Appendix B

Helistop Patient Landings and Relocated Helistop Noise Analysis

Children's Hospital Regional Medical Center
Projected Helistop Patient Landings
December, 2007

Health Facilities Planning and Development (HFPD) has employed a standard population/use rate methodology to project future helicopter air ambulance (Airlift Northwest) patient landings a Children's Hospital and Regional Medical Center (CHRMC) on-campus helistop. In summary, the methodology projects 62 total patient landings in 2010, growing to 71 by 2020, and 77 by 2030.

The steps employed in the projection methodology are detailed as follows:

1. Based upon historical Airlift Northwest data for pediatric patient transport to CHRMC, a geographic service area upon which the projections are based was defined. The service area consists of all Western Washington counties from the Canadian border south to Lewis and Pacific counties (inclusive). During the five year period from 2002-2006, 97% of all patient transports to CHRMC originated from this area.

2. Compile actual 2002-2006 historic semiannual data for patient landings at CHRMC's helistop, broken out by the County of origin for each flight. (Detailed data is presented in the table on the next page.) While on a semiannual basis the number of total landings has been trending downward, and has varied widely from a low of 21 to a high of 46, over the course of the 5-year study period the average total number of landings was 60.2 annually.

Children's Hospital Regional Medical Center
Historic Patient Landings at Campus Helistop by County of Flight Origin
2002-2006

	2002		2003		2004		2005		2006		5-Yr Annual Avg.
County	**Jan-Jun**	**Jul-Dec**	**Jan-Jun**	**Jul-Dec**	**Jan-Jun**	**Jul-Dec**	**Jan-Jun**	**Jul-Dec**	**Jan-Jun**	**Jul-Dec**	
Clallam	1	0	1	0	2	2	0	0	0	1	1.4
Grays Harbor	1	0	0	0	1	0	0	1	0	0	0.6
Island	5	1	2	4	6	1	1	3	3	1	5.4
Jefferson	0	0	1	0	1	0	0	0	2	0	0.8
King	9	8	8	4	14	5	7	14	2	10	16.2
Kitsap	2	2	2	4	3	3	2	2	2	2	4.8
Lewis	0	0	0	0	1	0	0	0	1	0	0.4
Mason	0	0	0	0	1	0	0	0	0	0	0.2
Pacific	0	0	0	0	0	0	0	0	0	0	0.0
Pierce	2	5	5	3	4	1	3	2	4	0	5.8
San Juan	0	0	0	0	0	0	1	0	0	0	0.2
Skagit	4	3	4	2	3	2	1	3	4	4	6.0
Snohomish	10	6	5	2	7	2	2	1	4	4	8.6
Thurston	2	0	0	0	0	0	0	0	2	0	0.8
Whatcom	6	3	3	4	3	3	3	3	5	3	7.2
Other	0	0	0	0	0	2	1	3	3	0	1.8
TOTAL PATIENT LANDINGS	42	28	31	23	46	21	21	32	32	25	60.2
(ANNUAL)	70		54		67		53		57		

Source: *Children's Hospital and Regional Medical Center*. Does not include pilot certification landings.

3. For the pediatric population of each service area County, HFPD used annual historic estimates (updated July, 2007) by the Washington State Office of Financial Management (OFM) for the age cohorts 0-4, 5-9, and 10-14. The estimated annual population in each cohort for the years 2002-2006 was averaged. The 5-year total age 0-14 average population was then applied to the historic landing data to derive a 5-year use rate for each County, expressed as CHRMC landings per 1,000 population age 0-14. As shown in the table on the following page, while the pediatric residents of King County account for more actual landings, several other counties in fact have higher landing rates.

Children's Hospital Regional Medical Center
5-Year Historic Patient Landing Use Rates by County
2002-2006

	2002-2006		
County of Origin	**Avg. Annual CHRMC Helistop Landings**	**Avg. Annual Pop. Age 0-14**	**Use Rate per 1,000**
Clallam	1.4	11,047	0.13
Grays Harbor	0.6	13,681	0.04
Island	5.4	15,183	0.36
Jefferson	0.8	3,985	0.20
King	16.2	323,163	0.05
Kitsap	4.8	50,355	0.10
Lewis	0.4	14,376	0.03
Mason	0.2	9,209	0.02
Pacific	0.0	3,371	0.00
Pierce	5.8	161,920	0.04
San Juan	0.2	2,206	0.09
Skagit	6.0	22,325	0.27
Snohomish	8.6	142,340	0.06
Thurston	0.8	43,066	0.02
Whatcom	7.2	33,674	0.21

Source: *HFPD. Landing data from CHRMC. Pop. estimates from OFM.*

4. Next, the above historic use rates were applied to OFM projections for the pediatric population of each County[1] to derive the total number of future patient landings originating from the service area.

5. Finally, the number of patient landings originating from outside the service area were projected to continue occurring at the historic rate of 3% of all landings.

Detailed projections resulting from the methodology are presented on the following page.

[1] WA State Office of Financial Management, County population projections by age at 5-year intervals through 2030, updated October, 2007.

Children's Hospital Regional Medical Center
Projected Helistop Patient Landings
2010-2030

	2010		2015		2020		2025		2030	
County of Origin	**Pop. Age 0-14**	**x Use Rate = Proj. Landings**	**Pop. Age 0-14**	**x Use Rate = Proj. Landings**	**Pop. Age 0-14**	**x Use Rate = Proj. Landings**	**Pop. Age 0-14**	**x Use Rate = Proj. Landings**	**Pop. Age 0-14**	**x Use Rate = Proj. Landings**
Clallam	10,658	1.4	11,216	1.4	12,309	1.6	12,973	1.6	13,135	1.7
Grays Harbor	13,721	0.6	14,706	0.6	15,750	0.7	16,144	0.7	16,215	0.7
Island	15,200	5.4	15,604	5.5	16,251	5.8	16,650	5.9	16,998	6.0
Jefferson	4,050	0.8	4,516	0.9	4,960	1.0	5,370	1.1	5,605	1.1
King	334,809	16.8	355,116	17.8	371,694	18.6	384,885	19.3	390,770	19.6
Kitsap	45,720	4.4	47,256	4.5	51,163	4.9	53,015	5.1	53,762	5.1
Lewis	15,857	0.4	17,223	0.5	18,758	0.5	19,731	0.5	20,145	0.6
Mason	10,154	0.2	11,028	0.2	11,662	0.3	12,329	0.3	12,697	0.3
Pacific	3,216	0.0	3,296	0.0	3,378	0.0	3,357	0.0	3,311	0.0
Pierce	170,749	6.1	182,330	6.5	192,228	6.9	200,739	7.2	206,022	7.4
San Juan	2,017	0.2	2,159	0.2	2,360	0.2	2,525	0.2	2,611	0.2
Skagit	24,795	6.7	27,780	7.5	31,269	8.4	34,113	9.2	36,124	9.7
Snohomish	146,838	8.9	153,974	9.3	163,571	9.9	172,759	10.4	179,399	10.8
Thurston	46,380	0.9	50,827	0.9	54,625	1.0	57,863	1.1	60,000	1.1
Whatcom	34,863	7.5	37,738	8.1	41,377	8.8	44,562	9.5	46,791	10.0
SERVICE AREA TOTAL PEDIATRICT POP.	879,027		934,769		991,355		1,037,015		1,063,585	
Other Patient Landings @ 3.0% of Total		1.9		2.0		2.1		2.2		2.3
TOTAL PATIENT LANDINGS		62.0		66.0		70.7		74.4		76.7
ROUNDED TOTAL		**62**		**66**		**71**		**74**		**77**

Source: *HFPD. County population projections from WA State Office of Financial Management.*

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Wyle Report

WR 08-14

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Executive Summary

Wyle Laboratories analyzed noise from existing and proposed Agusta A109 medivac helicopter operations at Children's Hospital and Regional Medical Center (CHRMC) in Seattle, Washington. As topography and shielding effects are a concern, Wyle modeled the existing and proposed medivac helicopter operations using the Department of Defense's NOISEMAP Version 7 computer program. NOISEMAP can model the effects of ground cover, elevation, and shielding, and contains acoustic source data for the subject Agusta A109 helicopter. The existing hospital buildings, the interim buildings, and the proposed buildings were modeled as landform plateaus. The scope of work did not include in-situ noise measurements or vibration measurements.

Considering only the helicopter noise during departure and arrival flight events, Day-Night Average Sound Level (DNL), Sound Exposure Level (SEL) of the loudest flyover event, and Maximum Sound Level (L_{max}) were computed for 12 points of interest (noise-sensitive receptors) for seven (7) operational conditions associated with the helistop's location. Currently, medivac aircraft operate from a helipad located south of the main driveway and north of the hospital building. The helipad is on the ground at an elevation of 130 feet above Mean Sea Level (MSL). During various phases of construction, medivac operations would utilize two temporary ground-based helipads at elevations of 150 feet MSL within 300 feet east-northeast and 105 feet MSL within 300 feet northwest of the existing helipad. The temporary helipads would be used consecutively and not concurrently. In each of the proposed final design alternatives, the helipad would be relocated to the roof of a bed tower at an elevation ranging from approximately 167 to 270 feet MSL depending on final building configuration.

Two (2) types of DNL were computed: Average Day DNL based on yearly sorties ranging from 60 to 77, and "Busiest Day" DNL based on 4 daily sorties. Two flight operations – an arrival and a departure – are associated with each sortie. Average Day DNL was based on 75 percent of the sorties occurring during the daytime (7am to 10pm) period and 25 percent occurring during the nighttime (10pm to 7am) period. Busiest Day DNL was based on a temporal distribution of 50 percent daytime and 50 percent nighttime. Daily operations were calculated for Average Day and Busiest Day, and then assigned to each of the seven operational conditions: the existing condition, the two interim conditions, and the eight proposed alternatives, with the Average Day operations accounting for forecast increases in medivac flights. Calculations for each condition included the effects of shielding due to terrain and the planned building configuration. In addition to the different helipad locations, differences in the operational conditions also included minor changes in flight tracks and associated flight profiles for each helipad location.

Average Day DNL values due to medivac operations at the existing helipad are currently less than 50 dBA at all modeled receptors. None of the modeled receptors experience Busiest Day DNL greater than 63 dBA, and five of the 12 receptors experience a Busiest Day DNL between 60 and 63 dBA. The modeled receptors experience an L_{max} between 72 and 90 dBA and loudest-flight-event SELs between 89 and 102 dBA.

Relative to existing noise exposure, computer modeling indicated that Average Day DNL would cause at worst an increase of 3 dB at modeled receptors for all helipad locations. Average Day DNL would increase by approximately 1 dB solely due to the increase in operations under any proposed alternative. Busiest Day DNL would increase by 1 dB or less for all helipad locations except Temporary Helipad 2, which would cause increases up to 3 dB at modeled receptors. Relative to existing conditions, L_{max} would change by +10 to -8 dB and maximum SEL would change by +3 to -10 dB for all helipad locations and modeled receptors. These results are summarized in Table ES1 below.

Table ES1: Summary of Noise Exposure Changes from Medivac Operations Relative to Baseline Conditions

Alternative Condition	Helipad Altitude (ft MSL)	Annual Average Daily DNL Changes					Busiest Day DNL Changes				
		Increase		Decrease		No Change	Increase		Decrease		No Change
		Max (dB)	# Sites Affected	Max (dB)	# Sites Affected		Max (dB)	# Sites Affected	Max (dB)	# Sites Affected	
Temporary Helipad 1	150	1	4	1	3	5	1	4	1	3	5
Temporary Helipad 2	105	3	5	3	4	3	3	3	3	7	2
Alt 3	270	2	8	1	1	3	-	-	2	4	8
Alt 6	266	1	8	1	1	3	-	-	2	6	6
Alt 7A	201	2	4	3	3	3	1	1	4	6	3
Alt 7B	182	1	1	4	6	3	-	-	5	10	-
Alt 7RA	167	2	4	3	3	3	1	3	4	6	1
Alt 7RB	182	2	5	3	4	1	1	1	4	6	3
Alt 8A	167	2	5	3	3	2	1	3	4	6	1
Alt 8B	182	2	5	3	3	2	1	1	4	6	3

Alternative Condition	Helipad Altitude (ft MSL)	Lmax Changes					SEL Changes				
		Increase		Decrease		No Change	Increase		Decrease		No Change
		Max (dB)	# Sites Affected	Max (dB)	# Sites Affected		Max (dB)	# Sites Affected	Max (dB)	# Sites Affected	
Temporary Helipad 1	150	5	10	1	1	1	2	3	2	5	4
Temporary Helipad 2	105	10	6	8	4	2	3	2	5	5	5
Alt 3	270	5	5	7	6	1	2	1	2	3	8
Alt 6	266	4	5	7	5	2	2	1	2	4	7
Alt 7A	201	4	6	5	4	-	1	2	5	7	1
Alt 7B	182	6	6	2	3	1	-	-	10	10	-
Alt 7RA	167	4	5	5	4	1	-	-	5	9	1
Alt 7RB	182	4	6	5	4	-	1	1	5	7	2
Alt 8A	167	4	5	5	4	1	-	-	5	9	1
Alt 8B	182	4	6	5	4	-	1	1	5	7	2

Note: *Relative to the existing condition with the helipad at an elevation of 130 ft MSL

Based on noise analysis Alternative 7B would be the best choice with a 1 dB increase at 1 receptor for Average Day DNL and a decrease of up to 4 dB at 6 receptors. If the Helistop location was not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition. Under Alternative 7B there would be a decrease in Busiest Day DNL of up to 5 dB at all receptors. Alternative 7B would not be as favorable with regard to L_{max} as it would cause an increase up to 6 dB at 6 receptors and decreases of up to 2 dB at 4 receptors. Changes in SEL are very favorable under Alternative 7B, causing a decrease of up to 10 dB at all 10 receptors.

Alternatives 7RA, 7RB, 8A, and 8B are similar with one another varying by 1 dB or less at all receptors. These four alternatives would cause up to a 2 dB increase at up to 5 receptors in Annual Average Daily DNL and as much as a 3 dB decrease at up to 4 receptors. The Busiest Day DNL would increase by only 1 dB at up to three receptors and decrease up to 4 dB at 6 receptors. The L_{max} would increase by up to 4 dB at 6 receptors and decrease up to 5 dB at 4 receptors. Under these Alternatives the SEL would increase at most 1 dB at 1 receptor and decrease up to 5 dB at 7 to 9 receptors. The final four Alternatives are nearly as good as Alternative 7B in terms of minimizing sound levels at the receptor locations.

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1.0 Introduction

In 1991, a Final Environmental Impact Statement (FEIS) was prepared for the introduction of a medical evacuation (medivac) helistop for the Children's Hospital and Regional Medical Center (CHRMC) in Seattle, Washington (City of Seattle, 1991). In August 2005, URS Corporation (URS) prepared a Noise Technical Report (URS, 2005) in support of the environmental documentation being prepared for the proposed relocation of the helistop to the roof of an expanded Emergency Department wing of the hospital. To supplement the Noise Technical Report and to reflect the evolving design of the hospital campus, URS requested Wyle Laboratories to perform additional noise analyses of existing, interim, and proposed helicopter operations.

This study analyzes the noise exposure due to medivac operations under various design alternatives in the Draft EIS for CHRMC's Major Institution Master Plan (CHRMC, 2008). The analysis covers the existing condition, six building design alternatives, and two temporary helipad locations planned for use during the construction. This analysis also uses a more rigorous noise propagation model than previous studies in order to account for the shielding effect of terrain and the hospital building on the noise exposure of the surrounding community.

Section 2 describes the noise metrics and computer noise models used in this analysis. Section 3 presents the existing helicopter operations and noise exposure. Section 4 describes the helicopter operations and noise exposure for each of the two temporary helipad locations and the interim building design. Section 5 presents the helicopter operations and noise exposure for the building design and helipad location under EIS Alternative 3. Section 6 presents the helicopter operations and noise exposure for the building design and helipad location under EIS Alternative 6, and Section 7 presents the helicopter operations and noise exposure for the building design and helipad locations under EIS Alternative 7. There are two possible helipad locations under Alternative 7 - Helipad Location 7A and Helipad Location 7B. There are two possible helipad locations under Revised Alternative 7 analyzed in Section 8 - Helipad Location 7RA and Helipad Location 7RB. There are two possible helipad locations under Alternative 8 analyzed in Section 9 - Helipad Location 8A and Helipad Location 8B. Section 10 of this report summarizes the results. Appendix A provides a general discussion of noise and its effects on people and the environment, and Appendix B presents maps of the modeled aircraft flight profiles for each scenario.

2.0 Noise Metrics and Analysis Tools

2.1 Noise Metrics

As used in environmental noise analyses, a noise metric refers to a unit that quantitatively measures the effect of noise on the environment. The pertinent metrics for individual noise events are Sound Exposure Level (SEL) and Maximum Sound Level (L_{max}). SEL describes flight events, whereas L_{max} can be used to describe flight events and ground run-up events. The long-term (24-hour) cumulative energy noise metric used throughout the US (except in California) is the Day-Night Average Sound Level (DNL).

The metrics and their uses are described below in subsections 2.1.1 through 2.1.4. All metrics in this report are calculated using the "A" frequency weighting, which approximates the human ear's sensitivity to different frequencies of sound. All values are given in units of A-weighted decibels (dBA).

2.1.1 Maximum Sound Level

The highest A-weighted sound level measured during a single event in which the sound level changes with time (e.g., an aircraft overflight) is called the maximum A-weighted sound level or Maximum Sound Level (L_{max}).

During an aircraft overflight, the noise level starts at the ambient or background noise level, rises to the maximum level as the aircraft passes the observer, and returns to the background level as the aircraft recedes into the distance. L_{max} indicates the maximum sound level occurring for a fraction of a second. For aircraft noise, the time over which the maximum level is defined is generally one eighth of a second (ANSI, 1988). The maximum sound level is important in judging a noise event's interference with conversation, TV or radio listening, sleep, and other common activities. Although it provides some measure of the intrusiveness of the event, it does not completely describe the event, because it does not account for the length of time over which the sound is heard.

2.1.2 Sound Exposure Level

SEL (or L_{AE}) is a composite metric that represents both the intensity of a sound and its duration. Individual time-varying noise events (e.g., aircraft overflights) have two main characteristics: a sound level that changes throughout the event and a period of time during which the event is heard. SEL provides a measure of the net impact of the entire acoustic event, but it does not directly represent the sound level heard at any given time. During an aircraft flyover, SEL would include both the maximum noise level and the lower noise levels produced during onset and recess periods of the overflight.

SEL is a logarithmic measure of the total acoustic energy transmitted to the listener during the event. Mathematically, it represents the A-weighted sound level of a constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For sound from aircraft overflights, which typically last more than one second, the SEL is usually greater than the L_{max} because an individual overflight takes many seconds and the L_{max} is measured instantaneously. SEL is considered the best metric to compare noise levels from different overflight events.

2.1.3 Day-Night Average Sound Level

The noise metric used for federal assessment of aircraft noise exposure in communities in the vicinity of airfields and airports is the Day-Night Average Sound Level (abbreviated DNL, or sometimes L_{dn}), in units of the A-weighted decibel (dBA). DNL is an average A-weighted sound level generated by all aviation-related

operations during an average or busy 24-hour period, with sound levels of nighttime noise events emphasized by adding a 10 dB "penalty". Nighttime is defined as the period from 10 p.m. to 7:00 a.m. the following morning. The added 10 dB accounts for the generally lower background sound levels and greater community sensitivity to noise during nighttime hours. DNL correlates with annoyance to noise, and has been found to provide the best measure of long-term community reaction to transportation noise, especially aircraft noise.

2.2 Analysis Tools

This section describes the analysis tools used to calculate the noise levels contained in this report, namely, the NOISEMAP suite of computer programs.

The programs described below are most accurate and useful for comparing "before and after" noise levels that would result from alternative scenarios when calculations are made in a consistent manner. The programs allow noise exposure prediction of such proposed actions without actual implementation or noise monitoring of those actions. The programs also have the flexibility of calculating sound levels at specified points on the ground, allowing the analysis of individual noise-sensitive receptors.

2.2.1 NOISEMAP

Analyses of aircraft noise exposure and compatible land uses can be accomplished using a group of computer-based programs, collectively called NOISEMAP (Czech and Plotkin, 1998; Wasmer Consulting, 2006a; Page, et. al., 2007; Wasmer Consulting, 2006b). The NOISEMAP suite of computer programs was primarily developed by the Air Force, which serves as the lead Department of Defense (DoD) agency for aircraft noise modeling. The NOISEMAP suite of computer programs includes BaseOps, OMEGA10, OMEGA11, NMAP and NMPlot. The suite also includes the NOISEFILE database of measured aircraft noise data.

The BaseOps program allows entry of runway coordinates, airfield information, flight tracks, flight profiles (engine thrust settings, altitudes, and speeds) along each flight track for each aircraft, numbers of daily flight operations, ground run-up locations, run-up profiles, and run-up operations. The OMEGA10 program then calculates the SEL for each model of aircraft from the NOISEFILE database, taking into consideration the specified speeds, engine thrust settings, and environmental conditions appropriate to each type of flight operation. The OMEGA11 program calculates maximum A-weighted sound levels from the NOISEFILE database for each model of aircraft, taking into consideration the engine thrust settings and environmental conditions appropriate to run-up operations. The core NMAP program incorporates the number of daytime and nighttime flight and run-up events, flight paths, and flight/run-up profiles of the aircraft and calculates the resulting sound level at points on the ground in the facility's vicinity. NMPlot is used to visualize and output the modeling results. In this study, NOISEMAP Version 7.2 was used to analyze rotary-wing aircraft operations.

2.2.2 Topography, Noise Contours and Points of Interest

The NOISEMAP Version 7.2 program includes algorithms for effects of atmospheric sound propagation over varying terrain, including hills and mountainous regions, as well as regions of varying acoustical impedance—for example, water around coastal regions. By including terrain in the propagation calculations, the shielding effect of landforms can be included in the analysis. Acoustical impedance describes how sound

is reflected or absorbed by the ground. Sound tends to travel farther over hard surfaces, such as pavement or water, than it does over soft surfaces, such as plowed earth or vegetation.

The elevation and acoustical impedance of the study area were used in computing the noise levels presented in this analysis. Elevation grid files were created from electronic elevation data in the U.S. Geological Survey's National Elevation Dataset (USGS, 2007). Roof outlines and elevations of buildings on the CHRMC campus were extracted from building plans, and the elevation grid files were modified to model the buildings as landforms. Impedance grid files were created from generic impedance grids, and the impedance was set to hard at the location of buildings and parking lots and soft everywhere else. A different elevation and impedance file set was created for each building scenario (existing, interim, Alternative 3, Alternative 6, and Alternative 7, Alternative 7R and Alternative 8).

The core NOISEMAP program can incorporate the number of day and night operations, flight paths, and profiles of the aircraft in order to calculate DNL at many points on the ground around the facility, including specific points of interest (e.g., noise-sensitive receptors) and to determine the primary contributors to the overall DNL at each point. Wyle developed a special version of the NOISEMAP program to compute L_{max}.

2.2.3 Exposure Calculation

DNL contours were not within the scope of this report, nor would they be meaningful due to the infrequent tempo of flights at the existing and proposed helistop. It was anticipated at the project's outset that the average daily contribution of the helicopters would be less than 55 dBA DNL and acoustically insignificant compared to the non-helicopter ambient noise environment at the community receptors. Thus, DNL contours were not generated (nor were associated land acreage and housing/population estimates), and noise exposure for this report is quantified by DNL, SEL, L_{max}, and the change in those values at the points of interest.

To represent the range in tempo of medivac flight operations at CHRMC, two (2) types of DNL were computed:

1) "Busiest Day" DNL based on 4 sorties per day,
2) Average daily DNL based on historical or projected annual traffic when each helipad location is planned to be in use (CHRMC, 2007):
    - 60 sorties per year for the existing helipad
    - 62 sorties per year for Temporary Helipad 1
    - 66 sorties per year for Temporary Helipad 2
    - 77 sorties per year for all other modeled helipads.

Each sortie consists of two operations – one arrival and one departure. Sections 3 through 9 describe the modeled helipad locations, and Section 3.2 describes how the flight tracks were modeled for the A109 medivac helicopter operations. No engine maintenance run-up operations are expected to be performed at the helistop, so none were modeled.

For each alternative and the existing condition, each helipad was modeled as a 40-foot runway centered on the helipad location and oriented toward the initial flight heading.

3.0 Existing Helipad Location and Noise Exposure

Section 3.1 discusses existing flight operations. Section 3.2 discusses the existing helipad location, flight track utilization, and flight profiles. Section 3.3 presents the resultant noise exposure due to aircraft operations.

3.1 Existing Flight Operations

All CHRMC medivac flight operations were modeled with the Agusta A109 helicopter. The A109 is considered a light high-speed twin-engine four-bladed general purpose helicopter with a length of approximately 43 feet (ft), a main rotor diameter of approximately 36 ft and a maximum takeoff weight of approximately 5,400 pounds. Its maximum cruising speed is 165 miles per hour with a maximum climb rate of 1,620 ft per minute (Gunston, 1980).

Flight operations at CHRMC are relative to the nature of emergency treatment in the region and are unpredictable. Typically, CHRMC has experienced three (3) daytime (7 am – 10 pm) sorties and one (1) nighttime (10 pm – 7am) sortie per month, on average. However, medivac flights on a given day have been as frequent as two (2) during the daytime hours and two (2) during the nighttime period (Blakeslee 2008A).

Table 1 shows the two operational scenarios modeled for the existing helipad location. The Average Day scenario is based on historical CHRMC medivac landing counts from 2002 through 2006 (CHRMC, 2007). During that period, there were an average of 60 sorties to CHRMC per year, with 75 percent occurring during the daytime period and 25 percent occurring during the nighttime period. Average daily flight operations are computed assigning a departure operation and an arrival operation to each sortie (1 sortie = 1 departure + 1 arrival) and dividing by 365. The Busiest Day scenario is based on 4 sorties per day, with half occurring during the nighttime (10:00 pm to 7:00 am) period (Blakeslee 2007A).

Table 1 – Medivac Flight Operations Modeled for Existing Helipad

Scenario	Number of Sorties	Operation Type	Daily Flight Operations		
			Day	Night	Total
Average Day	60/year	Departure	0.1233	0.0411	0.1644
		Arrival	0.1233	0.0411	0.1644
		Total	**0.2466**	**0.0822**	**0.3288**
Busiest Day	4/day	Departure	2	2	4
		Arrival	2	2	4
		Total	**4**	**4**	**8**

Notes: Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
One sortie is equal to two operations - one departure and one arrival.

3.2 Existing Helipad Location, Flight Tracks and Flight Profiles

Figure 1 shows the location of the existing helipad relative to the surrounding community. The existing helipad (labeled "HE" in the figure) is on the ground at an elevation of 130 ft MSL, between the north parking lot and the hospital building. Figure 1 also shows the typical flight tracks to/from the existing helipad (URS, 2005). The departure track to the south ultimately proceeds westward along Sand Point Way with a southwest initial heading (Track ED01). Departure tracks to the north ultimately proceed west along NE 55th Street via a northerly initial heading overflying the Burke-Gilman Playground Park (Track ED02) or via a northeast initial heading (Track ED03). Track utilization was assumed to be equal among all departure tracks.

A primary arrival track from the west mirrors the southwest departure track ED01 by initially proceeding eastward along Sand Point Way and turning northeast directly to CHRMC (Track EA01). Another primary arrival track from the west has the helicopter initially proceeding eastward along NE 55th Street and turning south over the Burke-Gilman Playground Park to CHRMC (Track ED02). Two secondary arrival tracks from the east have the helicopter initially proceeding west along NE 55th Street and either turning south over the Burke-Gilman Playground Park (Track EA03) or southwest direct to CHRMC (Track EA04). Track utilization was assumed to be equal among all arrival tracks.

URS had previously modeled the CHRMC helicopter flights with the FAA's Heliport Noise Model (FAA, 1994). Flight profiles from the Heliport Noise Model (HNM) modeling were converted to NOISEMAP. Helicopter flight profiles in NOISEMAP consist of power setting/configuration, airspeed and altitude at points along each modeled flight track. Power settings/configurations for the A109 aircraft consist of either Takeoff at 60 knots (kts), Flyover at 116 kts or Approach at 60 kts. In NOISEMAP, airspeeds for the A109 helicopter are fixed and cannot be changed.

For departures, the helicopter is modeled to use the Takeoff power setting (at 60 kts), attain 150 ft MSL when 50 ft from the pad, attain 630 ft MSL when 1000 ft from the pad, and ascend to 1100 ft MSL and change to Flyover power setting (116 kts) when 2000 ft from the pad. On approach, the helicopter starts its profile at 1100 ft MSL (Flyover power setting at 116 kts) and begins its descent 0.8 nautical mile (nm) away from the pad (Approach power setting at 60 kts), descending to an altitude of approximately 630 ft MSL at approximately 0.5 nm from the pad. A linear descent continues to the helipad. Appendix B shows the modeled NOISEMAP flight profiles for each flight track.

Figure 1.
Modeled Flight Tracks for Existing Helipad

3.3 Existing Noise Exposure

Table 2 lists the calculated noise exposure values for the 12 modeled receptors. In addition to the ten (10) receptor locations modeled by URS, Wyle also modeled Receptor Location 1 (4720-24 44th Avenue NE) and Receptor Location 2 (4530 45th Avenue NE) from the FEIS. In this report, FEIS Receptor Location 1 is called R11 and FEIS Location 2 is called R12.

Among the 12 receptors, DNLs range from 35 dBA to 63 dBA, L_{max} range from 72 dBA to 90 dBA and SELs range from 89 dBA to 102 dBA. Receptor R7 at 4200 NE 50th Street experiences the highest DNLs (47 dBA for an average day and 63 dBA for busiest day) but Receptor R11 along 44th Avenue experiences the highest L_{max} (90 dBA). As indicated by the rightmost column of Table 2, all of the maximum SEL events are due to arrival flights because the Augusta A109 helicopter is up to 4 dB louder on approach power than departure power.

Table 2 - Noise Exposure from Medivac Operations at Existing Helipad

Receptor		Noise Level (dBA)				Max SEL Track
ID	Address	AD† DNL	BD‡ DNL	Lmax	Max SEL	
R1	Laurelon Terrace, northernmost building	44	60	85	98	EA02
R2	Laurelon Terrace, south of R1	44	60	81	97	EA02
R3	4323 NE 45th St.	36	52	73	89	EA01
R4	4546 45th Ave. NE	38	54	73	92	EA04
R5	4554 45th Ave. NE	38	54	76	92	EA04
R6	4702 45th Ave. NE	45	61	89	101	EA04
R7	4200 NE 50th St.	47	63	89	102	EA03
R8	4545 Sand Point Way	41	57	87	98	EA01
R9	4412 43rd Ave. NE	35	52	75	90	EA01
R10	4415 43rd Ave. NE	36	52	77	91	EA01
R11*	4720-4724 44th St. NE	46	62	90	101	EA04
R12**	4530 45th St. NE	36	53	72	90	EA04

Notes: * Receptor Location 1 from 1991 FEIS (City of Seattle, 1991)
** Receptor Location 2 from 1991 FEIS (City of Seattle, 1991)
† AD = Average Day is 60 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

4.0 Temporary Helipad Locations and Noise Exposure

During the construction of the new hospital wings, CHRMC will require two temporary helipad locations. Section 4.1 discusses flight operations using the temporary helipads. Section 4.2 discusses the helipad locations, flight track utilization and flight profiles. Section 4.3 presents the resultant noise exposure due to aircraft operations at the temporary helipads.

4.1 Interim Flight Operations

The population of the area served by CHRMC is projected to increase over the course of the helipad relocation (CHRMC, 2007), so the flight operations in the Average Day scenario for each of the two temporary helipads were adjusted to model the operational tempo expected when each helipad is planned to be in use. The Busiest Day scenario is a worst-case scenario, and CHRMC does not expect an increase in busy day flight tempo relative to the existing condition. The operations used for the temporary helipads' Busiest Day DNL are the same as for the existing helipad.

Table 3 shows the two operational scenarios modeled for Temporary Helipad 1. The Average Day scenario is based on a projected 62 CHRMC medivac sorties per year, with 25 percent occurring during the nighttime period. Average daily flight operations were derived from annual sorties in the same manner as described in Section 3.1. As with the existing helipad, the Temporary Helipad 1 Busiest Day scenario is based on 4 sorties per day, with half occurring during the nighttime (10:00 pm to 7:00 am) period (Blakeslee 2008A).

Table 3 – Medivac Flight Operations Modeled for Temporary Helipad 1

Scenario	Number of Sorties	Operation Type	Daily Flight Operations		
			Day	Night	Total
Average Day	62/year	Departure	0.1274	0.0425	0.1699
		Arrival	0.1274	0.0425	0.1699
		Total	**0.2548**	**0.0850**	**0.3398**
Busiest Day	4/day	Departure	2	2	4
		Arrival	2	2	4
		Total	**4**	**4**	**8**

Notes: Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
One sortie is equal to two operations - one departure and one arrival.

Table 4 shows the two operational scenarios modeled for Temporary Helipad 2. The Average Day scenario is based on a projected 66 CHRMC medivac sorties per year, with 25 percent in the nighttime period. As with the existing helipad, the Temporary Helipad 2 Busiest Day scenario is based on 4 sorties per day, with half occurring during the nighttime period.

Table 4 – Medivac Flight Operations Modeled for Temporary Helipad 2

Scenario	Number of Sorties	Operation Type	Daily Flight Operations		
			Day	Night	Total
Average Day	66/year	Departure	0.1356	0.0452	0.1808
		Arrival	0.1356	0.0452	0.1808
		Total	**0.2712**	**0.0904**	**0.3616**
Busiest Day	4/day	Departure	2	2	4
		Arrival	2	2	4
		Total	**4**	**4**	**8**

Notes: Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
One sortie is equal to two operations - one departure and one arrival.

4.2 Temporary Helipad Locations, Flight Tracks and Flight Profiles

Figure 2 shows the location of the temporary helipads relative to the surrounding community. During various phases of construction, medivac operations would use two temporary helipads. The first temporary helipad location, called Temporary Helipad 1 in this report (labeled HT1 in the figure) would be on the ground approximately 175 ft east-northeast of the existing helipad at an elevation of 150 ft MSL, and would be used during the construction of the new Emergency Department wing. The second temporary location, called Temporary Helipad 2 (labeled HT2 in the figure) would be on the ground approximately 260 ft northwest of the current location, at an elevation of 105 ft MSL. The second temporary location would be used after the Emergency Department wing was completed, during construction of the nursing tower. Each temporary helipad would be used consecutively, not concurrently (Blakeslee 2007A). Figure 2 also shows the typical flight tracks to/from the temporary helipads. These tracks are nearly identical to the flight tracks for the existing condition in Figure 1 and thus their utilization is identical to the existing condition. See Section 3.2 for further discussion of the flight tracks and utilization percentages.

Departure and arrival flight profiles were transferred from the existing flight tracks to the flight tracks for the interim helipads, and adjusted to accommodate the new helipad heights while using the same cruise altitude. Helicopter arrivals are modeled with the same parameters for cruise altitude except descending to an altitude between 605 ft MSL and 650 ft MSL at approximately 0.5 nm from the pad. A linear descent would continue to the appropriate helipad. Due to the lower elevation of Temporary Helipad 2, the altitudes of some points in its arrival profiles were increased so the aircraft would fly over the hospital building. Appendix B contains the modeled NOISEMAP flight profiles for each temporary helipad location.

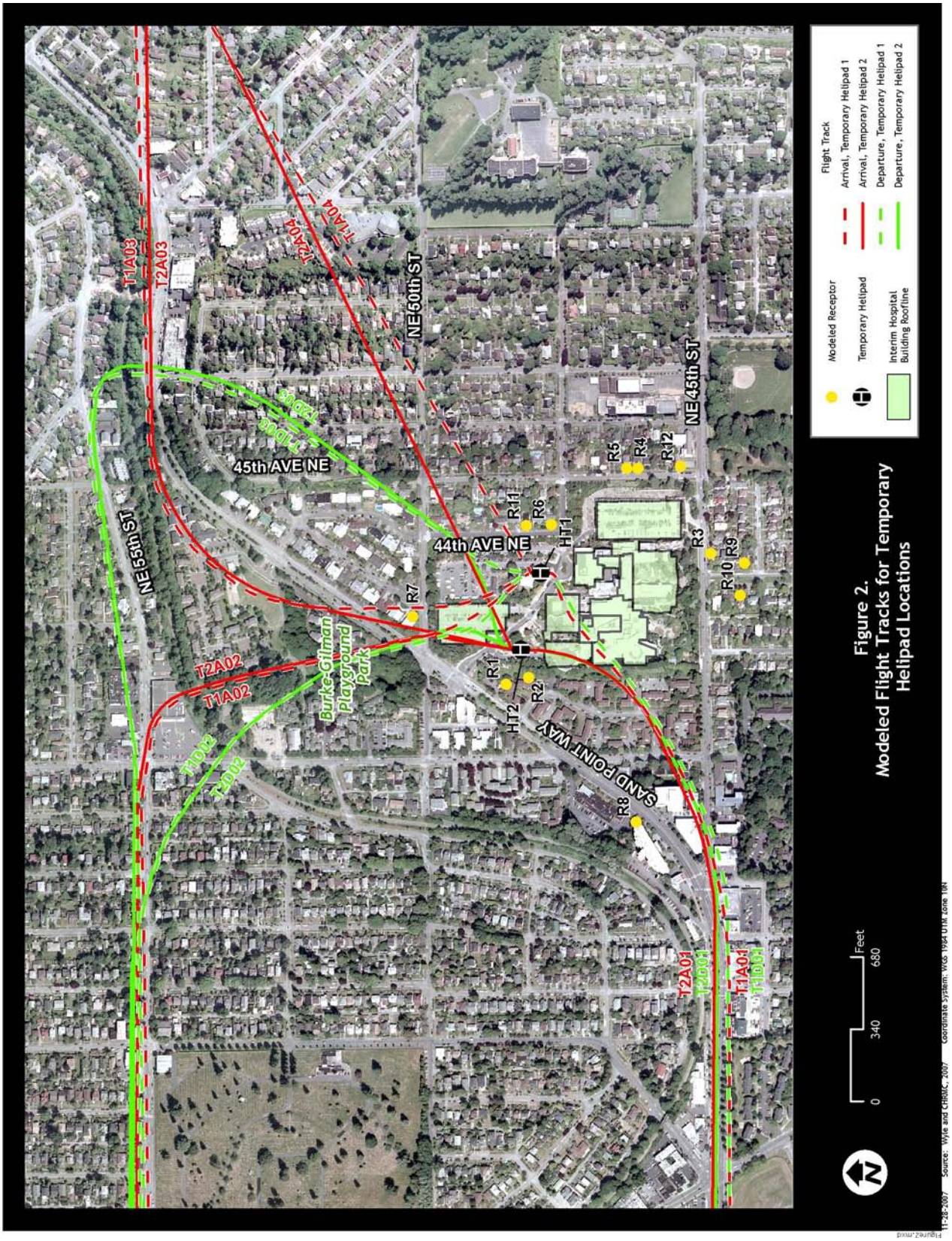


Figure 2.
Modeled Flight Tracks for Temporary Helipad Locations

4.3 Interim Noise Exposure

Tables 5 and 6 list the noise exposure values at the modeled receptors for the two temporary helipad locations. Among the 12 receptors, DNLs would range from 36 dBA to 64 dBA, L_{max} would range from 72 dBA to 92 dBA, and SELs would range from 89 dBA to 102 dBA. For operations at Temporary Helipad 1, receptors R7 and R11 would experience the highest DNL (47 dBA for an average day and 63 dBA for the busiest day). For operations at Temporary Helipad 2, receptor R7 would experience the highest DNL (46 dBA for an average day and 63 dBA for the busiest day). Receptors R7 and R11 would experience the highest L_{max} (92 dBA for Temporary Helipad 1). As indicated by the "Max SEL Track" column of Tables 5 and 6, all of the maximum SEL events are due to arrival flights because the Augusta A109 helicopter is up to 4 dB louder on approach power than departure power.

