AIRPORT MASTER PLAN UPDATE

F O R

SEATTLE-TACOMA INTERNATIONAL AIRPORT

P&D Aviation

TECHNICAL REPORT NO. 6

AIRSIDE OPTIONS EVALUATION

AIRPORT MASTER PLAN UPDATE
FOR
SEATTLE - TACOMA INTERNATIONAL AIRPORT

Prepared by:

P&D AVIATION

Prepared for:

The Port of Seattle
SEATTLE - TACOMA INTERNATIONAL AIRPORT

SEPTEMBER 19, 1994

The P&D Aviation Team

P&D Aviation • Barnard Dunkelberg & Company • Berk & Associates
Mestre Greve Associates • Murase Associates • O'Neill & Company
Parsons Brinckerhoff • Thompson Consultants International
Landrum & Brown • Claire Barrett & Associates

TECHNICAL REPORT NO. 6
AIRSIDE OPTIONS EVALUATION

TABLE OF CONTENTS

TECHNICAL REPORT NO. 6
AIRSIDE OPTIONS EVALUATION

LIST OF TABLES

TECHNICAL REPORT NO. 6
AIRSIDE OPTIONS EVALUATION

LIST OF TABLES
(Continued)

TECHNICAL REPORT NO. 6
AIRSIDE OPTIONS EVALUATION

LIST OF TABLES
(Continued)

TECHNICAL REPORT NO. 6
AIRSIDE OPTIONS EVALUATION

LIST OF FIGURES

Section 1
EXECUTIVE SUMMARY

SECTION 1
EXECUTIVE SUMMARY

BACKGROUND

During the past several years numerous studies have concluded Sea-Tac's runways will reach capacity near the turn of the century. Preliminary results of the most recent delay studies described herein have determined aircraft delays will quadruple over the next two decades. The additional aircraft operating cost resulting from these delays is estimated to reach $245 million per year in 20 years. Dramatic growth of projected delays at Sea-Tac occurs since only one of Sea-Tac's two runways can be used for landings during bad weather, which occurs up to 44 percent of the time.

In response to continuing growth demands, plans are being evaluated to improve the capacity and efficiency and to mitigate environmental impact at Sea-Tac. This work is being accomplished through an update to the Airport Master Plan and a detailed Environmental Impact Statement (EIS). The Sea-Tac Master Plan Update is being conducted to develop a plan for improving the efficiency of the runway and taxiway (airside) system as well as the terminal, roadway and parking (landside) facilities. Of particular importance to the airside studies is the work being accomplished by an FAA sponsored Capacity Enhancement Task Force. This group is overseeing a computer simulation of Sea-Tac's existing and future airside operations. Final results of the simulation analysis should be available in early 1995. Preliminary results of this simulation analysis are used in this report to quantify potential future aircraft delays.

REPORT OBJECTIVE

The objective of this report is to describe the evaluation of options for the airfield, including a range of new runway options. Topics covered include airside facility requirements, aircraft delays, runway development costs, and preliminary runway environmental screening studies. The delay, cost, and environmental studies have been conducted for a wide range of airside options as listed below.

AIRFIELD IMPROVEMENTS

In addition to describing the evaluation of new runway options, this report recommends and includes the costs for several other airfield improvements designed to improve the safety and efficiency of aircraft operations. Recommended airfield improvements not associated with a new runway are describe below.

Runway Safety Area Improvements

To meet current FAA safety criteria, a clear, graded rectangular area beyond the end of the runway know as a "Runway Safety Area (RSA)", is required. Since the RSAs for the existing runways do not meet new FAA criteria each of the airfield options discussed below, except Option 1, No Action, includes various approaches for meeting the updated RSA requirements. This is accomplished by relocating the existing runway thresholds either 300 or 325 feet to the south or by constructing additional safety areas at the north runway ends and relocating South 154th Street. Options which include a relocated threshold cause the existing west runway to be shortened by 325 feet.

Extension of East Runway

All of the airfield options, except Option 1, No Action, include a net addition of 600 feet to the east runway (16L/34R) to bring the total runway length to 12,500 feet. In cases where the north runway thresholds would be displaced due to the runway safety areas, a total of 900 feet would need to be added to the south end of the runway to make up for the 300 foot displacement. The increased length is designed to allow departures of fully loaded Boeing 747s destined for cities as far away as Hong Kong.

Dual Taxiway Capability

Sea-Tac now has dual parallel taxiways only on the north portion of the airfield east of the runways. Dual parallel taxiways the full length of the airfield are recommended to help improve the flow of aircraft on the ground and particularly in front of the passenger terminal where considerable congestion can occur between taxiing aircraft. This will require limiting the types of aircraft that can be parked at certain gates on Concourses B & C and the relocation of a service road on the aircraft parking apron.

High Speed Exits

Four new high speed exits are recommended for the east runway (16L/34R). The addition of 30 degree exits at about 5,500 feet and 7,700 feet from the beginning of the runway reduces the runway occupancy time by about 30 percent. This will allow departures to be released more quickly when following an arriving aircraft.

NEW RUNWAY OPTIONS

The runway options evaluated in this analysis are classified according to runway configurations. These options are designed to be consistent with the Master Plan Update Scope of Work and to test the effect of changes to length, separation and stagger on the north runway end. The eight runway options are described below.

Option 1 - Existing Condition. Existing 11,900-foot and 9,425-foot runways with 800 feet of separation between centerlines.

Option 2 - Commuter - Close Spaced. Additional 5,200-foot commuter runway with 1,500 feet of separation from existing Runway 16L-34R.

Option 3 - Commuter - Dependent. Additional 5,200-foot commuter runway with 2,500 feet of separation from Runway 16L-34R.

Option 4A - Dependent - Additional 7,000-foot runway with 2,500 feet of separation from Runway 16L-34R.

Option 4B - Dependent - Staggered. Same as Option 4A except the north end threshold is staggered 1,435 feet to the south.

Option 4C - Dependent - Staggered. Similar to Option 4B but with 7,500-foot runway. North end threshold is staggered 935 feet to the south.

Option 5 - Dependent - Maximum Length. Additional 8,500-foot runway with 2,500 feet of separation from Runway 16L-34R.

Option 6 - Independent - Maximum Length. Same as Option 5 except the runway separation is 3,300 feet from Runway 16L-34R.

Future delays, development costs, and environmental considerations for each of the options listed above are estimated herein with the aim of reducing the number of alternatives to be evaluated in the EIS. Completion of the EIS and the Master plan Update is scheduled for the end of 1995.

PRELIMINARY NEW RUNWAY LENGTH FINDINGS

The required takeoff and landing lengths for the mix of aircraft anticipated to operate at the airport in the future were determined from aircraft performance charts and operations manuals. The significant findings of these studies are:

- A new 5,200-foot commuter runway (Options 2 and 3) would be of sufficient length to accommodate about 31 percent of the takeoffs and 31 percent of the landings in the year 2020.
- A new 7,000-foot runway (Options 4A and 4B) would be able to serve 77 percent of takeoffs and 91 percent of landings in 2020.
- A new 7,500-foot runway (Option 4C) would be able to serve 85 percent of takeoffs and 97 percent of landings in 2020.
- A new 8,500-foot runway (Option 5) would accommodate 90 percent of takeoffs and 99 percent of landings in 2020.

The capability of the new runway to accommodate all aircraft types for landing determines the amount of delay reduction which can be achieved. If approaching aircraft must cross other approaching traffic to lineup for longer runways then additional delays can occur. The following delay analysis confirms the 8,500-foot runway options result in the greatest delay reduction. The fact that the 8,500-foot runway cannot accommodate 10 percent of the aircraft takeoff requirements is not a problem since the new runway would be used very seldom for departures.

PRELIMINARY DELAY ANALYSIS FINDINGS

Measurement of aircraft delays was accomplished using the Federal Aviation Administration's Airport and Airspace Simulation Model (SIMMOD). This model is a sophisticated computer simulation which realistically simulates the movement of every aircraft for a given runway option. The model produces quantitative measures of aircraft air arrival delays, departure delays, and ground taxi delays. Preliminary findings of these studies are summarized below:

- Average aircraft delays are currently estimated to be between 5 to 6 minutes per operation at Sea-Tac. During degraded weather conditions which occur 44 percent of the time at Sea-Tac, delays average 11 minutes per aircraft operation.
- By the year 2015, with no new runway, average annual delays are expected to increase by four times from 5 - 6 minutes to 22 minutes per aircraft operation. About 88 percent of the year 2015 delay can be attributed to arrival delay, 11 percent to departure delay, and 1 percent to taxi delay.
- The commuter runway options (Options 2 and 3) would result in delays in the year 2015 between 14 to 21 minutes per operation.
- The 2,500-foot runway separation options (Options 4A, 4B, 4C and 5) would decrease average delays to between 4 to 6 minutes per operation in the year 2015 assuming the runways are operated in a dependent manner.

- The 3,300-foot runway separation option (Option 6) would also reduce delays to about 4 minutes per operation in the year 2015 assuming independent arrival streams. The added benefit resulting from independent streams is not demonstrated until demand grows beyond the level projected for the year 2015.

As described above the commuter runway options do not reduce delay in the year 2015 below todays levels. In fact delays for these options are projected to increase by 2.5 to 4 times. The 8,500-foot options provide slightly greater delay reductions than the 7,000-foot or 7,500-foot options. The value of the year 2015 saving in annual aircraft operating cost is estimated to be $270 million per year for the 8,500-foot runway options.

PRELIMINARY DEVELOPMENT COST FINDINGS

Development cost estimates have been formulated based on information contained in the first draft of the Preliminary Engineering Report prepared by HNTB and dated March 31, 1994 and on land acquisition costs described by Landrum and Brown in a memorandum dated September 1997. To the extent possible, the same assumptions and unit cost data have been used as described in the Preliminary Engineering Report. The cost model provides estimates for 55 individual items for each runway option evaluated. Total project construction and acquisition costs are summarized as follows:

- Option 1 - $0 million
- Option 2 - $79 - 91 million
- Option 3 - $297 - 341 million
- Option 4A -$411 - 473 million
- Option 4B -$348 - 401 million
- Option 4C -$369 - 425 million
- Option 5 - $456 - 524 million
- Option 6 - $773 - 889 million

It is important to note that Option 6 costs an additional $317 - 365 million over Option 5 but provides no apparent delay savings by the year 2015. Option 5 costs $87 - 99 million more than Option 4C but provides an additional annual delay savings of about $12 million per year by the year 2015. Option 4A is more expensive than Option 4C but also provides $12 million less of a delay savings benefit in the year 2015.

ENVIRONMENTAL SCREENING FINDINGS

A preliminary evaluation of the environmental impacts of each of the airside options was conducted by the EIS consultant team. The purpose of this analysis was to allow environmental impacts to be considered early in the airside evaluation process and prior to the formulation of the EIS alternatives. The results of the preliminary environmental impact screening analysis for each of the airside options are presented in Table 1-1.

Option 6 clearly causes the greatest impact of all the options considered. Approximately 560 homes are displaced and 28 acres of wetlands are impacted. This compares to 360 homes and 5 acres of wetlands estimated for Options 4A, 4B, 4C, and 5. The total area within the 65 DNL noise contour ranges from 7.65 square miles to 7.84 square miles for Options 4A, 4B, 4C, and 5. The Option 6 65 DNL noise contour increases to 8.13 square miles which is the largest of the noise impact areas. Overall the impacts associated with Options 4A, 4B, 4C, and 5 are very similar.

CONCLUSIONS

A graphic comparison of the year 2015 annual aircraft delay savings and estimated construction and acquisition costs are shown for each option

TABLE 1-1
ENVIRONMENTAL IMPACTS SUMMARY
OF MASTER PLAN UPDATE AIRSIDE OPTIONS [a]

	Master Plan Update Airside Options [b]						
	1A	**1B**	**3**	**4A**	**4C**	**5**	**6**
Noise: Impacted Area in year 2020 (sq. mi.)							
65-70 DNL	4.25	4.41	4.26	4.29	4.26	4.40	4.62
70-75 DNL	1.81	1.88	1.85	1.92	1.92	1.91	2.04
75 DNL and greater	1.39	1.44	1.40	1.46	1.47	1.53	1.47
Total	7.45	7.73	7.51	7.67	7.65	7.84	8.13
60-65 DNL	10.12	10.51	10.05	10.06	10.09	10.08	10.17
Noise: Population Impacts in year 2020							
65-70 DNL	11,610	12,250	11,870	12,210	12,150	12,760	13,290
70-75 DNL	1,150	1,360	1,140	1,190	1,180	1,170	1,330
75 DNL and greater	40	40	40	50	50	100	420
Total	12,800	13,650	13,050	13,450	13,380	14,030	15,040
60-65 DNL	40,820	42,370	40,440	40,700	40,770	40,760	41,030
Noise: Housing Impacts in year 2020							
65-70 DNL	4,860	5,100	4,960	5,100	5,080	5,320	5,620
70-75 DNL	520	610	510	530	530	510	580
75 DNL and greater	10	20	20	20	20	40	160
Total	5,390	5,730	5,480	5,650	5,630	5,870	6,360
60-65 DNL	17,910	18,580	17,690	17,870	17,900	17,920	17,980
Air Inventory (tons per day in year 2020)							
Carbon Monoxide	13.86	13.86	10.18	6.82	6.82	5.86	4.86
Nitrogen Oxides	6.82	6.82	6.49	6.19	6.19	6.11	6.02
Particulate Matter (PM10)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sulfur Oxides	0.33	0.33	0.28	0.23	0.23	0.22	0.20
Wetland Impacts (acres)							
Wetland Impacts	0	0	4.2	5.4	5.0	5.4	27.7
100-Year Floodplain Impacts (acres)							
100-Year Floodplain Impacts	0	0	1	7	2	7	30
Stream Relocation (linear feet)							
Stream Relocation	0	0	2,760	2,970	2,760	2,970	12,240
Earth Impacts (million cubic yards)							
Earth Impacts	0	0	12	17	13	17	28
Construction Impact (units displaced)							
Properties	0	0	330	410	400	420	700
Homes	0	0	260	330	300	320	500
Parks	0	0	0	0	0	0	1
Historic/Cultural sites	0	0	1	1	1	1	3
Schools	0	0	0	0	0	0	1

TABLE 1-1
ENVIRONMENTAL IMPACTS SUMMARY
OF MASTER PLAN UPDATE AIRSIDE OPTIONS [a]

	Master Plan Update Airside Options [b]						
	1A	1B	3	4A	4C	5	6
Noise Impacted (65+ DNL in year 2020) [c]							
Parks	6	6	6	6	6	6	6
Historic/Cultural sites	3	4	3	4	4	4	5
Churches	13	13	13	13	13	13	15
Hospitals/Nursing homes	0	0	0	0	0	0	0
Libraries	1	1	1	1	1	1	1
Schools	8	9	9	8	8	8	8

[a] Sources: Landrum & Brown, Shapiro & Associates, and Gambrell Urban - Population and dwelling units using 1990 census. Impacts presented for the preliminary airside options are subject to update as additional information is collected and as the Master Plan Update and Environmental Impact Statement progress.

[b] Option 1A/1B - Do-Nothing (1A assumes existing distribution of traffic, 1B assumes additional night traffic due to delay).

Option 3 - Commuter Dependent (New 5,200 foot long new runway located 2,500 feet west of Runway 16L/34R)

Option 4A - Programmatic Baseline (New 7,000 ft long runway located 2,500 feet west of Runway 16L/34R)

Option 4C - 7,500 ft Staggered (New 7,500 ft long runway located 2,500 feet west of Runway 16L/34R, north end of new runway south of existing)

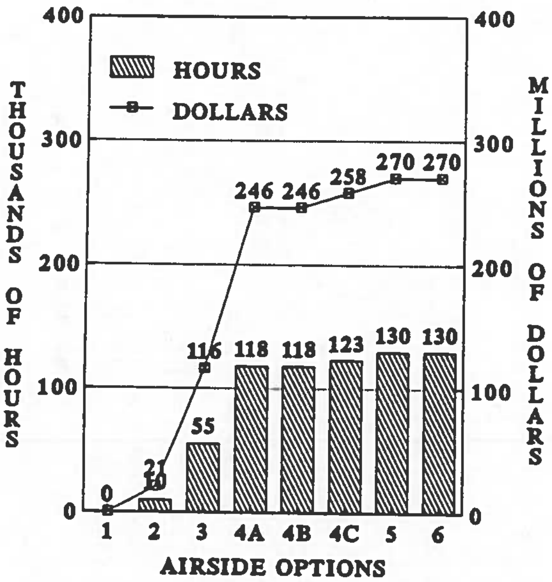
Option 5 - Dependent Maximum Length (New 8,500 ft long runway located 2,500 feet west of Runway 16L/34R)

Option 6 - Independent Maximum Length (New 8,500 ft long runway located 3,300 feet west of Runway 16L/34R)

[c] Noise impacted noise sensitive facilities noted above do not include the units displaced by construction.

in Figures 1-1 and 1-2 respectively. As can be seen, the increases in delay savings are not necessarily proportional with the increases in construction and acquisition costs. For example a two thirds increase in construction and acquisition costs in Option 6 when compared to Option 5 yields no delay improvement until demand exceeds 425,000 operations (about the year 2015).

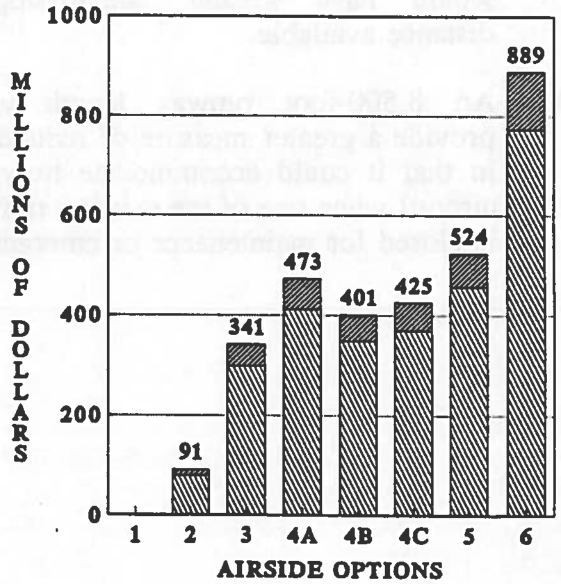
FIGURE 1-1
ANNUAL DELAY SAVINGS
YEAR 2015



Current research and advancements in technology suggest separation requirements for independent approaches will continue to be reduced. It is conceivable that by the year 2015, independent approaches will be possible to runways separated by 2,500 feet (Options 3, 4A, 4B, 4C and 5). Selection of Option 6 with its greater costs and impacts is therefore not recommended.

Although Options 2 and 3 are the least costly of the new runway alternatives and create the least impacts, these options provide a much lower amount of delay reduction when compared to the options with at least 7,000 feet of runway length. The lower benefits of these options is caused by the limited usage of the 5,200-foot long runway. Currently only about a third of the aircraft in the Sea-Tac fleet could use this shorter runway length. In the future this segment of the Sea-Tac aircraft fleet is projected to decrease. Therefore, due to the limited ability to reduce future delays, Options 2 and 3 are not recommended.

FIGURE 1-2
PRELIMINARY DEVELOPMENT COST ESTIMATES



When comparing the options with a 2,500-foot separation, delay savings are seen to increase as runway length increases. The greatest delay savings occur for Option 5 which is about 17 percent better than the next best option, Option 4C. Construction and acquisition costs are about 25 percent higher for Option 5 than for Option 4C. Using the year 2015 computed annual aircraft delay savings, the payback period for the added cost of Option 5 compared to Option 4C is about 6 to 7 years. For these reasons, Option 5 is recommended as the preferred operational alternative.

Specific benefits resulting from the selection of Option 5 are as follows:

- Aircraft delays are reduced to the lowest levels for demand expected through the year 2015.
- Fewer aircraft would be restricted from using the runway due to landing length limitations.
- All aircraft using a longer new runway would have greater takeoff/stopping distance available.
- An 8,500-foot runway length would provide a greater measure of redundancy in that it could accommodate heavy jet aircraft when one of the existing runways is closed for maintenance or emergency.

Section 2
AIRSIDE FACILITY REQUIREMENTS

SECTION 2
AIRSIDE FACILITY REQUIREMENTS

INTRODUCTION

In this section, airside facilities are identified which will be needed to satisfy the projected demand at Sea-Tac to the year 2020. Technical Report No. 5, Preliminary Forecast Report, describes the projections of aviation demand.

The process of determining facility requirements involves the application of established airport planning standards to the various forecast components to identify facility needs. These needs are then compared with existing facility capacities (a demand/capacity analysis) to determine new facility requirements.

The Federal Aviation Administration (FAA) has developed an extensive set of airport regulations and design guidelines and criteria, which are documented in FAA Advisory Circulars and Federal Aviation Regulations. In addition to FAA regulations and standards, various industry standards have been developed to estimate airport facility requirements from activity forecasts.

This report addresses only airside facility components. Landside elements, such as passenger terminal requirements, cargo needs and ground access needs will be addressed in another Technical Report. Airside requirements discussed below include runway length, runway pavement strength, runway safety areas and taxiways.

AIRPORT CLASSIFICATION

The FAA in its current AC 150/5300-13, Airport Design, has developed an airport reference code (ARC) system that relates airport design criteria and planning standards to two components: the operational and the physical characteristics of aircraft operating at or expected to operate at the airport. The first component of the ARC is a letter representing the aircraft approach speed and thus relates to operational characteristics. The aircraft approach category is a grouping of aircraft that is based on the approach speed (1.3 times the stalling speed) as follows:

Category	Approach Speed
A	Less than 91 knots
B	91 knots or more but less than 121 knots
C	121 knots or more but less than 141 knots
D	141 knots or more but less than 166 knots
E	166 knots or more

Current and projected aircraft operating at Sea-Tac are in approach Categories A through D.

The second component of the ARC is the airplane design group and relates to the wingspan of aircraft and therefore is a physical characteristic. The grouping of aircraft by wingspan (Airplane Design Group) is as follows:

Airplane Design Group	Wingspan
I	Up to but not including 49 ft
II	49 ft up to but not including 79 ft
III	79 ft up to but not including 118 ft
IV	118 ft up to but not including 171 ft
V	171 ft up to but not including 214 ft
VI	214 ft up to but not including 262 ft

The aircraft approach speed element of the ARC generally deals with runways and runway related facilities whereas the wingspan (and relevant Airplane Design Group) relates to separations required between airfield elements, such as runway-taxiway separations, taxilane and apron clearances, etc.

Today, the Boeing 747-400 is the critical aircraft in terms of airport geometrics and design, as it is the largest civil transport used at most major airports worldwide. With a 213 foot wingspan, the B747-400 is classified as an ADG V aircraft and thus is presently the most demanding in terms of facility requirements and clearances. Because of the anticipated need for even larger aircraft, with seating capacities from 500 to 800 passengers, airfield geometrics adequate for the B747-400 will not be adequate for the next generation "New Large Airplanes".

The next generation of airplanes is being studied by aircraft manufacturers for transport of high passenger volumes over very long distances, typical of mission requirements for airline routes to the Far East and Asia. While manufacturers are confident that mission requirements and performance specifications can be met, an important design issue is the compatibility of the size of the new large airplanes and existing airfield and terminal geometrics of major airports around the world. For example, the wingspans being considered for new large airplanes are in the 260 to 280 foot range. Based on present planning and design guidelines, such an aircraft would require 200-foot wide runways and runway to taxiway separations of at least 469 feet. This compares to a 150-foot runway width and 394-foot separation requirement for the B747-400.

If Sea-Tac is to compete as a major international airport in the long term, it must be capable of accommodating the next generation, high capacity aircraft. It is therefore recommended that planning and design standards based on projected new large airplane characteristics be applied in this master plan update. For these purposes the following general dimensions will be assumed:

- Wingspan - 280 feet
- Length - 260 feet
- Tail height - 78 feet
- Main landing gear track - up to 55 feet

The ARC resulting from these dimensions exceeds the largest category in the current FAA classification system as the above wingspan is greater than that covered by Aircraft Design Group VI. The FAA currently accommodates this anomaly with the design group designation VI+, and therefore the ARC to be applied will be D-VI+.

Table 2-1 presents the relevant airport planning standards to be used in this study. In some cases, standards based on specific aircraft dimensions differ from those for the aircraft design group. Planning and design standards for both the assumed aircraft dimensions and ARC are shown in Table 2-1. It should be noted that these standards reflect the long term geometric requirements, and that the timing of improvements to meet these standards will be better known after new airplane characteristics are further developed.

RUNWAY TAKEOFF LENGTH REQUIREMENTS

Many factors affect the runway takeoff length requirements at an airport. The current and expected mix of aircraft operating at the airport is a critical factor. Runway takeoff length is also affected by the aircraft stage length (distance of flight), runway slope (gradient), temperature, and wind direction and velocity. The discussion below includes consideration of runway length requirements for the existing

TABLE 2-1
AIRPORT PLANNING STANDARDS [a]

AIRPORT DESIGN AIRPLANE AND AIRPORT DATA (FEET)	
Aircraft Approach Category D and E	
Airplane Design Group VI+	
Airplane wingspan	280
Primary runway end is precision instrument 1/2-statute mile or less	
Other runway end is precision instrument 1/2-statute mile or less	
Airplane undercarriage width (1.15 x main gear track)	41.5
Airport elevation	429
Airplane tail height	78

RUNWAY AND TAXIWAY WIDTH AND CLEARANCE STANDARD DIMENSIONS (FEET)

	New Large Airplane [b]	ARC D-VI+
SEPARATION STANDARDS		
Runway centerline to parallel runway centerline for simultaneous operations when wake turbulence is a factor:		
VFR operations	2,500	2,500
IFR departures	2,500	2,500
IFR approach and departure with approach to near threshold	2,500	2,500
IFR approach and departure with approach to far threshold	2,500 [c]	2,500 [c]
IFR approaches	3,400	3,400
Runway centerline to parallel taxiway/taxilane centerline	469	600
Runway centerline to edge of aircraft parking	469	500
Taxiway centerline to parallel taxiway/taxilane centerline	346	346
Taxiway centerline to fixed or movable object	206	206
Taxilane centerline to parallel taxilane centerline	318	318
Taxilane centerline to fixed or movable object	178	178

TABLE 2-1
AIRPORT PLANNING STANDARDS [a]
(Continued)

RUNWAY PROTECTION ZONES		
Runway protection zone Runway 16 end:		
Length	2,500	2,500
Width 200 feet from runway end	1,000	1,000
Width 2,700 feet from runway end	1,750	1,750
Runway protection zone Runway 34 end:		
Length	2,500	2,500
Width 200 feet from runway end	1,000	1,000
Width 1,900 feet from runway end	1,750	1,750
Departure runway protection zone:		
Length	1,700	1,700
Width 200 feet from the far end of TORA	500	500
Width 1,900 feet from the far end of TORA	1,010	1,010
OBSTACLE FREE ZONES		
Runway obstacle free zone (OFZ) width	469	469
Runway obstacle free zone length beyond each runway end	200	200
Approach obstacle free zone width	469	469
Approach obstacle free zone length beyond approach light system	200	200
Approach obstacle free zone slope from 200 feet beyond threshold	50:1	50:1
Inner-transitional surface obstacle free zone slope	3:1	3:1
RUNWAY DESIGN STANDARDS		
Runway width	200	200
Runway shoulder width	40	40
Runway blast pad width	280	280
Runway blast pad length	400	400
Runway safety area (RSA) width	500	620
Runway safety area length beyond each runway end or stopway end, whichever is greater	1,000	1,000
Runway object free area (ROFA) width	800	800
Runway object free area length beyond each runway end or stopway end, whichever is greater	1,000	1,000
Clearway width	500	500
Stopway width	200	200

TABLE 2-1
AIRPORT PLANNING STANDARDS [a]
(Continued)

TAXIWAY DESIGN STANDARDS		
Taxiway width	103.3	103.3
Taxiway edge safety margin	20	20
Taxiway shoulder width	40	40
Taxiway safety area width	280	280
Taxiway object free area width	412	412
Taxilane object free area width	356	356
Taxiway wingtip clearance	66	66
Taxilane wingtip clearance	38	38
THRESHOLD SURFACES		
Threshold surface at primary runway end:		
Distance out from threshold to start of surface	200	200
Width of surface at start of trapezoidal section	1,000	1,000
Width of surface at end of trapezoidal section	4,000	4,000
Length of trapezoidal section	10,000	10,000
Length of rectangular section	0	0
Slope of surface	34:1	34:1
THRESHOLD SURFACES (Continued)		
Threshold surface at other runway end:		
Distance out from threshold to start of surface	200	200
Width of surface at start of trapezoidal section	1,000	1,000
Width of surface at end of trapezoidal section	4,000	4,000
Length of trapezoidal section	10,000	10,000
Length of rectangular section	0	0
Slope of surface	34:1	34:1

[a] Source: AC 150/5300-13, Airport Design.

[b] Standards based on a new large airplane with a wingspan of 280 feet. These standards can be used in lieu of ARC D-VI+ standards for wing span up to 280 feet.

[c] Plus 100 feet for each 500 feet of threshold stagger.

runways as well as a new third runway.

Maximum Aircraft Flight Distant

In current or recent service, Sea-Tac Airport has served non-stop markets as far away as Taipei, Taiwan, 6,066 statue miles from Sea-Tac Airport (Table 2-2). In order to estimate the farthest markets which would potentially be served by Sea-Tac Airport over the planning horizon (year 2020), non-stop service from San Francisco International Airport to the most distant cities was examined. The farthest non-stop city from Sea-Tac served by San Francisco International Airport in both passenger and all-cargo service is Hong Kong, which is 6,489 miles from Sea-Tac Airport (Table 2-2). San Francisco International has approximately the passenger traffic that is projected for Sea-Tac Airport between 2000 and 2020. It is concluded that Hong Kong should be considered the most distant market to be served by Sea-Tac Airport over the planning horizon with non-stop passenger and all-cargo service.

