civil Aeronautics Board Service Segment Data and International Edition of the Official Airline Guide.

4.2.5 Operations Forecast

Applying the data described thusfar to the operations forecast equation and dividing by the average number of seats for each aircraft type (B_i in the forecast equation, data from Table 4-6), the forecast of commercial operations for each sector/stage length is derived. An add factor of .836 was then divided into the commercial operations for each sector/stage length. The purpose of the add factor is to adjust for variations in projected load factors, passenger forecasts and average seat per aircraft category assumptions. Finally, adjustments to operations in several sector/stage length categories were made to the four-engine, wide-body aircraft type to constrain the forecasts to conform more closely to prior experience. The forecasts are summarized in Table 4-8 for each year and for each sector/stage length. Appendix B presents the same data in more detail, by aircraft category.

4.3 ALL-CARGO AVIATION FORECAST

Growth of air cargo at Sea-Tac has been essentially static since 1976. Because of the 20-year span of this forecast, however, some estimate of increased all-cargo operations must be planned in order to accommodate expanded population and associated commercial trade. Therefore, a token 0.5% per year was used to forecast all-cargo operations. The forecast is shown by sector/stage length in Appendix B.

4.4 GENERAL AVIATION AND AIR TAXI FORECAST

In 1980, general aviation operations totaled 27,876. An estimated 5,000 air taxi operations took place. Combined, this represented approximately 15% of the airport's total operations. With no facilities for permanently based general aviation aircraft, very few operations are pleasure- or recreation-oriented. Trip purposes are primarily attributed to: executive flying (i.e., corporate-owned aircraft used for business); business flying (i.e., aircraft owned by businessmen and used for business); and Customs clearance. Air taxi operators at Sea-Tac are primarily small airplane cargo couriers. The following sections describe the forecast of operations, the fleet mix projections, and the distribution of operations by sector/stage length for general aviation and air taxis.

TABLE 4-8

SUMMARY OF AIR CARRIER AND COMMUTER AIRCRAFT OPERATIONS FORECAST
BY SECTOR/STAGE LENGTH
(Annual Operations)

Sector/Stage Length	Year			
	1980	1985	1990	2000
Hawaii	1,760	2,070	2,260	2,840
Canada and Alaska				
0-500 nautical miles	6,160	3,970	4,400	5,460
500-1000 nautical miles	4,190	4,050	4,410	5,390
1000-1500 nautical miles	12,030	14,090	15,120	17,420
Southbound/West Coast				
0-500 nautical miles	57,510	35,550	38,140	44,200
500-1000 nautical miles	32,210	31,300	33,530	38,210
1000-15000 nautical miles	1,110	640	740	760
Southeast				
0-500 nautical miles	7,550	3,210	3,420	4,060
500-1000 nautical miles	10,370	11,030	11,500	13,200
1000-1500 nautical miles	5,540	5,580	5,940	6,560
1500-2500 nautical miles	3,590	4,830	5,230	6,270
East				
0-500 nautical miles	16,400	27,450	28,150	33,740
500-1000 nautical miles	290	300	330	360
1000-1500 nautical miles	12,070	14,860	15,900	19,280
1500-2500 nautical miles	2,700	3,830	4,140	5,160
Asia	3,460	3,350	3,670	4,620
Europe	2,390	2,820	3,090	3,890
Total	179,330	168,930	179,970	211,420

Source: The Port of Seattle

4.4.1 General Aviation Operations

General aviation operations for Sea-Tac are projected to increase at 2% per year over the forecast period. Despite an annual growth rate of over 11% between 1975 and 1979, general aviation operations declined by 22% between 1979 and 1980. The FAA report Aviation Forecasts: FY 1981-1992 (September 1980) has forecast a 3.1% growth rate nationally between 1980 and 1992 for general aviation operations at towered airports. The less optimistic forecast of 2% per year used in this study is based on the recent downturn in the economy, the decreasing purchases of general aviation aircraft and the decreasing growth rates of student pilot enrollments. The general aviation operations forecast at Sea-Tac is as follows:

Year	General Aviation Annual Operations
1980 reported	27,876
1985	30,800
1990	34,000
2000	41,400

4.4.2 Air Taxi Operations

Like general aviation operations, air taxi operations are projected to increase at 2% per year over the forecast period. This modest rate of growth reflects the general growth in the economy. The air taxi operations forecast at Sea-Tac are as follows:

Year	Air Taxi Annual Operations
1980 estimated	5,000
1985	5,500
1990	6,080
2000	7,450

4.4.3 General Aviation and Air Taxi Fleet Mix

The forecast of general aviation/air taxi fleet mix is based on a sample of Sea-Tac control tower operations data and the projected changes in fleet mix for the United States active general aviation aircraft fleet.3/ Table 4-9 illustrates the exceptionally high proportion of twin-engine piston and turbine aircraft at Sea-Tac as compared to the U.S. general aviation aircraft fleet. Sales reports support the historical trend toward the increasing number and proportion of multi-engine, turbine aircraft in the general aviation/air taxi fleet. This trend is reflected in the number of general aviation/air taxi operations forecasted for Sea-Tac. (See Table 4-10.)

4.4.4 General Aviation and Air Taxi Sector/Stage Length

Geographic origin and destination sectors for general aviation/air taxi are generally defined by the location of Victor Airways. (See Exhibit 4-2). Proportions of aircraft types within sectors and between sectors are assumed to remain constant through the forecast period. Distribution of operations between sectors is based on a sample of control tower operations data and is estimated to be as follows:

North	25%
West	25%
South/Southwest	10%
Southeast	15%
Northeast/East	25%
Total	100%

The stage length of general aviation/air taxi aircraft departures is not addressed in this forecast. No distinction is necessary as input into the noise exposure projections.

TABLE 4-9

GENERAL AVIATION AND AIR TAXI FLEET MIX FORECAST
SEA-TAC INTERNATIONAL AIRPORT
(Percentage of Operations)

Aircraft Type	1980 Est.	1980 U.S. [1]	1985	1990	2000
Single-engine piston	33%	80.3%	32.0%	31.5%	27.0%
Twin-engine piston	41%	11.8%	40.5%	40.0%	39.0%
Turboprop	11%	1.6%	11.5%	12.5%	15.0%
Turbojet and Turbofan	12%	1.5%	13.0%	13.0%	16.0%
Helicopter	3%	2.8%	3.0%	3.0%	3.0%
Other (balloons, dirigibles, gliders)	0%	2.0%	0	0	0
TOTAL	100%	100.0%	100.0%	100.0%	100.0%

[1]GAMA, General Aviation Statistical Data: 1980 Edition. Percentages are based on U.S. active general aviation aircraft.

Source: The Port of Seattle

TABLE 4-10

GENERAL AVIATION AND AIR TAXI FLEET MIX FORECAST
SEA-TAC INTERNATIONAL AIRPORT
(Annual Operations)

Aircraft Type	1980 Est.	1985	1990	2000
Single-engine piston	10,849	11,615	12,624	13,190
Twin-engine piston	13,479	14,701	16,030	19,052
Turboprop	3,617	4,174	5,010	7,328
Turbojet and Turbofan	3,945	4,719	5,210	7,816
Helicopter	986	1,089	1,202	1,466
TOTAL	32,876	36,298	40,076	48,852

Source: The Port of Seattle

4.5 MILITARY AVIATION FORECAST

Military operations have been steadily decreasing at Sea-Tac since 1973. In 1980, 541 military aircraft operations were reported. Annual operations are forecast to remain at approximately 540. Sector/stage lengths are projected through the forecast period to be 75% south and 25% north, each within the 0-500 nautical mile stage length.