For either temporary location, the maximum increase in DNL or SEL relative to the existing condition would be 2 dB or less at 10 of the 12 receptors. The maximum increase in DNL or SEL would be 3 dB for receptors R1 and R2. For Temporary Helipad 1, L_{max} would not change or would decrease by 1 dB at receptors R1 and R8, but would increase by 2 dB to 5 dB at the other 10 receptors. Temporary Helipad 1 is closer to the eastern edge of the CHRMC property than the existing helipad location, so aircraft would be earlier in their initial ascent and therefore at a lower altitude when flying past receptors to the north and east of the hospital. The aircraft would also be a shorter horizontal distance to receptors such as R6 and R11. The northeast wing of the building and the east parking ramp would provide less shielding between Temporary Helipad 1 and receptors to the east of the hospital than it does for the existing helipad. If the helistop location was not moved (and no construction occurred), average day DNL would increase by less than 0.2 dB, solely due to the increase in average daily flight operations relative to the existing condition.

For Temporary Helipad 2, L_{max} would not change or would decrease relative to the existing condition by 1 to 8 dB at receptors R4 through R6 and R8 through R12. L_{max} would increase by 1 to 10 dB at the other 5 receptors. In this case, Temporary Helipad 2 is closer to the western edge of the CHRMC property, so aircraft passing western receptors such as R1 and R2 would be horizontally closer to the receptors and flying lower than in the existing case. Comparing the change in L_{max} at R1 and R2 illustrates the effect of topography on noise exposure. R2 is closer to the embankment at the western edge of the CHRMC property, and the line of sight between the existing helipad and R2 is interrupted by the embankment and the northwest wing of the hospital. The closer location of Temporary Helipad 2 decreases the shielding effect, and the steep altitude profile of tracks T2A01 and T2D01 contribute to a greater increase relative to the existing condition. Receptors to the south and east of the hospital would experience the least increase in L_{max} (in some cases, the L_{max} would decrease) due to building shielding and greater distance from the flight tracks. If the helistop location was not moved (and no construction occurred), DNL would increase by less than 0.5 dB, solely due to the increase in average daily flight operations relative to the existing condition.

Table 5 - Noise Exposure from Medivac Operations at Temporary Helipad 1

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	Laurelon Terrace, northernmost building	43	59	85	96	T1A02	-1	-1	0	-2
R2	Laurelon Terrace, south of R1	43	59	83	96	T1A02	-1	-1	2	-1
R3	4323 NE 45th St.	36	52	75	90	T1A01	0	0	2	1
R4	4546 45th Ave. NE	38	54	78	91	T1A04	0	0	5	-1
R5	4554 45th Ave. NE	39	55	80	94	T1A04	1	1	4	2
R6	4702 45th Ave. NE	46	62	91	101	T1A04	1	1	2	0
R7	4200 NE 50th St.	47	63	92	102	T1A02	0	0	3	0
R8	4545 Sand Point Way	40	56	86	97	T1A01	-1	-1	-1	-1
R9	4412 43rd Ave. NE	36	52	77	90	T1A01	1	0	2	0
R10	4415 43rd Ave. NE	36	52	79	92	T1A01	0	0	2	1
R11*	4720-4724 44th St. NE	47	63	92	101	T1A04	1	1	2	0
R12**	4530 45th St. NE	36	52	74	89	T1A04	0	-1	2	-1

Notes: * Receptor Location 1 from 1991 FEIS (City of Seattle, 1991)
** Receptor Location 2 from 1991 FEIS (City of Seattle, 1991)
† AD = Average Day is 62 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

Table 6 - Noise Exposure from Medivac Operations at Temporary Helipad 2

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	Laurelon Terrace, northernmost building	47	63	89	99	T2A02	3	3	4	1
R2	Laurelon Terrace, south of R1	46	61	91	100	T2A01	2	1	10	3
R3	4323 NE 45th St.	36	51	74	89	T2A01	0	-1	1	0
R4	4546 45th Ave. NE	37	53	72	90	T2A04	-1	-1	-1	-2
R5	4554 45th Ave. NE	37	53	75	91	T2A04	-1	-1	-1	-1
R6	4702 45th Ave. NE	42	58	81	96	T2A04	-3	-3	-8	-5
R7	4200 NE 50th St.	48	64	91	102	T2A02	1	1	2	0
R8	4545 Sand Point Way	42	57	87	98	T2A01	1	0	0	0
R9	4412 43rd Ave. NE	36	51	76	90	T2A01	1	-1	1	0
R10	4415 43rd Ave. NE	36	52	78	91	T2A01	0	0	1	0
R11*	4720-4724 44th St. NE	44	59	84	98	T2A04	-2	-3	-6	-3
R12**	4530 45th St. NE	36	52	72	89	T2A01	0	-1	0	-1

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
† AD = Average Day is 66 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptors are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

5.0 Alternative 3 Helipad Location and Noise Exposure

Section 5.1 discusses flight operations for Alternative 3. Section 5.2 discusses the Alternative 3 helipad location, flight track utilization, and flight profiles. Section 5.3 presents the resultant noise exposure due to aircraft operations at the Alternative 3 helipad.

5.1 Alternative 3 Flight Operations

CHRMC does not expect an increase in *busy day* flight tempo relative to the existing condition, but an increase in *average* tempo is expected by the time the Alternative 3 helipad is completed (CHRMC, 2007). Table 7 shows the two operational scenarios modeled for the Alternative 3 helipad location. The Average Day scenario is based on a projected 77 CHRMC medivac sorties per year, with 25 percent occurring during the nighttime period. Average daily flight operations were derived from annual sorties in the same manner as described in Section 3.1. As with the existing helipad, the Alternative 3 helipad's Busiest Day scenario is based on 4 sorties per day, with half occurring during the nighttime period (Blakeslee 2008B).

Table 7 – Medivac Flight Operations Modeled for Alternative 3 Helipad

Scenario	Number of Sorties	Operation Type	Daily Flight Operations		
			Day	Night	Total
Average Day	77/year	Departure	0.1582	0.0527	0.2109
		Arrival	0.1582	0.0527	0.2109
		Total	**0.3164**	**0.1054**	**0.4218**
Busiest Day	4/day	Departure	2	2	4
		Arrival	2	2	4
		Total	**4**	**4**	**8**

Notes: Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
One sortie is equal to two operations - one departure and one arrival.

5.2 Alternative 3 Helipad Location, Flight Tracks and Flight Profiles

Figure 3 shows the location of the Alternative 3 helipad relative to the surrounding community. The proposed helipad would be on the roof of the bed tower, approximately 105 ft southwest of the existing helipad and at an elevation of 270 ft MSL (labeled HA3 in the figure). Figure 3 also shows the typical flight tracks to/from the helipad. These tracks are nearly identical to the flight tracks for the existing condition in Figure 1, thus their utilization is identical to the existing condition. See Section 3.2 for further discussion of the flight tracks and utilization percentages (Blakeslee 2007).

Departure and arrival flight profiles were transferred from the existing flight tracks to the flight tracks for the proposed helipad, and adjusted to accommodate the new helipad height while using the same cruise altitude. For departure, the helicopter is modeled to use the Takeoff power setting (at 60 kts), attain 290 ft MSL when 50 ft from the pad, attain 770 ft MSL when 1000 ft from the pad, and ascend to 1100 ft MSL and change to Flyover power setting (116 kts) when 2000 ft from the pad. On approach, the helicopter starts its profile at 1100 ft MSL (Flyover power setting at 116 kts) and begins its descent 0.8 nm away from the pad (Approach power setting at 60 kts), descending to an altitude of 750 ft MSL at approximately 0.5 nm from the pad. A linear descent would continue to the helipad. Appendix B contains the modeled NOISEMAP flight profiles for each flight track.

Figure 3.
Modeled Flight Tracks for Alternative 3 Helipad Location

5.3 Alternative 3 Noise Exposure

Table 8 lists the noise exposure values for the modeled receptors for the Alternative 3 helipad location. Among the 12 receptors, DNLs would range from 37 dBA to 62 dBA, L_{max} would range from 74 dBA to 88 dBA, and SELs would range from 90 dBA to 101 dBA. Receptor R7 at 4200 NE 50th Street would experience the highest DNLs (47 dBA for an average day and 62 dBA for the busiest day) and the highest L_{max} (88 dBA). As indicated by the "Max SEL Track" column of Table 8, all of the maximum SEL events are due to arrival flights because the Augusta A109 helicopter is up to 4 dB louder on approach power than departure power.

The maximum increase in DNL or SEL relative to the existing condition would be 2 dB or less at all 12 receptors. Due to the decreased shielding of the building, the increase in L_{max} would be between 2 and 5 dB at receptors R3, R4, R9, R10 and R12. R2 would experience no change in L_{max}. L_{max} would decrease by 1 to 7 dB at receptors R1, R5 through R8, and R11. Because the proposed helipad is 140 ft higher than the existing pad, aircraft that overfly receptors would do so at a higher altitude, decreasing their noise exposure. If the helistop location were not moved (and no construction occurred), average day DNL would increase by 1 dB, solely due to the increase in average daily flight operations relative to the existing condition.

Table 8 - Noise Exposure from Medivac Operations at Alternative 3 Helipad

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	Laurelon Terrace, northernmost building	45	60	82	98	PA02	1	0	-3	0
R2	Laurelon Terrace, south of R1	45	60	81	97	PA02	1	0	0	0
R3	4323 NE 45th St.	37	52	78	91	PA01	1	0	5	2
R4	4546 45th Ave. NE	39	54	75	92	PA04	1	0	2	0
R5	4554 45th Ave. NE	39	54	75	92	PA04	1	0	-1	0
R6	4702 45th Ave. NE	44	59	82	99	PA04	-1	-2	-7	-2
R7	4200 NE 50th St.	47	62	88	100	PA03	0	-1	-1	-2
R8	4545 Sand Point Way	41	56	85	97	PA01	0	-1	-2	-1
R9	4412 43rd Ave. NE	37	52	77	90	PA01	2	0	2	0
R10	4415 43rd Ave. NE	37	52	79	91	PA01	1	0	2	0
R11*	4720-4724 44th St. NE	46	61	87	101	PA04	0	-1	-3	0
R12**	4530 45th St. NE	38	53	74	90	PA04	2	0	2	0

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
† AD = Average Day is 77 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

6.0 Alternative 6 Helipad Location and Noise Exposure

Section 6.1 discusses flight operations for Alternative 6. Section 6.2 discusses Alternative 6 helipad location, flight track utilization and flight profiles. Section 6.3 presents the resultant noise exposure due to aircraft operations at the Alternative 6 helipad.

6.1 Alternative 6 Flight Operations

Flight operations under Alternative 6 would have the same tempo and temporal distribution as under Alternative 3. As stated previously, CHRMC does not expect an increase in *busy day* flight tempo relative to the existing condition, but an increase in *average* tempo is expected by the time the Alternative 6 helipad would be completed. (CHRMC, 2007) Table 9 shows the two operational scenarios modeled for the Alternative 6 helipad location. The Average Day scenario is based on a projected 77 CHRMC medivac sorties per year, with 25 percent occurring during the nighttime period. Average daily flight operations were derived from annual sorties in the same manner as described in Section 3.1. As with the existing helipad, the Alternative 6 helipad's Busiest Day scenario is based on 4 sorties per day, with half occurring during the nighttime period (Blakeslee 2008A).

Table 9 – Medivac Flight Operations Modeled for Alternative 6 Helipad

Scenario	Number of Sorties	Operation Type	Daily Flight Operations		
			Day	Night	Total
Average Day	77/year	Departure	0.1582	0.0527	0.2109
		Arrival	0.1582	0.0527	0.2109
		Total	**0.3164**	**0.1054**	**0.4218**
Busiest Day	4/day	Departure	2	2	4
		Arrival	2	2	4
		Total	**4**	**4**	**8**

Notes: Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
One sortie is equal to two operations - one departure and one arrival.

6.2 Alternative 6 Helipad Location, Flight Tracks and Flight Profiles

Figure 4 shows the location of the Alternative 6 helipad relative to the surrounding community. The proposed helipad would be on the roof of the north bed tower, approximately 80 ft west-southwest of the existing helipad and at an elevation of 266 ft MSL (labeled HA6 in the figure)(Blakeslee 2008C).

Figure 4 also shows the typical flight tracks to/from the helipad. Off the CHRMC property, these tracks are nearly identical to the flight tracks for the existing condition in Figure 1, thus their utilization is identical to the existing condition. See Section 3.2 for further discussion of the flight tracks and utilization percentages.

Departure and arrival flight profiles were transferred from the existing flight tracks to the flight tracks for the proposed helipad, and adjusted to accommodate the new helipad height while using the same cruise altitude.

Figure 4. Modeled Flight Tracks for Alternative 6 Helipad

6.3 Alternative 6 Noise Exposure

Table 10 lists the noise exposure values for the modeled receptors for the Alternative 6 helipad location. Among the 12 receptors, DNLs would range from 36 dBA to 62 dBA, L_{max} would range from 72 dBA to 91 dBA, and SELs would range from 90 dBA to 101 dBA. Receptor R7 at 4200 NE 50th Street would experience the highest DNLs (47 dBA for an average day and 62 dBA for the busiest day). Receptor R11 at 4720-4724 44th Ave. NE would experience the highest L_{max} (91 dBA). As indicated by the "Max SEL Track" column, all of the maximum SELs would be due to arrival flights.

The increase in DNL or SEL relative to the existing condition would be 2 dB or less at all 12 receptors. Due to the decreased building shielding, the increase in L_{max} would be between 1 and 4 dB at receptors R3, R4, R9, and R10. This increase is greatest for R3, which experiences the most building shielding of the receptors in the existing condition. Receptor R11 would experience a 1 dB increase in L_{max}, and receptors R2 and R12 would experience no change in L_{max}. L_{max} would decrease by 1 to 7 dB at receptor R1 and receptors R5 through R8. Because the proposed helipad is approximately 135 ft higher than the existing pad, aircraft that overfly receptors would do so at a higher altitude, decreasing their noise exposure. If the helistop location were not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition.

Table 10 - Noise Exposure from Medivac Operations at Alternative 6 Helipad

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	Laurelon Terrace, northernmost building	45	60	84	97	A6A02	1	0	-1	-1
R2	Laurelon Terrace, south of R1	45	60	81	97	A6A02	1	0	0	0
R3	4323 NE 45th St.	37	52	77	91	A6A01	1	0	4	2
R4	4546 45th Ave. NE	39	54	75	92	A6A04	1	0	2	0
R5	4554 45th Ave. NE	39	54	75	92	A6A04	1	0	-1	0
R6	4702 45th Ave. NE	44	59	82	99	A6A04	-1	-2	-7	-2
R7	4200 NE 50th St.	47	62	85	100	A6A03	0	-1	-4	-2
R8	4545 Sand Point Way	41	56	85	97	A6A01	0	-1	-2	-1
R9	4412 43rd Ave. NE	36	51	76	90	A6A01	1	-1	1	0
R10	4415 43rd Ave. NE	37	52	78	91	A6A01	1	0	1	0
R11*	4720-4724 44th St. NE	46	61	91	101	A6A04	0	-1	1	0
R12**	4530 45th St. NE	37	52	72	90	A6A04	1	-1	0	0

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
† AD = Average Day is 77 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

7.0 Alternative 7 Helipad Locations and Noise Exposure

There are two possible locations for the medivac helipad under Alternative 7 – Helipad Location 7A and Helipad Location 7B. For brevity, these configurations are referred to as Alternative 7A and Alternative 7B. Both locations are analyzed in this report, but only one would be constructed if Alternative 7 were selected. The building configuration modeled for Alternative 7A is the same as for 7B.

Section 7.1 discusses flight operations for Alternative 7. Section 7.2 discusses the two helipad locations, flight track utilization and flight profiles. Section 7.3 presents the resultant noise exposure due to aircraft operations at each helipad.

7.1 Alternative 7 Flight Operations

Flight operations under Alternative 7 would have the same tempo and temporal distribution as under Alternative 3 and Alternative 6. The operations analyzed for Alternative 7A are the same as for Alternative 7B. CHRMC does not expect an increase in *busy day* flight tempo relative to the existing condition, but an increase in *average* tempo is expected by the time either Alternative 7 helipad would be completed (CHRMC, 2007). Table 11 shows the two operational scenarios modeled for each helipad location. The Average Day scenario is based on a projected 77 CHRMC medivac sorties per year, with 25 percent occurring during the nighttime period. Average daily flight operations were derived from annual sorties in the same manner as described in Section 3.1. As with the existing helipad, the Alternative 7 helipads' Busiest Day scenarios are based on 4 sorties per day, with half occurring during the nighttime period (Blakeslee 2008A).

Table 11 – Medivac Flight Operations Modeled for Each Alternative 7 Helipad Location

Scenario	Number of Sorties	Operation Type	Daily Flight Operations		
			Day	Night	Total
Average Day	77/year	Departure	0.1582	0.0527	0.2109
		Arrival	0.1582	0.0527	0.2109
		Total	**0.3164**	**0.1054**	**0.4218**
Busiest Day	4/day	Departure	2	2	4
		Arrival	2	2	4
		Total	**4**	**4**	**8**

Notes: Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
One sortie is equal to two operations - one departure and one arrival.

7.2 Alternative 7 Helipad Locations, Flight Tracks and Flight Profiles

Figure 5 shows the locations of the Alternative 7 helipads relative to the surrounding community. Helipad Location 7A would be on the roof of the northernmost tower on the west side of the campus, approximately 400 ft west of the existing helipad and at an elevation of 202 ft MSL (labeled H7A in the figure). Helipad Location 7B would be on the roof of the center tower, approximately 440 ft southwest of the existing helipad and at an elevation of 182 ft MSL (labeled HA7B in the figure) (Blakeslee 2008C).

Under Alternative 7, the CHRMC property would be expanded such that Receptors R1 and R2 would be contained within CHRMC property. Therefore, those two receptors are not shown in Figure 5 and are not analyzed.

Figure 5 also shows the typical flight tracks to/from each helipad. Just off the CHRMC property, the Alternative 7 tracks would be shifted westward from the existing condition flight tracks shown in Figure 1, but their final headings would be the same. Thus, their utilization would be identical to the existing condition. See Section 3.2 for further discussion of the flight track utilization percentages.

Departure and arrival flight profiles were transferred from the existing flight tracks to the flight tracks for each Alternative 7 helipad, and adjusted to accommodate the new helipad height while using the same cruise altitude. Each flight profile was checked to ensure that the aircraft would clear the rooftop elevator structures between the bed towers. Appendix B contains the modeled NOISEMAP flight profiles for each flight track.

Figure 5.
Modeled Flight Tracks for
Alternative 7A and Alternative 7B
Helipad Locations

7.3 Alternative 7 Noise Exposure

Table 12 lists the noise exposure values for the modeled receptors for the Alternative 7A helipad. Exposure calculations were not performed for receptors R1 and R2 because they would be on CHRMC property under Alternative 7. Among the 10 analyzed receptors, DNLs would range from 37 dBA to 61 dBA, L_{max} would range from 75 dBA to 87 dBA, and SELs would range from 89 dBA to 98 dBA. Receptor R7 at 4200 NE 50th Street would experience the highest DNLs (46 dBA for an average day and 61 dBA for the busiest day) and the highest L_{max} (87 dBA). As indicated by the "Max SEL Track" column, all of the maximum SEL events are due to arrival flights because the Augusta A109 helicopter is up to 4 dB louder on approach power than departure power.

The increase in DNL or SEL relative to the existing condition would be 2 dB or less at all 10 receptors. Due to the decreased building shielding, the increase in L_{max} would be between 1 and 4 dB at receptors R3 through R5, R9, R10, and R12. This increase is greatest for R3 and R4 which experience the most building shielding of the receptors in the existing condition. L_{max} would decrease by 2 to 5 dB at receptors R11 and R6 through R8. Because the proposed helipad would be approximately 70 ft higher than the existing pad, aircraft that overfly receptors would do so at a higher altitude, decreasing their noise exposure. In addition, the westward shift of the helipad would shift the flight tracks farther away from R6, R7, and R11. If the helistop location were not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition.

Table 12 - Noise Exposure from Medivac Operations at Alternative 7A Helipad

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R2	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R3	4323 NE 45th St.	37	52	77	90	A7AA01	1	0	4	1
R4	4546 45th Ave. NE	38	53	77	90	A7AA04	0	-1	4	-2
R5	4554 45th Ave. NE	38	53	77	91	A7AA04	0	-1	1	-1
R6	4702 45th Ave. NE	42	57	84	96	A7AA04	-3	-4	-5	-5
R7	4200 NE 50th St.	46	61	87	98	A7AA03	-1	-2	-2	-4
R8	4545 Sand Point Way	41	57	85	97	A7AA01	0	0	-2	-1
R9	4412 43rd Ave. NE	37	52	77	90	A7AA01	2	0	2	0
R10	4415 43rd Ave. NE	38	53	79	92	A7AA01	2	1	2	1
R11*	4720-4724 44th Ave. NE	43	58	86	97	A7AA04	-3	-4	-4	-4
R12**	4530 45th Ave. NE	37	52	75	89	A7AA04	1	-1	3	-1

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
*** R1 and R2 would not be offsite noise-sensitive receptors under Alternative 7
† AD = Average Day is 77 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

Table 13 lists the noise exposure values for the modeled receptors for the Alternative 7B helipad. Exposure calculations were not performed for receptors R1 and R2 because they would be on CHRMC property under Alternative 7. Among the 10 analyzed receptors, DNLs would range from 37 dBA to 60 dBA, L_{max} would range from 75 dBA to 90 dBA, and SELs would range from 90 dBA to 100 dBA. Receptor R7 at 4200 NE 50th Street and receptor R11 at 4720-4724 44th St. NE would experience the highest DNLs (45 dBA for an average day and 60 dBA for the busiest day). Receptor R11 would experience the highest L_{max} (90 dBA). As indicated by the "Max SEL Track" column, all of the maximum SELs would be due to arrival flights.

The increase in DNL or SEL relative to the existing condition would be 2 dB or less at 8 of the 10 receptors, and the average day DNL would increase by 3 dB at Receptors R9 and R10. Due to the decreased building shielding, the increase in L_{max} would be between 1 and 6 dB at receptors R3 through R5, R9, R10, and R12. This increase is greatest for R3, which experiences the most building shielding of the receptors in the existing condition. L_{max} would stay the same at receptor R11, and would decrease by up to 2 dB at receptors R6 through R8. Because the proposed helipad would be approximately 50 ft higher than the existing pad, aircraft that overfly receptors would do so at a higher altitude, decreasing their noise exposure. In addition, the westward shift of the helipad would shift the flight tracks farther away from R6, R7, and R11. If the helistop location were not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition.

Table 13 - Noise Exposure from Medivac Operations at Alternative 7B Helipad

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R2	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R3	4323 NE 45th St.	38	53	75	90	A7BA04	2	1	2	1
R4	4546 45th Ave. NE	39	54	79	92	A7BA04	1	0	6	0
R5	4554 45th Ave. NE	39	54	80	93	A7BA04	1	0	4	1
R6	4702 45th Ave. NE	44	59	88	98	A7BA04	-1	-2	-1	-3
R7	4200 NE 50th St.	45	60	87	98	A7BA03	-2	-3	-2	-4
R8	4545 Sand Point Way	42	57	85	97	A7BA01	1	0	-2	-1
R9	4412 43rd Ave. NE	38	53	76	90	A7BA01	3	1	1	0
R10	4415 43rd Ave. NE	39	54	78	91	A7BA01	3	2	1	0
R11*	4720-4724 44th Ave. NE	45	60	90	100	A7BA04	-1	-2	0	-1
R12**	4530 45th Ave. NE	37	53	75	90	A7BA04	1	0	3	0

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
*** R1 and R2 would not be offsite noise-sensitive receptors under Alternative 7
† AD = Average Day is 77 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

8.0 Revised Alternative 7 Helipad Locations and Noise Exposure

There are two possible locations for the medivac helipad under Revised Alternative 7 – Helipad Location 7RA and Helipad Location 7RB. For brevity, these configurations are referred to as Alternative 7RA and Alternative 7RB. Both locations are analyzed in this report, but only one would be constructed if Revised Alternative 7 were selected. The building configuration modeled for Alternative 7RA is the same as for 7RB.

Section 8.1 discusses flight operations for Revised Alternative 7. Section 8.2 discusses the two helipad locations, flight track utilization and flight profiles. Section 8.3 presents the resultant noise exposure due to aircraft operations at each helipad.

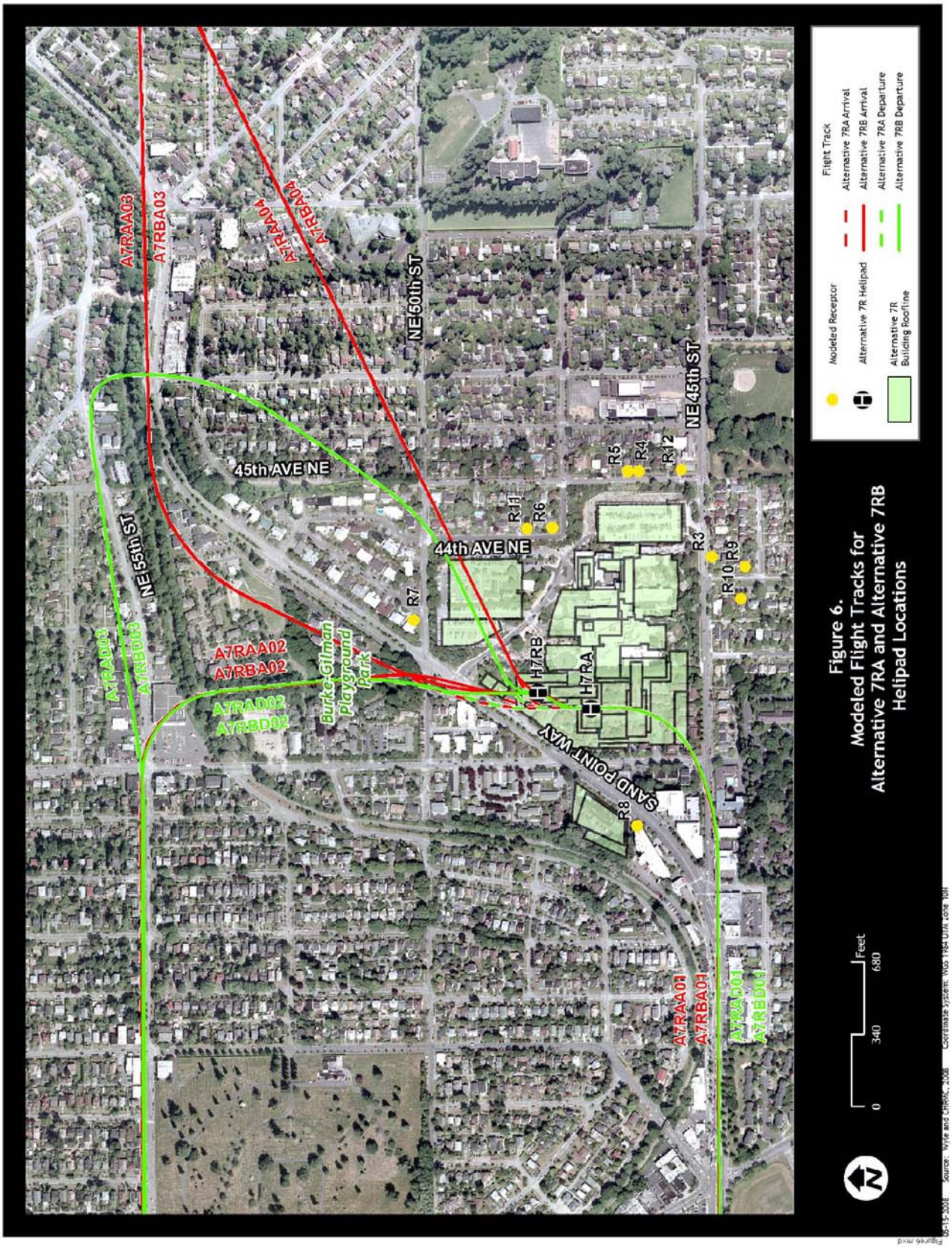
8.1 Revised Alternative 7 Flight Operations

Flight operations under Revised Alternative 7 would have the same tempo and temporal distribution as under Alternative 3 and Alternative 6. The operations analyzed for Alternative 7RA are the same as for Alternative 7RB. CHRMC does not expect an increase in *busy day* flight tempo relative to the existing condition, but an increase in *average* tempo is expected by the time either Revised Alternative 7 helipad would be completed (CHRMC, 2007). Table 14 shows the two operational scenarios modeled for each helipad location. The Average Day scenario is based on a projected 77 CHRMC medivac sorties per year, with 25 percent occurring during the nighttime period. Average daily flight operations were derived from annual sorties in the same manner as described in Section 3.1. As with the existing helipad, the Revised Alternative 7 helipads' Busiest Day scenarios are based on 4 sorties per day, with half occurring during the nighttime period (Blakeslee 2008B).

Table 14 – Medivac Flight Operations Modeled for Each Revised Alternative 7 Helipad Location

Scenario	Number of Sorties	Operation Type	Daily Flight Operations		
			Day	Night	Total
Average Day	77/year	Departure	0.1582	0.0527	0.2109
		Arrival	0.1582	0.0527	0.2109
		Total	**0.3164**	**0.1054**	**0.4218**
Busiest Day	4/day	Departure	2	2	4
		Arrival	2	2	4
		Total	**4**	**4**	**8**

Notes: Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
One sortie is equal to two operations - one departure and one arrival.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A7RBA03
A7RAA04
A7RBA04
NE 50th ST
NE 45th ST
45th AVE NE
44th AVE NE
NE 55th ST
A7RAD03
A7RBD03
A7RAA02
A7RBA02
A7RAD02
A7RBD02
Burke-Gilman Playground Park
H7RB
H7RA
SAND POINT WAY
A7RAA01
A7RBA01
A7RAD01
A7RBD01
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
Flight Track
Modeled Receptor
Alternative 7RA Arrival
Alternative 7R Helipad
Alternative 7RB Arrival
Alternative 7RA Departure
Alternative 7R Building Rooftime
Alternative 7RB Departure
0
340
680
Feet
Figure 6.
Modeled Flight Tracks for
Alternative 7RA and Alternative 7RB
Helipad Locations

8.2 Revised Alternative 7 Helipad Locations, Flight Tracks and Flight Profiles

Figure 6 shows the locations of the Revised Alternative 7 helipads relative to the surrounding community. Helipad Location 7RA would be on the roof of the center tower approximately 450 ft southwest of the existing helipad and at an elevation of 167 ft MSL (labeled H7RA in the figure). Helipad Location 7RB would be on the roof of the northernmost tower on the west side of the campus, approximately 400 ft west of the existing helipad and at an elevation of 182 ft MSL (labeled HA7B in the figure) (Blakeslee 2008D).

Under Revised Alternative 7, the CHRMC property would be expanded such that Receptors R1 and R2 would be contained within CHRMC property. Therefore, those two receptors are not shown in Figure 6 and are not analyzed.

Figure 6 also shows the typical flight tracks to/from each helipad. Just off the CHRMC property, the Revised Alternative 7 tracks would be shifted westward from the existing condition flight tracks shown in Figure 1, but their final headings would be the same. Thus, their utilization is identical to the existing condition. See Section 3.2 for further discussion of the flight track utilization percentages.

Departure and arrival flight profiles were transferred from the existing flight tracks to the flight tracks for each revised Alternative 7 helipad, and adjusted to accommodate the new helipad height while using the same cruise altitude. Each flight profile was checked to ensure that the aircraft would clear the rooftop elevator structures between the bed towers. Appendix B contains the modeled NOISEMAP flight profiles for each flight track.

8.3 Revised Alternative 7 Noise Exposure

Table 15 lists the noise exposure values for the modeled receptors for the Alternative 7RA helipad. Exposure calculations were not performed for receptors R1 and R2 because they would be on CHRMC property under Revised Alternative 7A. Among the 10 analyzed receptors, DNLs would range from 36 dBA to 61 dBA, L_{max} would range from 75 dBA to 87 dBA, and SELs would range from 89 dBA to 98 dBA. Receptor R7 at 4200 NE 50th Street would experience the highest DNLs (46 dBA for an average day and 61 dBA for the busiest day) and the highest L_{max} (87 dBA). As indicated by the "Max SEL Track" column, all of the maximum SEL events are due to arrival flights because the Augusta A109 helicopter is up to 4 dB louder on approach power than departure power.

The increase in DNL or SEL relative to the existing condition would be 2 dB or less at all 10 receptors with many receptors experiencing a decrease. Due to the decreased building shielding, the increase in L_{max} would be up to 4 dB higher at receptors R3 through R5 and R9 and R12. L_{max} would decrease by 1 to 5 dB at receptors R6, R7, R8 and R11. R10 would experience no measurable change in L_{max}. Because the proposed helipad is approximately 40 ft higher than the existing pad, aircraft that overfly receptors would do so at a higher altitude, decreasing their noise exposure. In addition, the westward shift of the helipad would shift the flight tracks farther away from R6, R7, and R11. If the helistop location were not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition.

Table 15 - Noise Exposure from Medivac Operations at Alternative 7RA Helipad

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R2	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R3	4323 NE 45th St.	36	52	75	89	A7RA-A01	0	0	2	0
R4	4546 45th Ave. NE	38	53	77	90	A7RA-A04	0	-1	4	-2
R5	4554 45th Ave. NE	38	53	77	91	A7RA-A04	0	-1	1	-1
R6	4702 45th Ave. NE	42	57	84	96	A7RA-A04	-3	-4	-5	-5
R7	4200 NE 50th St.	46	61	87	98	A7RA-A03	-1	-2	-2	-4
R8	4545 Sand Point Way	42	58	86	97	A7RA-A01	1	1	-1	-1
R9	4412 43rd Ave. NE	37	53	76	89	A7RA-A01	2	1	1	-1
R10	4415 43rd Ave. NE	38	53	77	90	A7RA-A01	2	1	0	-1
R11*	4720-4724 44th Ave. NE	43	58	86	97	A7RA-A04	-3	-4	-4	-4
R12**	4530 45th Ave. NE	37	52	75	89	A7RA-A04	1	-1	3	-1

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
*** R1 and R2 would not be offsite noise-sensitive receptors under Revised Alternative 7
† AD = Average Day is 77 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

Table 16 lists the noise exposure values for the modeled receptors for the Revised Alternative 7B helipad. Exposure calculations were not performed for receptors R1 and R2 because they would be on CHRMC property under Revised Alternative 7B. Among the 10 analyzed receptors, DNLs would range from 37 dBA to 61 dBA, maximum sound levels (L_{max}) would range from 75 dBA to 87 dBA, and SELs would range from 89 dBA to 98 dBA. Receptor R7 at 4200 NE 50th Street would experience the highest DNLs (46 dBA for an average day and 61 dBA for the busiest day). Receptor R7 would experience the highest L_{max} (87 dBA). As indicated by the "Max SEL Track" column, all of the maximum SELs would be due to arrival flights.

The increase in DNL or SEL relative to the existing condition would be 2 dB or less at all 10 receptors with many receptor experiencing a decrease. Due to the decreased building shielding, the increase in L_{max} would be between 1 and 4 dB at 6 of the 10 receptors. This increase is greatest for R4, which experiences the most building shielding of the receptors in the existing condition. L_{max} would decrease by 2 to 5 dB at receptors R6 through R8 and R11. Because the proposed helipad is approximately 50 ft higher than the existing pad, aircraft that overfly receptors would do so at a higher altitude, decreasing their noise exposure. In addition, the westward shift of the helipad would shift the flight tracks farther away from R6, R7, and R11. If the helistop location were not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition.