Affect of Aircraft Mix

Runway takeoff length requirements for aircraft models expected to operate at the airport between now and 2020 are shown in Table 2-3. Runway lengths are shown for typical maximum flight distances from Sea-Tac for each aircraft type. This table was developed to show the overall affect the aircraft type has on takeoff length requirements and is based on the following general assumptions:

- Zero runway gradient
- Zero winds
- Temperature of 84°F (unless footnoted otherwise)

This table identifies critical aircraft types for takeoff runway length at Sea-Tac.

For flights taking off to the north at Sea-Tac there is an uphill runway gradient of .71 to .72%. For this upward slope, approximately 4 to 7% greater runway length is required for takeoff than shown in Table 2-3. This table illustrates that the wide body aircraft, such as the B747 and MD-11, for long flight distances, require the greatest takeoff length. The critical aircraft is the B747 at maximum gross takeoff weight.

Figure 2-1 illustrates the percent of the projected aircraft takeoffs that would be accommodated by a given runway length for the projected aircraft fleet mixes in years 2000 and 2020 at the airport. The takeoff length requirements in this figure were taken from Table 2-1 and adjusted upward by 3% to account for the upward gradient on departures to the north. As shown in Figure 2-1, approximately 31% of takeoffs in the year 2020 can be accommodated on a runway of 5,200 feet in length, 77% on a 7,000-foot runway and 90% on an 8,500-foot runway.

Takeoff Length for Critical Aircraft

The two aircraft operating at Sea-Tac requiring the greatest runway length are the B747-200 and B747-400 operated at maximum gross takeoff weight. These aircraft are commonly used in long-haul all-cargo service throughout the world. Table 2-4 and Figure 2-2 illustrate the relationship between flight distance and payload weight and runway length. In Table 2-4 the runway length requirement for takeoff on Runways 16L and 16R are compared with Runways 34R and 34L to identify the affect of runway gradient on takeoff length required.

Several conclusions can be drawn from these data. The critical runways for takeoff are Runways 34R and 34L due to the uphill gradient. The critical aircraft is the B747-200, which requires a runway length of 12,500 feet

TABLE 2-2
COMPARISON OF LONGEST SCHEDULED FLIGHT DISTANCES FROM SEATTLE-TACOMA AND SAN FRANCISCO INTERNATIONAL AIRPORTS [a]

Non-Stop Service from San Francisco International Airport			Non-Stop Service from Seattle-Tacoma International Airport	
	Distance (Statute Miles)			
City	From San Francisco	From Seattle-Tacoma	City	Distance From Sea-Tac (Statute Miles)
Passenger Service to Europe				
Amsterdam, Netherlands	5,474	4,886	Amsterdam, Netherlands	4,886
Frankfurt, Germany	5,700	5,108	Copenhagen, Denmark	4,868
London, England	5,375	4,806	London, England	4,806
Paris, France	5,593	5,027		
Passenger Service to Asia				
Hong Kong, Hong Kong	6,913	6,489	Seoul, Korea	5,197
Osaka, Japan	5,389	5,015	Shanghai, China	5,723
Seoul, Korea	5,636	5,197	Taipei, Taiwan	6,066
Shanghai, China	6,154	5,723	Tokyo, Japan	4,797
Taipei, Taiwan	6,458	6,066		
Tokyo, Japan	5,155	4,797		
Cargo Service				
Hong Kong, Hong Kong	6,913	6,489	Amsterdam, Netherlands	4,886
London, England	5,375	4,806	Luxembourg, Luxembourg	5,075
Seoul, Korea	5,636	5,197	Shanghai, China	5,723
Taipei, Taiwan	6,458	6,066		
Tokyo, Japan	5,155	4,797		

[a] Sources: Official Airline Guides, OAG Desktop Flight Guide, OAG Air Cargo Guide, and OAG data files for 1993. Source shown is existing service.

TABLE 2-3
RUNWAY TAKEOFF LENGTH REQUIREMENTS FOR TYPICAL MAXIMUM FLIGHT DISTANCES FROM SEATTLE-TACOMA INTERNATIONAL AIRPORT

Aircraft Type [a]	Typical Maximum Flight Distance from Seattle-Tacoma [b]		Take-off Length Required [c] (Feet)
	Distance (Statute Miles)	City	
120 Seats and Under			
B737-200	679	San Francisco, California	4,900
B373-500	1,736	Chicago, Illinois	6,600
B737-200C [e]	1,448	Anchorage, Alaska	8,500
121 to 170 Seats			
B737-300	2,279	Charlotte, North Carolina	6,600
B737-400	1,533	Fairbanks, Alaska	6,100
MD 83	1,892	Houston, Texas	6,500
B727-100C [e]	1,971	Cincinnati, Ohio	8,600 [i]
171 to 240 Seats			
B757-200	2,408	New York, New York	5,500
B767-200 [f]	2,724	Miami, Florida	5,400
241 - 350 Seats			
B767-300ER	4,868	Copenhagen, Denmark	7,000
	4,886	Amsterdam, Netherlands	7,000
L1011-200	2,677	Honolulu, Hawaii	6,600
DC10-30 [g]	2,677	Honolulu, Hawaii	6,700
Over 350 Seats			
B747-200	4,797	Tokyo, Japan	8,800
B747-400	6,066	Taipei, Taiwan	8,400
B777 [h]	5,723	Shanghai, China	9,400 [i]
MD11	5,723	Shanghai, China	8,900
B747-200F [e]	5,075	Luxembourg, Luxembourg	12,200 [i]
B747-400F [e]	5,075	Luxembourg, Luxembourg	10,300
MD11F [e]	5,723	Shanghai, China	11,000 [i]

[a] Cargo aircraft are shown under the seating category for equivalent-sized aircraft.

[b] Cities and distances are farthest non-stop distances served from Sea-Tac currently or in the past for each aircraft type, unless footnoted otherwise.

[c] Runway take-off length requirements are based on the distance shown in the table, zero winds, temperature of 84°F (unless footnoted otherwise) and a zero runway gradient. Passenger aircraft requirement is based on a full passenger load (200 to 216 pounds per passenger for passenger and baggage) and no cargo. Cargo aircraft requirements are based on maximum aircraft payload if possible. If the flight distance is too great for the maximum payload, the take-off distance is based on the maximum gross take-off weight for the aircraft. For a 0.71 to 0.72 downward slope, approximately 2.5 to 5 percent less runway length is required for take-off. For a 0.71 to 0.72 upward slope, approximately 3 to 7 percent greater runway length is required for take-off.

[d] Runway landing length requirements are based on a zero runway gradient, wet runway, maximum flaps, and maximum landing weight.

TABLE 2-3
RUNWAY TAKEOFF LENGTH REQUIREMENTS FOR TYPICAL MAXIMUM FLIGHT DISTANCES FROM SEATTLE-TACOMA INTERNATIONAL AIRPORT

[e] Cargo aircraft.

[f] Based on 88°F.

[g] Based on 93°F.

[h] Potential future service.

[i] Aircraft is at maximum gross take-off weight.

FIGURE 2-1
CUMULATIVE TAKEOFF LENGTH REQUIREMENT AT SEATTLE-TACOMA INTERNATIONAL AIRPORT

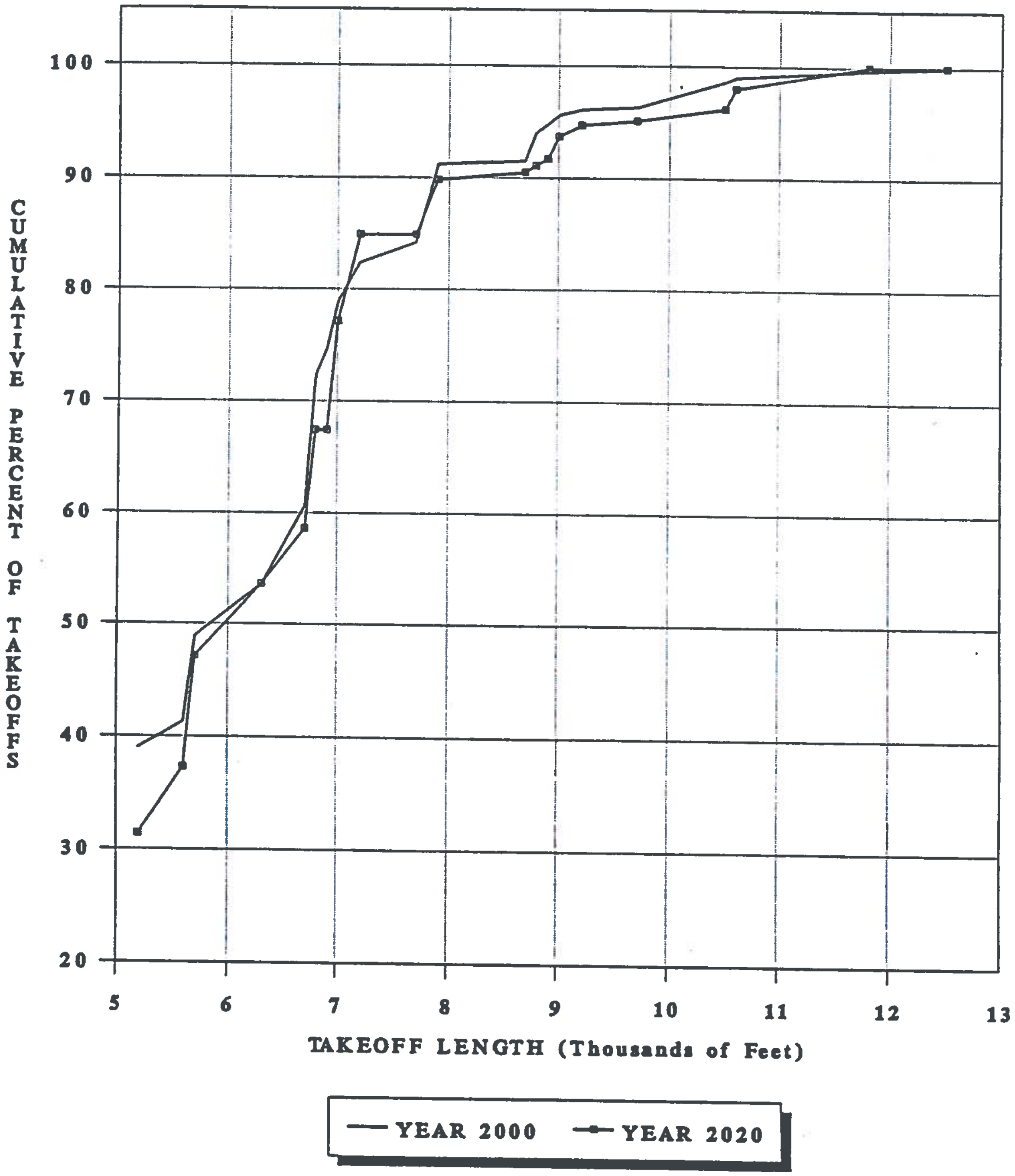


TABLE 2-4
RUNWAY TAKEOFF LENGTH REQUIREMENTS FOR B747-200 AND B747-400 AIRCRAFT AT SEATTLE-TACOMA INTERNATIONAL AIRPORT

Flight Distance (Statute Miles)	City [a]	Take-off Weight [b] (Thousands of Pounds)	Payload Weight [c] (Thousands of Pounds)	Runway Length Required for Takeoff [d] (Feet)	
				Runways 16L & 16R	Runways 34R & 34L
B747-200B (CF6-50E2 Engines) Full Passengers [e]					
4,797	Tokyo, Japan	740	96	8400	8,900
5,108	Frankfurt, Germany	750	96	8,700	9,200
5,723	Shanghai, China	785	96	9,800	10,500
6,066	Taipei, Taiwan	805	96	10,300	11,100
6,489	Hong Kong, Hong Kong	833	96	11,500	12,500
B747-200B (CF5-50E2 Engines) Full Passengers and Cargo [f]					
4,797	Tokyo, Japan	785	133	9,800	10,500
5,108	Frankfurt, Germany	805	133	10,300	11,100
5,723	Shanghai, China	833 [i]	125 [g]	11,500	12,500
B747-400 (CF5-80C2B1F Engines) Full Passengers [e]					
4,797	Tokyo, Japan	695	86	6,800	7,200
5,108	Frankfurt, Germany	705	86	7,000	7,400
5,723	Shanghai, China	740	86	7,800	8,200
6,066	Taipei, Taiwan	755	86	8,100	8,600
6,489	Hong Kong, Hong Kong [i]	775	86	8,500	9,100
7,740	Sydney, Australia [i]	840	86	10,300	11,000
B747-400 (CF6-80C2B1F Engines) Full Passengers and Cargo [f]					
4,797	Tokyo, Japan	745	123	7,900	8,300
5,108	Frankfurt, Germany	760	123	8,300	8,800
5,723	Shanghai, China	790	123	9,000	9,600
6,066	Taipei, Taiwan	810	123	9,400	10,000
6,489	Hong Kong, Hong Kong [i]	830	123	10,000	10,700
7,740	Sydney, Australia [i]	870 [j]	104 [g]	11,200	12,000
B747-200F (CF6-50E2 Engines) All-Cargo Service [h]					
4,797	Tokyo, Japan	833 [j]	164	11,500	12,500
4,886	Amsterdam, Netherlands	833 [j]	161	11,500	12,500
5,075	Luxembourg, Luxembourg	833 [j]	153	11,500	12,500
6,066	Taipei, Taiwan	833 [j]	125	11,500	12,500
4,797	Tokyo, Japan	796	140	10,200	10,900
4,886	Amsterdam, Netherlands	800	140	10,300	11,100
5,075	Luxembourg, Luxembourg	812	140	10,600	11,500
B747-400F (CF6-C2B1F Engines) All-Cargo Service [k]					
4,797	Tokyo, Japan	810	169	9,400	10,100
4,886	Amsterdam, Netherlands	815	169	9,500	10,200
5,075	Luxembourg, Luxembourg	825	169	9,900	10,600
6,066	Taipei, Taiwan [i]	870 [j]	164	11,200	12,000
6,489	Hong Kong, Hong Kong [i]	870 [j]	149	11,200	12,000

TABLE 2-4
RUNWAY TAKEOFF LENGTH REQUIREMENTS FOR B747-200 AND B747-400 AIRCRAFT
AT SEATTLE-TACOMA INTERNATIONAL AIRPORT

[a] Service is existing or past service except where footnoted otherwise.

[b] Gross aircraft take-off weight for passenger service is based on a) a full passenger load (452 passengers for B747-200 and 400 passengers for B747-400), and b) full passenger load and maximum belly cargo.

[c] Excludes aircraft empty weight and fuel.

[d] Source: P&D Aviation analysis based on zero winds, a temperature of 76°F, and data contained in aircraft operations manuals. Average runway gradients are: Runway 16L-34R, 0.72 percent upward to the north; Runway 16R-34L, 0.71 percent upward to the north.

[e] Full passengers only with no belly cargo.

[f] Full passengers and full belly cargo.

[g] Distance is too great to allow full passengers and full cargo. Take-off weight is maximum gross take-off weight.

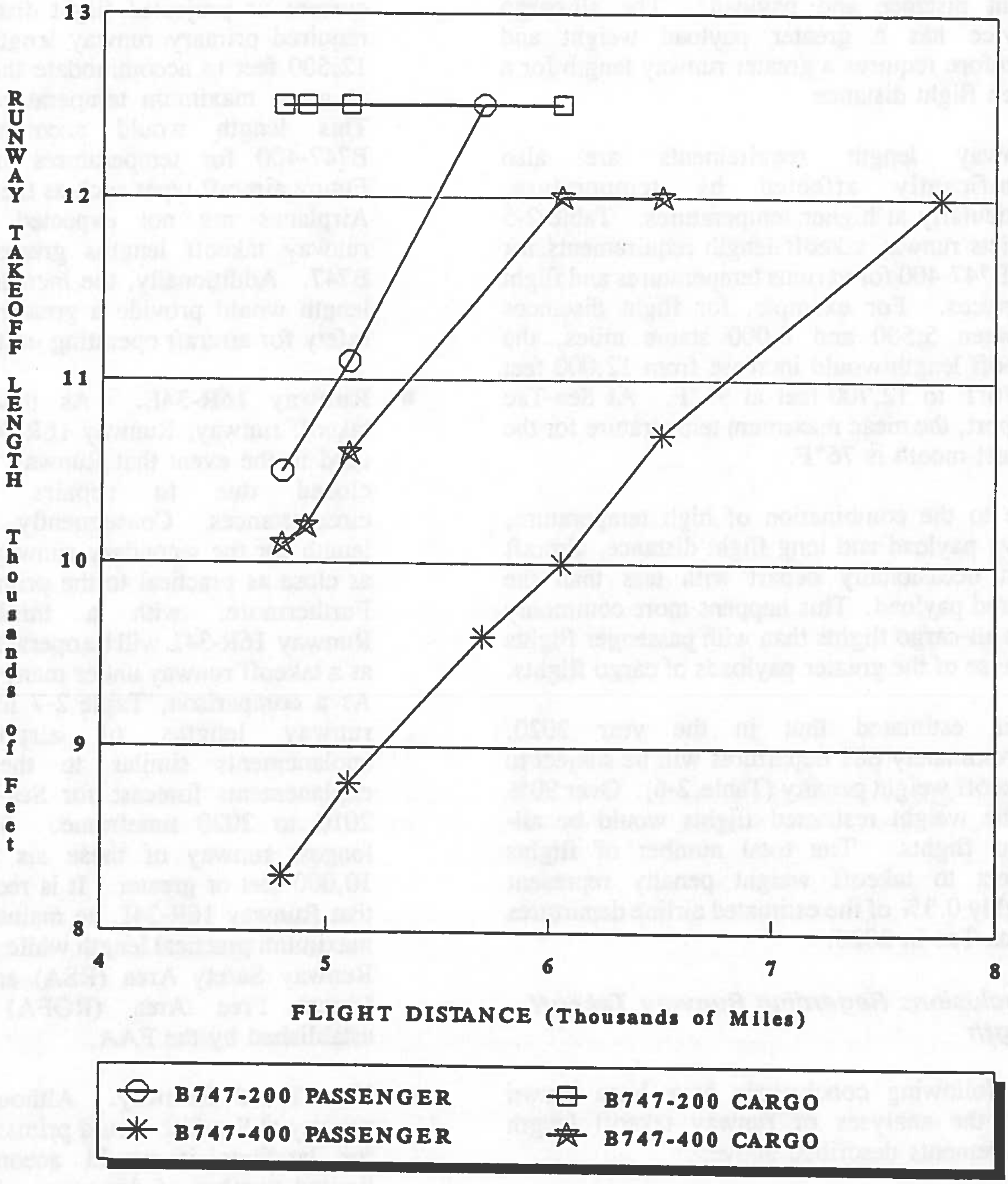
[h] For flight distances over 3,900 statute miles, the B747-200F must carry less than the maximum cargo payload limit of approximately 200,000 pounds. The take-off distances shown are for the maximum gross takeoff weight of the aircraft and the take-off weight required to carry 140,000 pounds, roughly 70 percent of the aircraft's payload limit.

[i] Potential future service.

[j] Maximum gross take-off weight of aircraft.

[k] Maximum payload is 169,000 pounds.

FIGURE 2-2
RUNWAY TAKEOFF LENGTH VS FLIGHT DISTANCE FOR B747-200 AND B747-400 AT SEA-TAC



for full passenger loads to Hong Kong, full passengers and cargo to Shanghai or fully load all-cargo service to Tokyo, Amsterdam, Luxembourg or Taipei. Takeoff runway requirements increase significantly with greater flight distance and payload. The all-cargo service has a greater payload weight and therefore requires a greater runway length for a given flight distance.

Runway length requirements are also significantly affected by temperature, particularly at higher temperatures. Table 2-5 depicts runway takeoff length requirements for the B747-400 for various temperatures and flight distances. For example, for flight distances between 5,500 and 6,000 statue miles, the takeoff length would increase from 12,000 feet at 76°F to 12,700 feet at 95°F. At Sea-Tac Airport, the mean maximum temperature for the hottest month is 76°F.

Due to the combination of high temperature, heavy payload and long flight distance, aircraft must occasionally depart with less than the desired payload. This happens more commonly with all-cargo flights than with passenger flights because of the greater payloads of cargo flights.

It is estimated that in the year 2020, approximately 681 departures will be subject to a takeoff weight penalty (Table 2-6). Over 90% of the weight restricted flights would be all-cargo flights. The total number of flights subject to takeoff weight penalty represent roughly 0.3% of the estimated airline departures at Sea-Tac in 2020.

Conclusions Regarding Runway Takeoff Length

The following conclusions have been drawn from the analyses of runway takeoff length requirements described above:

- **Runway 16L-34R.** The primary departure runway (Runway 16L-34R) should be capable of accommodating the critical aircraft commonly in service at the airport under maximum payload conditions for the current or projected flight distance. The required primary runway length would be 12,500 feet to accommodate the B747-200 at mean maximum temperature of 76°F. This length would accommodate the B747-400 for temperatures up to 90°. Future aircraft types such as the New Large Airplanes are not expected to require runway takeoff lengths greater than the B747. Additionally, the increased runway length would provide a greater margin of safety for aircraft operating on the runway.

- **Runway 16R-34L.** As the secondary takeoff runway, Runway 16R-34L must be used in the event that Runway 16L-34R is closed due to repairs or other circumstances. Consequently, the takeoff length for the secondary runway should be as close as practical to the primary length. Furthermore, with a third runway, Runway 16R-34L will be operated primarily as a takeoff runway under many conditions. As a comparison, Table 2-7 lists existing runway lengths of airport's with enplanements similar to the level of enplanements forecast for Sea-Tac in the 2010 to 2020 timeframe. The second longest runway of these six airports is 10,000 feet or greater. It is recommended that Runway 16R-34L be maintained at its maximum practical length while meeting the Runway Safety Area (RSA) and Runway Object Free Area (ROFA) standards established by the FAA.

- **New Third Runway.** Although a third runway at Sea-Tac would primarily be used for landings it would accommodate a limited number of departures during peak

TABLE 2-5
RUNWAY LENGTH REQUIREMENTS FOR DEPARTURES TO THE NORTH AT SEATTLE-TACOMA INTERNATIONAL AIRPORT [a]

Temperature (Fahrenheit)	Runway Length Required (in feet) for Distance (in Statute Miles)			
	4,500-5,000 Miles	5,000-5,500 Miles	5,500-6,000 Miles	6,000-6,500 Miles
B747-400 (CF6-80C2B1F Engines) Full Passengers and Cargo				
76°	8,500	9,200	9,900	10,700
80°	8,600	9,300	10,000	10,800
85°	8,800	9,400	10,100	10,900
90°	9,000	9,600	10,300	11,100
95°	9,300	10,000	10,800	11,600
B747-400 (CF6-80C2B1F Engines) All-Cargo Service				
76°	10,400	11,000	12,000	12,000 [b]
80°	10,700	11,100	12,100	12,100 [b]
85°	10,000	11,200	12,200	12,200 [b]
90°	10,400	11,400	12,400	12,400 [b]
95°	11,100	11,900	12,700	12,700 [b]

Note: Departures of the B747-400 to the north for temperatures and distance indicated by shaded area require a runway length greater than existing runways.

[a] Source: P&D Aviation analysis, based on data contained in aircraft operating manuals.

[b] All-cargo aircraft must operate at less than maximum payload in this distance range.

TABLE 2-6
ESTIMATED NUMBER OF DEPARTURES ON RUNWAY 34R SUBJECT TO WEIGHT PENALTY DUE TO EXISTING RUNWAY LENGTH, 2020 [a]

Range of Distance and Typical Cities [b]	Estimated Annual Departures [c]		Estimated Percent of Departures Subject to Takeoff Weight Penalty [d]		Estimated Departures Subject to Takeoff Weight Penalty		
	Passenger	All-Cargo	Passenger	All-Cargo	Passenger	All-Cargo	Total
Boeing 747-400							
6,000-6,500 miles Hong Kong Taipei	154	202	0	100	0	202	202
5,500-6,000 miles Shanghai	309	202	0	100	0	202	202
5,000-5,500 miles Paris Frankfurt Seoul	464	608	0	2	0	12	12
4,500-5,000 miles Tokyo London Amsterdam	618	1,013	0	0	0	0	0
Other Widebody Aircraft							
4,500-6,000 miles	3,090	2,025	2	10	62	203	265
Total Aircraft Departures Potentially Subject to Weight Penalty							
Total - Year 2020	4,635	4,050	1.3	15.3	62	619	681

[a] Source: P&D Aviation analysis. Based on 11,900 foot runway.

[b] Indicates the range of distances (statute miles) and the cities which potentially could be served by Sea-Tac.

[c] Based on forecast of departures for 2020 and aircraft fleet mix forecast (Technical Report No. 5, Table 5-17).

[d] Estimated based on temperature, flight distance and runway length requirement.

TABLE 2-7
RUNWAY LENGTHS OF AIRPORTS SIMILAR IN ENPLANEMENTS TO FORECAST FOR SEATTLE-TACOMA INTERNATIONAL AIRPORT, 1993 [a]

City and State	Existing Runway Lengths [b] (Feet)			
	Runway 1	Runway 2	Runway 3	Runway 4
Airports with Enplanements Similar to Sea-Tac in 1993				
Washington National, DC	6,869	5,189	4,505	--
Philadelphia, PA	10,499	9,500	5,460	--
Houston Intercontinental, TX	12,001	9,999	9,401	6,038
Seattle-Tacoma, WA	11,900	9,425		
Charlotte, NC	10,000	7,845	7,501	--
Orlando, FL	12,004	12,004	10,000	--
Pittsburgh, PA	11,500	10,502	8,100	8,039
Airports with Enplanements Similar to Sea-Tac Forecasts for 2010 to 2020				
Miami, FL	13,000	10,502	9,355	--
J.F. Kennedy, NY	14,572	11,351	10,000	8,400
Denver, CO (New)	12,000	12,000	12,000	12,000
San Francisco, CA	11,870	10,600	8,901	7,001
Atlanta, GA	11,889	10,000	9,000	9,000
Los Angeles International, CA	12,091	11,096	10,285	8,925

[a] Source: U.S. Department of Commerce, U.S. Terminal Procedures, January 6, 1994.

[b] Runway length requirements depend upon many local factors, including: temperature, airport elevation, winds and runway gradient, as well as aircraft type and distance flown. Therefore, these factors must be considered when comparing runway lengths of airports.

departure periods and other circumstances required by Air Traffic Control to maintain flexibility in the traffic flow at the airport. A runway length between 5,200 feet and 8,500 feet would accommodate from 39 to 91% of aircraft departures in the year 2000 and from 31% to 90% in the year 2020. For the third runway to operate effectively and efficiently, it should be capable of accommodating a share of departures within this range.

THIRD RUNWAY LANDING LENGTH ANALYSIS

Introduction

An analysis of landing length requirements for the proposed third runway was undertaken for the purpose of determining the optimum runway length in consideration of both aircraft operations and construction costs. It was assumed that the runway's primary role would be for landings although takeoffs would be performed during departure peak periods.

Factors affecting the runway landing length requirement include the aircraft mix, the condition of the pavement (wet versus dry), wind direction and velocity, and type of instrument approach (i.e., greater length requirement for Category IIIb approach).

The forecast aircraft mix for the years 2000 and 2020 was used in the analysis. Typical rather than maximum landing weights were used for each aircraft in the fleet. Typical landing weights were calculated at 90% of maximum landing weights based upon information supplied by two of the major carriers serving Sea-Tac.

Landing lengths were based upon wet pavements (plus 15% of base length) and an allowance (plus 15%) for accommodating CAT IIIb operations in accordance with FAR Part 121.195 and FAA AC 120/28C, respectively.

Aircraft Mix

The aircraft mix appearing in the demand forecast report was aggregated by ranges of the number of seats. This was disaggregated into individual aircraft models. The percent of total operations by aircraft model was calculated for the years 2000 and 2020. All commuter, general aviation and military aircraft were grouped into a single type since none of the aircraft in these categories were considered to be critical for runway length determination. Only Stage III aircraft were utilized in the analysis, since all Stage II aircraft will be phased out by the year 2000. Table 2-8 summarizes the aircraft fleet mix for 2000 and 2020 used in the runway landing length calculations together with the percent of total operations forecast to be performed by each aircraft type.

Runway Landing Length

Table 2-9 summarizes the data used and the results of landing length analysis for the aircraft models in the fleet mix. Figure 2-3 is a plot of runway lengths compared to percent of operations. Data were taken from Tables 2-8 and 2-9 to construct the graph.