4.6 FORECAST RANGE

Aside from the forecast presented in this chapter, two other forecasts were generated for air carrier operations. The results of those forecasts are presented in Table 4-11 as Alternative I and Alternative II. The methodology used to derive these forecasts are identical to that used to derive the forecast presented in this chapter with the following differences: (a) in Alternative I the add factor is omitted and (b) Alternative II represents the midpoint between the selected forecast and Alternative I. Both Alternative I and Alternative II represent lower forecasts of annual operations than the selected forecast.

In comparison with the three most recently prepared forecasts of annual operations at Sea-Tac by other governmental agencies, the selected forecast falls within a broad range of projected operations. This range of projections is presented in Exhibit 4-3. The Washington State Department of Transportation (WSDOT) forecast was prepared for the Washington State Airport System Plan (October 1980). The Federal Aviation Administration (FAA) forecast was prepared for the FAA Aviation Forecast--Seattle-Tacoma (December 1979). Both the WSDOT and FAA forecasts were prepared prior to airline deregulation and were not able to predict the new competitiveness which arose from the open-market environment of deregulation or to predict the current general downturn in the economy. Even though increases in commercial airline operations following deregulation exceeded the projections of both the WSDOT and FAA, growth rates forecasted by WSDOT and FAA are probably overly optimistic when viewed against the current general downturn in the economy, the air traffic controllers' strike, increasing aircraft operating costs, and the continuation of post-deregulation market

TABLE 4-11

RANGE OF FORECASTS
SEA-TAC INTERNATIONAL AIRPORT
(Annual Operations)

Categories	Selected Forecast	Alternative I	Alternative II
		1985	
Air Carrier	132,340	111,040	121,690
Commuter	36,590	36,590	36,590
GA/Air Taxi	36,300	36,300	36,300
Military	540	540	540
Total	205,770	184,470	195,120
		1990	
Air Carrier	141,320	118,530	129,920
Commuter	38,650	38,650	38,650
GA/Air Taxi	40,080	40,080	40,080
Military	540	540	540
Total	220,590	197,800	209,190
		2000	
Air Carrier	164,040	137,570	150,800
Commuter	47,380	47,380	47,380
GA/Air Taxi	48,850	48,850	48,850
Military	540	540	540
Total	260,810	234,340	247,570

Source: Port of Seattle

establishment (e.g., decrease in new market airline entrants, airline mergers, development of more profitable and energy-efficient airline route systems, introduction of large commuter-size aircraft into the Sea-Tac market, etc.). In contrast, the "high" and "low" forecasts prepared by the Puget Sound Council of Governments in the Air Carrier Demand Forecasts: Central Puget Sound Region (October 1980), project future levels of operations lower than the selected forecast through the year 1985 and through the year 2000 for the "low" PSCOG forecast.[4/] The lower projections of aircraft operations of both the PSCOG forecast and this study's selected forecast reflect such factors as lower projections of airline passengers, higher average seats per air carrier aircraft operation, a shift in the composition of the commuter airline fleet mix to larger commuter-sized aircraft, and lower forecasts of general aviation operations.

Footnotes

[1]/Puget Sound Council of Governments, Air Carrier Demand Forecasts: Central Puget Sound Region (October 1980).

[2]/Boeing, "Dimensions of Airline Growth", (March 1980).