Table 16 - Noise Exposure from Medivac Operations at Alternative 7RB Helipad

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R2	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R3	4323 NE 45th St.	37	52	76	90	A7RB-A01	1	0	3	1
R4	4546 45th Ave. NE	37	53	77	90	A7RB-A04	-1	-1	4	-2
R5	4554 45th Ave. NE	38	53	77	91	A7RB-A04	0	-1	1	-1
R6	4702 45th Ave. NE	42	57	84	96	A7RB-A04	-3	-4	-5	-5
R7	4200 NE 50th St.	46	61	87	98	A7RB-A03	-1	-2	-2	-4
R8	4545 Sand Point Way	42	57	86	97	A7RB-A01	1	0	-1	-1
R9	4412 43rd Ave. NE	37	52	76	90	A7RB-A01	2	0	1	0
R10	4415 43rd Ave. NE	38	53	78	91	A7RB-A01	2	1	1	0
R11*	4720-4724 44th Ave. NE	43	58	86	97	A7RB-A04	-3	-4	-4	-4
R12**	4530 45th Ave. NE	37	52	75	89	A7RB-A04	1	-1	3	-1

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
*** R1 and R2 would not be offsite noise-sensitive receptors under Revised Alternative 7
† AD = Average Day is 77 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

9.0 Alternative 8 Helipad Locations and Noise Exposure

There are two possible locations for the medivac helipad under Alternative 8 – Helipad Location 8A and Helipad Location 8B. For brevity, these configurations are referred to as Alternative 8A and Alternative 8B. Both locations are analyzed in this report, but only one would be constructed if Alternative 8 were selected. The building configuration modeled for Alternative 8A is the same as for 8B.

Section 9.1 discusses flight operations for Alternative 8. Section 9.2 discusses the two helipad locations, flight track utilization and flight profiles. Section 9.3 presents the resultant noise exposure due to aircraft operations at each helipad.

9.1 Alternative 8 Flight Operations

Flight operations under Alternative 8 would have the same tempo and temporal distribution as under Alternative 3 and Alternative 6. The operations analyzed for Alternative 8A are the same as for Alternative 8B. CHRMC does not expect an increase in *busy day* flight tempo relative to the existing condition, but an increase in *average* tempo is expected by the time either Alternative 8 helipad would be completed (CHRMC, 2007). Table 17 shows the two operational scenarios modeled for each helipad location. The Average Day scenario is based on a projected 77 CHRMC medivac sorties per year, with 25 percent occurring during the nighttime period. Average daily flight operations were derived from annual sorties in the same manner as described in Section 3.1. As with the existing helipad, the Alternative 8 helipads' Busiest Day scenarios are based on 4 sorties per day, with half occurring during the nighttime period (Blakeslee 2008B).

Table 17 – Medivac Flight Operations Modeled for Each Alternative 8 Helipad Location

Scenario	Number of Sorties	Operation Type	Daily Flight Operations		
			Day	Night	Total
Average Day	77/year	Departure	0.1582	0.0527	0.2109
		Arrival	0.1582	0.0527	0.2109
		Total	**0.3164**	**0.1054**	**0.4218**
Busiest Day	4/day	Departure	2	2	4
		Arrival	2	2	4
		Total	**4**	**4**	**8**

Notes: Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
One sortie is equal to two operations - one departure and one arrival.

9.2 Alternative 8 Helipad Locations, Flight Tracks and Flight Profiles

Figure 7 shows the locations of the Alternative 8 helipads relative to the surrounding community. Helipad Location 8A would be on the roof of the center tower approximately 450 ft southwest of the existing helipad and at an elevation of 167 ft MSL (labeled H8A in the figure). Helipad Location 8B would be on the roof of the northernmost tower on the west side of the campus, approximately 400 ft west of the existing helipad and at an elevation of 182 ft MSL (labeled H8B in the figure)(Blakeslee 2008D).

Figure 7.
Modeled Flight Tracks for
Alternative 8A and Alternative 8B
Helipad Locations

Under Alternative 8, the CHRMC property would be expanded such that Receptors R1 and R2 would be contained within CHRMC property. Therefore, those two receptors are not shown in Figure 7 and are not analyzed.

Figure 7 also shows the typical flight tracks to/from each helipad. Just off the CHRMC property, the Alternative 8 tracks would be shifted westward from the existing condition flight tracks shown in Figure 1, but their final headings would be the same. Thus, their utilization is identical to the existing condition. See Section 3.2 for further discussion of the flight track utilization percentages.

Departure and arrival flight profiles were transferred from the existing flight tracks to the flight tracks for each Alternative 7 helipad, and adjusted to accommodate the new helipad height while using the same cruise altitude. Each flight profile was checked to ensure that the aircraft would clear the rooftop elevator structures between the bed towers. Appendix B contains the modeled NOISEMAP flight profiles for each flight track.

9.3 Alternative 8 Noise Exposure

Table 18 lists the noise exposure values for the modeled receptors for the Alternative 8A helipad. Exposure calculations were not performed for receptors R1 and R2 because they would be on CHRMC property under Alternative 8A. Among the 10 analyzed receptors, DNLs would range from 37 dBA to 61 dBA, L_{max} would range from 75 dBA to 87 dBA, and SELs would range from 89 dBA to 98 dBA. Receptor R7 at 4200 NE 50th Street would experience the highest DNLs (46 dBA for an average day and 61 dBA for the busiest day) and the highest L_{max} (87 dBA). As indicated by the "Max SEL Track" column, all of the maximum SEL events are due to arrival flights because the Augusta A109 helicopter is up to 4 dB louder on approach power than departure power.

The increase in DNL or SEL relative to the existing condition would be 2 dB or less at all 10 receptors with many receptors experiencing a decrease. Due to the decreased building shielding, the increase in L_{max} would be up to 4 dB at receptors R3, R4, R5, R9 and R12. L_{max} would decrease by 1 to 5 dB at receptors R6 through R8 and R11. R10 would experience no measurable change in $L_{max.}$ Because the proposed helipad is approximately 40 ft higher than the existing pad, aircraft that overfly receptors would do so at a higher altitude, decreasing their noise exposure. In addition, the westward shift of the helipad would shift the flight tracks farther away from R6, R7, and R11. If the helistop location were not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition.

Table 18 - Noise Exposure from Medivac Operations at Alternative 8A Helipad

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R2	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R3	4323 NE 45th St.	37	52	76	89	A8A-A01	1	0	3	0
R4	4546 45th Ave. NE	38	53	77	90	A8A-A04	0	-1	4	-2
R5	4554 45th Ave. NE	38	53	77	91	A8A-A04	0	-1	1	-1
R6	4702 45th Ave. NE	42	57	84	96	A8A-A04	-3	-4	-5	-5
R7	4200 NE 50th St.	46	61	87	98	A8A-A03	-1	-2	-2	-4
R8	4545 Sand Point Way	43	58	86	97	A8A-A01	2	1	-1	-1
R9	4412 43rd Ave. NE	37	53	76	89	A8A-A01	2	1	1	-1
R10	4415 43rd Ave. NE	38	53	77	90	A8A-A01	2	1	0	-1
R11*	4720-4724 44th Ave. NE	43	58	86	97	A8A-A04	-3	-4	-4	-4
R12**	4530 45th Ave. NE	37	52	75	89	A8A-A04	1	-1	3	-1

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
*** R1 and R2 would not be offsite noise-sensitive receptors under Alternative 8
† AD = Average Day is 77 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

Table 19 lists the noise exposure values for the modeled receptors for the Alternative 8B helipad. Exposure calculations were not performed for receptors R1 and R2 because they would be on CHRMC property under Alternative 8B. Among the 10 analyzed receptors, DNLs would range from 37 dBA to 61 dBA, L_{max} would range from 75 dBA to 87 dBA, and SELs would range from 89 dBA to 98 dBA. Receptor R7 at 4200 NE 50th Street would experience the highest DNLs (46 dBA for an average day and 61 dBA for the busiest day). Receptor R7 would experience the highest L_{max} (87 dBA). As indicated by the "Max SEL Track" column, all of the maximum SELs would be due to arrival flights.

The increase in DNL or SEL relative to the existing condition would be 2 dB or less at all 10 receptors with many receptors experiencing a decrease. Due to the decreased building shielding, the increase in L_{max} would be between 1 and 4 dB at 6 of the 10 receptors. This increase is greatest for R4, which experiences the most building shielding of the receptors in the existing condition. L_{max} would decrease by 2 to 5 dB at receptors R6 through R8 and R11. Because the proposed helipad is approximately 50 ft higher than the existing pad, aircraft that overfly receptors would do so at a higher altitude, decreasing their noise exposure. In addition, the westward shift of the helipad would shift the flight tracks farther away from R6, R7, and R11. If the helistop location were not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition.

Table 19 - Noise Exposure from Medivac Operations at Alternative 8B Helipad

Receptor		Noise Level (dBA)				Max SEL Track	Change from Existing (dBA)			
ID	Address	AD† DNL	BD‡ DNL	L_{max}	Max SEL		AD† DNL	BD‡ DNL	L_{max}	Max SEL
R1	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R2	n/a***	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
R3	4323 NE 45th St.	37	52	76	90	A8B-A01	1	0	3	1
R4	4546 45th Ave. NE	38	53	77	90	A8B-A04	0	-1	4	-2
R5	4554 45th Ave. NE	38	53	77	91	A8B-A04	0	-1	1	-1
R6	4702 45th Ave. NE	42	57	84	96	A8B-A04	-3	-4	-5	-5
R7	4200 NE 50th St.	46	61	87	98	A8B-A03	-1	-2	-2	-4
R8	4545 Sand Point Way	42	57	86	97	A8B-A01	1	0	-1	-1
R9	4412 43rd Ave. NE	37	52	76	90	A8B-A01	2	0	1	0
R10	4415 43rd Ave. NE	38	53	78	91	A8B-A01	2	1	1	0
R11*	4720-4724 44th Ave. NE	43	58	86	97	A8B-A04	-3	-4	-4	-4
R12**	4530 45th Ave. NE	37	52	75	89	A8B-A04	1	-1	3	-1

Notes: * Receptor Location 1 from 1991 FEIS
** Receptor Location 2 from 1991 FEIS
*** R1 and R2 would not be offsite noise-sensitive receptors under Alternative 8
† AD = Average Day is 77 sorties per year, 75% during daytime, 25% during nighttime
‡ BD = Busiest Day is 2 daytime sorties and 2 nighttime sorties per day
Daytime is from 7:00 am until 10:00 pm, nighttime is from 10:00 pm until 7:00 am.
All receptor elevations are assumed to be 5 ft above ground level.
DNL = Day-Night Average Sound Level; Lmax = Maximum Sound Level;
SEL = Sound Exposure Level; dBA = A-weighted decibels re 20 µPa

10.0 Conclusion

Average Day DNL values due to medivac operations at the existing helipad are currently less than 50 dBA at all modeled receptors. None of the modeled receptors experience Busiest Day DNL greater than 63 dBA. Busiest day operations total 8 per day, with half of those during the DNL nighttime (10pm to 7am) period. Five of the 12 receptors currently experience a Busiest Day DNL between 60 and 63 dBA. The modeled receptors currently experience an L_{max} between 72 and 90 dBA and an SEL between 89 and 102 dBA. L_{max} occurs only instantaneously during any given helicopter flight.

Relative to existing noise exposure, computer modeling indicated that Average Day DNL would cause at worst an increase of 3 dB at modeled receptors for all helipad locations. Average Day DNL would increase by approximately 1 dB solely due to the increase in operations under any proposed alternative. Busiest Day DNL would increase by 1 dB or less for all helipad locations except Temporary Helipad 2, which would cause increases up to 3 dB at modeled receptors. Relative to existing conditions, L_{max} would change by +10 to -8 dB and maximum SEL would change by +3 to -10 dB for all helipad locations and modeled receptors. These results are summarized in Table 20 below.

Table 20: Summary of Noise Exposure Changes from Medivac Operations Relative to Baseline Conditions

Alternative Condition	Helipad Altitude (ft MSL)	Annual Average Daily DNL Changes					Busiest Day DNL Changes				
		Increase		Decrease		No Change	Increase		Decrease		No Change
		Max (dB)	# Sites Affected	Max (dB)	# Sites Affected		Max (dB)	# Sites Affected	Max (dB)	# Sites Affected	
Temporary Helipad 1	150	1	4	1	3	5	1	4	1	3	5
Temporary Helipad 2	105	3	5	3	4	3	3	3	3	7	2
Alt 3	270	2	8	1	1	3	-	-	2	4	8
Alt 6	266	1	8	1	1	3	-	-	2	6	6
Alt 7A	201	2	4	3	3	3	1	1	4	6	3
Alt 7B	182	1	1	4	6	3	-	-	5	10	-
Alt 7RA	167	2	4	3	3	3	1	3	4	6	1
Alt 7RB	182	2	5	3	4	1	1	1	4	6	3
Alt 8A	167	2	5	3	3	2	1	3	4	6	1
Alt 8B	182	2	5	3	3	2	1	1	4	6	3

Table 20: Summary of Noise Exposure Changes from Medivac Operations Relative to Baseline Conditions (concluded)

Alternative Condition	Helipad Altitude (ft MSL)	Lmax Changes					SEL Changes				
		Increase		Decrease		No Change	Increase		Decrease		No Change
		Max (dB)	# Sites Affected	Max (dB)	# Sites Affected		Max (dB)	# Sites Affected	Max (dB)	# Sites Affected	
Temporary Helipad 1	150	5	10	1	1	1	2	3	2	5	4
Temporary Helipad 2	105	10	6	8	4	2	3	2	5	5	5
Alt 3	270	5	5	7	6	1	2	1	2	3	8
Alt 6	266	4	5	7	5	2	2	1	2	4	7
Alt 7A	201	4	6	5	4	-	1	2	5	7	1
Alt 7B	182	6	6	2	3	1	-	-	10	10	-
Alt 7RA	167	4	5	5	4	1	-	-	5	9	1
Alt 7RB	182	4	6	5	4	-	1	1	5	7	2
Alt 8A	167	4	5	5	4	1	-	-	5	9	1
Alt 8B	182	4	6	5	4	-	1	1	5	7	2

Note: *Relative to the existing condition with the helipad at an elevation of 130 ft MSL

Based on noise exposure Alternative 7B would be the best choice with only a 1 dB increase at 1 receptor for Average Day DNL and a decrease of up to 4 dB at 6 receptors. If the Helistop location was not moved (and no construction occurred), average day DNL would increase by 1 dB solely due to the increase in average daily flight operations relative to the existing condition. Under Alternative 7B there would be a decrease in Busiest Day DNL of up to 5 dB at all receptors. Alternative 7B would not be as favorable with regard to L_{max} as it would cause an increase up to 6 dB at 6 receptors and decreases of up to 2 dB at 4 receptors. Changes in SEL are very favorable under Alternative 7B, causing a decrease of up to 10 dB at all 10 receptors.

Alternatives 7RA, 7RB, 8A, and 8B are similar with one another varying by 1 dB or less at all receptors. These four alternatives would cause up to a 2 dB increase at up to 5 receptors in Annual Average Daily DNL and as much as a 3 dB decrease at up to 4 receptors. The Busiest Day DNL would increase by only 1 dB at up to three receptors and decrease up to 4 dB at 6 receptors. The L_{max} would increase by up to 4 dB at 6 receptors and decrease up to 5 dB at 4 receptors. Under these Alternatives the SEL would increase at most 1 dB at 1 receptor and decrease up to 5 dB at 7 to 9 receptors. The final four Alternatives are nearly as good as Alternative 7B in terms of minimizing sound levels at the receptor locations.

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APPENDIX A

Discussion of Noise and Its Effect on the Environment

APPENDIX A
Discussion of Noise and Its Effect on the Environment

A.1 Basics of Sound

Noise is unwanted sound. Sound is all around us; sound becomes noise when it interferes with normal activities, such as sleep or conversation.

Sound is a physical phenomenon consisting of minute vibrations that travel through a medium, such as air, and are sensed by the human ear. Whether that sound is interpreted as pleasant (e.g., music) or unpleasant (e.g., jackhammers) depends largely on the listener's current activity, past experience, and attitude toward the source of that sound.

The measurement and human perception of sound involves three basic physical characteristics: intensity, frequency, and duration. First, intensity is a measure of the acoustic energy of the sound vibrations and is expressed in terms of sound pressure. The greater the sound pressure, the more energy carried by the sound and the louder the perception of that sound. The second important physical characteristic of sound is frequency, which is the number of times per second the air vibrates or oscillates. Low-frequency sounds are characterized as rumbles or roars, while high-frequency sounds are typified by sirens or screeches. The third important characteristic of sound is duration or the length of time the sound can be detected.

The loudest sounds that can be detected comfortably by the human ear have intensities that are a trillion times higher than those of sounds that can barely be detected. Because of this vast range, using a linear scale to represent the intensity of sound becomes very unwieldy. As a result, a logarithmic unit known as the decibel (abbreviated dB) is used to represent the intensity of a sound. Such a representation is called a sound level. A sound level of 0 dB is approximately the threshold of human hearing and is barely audible under extremely quiet listening conditions. Normal speech has a sound level of approximately 60 dB; sound levels above 120 dB begin to be felt inside the human ear as discomfort. Sound levels between 130 to 140 dB are felt as pain (Berglund and Lindvall 1995).

Because of the logarithmic nature of the decibel unit, sound levels cannot be arithmetically added or subtracted and are somewhat cumbersome to handle mathematically. However, some simple rules are useful in dealing with sound levels. First, if a sound's intensity is doubled, the sound level increases by 3 dB, regardless of the initial sound level. For example:

60 dB + 60 dB = 63 dB, and

80 dB + 80 dB = 83 dB.

Second, the total sound level produced by two sounds of different levels is usually only slightly more than the higher of the two. For example:

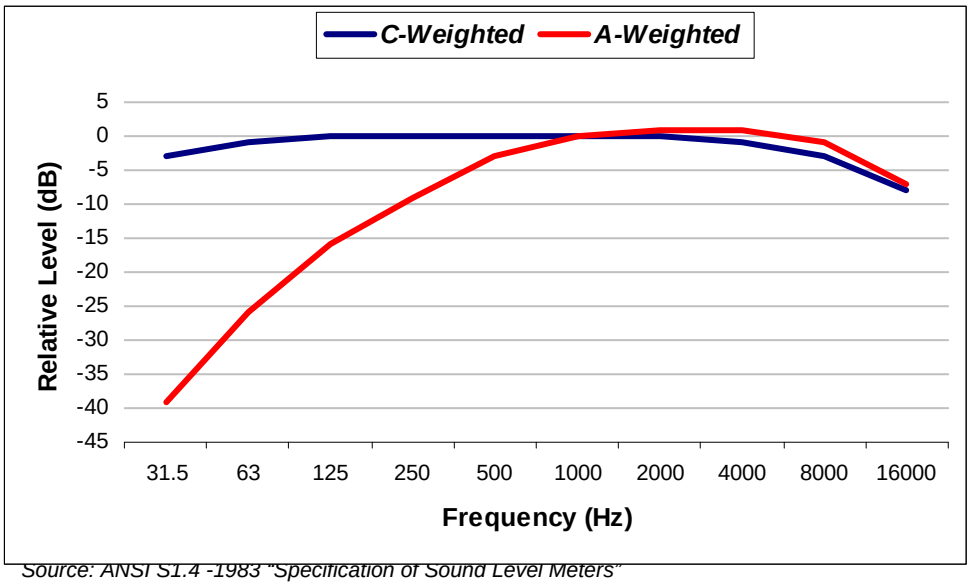
60.0 dB + 70.0 dB = 70.4 dB.

Because the addition of sound levels is different than that of ordinary numbers, such addition is often referred to as "decibel addition" or "energy addition." The latter term arises from the fact that what we are really doing when we add decibel values is first converting each decibel value to its

corresponding acoustic energy, then adding the energies using the normal rules of addition, and finally converting the total energy back to its decibel equivalent.

The minimum change in the sound level of individual events that an average human ear can detect is about 3 dB. On average, a person perceives a change in sound level of about 10 dB as a doubling (or halving) of the sound's loudness, and this relation holds true for loud and quiet sounds. A decrease in sound level of 10 dB actually represents a 90% decrease in sound intensity but only a 50% decrease in perceived loudness because of the nonlinear response of the human ear (similar to most human senses).

Sound frequency is measured in terms of cycles per second (cps), or hertz (Hz), which is the standard unit for cps. The normal human ear can detect sounds that range in frequency from about 20 Hz to about 15,000 Hz. All sounds in this wide range of frequencies, however, are not heard equally by the human ear, which is most sensitive to frequencies in the 1,000 to 4,000 Hz range. Weighting curves have been developed to correspond to the sensitivity and perception of different types of sound. A-weighting and C-weighting are the two most common weightings. A-weighting accounts for frequency dependence by adjusting the very high and very low frequencies (below approximately 500 Hz and above approximately 10,000 Hz) to approximate the human ear's lower sensitivities to those frequencies. C-weighting is nearly flat throughout the range of audible frequencies, hardly de-emphasizing the low frequency sound while approximating the human ear's sensitivity to higher intensity sounds. The two curves shown in Figure A-1 are also the most adequate to quantify environmental noises.



Source: ANSI S1.4 -1983 "Specification of Sound Level Meters"

Figure A-1. Frequency Response Characteristics of A and C Weighting Networks

A.1.2 A-weighted Sound Level

Sound levels that are measured using A-weighting, called A-weighted sound levels, are often denoted by the unit dBA or dB(A) rather than dB. When the use of A-weighting is understood, the adjective "A-weighted" is often omitted and the measurements are expressed as dB. In this report (as in most environmental impact documents), dB units refer to A-weighted sound levels.

Noise potentially becomes an issue when its intensity exceeds the ambient or background sound pressures. Ambient background noise in metropolitan, urbanized areas typically varies from 60 to 70 dB and can be as high as 80 dB or greater; quiet suburban neighborhoods experience ambient noise levels of approximately 45-50 dB (U.S. Environmental Protection Agency 1978).

Figure A-2 is a chart of A-weighted sound levels from typical sounds. Some noise sources (air conditioner, vacuum cleaner) are continuous sounds which levels are constant for some time. Some (automobile, heavy truck) are the maximum sound during a vehicle pass-by. Some (urban daytime, urban nighttime) are averages over extended periods. A variety of noise metrics have been developed to describe noise over different time periods, as discussed below.

Aircraft noise consists of two major types of sound events: aircraft takeoffs and landings, and engine maintenance operations. The former can be described as intermittent sounds and the latter as continuous. Noise levels from flight operations exceeding background noise typically occur beneath main approach and departure corridors, in local air traffic patterns around the airfield, and in areas immediately adjacent to parking ramps and aircraft staging areas. As aircraft in flight gain altitude, their noise contribution drops to lower levels, often becoming indistinguishable from the background.

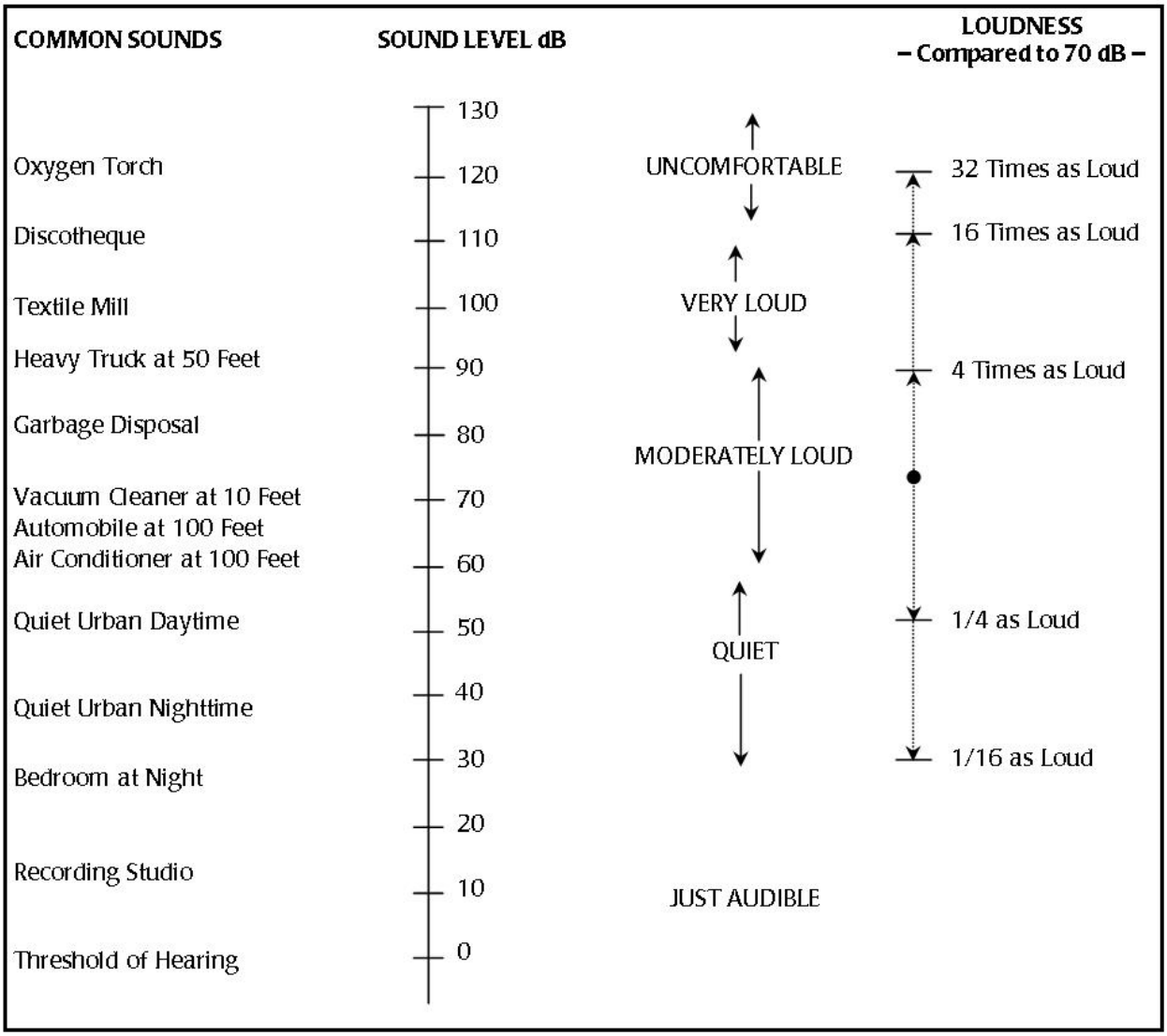
C-weighted Sound Level

Sound levels measured using a C-weighting are most appropriately called C-weighted sound levels (and denoted dBC). C-weighting is nearly flat throughout the audible frequency range, hardly de-emphasizing the low frequency. This weighting scale is generally used to describe impulsive sounds. Sounds that are characterized as impulsive generally contain low frequencies. Impulsive sounds may induce secondary effects, such as shaking of a structure, rattling of windows, inducing vibrations. These secondary effects can cause additional annoyance and complaints.

The following definitions in the American National Standard Institute (ANSI) Report S12.9, Part 4 provide general concepts helpful in understanding impulsive sounds (American National Standards Institute 1996).

Impulsive Sound: Sound characterized by brief excursions of sound pressure (acoustic impulses) that significantly exceeds the ambient environmental sound pressure. The duration of a single impulsive sound is usually less than one second (American National Standards Institute 1996).

Highly Impulsive Sound: Sound from one of the following enumerated categories of sound sources: small-arms gunfire, metal hammering, wood hammering, drop hammering, pile driving, drop forging, pneumatic hammering, pavement breaking, metal impacts during rail-yard shunting operation, and riveting.



Source: *Handbook of Noise Control*, C.M. Harris, Editor, McGraw-Hill Book Co., 1979, and FICAN 1992.

Figure A-2. Typical A-weighted Sound Levels of Common Sounds

High-energy Impulsive Sound: Sound from one of the following enumerated categories of sound sources: quarry and mining explosions, sonic booms, demolition and industrial processes that use high explosives, military ordnance (e.g., armor, artillery and mortar fire, and bombs), explosive ignition of rockets and missiles, explosive industrial circuit breakers, and any other explosive source where the equivalent mass of dynamite exceeds 25 grams.

A.2 Noise Metrics

As used in environmental noise analyses, a metric refers to the unit or quantity that quantitatively measures the effect of noise on the environment. To quantify these effects, the Department of Defense and the Federal Aviation Administration use three noise-measuring techniques, or metrics: first, a measure of the highest sound level occurring during an individual aircraft overflight (single event); second, a combination of the maximum level of that single event with its duration; and third, a description of the noise environment based on the cumulative flight and engine maintenance activity. Single noise events can be described with Sound Exposure Level or Maximum Sound Level. Another measure of instantaneous level is the Peak Sound Pressure Level. The cumulative energy noise metric used is the Day/Night Average Sound Level. Metrics related to DNL include the Onset-Rate Adjusted Day/Night Average Sound Level, and the Equivalent Sound Level. In the state of California, it is mandated that average noise be described in terms of Community Noise Equivalent Level (State of California 1990). CNEL represents the Day/Evening/Night average noise exposure, calculated over a 24-hour period. Metrics and their uses are described below.

A.2.1 Maximum Sound Level (L_{max})

The highest A-weighted integrated sound level measured during a single event in which the sound level changes value with time (e.g., an aircraft overflight) is called the maximum A-weighted sound level or maximum sound level.

During an aircraft overflight, the noise level starts at the ambient or background noise level, rises to the maximum level as the aircraft flies closest to the observer, and returns to the background level as the aircraft recedes into the distance. The maximum sound level indicates the maximum sound level occurring for a fraction of a second. For aircraft noise, the "fraction of a second" over which the maximum level is defined is generally 1/8 second, and is denoted as "fast" response (American National Standards Institute 1988). Slowly varying or steady sounds are generally measured over a period of one second, denoted "slow" response. The maximum sound level is important in judging the interference caused by a noise event with conversation, TV or radio listening, sleep, or other common activities. Although it provides some measure of the intrusiveness of the event, it does not completely describe the total event, because it does not include the period of time that the sound is heard.

A.2.2 Peak Sound Pressure Level (L_{pk})

The peak sound pressure level, is the highest instantaneous level obtained by a sound level measurement device. The peak sound pressure level is typically measured using a 20 microseconds or faster sampling rate, and is typically based on unweighted or linear response of the meter.

A.2.3 Sound Exposure Level (SEL)

Sound exposure level is a composite metric that represents both the intensity of a sound and its duration. Individual time-varying noise events (e.g., aircraft overflights) have two main characteristics: a sound level that changes throughout the event and a period of time during which the event is heard. SEL provides a measure of the net impact of the entire acoustic event, but it does not directly represent the sound level heard at any given time. During an aircraft flyover, SEL would

include both the maximum noise level and the lower noise levels produced during onset and recess periods of the overflight.

SEL is a logarithmic measure of the total acoustic energy transmitted to the listener during the event. Mathematically, it represents the sound level of a constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For sound from aircraft overflights, which typically lasts more than one second, the SEL is usually greater than the L_{max} because an individual overflight takes seconds and the maximum sound level (L_{max}) occurs instantaneously. SEL represents the best metric to compare noise levels from overflights.

A.2.4 Day-Night Average Sound Level (DNL) and Community Noise Equivalent Level (CNEL)

Day-Night Average Sound Level and Community Noise Equivalent Level are composite metrics that account for SEL of all noise events in a 24-hour period. In order to account for increased human sensitivity to noise at night, a 10 dB penalty is applied to nighttime events (10:00 p.m. to 7:00 a.m. time period). A variant of the DNL, the CNEL level includes a 5-decibel penalty on noise during the 7:00 p.m. to 10:00 p.m. time period, and a 10-decibel penalty on noise during the 10:00 p.m. to 7:00 a.m. time period.

The above-described metrics are average quantities, mathematically representing the continuous A-weighted or C-weighted sound level that would be present if all of the variations in sound level that occur over a 24-hour period were smoothed out so as to contain the same total sound energy. These composite metrics account for the maximum noise levels, the duration of the events (sorties or operations), and the number of events that occur over a 24-hour period. Like SEL, neither DNL nor CNEL represent the sound level heard at any particular time, but quantifies the total sound energy received. While it is normalized as an average, it represents all of the sound energy, and is therefore a cumulative measure.

The penalties added to both the DNL and CNEL metrics account for the added intrusiveness of sounds that occur during normal sleeping hours, both because of the increased sensitivity to noise during those hours and because ambient sound levels during nighttime are typically about 10 dB lower than during daytime hours.

The inclusion of daytime and nighttime periods in the computation of the DNL and CNEL reflects their basic 24-hour definition. It can, however, be applied over periods of multiple days. For application to civil airports, where operations are consistent from day to day, DNL and CNEL are usually applied as an annual average. For some military airbases, where operations are not necessarily consistent from day to day, a common practice is to compute a 24-hour DNL or CNEL based on an average busy day, so that the calculated noise is not diluted by periods of low activity.

Although DNL and CNEL provide a single measure of overall noise impact, they do not provide specific information on the number of noise events or the individual sound levels that occur during the 24-hour day. For example, a daily average sound level of 65 dB could result from a very few noisy events or a large number of quieter events.

Daily average sound levels are typically used for the evaluation of community noise effects (i.e., long-term annoyance), and particularly aircraft noise effects. In general, scientific studies and social surveys have found a high correlation between the percentages of groups of people highly annoyed and the level of average noise exposure measured in DNL (U.S. Environmental Protection Agency 1978 and Schultz 1978). The correlation from Schultz's original 1978 study is shown in Figure A-3. It represents the results of a large number of social surveys relating community responses to various types of noises, measured in day-night average sound level.

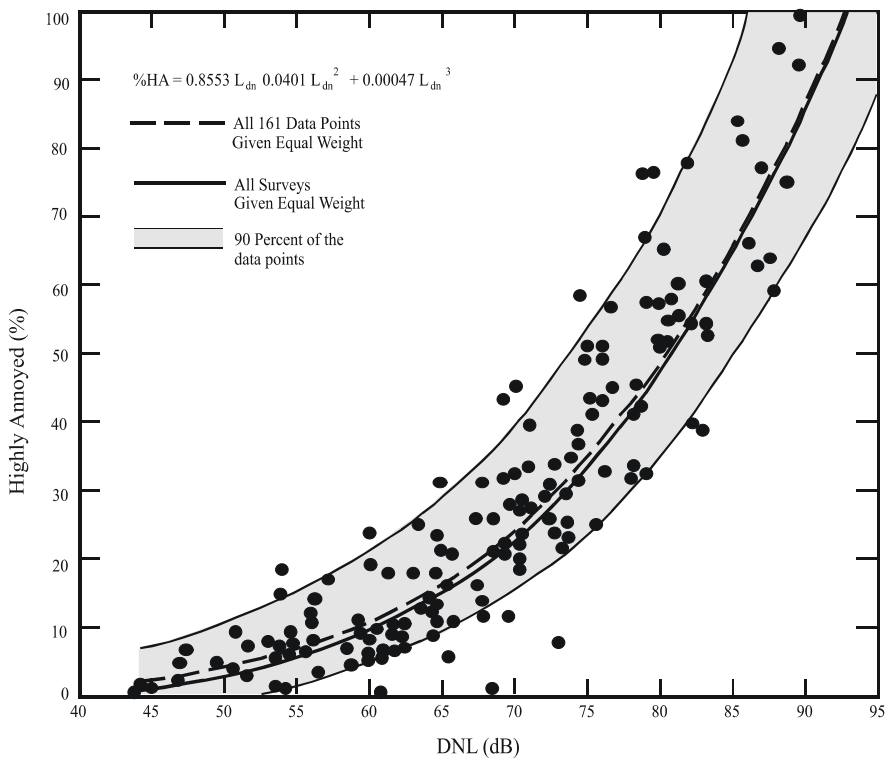


Figure A-3. Community Surveys of Noise Annoyance

A more recent study has reaffirmed this relationship (Fidell, et al. 1991). Figure A-4 (Federal Interagency Committee On Noise 1992) shows an updated form of the curve fit (Finegold, et al. 1994) in comparison with the original. The updated fit, which does not differ substantially from the original, is the current preferred form. In general, correlation coefficients of 0.85 to 0.95 are found between the percentages of groups of people highly annoyed and the level of average noise exposure. The correlation coefficients for the annoyance of individuals are relatively low, however, on the order of 0.5 or less. This is not surprising, considering the varying personal factors that influence the manner in which individuals react to noise. However, for the evaluation of community noise impacts, the scientific community has endorsed the use of DNL (American National Standards Institute 1980; American National Standards Institute 1988; U.S. Environmental Protection Agency 1974; Federal Interagency Committee On Urban Noise 1980 and Federal Interagency Committee On Noise 1992).

The use of DNL (CNEL in California) has been criticized as not accurately representing community annoyance and land-use compatibility with aircraft noise. Much of that criticism stems from a lack of understanding of the basis for the measurement or calculation of DNL. One frequent criticism is based

on the inherent feeling that people react more to single noise events and not as much to "meaningless" time-average sound levels.

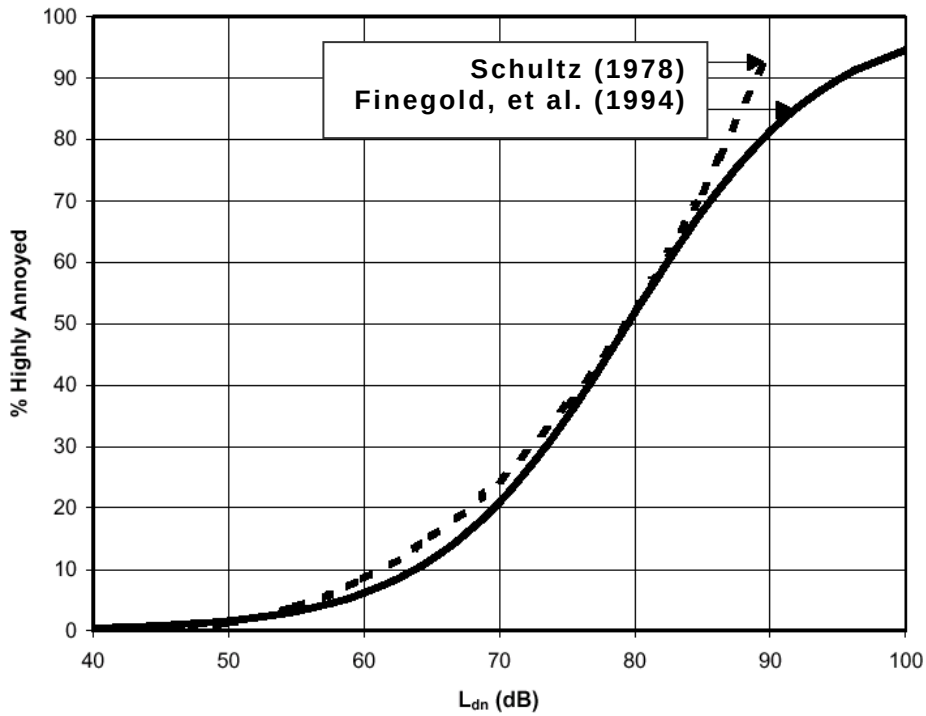


Figure A-4. Response of Communities to Noise; Comparison of Original (Schultz, 1978) and Current (Finegold, et al. 1994) Curve Fits

In fact, a time-average noise metric, such as DNL and CNEL, takes into account both the noise levels of all individual events that occur during a 24-hour period and the number of times those events occur. The logarithmic nature of the decibel unit causes the noise levels of the loudest events to control the 24-hour average.