An analysis of the data in Tables 2-8 and 2-9 can be summarized as follows:

Runway Length (Feet)	Percent of Operations Accommodated 2000	2020
7,000	94%	91%
7,500	98%	96%
8,500	99%	99%
11,000	100%	100%

TABLE 2-8
AIRCRAFT MIX AND PERCENT OF TOTAL OPERATIONS [a]

Aircraft	Percent of Total Operations	
	2000	2020
Commuter/GA/Military	38.4	30.8
F100	0.6	0.6
B727-200	3.5	0.0
B737-300	9.4	6.5
B737-400	4.7	6.5
B737-500	2.3	2.3
B747-400	0.3	0.7
B757-200	7.6	9.8
B767-200	2.3	5.9
B767-300	3.5	7.8
B777-200	0.2	0.4
MD80	7.0	5.0
MD90	7.0	4.9
MD11	0.3	0.7
MD12	0.2	0.3
DC 10-30	2.4	0.0
A300-600	1.2	3.2
A310-200	0.6	3.2
A319	1.8	1.8
A320-200	0.6	1.5
A340-200	0.6	1.3
A340-300	0.2	0.7
DC9F	0.8	0.6
B727F	0.8	0.6
DC8F	2.3	1.1
DC10F	0.7	2.0
B747F	0.7	1.8
TOTALS	100.0	100.0

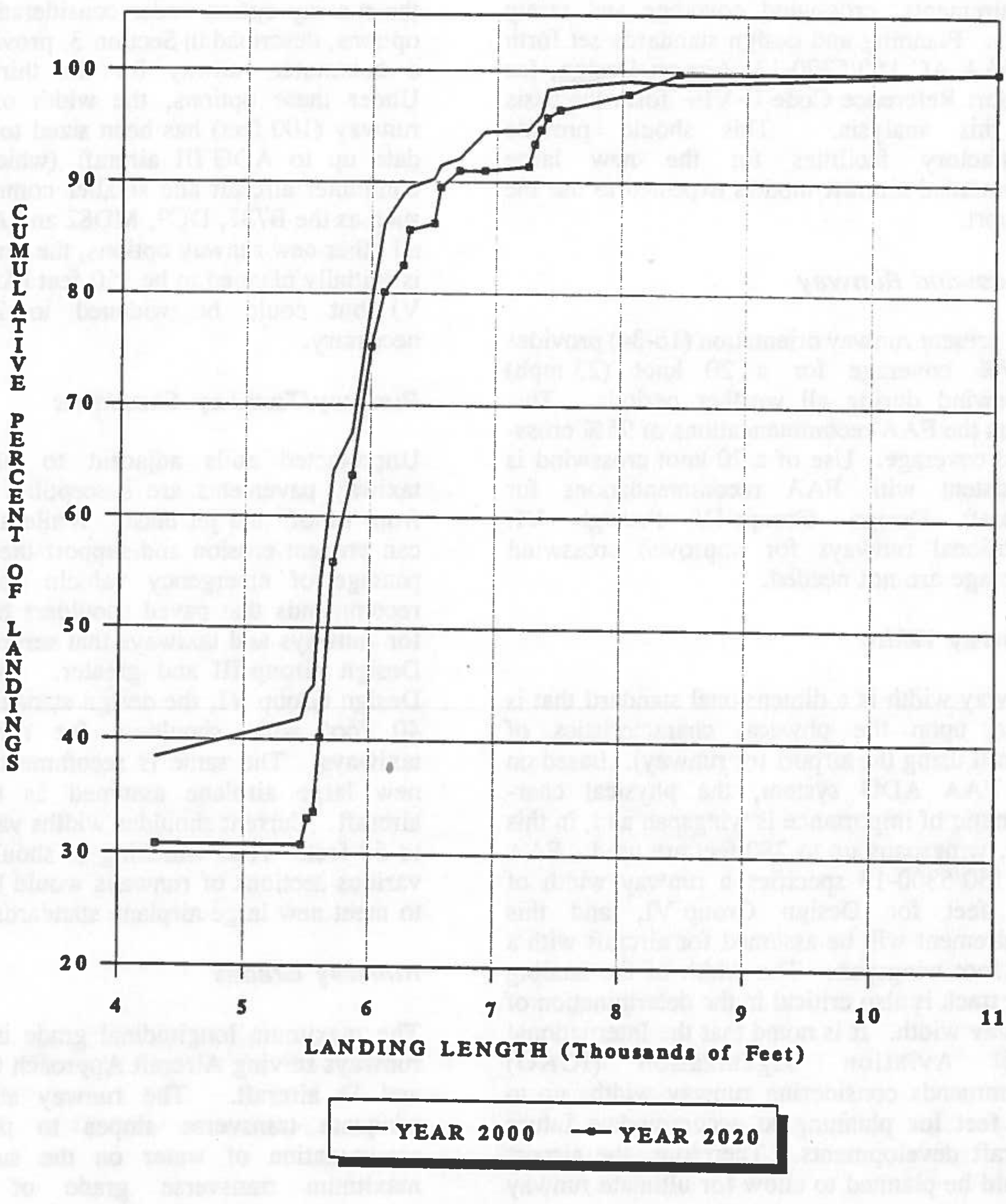
[a] Source: P&D Aviation analysis.

TABLE 2-9
RUNWAY LANDING LENGTH ANALYSIS [a]

Aircraft	Range (Nautical Miles)	Typical Landing Weight (Pounds)	Landing Lengths (Feet)		
			Base	Wet	CAT IIIb
Commuter/GA/Military	500-1,300	30,000-75,000	3,300	3,800	4,300
F100	1,310	79,200	4,270	4,900	5,550
B727-200	1,900	135,000	4,200	4,830	5,460
B737-300	2,200	102,600	4,300	4,945	5,590
B737-400	2,100	111,600	4,600	5,290	5,980
B737-500	2,400	99,000	4,250	4,885	5,525
B747-400	6,700	567,000	6,200	7,130	8,060
B757-200	4,000	178,200	4,400	5,060	5,720
B767-200	3,900	243,000	4,400	5,060	5,720
B767-300	3,500	270,000	4,500	5,175	5,850
B777-200	4,600	400,500	5,600	6,440	7,280
MD80	2,100	117,000	4,600	5,290	5,980
MD90	2,000 [b]	127,800	4,700	5,405	6,110
MD11	6,800	387,000	6,200	7,130	8,060
MD12	8,000	577,000	8,450	9,715	10,985
DC 10-30	4,300	362,700	5,300	6,095	6,890
A300-600	3,680	273,815	5,040	5,795	6,550
A310-200	4,225	244,100	4,850	5,580	6,300
A319	2,800	121,030	4,800	5,520	6,240
A320-200	2,870	145,835	5,150	5,920	6,700
A340-200	8,450	367,070	5,650	6,500	7,350
A340-300	7,650	376,990	5,750	6,600	7,500
DC9F	1,000	89,000	5,000	5,750	6,500
B727F	1,800	126,000	4,800	5,500	6,250
DC8F	3,200	225,000	5,700	6,555	7,400
DC10F	3,200	370,000	5,600	6,440	7,280
B747F	4,700	567,000	6,500	7,475	8,450

[a] Source: Individual aircraft manufacturers planning manuals and Jane's All the World's Aircraft - 1993-94.
[b] Estimated.

FIGURE 2-3
CUMULATIVE LANDING LENGTH REQUIREMENT FOR CATEGORY IIIB AT SEA-TAC AIRPORT



RUNWAY SYSTEM REQUIREMENTS

This section deals with runway requirements other than runway length needed to satisfy the forecast demand, such as pavement strength requirements, crosswind coverage and safety areas. Planning and design standards set forth in FAA AC 150/5300-13, Airport Design, for Airport Reference Code D-VI+ form the basis of this analysis. This should provide satisfactory facilities for the new large commercial aircraft models expected to use the Airport.

Crosswind Runway

The present runway orientation (16-34) provides 99.7% coverage for a 20 knot (23 mph) crosswind during all weather periods. This meets the FAA recommendations of 95% crosswind coverage. Use of a 20 knot crosswind is consistent with FAA recommendations for Aircraft Design Groups IV through VI. Additional runways for improved crosswind coverage are not needed.

Runway Width

Runway width is a dimensional standard that is based upon the physical characteristics of aircraft using the airport (or runway). Based on the FAA ADG system, the physical characteristic of importance is wingspan and, in this case, wingspans up to 280 feet are used. FAA AC 150/5300-13 specifies a runway width of 200 feet for Design Group VI, and this requirement will be assumed for aircraft with a 280 foot wingspan. The width of the landing gear track is also critical in the determination of runway width. It is noted that the International Civil Aviation Organization (ICAO) recommends considering runway widths up to 200 feet for planning to accommodate future aircraft developments. Therefore, the airport should be planned to allow for ultimate runway widths of 200 feet. Both runways are presently 150 feet wide but can be expanded to 200 feet if necessary.

The width of a third runway would depend on the runway option under consideration. Some options, described in Section 3, provide for only a commuter runway for the third runway. Under these options, the width of the third runway (100 feet) has been sized to accommodate up to ADG III aircraft (which includes commuter aircraft and smaller commercial jets such as the B737, DC9, MD82 and A320). For all other new runway options, the runway width is initially planned to be 150 feet (ADG IV and V) but could be widened to 200 feet if necessary.

Runway/Taxiway Shoulders

Unprotected soils adjacent to runway and taxiway pavements are susceptible to erosion from runoff and jet blast. While a turf cover can prevent erosion and support the occasional passage of emergency vehicle traffic, FAA recommends that paved shoulders be provided for runways and taxiways that serve aircraft in Design Group III and greater. For Aircraft Design Group VI, the design standard calls for 40 foot wide shoulders for runways and taxiways. The same is recommended for the new large airplane assumed as the critical aircraft. Current shoulder widths vary from 25 to 50 feet. Thus widening of shoulders along various sections of runways would be required to meet new large airplane standards.

Runway Grades

The maximum longitudinal grade is 1.5% for runways serving Aircraft Approach Category C and D aircraft. The runway should have adequate transverse slopes to prevent the accumulation of water on the surface. A maximum transverse grade of 1.5% is recommended for the airport by FAA with the acceptable range being 1.0% to 1.5%. The existing runway grades at the airport comply with these standards.

Pavement Strength

Future critical aircraft in terms of pavement design represented by the new large aircraft may be designed with maximum gross weights up to 1,700,000 pounds and have different landing gear configurations. The B777 for example has six wheel bogies. The runways at Sea-Tac are generally rated at 100,000 pounds for single wheel loads, 200,000 pounds for dual wheel loads, 350,000 pounds for dual tandem wheel loads, and 800,000 pounds for double dual tandem landing gears. Evaluation of runway pavements has been the subject of recent studies and is discussed below.

Runway 16L-34R. Runway 16L-34R was rehabilitated in 1993 through the construction of a 5-inch asphalt overlay. The rehabilitation project did not change the weight bearing capacity of the runway stated above. Based on a 20 year design life of the newly constructed overlay and use by existing aircraft, it is expected that another rehabilitation program will be required towards the end of the planning period of the master plan (year 2020). Long term pavement needs must consider future aircraft models, including new large airplanes currently under study.

Runway 16R-34L. An evaluation of Runway 16R-34L pavement, drainage, and safety areas was conducted in 1992. (Preliminary Engineering Report Runway 16R-34L Seattle-Tacoma International Airport, Pavement Consultants Inc., August 1992). The allowable loads for different sections of the runway are shown in Table 2-10. The evaluation concluded that certain sections of the runway cannot withstand projected traffic at maximum aircraft load levels and suggested the need to strengthen the runway. Additionally, the evaluation projected pavement conditions in 1996 and 2001 if no major improvements were completed (see Table 2-11). The evaluation was based on consideration of the present aircraft fleet and landing gear configurations. For the Master Plan Update it is recommended that future pavement strengthening and rehabilitation programs be planned and consider present aircraft models, as well as the projected fleet mix including new large aircraft being studied for possible development.

Runway Safety Areas

A runway safety area (RSA) is defined as a rectangular area centered about the runway that is cleared, drained, graded and usually turfed. Under normal conditions, this area should be capable of accommodating occasional aircraft that may veer off the runway, as well as fire fighting equipment. For Sea-Tac, the requirement for the RSA is an area 500 feet wide centered on the runway centerline and extending 1,000 feet beyond each runway end.

The existing runway safety areas do not meet FAA criteria (Table 2-12). The existing RSA for Runway 34R is 535 feet long and 500 feet wide. The Runway 16L RSA is 700 feet long with varying widths from 180 to 500 feet. The RSA for Runway 34L is 775 feet long and 500 feet wide. The RSA for Runway 16R is 645 feet long with the width varying from 180 to 500 feet. The reasons for not meeting the FAA standards are steep terrain and/or the presence of roads at the ends of the runways (Table 2-12).

In addition to dimensional standards, FAA has established longitudinal and transverse gradient standards for safety areas. For the first 200 feet of RSA beyond runway ends the longitudinal grade must be between zero and three percent

TABLE 2-10
ALLOWABLE LOADS FOR RUNWAY 16R-34L [a]

Runway Section	Allowable Load (Kips)					
	Single Wheel	Dual Wheel	Dual Tandem	MD-11	B747	L1011
1	over 75	160	240	540	740	420
2	over 75	145	240	460	700	420
3	over 75	160	280	540	760	460
4	over 75	140	280	500	720	430
5	over 75	150	300	540	800	460
6	over 75	170	280	560	790	450
7	over 75	150	260	560	780	440
8	over 75	170	380	540	800	460
Percent Maximum Takeoff	over 100	67	69	76	84	90
Percent Maximum Landing	over 100	87	80	98	114	114

[a] Source: Pavement Consultants, Inc., Preliminary Engineering Report Runway 16R-34L, August 1992.

TABLE 2-11
PROJECTED PAVEMENT CONDITION FOR RUNWAY 16R-34L
IN 1996 AND 2001, WITH NO MAJOR IMPROVEMENTS COMPLETED [a]

Section	1991		1996		2001	
	PCI	Rating	PCI	Rating	PCI	Rating
1B	59	Good	45	Fair	20	Very Poor
2B	76	Very Good	62	Good	37	Poor
3B	82	Very Good	68	Good	43	Fair
4B	73	Very Good	59	Good	34	Poor
5B	77	Very Good	63	Good	38	Poor
6B	78	Very Good	64	Good	39	Poor
7B	68	Good	54	Fair	29	Poor
8B	68	Good	54	Fair	29	Poor

[a] Source: Pavement Consultants, Inc., Preliminary Engineering Report Runway 16R-34L, August 1992.

TABLE 2-12
EXISTING AND REQUIRED RUNWAY SAFETY AREAS AT SEATTLE-TACOMA INTERNATIONAL AIRPORT, 1994

Description	Runway Safety Area Dimension (Feet)			
	Runway 16L	Runway 34R	Runway 16R	Runway 34L
Existing Safety Area				
Length Beyond Runway End Width Length at Full Width (500 Feet)	700 180-500 500	535 500 535	645 180-500 230	775 500 775
Required Safety Area				
Length Beyond Runway End Width	1,000 500	1,000 500	1,000 500	1,000 500
Constraints				
Primary Constraints to Runway Safety Area Expansion	1. 154th Street is 800 feet north of runway end.	1. Steep terrain to the south of existing safety area.	1. 154th Street is 900 feet north of runway end.	1. An airport service road is located 800 feet south of runway end.
	2. 154th Street is 50 feet lower in elevation than runway end.		2. 154th Street is 100 feet lower in elevation than runway end.	

with any slope being downward from the runway end. For the remainder of the extended RSA the maximum longitudinal grade is such that no part of the runway safety area penetrates the approach surface as specified in FAR Part 77. The maximum negative grade allowed is 5%. Transverse grades are limited to between 1.5 and 5% with the maximum recommended to promote drainage.

It is recommended that all runway safety areas be modified to fully comply with FAA criteria. In all initial airfield options, with the exception of Option 1 - Do Nothing, described in Section 3, the RSAs meet FAA standards. FAA compliance would be obtained by either relocating roads, adding fill material, and/or shortening the runway.

Object Free Areas

The runway object free area (ROFA) is a two dimensional ground area surrounding the runway. Its clearing standard precludes parked aircraft and objects, except objects whose location is fixed by function. As such, it replaces former criteria for aircraft parking limit lines and was the result of an agreement that a minimum 400 foot separation be provided between the runway centerline and equipment shelters (except localizer equipment shelters). At Sea-Tac, the ROFAs extend 400 feet on either side of the runway centerlines, along the entire length of runways and 1,000 feet beyond each end.

The following objects are located within the ROFA at Sea-Tac:

- Runway 16R - road (South 154th Street).
- Runway 16L - road (South 154th Street), localizer transmitter building and ALS regulator building.
- Runway 34L - localizer antenna and equipment shelter, RVR transmissometer and receiver. VORTAC and rotating beam ceilometer (RBC).
- Runway 34R - ALS substation.

With the exception of the road, all object locations are fixed by function and related to navaids and airport electronic equipment. Therefore, the navaids and electronic equipment are allowed to be within the ROFAs by FAA standards. Under all airfield development options to be considered, the ROFAs would be modified to fully comply with FAA criteria.

Approach Surfaces and Runway Protection Zones

The approach surface and the runway protection zone (formerly called clear zone) are important elements in the design of runways which help to ensure the safe operations of aircraft. A brief description of these two areas follows:

- *The Approach Surface* is an imaginary inclined plane beginning at the end of the primary surface (which extends 200 feet from the end of the runway) and extending outward to distances up to 10 miles depending on runway use and nav-aids (i.e., size of aircraft and instrument or visual approaches). The width and slope of the approach surface are also dependent on runway use and navaids. Objects should not penetrate or extend above the approach surface. If they do, they are classified as obstructions and must be either marked or removed.

- *The Runway Protection Zone (RPZ)* is an area at ground level that provides for the unobstructed passage of landing aircraft through the above airspace. The runway protection zone begins at the end of the primary surface and has a size which varies with the designated use of the runway.

Federal Aviation Regulations Part 77 indicates that the approach surface should be kept free of obstructions to permit the unrestricted flight of aircraft in the vicinity of the airport. As the type of instrument approach to a runway becomes more precise, the approach surface increases in size and the required approach slope becomes more restrictive.

The runway protection zone is the most critical safety area under the approach path. No structure should be permitted nor the congregation of people allowed within the runway protection zone. Control of the runway protection zone by the airport owner is essential. It is desirable, therefore, that the airport owner acquire adequate property interests, preferably in fee title, in the runway protection zone to ensure compliance with the above.

For the existing runways at Sea-Tac, the approach surface and RPZ dimensional standards are for precision instrument runways.

Approach surface dimensions are:

Length	50,000 feet
Inner Width	1,000 feet
Outer Width	4,000 feet
Slope	
First 10,000 feet	50:1
Next 40,000 feet	40:1

Runway protection zone dimensions are:

Length	2,500 feet
Inner Width	1,000 feet
Outer Width	1,750 feet
Area	78.9 acres

Under all third runway development options described in Section 3, except a new close-in commuter runway, the third runway would be designed to meet the same dimensional standards as for the existing runways. The approach surface and RPZ dimensions for the close-in commuter runway option will be different due to different navaids for that option.

TAXIWAYS

While an essential element of this master plan update is the third runway and its impact on airfield capacity, the ability of the taxiway system to efficiently serve aircraft on the ground is equally important. The function of the taxiway system is to facilitate access from the runways to various terminal elements. In doing so, interference between arriving and departing aircraft should be minimized.

The planning and design standards previously presented in this section defined the recommended geometric criteria for planning future runway and taxiway facilities. In light of the objective of planning the airport to accommodate the next generation large aircraft in the future, these standards must be considered when evaluating the existing airfield and terminal development area.

The discussion of taxiway requirements is organized into three subsections which address the parallel taxiway requirement on the east side (passenger terminal side) of the airfield, exits for the existing runways, and taxiway requirements for a new runway. Taxiway design criteria are shown in Table 2-1.

Parallel Taxiways

The separation between Runway 16L-34R and Taxiway A North (400 feet) is adequate for aircraft up to the B747-400. The separation between Taxiways A and B North (300 feet) is also adequate for the B747-400. However, adequate separation between the runway and Taxiway A North to support operations by the assumed new large airplanes (Aircraft Design Group VI+) is not provided. This suggests either a long term realignment of the taxiway, or use of Taxiway B North by new large aircraft. The latter would preclude use of Taxiway A North when a new large aircraft is operating on the runway and dual taxiway capability during those times when Taxiway B North is utilized by new large aircraft. In order to maintain dual taxiway capability for new large aircraft both taxiways would have to be relocated. On the south end of the airfield, the existing runway-taxiway separation is sufficient to accommodate the new large aircraft.

Dual parallel taxiways are required at airports where simultaneous taxiing in opposite directions frequently occurs. By providing unidirectional dual parallel taxiways, interference with opposite flow traffic is minimized. A partial dual parallel system exists for the north half of the airfield (Taxiways A and B North). The depth of the terminal apron is sufficient to also provide a dual taxiway capability for aircraft up to ADG IV, provided that aircraft parking at certain gates in Concourses B and C are limited to certain aircraft models. Pertinent criteria for aircraft design group IV leading to this conclusion are:

Taxiway centerline to parallel taxiway/taxi-lane centerline . . . . . 215 feet

Taxiway centerline to fixed or movable object . . . . 130 feet.

The density of traffic in the terminal area suggests that dual taxiway capability on the terminal apron would be beneficial. The apron presently is used as a dual taxiway for narrow-body aircraft, however, the apron pavement is not marked for dual taxiways. A factor that limits the provision of dual taxiway capability on the terminal apron is the presence of a service road. The road is used by various ground vehicles for servicing parked aircraft. The significance of the road is that as it is currently aligned, it violates clearance criteria for the Taxiway Object Free Area (TOFA). Relocation of the service road outside the TOFA is possible but would impact the extent of the aircraft parking area at the terminal concourses.

Table 2-13 indicates the affected gates and the aircraft that could be parked with dual parallel taxiways on the apron designed to ADG IV standards. The aircraft models indicated as being accommodated are based on the mix of aircraft contained in the forecasts of air traffic activity previously presented in Technical Report No. 5.

Determination of parallel taxiway requirements are critical in that the required clearances and set backs will impact the ability to site buildings, facilities and aircraft parking areas. Regarding larger, ADG V aircraft, the ultimate strategy may be to restrict the terminal area as a single taxiway when taxiing by aircraft from ADG V and larger is conducted.

Exit Taxiways

An in-depth analysis of exit taxiway requirements was conducted by the Port of Seattle in 1991 (Taxiway Improvements Study Seattle-Tacoma International Airport, Aviation Planning, Port of Seattle, September 1991). This study recommended a number of new exit taxiways for Runway 16R-34L as follows:

New Taxiway	Distance From Approach End (Feet)
South Flow	
C7	4,495
C10/B10	7,020

TABLE 2-13
AIRCRAFT PARKING RESTRICTIONS FOR DUAL PARALLEL APRON TAXIWAYS

Gate	Accommodated Aircraft
B7	B727, B737-500/300/400, MD80, MD90, A319, A320, B757-200, B767-200, A310, A321
B9	B737-500/300/400, MD80, A319, A320, A321
B11	B727, B737-500/300/400, MD80, MD90, A319, A320, A321, A310
C6	B737s, B727, MD80, MD90, A320, A319
C8	B737-500/300/400, A319, A320, A321
C10	B737-500/300/400, MD80, A319, A320, A321
C12	B737-500/300/400, B727, A319, A320
C14	B737-500
C16	ATR 72, RJ 70/85
S12	B727, B737-500/300/400, MD80, MD90, A319, A320, A321, A310, B757-200

Note: Aircraft accommodated assumes airport service road is relocated outside taxiway object free area for a parallel apron taxiway designed to ADG IV standards.

North Flow

C6	3,172
C1A/B1A	6,430

The recommendations were based on the current airport layout and the premise that Runway 16R-34L would continue to serve primarily arrivals until a third runway is available. The four new exit taxiways are currently under construction.

Under a two-runway configuration, Runway 16L-34R will serve primarily departures. However, under a three-runway configuration, Runway 16L-34R is expected to be used frequently as an arrival runway, especially during poor weather conditions and peak arrival periods. In light of this, enhancements of exits to Runway 16L-34R were explored. An assessment of exits was conducted for Runway 16L-34R using the Runway Exit Design Interactive Model (REDIM), a simulation model developed at the Center for Transportation Research (CTR), Virginia Tech University under NASA and FAA sponsorship.

The model determines the optimal location of exits on a runway to minimize runway occupancy time. The model incorporates airport environmental factors and physical characteristics such as airfield elevation, runway configuration, weather conditions, and operational factors such as aircraft mix, and aircraft piloting techniques to determine the potential location of high-speed exits. REDIM then quantifies a weighted average runway occupancy time (WAROT).

The model was applied to assess the existing runway efficiency and potential benefits in terms of additional exits. A mix of aircraft based on the long range forecast fleet mix was assumed. Findings of the analysis are presented below.

Runway 16L. In south traffic flows, the WAROT for Runway 16L and its existing system of turnoffs is 75.9 seconds. Most aircraft are able to exit at the "Broad Ramp", except the B747 and MD-11, especially during wet runway conditions. Wet runways are estimated to exist 55% of the time. By adding 30° exits at 5,568 and 7,756 feet, the WAROT is reduced to 54.1 seconds, a reduction of almost 29%. The shorter exit would allow many aircraft currently turning off at Broad Ramp to exit earlier, while the longer exit would serve most of the B747s and MD-11s.

Runway 34R. The existing exit performance of the runway measured in WAROT is 83.5 seconds. Adding 30° exit taxiways at approximately 5,500 and 7,700 feet will reduce WAROT to 57.3 seconds or by about 31%.

The four additional 30° exits described above were also reviewed with FAA air traffic personnel. It was felt these exits would allow aircraft to clear the runway sooner, and thus provide greater opportunities to release departures. The proposed future full length parallel taxiway will also encourage frequent use of these exits.

Taxiways for New Runway

Taxiway requirements for a new parallel runway will vary depending on its role and size. Potential lengths for the new runway, discussed in greater detail later in this report, include commuter use (5,200 foot long runway), 7,000 feet, 7,500 feet and 8,500 feet. Since each runway length will accommodate different aircraft types, the configuration and design criteria for the taxiway system will vary. The various requirements are highlighted in the following paragraphs.

Commuter Runway. A 5,200 foot long commuter runway would be expected to accommodate aircraft up to Design Group III, with Fokker F-28s such as those operated by Horizon representing the critical aircraft in this scenario. Taxiway widths of 50 feet and runway-to-taxiway centerline separation of 400 feet will be adequate for commuter operations. Acute angle turnoffs at approximately 4,000 feet from the landing threshold, plus a midfield right angle exit represent an effective complement of exits in this scenario.

7,000 foot Runway. This size runway would be expected to accommodate most air carrier transports except the B747 and MD-11. Taxiway widths of 75 feet will be satisfactory for the mix of aircraft accommodated on the runway and will compliment the assumed runway width of 150 feet. An acute angle exit taxiway located at 5,200 feet from the landing threshold and a midfield right angle taxiway would effectively serve this runway.

7,500 foot Runway. An extension of the 7,000 foot runway option increases the percent of landing operations accommodated from 94.7% to 96.5%. A 7,500 foot runway can also be positioned to avoid some of the fill requirement and road relocations caused by the 8,500 foot runway option. Taxiway locations for this option are very similar to the 7,000 foot runway option.

8,500 foot Runway. An evaluation of the exit taxiway system for an 8,500 foot long runway as proposed by the runway design consultant (HNTB, Inc.) was conducted by P&D Aviation using REDIM. The proposed exit taxiway system consists of high speed exits at 5,200 and 6,400 feet and right angle exits at 3,500 and 5,000 feet. For the long range forecast mix, the WAROT is calculated at 56 seconds. The series of exits is adequate for most aircraft under most conditions, with the exceptions being large aircraft (B747 and MD-11). It was noted that the longest high speed exit (6,400 feet) was suitably located to serve approximately two-thirds of the B747 and MD-11 mix in dry conditions. During wet runway conditions, most B747 and MD-11 aircraft will not make the 6,400 foot turnoff, and in fact the model indicates some (approximately 15%) have difficulty landing within the available runway length (8,500 feet), indicating potentially limited use of the runway by these heavy aircraft in wet weather.

In terms of facilitating access to the terminal for those heavy aircraft using the runway, the option of a high speed exit at the end of the runway may be considered. This is not to suggest use of the taxiway as a substitute for available runway landing distance. However, for those heavy aircraft capable of landing on the available runway, a high speed exit at the end will expedite flow of traffic from the runway.

NAVIGATIONAL AIDS

Sea-Tac is presently equipped with instrument landing systems (ILS) on Runways 34L, 34R and 16R. Runway 16R accommodates Category IIIb ILS approaches down to weather conditions (visibility) of RVR 300 feet. The Sea-Tac VORTAC is also located on the south end of the airfield. Non-directional radiobeacons located to the north and south of the airport are used for navigational purposes.

For the period 1988 through 1992, instrument approaches at the airport averaged 43,500 a year, or approximately 13% of annual operations. Applying this relationship to forecast operations indicates that annual instrument approaches in the year 2020 will increase to approximately 58,000, with 71% being in a south flow and 29% in north flow traffic configurations.

Existing Airfield

Installation of an ILS on Runway 16L is

planned for construction in the 1996-1997 time frame. Touchdown zone lighting is already in place in anticipation of the ILS. Category IIIb minimums are planned and an initial feasibility assessment conducted by the Port did not identify any fatal flaws. The ILS improvement for 16L is assumed to be common to each airfield option described in Section 3. Additional navigational aid (navaid) requirements for each runway development option are discussed in the next section.

Other Considerations

The construction of a new runway will impact two installations used for air traffic control. These are the Airport Surveillance Radar (ASR) and Airport Surface Detection Equipment. Both are critical to the flow of traffic, particularly during periods of poor visibility, and should be relocated.

Section 3
INITIAL AIRSIDE OPTIONS

SECTION 3
INITIAL AIRSIDE OPTIONS

INTRODUCTION

This section describes the seven initial airside options which were developed for purposes of a preliminary airside screening analysis. Options which pass this preliminary evaluation (or derivations of these options) will be the subject of further study, in which environmental and other considerations will be addressed. The Airport Master Plan Update will also consider non-airfield options (such as terminal and roadway options) as well as alternatives relating to demand management, diversion of demand to high speed rail, and supplemental airports.

Types of Considerations

The airside options considered here generally consist of alternatives for the improvement of the existing airfield and third runway improvements. Improvements to the existing airfield include measures to obtain RSA and ROFA compliance with FAA standards, and taxiway improvements. Third runway considerations focus primarily on runway length and separation standards.

Range of Options

Airfield options were chosen to represent the widest practical range of alternatives for a third runway. Runway lengths were sized to existing site constraints and aircraft operating requirements. Runway separations were determined on the basis of FAA requirements for various visual and instrument operating conditions. The initial development options range from a 5,200-foot runway 700 feet west of Runway 16R-34L to an 8,500-foot runway 2,500 feet west of Runway 16R-34L.

MEASURES TO IMPROVE EXISTING AIRFIELD

Section 2 described several potential improvements to the existing runway/taxiway system to improve the safety and efficiency of aircraft operations. Recommended improvements are in compliance with FAA standards for the RSAs and ROFAs, and additional exit taxiways for Runway 16L-34R.

Compliance with RSA and ROFA Standards

Runway 16L-34R. Three documents by the Port of Seattle describe recent studies of extending the RSAs of Runway 16L-34R to comply with FAA standards ("Sea-Tac International Airport, Runway 16L-34R Safety Area Expansion," Port of Seattle Memorandum, December 2, 1992; Seattle-Tacoma International Airport, Runway 16L Safety Area Expansion, Engineering Report, March 29, 1993; and Runway 34R Safety Area Expansion, Sea-Tac International Airport, August 1993). It was concluded by these studies that the RSA of Runway 16L could be lengthened to 700 feet beyond the existing runway by the addition of fill material and the construction of retaining walls along the north perimeter road adjacent to South 154th Street. To obtain the full 1,000-foot safety area, under this configuration, the take-off threshold of Runway 16L would be relocated 300 feet to the south, and South 154th Street would remain outside the ROFA and would not have to be relocated.