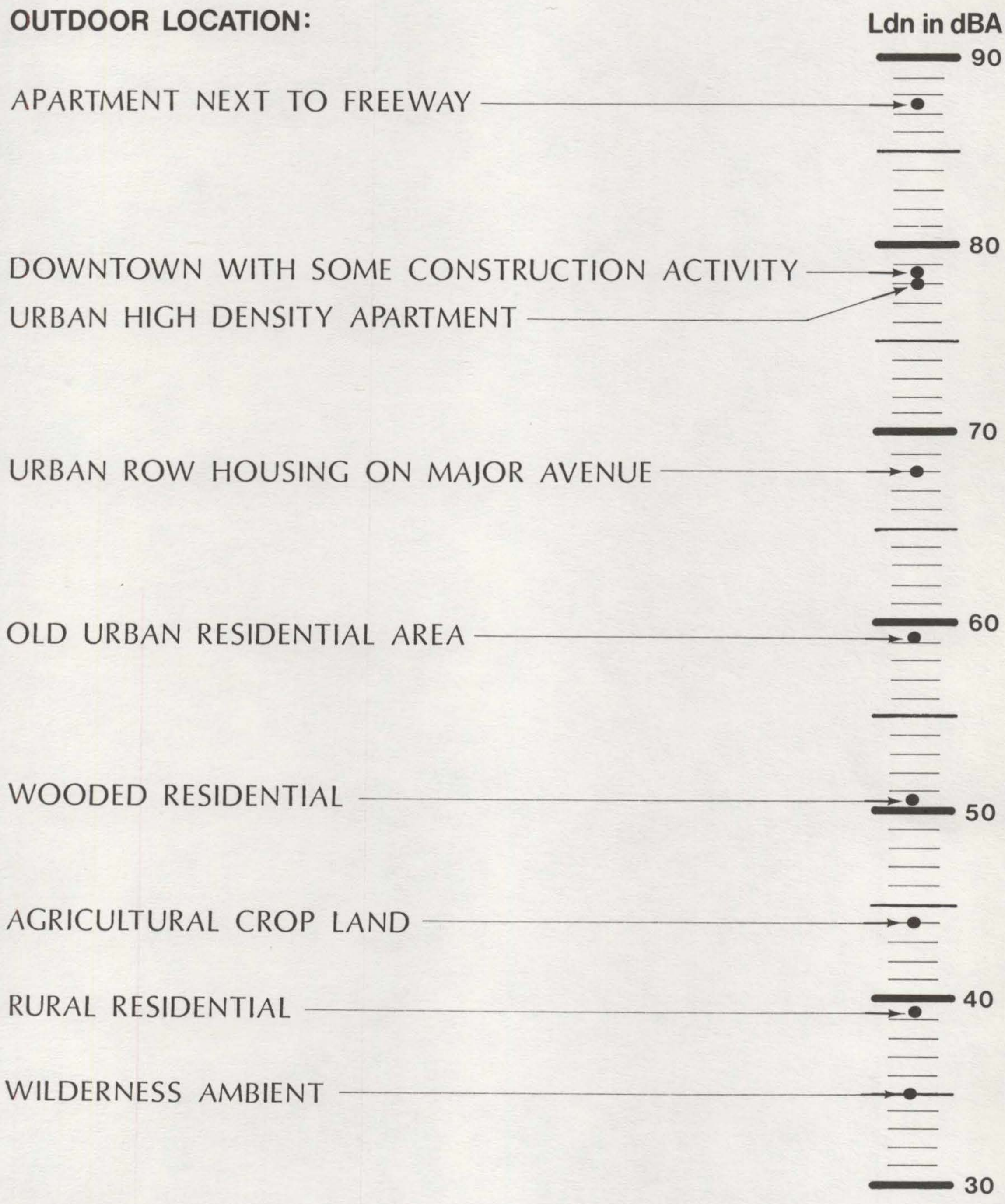
[3]/General Aviation Manufacturers Association, General Aviation Statistical Data: 1980 Edition.

[4]/The PSCOG forecast includes operations of passenger air carrier, all-cargo, commuter and air taxi operations. Operations of military and general aviation from the selected forecast were added for purposes of comparison.

CHAPTER 4

FORECAST OF AVIATION DEMAND

Comparative Ldn Values at Various Locations



SOURCE: ENVIRONMENTAL PROTECTION AGENCY, "PROTECTIVE NOISE LEVELS: CONDENSED VERSION OF EPA LEVELS DOCUMENT", (NOVEMBER 1978).

Exhibit 3-5