As a simple example of this characteristic, consider a case in which only one aircraft overflight occurs during the daytime over a 24-hour period, creating a sound level of 100 dB for 30 seconds. During the remaining 23 hours, 59 minutes, and 30 seconds of the day, the ambient sound level is 50 dB. The day-night average sound level for this 24-hour period is 65.9 dB. Assume, as a second example, that 10 such 30-second overflights occur during daytime hours during the next 24-hour period, with the same ambient sound level of 50 dB during the remaining 23 hours and 55 minutes of the day. The day-night average sound level for this 24-hour period is 75.5 dB. Clearly, the averaging of noise over a 24-hour period does not ignore the louder single events and tends to emphasize both the sound levels and number of those events.

A.2.5 Equivalent Sound Level (L_{eq})

Another cumulative noise metric that is useful in describing noise is the equivalent sound level. L_{eq} is calculated to determine the steady-state noise level over a specified time period. The L_{eq} metric can provide a more accurate quantification of noise exposure for a specific period, particularly for daytime periods when the nighttime penalty under the DNL metric is inappropriate.

Just as SEL has proven to be a good measure of the noise impact of a single event, L_{eq} has been established to be a good measure of the impact of a series of events during a given time period. Also, while L_{eq} is defined as an average, it is effectively a sum over that time period and is, thus, a measure of the cumulative impact of noise. For example, the sum of all noise-generating events during the period of 7 a.m. to 4 p.m. could provide the relative impact of noise generating events for a school day.

A.2.6 Rate Adjusted Day-Night Average Sound Level (L_{dnr})

Military aircraft flying on Military Training Routes (MTRs) and in Restricted Areas/Ranges generate a noise environment that is somewhat different from that associated with airfield operations. As opposed to patterned or continuous noise environments associated with airfields, overflights along MTRs are highly sporadic, ranging from 10 per hour to less than one per week. Individual military overflight events also differ from typical community noise events in that noise from a low-altitude, high-airspeed flyover can have a rather sudden onset, exhibiting a rate of increase in sound level (onset rate) of up to 150 dB per second.

To represent these differences, the conventional SEL metric is adjusted to account for the "surprise" effect of the sudden onset of aircraft noise events on humans with an adjustment ranging up to 11 dB above the normal Sound Exposure Level (Stusnick, et al. 1992). Onset rates between 15 to 150 dB per second require an adjustment of 0 to 11 dB, while onset rates below 15 dB per second require no adjustment. The adjusted SEL is designated as the onset-rate adjusted sound exposure level (SEL_r).

Because of the sporadic, often seasonal, occurrences of aircraft overflights along MTRs and in Restricted Areas/Ranges, the number of daily operations is determined from the number of flying days in the calendar month with the highest number of operations in the affected airspace or MTR. This avoids dilution of the exposure from periods of low activity, much the way that the average busy day is used around military airbases. The cumulative exposure to noise in these areas is computed by DNL over the busy month, but using SEL_r instead of SEL. This monthly average is denoted L_{dnmr}. If onset rate adjusted DNL is computed over a period other than a month, it would be designated L_{dnr} and the period must be specified. In the state of California, a variant of the L_{dnmr} includes a penalty for evening operations (7 p.m. to 10 p.m) and is denoted $CNEL_{mr}$.

A.3 Noise Effects

A.3.1 Annoyance

The primary effect of aircraft noise on exposed communities is one of long-term annoyance. Noise annoyance is defined by the EPA as any negative subjective reaction on the part of an individual or group (U.S. Environmental Protection Agency 1974). As noted in the discussion of DNL above, community annoyance is best measured by that metric.

The results of attitudinal surveys, conducted to find percentages of people who express various degrees of annoyance when exposed to different levels of DNL, are very consistent. The most useful metric for assessing people's responses to noise impacts is the percentage of the exposed population expected to be "highly annoyed." A wide variety of responses have been used to determine intrusiveness of noise and disturbances of speech, sleep, television or radio listening, and outdoor living. The concept of "percent highly annoyed" has provided the most consistent response of a

community to a particular noise environment. The response is remarkably complex, and when considered on an individual basis, widely varies for any given noise level (Federal Interagency Committee On Noise 1992).

A number of nonacoustic factors have been identified that may influence the annoyance response of an individual. Newman and Beattie (1985) divided these factors into emotional and physical variables:

Emotional Variables

- Feelings about the necessity or preventability of the noise;
- Judgment of the importance and value of the activity that is producing the noise;
- Activity at the time an individual hears the noise;
- Attitude about the environment;
- General sensitivity to noise;
- Belief about the effect of noise on health; and
- Feeling of fear associated with the noise.

Physical Variables

- Type of neighborhood;
- Time of day;
- Season;
- Predictability of noise;
- Control over the noise source; and
- Length of time an individual is exposed to a noise.

A.3.2 Speech Interference

Speech interference associated with aircraft noise is a primary cause of annoyance to individuals on the ground. The disruption of routine activities such as radio or television listening, telephone use, or family conversation gives rise to frustration and irritation. The quality of speech communication is also important in classrooms, offices, and industrial settings and can cause fatigue and vocal strain in those who attempt to communicate over the noise. Speech is an acoustic signal characterized by rapid fluctuations in sound level and frequency pattern. It is essential for optimum speech intelligibility to recognize these continually shifting sound patterns. Not only does noise diminish the ability to perceive the auditory signal, but it also reduces a listener's ability to follow the pattern of signal fluctuation. In general, interference with speech communication occurs when intrusive noise exceeds about 60 dB (Federal Interagency Committee On Noise 1992).

Indoor speech interference can be expressed as a percentage of sentence intelligibility among two people speaking in relaxed conversation approximately 3 feet apart in a typical living room or bedroom (U.S. Environmental Protection Agency 1974). The percentage of sentence intelligibility is a non-linear function of the (steady) indoor background A-weighted sound level. Such a curve-fit yields 100 percent sentence intelligibility for background levels below 57 dB and yields less than 10 percent intelligibility for background levels above 73 dB. The function is especially sensitive to changes in sound level between 65 dB and 75 dB. As an example of the sensitivity, a 1 dB increase in background sound level from 70 dB to 71 dB yields a 14 percent decrease in sentence intelligibility. The sensitivity of speech interference to noise at 65 dB and above is consistent with the criterion of DNL 65 dB

generally taken from the Schultz curve. This is consistent with the observation that speech interference is the primary cause of annoyance.

A.3.3 Sleep Interference

Sleep interference is another source of annoyance and potential health concern associated with aircraft noise. Because of the intermittent nature and content of aircraft noise, it is more disturbing than continuous noise of equal energy. Given that quality sleep is requisite for good health, repeated occurrences of sleep interference could have an effect on overall health.

Sleep interference may be measured in either of two ways. "Arousal" represents actual awakening from sleep, while a change in "sleep stage" represents a shift from one of four sleep stages to another stage of lighter sleep without actual awakening. In general, arousal requires a somewhat higher noise level than does a change in sleep stage.

Sleep is not a continuous, uniform condition but a complex series of states through which the brain progresses in a cyclical pattern. Arousal from sleep is a function of a number of factors that include age, sex, sleep stage, noise level, frequency of noise occurrences, noise quality, and pre-sleep activity. Because individuals differ in their physiology, behavior, habitation, and ability to adapt to noise, few studies have attempted to establish noise criterion levels for sleep disturbance.

Lukas (1978) concluded the following with regard to human sleep response to noise:

- Children 5 to 8 years of age are generally unaffected by noise during sleep.
- Older people are more sensitive to sleep disturbance than younger people.
- Women are more sensitive to noise than men, in general.
- There is a wide variation in the sensitivity of individuals to noise even within the same age group.
- Sleep arousal is directly proportional to the sound intensity of aircraft flyover. While there have been several studies conducted to assess the effect of aircraft noise on sleep, none have produced quantitative dose-response relationships in terms of noise exposure level, DNL, and sleep disturbance. Noise-sleep disturbance relationships have been developed based on single-event noise exposure.

An analysis sponsored by the U.S. Air Force summarized 21 published studies concerning the effects of noise on sleep (Pearsons, et al. 1989). The analysis concluded that a lack of reliable studies in homes, combined with large differences among the results from the various laboratory studies, did not permit development of an acceptably accurate assessment procedure. The noise events used in the laboratory studies and in contrived in-home studies were presented at much higher rates of occurrence than would normally be experienced in the home. None of the laboratory studies were of sufficiently long duration to determine any effects of habituation, such as that which would occur under normal community conditions.

A study of the effects of nighttime noise exposure on the in-home sleep of residents near one military airbase, near one civil airport, and in several households with negligible nighttime aircraft noise exposure, revealed SEL as the best noise metric predicting noise-related awakenings. It also determined that out of 930 subject nights, the average spontaneous (not noise-related) awakenings per night was 2.07 compared to the average number of noise-related awakenings per night of 0.24 (Fidell,

et al. 1994). Additionally, a 1995 analysis of sleep disturbance studies conducted both in the laboratory environment and in the field (in the sleeping quarters of homes) showed that when measuring awakening to noise, a 10 dB increase in SEL was associated with only an 8 percent increase in the probability of awakening in the laboratory studies, but only a 1 percent increase in the field (Pearsons, et al. 1995). Pearsons, et al. (1995), reported that even SEL values as high as 85 dB produced no awakenings or arousals in at least one study. This observation suggests a strong influence of habituation on susceptibility to noise-induced sleep disturbance. A 1984 study (Kryter 1984) indicates that an indoor SEL of 65 dB or lower should awaken less than 5 percent of exposed individuals.

Nevertheless, some guidance is available in judging sleep interference. The EPA identified an indoor DNL of 45 dB as necessary to protect against sleep interference (U.S. Environmental Protection Agency 1978). Assuming a very conservative structural noise insulation of 20 dB for typical dwelling units, this corresponds to an outdoor day-night average sound level of 65 dB to minimize sleep interference.

In 1997, the Federal Interagency Committee on Aviation Noise (FICAN) adopted an interim guideline for sleep awakening prediction. The new curve, based on studies in England (Ollerhead, et al. 1992) and at two U.S. airports (Los Angeles International and Denver International), concluded that the incidence of sleep awakening from aircraft noise was less than identified in a 1992 study (Federal Interagency Committee On Noise 1992). Using indoor single-event noise levels represented by SEL, potential sleep awakening can be predicted using the curve presented in Figure A-5. Typically, homes in the United States provide 15 dB of sound attenuation with windows open and 25 dB with windows closed and air conditioning operating. Hence, the outdoor SEL of 107 dB would be 92 dB indoors with windows open and 82 dB indoors with windows closed and air conditioning operating.

Using Figure A-5, the potential sleep awakening would be 15% with windows open and 10% with windows closed in the above example.

The new FICAN curve does not address habituation over time by sleeping subjects and is applicable only to adult populations. Nevertheless, this curve provides a reasonable guideline for assessing sleep awakening. It is conservative, representing the upper envelope of field study results.

The FICAN curve shown in Figure A-5 represents awakenings from single events. To date, no exact quantitative dose-response relationship exists for noise-related sleep interference from multiple events; yet, based on studies conducted to date and the USEPA guideline of a 45 DNL to protect sleep interference, useful ways to assess sleep interference have emerged. If homes are conservatively estimated to have a 20-dB noise insulation, an average of 65 DNL would produce an indoor level of 45 DNL and would form a reasonable guideline for evaluating sleep interference. This also corresponds well to the general guideline for assessing speech interference. Annoyance that may result from sleep disturbance is accounted for in the calculation of DNL, which includes a 10-dB penalty for each sortie occurring after 10 pm or before 7 am.

A.3.4 Hearing Loss

Considerable data on hearing loss have been collected and analyzed. It has been well established that continuous exposure to high noise levels will damage human hearing (U.S. Environmental Protection Agency 1978). People are normally capable of hearing up to 120 dB over a wide frequency range. Hearing loss is generally interpreted as the shifting of a higher sound level of the ear's sensitivity or

acuity to perceive sound. This change can either be temporary, called a temporary threshold shift (TTS), or permanent, called a permanent threshold shift (PTS) (Berger, et al. 1995).

The EPA has established 75 dB for an 8-hour exposure and 70 dB for a 24-hour exposure as the average noise level standard requisite to protect 96% of the population from greater than a 5 dB PTS (U.S. Environmental Protection Agency 1978). Similarly, the National Academy of Sciences Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) identified 75 dB as the minimum level at which hearing loss may occur (Committee on Hearing, Bioacoustics, and Biomechanics 1977). However, it is important to note that continuous, long-term (40 years) exposure is assumed by both EPA and CHABA before hearing loss may occur.

Federal workplace standards for protection from hearing loss allow a time-average level of 90 dB over an 8-hour work period or 85 dB over a 16-hour period. Even the most protective criterion (no measurable hearing loss for the most sensitive portion of the population at the ear's most sensitive frequency, 4,000 Hz, after a 40-year exposure) is a time-average sound level of 70 dB over a 24-hour period.

Studies on community hearing loss from exposure to aircraft flyovers near airports showed that there is no danger, under normal circumstances, of hearing loss due to aircraft noise (Newman and Beattie 1985).

A laboratory study measured changes in human hearing from noise representative of low-flying aircraft on MTRs. (Nixon, et al. 1993). In this study, participants were first subjected to four overflight noise exposures at A-weighted levels of 115 dB to 130 dB. One-half of the subjects showed no change in hearing levels, one-fourth had a temporary 5-dB increase in sensitivity (the people could hear a 5-dB wider range of sound than before exposure), and one-fourth had a temporary 5-dB decrease in sensitivity (the people could hear a 5-dB narrower range of sound than before exposure). In the next phase, participants were subjected to a single overflight at a maximum level of 130 dB for eight successive exposures, separated by 90 seconds or until a temporary shift in hearing was observed. The temporary hearing threshold shifts resulted in the participants hearing a wider range of sound, but within 10 dB of their original range.

In another study of 115 test subjects between 18 and 50 years old, temporary threshold shifts were measured after laboratory exposure to military low-altitude flight (MLAF) noise (Ising, et al. 1999). According to the authors, the results indicate that repeated exposure to MLAF noise with L_{max} greater than 114 dB, especially if the noise level increases rapidly, may have the potential to cause noise induced hearing loss in humans.

Because it is unlikely that airport neighbors will remain outside their homes 24 hours per day for extended periods of time, there is little possibility of hearing loss below a day-night average sound level of 75 dB, and this level is extremely conservative.

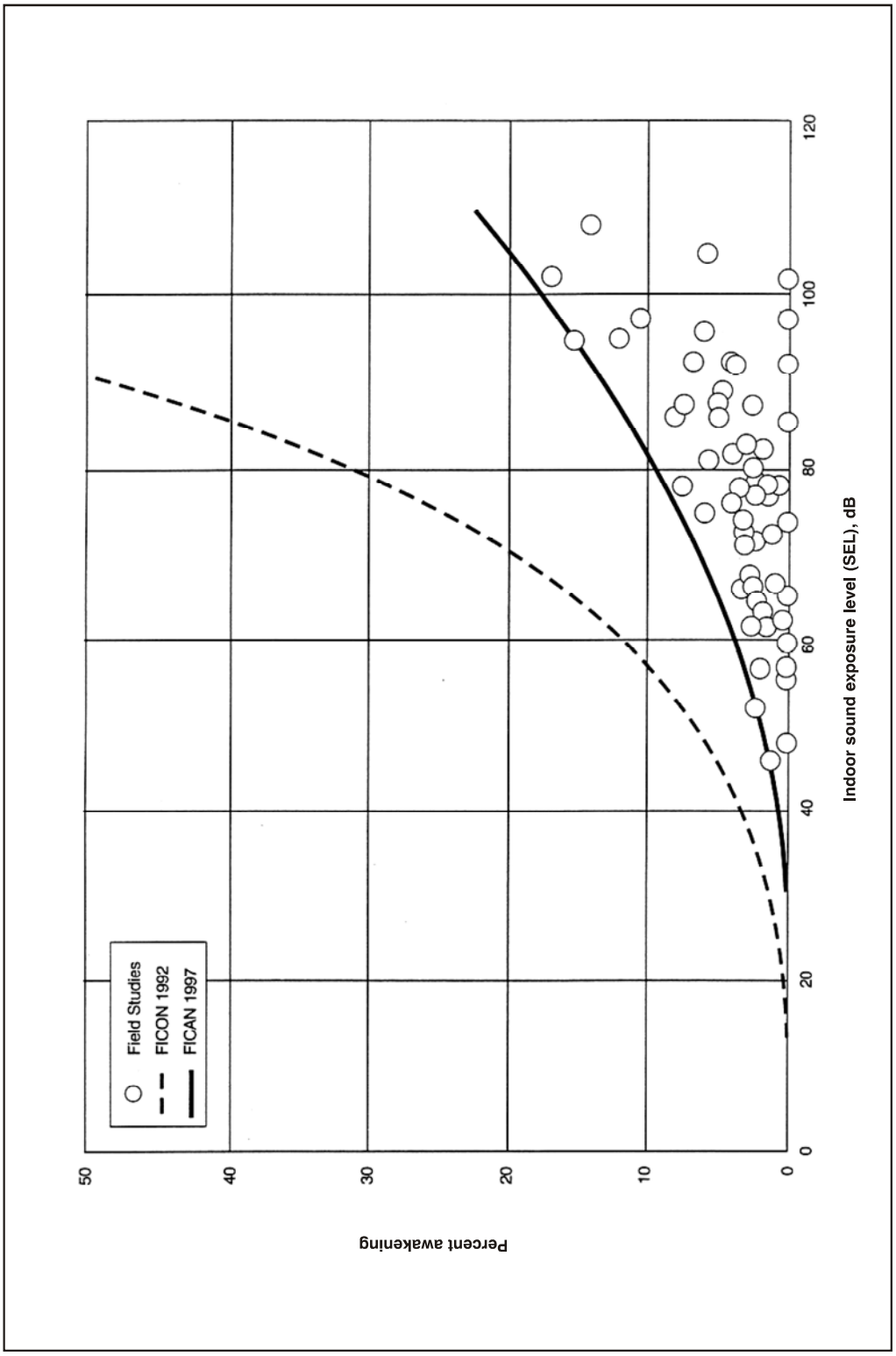


Figure A-5. Recommended Sleep Disturbance Dose-Response Relationship

A.3.5 Nonauditory Health Effects

Studies have been conducted to determine whether correlations exist between noise exposure and cardiovascular problems, birth weight, and mortality rates. The nonauditory effect of noise on humans is not as easily substantiated as the effect on hearing. The results of studies conducted in the United States, primarily concentrating on cardiovascular response to noise, have been contradictory (Cantrell 1974). Cantrell (1974) concluded that the results of human and animal experiments show that average or intrusive noise can act as a stress-provoking stimulus. Prolonged stress is known to be a contributor to a number of health disorders. Kryter and Poza (1980) state, "It is more likely that noise-related general ill-health effects are due to the psychological annoyance from the noise interfering with normal everyday behavior, than it is from the noise eliciting, because of its intensity, reflexive response in the autonomic or other physiological systems of the body." Psychological stresses may cause a physiological stress reaction that could result in impaired health.

The National Institute for Occupational Safety and Health and EPA commissioned CHABA in 1981 to study whether established noise standards are adequate to protect against health disorders other than hearing defects. CHABA's conclusion was that:

Evidence from available research reports is suggestive, but it does not provide definitive answers to the question of health effects, other than to the auditory system, of long-term exposure to noise. It seems prudent, therefore, in the absence of adequate knowledge as to whether or not noise can produce effects upon health other than damage to auditory system, either directly or mediated through stress, that insofar as feasible, an attempt should be made to obtain more critical evidence.

Since the CHABA report, there have been more recent studies that suggest that noise exposure may cause hypertension and other stress-related effects in adults. Near an airport in Stockholm, Sweden, the prevalence of hypertension was reportedly greater among nearby residents who were exposed to energy averaged noise levels exceeding 55 dB and maximum noise levels exceeding 72 dB, particularly older subjects and those not reporting impaired hearing ability (Rosenlund, et al. 2001). A study of elderly volunteers who were exposed to simulated military low-altitude flight noise reported that blood pressure was raised by L_{max} of 112 dB and high speed level increase (Michalak, et al. 1990). Yet another study of subjects exposed to varying levels of military aircraft or road noise found no significant relationship between noise level and blood pressure (Pulles, et al. 1990).

The U.S. Department of the Navy prepared a programmatic Environmental Assessment (EA) for the continued use of non-explosive ordnance on the Vieques Inner Range. Following the preparation of the EA, it was learned that research conducted by the University of Puerto Rico, Ponce School of Medicine, suggested that Vieques fishermen and their families were experiencing symptoms associated with vibroacoustic disease (VAD) (U.S. Department of the Navy 2002). The study alleged that exposure to noise and sound waves of large pressure amplitudes within lower frequency bands, associated with Navy training activities--specifically, air-to-ground bombing or naval fire support--was related to a larger prevalence of heart anomalies within the Vieques fishermen and their families. The Ponce School of Medicine study compared the Vieques group with a group from Ponce Playa. A 1999 study conducted on Portuguese aircraft-manufacturing workers from a single factory reported effects of jet aircraft noise exposure that involved a wide range of symptoms and disorders, including the cardiac issues on which the Ponce School of Medicine study focused. The 1999 study identified these effects as VAD.

Johns Hopkins University (JHU) conducted an independent review of the Ponce School of Medicine study, as well as the Portuguese aircraft workers study and other relevant scientific literature. Their findings concluded that VAD should not be accepted as a syndrome, given that exhaustive research across a number of populations has not yet been conducted. JHU also pointed out that the evidence supporting the existence of VAD comes largely from one group of investigators and that similar results would have to be replicated by other investigators. In short, JHU concluded that it had not been established that noise was the causal agent for the symptoms reported and no inference can be made as to the role of noise from naval gunfire in producing echocardiographic abnormalities (U.S. Department of the Navy 2002).

Most studies of nonauditory health effects of long-term noise exposure have found that noise exposure levels established for hearing protection will also protect against any potential nonauditory health effects, at least in workplace conditions. One of the best scientific summaries of these findings is contained in the lead paper at the National Institutes of Health Conference on Noise and Hearing Loss, held on 22 to 24 January 1990 in Washington, D.C.:

> "The nonauditory effects of chronic noise exposure, when noise is suspected to act as one of the risk factors in the development of hypertension, cardiovascular disease, and other nervous disorders, have never been proven to occur as chronic manifestations at levels below these criteria (an average of 75 dBA for complete protection against hearing loss for an 8-hour day). At the recent (1988) International Congress on Noise as a Public Health Problem, most studies attempting to clarify such health effects did not find them at levels below the criteria protective of noise-induced hearing loss, and even above these criteria, results regarding such health effects were ambiguous. Consequently, one comes to the conclusion that establishing and enforcing exposure levels protecting against noise-induced hearing loss would not only solve the noise-induced hearing loss problem, but also any potential nonauditory health effects in the work place" (von Gierke 1990).

Although these findings were specifically directed at noise effects in the workplace, they are equally applicable to aircraft noise effects in the community environment. Research studies regarding the nonauditory health effects of aircraft noise are ambiguous, at best, and often contradictory. Yet, even those studies that purport to find such health effects use time-average noise levels of 75 dB and higher for their research.

For example, two UCLA researchers apparently found a relationship between aircraft noise levels under the approach path to Los Angeles International Airport (LAX) and increased mortality rates among the exposed residents by using an average noise exposure level greater than 75 dB for the "noise-exposed" population (Meacham and Shaw 1979). Nevertheless, three other UCLA professors analyzed those same data and found no relationship between noise exposure and mortality rates (Frerichs, et al. 1980).

As a second example, two other UCLA researchers used this same population near LAX to show a higher rate of birth defects for 1970 to 1972 when compared with a control group residing away from the airport (Jones and Tauscher 1978). Based on this report, a separate group at the Center for Disease Control performed a more thorough study of populations near Atlanta's Hartsfield International Airport (ATL) for 1970 to 1972 and found no relationship in their study of 17 identified categories of birth defects to aircraft noise levels above 65 dB (Edmonds, et al. 1979).

In summary, there is no scientific basis for a claim that potential health effects exist for aircraft time-average sound levels below 75 dB.

The potential for noise to affect physiological health, such as the cardiovascular system, has been speculated; however, no unequivocal evidence exists to support such claims (Harris 1997). Conclusions drawn from a review of health effect studies involving military low-altitude flight noise with its unusually high maximum levels and rapid rise in sound level have shown no increase in cardiovascular disease (Schwartze and Thompson 1993). Additional claims that are unsupported include flyover noise producing increased mortality rates and increases in cardiovascular death, aggravation of post-traumatic stress syndrome, increased stress, increase in admissions to mental hospitals, and adverse affects on pregnant women and the unborn fetus (Harris 1997).

A.3.6 Performance Effects

The effect of noise on the performance of activities or tasks has been the subject of many studies. Some of these studies have established links between continuous high noise levels and performance loss. Noise-induced performance losses are most frequently reported in studies employing noise levels in excess of 85 dB. Little change has been found in low-noise cases. It has been cited that moderate noise levels appear to act as a stressor for more sensitive individuals performing a difficult psychomotor task.

While the results of research on the general effect of periodic aircraft noise on performance have yet to yield definitive criteria, several general trends have been noted including:

- A periodic intermittent noise is more likely to disrupt performance than a steady-state continuous noise of the same level. Flyover noise, due to its intermittent nature, might be more likely to disrupt performance than a steady-state noise of equal level.
- Noise is more inclined to affect the quality than the quantity of work.
- Noise is more likely to impair the performance of tasks that place extreme demands on the worker.

A.3.7 Noise Effects on Children

In response to noise-specific and other environmental studies, Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks (1997), requires federal agencies to ensure that policies, programs, and activities address environmental health and safety risks to identify any disproportionate risks to children.

A review of the scientific literature indicates that there has not been a tremendous amount of research in the area of aircraft noise effects on children. The research reviewed does suggest that environments with sustained high background noise can have variable effects, including noise effects on learning and cognitive abilities, and reports of various noise-related physiological changes.

A.3.7.1 Effects on Learning and Cognitive Abilities

In the recent release (2002) of the "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools," the American National Standards Institute refers to studies that suggest that loud and frequent background noise can affect the learning patterns of young children. ANSI provides discussion on the relationships between noise and learning, and stipulates design requirements and acoustical performance criteria for outdoor-to-indoor noise isolation. School design is directed to be cognizant of, and responsive to, surrounding land uses and the shielding of outdoor noise from the indoor environment. ANSI has approved a new standard for acoustical performance criteria in schools. The new criteria include the requirement that the one-hour-average background noise level shall not exceed 35 dBA in core learning spaces smaller than 20,000 cubic-feet and 40 dBA in core learning spaces with enclosed volumes exceeding 20,000 cubic-feet. This would require schools be constructed such that, in quiet neighborhoods indoor noise levels are lowered by 15 to 20 dBA relative to outdoor levels. In schools near airports, indoor noise levels would have to be lowered by 35 to 45 dBA relative to outdoor levels (American National Standards Institute 2002).

The studies referenced by ANSI to support the new standard are not specific to jet aircraft noise and the potential effects on children. However, there are references to studies that have shown that children in noisier classrooms scored lower on a variety of tests. Excessive background noise or reverberation within schools causes interferences of communication and can therefore create an acoustical barrier to learning (American National Standards Institute 2002). Studies have been performed that contribute to the body of evidence emphasizing the importance of communication by way of the spoken language to the development of cognitive skills. The ability to read, write, comprehend, and maintain attentiveness, are, in part, based upon whether teacher communication is consistently intelligible (American National Standards Institute 2002).

Numerous studies have shown varying degrees of effects of noise on the reading comprehension, attentiveness, puzzle-solving, and memory/recall ability of children. It is generally accepted that young children are more susceptible than adults to the effects of background noise. Because of the developmental status of young children (linguistic, cognitive, and proficiency), barriers to hearing can cause interferences or disruptions in developmental evolution.

Research on the impacts of aircraft noise, and noise in general, on the cognitive abilities of school-aged children has received more attention in recent years. Several studies suggest that aircraft noise can affect the academic performance of schoolchildren. Although many factors could contribute to learning deficits in school-aged children (e.g., socioeconomic level, home environment, diet, sleep patterns), evidence exists that suggests that chronic exposure to high aircraft noise levels can impair learning.

Specifically, elementary school children attending schools near New York City's two airports demonstrated lower reading scores than children living farther away from the flight paths (Green, et al. 1982). Researchers have found that tasks involving central processing and language comprehension (such as reading, attention, problem solving, and memory) appear to be the most affected by noise (Evans and Lepore 1993; Hygge 1994; and Evans, et al. 1995). It has been demonstrated that chronic exposure of first- and second-grade children to aircraft noise can result in reading deficits and impaired speech perception (i.e., the ability to hear common, low-frequency [vowel] sounds but not high frequencies [consonants] in speech) (Evans and Maxwell 1997).

The Evans and Maxwell (1997) study found that chronic exposure to aircraft noise resulted in reading deficits and impaired speech perception for first- and second-grade children. Other studies found that children residing near the Los Angeles International Airport had more difficulty solving cognitive problems and did not perform as well as children from quieter schools in puzzle-solving and attentiveness (Bronzaft 1997; Cohen, et al. 1980). Children attending elementary schools in high aircraft noise areas near London's Heathrow Airport demonstrated poorer reading comprehension and selective cognitive impairments (Haines, et al. 2001a, b). Similarly, a study conducted by Hygge (1994) found that students exposed to aircraft noise (76 dBA) scored 20% lower on recall ability tests than students exposed to ambient noise (42-44 dBA). Similar studies involving the testing of attention, memory, and reading comprehension of schoolchildren located near airports showed that their tests exhibited reduced performance results compared to those of similar groups of children who were located in quieter environments (Evans, et al. 1995; Haines, et al. 1998). The Haines and Stansfeld study indicated that there may be some long-term effects associated with exposure, as one-year follow-up testing still demonstrated lowered scores for children in higher noise schools (Haines et al., 2001a and 2001b). In contrast, a study conducted by Hygge, et al. (2002) found that although children living near the old Munich airport scored lower in standardized reading and long-term memory tests than a control group, their performance on the same tests was equal to that of the control group once the airport was closed.

Finally, although it is recognized that there are many factors that could contribute to learning deficits in school-aged children, there is increasing awareness that chronic exposure to high aircraft noise levels may impair learning. This awareness has led the World Health Organization and a North Atlantic Treaty Organization working group to conclude that daycare centers and schools should not be located near major sources of noise, such as highways, airports, and industrial sites (World Health Organization 2000; North Atlantic Treaty Organization 2000).

A.3.7.2 Health Effects

Physiological effects in children exposed to aircraft noise and the potential for health effects have also been the focus of limited investigation. Studies in the literature include examination of blood pressure levels, hormonal secretions, and hearing loss.

As a measure of stress response to aircraft noise, authors have looked at blood pressure readings to monitor children's health. Children who were chronically exposed to aircraft noise from a new airport near Munich, Germany, had modest (although significant) increases in blood pressure, significant increases in stress hormones, and a decline in quality of life (Evans, et al. 1998). Children attending noisy schools had statistically significant average systolic and diastolic blood pressure ($p<0.03$). Systolic blood pressure means were 89.68 mm for children attending schools located in noisier environments compared to 86.77 mm for a control group. Similarly, diastolic blood pressure means for the noisier environment group were 47.84 mm and 45.16 for the control group (Cohen, et al. 1980).

Although the literature appears limited, relatively recent studies focused on the wide range of potential effects of aircraft noise on school children have also investigated hormonal levels between groups of children exposed to aircraft noise compared to those in a control group. Specifically, Haines, et al. (2001b and 2001c) analyzed cortisol and urinary catecholamine levels in school children as measurements of stress response to aircraft noise. In both instances, there were no differences between the aircraft-noise-exposed children and the control groups.

Other studies have reported hearing losses from exposure to aircraft noise. Noise-induced hearing loss was reportedly higher in children who attended a school located under a flight path near a Taiwan airport, as compared to children at another school far away (Chen, et al. 1997). Another study reported that hearing ability was reduced significantly in individuals who lived near an airport and were frequently exposed to aircraft noise (Chen and Chen 1993). In that study, noise exposure near the airport was reportedly uniform, with DNL greater than 75 dB and maximum noise levels of about 87 dB during overflights. Conversely, several other studies that were reviewed reported no difference in hearing ability between children exposed to high levels of airport noise and children located in quieter areas (Fisch 1977; Andrus, et al. 1975; Wu, et al. 1995).

A.3.8 Effects on Domestic Animals and Wildlife

Hearing is critical to an animal's ability to react, compete, reproduce, hunt, forage, and survive in its environment. While the existing literature does include studies on possible effects of jet aircraft noise and sonic booms on wildlife, there appears to have been little concerted effort in developing quantitative comparisons of aircraft noise effects on normal auditory characteristics. Behavioral effects have been relatively well described, but the larger ecological context issues, and the potential for drawing conclusions regarding effects on populations, has not been well developed.

The relationships between potential auditory/physiological effects and species interactions with their environments are not well understood. Manci, et al. (1988), assert that the consequences that physiological effects may have on behavioral patterns is vital to understanding the long-term effects of noise on wildlife. Questions regarding the effects (if any) on predator-prey interactions, reproductive success, and intra-inter specific behavior patterns remain.

The following discussion provides an overview of the existing literature on noise effects (particularly jet aircraft noise) on animal species. The literature reviewed here involves those studies that have focused on the observations of the behavioral effects that jet aircraft and sonic booms have on animals.

A great deal of research was conducted in the 1960's and 1970's on the effects of aircraft noise on the public and the potential for adverse ecological impacts. These studies were largely completed in response to the increase in air travel and as a result of the introduction of supersonic jet aircraft. According to Manci, et al. (1988), the foundation of information created from that focus does not necessarily correlate or provide information specific to the impacts to wildlife in areas overflown by aircraft at supersonic speed or at low altitudes.

The abilities to hear sounds and noise and to communicate assist wildlife in maintaining group cohesiveness and survivorship. Social species communicate by transmitting calls of warning, introduction, and other types that are subsequently related to an individual's or group's responsiveness.

Animal species differ greatly in their responses to noise. Noise effects on domestic animals and wildlife are classified as primary, secondary, and tertiary. Primary effects are direct, physiological changes to the auditory system, and most likely include the masking of auditory signals. Masking is defined as the inability of an individual to hear important environmental signals that may arise from mates, predators, or prey. There is some potential that noise could disrupt a species' ability to communicate or could interfere with behavioral patterns (Manci, et al. 1988). Although the effects are likely temporal, aircraft noise may cause masking of auditory signals within exposed faunal communities. Animals rely on hearing to avoid predators, obtain food, and communicate with, and

attract, other members of their species. Aircraft noise may mask or interfere with these functions. Other primary effects, such as ear drum rupture or temporary and permanent hearing threshold shifts, are not as likely given the subsonic noise levels produced by aircraft overflights. Secondary effects may include non-auditory effects such as stress and hypertension; behavioral modifications; interference with mating or reproduction; and impaired ability to obtain adequate food, cover, or water. Tertiary effects are the direct result of primary and secondary effects, and include population decline and habitat loss. Most of the effects of noise are mild enough that they may never be detectable as variables of change in population size or population growth against the background of normal variation (Bowles 1995). Other environmental variables (e.g., predators, weather, changing prey base, ground-based disturbance) also influence secondary and tertiary effects, and confound the ability to identify the ultimate factor in limiting productivity of a certain nest, area, or region (Smith, et al. 1988). Overall, the literature suggests that species differ in their response to various types, durations, and sources of noise (Manci, et al. 1988).

Many scientific studies have investigated the effects of aircraft noise on wildlife, and some have focused on wildlife "flight" due to noise. Apparently, animal responses to aircraft are influenced by many variables, including size, speed, proximity (both height above the ground and lateral distance), engine noise, color, flight profile, and radiated noise. The type of aircraft (e.g., fixed wing versus rotor-wing [helicopter]) and type of flight mission may also produce different levels of disturbance, with varying animal responses (Smith, et al. 1988). Consequently, it is difficult to generalize animal responses to noise disturbances across species.

One result of the 1988 Manci, et al., literature review was the conclusion that, while behavioral observation studies were relatively limited, a general behavioral reaction in animals from exposure to aircraft noise is the startle response. The intensity and duration of the startle response appears to be dependent on which species is exposed, whether there is a group or an individual, and whether there have been some previous exposures. Responses range from flight, trampling, stampeding, jumping, or running, to movement of the head in the apparent direction of the noise source. Manci, et al. (1988), reported that the literature indicated that avian species may be more sensitive to aircraft noise than mammals.

A.3.8.1 Domestic Animals

Although some studies report that the effects of aircraft noise on domestic animals is inconclusive, a majority of the literature reviewed indicates that domestic animals exhibit some behavioral responses to military overflights but generally seem to habituate to the disturbances over a period of time. Mammals in particular appear to react to noise at sound levels higher than 90 dB, with responses including the startle response, freezing (i.e., becoming temporarily stationary), and fleeing from the sound source. Many studies on domestic animals suggest that some species appear to acclimate to some forms of sound disturbance (Manci, et al. 1988). Some studies have reported such primary and secondary effects as reduced milk production and rate of milk release, increased glucose concentrations, decreased levels of hemoglobin, increased heart rate, and a reduction in thyroid activity. These latter effects appear to represent a small percentage of the findings occurring in the existing literature.

Some reviewers have indicated that earlier studies, and claims by farmers linking adverse effects of aircraft noise on livestock, did not necessarily provide clear-cut evidence of cause and effect

(Cottereau 1978). In contrast, many studies conclude that there is no evidence that aircraft overflights affect feed intake, growth, or production rates in domestic animals.