An alternate approach to compliance would be a full 1,000 foot RSA and ROFA beyond the present Runway 16L end. This approach would require relocating South 154th Street to the north but would allow the take-off threshold of Runway 16L to remain in its present location.

The Port of Seattle studies cited above concluded that the RSA for Runway 34R can be extended to the south. To accomplish this, additional fill material will be required to maintain the necessary grades. Furthermore, the existing approach light towers and electrical systems in the RSA area must be modified.

Runway 16R-34L. A report prepared for the Port describes alternatives for achieving RSA compliance of Runway 16R-34L (Pavement Consultants, Inc., Preliminary Engineering Report, Runway 16R-34L, Seattle-Tacoma International Airport, August 13, 1992). For Runway 16R that study recommended, in order of preference: 1) providing the full 1,000 foot RSA north of the existing threshold and relocating South 154th Street to the north, 2) providing 550 feet of RSA beyond the existing threshold and relocation the threshold 450 feet to the south, thereby avoiding the relocation of South 154th Street, or 3) providing 750 feet of RSA beyond the existing threshold and relocating the threshold 250 feet to the south and construction a retaining wall at the north end of the RSA to avoid relocating south 154th street. The runway 16R threshold would have to be relocated approximately 325 feet to the south if South 154th Street, in its present alignment, is not to penetrate the ROFA.

The study cited above concluded that the RSA for Runway 34L could be extended to 1,000 feet. This will require the relocation of the airport service road and minor grading to meet FAA standards. The end of the extended RSA would be approximately 175 feet from 188th Street.

Taxiway Exit Improvements

Section 2 described taxiway improvements underway to Runway 16R-34L (four additional exit taxiways) and recommended improvements to Runway 16L-34R (four additional exit taxiways). The improvements will enhance the flow of aircraft operations and improve the efficiency of the existing airfield under the new runway development alternatives. Therefore, they will be included in the airfield development options.

THIRD RUNWAY CONCEPTS

Based on the results of earlier studies, six third runway concepts were developed jointly by P&D Aviation and the Port of Seattle and included in the Scope of Work for the Airport Master Plan Update project:

- Existing conditions (existing 11,900-foot and 9,425 foot runways with 800-foot separation). No third runway would be built under this concept.

- Close-in Commuter Runway (new 5,200-foot runway 1,500 feet west of Runway 16L-34R). This runway would serve primarily commuter operations and would be too closely spaced to allow two arrival streams under IFR weather conditions. The 5,200-foot runway length is required for the F-28 under maximum gross takeoff weight conditions. Although the F-28 seats up to 65 passengers, it was used as the critical aircraft for the commuter runway because it is in use by airlines typically flying commuter aircraft (60 seats or less).

- Dependent Commuter runway (new 5,200-foot runway 2,500 feet west of Runway 16L-34R). This runway would serve primarily commuter operations, but the 2,500-foot separation would allow two dependent IFR radar-controlled arrival streams, simultaneous radar-controlled departures, and simultaneous radar-controlled approaches and departures. Additionally, a 2,500-foot separation of parallel runways minimizes the need for air traffic control personnel to implement wake turbulence avoidance procedures. Aircraft in dual arrival streams (for dependent runways) would be subject to a diagonal separation of no less than two nautical miles.

- Dependent Runway-Programmatic Baseline (new 7,000-foot runway, 2,500 feet west of Runway 16L-34R). The length of 7,000 feet originates form the Puget Sound Air Transportation Committee Flight Plan Study, The baseline runway length proposed by the Flight Plan Study was 7,000 feet.

  Two variations of this concept have been considered in the airside evaluations: a staggered 7,000 foot runway (with the north threshold staggered 1,435 feet to the south) and a staggered 7,500-foot runway. The staggered 7,000-foot runway would eliminate the need to relocate South 156th Way to accommodate the new runway. The 7,500-foot runway would be staggered approximately 935 feet south of the existing north thresholds and would require the relocation of South 156th Way.

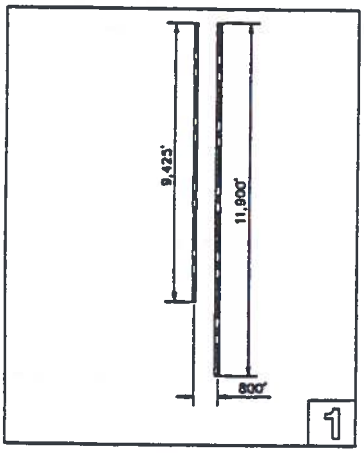
- Dependent Runway-Maximum Length (new 8,500-foot runway 2,500 feet west of Runway 16L-34R). The 8,500-foot length is the maximum that can be obtained while meeting the FAAs, RSA and ROFA criteria and aligning the north end of the new runway with the existing runway ends.

- Independent Runway-Maximum Length (new 8,500-foot runway 3,300 feet west of Runway 16L-34R). This configuration would allow dual IFR arrival streams on the two westerly runways. Under this configuration, the long runway, Runway 16L-34R, would be primarily a departure runway and aircraft needing the larger takeoff length of Runway 16L-34R would not have to interrupt a landing stream.

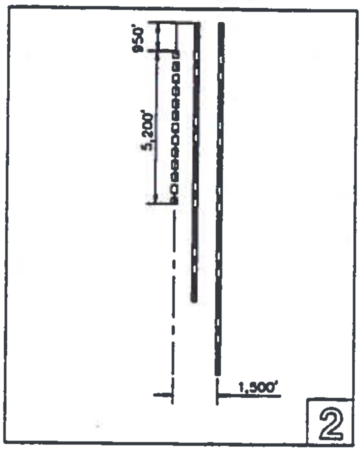
  This option also would presumably allow, in the future, two independent arrival streams under IFR conditions. Independent arrival streams do not have diagonal separation limits as do dual independent arrival streams. Although FAA standards currently require a 3,400-foot separation between parallel runways for independent arrivals (with the use of special radar and monitoring equipment), a 3,300-foot separation for independent arrivals is being tested now by the FAA. Due to the increasing precision of navaids over the past 25 years, the standard for independent arrivals has been successively reduced from 5,000 feet to 4,300 feet to 3,400 feet, and it is expected that the runway separation requirement will be reduced further through future technological improvements. In the delay analysis described in Section 4, it is assumed that runways with a 3,300 separation will be able to support independent arrival streams by the year 2020.

INITIAL AIRSIDE OPTIONS

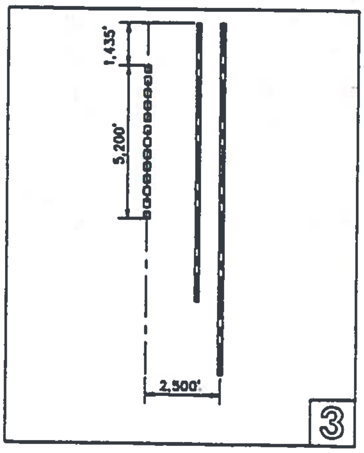
Initial airfield options were developed by combining the features of the alternatives for improving the existing airfield and alternatives for adding a third runway. Seven options were identified. These options are illustrated schematically in Figure 3-1 and shown in greater detail in Figures 3-2 through 3-9. The four new exits to Runway 16R-34L are shown as existing because construction of these taxiways is in progress. The takeoff and landing lengths of each runway under the options evaluated are shown in Table 3-1.