Cattle

In response to concerns about overflight effects on pregnant cattle, milk production, and cattle safety, the U.S. Air Force prepared a handbook for environmental protection that summarizes the literature on the impacts of low-altitude flights on livestock (and poultry) and includes specific case studies conducted in numerous airspaces across the country. Adverse effects have been found in a few studies but have not been reproduced in other similar studies. One such study, conducted in 1983, suggested that 2 of 10 cows in late pregnancy aborted after showing rising estrogen and falling progesterone levels. These increased hormonal levels were reported as being linked to 59 aircraft overflights. The remaining eight cows showed no changes in their blood concentrations and calved normally (U.S. Air Force 1994b). A similar study reported abortions occurred in three out of five pregnant cattle after exposing them to flyovers by six different aircraft (U.S.Air Force 1994b). Another study suggested that feedlot cattle could stampede and injure themselves when exposed to low-level overflights (U.S. Air Force 1994b).

A majority of the studies reviewed suggests that there is little or no effect of aircraft noise on cattle. Studies presenting adverse effects to domestic animals have been limited. A number of studies (Parker and Bayley 1960; Casady and Lehmann 1967; Kovalcik and Sottnik 1971) investigated the effects of jet aircraft noise and sonic booms on the milk production of dairy cows. Through the compilation and examination of milk production data from areas exposed to jet aircraft noise and sonic boom events, it was determined that milk yields were not affected. This was particularly evident in those cows that had been previously exposed to jet aircraft noise.

A study examined the causes of 1,763 abortions in Wisconsin dairy cattle over a one-year time period and none were associated with aircraft disturbances (U.S.Air Force 1993). In 1987, Anderson contacted seven livestock operators for production data, and no effects of low-altitude and supersonic flights were noted. Three out of 43 cattle previously exposed to low-altitude flights showed a startle response to an F/A-18 aircraft flying overhead at 500 feet above ground level and 400 knots by running less than 10 meters. They resumed normal activity within one minute (U.S.Air Force 1994b). Beyer (1983) found that helicopters caused more reaction than other low-aircraft overflights, and that the helicopters at 30 to 60 feet overhead did not affect milk production and pregnancies of 44 cows and heifers in a 1964 study (U.S. Air Force 1994b).

Additionally, Beyer reported that five pregnant dairy cows in a pasture did not exhibit fright-flight tendencies or disturb their pregnancies after being overflown by 79 low-altitude helicopter flights and 4 low-altitude, subsonic jet aircraft flights (U.S. Air Force 1994b). A 1956 study found that the reactions of dairy and beef cattle to noise from low-altitude, subsonic aircraft were similar to those caused by paper blowing about, strange persons, or other moving objects (U.S. Air Force 1994b).

In a report to Congress, the U. S. Forest Service concluded that "evidence both from field studies of wild ungulates and laboratory studies of domestic stock indicate that the risks of damage are small (from aircraft approaches of 50 to 100 meters), as animals take care not to damage themselves (U.S. Forest Service 1992). If animals are overflown by aircraft at altitudes of 50 to 100 meters, there is no evidence that mothers and young are separated, that animals collide with obstructions (unless confined) or that they traverse dangerous ground at too high a rate." These varied study results

suggest that, although the confining of cattle could magnify animal response to aircraft overflight, there is no proven cause-and-effect link between startling cattle from aircraft overflights and abortion rates or lower milk production.

Horses

Horses have also been observed to react to overflights of jet aircraft. Several of the studies reviewed reported a varied response of horses to low-altitude aircraft overflights. Observations made in 1966 and 1968 noted that horses galloped in response to jet flyovers (U.S. Air Force 1993). Bowles (1995) cites Kruger and Erath as observing horses exhibiting intensive flight reactions, random movements, and biting/kicking behavior. However, no injuries or abortions occurred, and there was evidence that the mares adapted somewhat to the flyovers over the course of a month (U.S. Air Force 1994b). Although horses were observed noticing the overflights, it did not appear to affect either survivability or reproductive success. There was also some indication that habituation to these types of disturbances was occurring.

LeBlanc, et al. (1991), studied the effects of F-14 jet aircraft noise on pregnant mares. They specifically focused on any changes in pregnancy success, behavior, cardiac function, hormonal production, and rate of habituation. Their findings reported observations of "flight-fright" reactions, which caused increases in heart rates and serum cortisol concentrations. The mares, however, did habituate to the noise. Levels of anxiety and mass body movements were the highest after initial exposure, with intensities of responses decreasing thereafter. There were no differences in pregnancy success when compared to a control group.

Swine

Generally, the literature findings for swine appear to be similar to those reported for cows and horses. While there are some effects from aircraft noise reported in the literature, these effects are minor. Studies of continuous noise exposure (i.e., 6 hours, 72 hours of constant exposure) reported influences on short-term hormonal production and release. Additional constant exposure studies indicated the observation of stress reactions, hypertension, and electrolyte imbalances (Dufour 1980). A study by Bond, et al. (1963), demonstrated no adverse effects on the feeding efficiency, weight gain, ear physiology, or thyroid and adrenal gland condition of pigs subjected to observed aircraft noise. Observations of heart rate increase were recorded, noting that cessation of the noise resulted in the return to normal heart rates. Conception rates and offspring survivorship did not appear to be influenced by exposure to aircraft noise.

Similarly, simulated aircraft noise at levels of 100 dB to 135 dB had only minor effects on the rate of feed utilization, weight gain, food intake, or reproduction rates of boars and sows exposed, and there were no injuries or inner ear changes observed (Manci, et al. 1988; Gladwin, et al. 1988).

Domestic Fowl

According to a 1994 position paper by the U.S. Air Force on effects of low-altitude overflights (below 1,000 ft) on domestic fowl, overflight activity has negligible effects (U.S. Air Force 1994a). The paper did recognize that given certain circumstances, adverse effects can be serious. Some of the effects can be panic reactions, reduced productivity, and effects on marketability (e.g., bruising of the meat caused during "pile-up" situations).

The typical reaction of domestic fowl after exposure to sudden, intense noise is a short-term startle response. The reaction ceases as soon as the stimulus is ended, and within a few minutes all activity returns to normal. More severe responses are possible depending on the number of birds, the frequency of exposure, and environmental conditions. Large crowds of birds, and birds not previously exposed, are more likely to pile up in response to a noise stimulus (U.S. Air Force 1994a). According to studies and interviews with growers, it is typically the previously unexposed birds that incite panic crowding, and the tendency to do so is markedly reduced within five exposures to the stimulus (U.S. Air Force 1994a). This suggests that the birds habituate relatively quickly. Egg productivity was not adversely affected by infrequent noise bursts, even at exposure levels as high as 120 to 130 dBA.

Between 1956 and 1988, there were 100 recorded claims against the Navy for alleged damage to domestic fowl. The number of claims averaged three per year, with peak numbers of claims following publications of studies on the topic in the early 1960s (U.S. Air Force 1994a). Many of the claims were disproved or did not have sufficient supporting evidence. The claims were filed for the following alleged damages: 55% for panic reactions, 31% for decreased production, 6% for reduced hatchability, 6% for weight loss, and less than 1% for reduced fertility (U.S. Air Force 1994a).

Turkeys

The review of the existing literature suggests that there has not been a concerted or widespread effort to study the effects of aircraft noise on commercial turkeys. One study involving turkeys examined the differences between simulated versus actual overflight aircraft noise, turkey responses to the noise, weight gain, and evidence of habituation (Bowles, et al. 1990). Findings from the study suggested that turkeys habituated to jet aircraft noise quickly, that there were no growth rate differences between the experimental and control groups, and that there were some behavioral differences that increased the difficulty in handling individuals within the experimental group.

Low-altitude overflights were shown to cause turkey flocks that were kept inside turkey houses to occasionally pile up and experience high mortality rates due to the aircraft noise and a variety of disturbances unrelated to aircraft (U.S. Air Force 1994a).

A.3.8.2 Wildlife

Studies on the effects of overflights and sonic booms on wildlife have been focused mostly on avian species and ungulates such as caribou and bighorn sheep. Few studies have been conducted on marine mammals, small terrestrial mammals, reptiles, amphibians, and carnivorous mammals. Generally, species that live entirely below the surface of the water have also been ignored due to the fact they do not experience the same level of sound as terrestrial species (National Park Service 1994). Wild ungulates appear to be much more sensitive to noise disturbance than domestic livestock (Manci, et al. 1988). This may be due to previous exposure to disturbances. One common factor appears to be that low-altitude flyovers seem to be more disruptive in terrain where there is little cover (Manci, et al. 1988).

A.3.8.2.1 MAMMALS

Terrestrial Mammals

Studies of terrestrial mammals have shown that noise levels of 120 dBA can damage mammals' ears, and levels at 95 dBA can cause temporary loss of hearing acuity. Noise from aircraft has affected other large carnivores by causing changes in home ranges, foraging patterns, and breeding behavior. One study recommended that aircraft not be allowed to fly at altitudes below 2,000 feet above ground level over important grizzly and polar bear habitat (Dufour 1980). Wolves have been frightened by low-altitude flights that were 25 to 1,000 feet off the ground. However, wolves have been found to adapt to aircraft overflights and noise as long as they were not being hunted from aircraft (Dufour 1980).

Wild ungulates (American bison, caribou, bighorn sheep) appear to be much more sensitive to noise disturbance than domestic livestock (Weisenberger, et al. 1996). Behavioral reactions may be related to the past history of disturbances by such things as humans and aircraft. Common reactions of reindeer kept in an enclosure exposed to aircraft noise disturbance were a slight startle response, raising of the head, pricking ears, and scenting of the air. Panic reactions and extensive changes in behavior of individual animals were not observed. Observations of caribou in Alaska exposed to fixed-wing aircraft and helicopters showed running and panic reactions occurred when overflights were at an altitude of 200 feet or less. The reactions decreased with increased altitude of overflights, and, with more than 500 feet in altitude, the panic reactions stopped. Also, smaller groups reacted less strongly than larger groups. One negative effect of the running and avoidance behavior is increased expenditure of energy. For a 90-kg animal, the calculated expenditure due to aircraft harassment is 64 kilocalories per minute when running and 20 kilocalories per minute when walking. When conditions are favorable, this expenditure can be counteracted with increased feeding; however, during harsh winter conditions, this may not be possible. Incidental observations of wolves and bears exposed to fixed-wing aircraft and helicopters in the northern regions suggested that wolves are less disturbed than wild ungulates, while grizzly bears showed the greatest response of any animal species observed.

It has been proven that low-altitude overflights do induce stress in animals. Increased heart rates, an indicator of excitement or stress, have been found in pronghorn antelope, elk, and bighorn sheep. As such reactions occur naturally as a response to predation, infrequent overflights may not, in and of themselves, be detrimental. However, flights at high frequencies over a long period of time may cause harmful effects. The consequences of this disturbance, while cumulative, is not additive. It may be that aircraft disturbance may not cause obvious and serious health effects, but coupled with a harsh winter, it may have an adverse impact. Research has shown that stress induced by other types of disturbances produces long-term decreases in metabolism and hormone balances in wild ungulates.

Behavioral responses can range from mild to severe. Mild responses include head raising, body shifting, or turning to orient toward the aircraft. Moderate disturbance may be nervous behaviors, such as trotting a short distance. Escape is the typical severe response.

Marine Mammals

The physiological composition of the ear in aquatic and marine mammals exhibits adaptation to the aqueous environment. These differences (relative to terrestrial species) manifest themselves in the auricle and middle ear (Manci, et al. 1988). Some mammals use echolocation to perceive objects in

their surroundings and to determine the directions and locations of sound sources (Simmons 1983 in Manci, et al. 1988).

In 1980, the Acoustical Society of America held a workshop to assess the potential hazard of manmade noise associated with proposed Alaska Arctic (North Slope-Outer Continental Shelf) petroleum operations on marine wildlife and to prepare a research plan to secure the knowledge necessary for proper assessment of noise impacts (Acoustical Society of America, 1980). Since 1980 it appears that research on responses of aquatic mammals to aircraft noise and sonic booms has been limited. Research conducted on northern fur seals, sea lions, and ringed seals indicated that there are some differences in how various animal groups receive frequencies of sound. It was observed that these species exhibited varying intensities of a startle response to airborne noise, which was habituated over time. The rates of habituation appeared to vary with species, populations, and demographics (age, sex). Time of day of exposure was also a factor (Muyberg 1978 in Manci, et al. 1988).

Studies accomplished near the Channel Islands were conducted near the area where the space shuttle launches occur. It was found that there were some response differences between species relative to the loudness of sonic booms. Those booms that were between 80 and 89 dBA caused a greater intensity of startle reactions than lower-intensity booms at 72 to 79 dBA. However, the duration of the startle responses to louder sonic booms was shorter (Jehl and Cooper 1980 in Manci, et al. 1988).

Jehl and Cooper (1980) indicated that low-flying helicopters, loud boat noises, and humans were the most disturbing to pinnipeds. According to the research, while the space launch and associated operational activity noises have not had a measurable effect on the pinniped population, it also suggests that there was a greater "disturbance level" exhibited during launch activities. There was a recommendation to continue observations for behavioral effects and to perform long-term population monitoring (Jehl and Cooper 1980).

The continued presence of single or multiple noise sources could cause marine mammals to leave a preferred habitat. However, it does not appear likely that overflights could cause migration from suitable habitats as aircraft noise over water is mobile and would not persist over any particular area. Aircraft noise, including supersonic noise, currently occurs in the overwater airspace of Eglin, Tyndall, and Langley AFBs from sorties predominantly involving jet aircraft. Survey results reported in Davis, et al. (2000), indicate that cetaceans (i.e., dolphins) occur under all of the Eglin and Tyndall marine airspace. The continuing presence of dolphins indicates that aircraft noise does not discourage use of the area and apparently does not harm the locally occurring population.

In a summary by the National Parks Service (1994) on the effects of noise on marine mammals, it was determined that gray whales and harbor porpoises showed no outward behavioral response to aircraft noise or overflights. Bottlenose dolphins showed no obvious reaction in a study involving helicopter overflights at 1,200 to 1,800 feet above the water. Neither did they show any reaction to survey aircraft unless the shadow of the aircraft passed over them, at which point there was some observed tendency to dive (Richardson, et al. 1995). Other anthropogenic noises in the marine environment from ships and pleasure craft may have more of an effect on marine mammals than aircraft noise (U.S. Air Force 2000). The noise effects on cetaceans appear to be somewhat attenuated by the air/water interface. The cetacean fauna along the coast of California have been subjected to sonic booms from military aircraft for many years without apparent adverse effects (Tetra Tech, Inc. 1997).

Manatees appear relatively unresponsive to human-generated noise to the point that they are often suspected of being deaf to oncoming boats [although their hearing is actually similar to that of pinnipeds (Bullock, et al. 1980)]. Little is known about the importance of acoustic communication to manatees, although they are known to produce at least ten different types of sounds and are thought to have sensitive hearing (Richardson, et al. 1995). Manatees continue to occupy canals near Miami International Airport, which suggests that they have become habituated to human disturbance and noise (Metro-Dade County 1995). Since manatees spend most of their time below the surface and do not startle readily, no effect of aircraft overflights on manatees would be expected (Bowles, et al. 1991).

A.3.8.2.2 BIRDS

Auditory research conducted on birds indicates that they fall between the reptiles and the mammals relative to hearing sensitivity. According to Dooling (1978), within the range of 1 to 5 kHz, birds show a level of hearing sensitivity similar to that of the more sensitive mammals. In contrast to mammals, bird sensitivity falls off at a greater rate to increasing and decreasing frequencies. Passive observations and studies examining aircraft bird strikes indicate that birds nest and forage near airports. Aircraft noise in the vicinity of commercial airports apparently does not inhibit bird presence and use.

High-noise events (like a low-altitude aircraft overflight) may cause birds to engage in escape or avoidance behaviors, such as flushing from perches or nests (Ellis, et al. 1991). These activities impose an energy cost on the birds that, over the long term, may affect survival or growth. In addition, the birds may spend less time engaged in necessary activities like feeding, preening, or caring for their young because they spend time in noise-avoidance activity. However, the long-term significance of noise-related impacts is less clear. Several studies on nesting raptors have indicated that birds become habituated to aircraft overflights and that long-term reproductive success is not affected (Grubb and King 1991; Ellis, et al. 1991). Threshold noise levels for significant responses range from 62 dB for Pacific black brant (Branta bernicla nigricans) (Ward and Stehn 1990) to 85 dB for crested tern (Sterna bergii) (Brown 1990).

Songbirds were observed to become silent prior to the onset of a sonic boom event (F-111 jets), followed by "raucous discordant cries." There was a return to normal singing within 10 seconds after the boom (Higgins 1974 in Manci, et al., 1988). Ravens responded by emitting protestation calls, flapping their wings, and soaring.

Manci, et al. (1988), reported a reduction in reproductive success in some small territorial passerines (i.e., perching birds or songbirds) after exposure to low-altitude overflights. However, it has been observed that passerines are not driven any great distance from a favored food source by a nonspecific disturbance, such as aircraft overflights (U.S. Forest Service 1992). Further study may be warranted.

A recent study, conducted cooperatively between the DoD and the USFWS, assessed the response of the red-cockaded woodpecker to a range of military training noise events, including artillery, small arms, helicopter, and maneuver noise (Pater, et al. 1999). The project findings show that the red-cockaded woodpecker successfully acclimates to military noise events. Depending on the noise level that ranged from innocuous to very loud, the birds responded by flushing from their nest cavities. When the noise source was closer and the noise level was higher, the number of flushes increased proportionately. In all cases, however, the birds returned to their nests within a relatively short period of time (usually within 12 minutes). Additionally, the noise exposure did not result in any mortality

or statistically detectable changes in reproductive success (Pater, et al. 1999). Red-cockaded woodpeckers did not flush when artillery simulators were more than 122 meters away and SEL noise levels were 70 dBA.

Lynch and Speake (1978) studied the effects of both real and simulated sonic booms on the nesting and brooding eastern wild turkey (Meleagris gallopavo silvestris) in Alabama. Hens at four nest sites were subjected to between 8 and 11 combined real and simulated sonic booms. All tests elicited similar responses, including quick lifting of the head and apparent alertness for between 10 and 20 seconds. No apparent nest failure occurred as a result of the sonic booms.

Twenty-one brood groups were also subjected to simulated sonic booms. Reactions varied slightly between groups, but the largest percentage of groups reacted by standing motionless after the initial blast. Upon the sound of the boom, the hens and poults fled until reaching the edge of the woods (approximately 4 to 8 meters). Afterward, the poults resumed feeding activities while the hens remained alert for a short period of time (approximately 15 to 20 seconds). In no instances were poults abandoned, nor did they scatter and become lost. Every observation group returned to normal activities within a maximum of 30 seconds after a blast.

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In a literature review of raptor responses to aircraft noise, Manci, et al. (1988), found that most raptors did not show a negative response to overflights. When negative responses were observed they were predominantly associated with rotor-winged aircraft or jet aircraft that were repeatedly passing within 0.5 mile of a nest.

Ellis, et al. (1991), performed a study to estimate the effects of low-level military jet aircraft and mid- to high-altitude sonic booms (both actual and simulated) on nesting peregrine falcons and seven other raptors (common black-hawk, Harris' hawk, zone-tailed hawk, red-tailed hawk, golden eagle, prairie falcon, bald eagle). They observed responses to test stimuli, determined nest success for the year of the testing, and evaluated site occupancy the following year. Both long- and short-term effects were noted in the study. The results reported the successful fledging of young in 34 of 38 nest sites (all eight species) subjected to low-level flight and/or simulated sonic booms. Twenty-two of the test sites were revisited in the following year, and observations of pairs or lone birds were made at all but one nest. Nesting attempts were underway at 19 of 20 sites that were observed long enough to be certain of breeding activity. Reoccupancy and productivity rates were within or above expected values for self-sustaining populations.

Short-term behavior responses were also noted. Overflights at a distance of 150 m or less produced few significant responses and no severe responses. Typical responses consisted of crouching or, very rarely, flushing from the perch site. Significant responses were most evident before egg laying and after young were "well grown." Incubating or brooding adults never burst from the nest, thus preventing egg breaking or knocking chicks out of the nest. Jet passes and sonic booms often caused noticeable alarm; however, significant negative responses were rare and did not appear to limit productivity or reoccupancy. Due to the locations of some of the nests, some birds may have been habituated to aircraft noise. There were some test sites located at distances far from zones of frequent military aircraft usage, and the test stimuli were often closer, louder, and more frequent than would be likely for a normal training situation.

Manci, et al. (1988), noted that a female northern harrier was observed hunting on a bombing range in Mississippi during bombing exercises. The harrier was apparently unfazed by the exercises, even when a bomb exploded within 200 feet. In a similar case of habituation/non-disturbance, a study on the Florida snail-kite stated the greatest reaction to overflights (approximately 98 dBA) was "watching the aircraft fly by." No detrimental impacts to distribution, breeding success, or behavior were noted.

Bald Eagle

A study by Grubb and King (1991) on the reactions of the bald eagle to human disturbances showed that terrestrial disturbances elicited the greatest response, followed by aquatic (i.e., boats) and aerial disturbances. The disturbance regime of the area where the study occurred was predominantly characterized by aircraft noise. The study found that pedestrians consistently caused responses that were greater in both frequency and duration. Helicopters elicited the highest level of aircraft-related responses. Aircraft disturbances, although the most common form of disturbance, resulted in the lowest levels of response. This low response level may have been due to habituation; however, flights less than 170 meters away caused reactions similar to other disturbance types. Ellis, et al. (1991), showed that eagles typically respond to the proximity of a disturbance, such as a pedestrian or aircraft within 100 meters, rather than the noise level. Fleischner and Weisberg (1986) stated that reactions of bald eagles to commercial jet flights, although minor (e.g., looking), were twice as likely to occur when the jets passed at a distance of 0.5 mile or less. They also noted that helicopters were four times more likely to cause a reaction than a commercial jet and 20 times more likely to cause a reaction than a propeller plane.

The USFWS advised Cannon AFB that flights at or below 2,000 feet AGL from October 1 through March 1 could result in adverse impacts to wintering bald eagles (U.S. Fish and Wildlife Serice 1998). However, Fraser, et al. (1985), suggested that raptors habituate to overflights rapidly, sometimes tolerating aircraft approaches of 65 feet or less.

Osprey

A study by Trimper, et al. (1998), in Goose Bay, Labrador, Canada, focused on the reactions of nesting osprey to military overflights by CF-18 Hornets. Reactions varied from increased alertness and focused observation of planes to adjustments in incubation posture. No overt reactions (e.g., startle response, rapid nest departure) were observed as a result of an overflight. Young nestlings crouched as a result of any disturbance until they grew to 1 to 2 weeks prior to fledging. Helicopters, human presence, float planes, and other ospreys elicited the strongest reactions from nesting ospreys. These responses included flushing, agitation, and aggressive displays. Adult osprey showed high nest occupancy rates during incubation regardless of external influences.

The osprey observed occasionally stared in the direction of the flight before it was audible to the observers. The birds may have been habituated to the noise of the flights; however, overflights were strictly controlled during the experimental period. Strong reactions to float planes and helicopter may have been due to the slower flight and therefore longer duration of visual stimuli rather than noise-related stimuli.

Red-tailed Hawk

Anderson, et al. (1989), conducted a study that investigated the effects of low-level helicopter overflights on 35 red-tailed hawk nests. Some of the nests had not been flown over prior to the study.

The hawks that were naïve (i.e., not previously exposed) to helicopter flights exhibited stronger avoidance behavior (nine of 17 birds flushed from their nests) than those that had experienced prior overflights. The overflights did not appear to affect nesting success in either study group. These findings were consistent with the belief that red-tailed hawks habituate to low-level air traffic, even during the nesting period.

A.3.8.2.2.2 MIGRATORY WATERFOWL

A study of caged American black ducks was conducted by Fleming, et al., in 1996. It was determined that noise had negligible energetic and physiologic effects on adult waterfowl. Measurements included body weight, behavior, heart rate, and enzymatic activity. Experiments also showed that adult ducks exposed to high noise events acclimated rapidly and showed no effects.

The study also investigated the reproductive success of captive ducks, which indicated that duckling growth and survival rates at Piney Island, North Carolina, were lower than those at a background location. In contrast, observations of several other reproductive indices (i.e., pair formation, nesting, egg production, and hatching success) showed no difference between Piney Island and the background location. Potential effects on wild duck populations may vary, as wild ducks at Piney Island have presumably acclimated to aircraft overflights. It was not demonstrated that noise was the cause of adverse impacts. A variety of other factors, such as weather conditions, drinking water and food availability and variability, disease, and natural variability in reproduction, could explain the observed effects. Fleming noted that drinking water conditions (particularly at Piney Island) deteriorated during the study, which could have affected the growth of young ducks. Further research would be necessary to determine the cause of any reproductive effects.

Another study by Conomy, et al. (1998) exposed previously unexposed ducks to 71 noise events per day that equaled or exceeded 80 dBA. It was determined that the proportion of time black ducks reacted to aircraft activity and noise decreased from 38 percent to 6 percent in 17 days and remained stable at 5.8 percent thereafter. In the same study, the wood duck did not appear to habituate to aircraft disturbance. This supports the notion that animal response to aircraft noise is species-specific. Because a startle response to aircraft noise can result in flushing from nests, migrants and animals living in areas with high concentrations of predators would be the most vulnerable to experiencing effects of lowered birth rates and recruitment over time. Species that are subjected to infrequent overflights do not appear to habituate to overflight disturbance as readily.

Black brant studied in the Alaska Peninsula were exposed to jets and propeller aircraft, helicopters, gunshots, people, boats, and various raptors. Jets accounted for 65% of all the disturbances. Humans, eagles, and boats caused a greater percentage of brant to take flight. There was markedly greater reaction to Bell-206-B helicopter flights than fixed wing, single-engine aircraft (Ward, et al. 1986).

The presence of humans and low-flying helicopters in the Mackenzie Valley North Slope area did not appear to affect the population density of Lapland longspurs, but the experimental group was shown to have reduced hatching and fledging success and higher nest abandonment. Human presence appeared to have a greater impact on the incubating behavior of the black brant, common eider, and Arctic tern than fixed-wing aircraft (Gunn and Livingston 1974).

Gunn and Livingston (1974) found that waterfowl and seabirds in the Mackenzie Valley and North Slope of Alaska and Canada became acclimated to float plane disturbance over the course of three days. Additionally, it was observed that potential predators (bald eagle) caused a number of birds to

leave their nests. Non-breeding birds were observed to be more reactive than breeding birds. Waterfowl were affected by helicopter flights, while snow geese were disturbed by Cessna 185 flights. The geese flushed when the planes were under 1,000 feet, compared to higher flight elevations. An overall reduction in flock sizes was observed. It was recommended that aircraft flights be reduced in the vicinity of premigratory staging areas.

Manci, et al. 1988 reported that waterfowl were particularly disturbed by aircraft noise. The most sensitive appeared to be snow geese. Canada geese and snow geese were thought to be more sensitive than other animals such as turkey vultures, coyotes, and raptors (Edwards, et al. 1979).

A.3.8.2.2.3 WADING AND SHORE BIRDS

Black, et al. (1984), studied the effects of low-altitude (less than 500 feet AGL) military training flights with sound levels from 55 to 100 dBA on wading bird colonies (i.e., great egret, snowy egret, tricolored heron, and little blue heron). The training flights involved three or four aircraft, which occurred once or twice per day. This study concluded that the reproductive activity--including nest success, nestling survival, and nestling chronology--was independent of F-16 overflights. Dependent variables were more strongly related to ecological factors, including location and physical characteristics of the colony and climatology. Another study on the effects of circling fixed-wing aircraft and helicopter overflights on wading bird colonies found that at altitudes of 195 to 390 feet, there was no reaction in nearly 75% of the 220 observations. Ninety percent displayed no reaction or merely looked toward the direction of the noise source. Another 6 percent stood up, 3 percent walked from the nest, and 2 percent flushed (but were without active nests) and returned within 5 minutes (Kushlan 1978). Apparently, non-nesting wading birds had a slightly higher incidence of reacting to overflights than nesting birds. Seagulls observed roosting near a colony of wading birds in another study remained at their roosts when subsonic aircraft flew overhead (Burger 1981). Colony distribution appeared to be most directly correlated to available wetland community types and was found to be distributed randomly with respect to military training routes. These results suggest that wading bird species presence was most closely linked to habitat availability and that they were not affected by low-level military overflights (U.S. Air Force 2000).

Burger (1986) studied the response of migrating shorebirds to human disturbance and found that shorebirds did not fly in response to aircraft overflights, but did flush in response to more localized intrusions (i.e., humans and dogs on the beach). Burger (1981) studied the effects of noise from JFK Airport in New York on herring gulls that nested less than 1 kilometer from the airport. Noise levels over the nesting colony were 85 to 100 dBA on approach and 94 to 105 dBA on takeoff. Generally, there did not appear to be any prominent adverse effects of subsonic aircraft on nesting, although some birds flushed when the concorde flew overhead and, when they returned, engaged in aggressive behavior. Groups of gulls tended to loaf in the area of the nesting colony, and these birds remained at the roost when the concorde flew overhead. Up to 208 of the loafing gulls flew when supersonic aircraft flew overhead. These birds would circle around and immediately land in the loafing flock (U.S. Air Force 2000).

In 1969, sonic booms were potentially linked to a mass hatch failure of Sooty Terns on the Dry Tortugas (Austin et al, 1969). The cause of the failure was not certain, but it was conjectured that sonic booms from military aircraft or an overgrowth of vegetation were factors. In the previous season, Sooties were observed to react to sonic booms by rising in a “panic flight,” circling over the island, then usually settling down on their eggs again. Hatching that year was normal. Following the 1969

hatch failure, excess vegetation was cleared and measures were taken to reduce supersonic activity. The 1970 hatch appeared to proceed normally. A colony of Noddies on the same island hatched successfully in 1969, the year of the Sooty hatch failure.

Subsequent laboratory tests of exposure of eggs to sonic booms and other impulsive noises (Bowles et al 1991; Bowles et al 1994; Cottereau 1972; Cogger and Zegarra 1980) failed to show adverse effects on hatching of eggs. A structural analysis (Ting et al, 2002) showed that, even under extraordinary circumstances, sonic booms would not damage an avian egg.

Burger (1981) observed no effects of subsonic aircraft on herring gulls in the vicinity of JFK International Airport. The concorde aircraft did cause more nesting gulls to leave their nests (especially in areas of higher density of nests), causing the breakage of eggs and the scavenging of eggs by intruder prey. Clutch sizes were observed to be smaller in areas of higher-density nesting (presumably due to the greater tendency for panic flight) than in areas where there were fewer nests.

A.3.8.3 Fish, Reptiles, and Amphibians

The effects of overflight noise on fish, reptiles, and amphibians have been poorly studied, but conclusions regarding their expected responses have involved speculation based upon known physiologies and behavioral traits of these taxa (Gladwin, et al. 1988). Although fish do startle in response to low-flying aircraft noise, and probably to the shadows of aircraft, they have been found to habituate to the sound and overflights. Reptiles and amphibians that respond to low frequencies and those that respond to ground vibration, such as spadefoots (genus Scaphiopus), may be affected by noise. Limited information is available on the effects of short-duration noise events on reptiles. Dufour (1980) and Manci, et al. (1988), summarized a few studies of reptile responses to noise. Some reptile species tested under laboratory conditions experienced at least temporary threshold shifts or hearing loss after exposure to 95 dB for several minutes. Crocodilians in general have the most highly developed hearing of all reptiles. Crocodile ears have lids that can be closed when the animal goes under water. These lids can reduce the noise intensity by 10 to 12 dB (Wever and Vernon 1957). On Homestead Air Reserve Station, Florida, two crocodilians (the American Alligator and the Spectacled Caiman) reside in wetlands and canals along the base runway suggesting that they can coexist with existing noise levels of an active runway including DNLs of 85 dB.

A.3.8.4 Summary

Some physiological/behavioral responses such as increased hormonal production, increased heart rate, and reduction in milk production have been described in a small percentage of studies. A majority of the studies focusing on these types of effects have reported short-term or no effects.

The relationships between physiological effects and how species interact with their environments have not been thoroughly studied. Therefore, the larger ecological context issues regarding physiological effects of jet aircraft noise (if any) and resulting behavioral pattern changes are not well understood.

Animal species exhibit a wide variety of responses to noise. It is therefore difficult to generalize animal responses to noise disturbances or to draw inferences across species, as reactions to jet aircraft noise appear to be species-specific. Consequently, some animal species may be more sensitive than other species and/or may exhibit different forms or intensities of behavioral responses. For instance, wood ducks appear to be more sensitive and more resistant to acclimation to jet aircraft noise than

Canada geese in one study. Similarly, wild ungulates seem to be more easily disturbed than domestic animals.

The literature does suggest that common responses include the "startle" or "fright" response and, ultimately, habituation. It has been reported that the intensities and durations of the startle response decrease with the numbers and frequencies of exposures, suggesting no long-term adverse effects. The majority of the literature suggests that domestic animal species (cows, horses, chickens) and wildlife species exhibit adaptation, acclimation, and habituation after repeated exposure to jet aircraft noise and sonic booms.

Animal responses to aircraft noise appear to be somewhat dependent on, or influenced by, the size, shape, speed, proximity (vertical and horizontal), engine noise, color, and flight profile of planes. Helicopters also appear to induce greater intensities and durations of disturbance behavior as compared to fixed-wing aircraft. Some studies showed that animals that had been previously exposed to jet aircraft noise exhibited greater degrees of alarm and disturbance to other objects creating noise, such as boats, people, and objects blowing across the landscape. Other factors influencing response to jet aircraft noise may include wind direction, speed, and local air turbulence; landscape structures (i.e., amount and type of vegetative cover); and, in the case of bird species, whether the animals are in the incubation/nesting phase.

A.3.9 Property Values

Property within a noise zone (or Accident Potential Zone) may be affected by the availability of federally guaranteed loans. According to U.S. Department of Housing and Urban Development (HUD), Federal Housing Administration (FHA), and Veterans Administration (VA) guidance, sites are acceptable for program assistance, subsidy, or insurance for housing in noise zones of less than 65 DNL, and sites are conditionally acceptable with special approvals and noise attenuation in the 65 to 75 DNL noise zone and the greater than 75 DNL noise zone. HUD's position is that noise is not the only determining factor for site acceptability, and properties should not be rejected only because of airport influences if there is evidence of acceptability within the market and if use of the dwelling is expected to continue. Similar to the Navy's and Air Force's Air Installation Compatible Use Zone Program, HUD, FHA, and VA recommend sound attenuation for housing in the higher noise zones and written disclosures to all prospective buyers or lessees of property within a noise zone (or Accident Potential Zone).

Newman and Beattie (1985) reviewed the literature to assess the effect of aircraft noise on property values. One paper by Nelson (1978), reviewed by Newman and Beattie, suggested a 1.8 to 2.3 percent decrease in property value per decibel at three separate airports, while at another period of time, they found only a 0.8 percent devaluation per decibel change in DNL. However, Nelson also noted a decline in noise depreciation over time which he theorized could be due to either noise sensitive people being replaced by less sensitive people or the increase in commerical value of the property near airports; both ideas were supported by Crowley (1978). Ultimately, Newman and Beattie summarized that while an effect of noise was observed, noise is only one of the many factors that is part of a decision to move close to, or away from, an airport, but which is sometimes considered an advantage due to increased opportunities for employment or ready access to the airport itself. With all the issues associated with determining property values, their reviews found that decreases in property values usually range from 0.5 to 2 percent per decibel increase of cumulative noise exposure.

More recently Fidell et al (1996) studied the influences of aircraft noise on actual sale prices of residential properties in the vicinity of two military facilities and found that equations developed for one area to predict residential sale prices in areas unaffected by aircraft noise worked equally well when applied to predicting sale prices of homes in areas with aircraft noise in excess of LDN 65dB. Thus, the model worked equally well in predicting sale prices in areas with and without aircraft noise exposure. This indicates that aircraft noise had no meaningful effect on residential property values. In some cases, the average sale prices of noise exposed properties were somewhat higher than those elsewhere in the same area. In the vicinity of Davis-Monthan AFB/Tucson, AZ, Fidell found the homes near the airbase were much older, smaller and in poorer condition than homes elsewhere. These factors caused the equations developed for predicting sale prices in areas further away from the base to be inapplicable with those nearer the base. However, again Fidell found that, similar to other researchers, differences in sale prices between homes with and without aircraft noise were frequently due to factors other than noise itself.

A.3.10 Noise Effects on Structures

Normally, the most sensitive components of a structure to airborne noise are the windows and, infrequently, the plastered walls and ceilings. An evaluation of the peak sound pressures impinging on the structure is normally used to determine the possibility of damage. In general, with peak sound levels above 130 dB, there is the possibility of the excitation of structural component resonances. While certain frequencies (such as 30 hertz for window breakage) may be of more concern than other frequencies, conservatively, only sounds lasting more than one second above a sound level of 130 dB are potentially damaging to structural components (Committee on Hearing, Bioacoustics, and Biomechanics 1977).

Noise-induced structural vibration may also cause annoyance to dwelling occupants because of induced secondary vibrations, or rattling of objects within the dwelling such as hanging pictures, dishes, plaques, and bric-a-brac. Window panes may also vibrate noticeably when exposed to high levels of airborne noise. In general, such noise-induced vibrations occur at peak sound levels of 110 dB or greater. Thus, assessments of noise exposure levels for compatible land use should also be protective of noise-induced secondary vibrations.

A.3.11 Noise Effects on Terrain

It has been suggested that noise levels associated with low-flying aircraft may affect the terrain under the flight path by disturbing fragile soil or snow, especially in mountainous areas, causing landslides or avalanches. There are no known instances of such effects, and it is considered improbable that such effects would result from routine, subsonic aircraft operations.

A.3.12 Noise Effects on Historical and Archaeological Sites

Because of the potential for increased fragility of structural components of historical buildings and other historical sites, aircraft noise may affect such sites more severely than newer, modern structures. Particularly in older structures, seemingly insignificant surface cracks initiated by vibrations from aircraft noise may lead to greater damage from natural forces (Hanson, et al. 1991). There are few scientific studies of such effects to provide guidance for their assessment.

One study involved the measurements of sound levels and structural vibration levels in a superbly restored plantation house, originally built in 1795, and now situated approximately 1,500 feet from the

centerline at the departure end of Runway 19L at Washington Dulles International Airport. These measurements were made in connection with the proposed scheduled operation of the supersonic Concorde airplane at Dulles (Wesler 1977). There was special concern for the building's windows, since roughly half of the 324 panes were original. No instances of structural damage were found. Interestingly, despite the high levels of noise during Concorde takeoffs, the induced structural vibration levels were actually less than those induced by touring groups and vacuum cleaning.

As noted above for the noise effects of noise-induced vibrations of conventional structures, assessments of noise exposure levels for normally compatible land uses should also be protective of historic and archaeological sites.

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APPENDIX B

Maps of Modeled Flight Profiles

APPENDIX B
Maps of Modeled Flight Profiles

B.1 Flight Profiles for Existing Helipad....B-3

B.2 Flight Profiles for Temporary Helipad Location 1....B-10

B.3 Flight Profiles for Temporary Helipad Location 2....B-17

B.4 Flight Profiles for Alternative 3 Helipad Location....B-24

B.5 Flight Profiles for Alternative 6 Helipad Location....B-31

B.6 Flight Profiles for Alternative 7A Helipad Location....B-38

B.7 Flight Profiles for Alternative 7B Helipad Location....B-45

B.8 Flight Profiles for Alternative 7RA Helipad Location....B-52

B.9 Flight Profiles for Alternative 7RB Helipad Location....B-59

B.10 Flight Profiles for Alternative 8A Helipad Location....B-66

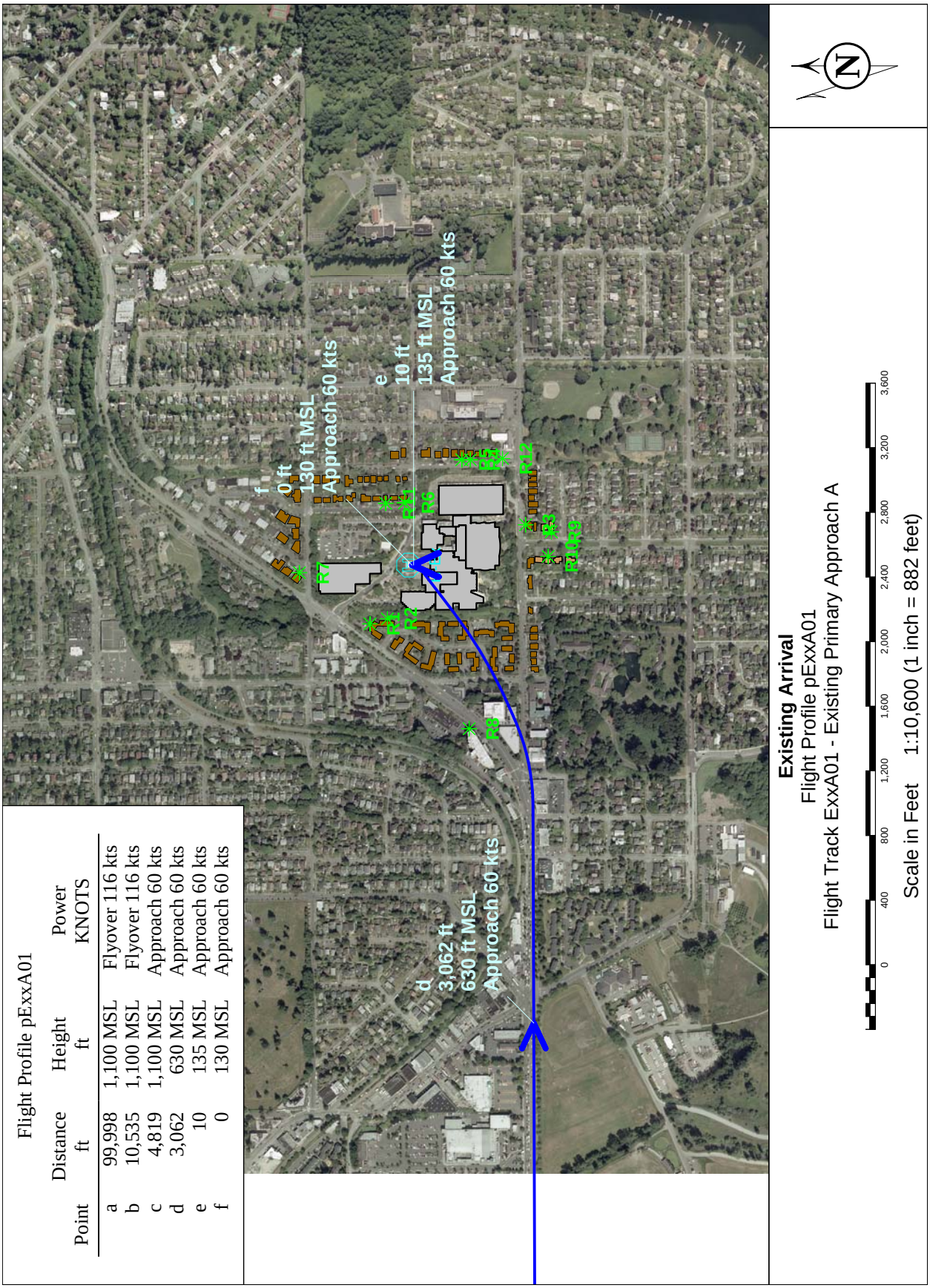
B.11 Flight Profiles for Alternative 8B Helipad Location....B-73

Table B1 – Pad Elevation Summary

Alternative	Pad	Pad Elevation (feet MSL)
Existing	H-Ex	130
Temporary 1	H-T1	150
Temporary 2	H-T2	105
Alternative 3	H-Pr	270
Alternative 6	HA6	266
Alternative 7	H7A	201
	H7B	182
Alternative 7R	H7RA	167
	H7RB	182
Alterive 8	H8A	167
	H8B	182

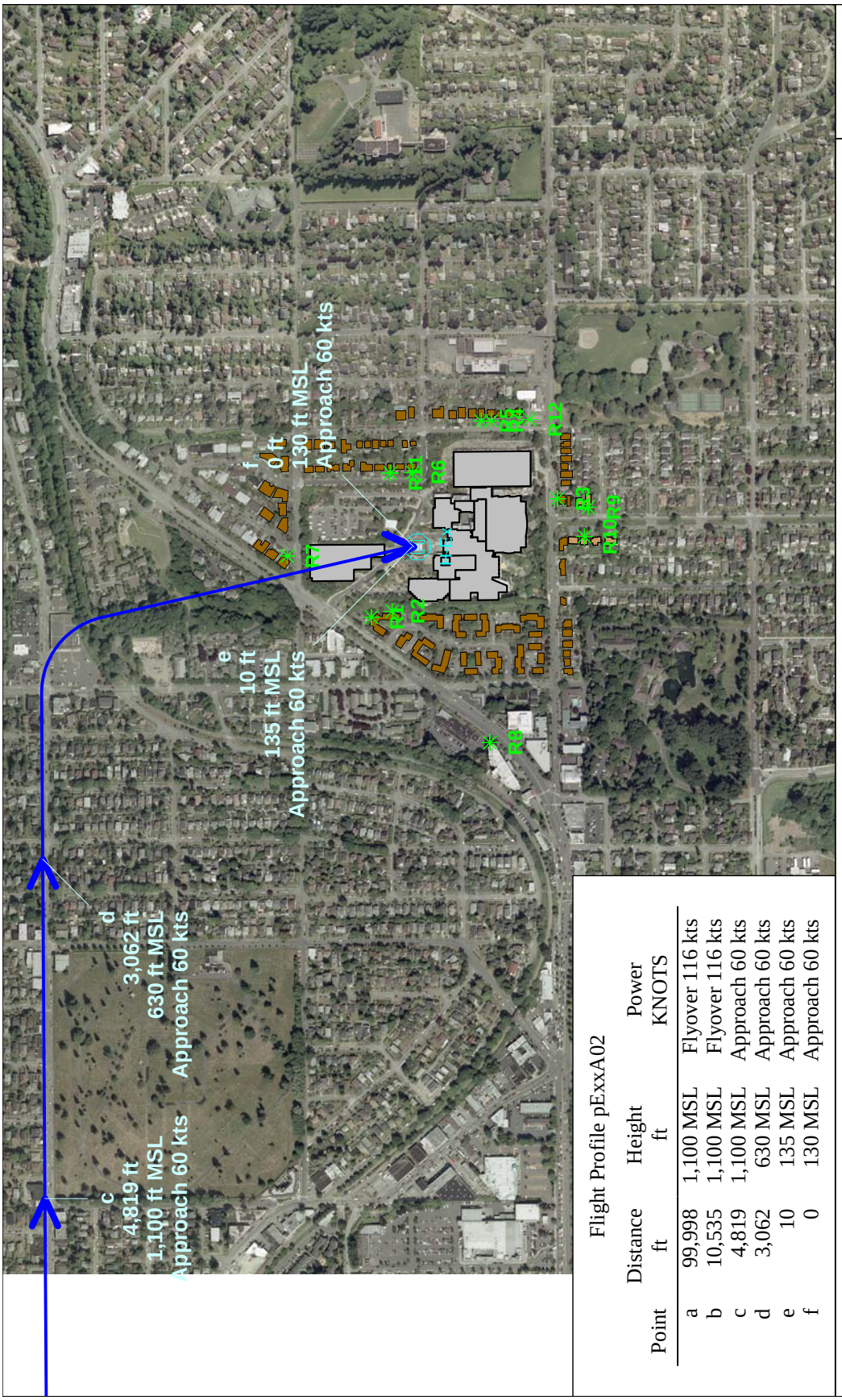
Note: MSL = Mean Sea Level

All profiles scenarios modeled an Augusta A109 Helocopter with an Allison 250-C20B engine.



Flight Profile pExxA01

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	630 MSL	Approach 60 kts
e	10	135 MSL	Approach 60 kts
f	0	130 MSL	Approach 60 kts

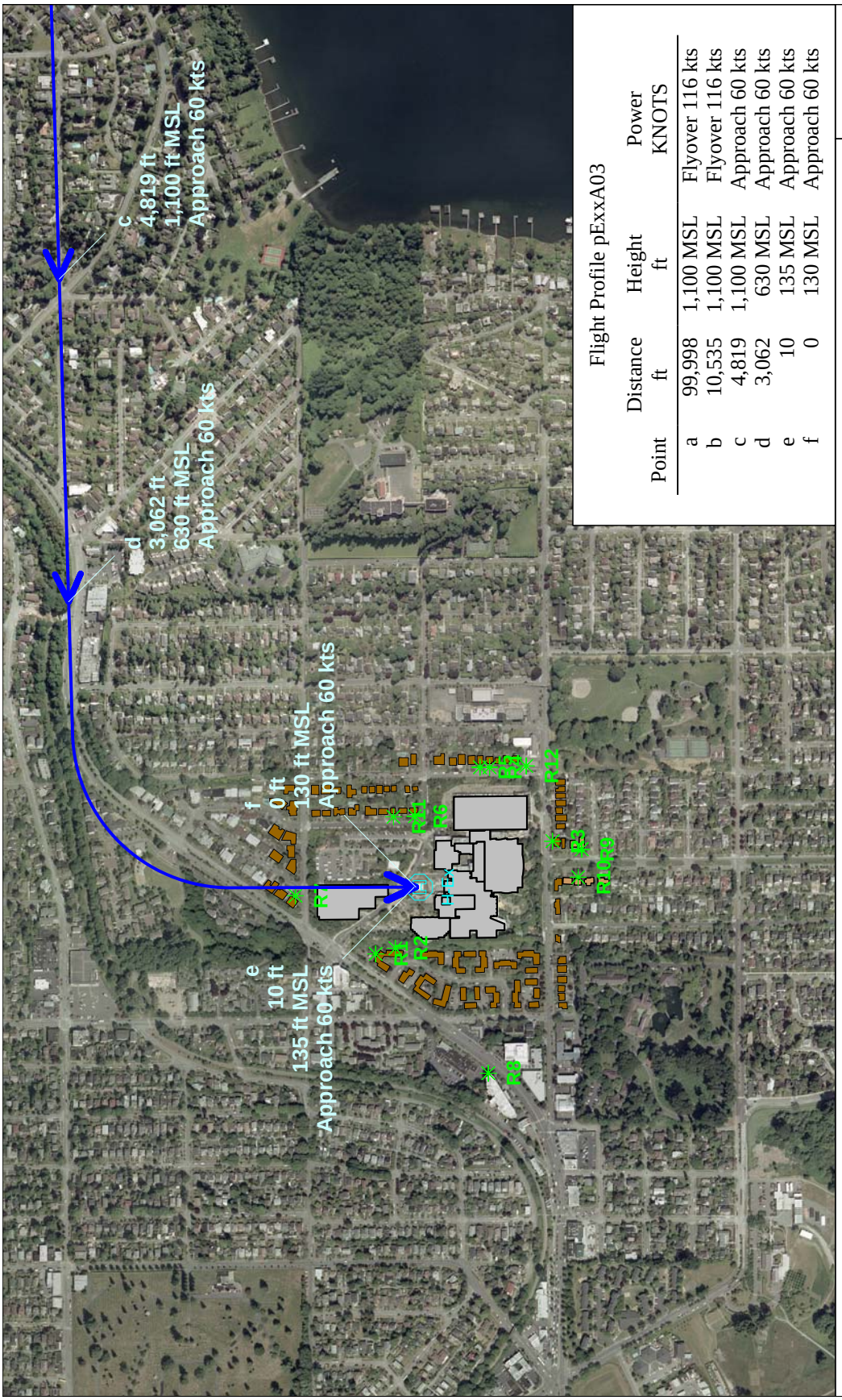


Flight Profile pExxA02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	630 MSL	Approach 60 kts
e	10	135 MSL	Approach 60 kts
f	0	130 MSL	Approach 60 kts

Existing Arrival
Flight Profile pExxA02
Flight Track ExxA02 - Existing Primary Approach B

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,620 (1 inch = 802 feet)

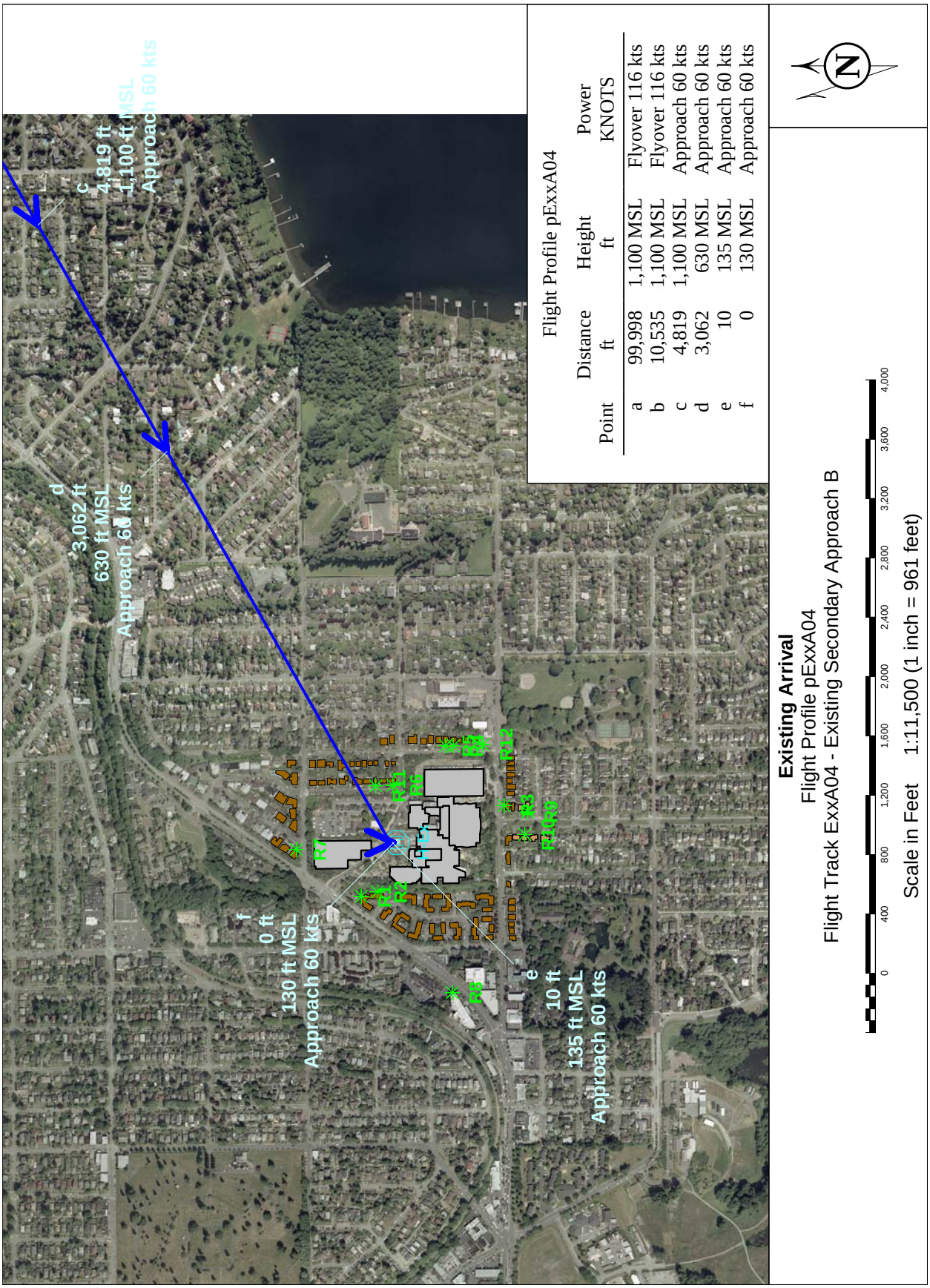


Flight Profile pExxA03

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	630 MSL	Approach 60 kts
e	10	135 MSL	Approach 60 kts
f	0	130 MSL	Approach 60 kts

Existing Arrival
Flight Profile pExxA03
Flight Track ExxA03 - Existing Secondary Approach A

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:10,100 (1 inch = 843 feet)

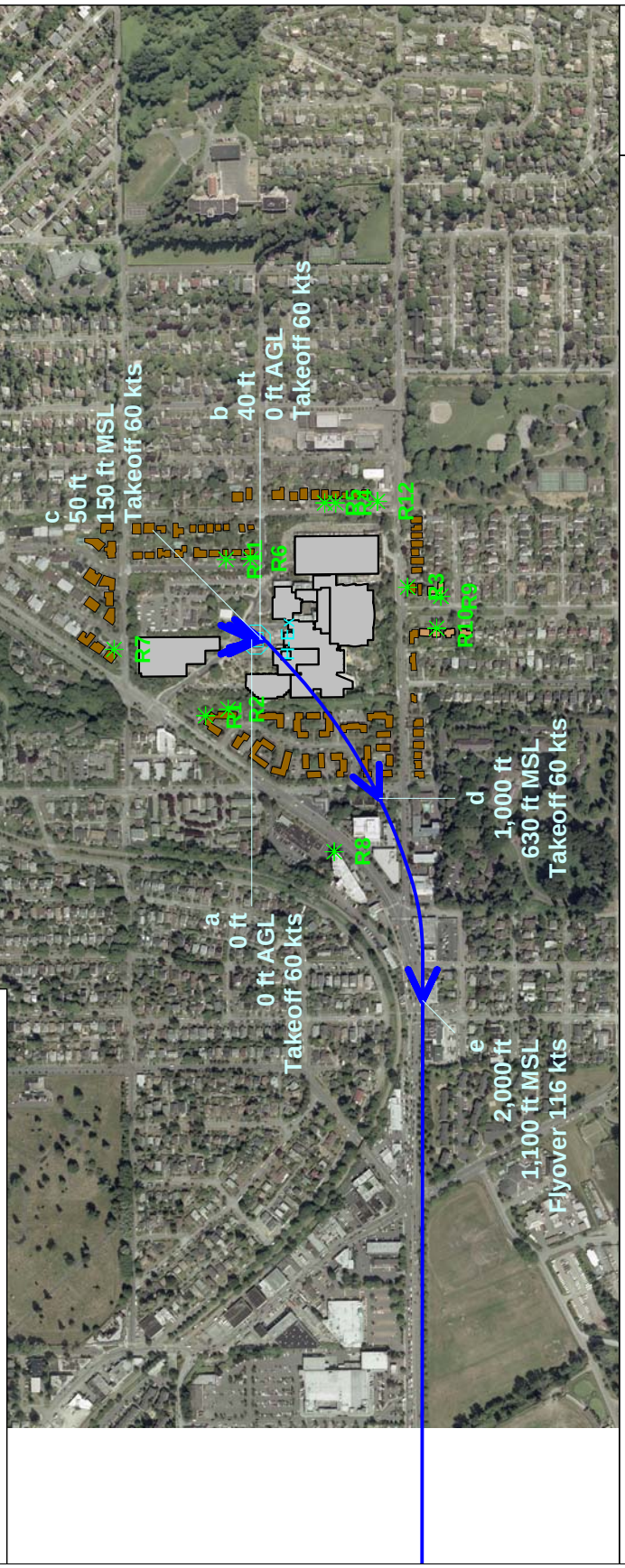


Flight Profile pExxA04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	630 MSL	Approach 60 kts
e	10	135 MSL	Approach 60 kts
f	0	130 MSL	Approach 60 kts

Flight Profile pExxD01

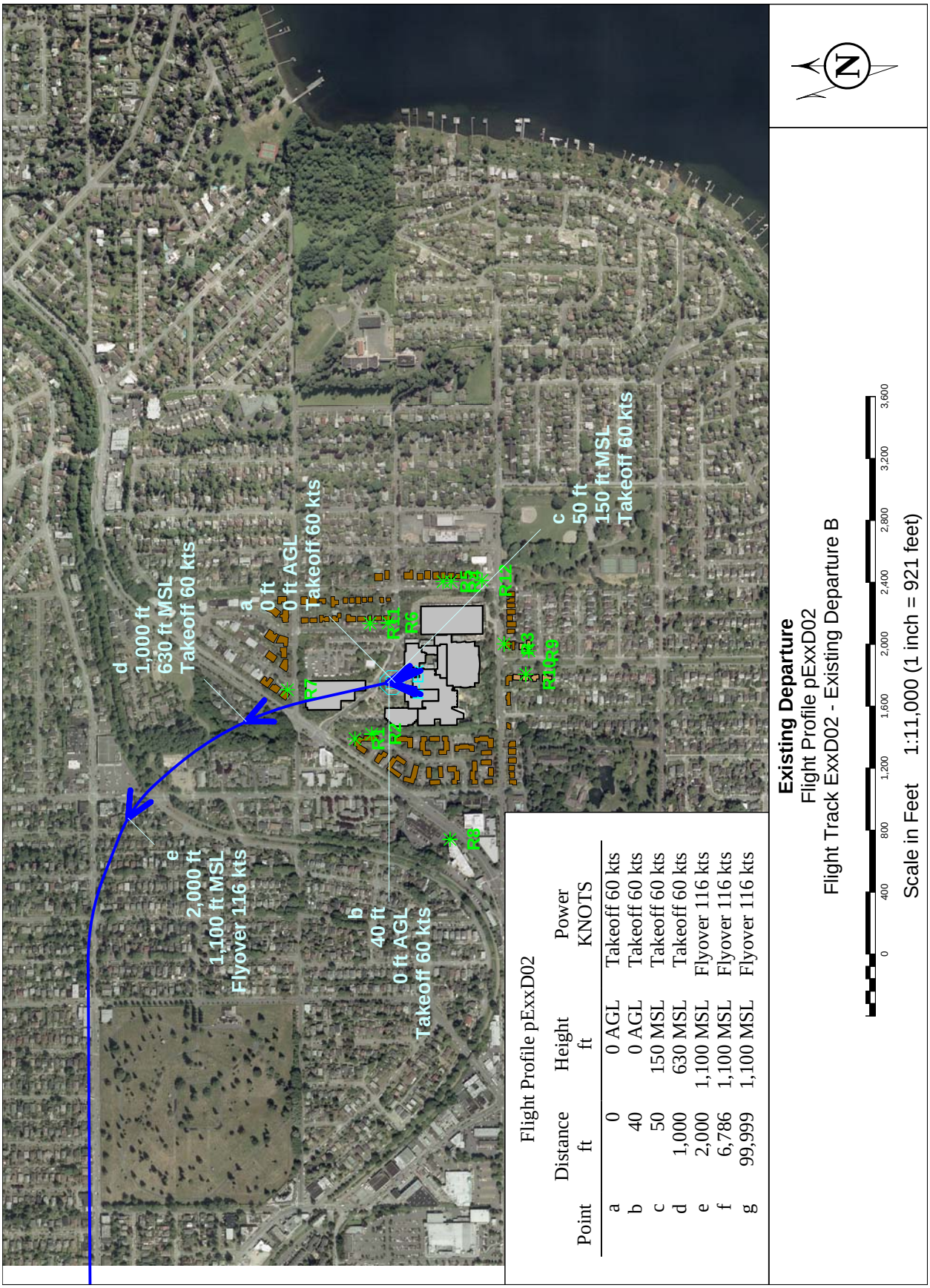
Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	150 MSL	Takeoff 60 kts
d	1,000	630 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



Existing Departure
Flight Profile pExxD01
Flight Track ExxD01 - Existing Departure A

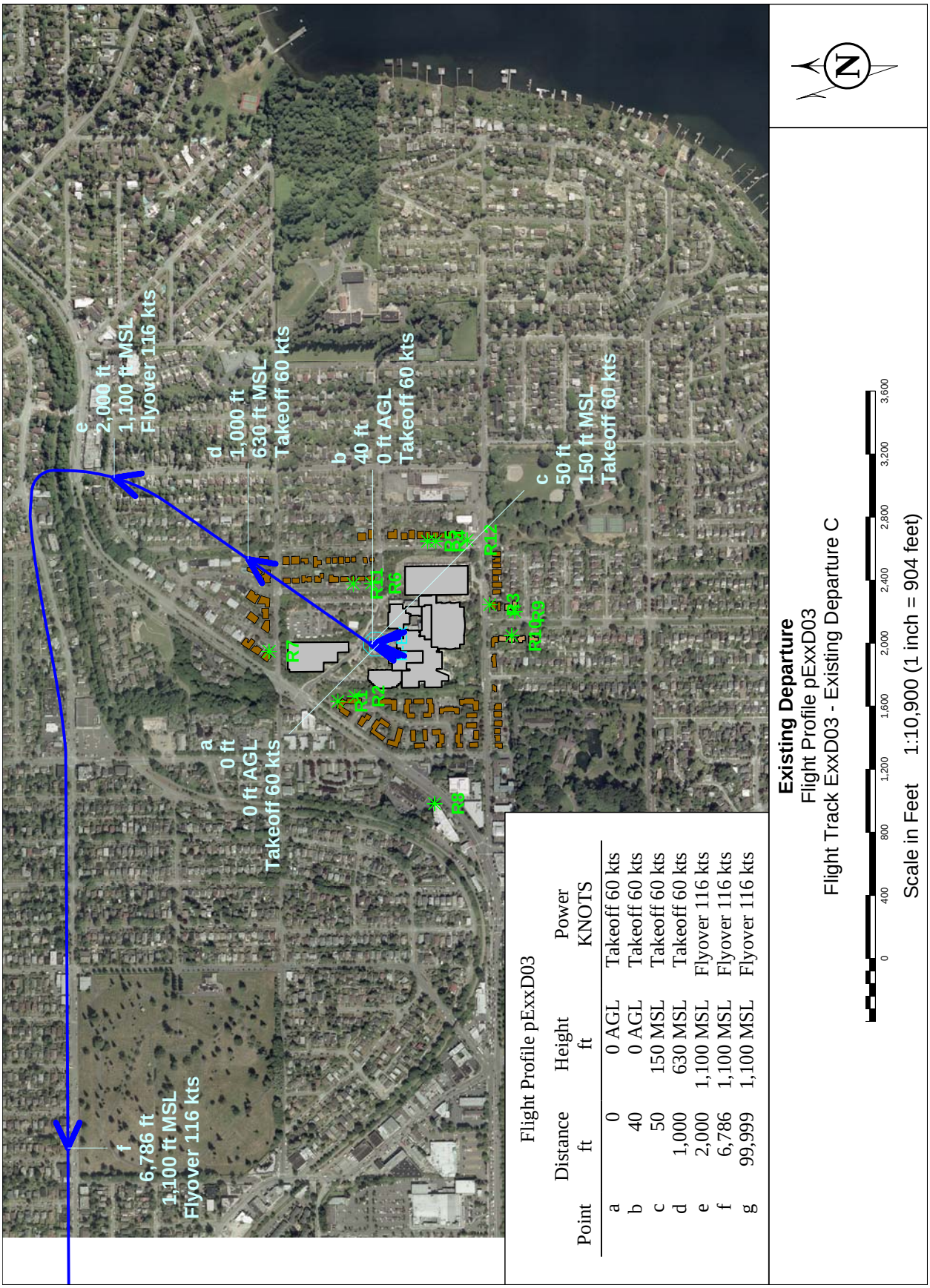
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

Scale in Feet 1:9,940 (1 inch = 828 feet)



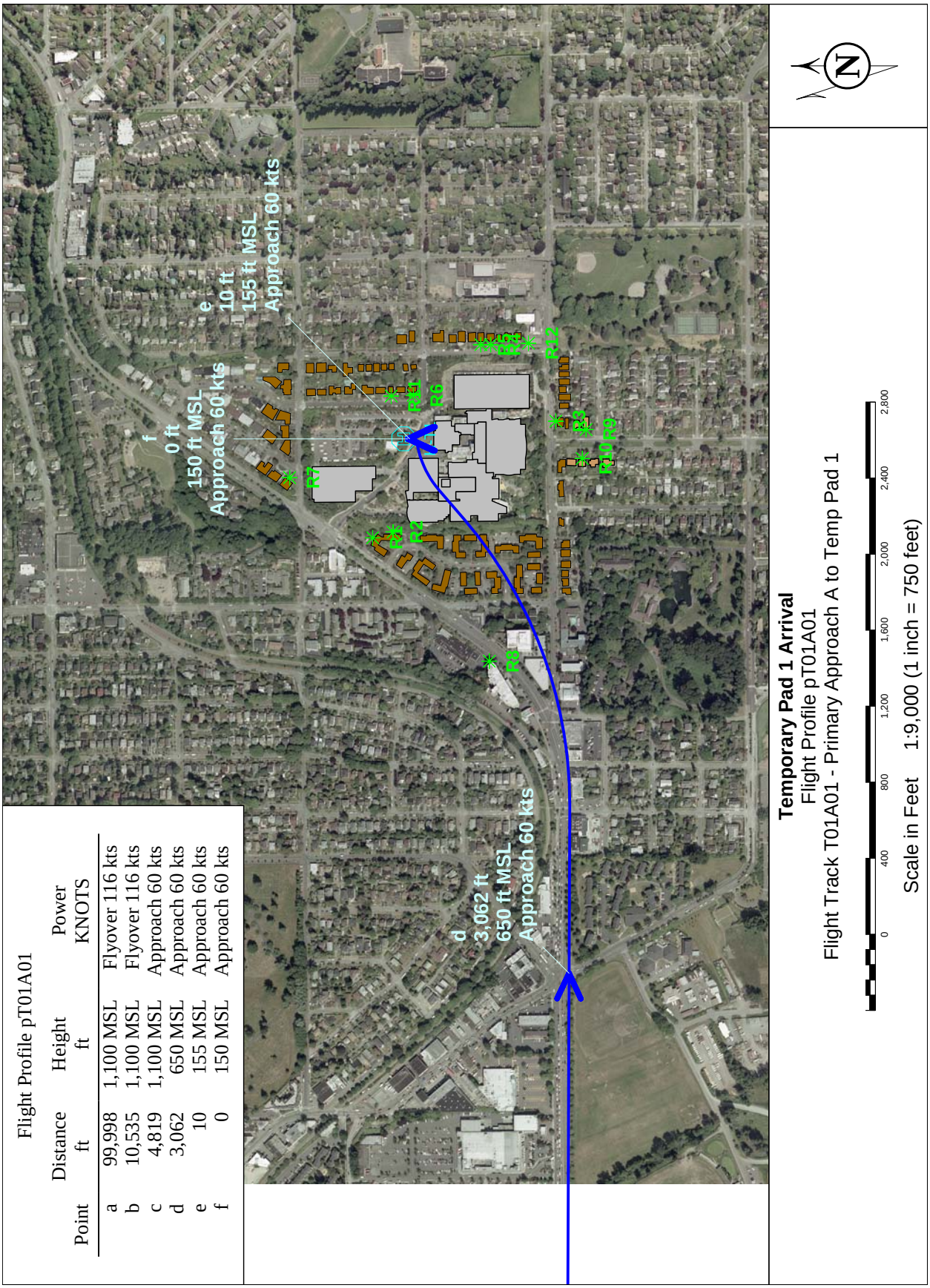
Flight Profile pExxD02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	150 MSL	Takeoff 60 kts
d	1,000	630 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



Flight Profile pExxD03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	150 MSL	Takeoff 60 kts
d	1,000	630 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

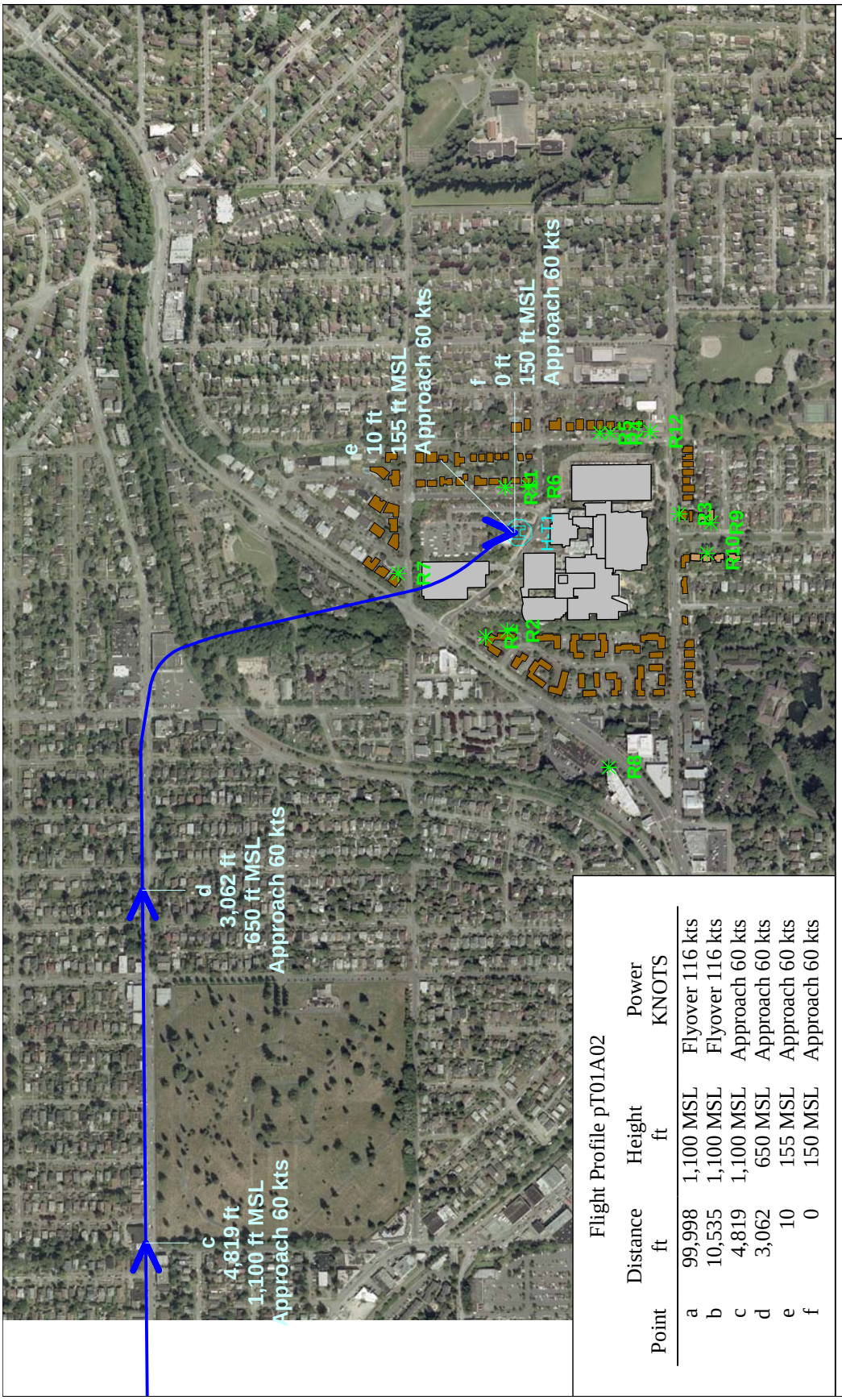


Flight Profile pT01A01

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	650 MSL	Approach 60 kts
e	10	155 MSL	Approach 60 kts
f	0	150 MSL	Approach 60 kts

Temporary Pad 1 Arrival
Flight Profile pT01A01
Flight Track T01A01 - Primary Approach A to Temp Pad 1

Scale in Feet 1:9,000 (1 inch = 750 feet)