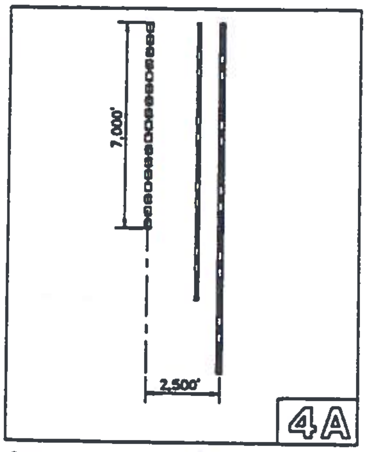
Option1. Existing Conditions



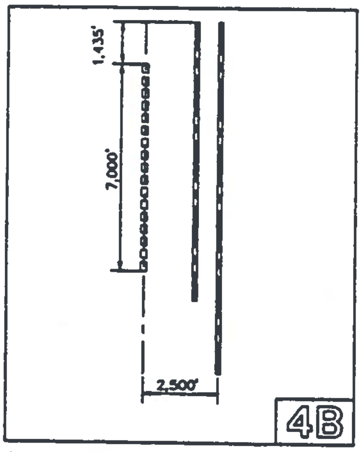
Option 2. Commuter -- Close



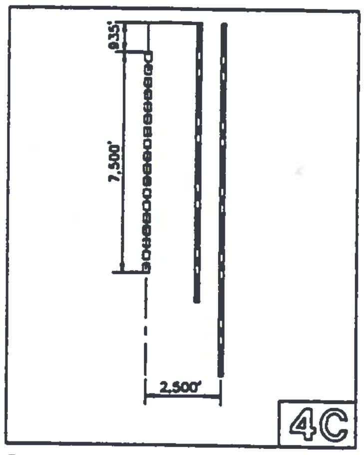
Option 3. Commuter -- Dependent



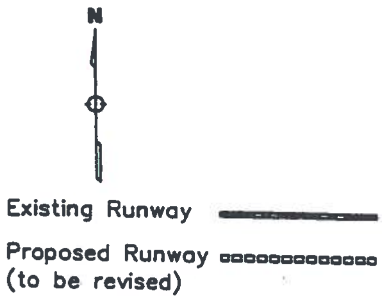
Option 4A. Programatic Baseline

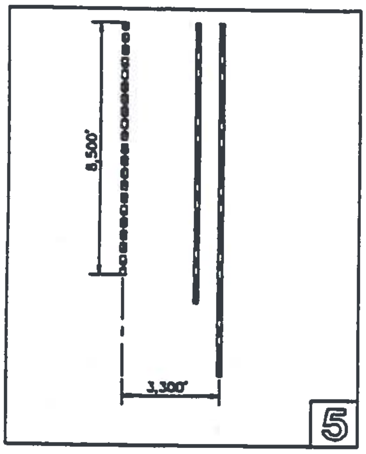


Option 4B. Programatic Baseline -- Staggered

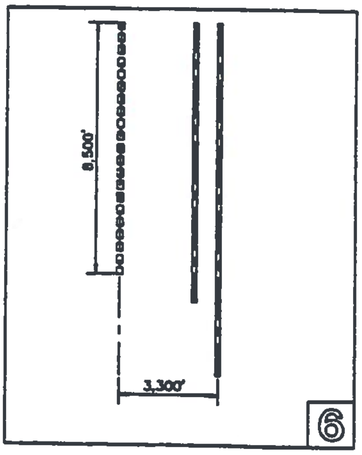


Option 4C. Staggered 7,500 - Foot Runway





Option 6. Dependent -- Maximum Length



Option 6. Independent -- Maximum Length

Figure 3-1
THIRD RUNWAY OPTIONS

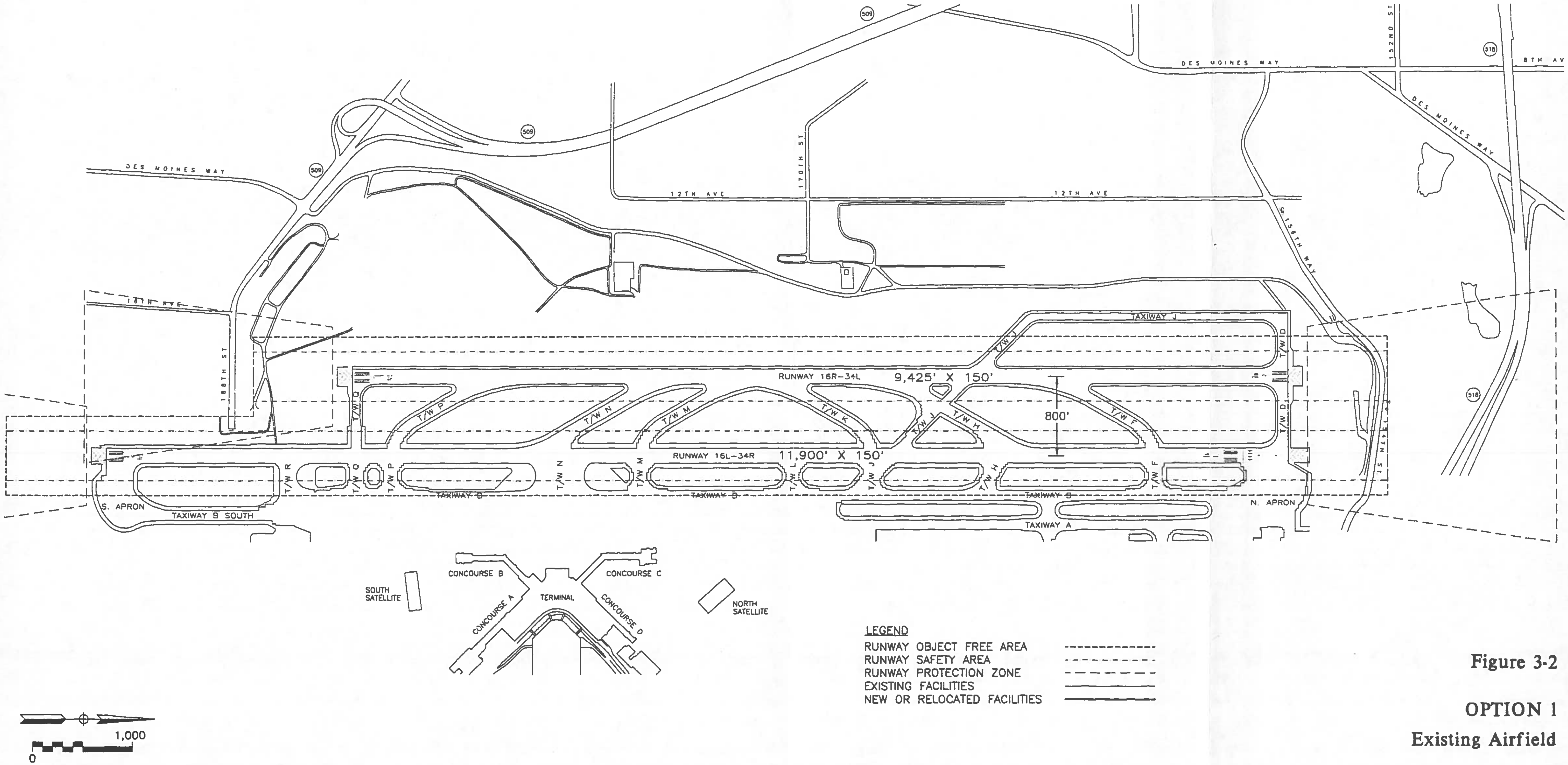


Figure 3-2

OPTION 1

Existing Airfield

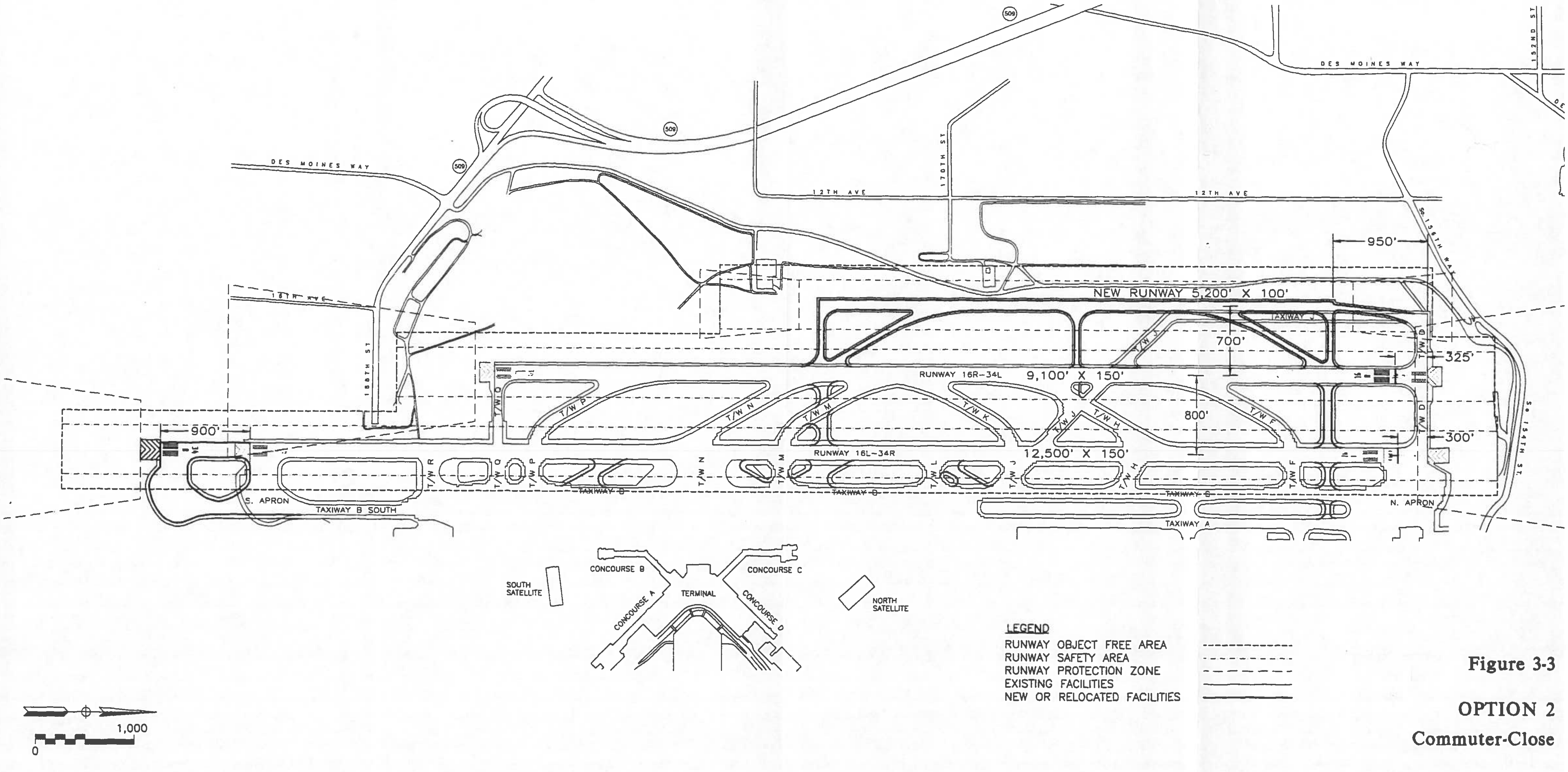


Figure 3-3

OPTION 2

Commuter-Close

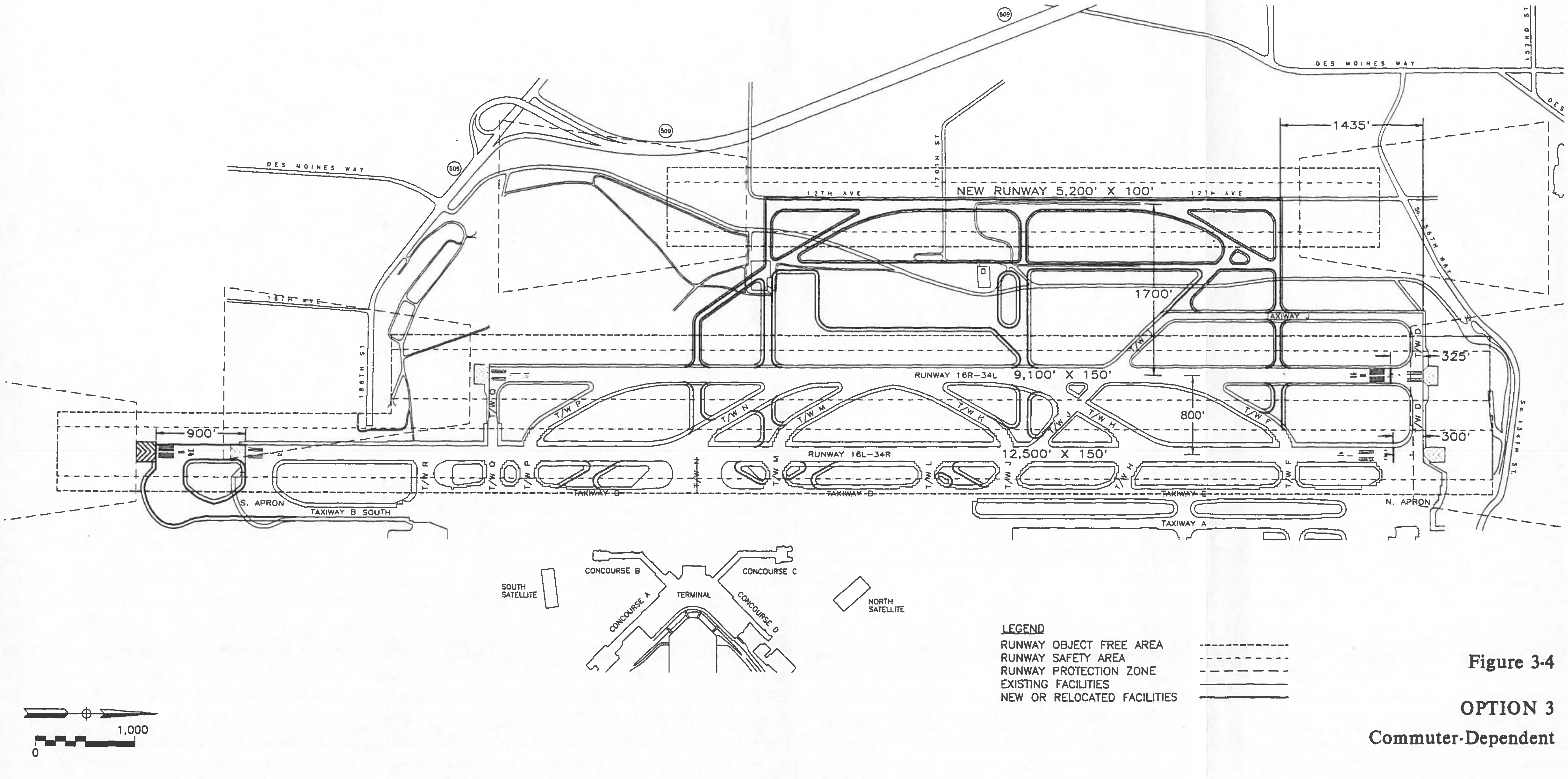


Figure 3-4

OPTION 3

Commuter-Dependent

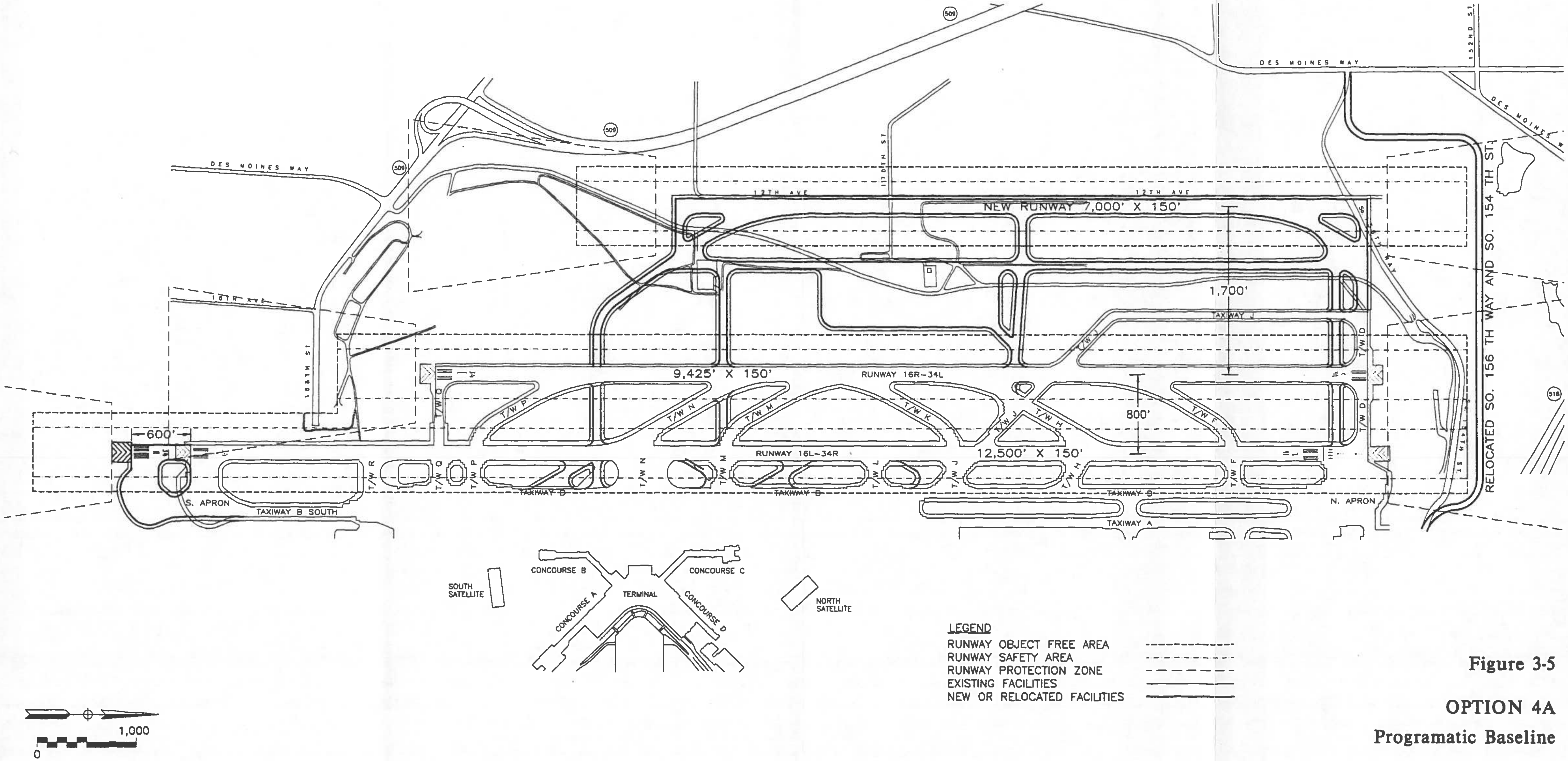


Figure 3-5

OPTION 4A

Programatic Baseline

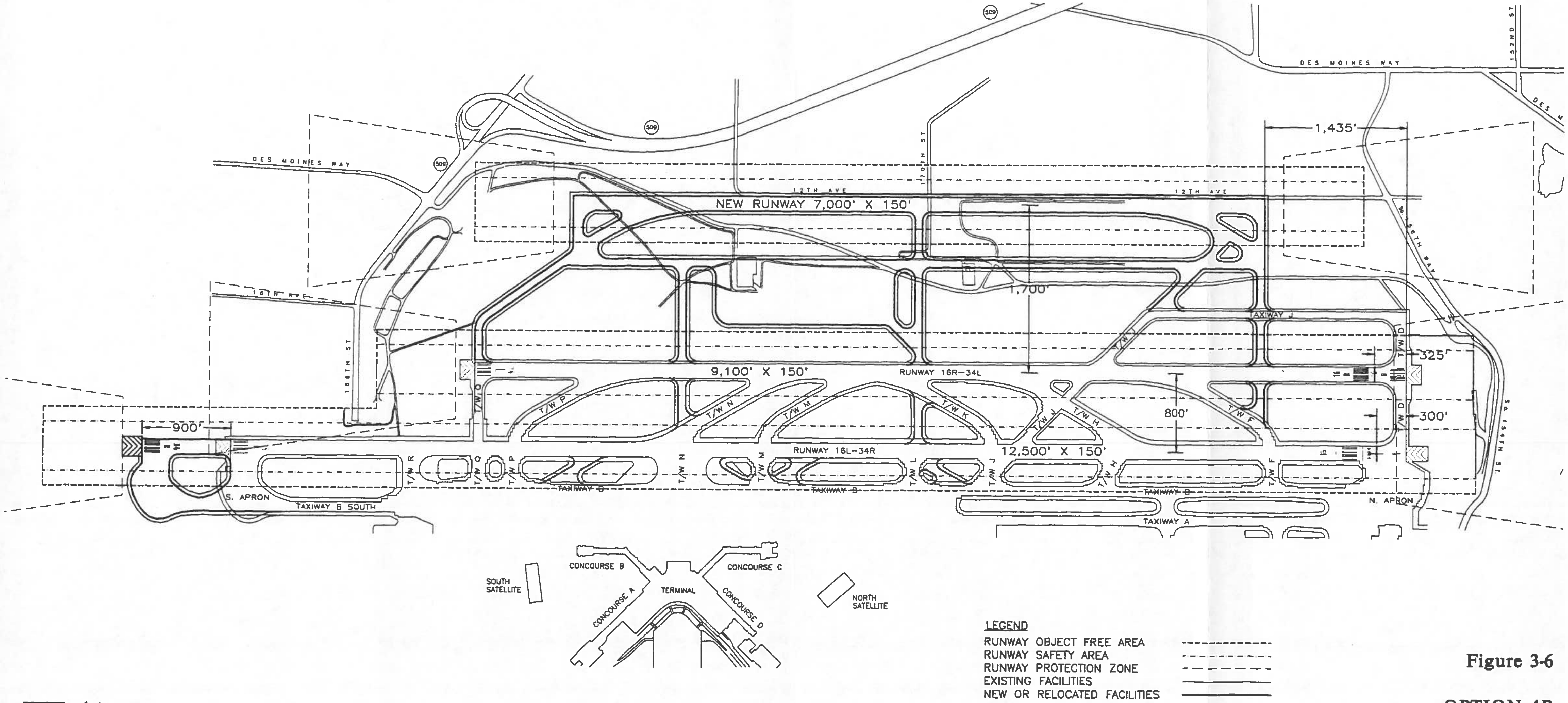


Figure 3-6

OPTION 4B

Programatic Baseline Staggered

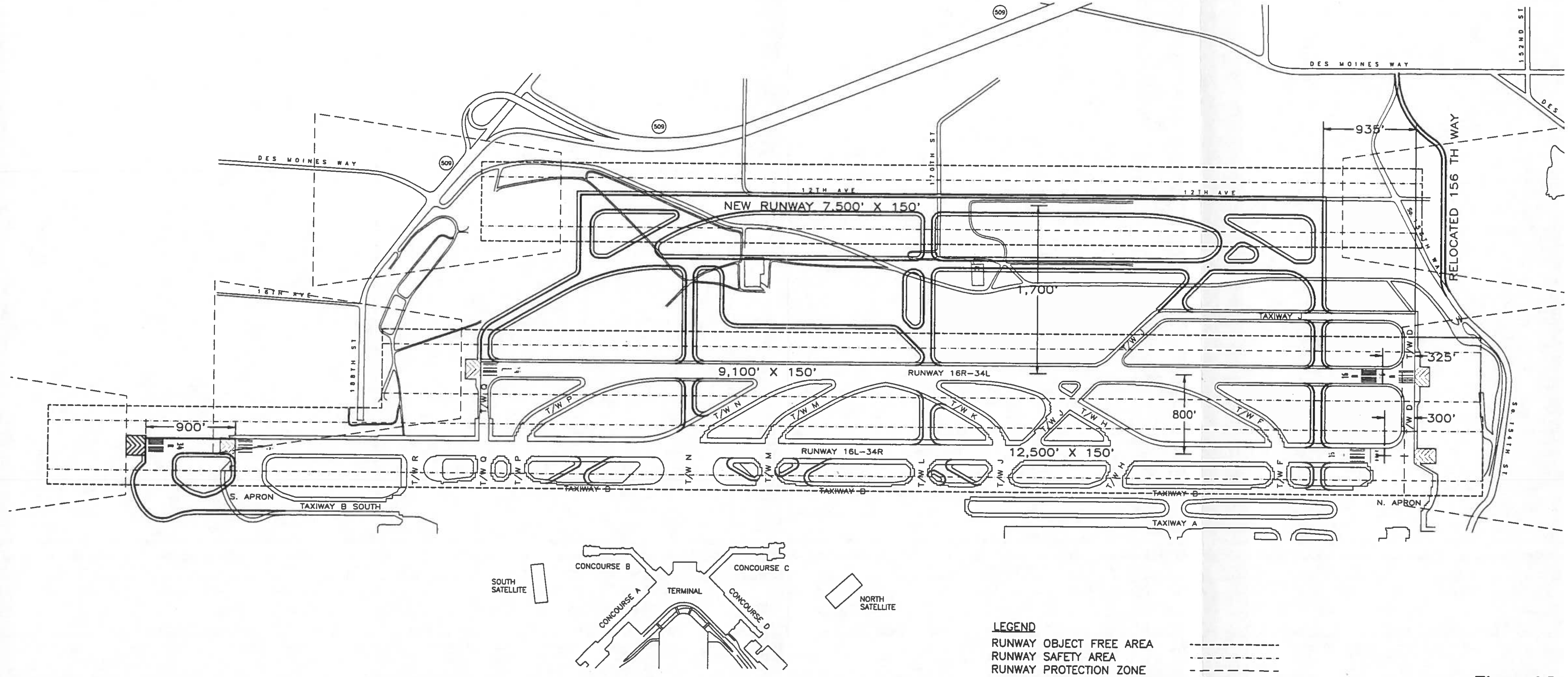


Figure 3-7

OPTION 4C

Staggered 7,500-Foot Runway

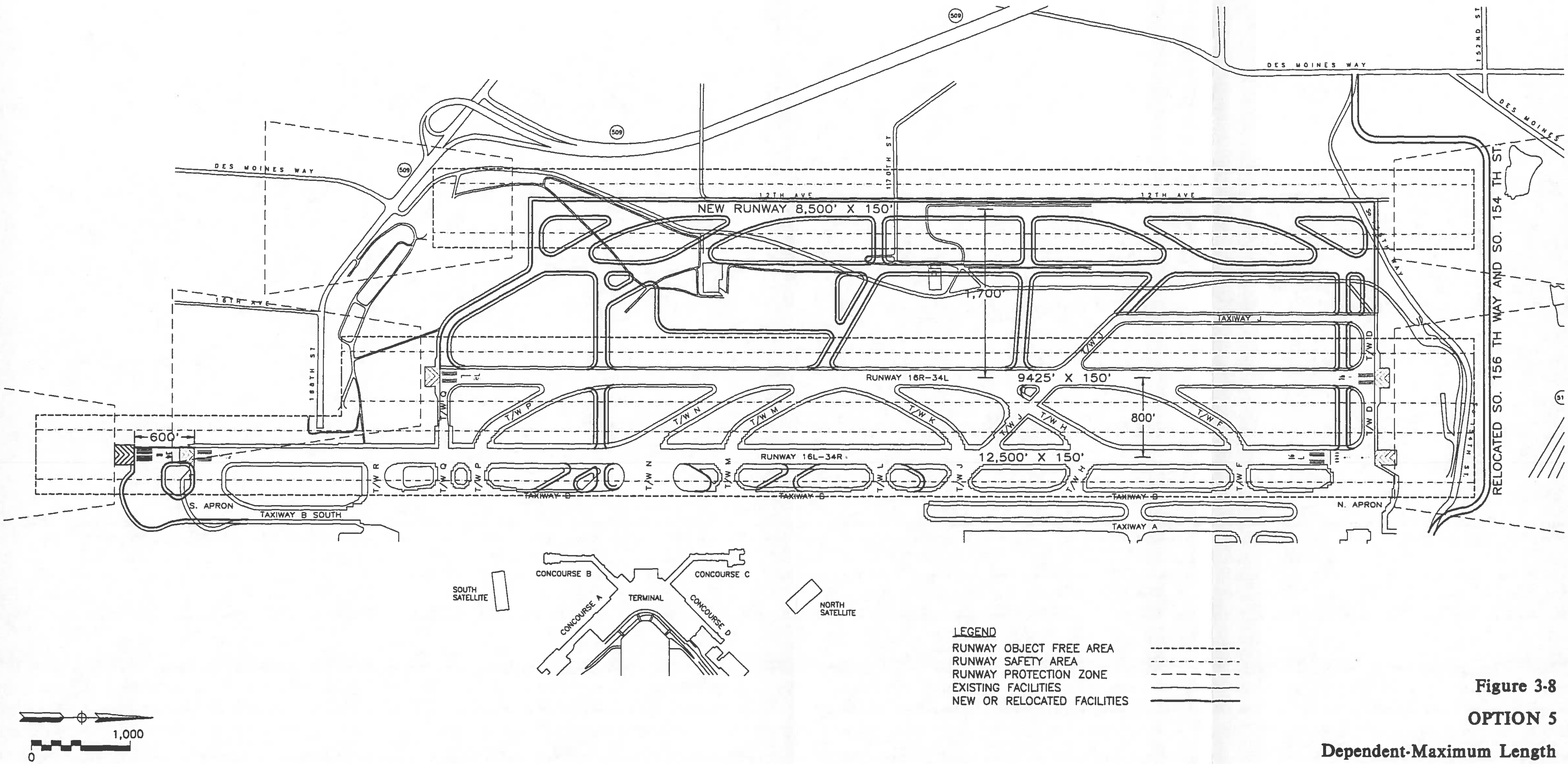
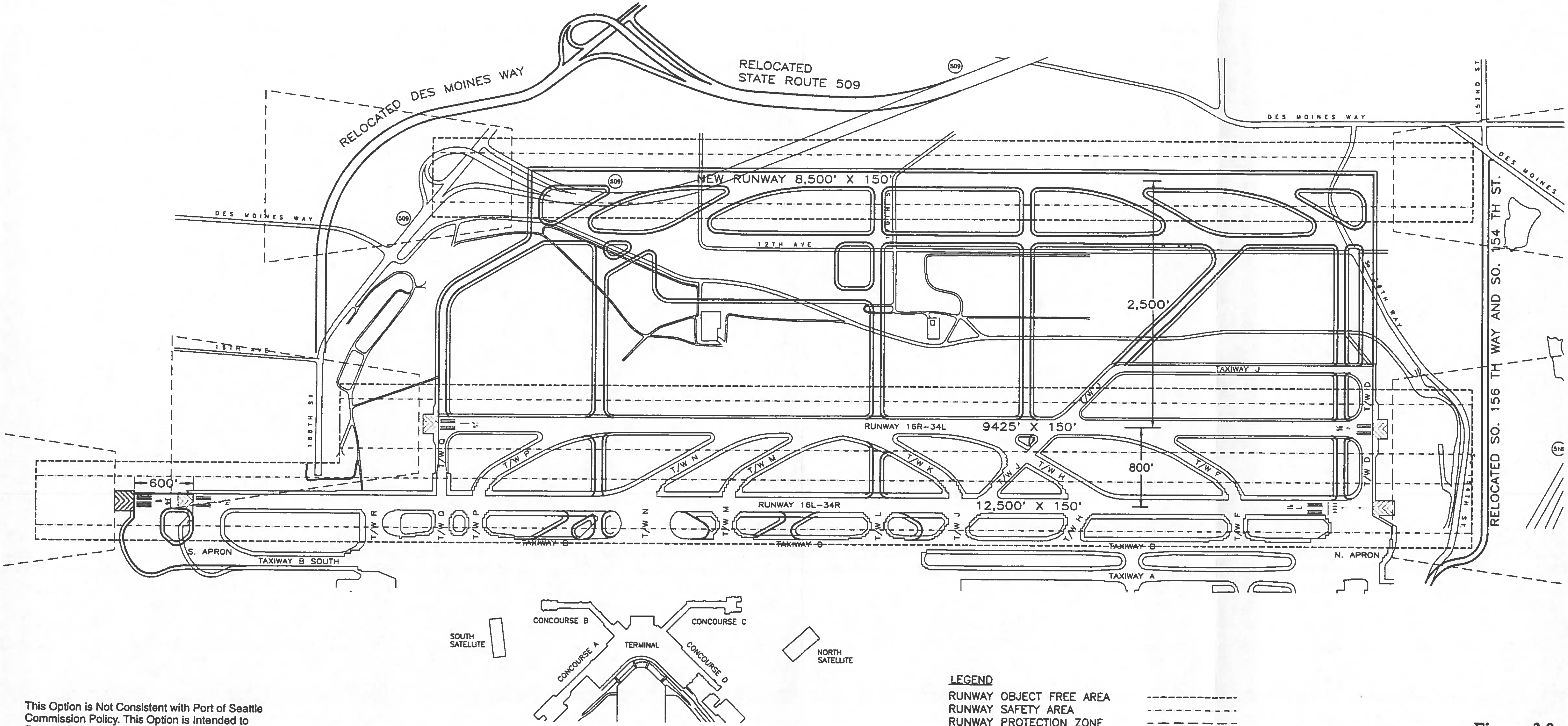


Figure 3-8

OPTION 5

Dependent-Maximum Length



LEGEND
RUNWAY OBJECT FREE AREA
RUNWAY SAFETY AREA
RUNWAY PROTECTION ZONE
EXISTING FACILITIES
NEW OR RELOCATED FACILITIES

This Option is Not Consistent with Port of Seattle Commission Policy. This Option is Intended to Reassess Cost-Benefit Analysis.

0 1,000

Figure 3-9

OPTION 6

Independent-Maximum Length

TABLE 3-1
RUNWAY LENGTHS FOR INITIAL AIRSIDE OPTIONS AT SEATTLE-TACOMA INTERNATIONAL AIRPORT [a]

Item	Takeoff or Landing Length (Feet)						
	Option 1 Existing Airfield	Option 2 Commuter Close	Option 3 Commuter Dependent	Option 4A Program-matic Baseline	Option 4B Program-matic Baseline Staggered	Option 5 Dependent Maximum	Option 6 Independent Maximum
Runway 16L-34R							
Runway 16L							
Landing Length	11,410	12,310	12,310	12,010	12,310	12,010	12,010
Takeoff Length	11,900	12,500	12,500	12,500	12,500	12,500	12,500
Runway 34R							
Landing Length	11,900	12,500	12,500	12,500	12,500	12,500	12,500
Takeoff Length	11,900	12,500	12,500	12,500	12,500	12,500	12,500
Runway 16R-34L							
Runway 16R							
Landing Length	9,425	9,100	9,100	9,425	9,100	9,425	9,425
Takeoff Length	9,425	9,100	9,100	9,425	9,100	9,425	9,425
Runway 34L							
Landing Length	9,425	9,100	9,100	9,425	9,100	9,425	9,425
Takeoff Length	9,425	9,100	9,100	9,425	9,100	9,425	9,425
New Runway							
Runway 16 New							
Landing Length	-	5,200	5,200	7,000	7,000	8,500	8,500
Takeoff Length	-	5,200	5,200	7,000	7,000	8,500	8,500
Runway 34 New							
Landing Length	-	5,200	5,200	7,000	7,000	8,500	8,500
Takeoff Length	-	5,200	5,200	7,000	7,000	8,500	8,500

[a] Source: P&D Aviation analysis.

Option 1: Existing Airfield

Under this option, no improvements would be made to the airfield beyond those already underway (new taxiways). This "do nothing" option is included in the analysis of alternatives to estimate the likely effects (for example, additional aircraft delays) of not providing additional airfield capacity. It will provide a benchmark by which the other options are measured.

The following options have several development items in common. Improvements to the existing airfield under the remaining options include four new taxiway exits to Runway 16L-34R, extending Runway 16L-34R to 12,500 feet, and extending the RSAs and ROFAs of all four runway ends to meet FAA's standards.

The method of achieving FAA compliance with the RSAs and ROFAs varies among the options. In some cases, compliance would be obtained by relocating the runway thresholds; in other cases RSA and ROFA area would be added at the end of the runway. In the options in which the RSA and ROFA were extended to the north without relocating the runway thresholds, the relocation of South 154th Street and 156th Way would be necessary. Under all options, Runway 16L-34R would be extended to 12,500 feet (takeoff length) because it was concluded, as described in Section 2, that this is the maximum runway length required for departures at Sea-Tac.

Option 2: Commuter-Close

Under Option 2, a new 5,200 foot by 100 foot commuter runway would be constructed 1,500 feet west of Runway 16L-34R (Figure 3-3). The new runway would serve primarily commuter and general aviation operations. However, it would be capable of accommodating Airplane Design Group III Aircraft which include small air carrier jets such as the B737 and MD82. The north threshold of the new runway would be 950 feet south of the existing north runway ends.

Option 2 represents the lowest cost approach of all options considered. There would be no relocation of adjacent roadways (other than airport service roads) and safety area standards would be met by relocating the north threshold of Runway 16L-34R 300 feet to the south and Runway 16R-34L 325 feet to the south. This would result in the shortening of Runway 16R-34L to 9,100 feet.

Precision instrument approach navaids would not be installed under Option 2 because the separation between the runways would not permit an additional IFR arrival stream. The new runway would be used primarily for VFR traffic conditions.

Option 3: Commuter Dependant

Airfield improvements under Option 3 would be similar to Option 2, with the exception that the new commuter runway would be 2,500 feet west of Runway 16L-34R (Figure 3-4). This greater separation would allow for two arrival streams under IFR conditions. The north threshold of the new runway would be located 1,435 feet south of the north ends of the existing runways. The greater runway separation would allow for an aircraft parking area to be located between Runway 16R-34L and the new runway. This area would be used to park aircraft which remain overnight at the airport or which must be temporarily parked for maintenance reasons.

Compliance with RSA and ROFA standards would be achieved by relocating to the south the thresholds at the north end of the existing runways.

The landing threshold of Runway 16L is

currently displaced 490 feet to the south of the runway end. With the 300 foot relocation of the runway end to the south, the landing threshold will be displaced 190 feet. Although this displacement could be eliminated, it is assumed for purposes of this analyses that the displacement would be maintained to prevent relocating the approach light system to Runway 16L.

In this scenario, there would be sufficient separation (2,500 feet) between outboard runways to conduct simultaneous IFR approaches and departures, and parallel (staggered but not simultaneous) ILS approaches. The runway configuration permits the use of two IFR arrival streams and therefore the new runway would function in an IFR capacity. As such, precision approach capability should be provided for both south and north traffic flow conditions. It is assumed for purposes of this comparison that a Category I ILS systems would be installed on both ends of the new runway under this option.

Option 4A: Programmatic Baseline

With Option 4A, a new 7,000 foot by 150 foot runway would be constructed 2,500 feet west of Runway 16L-34R (Figure 3-5). The north end of the new runway would be aligned with the north ends of the existing runways. To achieve RSA and ROFA compliance, South 154th Street and South 150th Way would be relocated to the north around the new and existing runways. Because the roads would be relocated, the north thresholds of the existing runways do not need to be relocated. Therefore, Runway 16R-34L could be maintained at its present 9,425 foot length. Runway 16L-34R would be extended 600 feet to the south to achieve an overall length of 12,500 feet.

The 2,500-foot separation between outboard runways is sufficient to permit parallel (staggered) ILS approaches. To provide maximum IFR benefits, each end of the new runway would be equipped for precision instrument approaches. Since Runway 16L will soon accommodate Category IIIb approaches and adequate separation will exist between it and the new runway, it is recommended that the new runway also be equipped for Category IIIb approaches. This will permit parallel Category IIIb ILS approaches and thus enhance capacity during periods of extremely low visibility. Use of Runway 16R as the Category IIIb runway can continue until such time that demand indicates the need for dual, low visibility arrival streams. It is also recommended that the new runway be planned for Category IIIb capability for north flow operations.

The layout of the runway and taxiway system for the new runway, under Option 4A, was developed by the HNTB Corporation (Seattle-Tacoma International Airport, Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994). The HNTB Preliminary Engineering Studies have include topography and soils investigations, roadway and utility relocations, and other factors which potentially would impact the construction of the new runway.

Option 4B: Programmatic Baseline Staggered

Option 4B is similar to Option 4A, except the north threshold of the new runway would be staggered approximately 1,435 feet to the south to eliminate the need to relocate South 156th Way and to reduce the fill requirements at the north end of the runway (Figure 3-6). The terrain at the north end of the new runway drops steeply to the north and offsetting the new runway to the south would substantially reduce the amount of fill material required and the construction cost. Under this option, the relocation of South 154th Street as well as South

156th Way would not be necessary.

Accordingly, the north thresholds of the existing runways would be relocated to provide RSAs and ROFAs which meet FAA standards. Note that a 7,000 foot runway is approximately the longest runway which can be accommodated at this separation without relocating existing public roadways and achieving RSA and ROFA standards. The new runway would be equipped with Category IIIb precision instrument landing systems at each end, as in Option 4A.

Option 4C: Staggered 7,500-foot Runway

Under this option, the new runway would be 7,500 feet long. This length was chosen to provide an option in which the runway length would be between that of Options 4A/4B and Option 5. To allow the necessary RSA and ROFA at the south end of the new runway, it could be staggered at most about 935 feet to the south of the existing runway thresholds. For this reason, South 156th Way would need to be relocated to the north to accommodate the RSA and ROFA at the north end of the new runway. In other respects, this option is similar to Option 4B.

Option 5: Dependent-Maximum Length

Option 5 includes the construction of a new 8,500 foot by 150 foot runway, 2,500 feet west of Runway 16L-34R (Figure 3-7). The north end of this runway would be in alignment with the north ends of the existing runways. South 154th Street and South 156th Way would be relocated to the north as in Option 4A. With the north threshold of the new runway located as described above, 8,500 feet is the maximum length obtainable to comply with RSA and ROFA standards.

The layout of the runway and taxiway system for the new runway, under Option 5, was developed by the HNTB Corporation (Seattle-Tacoma International Airport, Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994). The HNTB Preliminary Engineering Studies have include topography and soils investigations, roadway and utility relocations, and other factors which potentially would impact the construction of the new runway.

Because dual arrival streams are possible, the navaids described for Options 4A and 4B are applicable to this option. Therefore, each end of the new runway would be capable of Category IIIb approaches.

Option 6: Independent-Maximum Length

In Option 6, a new 8,500 foot by 150 foot runway would be constructed 3,300 feet west of Runway 16L-34R (Figure 3-8). Due to the greater separation of the new runway from the existing runways under this option, extensive road relocations would be necessary. In addition to the relocation of South 156th Way and South 154th Street, approximately one mile of State Route 509 and one mile of Des Moines Way would have to be relocated. The relocations would include the 2 level interchange between State Route 509 and Des Moines Way.

In addition, this option would require substantial property acquisition and the relocation of many more homes and businesses than under the other options. The estimated costs of land acquisitions and relocations under each option are included in Section 5.

Due to the proximity of the new runway to Des Moines Way west of the airport, the relocated South 156th Way would join 152nd Street at its intersection with Des Moines Way rather than retaining the connection with 156th Street at Des Moines Way (Figure 3-8).

The advantage of Option 6 is that it would provide for dual dependent IFR arrival streams on the two westerly runways, leaving the long runway, Runway 16L-34R, available for departures. Furthermore, the two outboard runways would be separated by 3,300 feet, which in the future will presumably permit simultaneously independent ILS approaches. Thus, this option has the greatest capacity for handling air traffic under IFR conditions and would result in fewer aircraft operational delays than the other options. Navaids for Option 6 would be the same as those for Options 3 through 5, Category IIIb approaches for both north and south operating conditions.

RUNWAY USES FOR INITIAL AIRSIDE OPTIONS

The use (arrivals vs. departures) of new and existing runways would vary according to the option and weather conditions (wind direction and ceiling and visibility minimums). Figure 3-10 depicts generalized runway uses of options under various weather conditions. Future runway use patterns for the airfield options were obtained from the FAA air traffic control tower at Sea-Tac.

The runway use patterns have been generalized to show only the primary flow patterns. For example, under most configurations, the new runway is shown as primarily a landing runway but the runway would occasionally be used for departures under some of these configurations when conditions permit.

The weather conditions shown in Figure 3-10 are:

- VMC -- visual meteorological conditions (visibility at least 5 statute miles; ceiling at least 5,000 feet)
- MMC -- marginal meteorological conditions (visibility less than VMC, but at least 2.5 statute miles; ceiling below VMC, but at least 900 feet)
- IMC -- instrument meteorological conditions (visibility and/or cloud ceiling below MMC)

South Flow

Under VMC south flow conditions, which occur 49 percent of the time, the third runway would be used primarily for arrivals in all development options. The existing runways would be operated as they are today (Runway 16L for departures and Runway 16R for arrivals) under Options 2, 3, and 6. Under Options 4A, 4B and 5, Runway 16L would become primarily an arrival runway and Runway 16R would be used primarily for departures.

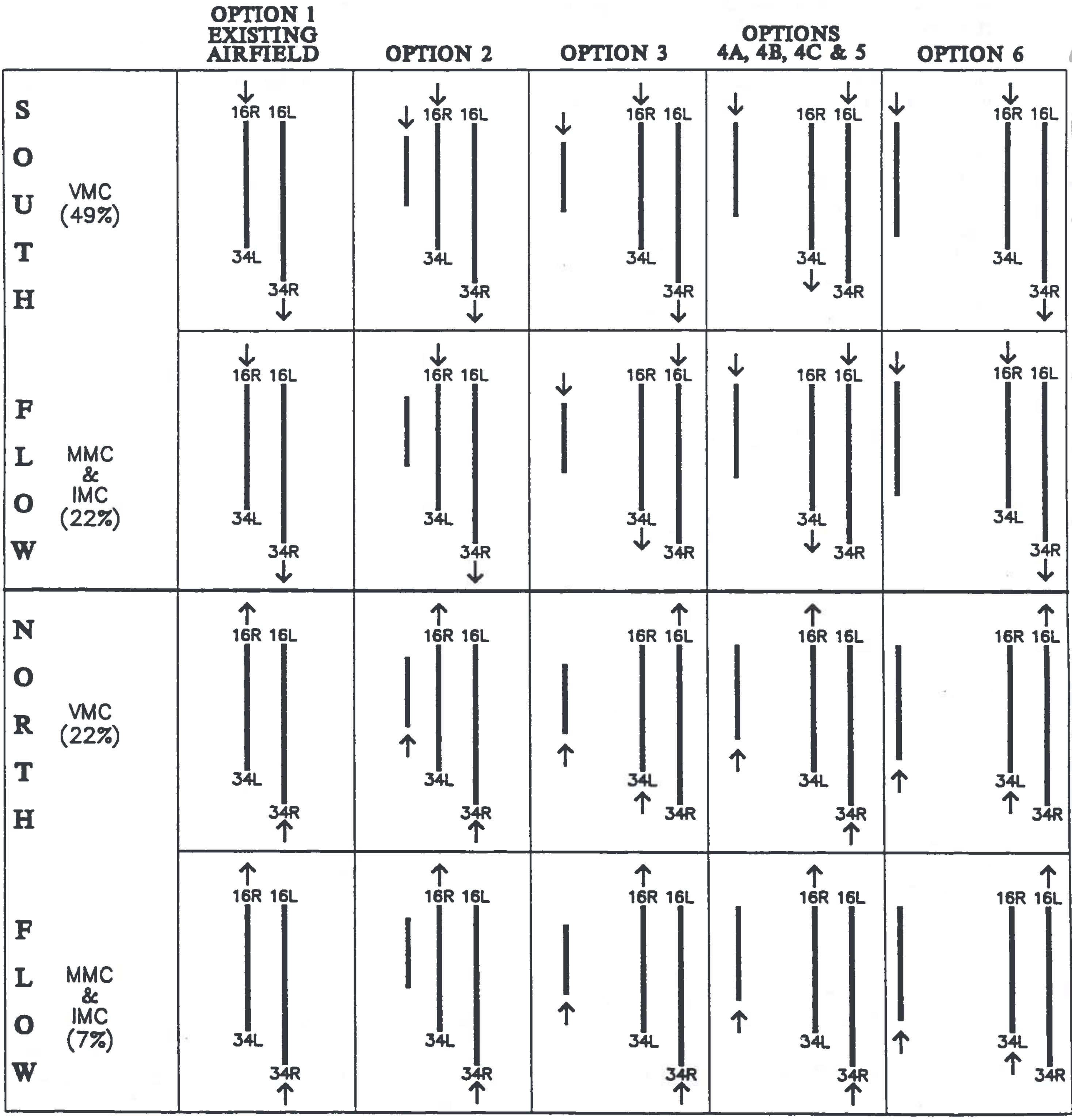
During MMC and IMC south flows (22 percent of the time), assignments would be as under VMC conditions except under Options 2 and 3. Under Option 2, the third runway would normally not be used because the separation would not allow two arrival streams. Under Option 3, the assignments of the existing runways would be reversed.

North Flow

In VMC north flow conditions (22 percent of the time), the third runway would be primarily used for arrivals. The existing runways would be used as they are today (Runway 34R for arrivals and Runway 34L for departures) except under Options 3 and 6. Under those options, the primary assignments of the existing runways would be reversed.

During MMC and IMC north flow (seven percent of the time), the runway use would be the same as under VMC except for Options 2 and 3. In Option 2, the third runway would normally not be used because the separation

FIGURE 3-10
PRIMARY RUNWAY ASSIGNMENTS FOR INITIAL AIRFIELD OPTIONS



would not allow dual arrival streams. Under Option 3, the existing runways would be used as they are today.

In the next two sections, the eight initial airfield options described in this section are evaluated in terms of airfield delay and taxi times (Section 4) and construction and property acquisition costs (Section 5).

Section 4
AIRSIDE OPERATIONS ANALYSIS

SECTION 4
AIRSIDE OPERATIONS ANALYSIS

INTRODUCTION

This section describes the results of the operational analyses of the initial airfield options identified in Section 3. The operational analyses consists of estimating average airfield approach and departure delays and average taxiing times.

AIRFIELD DELAYS

Methodology

The Federal Aviation Administration's Airport and Airspace Simulation Model (SIMMOD) was used in this analysis. SIMMOD is a sophisticated computer simulation model which realistically simulates the movement of every aircraft, step by step, resolving conflicts and monitoring time along each segment of a flight or taxi path. These capabilities allow existing and future flight schedules to be input and used to forecast the effects of proposed runway changes. The model produces quantitative measures of aircraft air arrival delays, departure queue delays, and ground taxi delays.

The conduct of these studies was overseen by the Seattle-Tacoma Airport Capacity Design Team. This team was formed to evaluate means of increasing capacity and efficiency at Sea-Tac and reducing costly aircraft delays. The Capacity Team was composed of representatives from the Port of Seattle, FAA, airlines, and consultants.