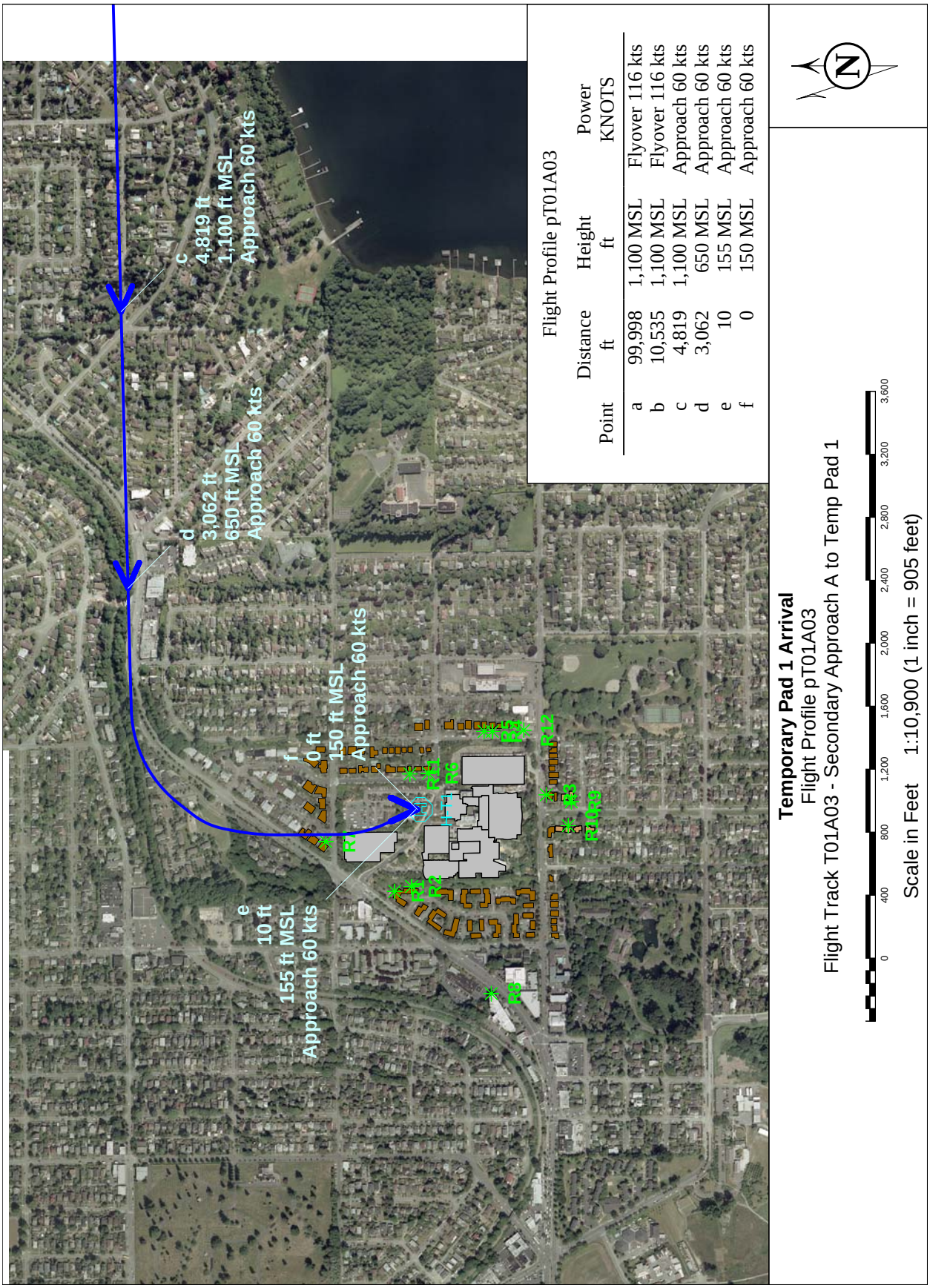
Flight Profile pT01A02

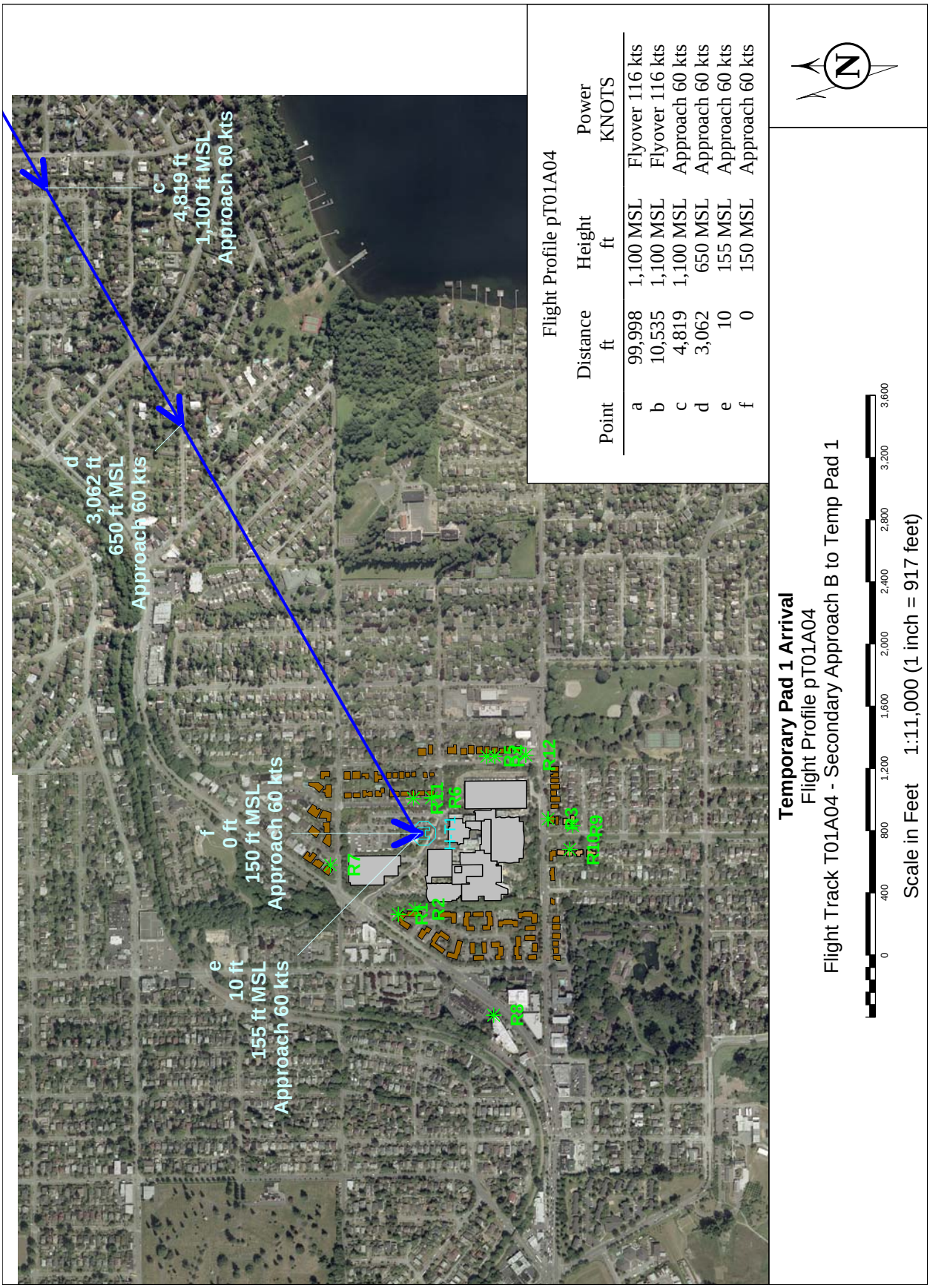
Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	650 MSL	Approach 60 kts
e	10	155 MSL	Approach 60 kts
f	0	150 MSL	Approach 60 kts

Temporary Pad 1 Arrival
Flight Profile pT01A02
Flight Track T01A02 - Primary Approach B to Temp Pad 1

0 400 800 1,200 1,600 2,000 2,400 2,800

Scale in Feet 1:9,260 (1 inch = 772 feet)


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
650 ft MSL
Approach 60 kts
f
0 ft
150 ft MSL
Approach 60 kts
e
10 ft
155 ft MSL
Approach 60 kts
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
Flight Profile pT01A03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 650 MSL | Approach 60 kts
e | 10 | 155 MSL | Approach 60 kts
f | 0 | 150 MSL | Approach 60 kts
N
Temporary Pad 1 Arrival
Flight Profile pT01A03
Flight Track T01A03 - Secondary Approach A to Temp Pad 1
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200 3,600
Scale in Feet 1:10,900 (1 inch = 905 feet)

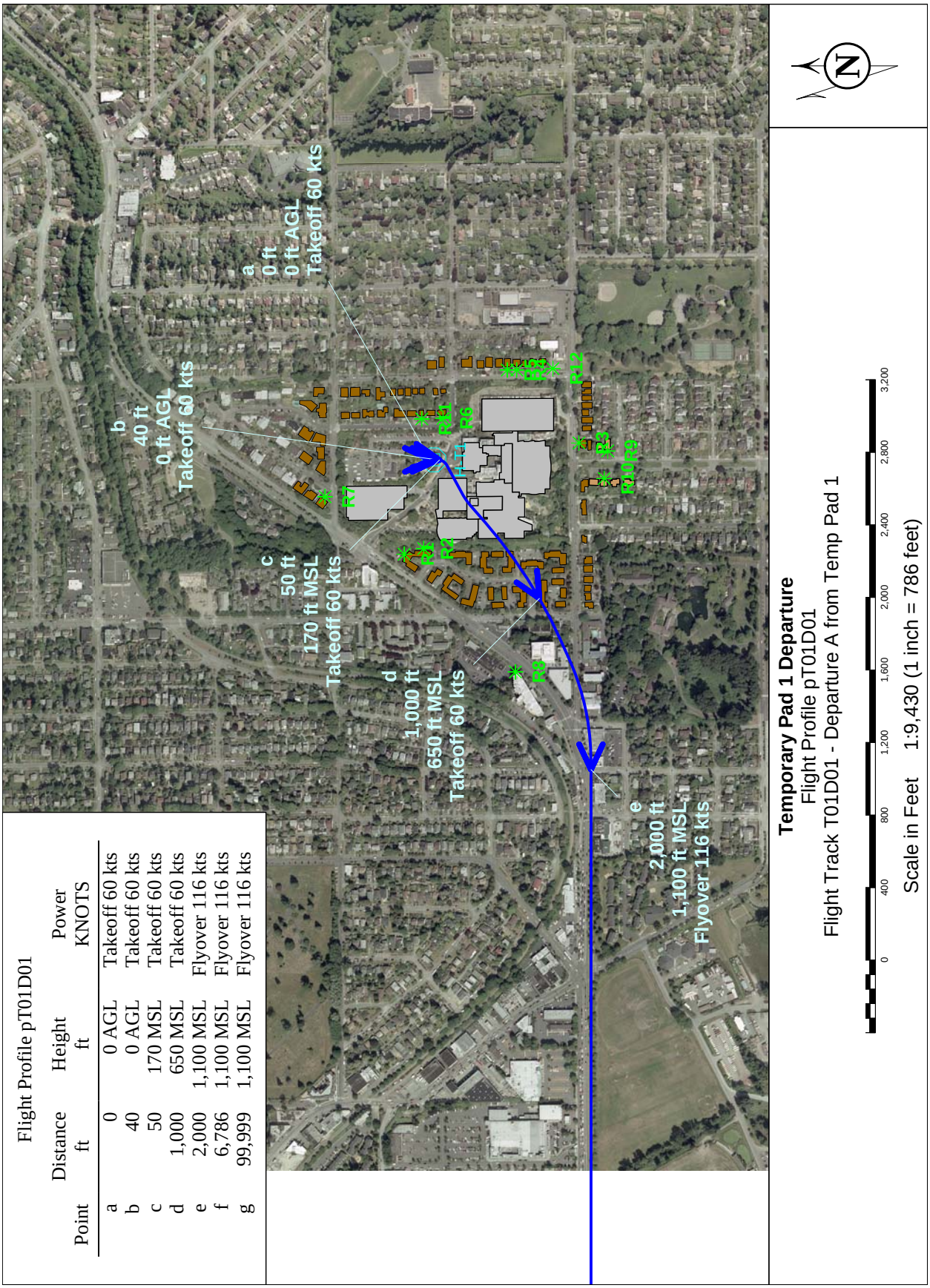


Flight Profile pT01A04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	650 MSL	Approach 60 kts
e	10	155 MSL	Approach 60 kts
f	0	150 MSL	Approach 60 kts

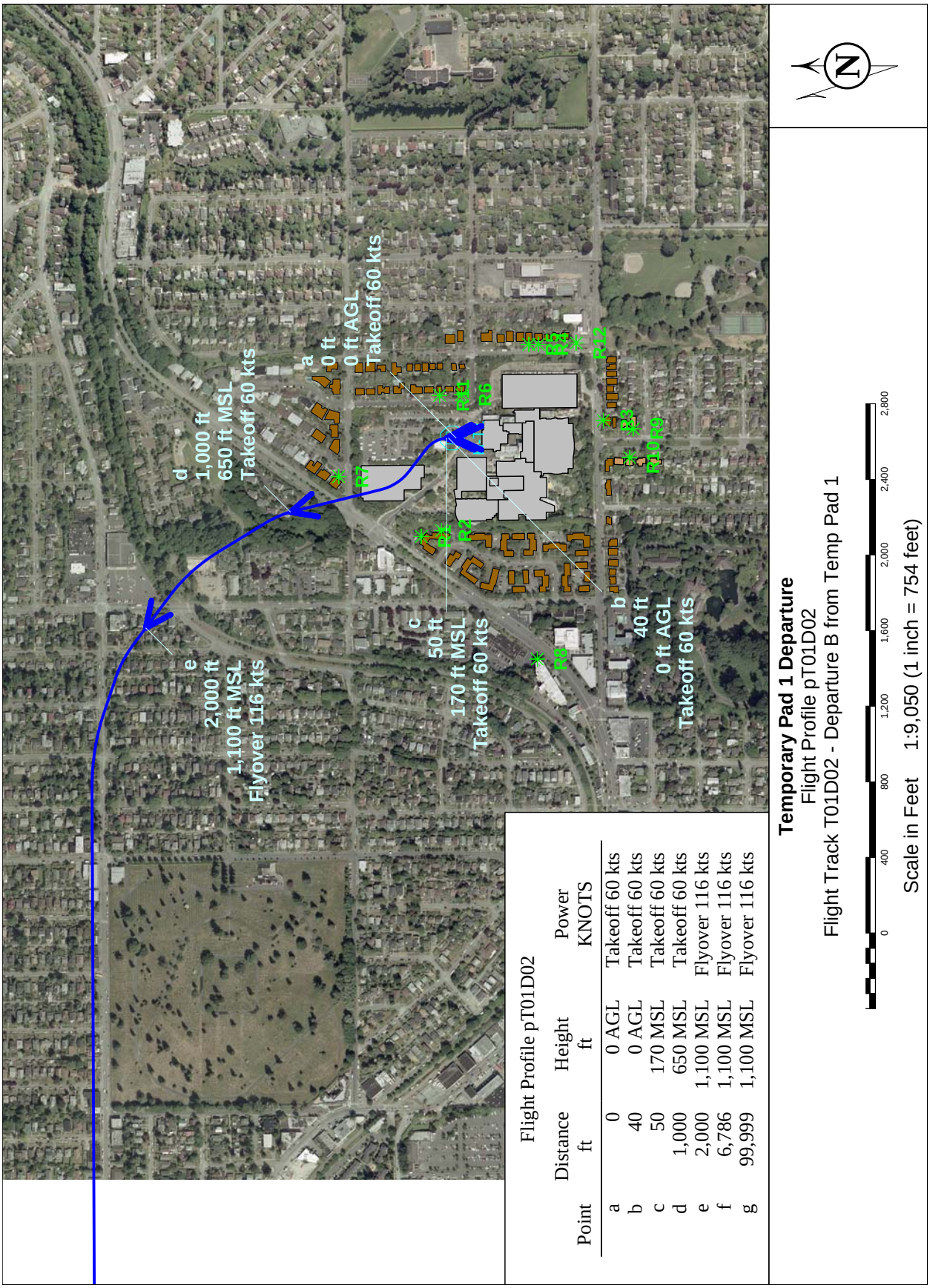
Temporary Pad 1 Arrival
Flight Profile pT01A04
Flight Track T01A04 - Secondary Approach B to Temp Pad 1

Scale in Feet 1:11,000 (1 inch = 917 feet)



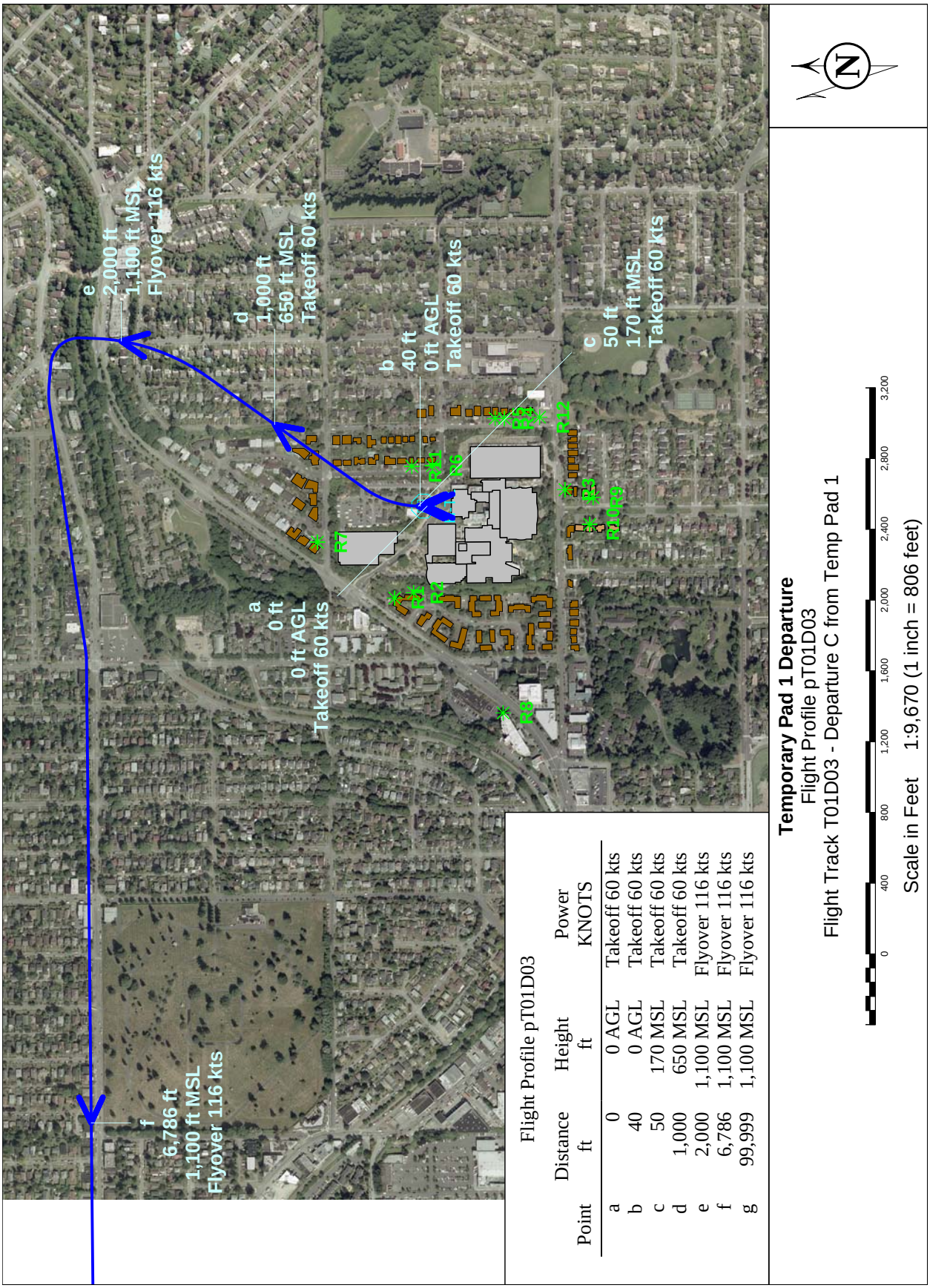
Flight Profile pT01D01

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	170 MSL	Takeoff 60 kts
d	1,000	650 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



Flight Profile pT01D02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	170 MSL	Takeoff 60 kts
d	1,000	650 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

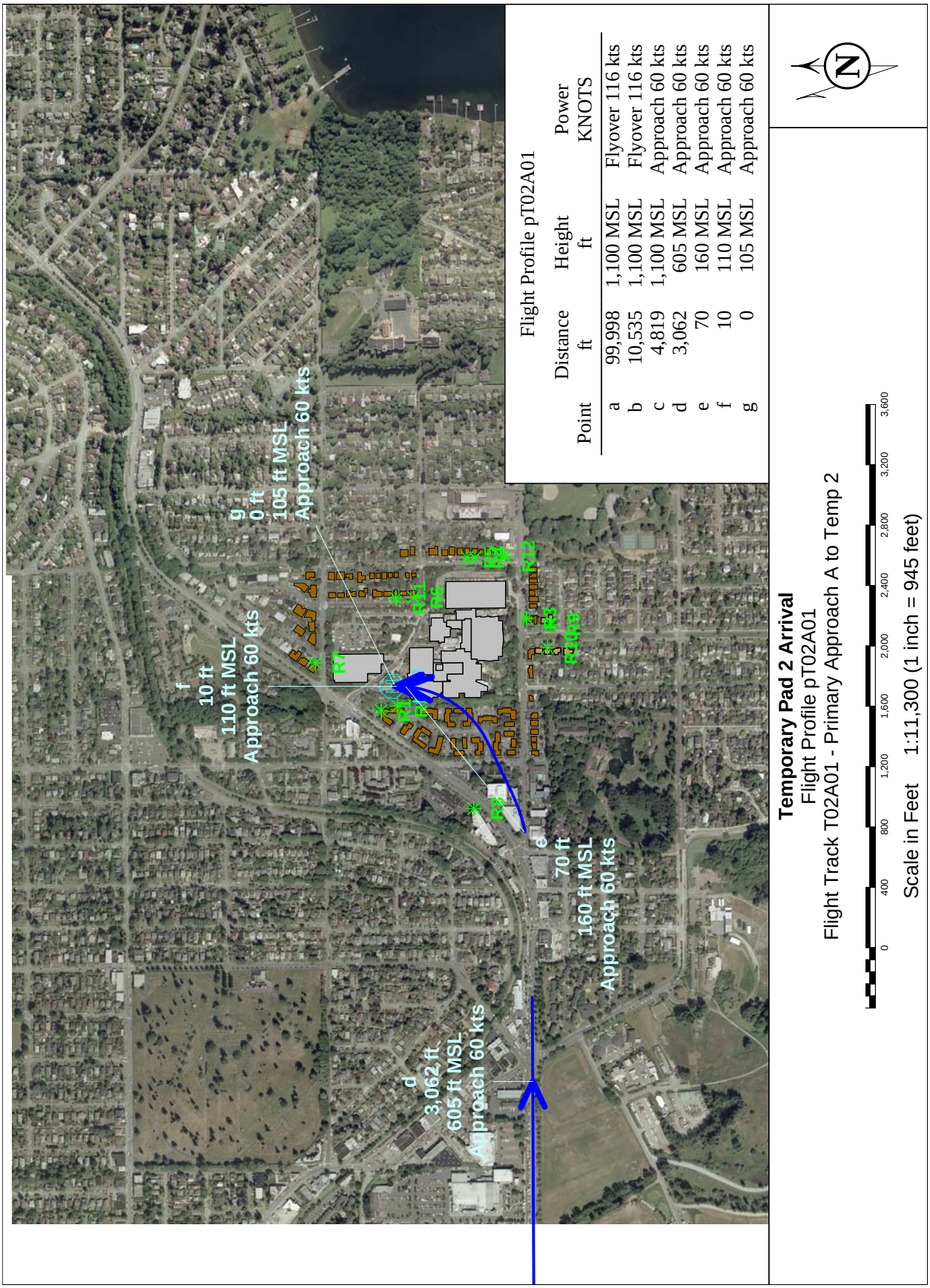


Flight Profile pT01D03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	170 MSL	Takeoff 60 kts
d	1,000	650 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

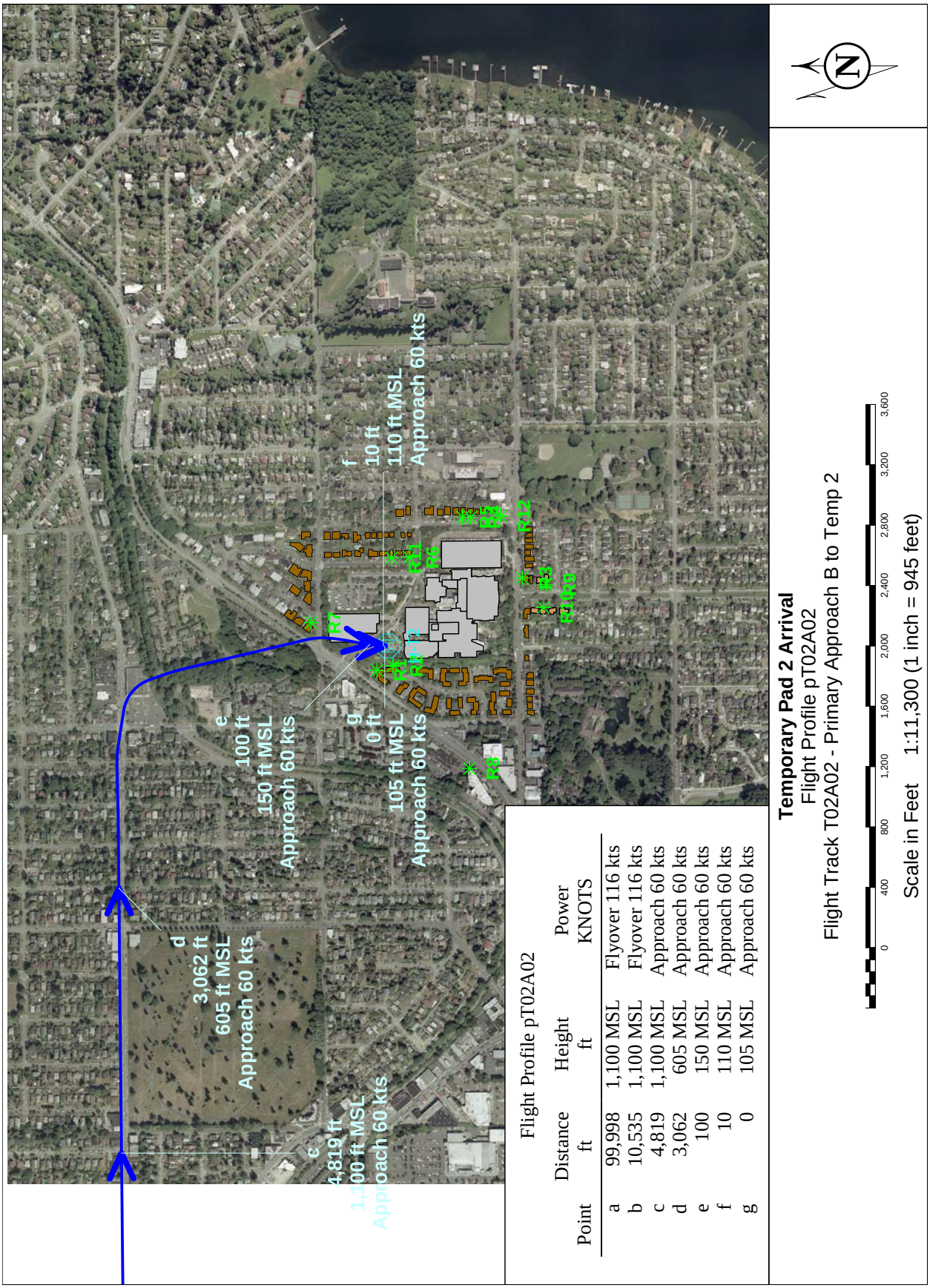
Temporary Pad 1 Departure
Flight Profile pT01D03
Flight Track T01D03 - Departure C from Temp Pad 1

Scale in Feet 1:9,670 (1 inch = 806 feet)



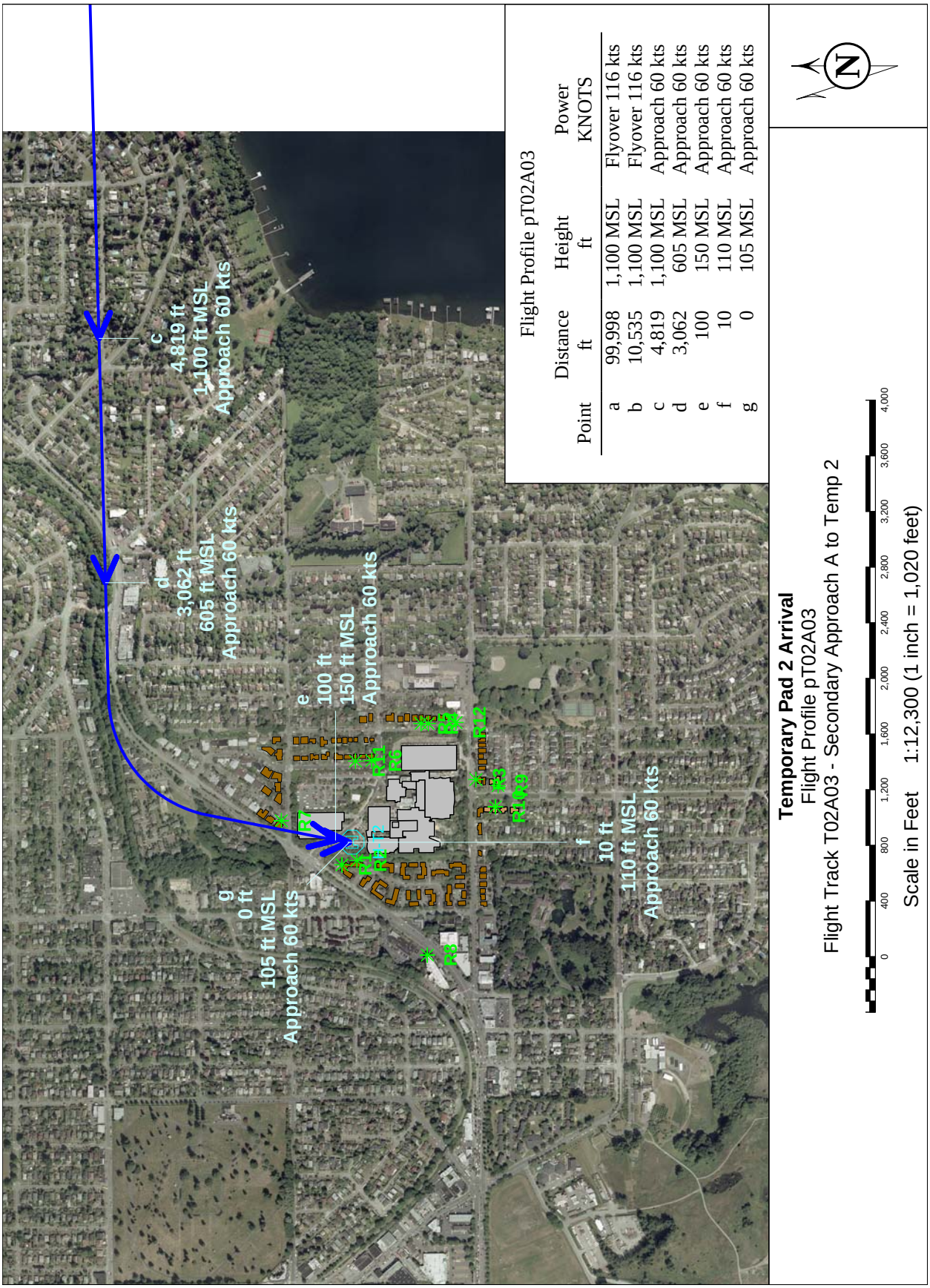
Flight Profile pT02A01

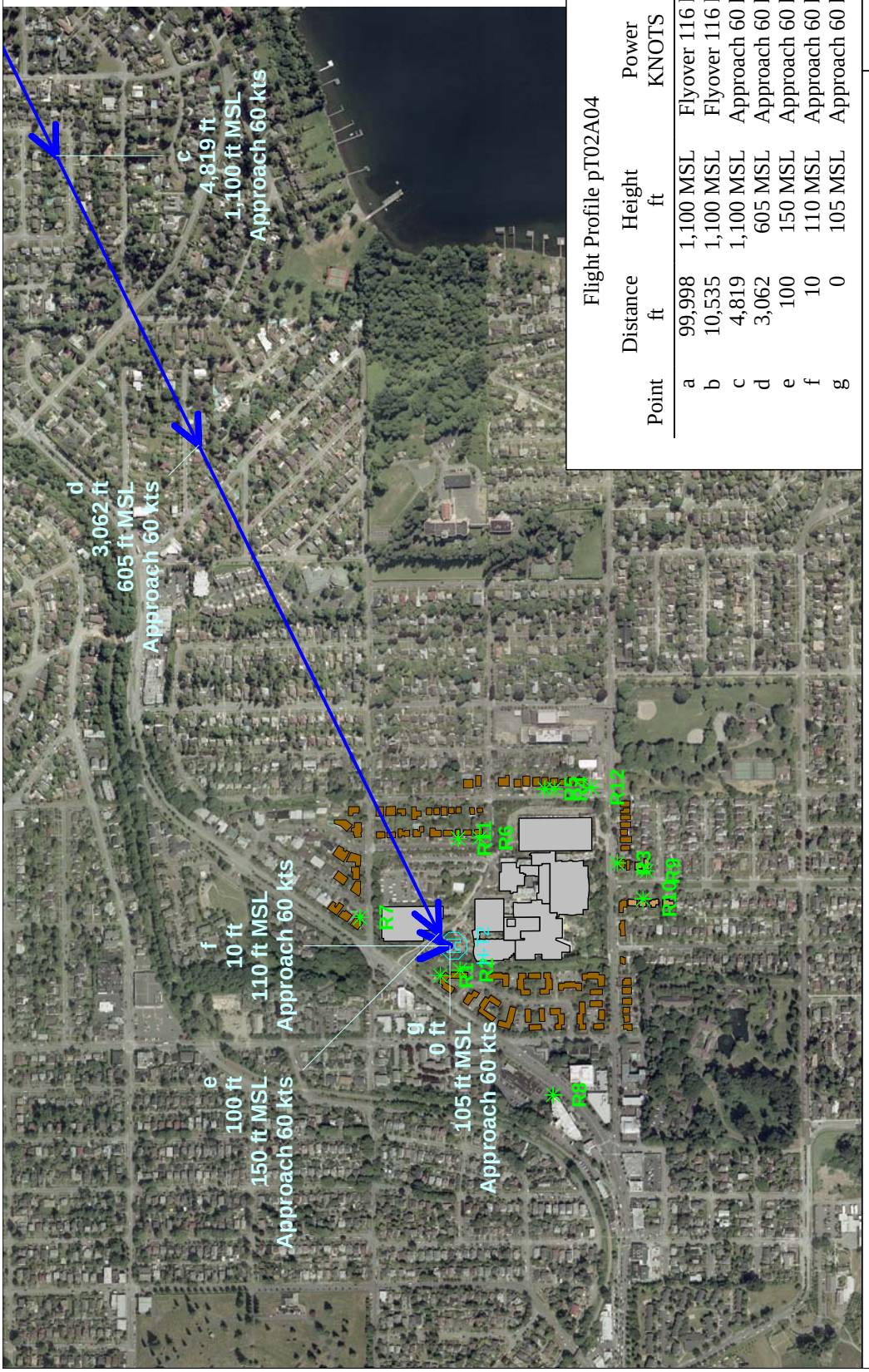
Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	605 MSL	Approach 60 kts
e	70	160 MSL	Approach 60 kts
f	10	110 MSL	Approach 60 kts
g	0	105 MSL	Approach 60 kts



Flight Profile pT02A02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	605 MSL	Approach 60 kts
e	100	150 MSL	Approach 60 kts
f	10	110 MSL	Approach 60 kts
g	0	105 MSL	Approach 60 kts


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
605 ft MSL
Approach 60 kts
e
100 ft
150 ft MSL
Approach 60 kts
g
0 ft
105 ft MSL
Approach 60 kts
f
10 ft
110 ft MSL
Approach 60 kts
R7
R1
R2
R4
R5
R6
R8
R9
R10
R11
R12
R13
Flight Profile pT02A03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 605 MSL | Approach 60 kts
e | 100 | 150 MSL | Approach 60 kts
f | 10 | 110 MSL | Approach 60 kts
g | 0 | 105 MSL | Approach 60 kts
N
Temporary Pad 2 Arrival
Flight Profile pT02A03
Flight Track T02A03 - Secondary Approach A to Temp 2
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200 3,600 4,000
Scale in Feet 1:12,300 (1 inch = 1,020 feet)



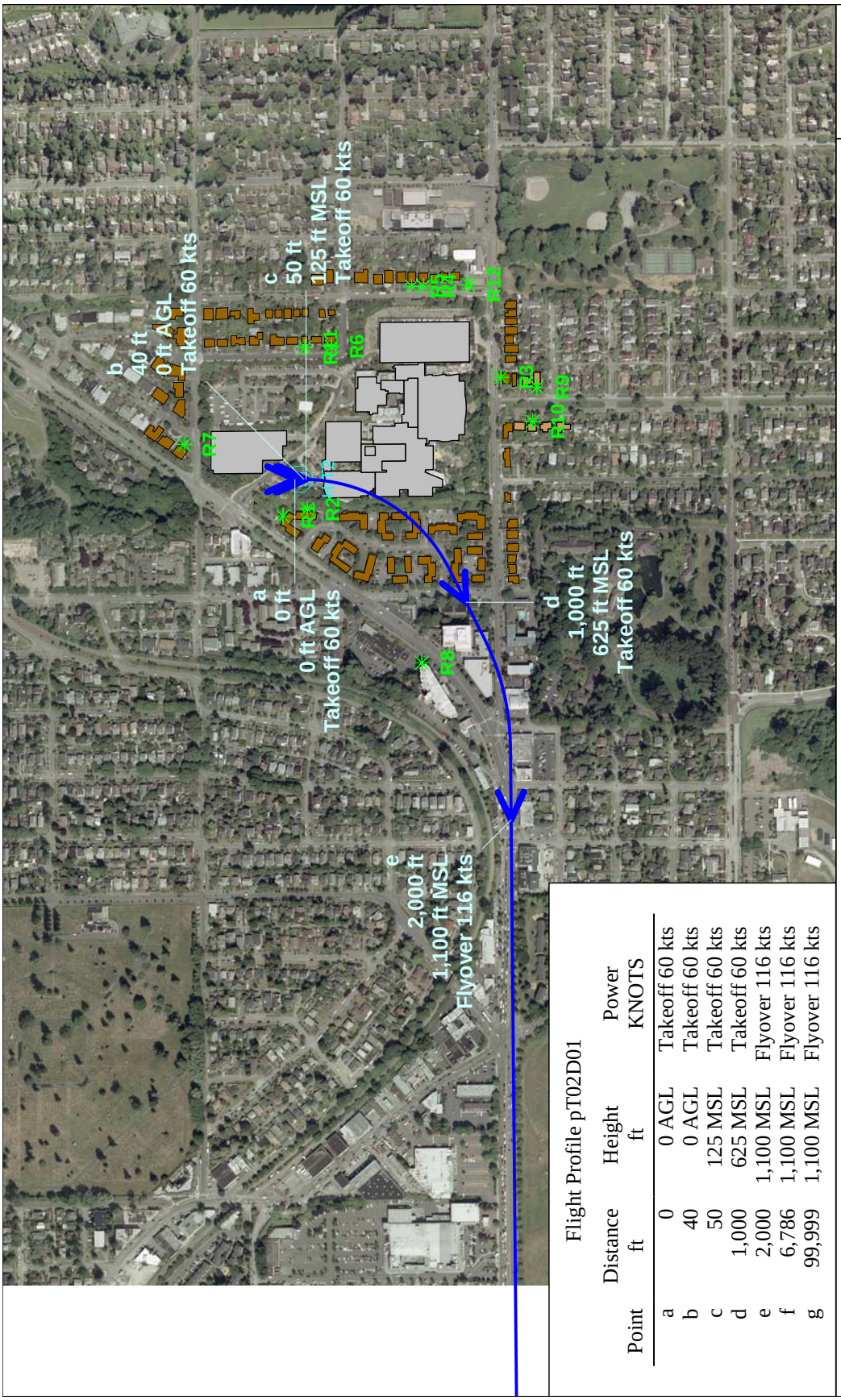
Flight Profile pT02A04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	605 MSL	Approach 60 kts
e	100	150 MSL	Approach 60 kts
f	10	110 MSL	Approach 60 kts
g	0	105 MSL	Approach 60 kts