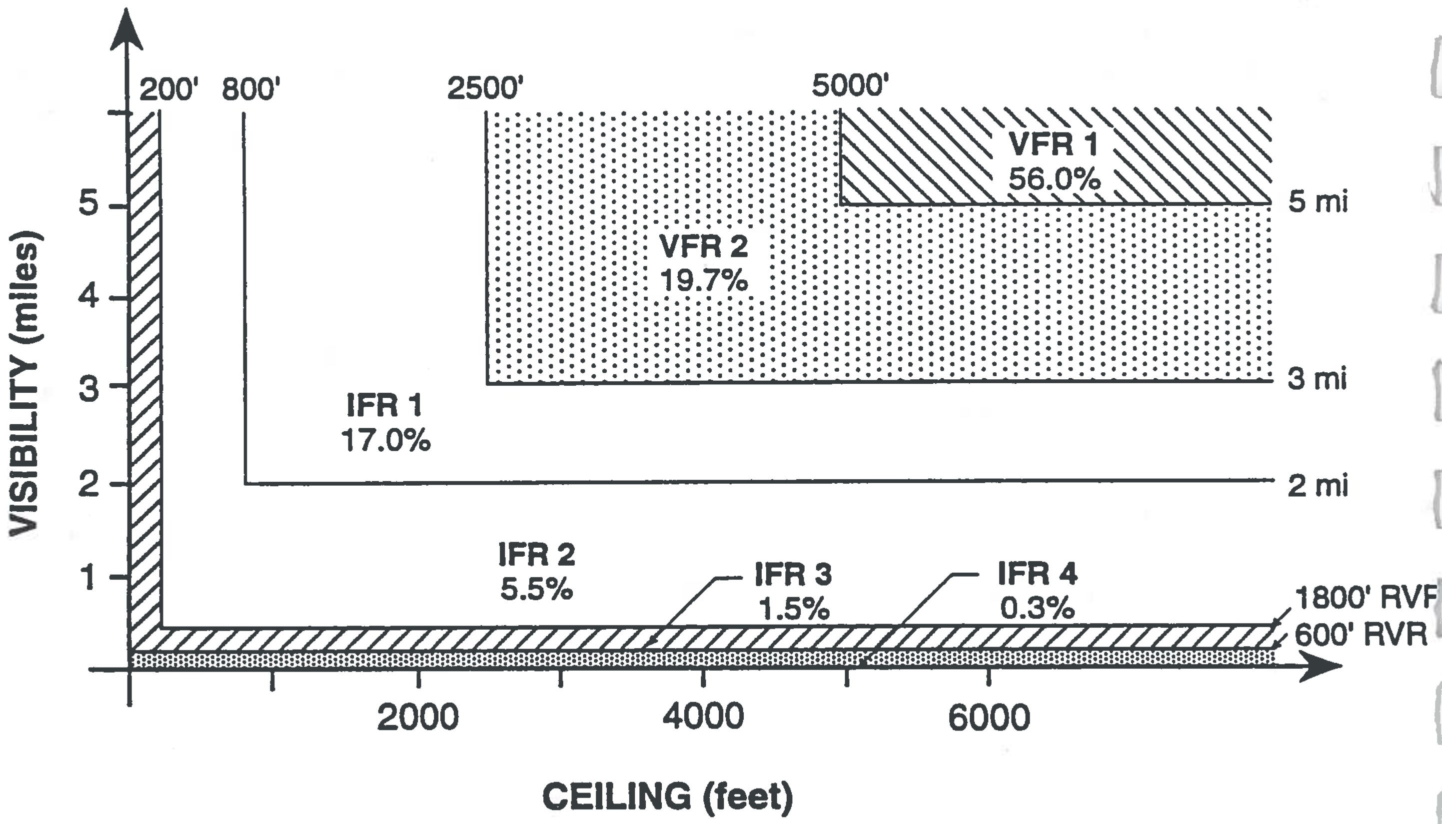
The prime objective of the Capacity Team was to identify and assess various actions at Sea-Tac which would increase airport capacity, improve efficiency of operations, and reduce aircraft delays. The purpose of the process was to ascertain the technical merits of each alternative action and its impact on aircraft delay. The Team began these studies in October 1993 and will complete this work in early 1995. The results presented herein are therefore preliminary and subject to further refinement.

Inputs and assumptions used in the analysis are described below.

Weather Conditions. Weather conditions and their patterns of occurrence are important considerations when calculating airport capacity and aircraft delays. The spacing between aircraft specified by the FAA and the applicable air traffic control (ATC) operational rules, differ depending on the weather, i.e., the cloud ceiling and visibility. For example, when the cloud ceiling and visibility are high enough to permit aircraft pilots to maintain visual separation from each other, aircraft can land simultaneously on the two closely spaced parallel runway at the Airport. During less-favorable weather conditions, radar separation must be provided by ATC, resulting in a single aircraft arrival stream and greater in-trail spacing between arriving aircraft. The time of occurrence of various weather conditions versus the demand for landing and take-offs is also important.

Figure 4-1 illustrates the frequency of occurrence of various types of weather conditions at Sea-Tac. During VFR 1 (Visual Flight Rules) weather, simultaneous visual approaches can be conducted to both existing runways or to a third parallel runway at the Airport. -- i.e., up to three arrival streams. During VFR 2 conditions dual arrival streams

FIGURE 4-1
SEA-TAC WEATHER CONDITIONS



Source: Sea-Tac Airport Weather Station, Hourly Observations from 1/1/82 to 3/31/92.

can be maintained only if pilots can make visual contact with other approaching aircraft. Thus, dual arrival streams can only be guaranteed at Sea-Tac 56 percent of the time.

During IFR (Instrument Flight Rules) conditions, only a single arrival stream and a single runway can be used because of the existing 800 foot spacing between runways. Current rules require at least a 2,500 foot spacing between parallel runway centerlines for two "staggered," or "dependent" aircraft arrival streams during IFR and VFR 2 conditions. These conditions occur 44 percent of the time at Sea-Tac.

With 2,500 foot spacing between runway centerlines, FAA permits a minimum diagonal spacing between arriving aircraft of 1.5 nautical miles. On the basis of conversations with control tower representatives, it was determined this minimum spacing cannot be realistically maintained on a continuous basis. The simulation studies therefore assume an average diagonal spacing between aircraft arrivals of about 2 nautical miles. Airside Options 3, 4A, 4B, 4C, and 5 meet this criteria.

Under current FAA rules, for two simultaneous independent arrival streams, at least a 3,400 foot spacing is required between runway centerlines, along with fast update precision radar monitoring equipment (PRM). For purposes of this analysis, it is assumed that future technology will permit the runway spacing for independent approaches to be reduced to 3,300 feet as provided in Option 6.

Arrival Aircraft Separation. The FAA's SIMMOD model enforces minimum separation requirements between successive arriving aircraft over the length of the common approach path to each arrival runway. This separation enforcement considers runway occupancy times, weather condition, and the approach category of the lead and following aircraft. The minimum separations between arrival aircraft used in the analysis are listed in Table 4-1.

Common Approach Path Lengths. For modelling purposes, the common final approach course length is assumed to be that portion of the arrival flight path where airspeed and maneuvering adjustments required to maintain in-trail spacing between successive arriving aircraft are minimal. When visual approaches can be conducted (i.e., during VFR 1), aircraft can turn onto the final approach course closer to the airport at higher speeds and with reduced in-trail spacing than under VFR 2 and IFR. Therefore, for runway capacity and aircraft delay calculation purposes, the most important categorization of weather conditions is the split between VFR 1 and VFR 2/IFR.

The common final approach course lengths (as identified in the FAA Capacity Enhancement Plan Update "Seattle-Tacoma International Airport Data Package No. 6," August 1994) used in the analysis are as follows:

- VFR 1 -- 6 nautical miles for approach Category B, C, and D aircraft and 3 nautical miles for approach Category A aircraft.
- VFR 2 and IFR -- 6 nautical miles for all aircraft categories.

Runway Occupancy Times. The runway occupancy times (ROT) for arrival aircraft used in the analysis are based on observations conducted by the FAA Technical Center at the Airport during the weeks of October 25 and November 1, 1993 as described in the FAA Capacity Enhancement Plan Update "Seattle-Tacoma International Airport Data Package No. 2," January 1994). For purposes of this analysis, it is assumed that these ROTs will not differ materially in the future for the proposed new runways. The ROTs used in the analysis

TABLE 4-1
MINIMUM SEPARATIONS BETWEEN ARRIVAL AIRCRAFT [a]
(Nautical Miles)

Approach Category of Leading Aircraft Arrival [b]	Approach Category of Trailing Aircraft [a] (Nautical Miles)			
	A	B	C	D
VFR Separations				
A	2.7	3.0	3.2	3.4
B	3.4	3.0	3.2	3.4
C	3.4	3.0	3.2	3.4
D	5.0	4.7	5.0	4.8
IFR Separations				
A	4.0	4.1	4.2	4.3
B	5.0	4.1	4.2	4.3
C	5.0	4.1	4.2	4.3
D	7.0	6.1	5.2	5.3

[a] Source: FAA Airport Capacity Enhancement Plan Update, "Seattle-Tacoma International Airport Data package No. 6", August 1994. Note: Spacings listed in the data package have been rounded to one decimal place for model input.

[b] Approach categories are defined as follows; A = Single-engine and small twin-engine propeller aircraft weighing less than 12,500 lbs; B = Twin engine aircraft weighing 12,500 lbs or more; C = All non-heavy jet aircraft; D = heavy aircraft with takeoff weigh of 300,000 lbs or more.

are as follows:

Aircraft Approach Category	ROT (Seconds)
A	54
B	49
C	52
D	68

Annual and Daily Demand. Several demand levels were selected for the delay analysis. These are shown in Table 4-2. The baseline is intended to represent current conditions at the airport. Future 1 corresponds to traffic levels which are expected to occur about the year 2015 based on the Master Plan Update forecasts. Future 2 is not expected to occur until well after the year 2020 but has been selected to test the capability of the runways to perform under significantly higher demand levels.

Fleet Mix. Table 4-3 illustrates the fleet mix assumptions which are being used in the delay analysis studies. As can be seen a constant fleet mix is currently being assumed to simplify the number of cases which are analyzed. The Master Plan Update forecasts project a greater percentage of Category D (Heavy) aircraft in the future than is shown in Table 4-3. This will cause the delays estimated in the future to be slightly higher for all options since aircraft separations will be increased. As the percentage of heavy aircraft increase, delays for the existing runway and commuter runway configurations (Options 1, 2, and 3) will increase most among the options being considered. In these options wake vortex required separations of at least 2500 feet between two arrival streams is not achieved and thus greater in-trail separations will be necessary.

Traffic Distribution Assumption. For delay calculations, it is important to know when demand occurs and the composition of arrivals and departures within the demand periods. Hourly traffic distribution assumptions used in this analysis are summarized in Table 4-4. According to airline representatives, previous attempts by airlines to schedule operations during off-peak times have not proven economically successful. Therefore, for purposes of this analysis, it is assumed that the demand patterns will remain essentially unchanged in the future, although some natural flattening of peaks may occur.

Airfield Delay Findings

The estimated average annual aircraft delays for each of the options analyzed are summarized in Table 4-5 and are depicted graphically in Figure 4-2 for the Baseline and Future 1 conditions. The delay estimates represent weighted average annual values for six basic weather conditions and the two flow directions as they occur throughout the year. Estimated delays are shown in terms of both minutes and dollars of delay savings in Table 4-5. Delay savings are stated in terms of 1992/1993 dollars. Delay costs were computed from average aircraft operating costs per hour for the baseline and Master Plan Update forecast year 2015 fleet mix ($2,094 per hour or $34.90 per minute). Aircraft operating costs were obtained from Quarterly Aircraft Operating Costs and Statistics, Quarter and Year Ending March 31, 1993, 1994 by Avmark, Inc. Findings of this analysis for the various options are summarized below.

Option 1 (Existing Conditions). As shown in Table 4-5, average annual aircraft delays at Sea-Tac Airport are presently on the order of 5.5 minutes per aircraft operation ($51 million per year). With no additional runways, average annual aircraft delays could be expected to increase to about 22.0 minutes by the year 2015 ($352 million per year).

TABLE 4-2
ANNUAL AND DAILY DEMAND

Year	Annual Operations	Daily Operations	Equivalent Days
Baseline	345,000	1,040	332
Future 1	425,000	1,280	332
Future 2	525,000	1,581	332

Source: Airport Capacity Enhancement Plan Update, "Seattle-Tacoma International Airport, Data Package 6", August 1994.

TABLE 4-3
FLEET MIX ASSUMPTIONS

	Category D	Category C	Category B	Category A
Baseline	**8.6%**	**54.2%**	**31.3%**	**5.9%**
Future 1	**8.6%**	**54.2%**	**31.3%**	**5.9%**
Future 2	**8.6%**	**54.2%**	**31.3%**	**5.9%**

Source: Airport Capacity Enhancement Plan Update, "Seattle-Tacoma International Airport, Data Package 6", August 1994.

TABLE 4-4
HOURLY DISTRIBUTION OF DEMAND [a]

Hour	Arrivals [b]	Departures [c]	Totals
00:00 - 00:59	6	6	12
01:00 - 01:59	1	2	3
02:00 - 02:59	0	0	0
03:00 - 03:59	4	0	4
04:00 - 04:59	1	0	1
05:00 - 05:59	8	4	12
06:00 - 06:59	13	24	37
07:00 - 07:59	21	43	64
08:00 - 08:59	20	42	62
09:00 - 09:59	33	21	54
10:00 - 10:59	40	31	71
11:00 - 11:59	38	30	68
12:00 - 12:59	29	38	67
13:00 - 13:59	32	39	71
14:00 - 14:59	26	32	58
15:00 - 15:59	33	26	59
16:00 - 16:59	20	30	50
17:00 - 17:59	32	23	55
18:00 - 18:59	42	34	76
19:00 - 19:59	35	30	65
20:00 - 20:59	33	24	57
21:00 - 21:59	23	16	39
22:00 - 22:59	22	10	32
23:00 - 23:59	8	15	23
Totals	520	520	1,040

[a] Source: Airport Capacity Enhancement Plan Update, "Seattle-Tacoma International Airport, Data Package 6", August 1994, Port of Seattle.

[b] Arrival time is time at 30 nautical miles for Sea-Tac.

[c] Departure time is time at push-back from gate.

TABLE 4-5
DELAY ANALYSIS RESULTS [a]

Runway Description	Demand	New Runway Use	Average Delay (Minutes/Operation)				Annual Delay Savings	
			Arrival	Departure	Taxi	Total	Time (Hours)	Amount ($Millions)
Existing	Baseline	NA	4.3	1.1	0.1	5.5	NA	NA
Existing	Future 1	NA	19.4	2.4	0.2	22.0	0	0
Close Commuter	Future 1	Limited Use [b]	18.0	2.4	0.2	20.6	10,000	21
Dependent	Future 1	Full Use [c]	1.6	2.0	0.2	3.8	130,000	270
Independent	Future 1	Full Use	1.5	2.0	0.3	3.8	130,000	270

[a] Source: Preliminary Results, Airport Capacity Enhancement Plan Update, "Seattle-Tacoma International Airport, Data Package No. 6" plus amendments, August, September 1994.

[b] Limited Use = Used by Category A and B aircraft only.

[c] Full Use = Used by Categories A, B, C, and D aircraft.

Options 2 and 3 (Commuter Runway). Options 2 and 3, an additional commuter runway, would result in relatively modest savings compared to the other options. By the Year 2015 Option 2 would result in average annual delays of about 20.6 minutes per operation whereas Option 3 would lower this figure to 14.2 minutes per operation. These comparisons are shown in Figure 4-2.

Options 4A, 4B, and 4C (Dependent Air Carrier Runway 7000 feet and 7500 feet in length). Options 4A, 4B, and 4C, which include a third air carrier runway spaced 2,500 feet west of Runway 16L/34R, would provide more significant delay savings. For Options 4A and 4B, annual aircraft delays would be on the order of 5.4 minutes per operation. For Option 4C, the longer runway length would accommodate a greater percentage of the fleet and the average delay would be slightly lower, or about 4.6 minutes per operation.

Options 5 and 6. Options 5 and 6 would provide the greatest delay reduction. Both of these options reduce the average annual aircraft delay to about 3.8 minutes per operation by the Year 2015. This results in an annual delay savings of about $290 million when compared to Option 1.

At a demand level of 425,000 operations, the independent runway option (Option 6) does not show an advantage over the dependent runway option (Option 5) based on the results of the SIMMOD computer simulation analysis. This is explained by the fact that with the independent option, the greater flexibility in positioning arriving aircraft is offset by the longer taxi distance. As demand increases beyond 425,000 operations however, the independent runway option could result in improved delay savings. If this does not occur until the Year 2015 then it is possible that advances in technology may allow independent approaches to be made to parallel runways separated by less than 3,400 feet.

CONCLUSIONS

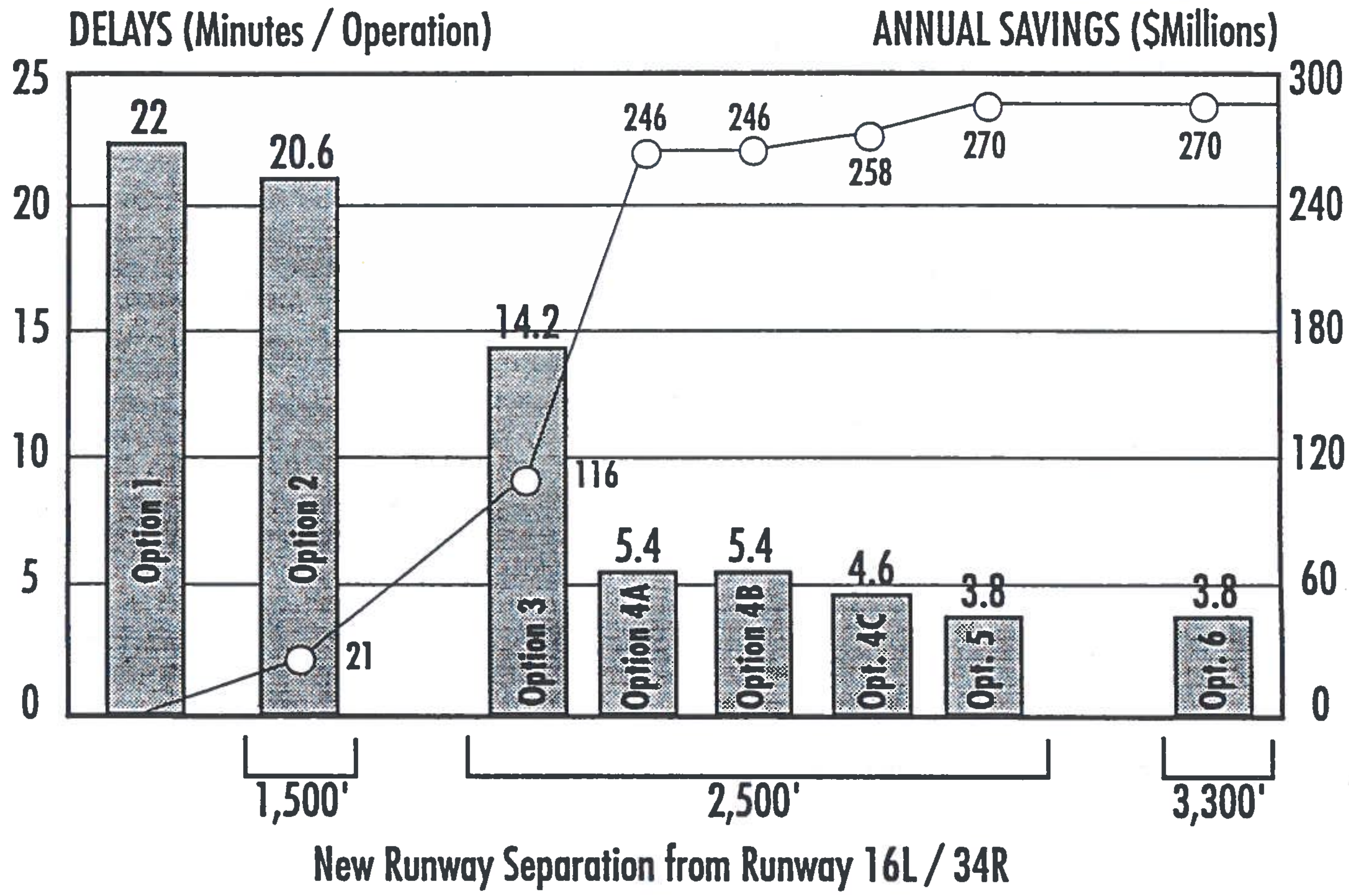
As shown in Table 4-5 and Figure 4-2, Option 1, No New Runway, would result in very high aircraft delays as demand approaches 425,000 operations. The delay at this activity level would average 22 minutes per operation and result in additional aircraft operating costs of about $245 million per year.

Option 2, an additional closely spaced commuter aircraft runway, would provide only nominal delay savings compared with Option 1. Option 2 would be useful primarily to provide a third aircraft arrival stream for commuter and general aviation aircraft during visual weather conditions. Under these favorable weather conditions, additional capacity is least needed. Two other factors weigh against further consideration of Option 2: (1) the airborne delay savings with this option would be largely offset by additional taxiing distances and runway crossing delays, and (2) the percentage of aircraft able to use a commuter runway is forecast to decline.

Option 3, a commuter runway spaced 2,500 feet from the east runway, would provide a second "dependent," aircraft arrival stream under both visual and instrument weather conditions. Although, as in Option 2, it would primarily serve only commuter aircraft, it would allow delay savings compared with Options 1 and 2.

Of the alternatives analyzed, Options 4A/B/C and 5, a dependent air carrier runway and Option 6, an independent air carrier runway, would provide the greatest reduction in future aircraft delays. In addition to delay and cost savings, the 8,500-foot runway length proposed for Options 5 and 6 would provide an additional margin of ATC operational flexibility and

FIGURE 4-2
RUNWAY OPTION DELAY COMPARISONS



Source: Table 4-5, plus interpolated estimates for Options 3, 4A, 4B, and 4C efficiency and potential safety, because (1) heavy jet aircraft would not be restricted to the existing two runways, (2) all aircraft using a longer runway would have a greater takeoff/stopping distance available, (3) the number of heavy jet aircraft operations is forecast to increase at Sea-Tac, and (4) an 8,500-foot runway length would provide a greater measure of redundancy in that it could accommodate heavy jet aircraft when one of the existing runways is closed for maintenance or emergency.

Options 5 and 6 provide the greatest delay improvement since the 8,500-foot runway length can accommodate the highest percentage of the fleet for landings. This greater capability will result in fewer aircraft crossing on approach. The seemingly greater delay benefit offered by the independent arrival capability in Option 6 does not occur until demand increases beyond 425,000 operations. By this time, independent arrivals may be possible to runways spaced closer than 3,400 feet. While not an assumption of this analysis, it is conceivable that technological advances, for example, differential global positioning system (DGPS) procedures currently being evaluated by the FAA, will permit future simultaneous independent approaches to parallel runway with 2,500-foot spacing (Options 3, 4A, 4B., 4C, and 5).

In the next section, the options are further evaluated on the basis of construction and acquisition costs.

Section 5
DEVELOPMENT COSTS AND CONSIDERATIONS

SECTION 5
DEVELOPMENT COSTS AND CONSIDERATIONS

Cost estimates were prepared for each of the airfield development options. Estimated costs include all costs associated with the development of each airside option discussed in this report: construction of airfield and related facilities, installation of radar and navaids, property acquisition and reimbursement for relocation assistance. The methodology, assumptions and resulting cost estimates are discussed in this section.

ESTIMATED CONSTRUCTION COSTS

The construction cost estimates that are developed herein should be considered as order of magnitude conceptual costs and be used for comparison purposes only. As much as possible, the same assumptions and unit costs are used as those presented in the Preliminary Engineering Report, Volumes 1 and 2, prepared by HNTB, dated March 31, 1994 (First Draft). Other sources used in developing these construction costs are: Port of Seattle, Runway 16L-34R Safety Area Expansion Study, dated December 2, 1992; Reid Middleton, Runway 34R Safety Area Expansion Conceptual Design Report; PCI, Runway 16R-34L Preliminary Engineering Report, dated August 13, 1992; Seattle-Tacoma International Airport, Runway 16L Safety Area Expansion Engineering Report, dated March 29, 1993.

Construction costs were estimated for each airside option as depicted in Figures 3-2 through 3-9. The total construction costs, including Runway Safety Area extensions, are summarized as follows:

Option 1	$0
Option 2	$79,000,000
Option 3	$255,000,000
Option 4A	$347,000,000
Option 4B	$279,000,000
Option 4C	$294,000,000
Option 5	$364,000,000
Option 6	$596,000,000

The construction costs fall under thirteen categories:

1. Mobilization
2. Relocation Items
3. Demolition
4. Earthwork
5. Drainage
6. On-Site Water
7. Electrical
8. Paving
9. Miscellaneous
10. Existing R.S.A.'s and Cross Taxiways
11. Other Construction Items (20 percent of subtotal)
12. Engineering and Contingencies (15 percent of Subtotal)
13. Radar and Navaids

These construction costs for each of the options are presented by category in Table 5-1. Detailed costs for the development options are shown in Tables 5-2 through 5-8. Tables 5-9 and 5-10 give cost estimates for runway safety area improvements.

TABLE 5-1
SUMMARY OF CONSTRUCTION COST ESTIMATES FOR INITIAL AIRSIDE OPTIONS AT SEATTLE-TACOMA INTERNATIONAL AIRPORT

Item	Estimated Construction Cost (Millions of 1994 Dollars)						
	Option 2 Commuter Close-in	Option 3 Commuter Dependent	Option 4A Program-matic Baseline	Option 4B Program-matic Baseline Staggered	Option 4C Staggered 7,500-Foot Runway	Option 5 Dependent Maximum Length	Option 6 Independent Maximum Length
Mobilization	4.0	13.0	15.0	15.0	15.0	15.0	25.0
Relocation	0.1	2.3	8.9	3.2	3.2	8.9	16.3
Demolition	0.3	1.1	1.4	1.1	1.3	1.4	3.5
Earthwork	2.0	75.7	112.9	81.6	91.0	118.6	198.3
Drainage	2.7	27.1	27.3	27.3	27.4	28.6	33.8
On-Site Water	0.2	0.5	0.8	0.8	0.8	0.8	1.1
Electrical	5.4	7.5	8.4	8.8	9.0	10.4	10.8
Paving	4.6	13.1	18.3	18.3	19.0	21.8	46.2
Miscellaneous	0.1	3.4	4.2	4.1	4.1	4.3	10.1
Ex. R.S.A.'s	36.0	36.0	48.0	36.0	36.0	48.0	48.0
Subtotal	55.4	179.8	245.2	196.2	206.9	257.8	393.1
All Other (20%)	11.1	36.0	49.0	39.2	41.4	51.6	117.9 [a]
Subtotal	66.5	215.8	294.2	235.4	248.3	309.4	511.0
Engineering & Contin-gencies (15%)	10.0	32.4	44.1	35.3	37.2	46.4	76.7
Radar and Navaids	2.5	6.9	8.5	8.5	8.5	8.5	8.5
Total	79.0	255.0	346.8	279.2	294.0	364.3	596.2

[a] All other (30%).

TABLE 5-2
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 2: COMMUTER - CLOSE [a]

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
1	MOBILIZATION	1 LS	$4,000,000	$4,000,000
	RELOCATION ITEMS			
2	Southwest Suburban Miller Creek Interceptor	1 LS	$0	$0
3	Sewer Dist. Local Service Abandonment	1 LS	$0	$0
4	Seattle Water Dept. Watermain Protection	1 LS	$100,000	$100,000
5	Port of Seattle Sanitary Sewer Relocation	1 LS	$0	$0
6	Water Dist. No.20 Local Service Abandonment	1 LS	$0	$0
7	Water Dist. No.49 Local Service Abandonment	1 LS	$0	$0
8	Water Dist. No.125 Local Service Abandonment	1 LS	$0	$0
9	Wash. Natural Gas Local Service Abandonment	1 LS	$0	$0
10	Miller Creek	1 LS	$0	$0
	SUBTOTAL			$100,000
	DEMOLITION			
11	Demolition of Small Structures	0 EA	$2,500	$0
12	Demolition of Hanger	1 LS	$178,500	$178,500
13	Demolition of Airfield Pavement	32,000 SY	$4	$128,000
14	Demolition of Streets and Roads	0 SY	$2	$0
15	Demolition of Miscellaneous Utilities	1 LS	$10,000	$10,000
	SUBTOTAL			$316,500
	EARTHWORK			
16	Clearing and Grubbing	116 Acre	$500	$58,000
17	Erosion Control	1 LS	$10,000	$10,000
18	Common Excavation	200,000 CY	$3	$600,000
19	Borrow - Zone A	113,000 CY	$12	$1,356,000
20	Borrow - Zone B	0 CY	$8	$0
21	Borrow - Zone C	0 CY	$5	$0
	SUBTOTAL			$2,024,000
	DRAINAGE			
22	Conveyance System	1 LS	$500,000	$500,000
23	Flow Diversion	1 LS	$150,000	$150,000
24	Detention Ponds	1 LS	$2,000,000	$2,000,000
	SUBTOTAL			$2,650,000
	ON-SITE WATER			
25	Lateral Water Lines	3,000 LF	$36	$108,000
26	Trunk Water Lines	2,000 LF	$58	$116,000
27	Hydrants	5 EA	$380	$1,900
	SUBTOTAL			$225,900

TABLE 5-2
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 2: COMMUTER - CLOSE [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	ELECTRICAL			
28	Restoration of Sea-Tac Third Metering Point	1 LS	$0	$0
29	Rerouting of Main Telephone Service	1 LS	$0	$0
30	Modifications to Airfield Lighting in Control Tower	1 LS	$100,000	$100,000
31	Modifications to Stop Bar in Control Tower	1 LS	$250,000	$250,000
32	Rearrangement of Control Panels in Control Tower	1 LS	$75,000	$75,000
33	Vault Building	1 LS	$150,000	$150,000
34	Vault Building Generators	1 LS	$230,000	$230,000
35	Vault Building Regulators	1 LS	$270,000	$270,000
36	Electrical System	1 LS	$1,140,000	$1,140,000
37	Runway Lighting	1 LS	$2,185,000	$2,185,000
38	Taxiway Lighting	1 LS	$500,000	$500,000
39	Stop Bar/Hold Bar Lighting	1 LS	$229,000	$229,000
40	Airfield Signs	1 LS	$250,000	$250,000
41	Utility Work	1 LS	$0	$0
	SUBTOTAL			$5,379,000
	PAVING			
42	Runway Pavement	57,800 SY	$35	$2,023,000
43	Taxiway Pavement	54,900 SY	$35	$1,921,500
44	A.C.P. Runway Shoulder Pavement	4,124 Ton	$35	$144,340
45	A.C.P.Taxiway Shoulder Pavement	6,458 Ton	$35	$226,030
46	A.C.P.Blast Pad Pavement	1,500 Ton	$35	$52,500
47	A.C.P. Perimeter Road and Access Roads	9,000 Ton	$22	$198,000
48	P.C.C. Parking Apron Pavement	0 SY	$40	$0
49	A.C.P. Road and Street Pavement	0 SY	$30	$0
	SUBTOTAL			$4,565,370
	MISCELLANEOUS			
50	Bridge Structures	0 SF	$100	$0
51	Retaining Walls	0 SF	$45	$0
52	Fencing	0 LF	$10	$0
53	Seeding	116 Acre	$500	$58,000
54	Landscaping	0 Acre	$2,000	$0
	SUBTOTAL			$58,000
	RUNWAY SAFETY AREAS AND CROSS			
55	900' Extension (See Table 5-9)	1 LS	$36,000,000	$36,000,000
	All Other Construction Items @ 20%			$11,063,754
	SUBTOTAL			$66,382,524
	Engineering and Contingencies @ 15%			$9,957,379

TABLE 5-2
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 2: COMMUTER - CLOSE [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	SUBTOTAL (THIRD RUNWAY CONSTRUCTION)			$76,339,903
	RADAR AND NAVAIDS			
	ASR Relocation	1 LS	$2,000,000	$2,000,000
	ASDE Relocation	1 LS	$350,000	$350,000
	North Approach Glide Slope	1 LS	$0	$0
	South Approach Glide Slope	1 LS	$0	$0
	North Approach Localizer	1 LS	$0	$0
	South Approach Localizer	1 LS	$0	$0
	RVR Facilities	1 LS	$0	$0
	North Approach Markers (Inner, Middle, Outer)	1 LS	$0	$0
	South Approach Markers	1 LS	$0	$0
	PAPI	1 LS	$100,000	$100,000
	Approach Lighting - North Approach (ALSF-II)	1 LS	$0	$0
	Approach Lighting - South Approach (ALSF-II)	1 LS	$0	$0
	RADAR AND NAVAIDS SUBTOTAL			$2,450,000
	PROJECT TOTAL (THIRD RUNWAY) Rounded to Nearest $1 Million			$78,789,903 $79,000,000

[a] Source: P&D Aviation analysis. Many of the quantities and unit costs were taken from: HNTB Corporation, Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994.

[b] Abbreviation used in this table are:

CY = cubic yards
EA = each
LF = lineal feet
LS = lump sum
SY = square yards

TABLE 5-3
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 3: COMMUTER - DEPENDENT [a]

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
1	MOBILIZATION	1 LS	$13,000,000	$13,000,000
	RELOCATION ITEMS			
2	Southwest Suburban Miller Creek Interceptor	1 LS	$500,000	$500,0000
3	Sewer Dist. Local Service Abandonment	1 LS	$38,000	$38,0000
4	Seattle Water Dept. Watermain Protection	1 LS	$1,744,000	$1,744,000
5	Port of Seattle Sanitary Sewer Relocation	1 LS	$0	$0
6	Water Dist. No.20 Local Service Abandonment	1 LS	$16,900	$16,900
7	Water Dist. No.49 Local Service Abandonment	1 LS	$17,900	$17,900
8	Water Dist. No.125 Local Service Abandonment	1 LS	$15,000	$15,000
9	Wash. Natural Gas Local Service Abandonment	1 LS	$15,500	$15,500
10	Miller Creek	1 LS	$0	$0
	SUBTOTAL			$2,347,300
	DEMOLITION			
11	Demolition of Small Structures	256 EA	$2,500	$640,500
12	Demolition of Hanger	1 LS	$178,500	$178,500
13	Demolition of Airfield Pavement	8,500 SY	$4	$34,000
14	Demolition of Streets and Roads	35,000 SY	$2	$70,000
15	Demolition of Miscellaneous Utilities	1 LS	$200,000	$200,000
	SUBTOTAL			$1,122,500
	EARTHWORK			
16	Clearing and Grubbing	260 Acre	$500	$130,000
17	Erosion Control	1 LS	$10,000	$100,000
18	Common Excavation	2,600,000 CY	$3	$7,800,000
19	Borrow - Zone A	972,000 CY	$12	$11,664,000
20	Borrow - Zone B	5,550,000 CY	$8	$44,400,000
21	Borrow - Zone C	2,320,000 CY	$5	$11,600,000
	SUBTOTAL			$75,694,000
	DRAINAGE			
22	Conveyance System	1 LS	$6,500,000	$6,500,000
23	Flow Diversion	1 LS	$1,265,000	$1,265,000
24	Detention Ponds	1 LS	$19,350,000	$19,350,000
	SUBTOTAL			$27,115,000
	ON-SITE WATER			
25	Lateral Water Lines	1,600 LF	$36	$57,600
26	Trunk Water Lines	7,500 LF	$58	$435,000
27	Hydrants	8 EA	$380	$3,040
	SUBTOTAL			$495,640

TABLE 5-3
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 3: COMMUTER - DEPENDENT [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	ELECTRICAL			
28	Restoration of Sea-Tac Third Metering Point	1 LS	$419,000	$419,000
29	Rerouting of Main Telephone Service	1 LS	$350,000	$350,000
30	Modifications to Airfield Lighting in Control Tower	1 LS	$100,000	$100,000
31	Modifications to Stop Bar in Control Tower	1 LS	$250,000	$250,000
32	Rearrangement of Control Panels in Control Tower	1 LS	$75,000	$75,000
33	Vault Building	1 LS	$150,000	$150,000
34	Vault Building Generators	1 LS	$230,000	$230,000
35	Vault Building Regulators	1 LS	$270,000	$270,000
36	Electrical System	1 LS	$1,140,000	$1,140,000
37	Runway Lighting	1 LS	$2,185,000	$2,185,000
38	Taxiway Lighting	1 LS	$1,240,000	$1,240,000
39	Stop Bar/Hold Bar Lighting	1 LS	$229,000	$229,000
40	Airfield Signs	1 LS	$496,000	$496,000
41	Utility Work	1 LS	$400,000	$400,000
	SUBTOTAL			$7,534,000
	PAVING			
42	Runway Pavement	58,000 SY	$35	$2,030,000
43	Taxiway Pavement	141,390 SY	$37	$5,231,430
44	A.C.P. Runway Shoulder Pavement	4,124 Ton	$35	$144,340
45	A.C.P.Taxiway Shoulder Pavement	17,345 Ton	$35	$607,075
46	A.C.P.Blast Pad Pavement	1,500 Ton	$35	$52,500
47	A.C.P. Perimeter Road and Access Roads	12,300 Ton	$22	$270,600
48	P.C.C. Parking Apron Pavement	116,500 SY	$40	$4,660,000
49	A.C.P. Road and Street Pavement	3,500 SY	$30	$105,000
	SUBTOTAL			$13,100,945
	MISCELLANEOUS			
50	Bridge Structures	0 SF	$100	$0
51	Retaining Walls	67,800 SF	$45	$3,051,000
52	Fencing	19,000 LF	$10	$190,000
53	Seeding	260 Acre	$500	$130,000
54	Landscaping	15 Acre	$2,000	$30,000
	SUBTOTAL			$3,401,000
	RUNWAYS SAFETY AREAS & CROSS TAXIWAYS			
55	900' Extension (See Table 5-9)	1 LS		$36,000,000
	All Other Construction Items @ 20%			$35,962,077
	SUBTOTAL			$215,772,462
	Engineering and Contingencies @ 15%			$32,365,869
	TOTAL FOR THIRD RUNWAY CONSTRUCTION			$248,138,331

TABLE 5-3
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 3: COMMUTER - DEPENDENT [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	RADAR AND NAVAIDS			
	ASR Relocation	1 LS	$2,000,000	$2,000,000
	ASDE Relocation	1 LS	$350,000	$350,000
	North Approach Glide Slope	1 LS	$400,000	$400,000
	South Approach Glide Slope	1 LS	$400,000	$400,000
	North Approach Localizer	1 LS	$375,000	$375,000
	South Approach Localizer	1 LS	$375,000	$375,000
	RVR Facilities	1 LS	$200,000	$200,000
	North Approach Markers (Inner, Middle, Outer)	1 LS	$350,000	$350,000
	South Approach Markers	1 LS	$350,000	$350,000
	PAPI	1 LS	$100,000	$100,000
	Approach Lighting - North Approach (ALSF-II)	1 LS	$1,000,000	$1,000,000
	Approach Lighting - South Approach (ALSF-II)	1 LS	$1,000,000	$1,000,000
	RADAR AND NAVAIDS SUBTOTAL			$6,900,000
	PROJECT TOTAL (THIRD RUNWAY)			$255,038,331
	Rounded to nearest $1 Million			$255,000,000

[a] Source: P&D Aviation analysis. Many of the quantities and unit costs were taken from: HNTB Corporation, Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994.

[b] Abbreviation used in this table are:

CY = cubic yards
EA = each
LF = lineal feet
LS = lump sum
SY = square yards

TABLE 5-4
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4A: PROGRAMMATIC BASELINE [a]

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
1	MOBILIZATION	1 LS	$15,000,000	$15,000,000
	RELOCATION ITEMS			
2	Southwest Suburban Miller Creek Interceptor	1 LS	$1,962,000	$1,962,000
3	Sewer Dist. Local Service Abandonment	1 LS	$38,000	$38,000
4	Seattle Water Dept. Watermain Protection	1 LS	$1,744,000	$1,744,000
5	Port of Seattle Sanitary Sewer Relocation	1 LS	$155,000	$155,000
6	Water Dist. No.20 Local Service Abandonment	1 LS	$16,900	$16,900
7	Water Dist. No.49 Local Service Abandonment	1 LS	$17,900	$17,900
8	Water Dist. No.125 Local Service Abandonment	1 LS	$15,000	$15,000
9	Wash. Natural Gas Local Service Abandonment	1 LS	$15,500	$15,500
10	Miller Creek	1 LS	$4,960,000	$4,960,000
	SUBTOTAL			$8,924,300
	DEMOLITION			
11	Demolition of Small Structures	335 EA	$2,500	$837,500
12	Demolition of Hanger	1 LS	$178,500	$178,500
13	Demolition of Airfield Pavement	8,500 SY	$4	$34,000
14	Demolition of Streets and Roads	51,000 SY	$2	$102,000
15	Demolition of Miscellaneous Utilities	1 LS	$250,000	$250,000
	SUBTOTAL			$1,402,000
	EARTHWORK			
16	Clearing and Grubbing	380 Acre	$500	$180,000
17	Erosion Control	1 LS	$100,000	$100,000
18	Common Excavation	2,900,000 CY	$3	$8,700,000
19	Borrow - Zone A	1,350,000 CY	$12	$16,200,000
20	Borrow - Zone B	8,370,000 CY	$8	$66,980,000
21	Borrow - Zone C	4,150,000 CY	$5	$20,750,000
	SUBTOTAL			$112,910,000
	DRAINAGE			
22	Conveyance System	1 LS	$6,711,000	$6,711,000
23	Flow Diversion	1 LS	$1,265,000	$1,265,000
24	Detention Ponds	1 LS	$19,350,000	$19,350,000
	SUBTOTAL			$27,326,000
	ON-SITE WATER			
25	Lateral Water Lines	3,800 LF	$36	$108,600
26	Trunk Water Lines	12,500 LF	$58	$725,000
27	Hydrants	13 EA	$380	$4,940
	SUBTOTAL			$838,540

TABLE 5-4
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4A: PROGRAMMATIC BASELINE [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	ELECTRICAL			
28	Restoration of Sea-Tac Third Metering Point	1 LS	$419,000	$419,000
29	Rerouting of Main Telephone Service	1 LS	$350,000	$350,000
30	Modifications to Airfield Lighting in Control Tower	1 LS	$100,000	$100,000
31	Modifications to Stop Bar in Control Tower	1 LS	$250,000	$250,000
32	Rearrangement of Control Panels in Control Tower	1 LS	$75,000	$75,000
33	Vault Building	1 LS	$150,000	$150,000
34	Vault Building Generators	1 LS	$230,000	$230,000
35	Vault Building Regulators	1 LS	$270,000	$270,000
36	Electrical System	1 LS	$1,140,000	$1,140,000
37	Runway Lighting	1 LS	$2,941,000	$2,941,000
38	Taxiway Lighting	1 LS	$1,370,000	$1,370,000
39	Stop Bar/Hold Bar Lighting	1 LS	$229,000	$229,000
40	Airfield Signs	1 LS	$496,000	$496,000
41	Utility Work	1 LS	$400,000	$400,000
	SUBTOTAL			$8,420,000
	PAVING			
42	Runway Pavement	116,700 SY	$40	$4,668,000
43	Taxiway Pavement	149,000 SY	$40	$5,960,000
44	A.C.P. Runway Shoulder Pavement	12,500 Ton	$35	$437,500
45	A.C.P.Taxiway Shoulder Pavement	34,500 Ton	$35	$1,207,500
46	A.C.P.Blast Pad Pavement	3,500 Ton	$35	$122,500
47	A.C.P. Perimeter Road and Access Roads	14,000 Ton	$22	$308,000
48	P.C.C. Parking Apron Pavement	118,000 SY	$40	$4,720,000
49	A.C.P. Road and Street Pavement	30,000 SY	$30	$900,000
	SUBTOTAL			$18,323,500
	MISCELLANEOUS			
50	Bridge Structures	7,500 SF	$100	$750,000
51	Retaining Walls	67,800 SF	$45	$3,051,000
52	Fencing	20,000 LF	$10	$200,000
53	Seeding	380 Acre	$500	$190,000
54	Landscaping	20 Acre	$2,000	$40,000
	SUBTOTAL			$4,231,000
	RUNWAY SAFETY AREAS & CROSS TAXIWAYS			
55	600' Extension (See Table 5-10)	1 LS	$48,000,000	$48,000,000
	All Other Construction Items @ 20%			$49,000,000
	SUBTOTAL			$294,200,000
	Engineering and Contingencies @ 15%			$44,100,000
	TOTAL FOR THIRD RUNWAY CONSTRUCTION			$338,300,000

TABLE 5-4
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4A: PROGRAMMATIC BASELINE [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	RADAR AND NAVAIDS			
	ASR Relocation	1 LS	$2,000,000	$2,000,000
	ASDE Relocation	1 LS	$350,000	$350,000
	North Approach Glide Slope	1 LS	$600,000	$600,000
	South Approach Glide Slope	1 LS	$600,000	$600,000
	North Approach Localizer	1 LS	$600,000	$600,000
	South Approach Localizer	1 LS	$600,000	$600,000
	RVR Facilities	1 LS	$300,000	$300,000
	North Approach Markers (Inner, Middle, Outer)	1 LS	$175,000	$175,000
	South Approach Markers	1 LS	$175,000	$175,000
	PAPI	1 LS	$100,000	$100,000
	Approach Lighting - North Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	Approach Lighting - South Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	RADAR AND NAVAIDS SUBTOTAL			$8,500,000
	PROJECT TOTAL (THIRD RUNWAY)			$346,800,000
	(Rounding to the nearest $1 Million)			$347,000,000

[a] Source: HNTB Corporation, Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994. Costs for Runway Safety Area improvements, extension of Runway 16L-34R and additional taxiway exits for Runway 16L-34R were added by P&D Aviation.

[b] Abbreviation used in this table are:

CY = cubic yards
EA = each
LF = lineal feet
LS = lump sum
SY = square yards

TABLE 5-5
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4B: PROGRAMMATIC BASELINE STAGGERED (7,000' RUNWAY) [a]

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
1	MOBILIZATION	1 LS	$15,000,000	$15,000,000
	RELOCATION ITEMS			
2	Southwest Suburban Miller Creek Interceptor	1 LS	$500,000	$500,0000
3	Sewer Dist. Local Service Abandonment	1 LS	$38,000	$38,0000
4	Seattle Water Dept. Watermain Protection	1 LS	$1,744,000	$1,744,000
5	Port of Seattle Sanitary Sewer Relocation	1 LS	$0	$0
6	Water Dist. No.20 Local Service Abandonment	1 LS	$9,000	$9,000
7	Water Dist. No.49 Local Service Abandonment	1 LS	$17,900	$17,900
8	Water Dist. No.125 Local Service Abandonment	1 LS	$15,000	$15,000
9	Wash. Natural Gas Local Service Abandonment	1 LS	$15,500	$15,500
10	Miller Creek	1 LS	$820,000	$820,000
	SUBTOTAL			$3,159,400
	DEMOLITION			
11	Demolition of Small Structures	256 EA	$2,500	$640,000
12	Demolition of Hanger	1 LS	$178,500	$178,500
13	Demolition of Airfield Pavement	8,500 SY	$4	$34,000
14	Demolition of Streets and Roads	35,000 SY	$2	$70,000
15	Demolition of Miscellaneous Utilities	1 LS	$200,000	$200,000
	SUBTOTAL			$1,122,500
	EARTHWORK			
16	Clearing and Grubbing	400 Acre	$500	$200,000
17	Erosion Control	1 LS	$100,000	$100,000
18	Common Excavation	3,000,000 CY	$3	$9,000,000
19	Borrow - Zone A	1,350,000 CY	$12	$16,200,000
20	Borrow - Zone B	5,600,000 CY	$8	$44,800,000
21	Borrow - Zone C	2,250,000 CY	$5	$11,250,000
	SUBTOTAL			$81,550,000
	DRAINAGE			
22	Conveyance System	1 LS	$6,711,000	$6,711,000
23	Flow Diversion	1 LS	$1,265,000	$1,265,000
24	Detention Ponds	1 LS	$19,350,000	$19,350,000
	SUBTOTAL			$27,326,000
	ON-SITE WATER			
25	Lateral Water Lines	3,000 LF	$36	$108,000
26	Trunk Water Lines	12,500 LF	$58	$725,000
27	Hydrants	13 EA	$380	$4,940
	SUBTOTAL			$837,940

TABLE 5-5
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4B: PROGRAMMATIC BASELINE STAGGERED (7,000' RUNWAY)
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars Unit Cost	Estimated Cost
	ELECTRICAL			
28	Restoration of Sea-Tac Third Metering Point	1 LS	$523,000	$523,000
29	Rerouting of Main Telephone Service	1 LS	$600,000	$600,000
30	Modifications to Airfield Lighting in Control Tower	1 LS	$100,000	$100,000
31	Modifications to Stop Bar in Control Tower	1 LS	$250,000	$250,000
32	Rearrangement of Control Panels in Control Tower	1 LS	$75,000	$75,000
33	Vault Building	1 LS	$150,000	$150,000
34	Vault Building Generators	1 LS	$230,000	$230,000
35	Vault Building Regulators	1 LS	$270,000	$270,000
36	Electrical System	1 LS	$1,140,000	$1,140,000
37	Runway Lighting	1 LS	$2,941,000	$2,941,000
38	Taxiway Lighting	1 LS	$1,370,000	$1,370,000
39	Stop Bar/Hold Bar Lighting	1 LS	$229,000	$229,000
40	Airfield Signs	1 LS	$496,000	$496,000
41	Utility Work	1 LS	$400,000	$400,000
	SUBTOTAL			$8,774,000
	PAVING			
42	Runway Pavement	116,700 SY	$40	$4,668,000
43	Taxiway Pavement	173,000 SY	$40	$6,920,000
44	A.C.P. Runway Shoulder Pavement	12,500 Ton	$35	$437,500
45	A.C.P.Taxiway Shoulder Pavement	28,700 Ton	$35	$1,004,500
46	A.C.P.Blast Pad Pavement	3,500 Ton	$35	$122,500
47	A.C.P. Perimeter Road and Access Roads	12,300 Ton	$22	$270,600
48	P.C.C. Parking Apron Pavement	118,000 SY	$40	$4,720,000
49	A.C.P. Road and Street Pavement	6,300 SY	$30	$189,000
	SUBTOTAL			$18,332,100
	MISCELLANEOUS			
50	Bridge Structures	6,000 SF	$100	$600,000
51	Retaining Walls	67,800 SF	$45	$3,051,000
52	Fencing	20,400 LF	$10	$204,000
53	Seeding	400 Acre	$500	$200,000
54	Landscaping	20 Acre	$2,000	$40,000
	SUBTOTAL			$4,095,000
	RUNWAYS SAFETY AREAS & CROSS TAXIWAYS			
55	900' Extension (See Table 5-9)	1 LS	36,000,000	36,000,000
	All Other Construction Items @ 20%			$39,239,388
	SUBTOTAL			$235,436,328
	Engineering and Contingencies @ 15%			$35,315,449
	TOTAL FOR THIRD RUNWAY CONSTRUCTION			$270,751,777

TABLE 5-5
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4B: PROGRAMMATIC BASELINE STAGGERED (7,000' RUNWAY)
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	RADAR AND NAVAIDS			
	ASR Relocation	1 LS	$2,000,000	$2,000,000
	ASDE Relocation	1 LS	$350,000	$350,000
	North Approach Glide Slope	1 LS	$600,000	$600,000
	South Approach Glide Slope	1 LS	$600,000	$600,000
	North Approach Localizer	1 LS	$600,000	$600,000
	South Approach Localizer	1 LS	$600,000	$600,000
	RVR Facilities	1 LS	$300,000	$300,000
	North Approach Markers (Inner, Middle, Outer)	1 LS	$175,000	$175,000
	South Approach Markers	1 LS	$175,000	$175,000
	PAPI	1 LS	$100,000	$100,000
	Approach Lighting - North Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	Approach Lighting - South Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	RADAR AND NAVAIDS SUBTOTAL			$8,500,000
	PROJECT TOTAL (THIRD RUNWAY)			$279,251,777
	(Rounding to the nearest $1 Million)			$279,000,000

[a] Source: P&D Aviation analysis. Many of the quantities and unit costs were taken from: HNTB Corporation, Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994.

[b] Abbreviation used in this table are:

CY = cubic yards
EA = each
LF = lineal feet
LS = lump sum
SY = square yards

TABLE 5-6
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4C: STAGGERED 7,500-FOOT RUNWAY [a]

Item No.	Item	Quantity [b]	1994 Dollars Unit Cost	1994 Dollars Estimated Cost
1	MOBILIZATION	1 LS	$15,000,000	$15,000,000
	RELOCATION ITEMS			
2	Southwest Suburban Miller Creek Interceptor	1 LS	$500,000	$500,000
3	Sewer Dist. Local Service Abandonment	1 LS	$38,000	$38,000
4	Seattle Water Dept. Watermain Protection	1 LS	$1,744,000	$1,744,000
5	Port of Seattle Sanitary Sewer Relocation	1 LS	$0	$0
6	Water Dist. No.20 Local Service Abandonment	1 LS	$12,000	$12,000
7	Water Dist. No.49 Local Service Abandonment	1 LS	$17,900	$17,900
8	Water Dist. No.125 Local Service Abandonment	1 LS	$15,000	$15,000
9	Wash. Natural Gas Local Service Abandonment	1 LS	$15,500	$15,500
10	Miller Creek	1 LS	$820,000	$820,000
	SUBTOTAL			$3,162,400
	DEMOLITION			
11	Demolition of Small Structures	298 EA	$2,500	$745,000
12	Demolition of Hangar	1 LS	$178,500	$178,500
13	Demolition of Airfield Pavement	8,500 SY	$4	$34,000
14	Demolition of Streets and Roads	48,000 SY	$2	$96,000
15	Demolition of Miscellaneous Utilities	1 LS	$250,000	$250,000
	SUBTOTAL			$1,303,500
	EARTHWORK			
16	Clearing and Grubbing	410 Acre	$500	$205,000
17	Erosion Control	1 LS	$100,000	$100,000
18	Common Excavation	3,000,000 CY	$3	$9,000,000
19	Borrow - Zone A	1,398,000 CY	$12	$16,776,000
20	Borrow - Zone B	6,450,000 CY	$8	$51,600,000
21	Borrow - Zone C	2,670,000 CY	$5	$13,350,000
	SUBTOTAL			$91,031,000
	DRAINAGE			
22	Conveyance System	1 LS	$6,800,000	$6,800,000
23	Flow Diversion	1 LS	$1,265,000	$1,265,000
24	Detention Ponds	1 LS	$19,350,000	$19,350,000
	SUBTOTAL			$27,415,000
	ON-SITE WATER			
25	Lateral Water Lines	3,000 LF	$36	$108,000
26	Trunk Water Lines	12,500 LF	$58	$725,000
27	Hydrants	13 EA	$380	$4,940
	SUBTOTAL			$837,940

TABLE 5-6
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4C: STAGGERED 7,500-FOOT RUNWAY [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	ELECTRICAL			
28	Restoration of Sea-Tac Third Metering Point	1 LS	$523,000	$523,000
29	Rerouting of Main Telephone Service	1 LS	$600,000	$600,000
30	Modifications to Airfield Lighting in Control Tower	1 LS	$100,000	$100,000
31	Modifications to Stop Bar in Control Tower	1 LS	$250,000	$250,000
32	Rearrangement of Control Panels in Control Tower	1 LS	$75,000	$75,000
33	Vault Building	1 LS	$150,000	$150,000
34	Vault Building Generators	1 LS	$230,000	$230,000
35	Vault Building Regulators	1 LS	$270,000	$270,000
36	Electrical System	1 LS	$1,140,000	$1,140,000
38	Runway Lighting	1 LS	$3,151,000	$3,151,000
38	Taxiway Lighting	1 LS	$1,420,000	$1,420,000
39	Stop Bar/Hold Bar Lighting	1 LS	$229,000	$229,000
40	Airfield Signs	1 LS	$496,000	$496,000
41	Utility Work	1 LS	$400,000	$400,000
	SUBTOTAL			$9,034,000
	PAVING			
42	Runway Pavement	125,000 SY	$40	$500,000
43	Taxiway Pavement	177,000 SY	$40	$7,080,000
44	A.C.P. Runway Shoulder Pavement	13,600 Ton	$35	$476,000
45	A.C.P. Taxiway Shoulder Pavement	29,600 Ton	$35	$1,036,000
46	A.C.P. Blast Pad Pavement	3,500 Ton	$35	$122,500
47	A.C.P. Perimeter Road and Access Roads	14,200 Ton	$22	$312,400
48	P.C.C. Parking Apron Pavement	118,000 SY	$40	$4,720,000
49	A.C.P. Road and Street Pavement	9,100 SY	$30	$273,000
	SUBTOTAL			$19,019,900
	MISCELLANEOUS			
50	Bridge Structures	6,000 SF	$100	$600,000
51	Retaining Walls	67,800 SF	$45	$3,051,000
52	Fencing	20,900 LF	$10	$209,000
53	Seeding	400 Acre	$500	$200,000
54	Landscaping	20 Acre	$2,000	$40.000
	SUBTOTAL			$4,100,000
	RUNWAY SAFETY AREAS & CROSS TAXIWAYS			
55	900' on south end cross taxiways (See Table 5-9)	1 LS	$36,000,000	$36,000,000
	All Other Construction Items @ 20%			$41,380,748
	SUBTOTAL			$248,284,488
	Engineering and Contingencies @ 15%			$37,242,673
	TOTAL FOR THIRD RUNWAY CONSTRUCTION			$285,527,161

TABLE 5-6
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 4C: STAGGERED 7,500-FOOT RUNWAY [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	RADAR AND NAVAIDS			
	ASR Relocation	1 LS	$2,000,000	$2,000,000
	ASDE Relocation	1 LS	$350,000	$350,000
	North Approach Glide Slope	1 LS	$600,000	$600,000
	South Approach Glide Slope	1 LS	$600,000	$600,000
	North Approach Localizer	1 LS	$600,000	$600,000
	South Approach Localizer	1 LS	$600,000	$600,000
	RVR Facilities	1 LS	$300,000	$300,000
	North Approach Markers (Outer)	1 LS	$175,000	$175,000
	South Approach Markers (Outer)	1 LS	$175,000	$175,000
	VASI	1 LS	$100,000	$100,000
	Approach Lighting - North Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	Approach Lighting - South Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	RADAR AND NAVAIDS SUBTOTAL			$8,500,000
	PROJECT TOTAL (Third Runway (Rounding to nearest $1 million)			$294,027,161 $294,000,000

[a] Source: P&D Aviation analysis. Many of the quantities and unit costs were taken from: HNTB Corporation, Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994.

[b] Abbreviation used in this table are:

- CY = cubic yards
- EA = each
- LF = lineal feet
- LS = lump sum
- SY = square yards

TABLE 5-7
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 5: DEPENDENT MAXIMUM LENGTH [a]

Item No.	Item	Quantity [a]	1994 Dollars	
			Unit Cost	Estimated Cost
1	MOBILIZATION	1 LS	$15,000,000	$15,000,000
	RELOCATION ITEMS			
2	Southwest Suburban Miller Creek Interceptor	1 LS	$1,962,000	$1,962,000
3	Sewer Dist. Local Service Abandonment	1 LS	$38,000	$38,000
4	Seattle Water Dept. Watermain Protection	1 LS	$1,744,000	$1,744,000
5	Port of Seattle Sanitary Sewer Relocation	1 LS	$155,000	$155,000
6	Water Dist. No.20 Local Service Abandonment	1 LS	$16,900	$16,900
7	Water Dist. No.49 Local Service Abandonment	1 LS	$17,900	$17,900
8	Water Dist. No.125 Local Service Abandonment	1 LS	$15,000	$15,000
9	Wash. Natural Gas Local Service Abandonment	1 LS	$15,500	$15,500
10	Miller Creek	1 LS	$4,960,000	$4,960,000
	SUBTOTAL			$8,924,300
	DEMOLITION			
11	Demolition of Small Structures	335 EA	$2,500	$837,500
12	Demolition of Hanger	1 LS	$178,500	$178,500
13	Demolition of Airfield Pavement	8,500 SY	$4	$34,000
14	Demolition of Streets and Roads	51,000 SY	$2	$102,000
15	Demolition of Miscellaneous Utilities	1 LS	$250,000	$250,000
	SUBTOTAL			$1,402,000
	EARTHWORK			
16	Clearing and Grubbing	440 Acre	$500	$220,000
17	Erosion Control	1 LS	$150,000	$150,000
18	Common Excavation	3,100,000 CY	$3	$9,300,000
19	Borrow - Zone A	1,750,000 CY	$12	$21,000,000
20	Borrow - Zone B	8,650,000 CY	$8	$69,200,000
21	Borrow - Zone C	3,750,000 CY	$5	$18,750,000
	SUBTOTAL			$118,620,000
	DRAINAGE			
22	Conveyance System	1 LS	$6,893,000	$6,893,000
23	Flow Diversion	1 LS	$1,265,000	$1,265,000
24	Detention Ponds	1 LS	$20,456,000	$20,456,000
	SUBTOTAL			$28,614,000
	ON-SITE WATER			
25	Lateral Water Lines	3,000 LF	$36	$108,600
26	Trunk Water Lines	12,500 LF	$58	$725,000
27	Hydrants	13 EA	$380	$4,940
	SUBTOTAL			$838,540

TABLE 5-7
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 5: DEPENDENT MAXIMUM LENGTH [a]
(Continued)

Item No.	Item	Quantity [a]	1994 Dollars	
			Unit Cost	Estimated Cost
	ELECTRICAL			
28	Restoration of Sea-Tac Third Metering Point	1 LS	$523,000	$523,000
29	Rerouting of Main Telephone Service	1 LS	$600,000	$600,000
30	Modifications to Airfield Lighting in Control Tower	1 LS	$100,000	$100,000
31	Modifications to Stop Bar in Control Tower	1 LS	$250,000	$250,000
32	Rearrangement of Control Panels in Control Tower	1 LS	$75,000	$75,000
33	Vault Building	1 LS	$150,000	$150,000
34	Vault Building Generators	1 LS	$280,000	$280,000
35	Vault Building Regulators	1 LS	$320,000	$320,000
36	Electrical System	1 LS	$1,300,000	$1,300,000
37	Runway Lighting	1 LS	$3,570,000	$3,570,000
38	Taxiway Lighting	1 LS	$1,830,000	$1,830,000
39	Stop Bar/Hold Bar Lighting	1 LS	$316,000	$316,000
40	Airfield Signs	1 LS	$665,000	$665,000
41	Utility Work	1 LS	$400,000	$400,000
	SUBTOTAL			$10,379,000
	PAVING			
42	Runway Pavement	142,000 SY	$40	$5,680,000
43	Taxiway Pavement	206,000 SY	$40	$8,240,000
44	A.C.P. Runway Shoulder Pavement	15,000 Ton	$35	$525,000
45	A.C.P.Taxiway Shoulder Pavement	38,000 Ton	$35	$1,330,000
46	A.C.P.Blast Pad Pavement	3,500 Ton	$35	$122,500
47	A.C.P. Perimeter Road and Access Roads	14,000 Ton	$22	$308,000
48	P.C.C. Parking Apron Pavement	118,000 SY	$40	$4,720,000
49	A.C.P. Road and Street Pavement	30,000 SY	$30	$900,000
	SUBTOTAL			$21,825,500
	MISCELLANEOUS			
50	Bridge Structures	7,500 SF	$100	$750,000
51	Retaining Walls	67,800 SF	$45	$3,051,000
52	Fencing	21,000 LF	$10	$210,000
53	Seeding	450 Acre	$500	$225,000
54	Landscaping	20 Acre	$2,000	$40,000
	SUBTOTAL			$4,276,000
	RUNWAY SAFETY AREAS & CROSS TAXIWAYS			
55	600' Extension (See Table 5-10)	1 LS	$48,000,000	$48,000,000
	All Other Construction Items @ 20%			$51,600,000
	SUBTOTAL			$309,400,000
	Engineering and Contingencies @ 15%			$46,400,000
	TOTAL FOR THIRD RUNWAY CONSTRUCTION			$355,800,000

TABLE 5-7
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 5: DEPENDENT MAXIMUM LENGTH [a]
(Continued)

Item No.	Item	Quantity [a]	1994 Dollars	
			Unit Cost	Estimated Cost
	RADAR AND NAVAIDS			
	ASR Relocation	1 LS	$2,000,000	$2,000,000
	ASDE Relocation	1 LS	$350,000	$350,000
	North Approach Glide Slope	1 LS	$600,000	$600,000
	South Approach Glide Slope	1 LS	$600,000	$600,000
	North Approach Localizer	1 LS	$600,000	$600,000
	South Approach Localizer	1 LS	$600,000	$600,000
	RVR Facilities	1 LS	$300,000	$300,000
	North Approach Markers (Inner, Middle, Outer)	1 LS	$175,000	$175,000
	South Approach Markers	1 LS	$175,000	$175,000
	PAPI	1 LS	$100,000	$100,000
	Approach Lighting - North Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	Approach Lighting - South Approach (ALSF-II)	1 LS	$1,000,000	$1,000,000
	RADAR AND NAVAIDS SUBTOTAL			$8,500,000
	PROJECT TOTAL (THIRD RUNWAY)			$364,300,000
	(Rounding to the nearest $1 Million)			$364,000,000

[a] Source: HNTB Corporation, Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994. Costs for Runway Safety Area improvements, extension of Runway 16L-34R and additional taxiway exits for Runway 16L-34R were added by P&D Aviation.

[b] Abbreviation used in this table are:

CY = cubic yards
EA = each
LF = lineal feet
LS = lump sum
SY = square yards

TABLE 5-8
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 6: INDEPENDENT - MAXIMUM LENGTH [a]

Item No.	Item	Quantity [b]	1994 Dollars Unit Cost	Estimated Cost
1	MOBILIZATION	1 LS	$25,000,000	$25,000,000
	RELOCATION ITEMS			
2	Southwest Suburban Miller Creek Interceptor	1 LS	$1,962.00	$1,962.00
3	Sewer Dist. Local Service Abandonment	1 LS	$90,000	$90,000
4	Seattle Water Dept. Watermain Relocation	1 LS	$2,442,000	$2,442,000
5	Port of Seattle Sanitary Sewer Relocation	1 LS	$300,000	$300,000
6	Water Dist. No.20 Local Service Abandonment	1 LS	$25,000	$25,000
7	Water Dist. No.49 Local Service Abandonment	1 LS	$50,000	$50,000
8	Water Dist. No.125 Local Service Abandonment	1 LS	$20,000	$20,000
9	Wash. Natural Gas Local Service Abandonment	1 LS	$30,000	$30,000
10	Miller Creek	1 LS	$10,600,000	$10,600,000
11	Seattle City Lights Stripping	1 LS	$400,000	$400,000
12	Puget Power Distribution System	1 LS	$500,000	$500,000
13	6" Gas Line in relocated Des Moines Way	1 LS	$200,000	$200,000
	SUBTOTAL			$16,269,000
	DEMOLITION			
14	Demolition of Small Structures	585 EA	$2,500	$1,462,500
15	Demolition of Commerical Buildings	20 EA	$50,000	$1,000,000
16	Demolition of Hangar	1 LS	$178,500	$178,500
17	Demolition of Airfield Pavement	8,500 SY	$4	$34,000
18	Demolition of Streets and Roads	180,000 SY	$2	$360,000
19	Demolition of Miscellaneous Utilities	1 LS	$500,000	$500,000
	SUBTOTAL			$3,535,000
	EARTHWORK			
20	Clearing and Grubbing	700 Acre	$500	$350,000
21	Erosion Control	1 LS	$200,000	$200,000
22	Common Excavation	8,210,000 CY	$3	$24,630,000
23	Borrow - Zone A	2,000,000 CY	$12	$24,000,000
24	Borrow - Zone B	14,700,000 CY	$8	$117,600,000
25	Borrow - Zone C	6,300,000 CY	$5	$31,500,000
	SUBTOTAL			$198,280,000
	DRAINAGE			
26	Conveyance System	1 LS	$8,500,000	$8,500,000
27	Flow Diversion	1 LS	$1,265,000	$1,265,000
28	Detention Ponds	1 LS	$24,000,000	$24.000,000
	SUBTOTAL			$33,765,000
	ON-SITE WATER			
29	Lateral Water Lines	7,800 LF	$36	$280,800
30	Trunk Water Lines	14,100 LF	$58	$817,800
31	Hydrants	13 EA	$380	$4,940
	SUBTOTAL			$1,103,540

TABLE 5-8
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 6: INDEPENDENT - MAXIMUM LENGTH [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	ELECTRICAL			
32	Restoration of Sea-Tac Third Metering Point	1 LS	$523,000	$523,000
33	Rerouting of Main Telephone Service	1 LS	$600,000	$600,000
34	Modifications to Airfield Lighting in Control Tower	1 LS	$100,000	$100,000
35	Modifications to Stop Bar in Control Tower	1 LS	$250,000	$250,000
36	Rearrangement of Control Panels in Control Tower	1 LS	$75,000	$75,000
37	Vault Building	1 LS	$150,000	$150,000
38	Vault Building Generators	1 LS	$280,000	$280,000
39	Vault Building Regulators	1 LS	$320,000	$320,000
40	Electrical System	1 LS	$1,300,000	$1,300,000
41	Runway Lighting	1 LS	$3,570,000	$3,570,000
42	Taxiway Lighting	1 LS	$2,300,000	$2,300,000
43	Stop Bar/Hold Bar Lighting	1 LS	$316,000	$316,000
44	Airfield Signs	1 LS	$665,000	$665,000
45	Utility Work	1 LS	$400,000	$400,000
	SUBTOTAL			$10,849,000
	PAVING			
46	Runway Pavement	141,700 SY	$40	$5,668,000
47	Taxiway Pavement	312,000 SY	$40	$12,480,000
48	A.C.P. Runway Shoulder Pavement	13,520 Ton	$35	$473,200
49	A.C.P. Taxiway Shoulder Pavement	46,650 Ton	$35	$1,632,750
50	A.C.P. Blast Pad Pavement	5,000 Ton	$35	$175,000
51	A.C.P. Perimeter Road and Access Roads	16,000 Ton	$22	$352,000
52	P.C.C. Parking Apron Pavement	116,500 SY	$40	$4,660,000
53	A.C.P. Road and Street Pavement	20,000 SY	$30	$600,000
54	Relocated Des Moines Way	1 SY	$1,200,000	$1,200,000
55	Relocated SR 509 (see attachment)	1 SY	$19,000,000	$19,000,000
	SUBTOTAL			$46,240,950
	MISCELLANEOUS			
56	Bridge Structures	42,000 SF	$100	$4,200,000
57	Retaining Walls	120,000 SF	$45	$5,400,000
58	Fencing	23,000 LF	$10	$230,000
59	Seeding	500 Acre	$500	$250,000
60	Landscaping	20 Acre	$2,000	$40,000
	SUBTOTAL			$10,120,000
	RUNWAY SAFETY AREAS & CROSS TAXIWAYS			
61	600' Extension (see Table 5-10)	1 LS	$48,000,000	$48,000,000
	All Other Construction Items @ 30%			$117,948,747
	Subtotal			$511,111,237
	Engineering and Contingencies @ 15%			$76,666,686
	TOTAL FOR THIRD RUNWAY CONSTRUCTION			$587,777,923

TABLE 5-8
CONCEPTUAL CONSTRUCTION COST ESTIMATE
FOR OPTION 6: INDEPENDENT - MAXIMUM LENGTH [a]
(Continued)

Item No.	Item	Quantity [b]	1994 Dollars	
			Unit Cost	Estimated Cost
	RADAR AND NAVAIDS			
	ASR Relocation	1 LS	$2,000,000	$2,000,000
	ASDE Relocation	1 LS	$350,000	$350,000
	North Approach Glide Slope	1 LS	$600,000	$600,000
	South Approach Glide Slope	1 LS	$600,000	$600,000
	North Approach Localizer	1 LS	$600,000	$600,000
	South Approach Localizer	1 LS	$600,000	$600,000
	RVR Facilities	1 LS	$300,000	$300,000
	North Approach Markers (Outer)	1 LS	$175,000	$175,000
	South Approach Markers (Outer)	1 LS	$175,000	$175,000
	VASI	1 LS	$100,000	$100,000
	Approach Lighting - North Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	Approach Lighting - South Approach (ALSF-II)	1 LS	$1,500,000	$1,500,000
	RADAR AND NAVAIDS SUBTOTAL			$8,500,000
	PROJECT TOTAL (Third Runway)			$596,277,923
	(Rounding to nearest $1 million)			$596,000,000

[a] Source: P&D Aviation analysis. Many of the quantities and unit costs were taken from: HNTB Corporation, Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994.

[b] Abbreviation used in this table are:

CY = cubic yards
EA = each
LF = lineal feet
LS = lump sum
SY = square yards

TABLE 5-9
CONCEPTUAL CONSTRUCTION COST ESTIMATE FOR RUNWAY SAFETY AREAS AND CROSS TAXIWAYS FOR OPTIONS 2, 3, 4B AND 4C

34R RSA AND CROSS TAXIWAYS	
Order of Magnitude Cost, for extending existing RSA by 465' to meet 1,000' requirement	$10,000,000 [a]
EXTENDING RUNWAY AND PARALLEL TAXIWAY BY 900'	
Mobilization	$1,000,000
Earthwork	$14,000,000
Paving	$3,100,000
Electrical	$500,000
Approach Lighting	$1,500,000
Glide Slope	$600,000
Other Items	$300,000
SUBTOTAL	$21,000,000
ADJUST FOR DUPLICATION OF ITEMS	
Earthwork	$3,000,000
Approach Lighting	$500,000
SUBTOTAL	$3,500,000
ADJUSTED PROJECT TOTAL	$27,500,000
16L RSA	
Order of Magnitude Cost for extending existing RSA to 700' from Rwy end	$2,200,000 [a]
16R AND 34L RSA's	
Order of Magnitude Cost for displacing threshold at north end and providing full RSA's at both ends	$6,000,000 [b]
PROJECT TOTAL	$36,000,000

[a] Source: Port of Seattle Runway 16L-34R Safety Area Expansion Study, December 2, 1992.
[b] Source: Reid Middleton Runway 34R Safety Area Expansion, Conceptual Design Report, August 1993.

Note: This project applies to Options 2, 3, 4B, and 4C.

TABLE 5-10
CONCEPTUAL CONSTRUCTION COST ESTIMATE FOR RUNWAY SAFETY AREAS AND CROSS TAXIWAYS FOR OPTIONS 4A, 5 AND 6

34R RSA AND CROSS TAXIWAYS	
Order of Magnitude Cost for extending existing RSA by 465' to meet 1,000' requirement	**$10,000,000 [a]**
EXTENDING RUNWAY AND PARALLEL TAXIWAY BY 600'	**$1,000,000**
Mobilization	**$10,000,000**
Earthwork	**$2,400,000**
Paving	**$400,000**
Electrical	**$1,500,000**
Approach Lighting	**$600,000**
Glide Slope	**$300,000**
Other Items	**$16,200,000**
SUBTOTAL	
ADJUST FOR DUPLICATION OF ITEMS	
Earthwork	**$3,000,000**
Approach Lighting	**$500,000**
SUBTOTAL	**$3,500,000**
ADJUSTED PROJECT TOTAL	**$22,700,000**
16L RSA	
Order of Magnitude Costs for extending existing RSA to 700' from Rwy end	**$2,200,000 [A]**
EXTENDING RSA ADDITIONAL 300'	**$1,400,000**
Earthwork (280,000 CY)	**$350,000**
Utility Relocations (City Lights Transmission)	**$150,000**
S. 154th St. Relocation Paving (4,444 SY)	**$600,000**
S. 154th St. Relocation Earthwork (125k CY)	**$300,000**
Other Items	**$2,800,000**
SUBTOTAL	
PROJECT TOTAL	**$5,000,000**
16R AND 34L RSA's	
Order of Magnitude Cost for extending existing RSA to meet 1,000' requirement	**$20,000,000 [b]**
PROJECT TOTAL	**$48,000,000**

[a] Source: Port of Seattle Runway 16L-34R Safety Area Expansion Study, December 2, 1992.
[b] Source: Reid Middleton Runway 34R Safety Area Expansion, Conceptual Design Report, August 1993.

Note: This project applies to Options 4A, 5, and 6.

BASIS OF CONSTRUCTION COST ESTIMATES

In developing the comparable costs for Options 2, 3, 4B, 4C and 6 the construction cost items identified in the Preliminary Engineering Report for Options 4A and 5 for the third runway, have been evaluated and the associated costs adjusted where appropriate. Costs were similarly developed and included herein for construction of additional cross field taxiways between existing runways, for improving the existing runway safety areas and for extending Runway 34R. The costs for the relocation of SR509, and for the construction of some other items unique to Option 6 were developed from field observations, review of as-built plans, utility atlas sheets and contract documents and interviews with several agencies having jurisdiction over the items involved.

Option 2 - Commuter-Close

Construct a 5,200-foot commuter runway with a 700-foot centerline separation with Runway 16R-34L, and associated cross-field taxiways.

- Mobilization. Mobilization cost is calculated based on a percentage of the overall cost of construction and consistent with the amounts used in the Preliminary Engineering Report.

- Demolition. This option negates the need to extend into non airport property. Demolition items are therefore only restricted to airport structures and pavement.

- Earthwork. The commuter runway elevation was set at the same elevation as Runway 16R-34L and the infield graded to a 2 percent slope (Available topography indicates the existing slope to be at about a 1 percent slope). This is a conservative approach as common excavation could be increased, in an effort to minimize borrow quantities, by steepening the slopes of the infield.

- Drainage. These costs were developed by performing some modifications to the existing conveyance system and adding two small detention ponds with corresponding flow diversion costs.

- On-Site Water. The hydrant system and related water lines would be significantly smaller than the systems laid out for Options 4A and 5 and calculated accordingly using the same unit costs.

- Electrical. There is no need to restore the Sea-Tac Third Metering Point as well as rerouting the telephone service. Otherwise all modifications to the Control Tower due to the additional runway as well as construction costs for a vault building and related equipment is left the same as those developed in the Preliminary Engineering Report for Options 4A and 5. The runway and taxiway lighting cost is reduced proportionately by its length, while signage is based on the number of airfield intersections. The difference in cost of fixtures between CAT I and CAT III runway lighting (edge lighting vs center flush mounted) is considered offset by the difference in amount of fixtures.

- Paving. The geometry of the runway, taxiways and related shoulders were calculated in order to determine the respective quantities. The unit costs were also adjusted to take into consideration the thinner structural section required by this option.

- Miscellaneous. No bridge structures, retaining walls, fencing or landscaping is anticipated.

- Runway Safety Area Improvements and Cross Taxiways. Costs were developed with the aid of past reports and earthwork, paving and electrical cost calculations. Costs were not included for possible golf course mitigation.

- Radar and Navaids. This option does not require an ILS system. PAPI is required as well as the relocations of the ASR and ASDE.

Option 3 - Commuter-Dependent

Construct a 5,200-foot commuter runway with a 1,700-foot centerline separation with Runway 16R-34L, and parallel taxiway, associated cross taxiways and overnight parking apron.

- Mobilization. Mobilization cost is calculated based on a percentage of the overall cost of construction and consistent with the amounts used in the Preliminary Engineering Report.

- Demolition. A lesser amount of property acquisition west of the airport would be required compared with Options 4A and 5. South 156th Street does not need to be relocated.

- Earthwork. The same elevations are assumed for the proposed runway and parallel taxiway as developed by HNTB for Options 5 and 4A. The embankment criteria are also similar. The area of grading however is somewhat smaller. Less excavation will be generated due to less construction to the south. The embankment requirement to the north will be reduced by having the threshold about 1,450 feet further south than Options 5 and 4A. Borrow zone A is calculated as being proportional to the area of paving. The reduction in embankment is shared proportionately between Zones B and C.

- Drainage. The reduced estimated cost for the conveyance system is based on the reduced area of improvements. The same costs are used for the flow diversions and detention ponds.

- On-Site Water. A modified version of the systems laid out for Options 4A and 5 was developed.

- Electrical. The Sea-Tac Third Metering Point and the rerouting of the telephone service is estimated to cost the same as for Option 4A. All modifications to the Control Tower due to the additional runway as well as construction costs for a vault building and related equipment is left the same as those developed by HNTB for Options 4A and 5. The runway and taxiway lighting cost is reduced proportionately by its length, while signage is based on the number of airfield intersections.

- Paving. The geometry of the runway, taxiways and related shoulders were calculated in order to determine the respective quantities. The unit cost of the runway pavement was adjusted to take into consideration the thinner structural section required by this option. The taxiways are proposed with a variety of structural sections and the unit cost selected accordingly.

- Miscellaneous. The same retaining walls have been incorporated in this option as with Options 5 and 4A.

- Runway Safety Area Improvements and Cross Taxiways. Costs were developed with the aid of past reports and earthwork, paving and electrical cost calculations. Costs were not included for possible golf course mitigation.

- Radar and Navaids. The third runway will be equipped with ILS, except a CAT I is assumed since it is a commuter runway, versus CAT III systems associated with air carrier runways (Options 4 - 6).

Option 4A: Programmatic Baseline

Construct a 7,000-foot runway with a 1,700-foot centerline separation with Runway 16R-34L, and parallel taxiway, associated cross taxiways and overnight parking apron. The north threshold of the new runway would be aligned with the ends of the existing runways.

Costs for this alternative were taken from Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994, by HNTB Corporation. Costs for the following items were added to the Preliminary Engineering Report cost estimate: Runway Safety Areas at all runway ends to meet FAA standards, extension of Runway 16L-34R by 600 feet and additional exit taxiways for Runway 16L-34R.

Option 4B - Programmatic Baseline Staggered

Construct a 7,000-foot runway with a 1,700-foot centerline separation with Runway 16R-34L, and parallel taxiway, associated cross taxiways and overnight parking apron. The north threshold of the new runway would be staggered 1,435 feet south of the north ends of the existing runways.

- Mobilization. The same mobilization cost is used as estimated by HNTB for Options 4A and 5.

- Demolition. A lesser amount of property acquisition west of the airport would be required compared with Options 4A and 5. South 156th St. does not need to be relocated. A reduced impact on the Southwest Suburban Miller Creek Interceptor is assumed. Reduced impact also occurs on Miller Creek.

- Earthwork. The same elevations are assumed for the proposed runway and parallel taxiway as developed by HNTB for Options 5 and 4A. The embankment criteria are also similar. The main difference is the staggering of the runway threshold by moving it south. This results in less fill required to the north. Borrow Zone A is assumed to be the same as for Option 4A. The reduction in embankment is shared proportionately between Zones B and C.

- Drainage. The drainage costs are

assumed to be similar to Option 4A.

- On-Site Water. These costs are assumed to be similar to Option 4A.
- Electrical. The Sea-Tac Third Metering Point and the rerouting of the telephone service is estimated to cost the same as for Option 5. All modifications to the Control Tower due to the additional runway as well as construction costs for a vault building and related equipment is left the same as those developed by HNTB for Options 4A and 5. The runway and taxiway lighting cost is reduced proportionately by its length, while signage is based on the number of airfield intersections.
- Paving. The geometry of the runway, taxiways and related shoulders were calculated in order to determine the respective quantities. The unit cost used were the same as those developed by HNTB in the Preliminary Engineering Report.
- Miscellaneous. A bridge is assumed for relocated South 156/154th Street.
- Runway Safety Area Improvements and Cross Taxiways. Costs were developed with the aid of past reports and earthwork, paving and electrical cost calculations. Costs were not included for possible golf course mitigation.
- Radar and Navaids. The third runway is assumed to be equipped for CAT III operations.

Option 4C: Staggered 7,500-foot Runway

Construct a 7,500-foot runway with a 1,700-foot centerline separation with Runway 16R-34L, and parallel taxiway, associated cross taxiways and overnight parking apron. The north Threshold of the new runway would be staggered 935 feet to the south of the north ends of the existing runways.

- Mobilization. The same mobilization cost is used as estimated by HNTB for Options 4A and 5.
- Demolition. A lesser amount of property acquisition west of the airport would be required compared with Options 4A and 5. A portion of South 156th St. must be relocated to provide the necessary Runway Safety Area at the north end of the new runway. The impact on the Southwest Suburban Miller Creek Interceptor and on Miller Creek would be the same as under Option 4B.
- Earthwork. The same elevations are assumed for the proposed runway and parallel taxiway as developed by HNTB for Options 5 and 4A. The embankment criteria are also similar. The main difference is the staggering of the runway threshold by moving it south 935 feet. This results in less fill required to the north, compared with Options 4A and 5 but less than under Option 4B.
- Drainage. The drainage conveyance system of Option 4C takes into account the additional 500 feet of runway compared with Option 4B. Flow diversion and detention ponds are the same as Option 4B.

- On-Site Water. These costs are assumed to be similar to Option 4A.

- Electrical. The Sea-Tac Third Metering Point and the rerouting of the telephone service is estimated to cost the same as for Option 5. All modifications to the Control Tower due to the additional runway as well as construction costs for a vault building and related equipment is left the same as those developed by HNTB for Options 4A and 5. The runway and taxiway lighting cost is reduced proportionately by its length, while signage is based on the number of airfield intersections.

- Paving. The geometry of the runway, taxiways and related shoulders were calculated in order to determine the respective quantities. The unit cost used were the same as those developed by HNTB in the Preliminary Engineering Report.

- Miscellaneous. A bridge over Miller Creek is assumed for relocated South 156/154th Street.

- Runway Safety Area Improvements and Cross Taxiways. Costs were developed with the aid of past reports and earthwork, paving and electrical cost calculations. Costs were not included for possible golf course mitigation.

- Radar and Navaids. The third runway is assumed to be equipped for CAT III operations.

Option 5: Dependent-Maximum Length

Construct an 8,500-foot runway with a 1,700-foot centerline separation with Runway 16R-34L, and parallel taxiway, associated cross taxiways and overnight parking apron. The threshold of the new runway would be aligned with the north ends of the existing runways.

Costs for this alternative were taken from Seattle-Tacoma International Airport Third Dependent Runway, Preliminary Engineering Report, Volumes 1 and 2, First Draft, March 31, 1994, by HNTB Corporation. Costs for the following items were added to the Preliminary Engineering Report cost estimate: Runway Safety Areas at all runway ends to meet FAA standards, extension of Runway 16L-34R by 600 feet and additional exit taxiways for Runway 16L-34R.

Option 6 - Independent - Maximum Length

Construct an 8,500-foot runway with a 2,500-foot centerline separation with Runway 16R-34L, and parallel taxiway, associated cross taxiways and overnight parking apron.

- Mobilization. Mobilization cost is calculated based on a percentage of the overall cost of construction and consistent with the amounts used in the Preliminary Engineering Report.

- Demolition. A new limit of property acquisition was developed based on the toe of the embankment and provisions for space made for a relocated Miller Creek and new wetlands east of Des Moines Way. To the north, property acquisition limits were affected by modifications to South 152nd Street at Des Moines.

Demolition costs have not been included however for properties within the north runway approach zone since this is considered an area which is likely to be purchased over time and not necessarily as a part of this project.

- Earthwork. The third runway elevations were set based on checking both the Part 77 surfaces and the longitudinal grade of the cross taxiways. The latter was found to control. Earthwork calculations were performed using the topography available assuming the same typical sections used in the Preliminary Engineering Report and assuming 2:1 slopes for the embankment. The raw fill volume was proportioned accordingly into the various zone types.

Drainage. While the conveyance system was revised to reflect increased coverage and subareas, the flow diversion costs were left similar to those developed for Option 5. Detention pond A, located near SR509, is in an area of higher ground and pond C is bigger. Costs increased by 25 percent.

- On-Site Water. Revised system. Costs were increased accordingly.

- Electrical. Even though the points of connection are not likely to be from 176th Street, the Sea-Tac Third Metering Point and the rerouting of the telephone service is estimated to cost the same as for Option 5. The new connection points are expected to be near the proposed intersection of SR509 and Des Moines. All modifications to the Control Tower due to the additional runway as well as construction costs for a vault building and related equipment is left the same as those developed by HNTB for Options 4A and 5. The runway and taxiway lighting cost is reduced proportionately by its length, while signage is based on the number of airfield intersections.

- Paving. The geometry of the runway, taxiways and related shoulders were calculated in order to determine the respective quantities. The unit costs used were the same as those developed by HNTB in the Preliminary Engineering Report.

- SR509. Construction documents of SR509 were analyzed in obtaining a cost which used actual construction costs in 1978 inflated by using ENR Construction Cost Indexing for Seattle and making provisions for maintaining traffic flows and for additional earthwork required.

- Miscellaneous. A longer bridge is assumed for relocating South 156/154th Street through wetlands. Additional retaining walls used along Des Moines Way.

- Runway Safety Area Improvements and Cross Taxiways. Costs were developed with the aid of past reports and earthwork, paving and electrical cost calculations. Costs were not included for possible golf course mitigation.

- Radar and Navaids. Third runway is assumed to be equipped for CAT III operations.

ESTIMATED COSTS OF PROPERTY ACQUISITION AND RELOCATIONS

Costs of property acquisition and relocations for each airside option were estimated by Landrum & Brown (Table 5-11). Property acquisition costs were estimated from tax assessor's data. The total assessed value of each property affected was increased to market (sales) value using a ratio of assessed value to sales value of 20 percent. For residential relocation cost, the California Relocation Act maximum of $22,500 was used for each residence. Property acquisition costs include the property in the future Runway Protection Zones, at the ends of the new runway.

Total costs of each option are shown in Table 5-11 for a range in which the lower value is the sum of construction, acquisition and relocation costs, and the upper value is 15 percent greater to allow for contingencies. Development costs range from $79-$91 million for Option 2 to $773-$889 million for Option 6.

TABLE 5-11
TOTAL ESTIMATED COSTS OF CONSTRUCTION, PROPERTY ACQUISITION AND RELOCATIONS FOR AIRSIDE OPTIONS

Airside Option	Cost in 1994 Dollars			
	Construction	Property Acquisition and Relocation [b]	Baseline Total	Baseline Plus 15% Contingency
Option 2: Commuter-Close	78,790,000	0	78,790,000	90,609,000
Option 3: Commuter-Dependent	255,038,000	41,531,000	296,569,000	341,054,000
Option 4A: Programmatic Baseline	346,800,000	64,135,000	410,935,000	472,575,000
Option 4B: Programmatic Baseline-Staggered	279,252,000	69,063,000	348,315,000	400,562,000
Option 4C: Staggered 7,500-foot Runway	294,027,000	75,365,000	369,392,000	424,801,000
Option 5: Dependent-Maximum Length	364,300,000	91,420,000	455,720,000	524,078,000
Option 6: Independent-Maximum Length	596,278,000	176,926,000	773,204,000	889,185,000

[a] Sources: Tables 5-2 through 5-10.

[b] Sources: Landrum & Brown, Letter dated August 15, 1994 to Port of Seattle, and revised cost estimates dated September 6, 1994, Costs include acquisition of property in the future Runway Protection Zones. Costs are based on Landrum & Brown's Cost Method 1, which reflects acquisition costs calculated as the sum of assessed value for each property affected, increased to market (sales) value, plus relocation costs. For residential relocation, the Uniform Relocation Act maximum of $22,500 per residence was used.