Temporary Pad 2 Arrival
Flight Profile pT02A04
Flight Track T02A04 - Secondary Approach B to Temp 2

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200 3,600

Scale in Feet 1:10,400 (1 inch = 870 feet)



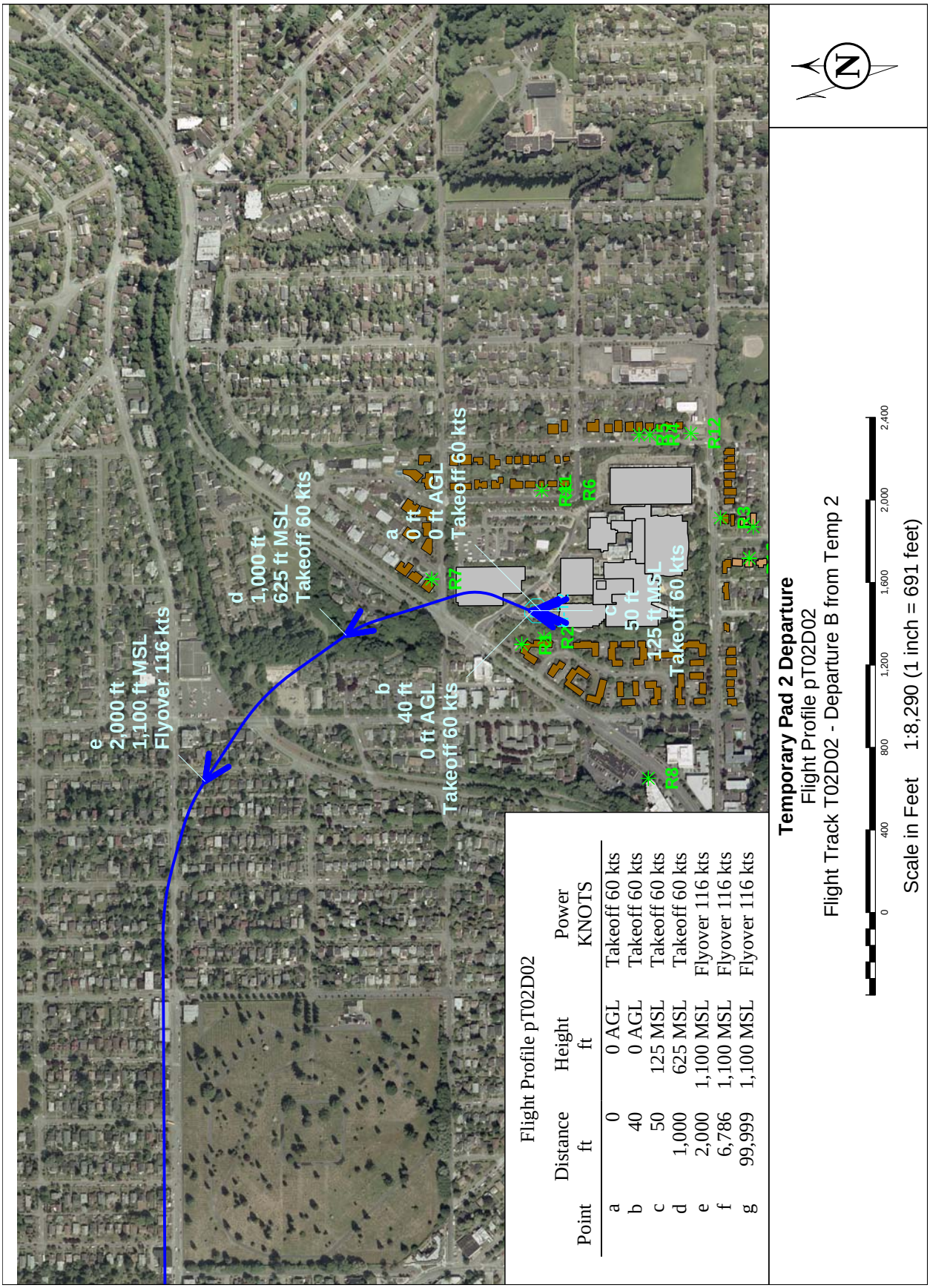
Flight Profile pT02D01

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	125 MSL	Takeoff 60 kts
d	1,000	625 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Temporary Pad 2 Departure
Flight Profile pT02D01
Flight Track T02D01 - Departure A from Temp 2

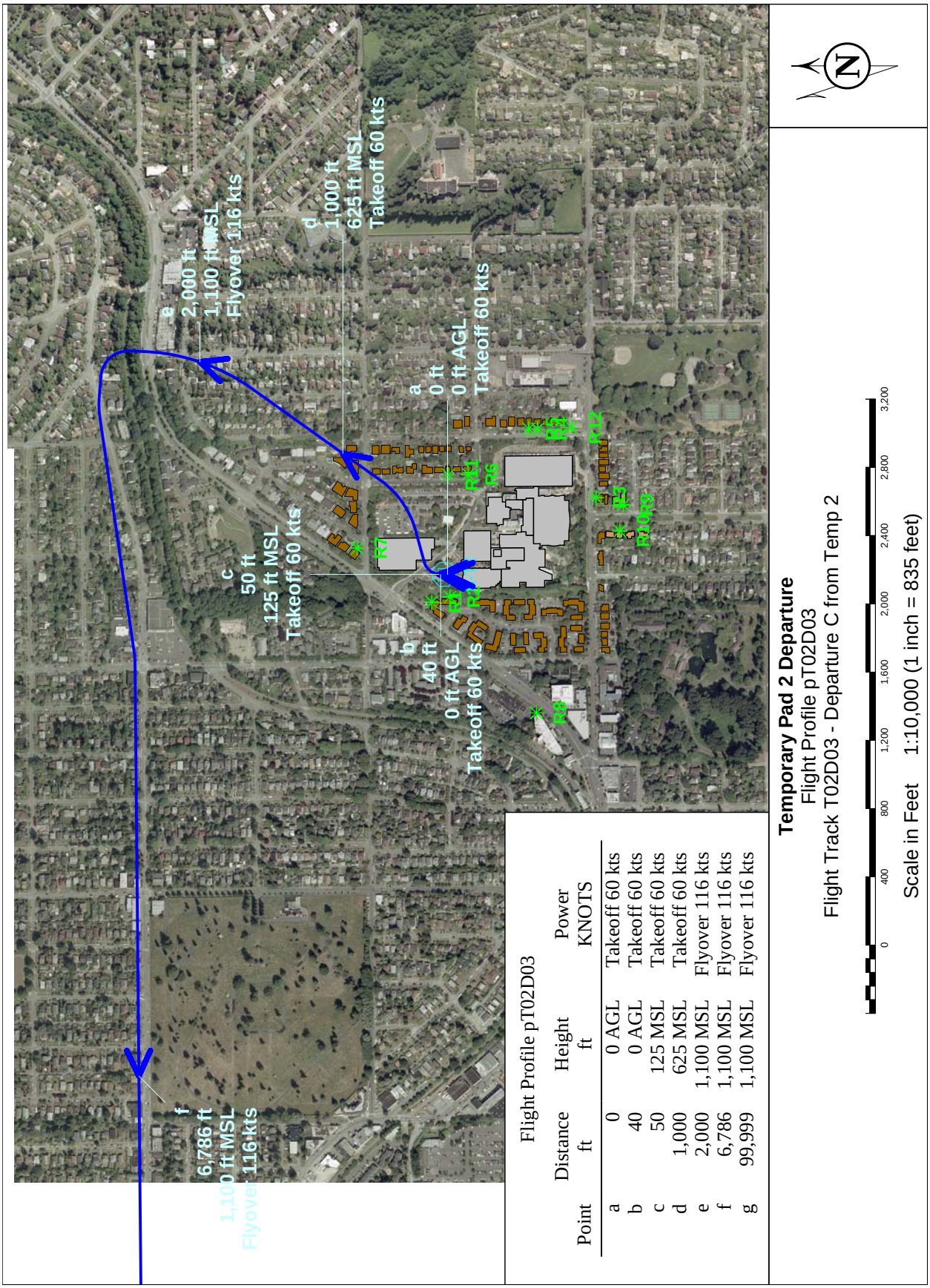
Scale in Feet 1:8,220 (1 inch = 685 feet)

0 400 800 1,200 1,600 2,000 2,400



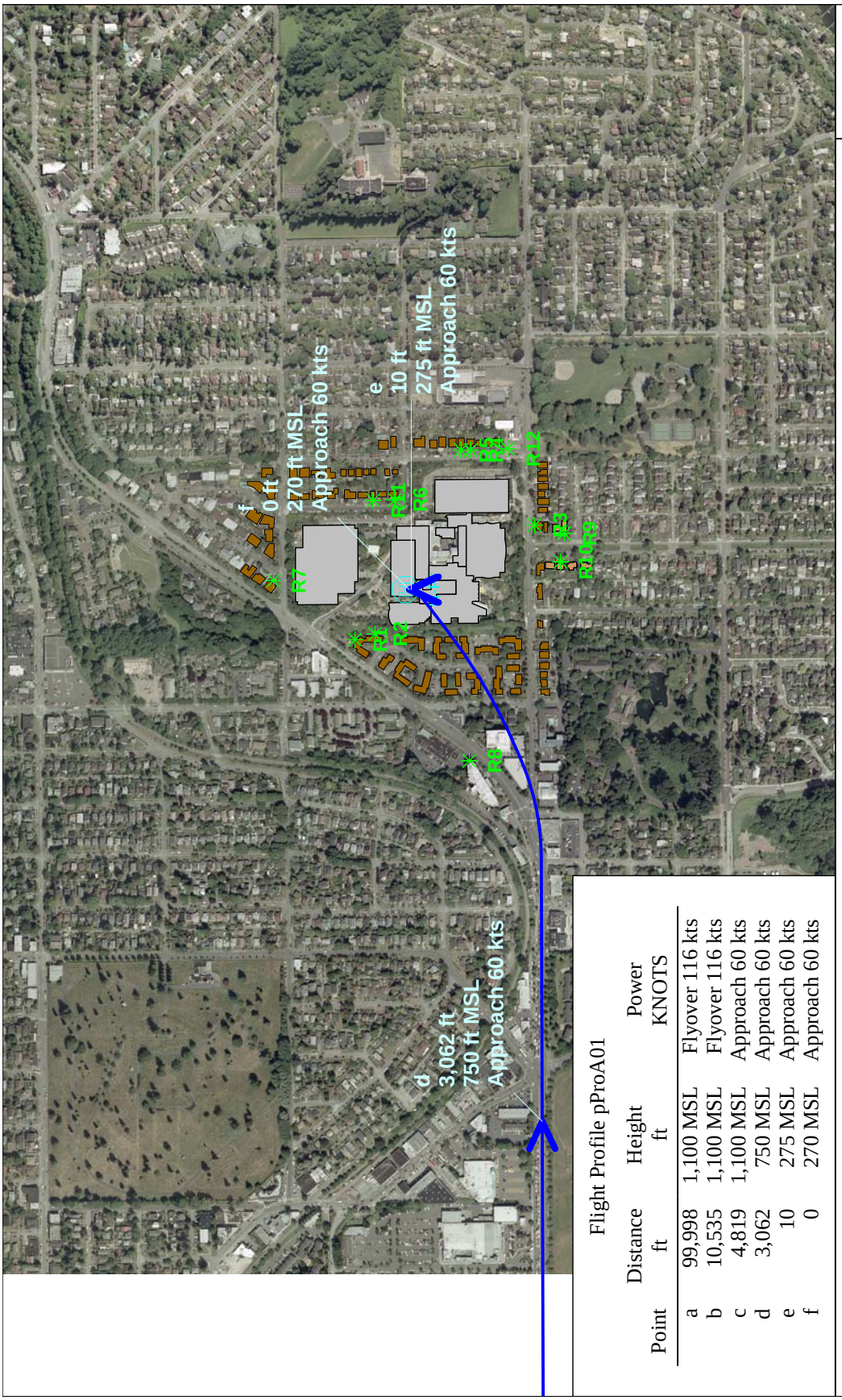
Flight Profile pT02D02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	125 MSL	Takeoff 60 kts
d	1,000	625 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



Flight Profile pT02D03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	125 MSL	Takeoff 60 kts
d	1,000	625 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



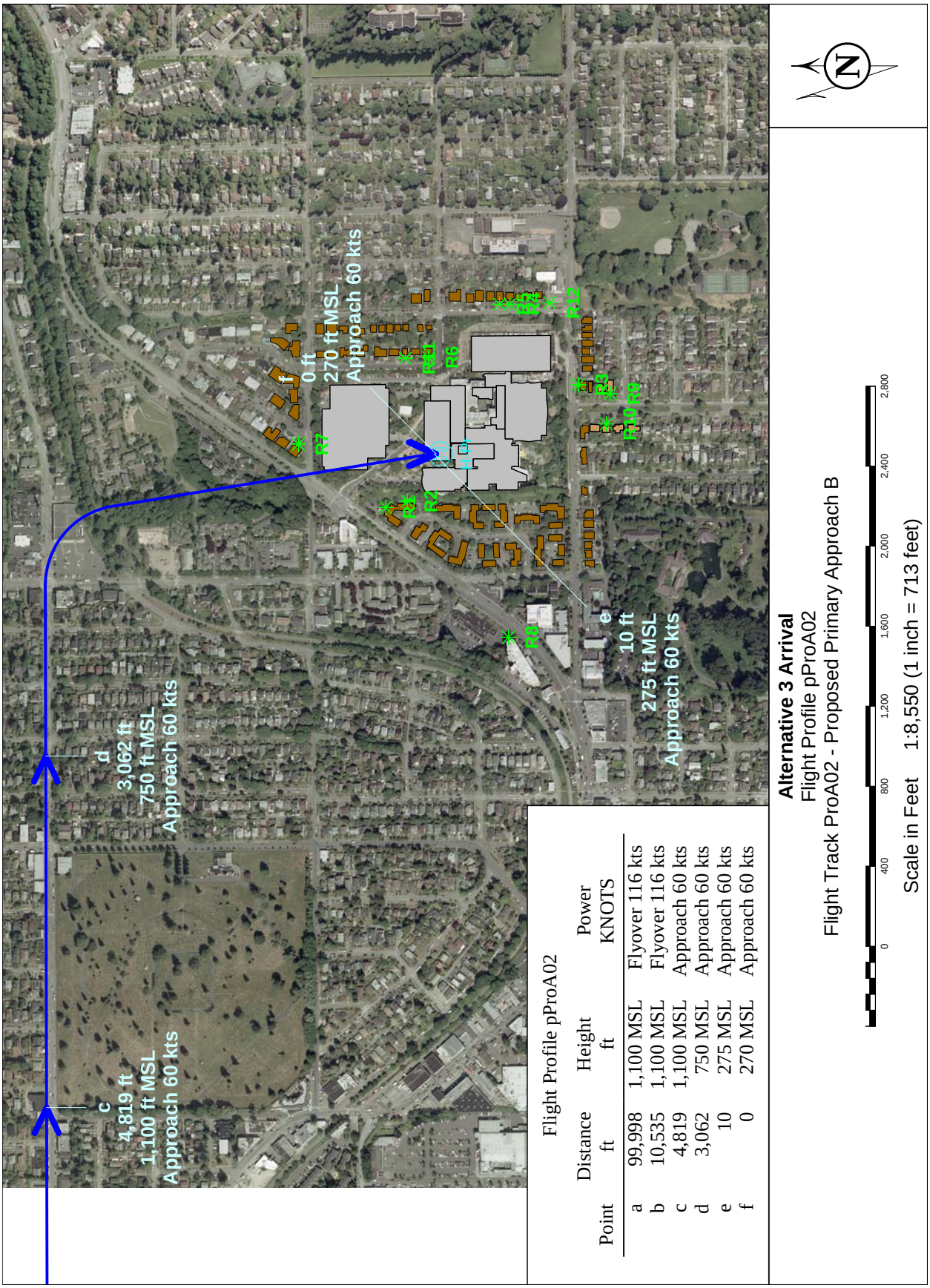
Flight Profile pProA01

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	750 MSL	Approach 60 kts
e	10	275 MSL	Approach 60 kts
f	0	270 MSL	Approach 60 kts

Alternative 3 Arrival
Flight Profile pProA01
Flight Track ProA01 - Proposed Primary Approach A

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

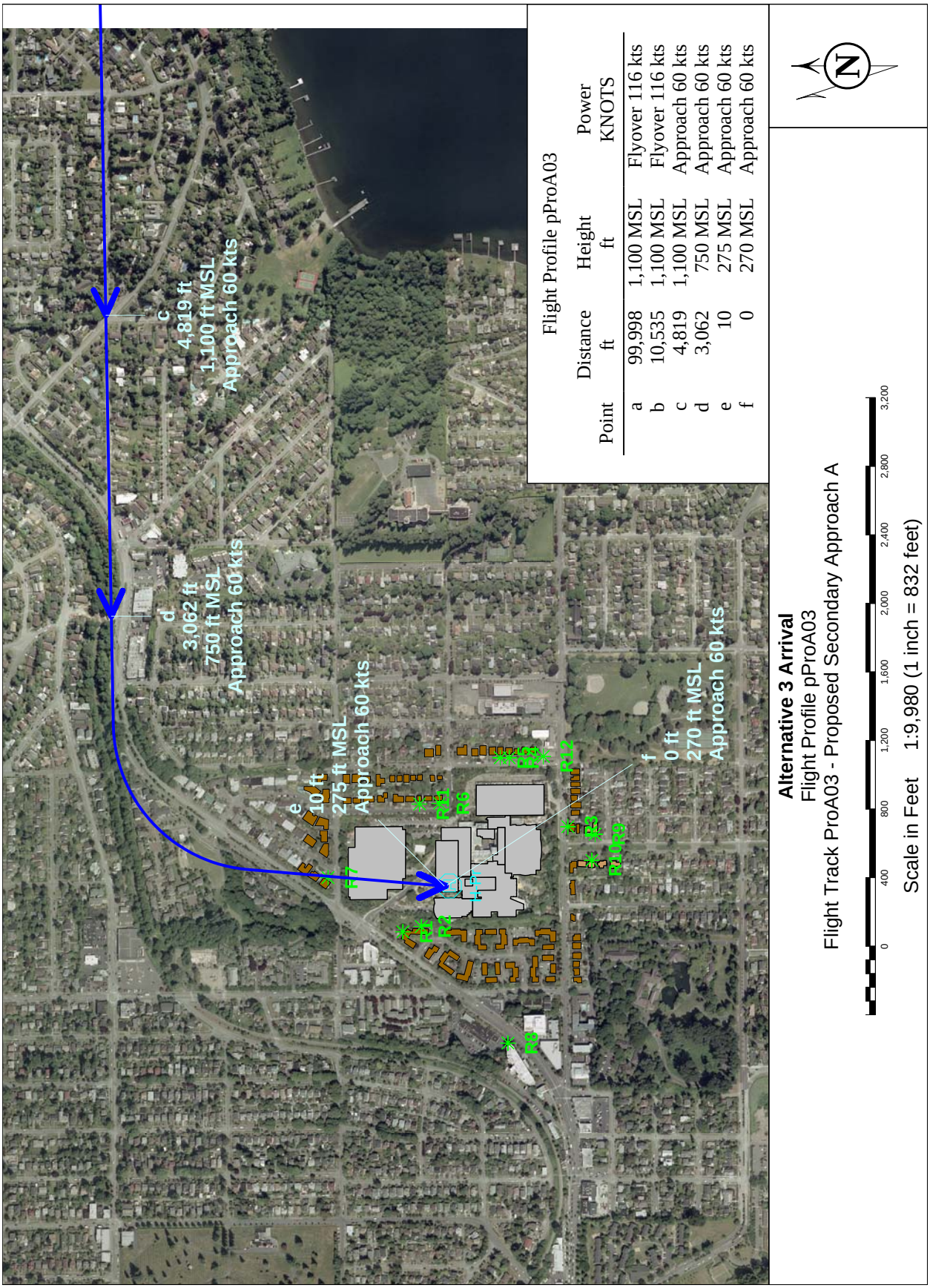
Scale in Feet 1:9,960 (1 inch = 830 feet)

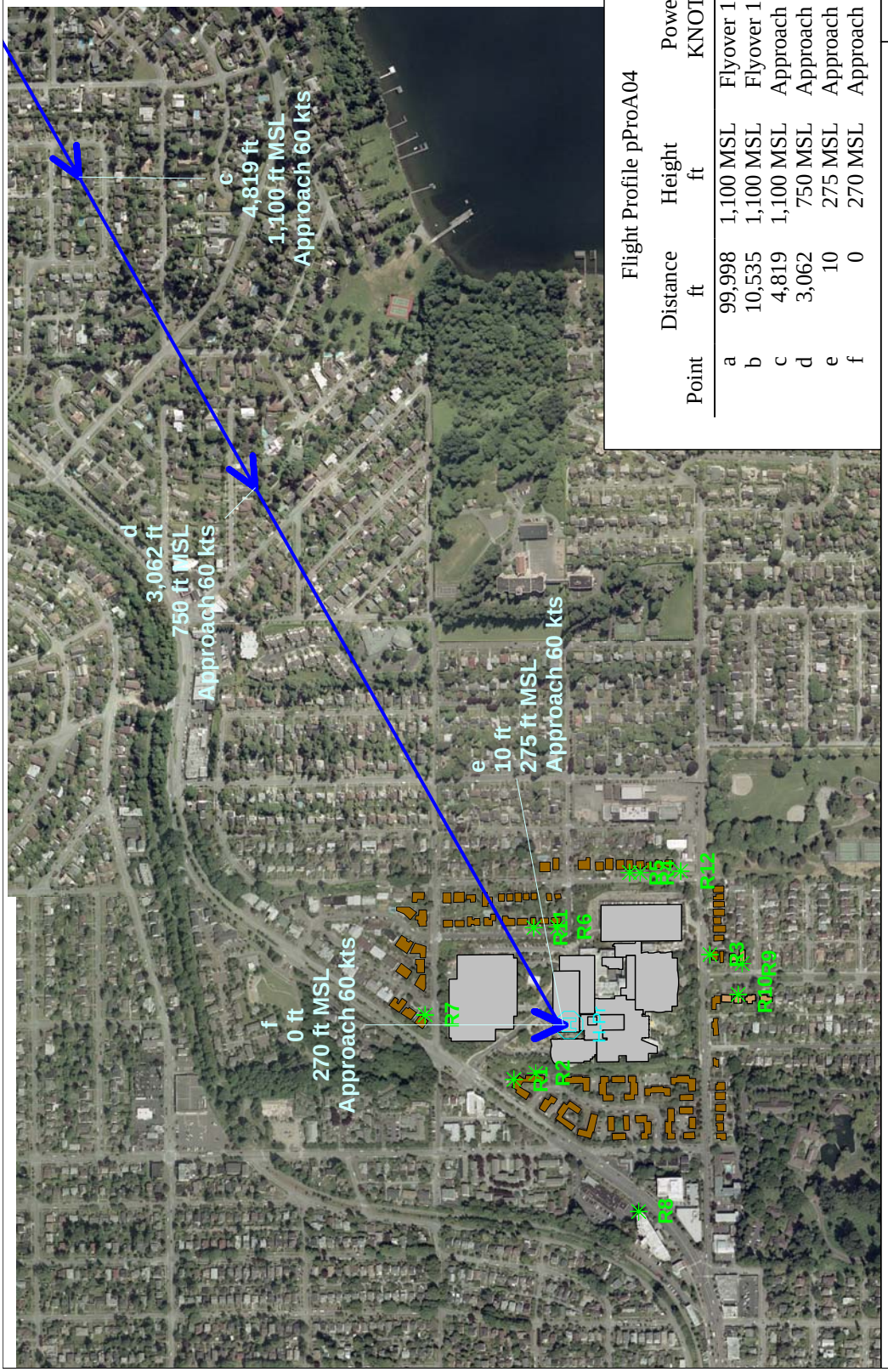


Flight Profile pProA02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	750 MSL	Approach 60 kts
e	10	275 MSL	Approach 60 kts
f	0	270 MSL	Approach 60 kts

Alternative 3 Arrival
Flight Profile pProA02
Flight Track ProA02 - Proposed Primary Approach B


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
750 ft MSL
Approach 60 kts
e
10 ft
275 ft MSL
Approach 60 kts
f
0 ft
270 ft MSL
Approach 60 kts
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
Flight Profile pProA03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 750 MSL | Approach 60 kts
e | 10 | 275 MSL | Approach 60 kts
f | 0 | 270 MSL | Approach 60 kts
N
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Alternative 3 Arrival
Flight Profile pProA03
Flight Track ProA03 - Proposed Secondary Approach A
Scale in Feet 1:9,980 (1 inch = 832 feet)



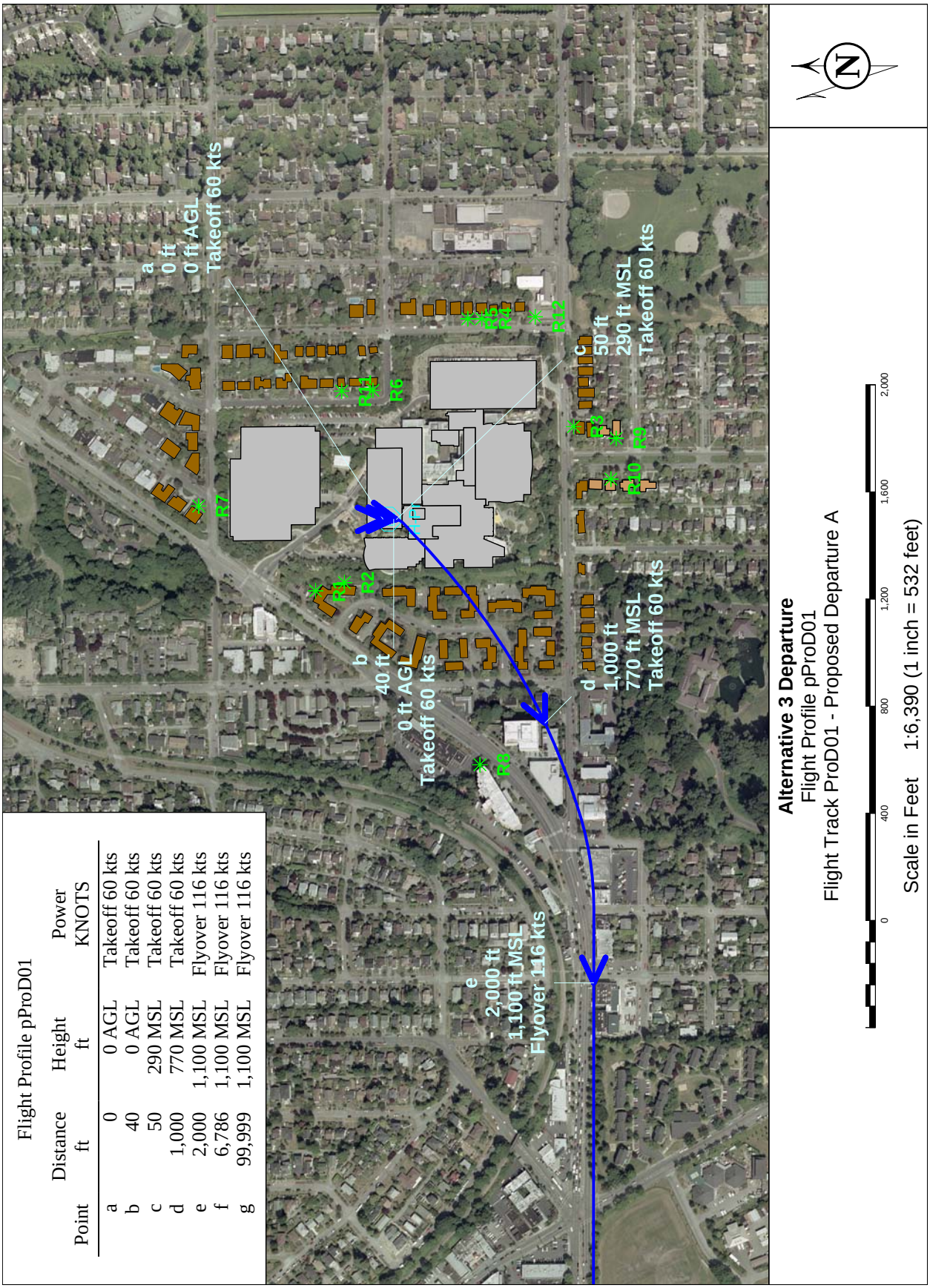
Flight Profile pProA04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	750 MSL	Approach 60 kts
e	10	275 MSL	Approach 60 kts
f	0	270 MSL	Approach 60 kts

Alternative 3 Arrival
Flight Profile pProA04
Flight Track ProA04 - Proposed Secondary Approach B

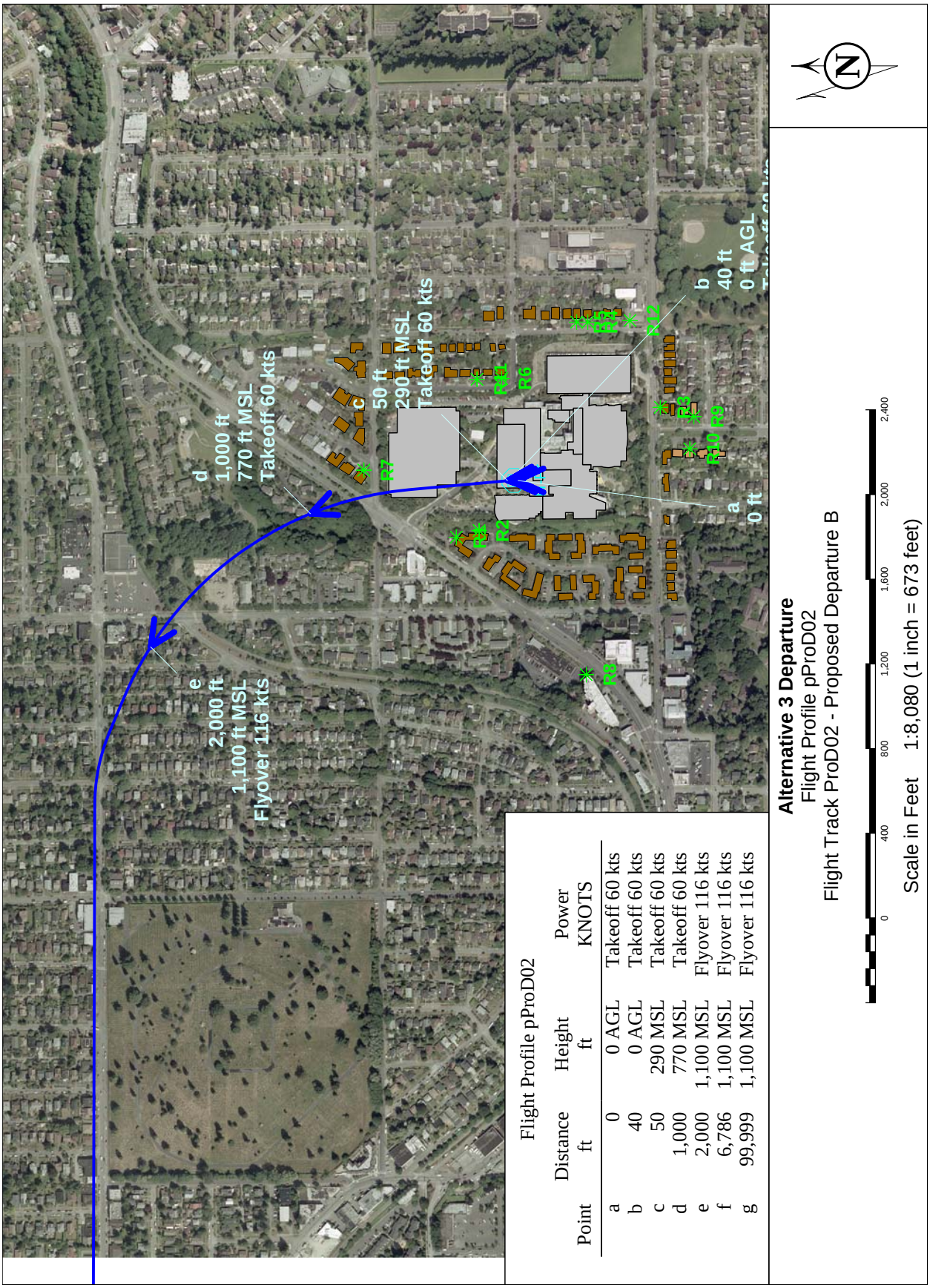
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

Scale in Feet 1:9,640 (1 inch = 803 feet)



Flight Profile pProD01

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	290 MSL	Takeoff 60 kts
d	1,000	770 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

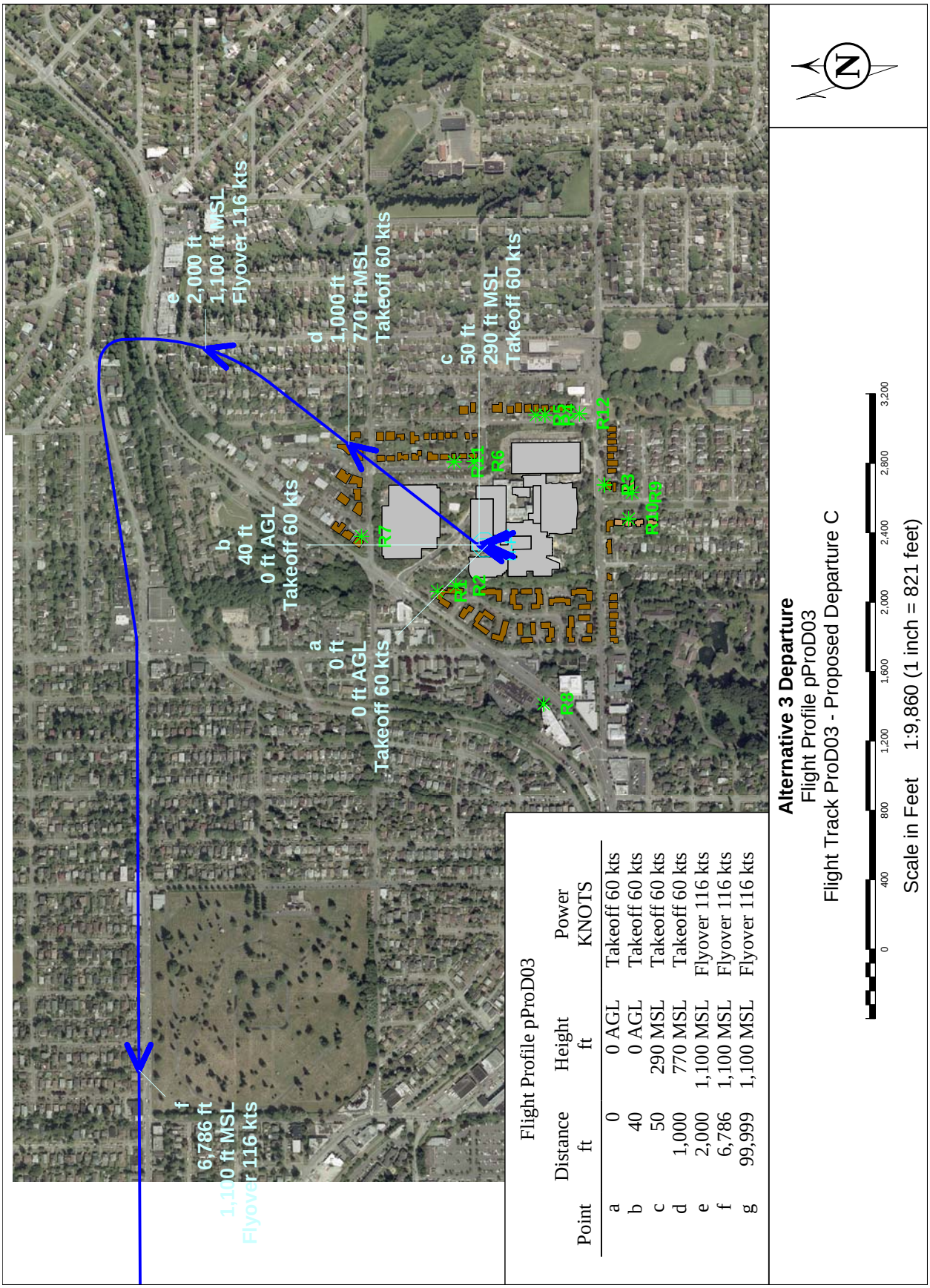


Flight Profile pProD02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	290 MSL	Takeoff 60 kts
d	1,000	770 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

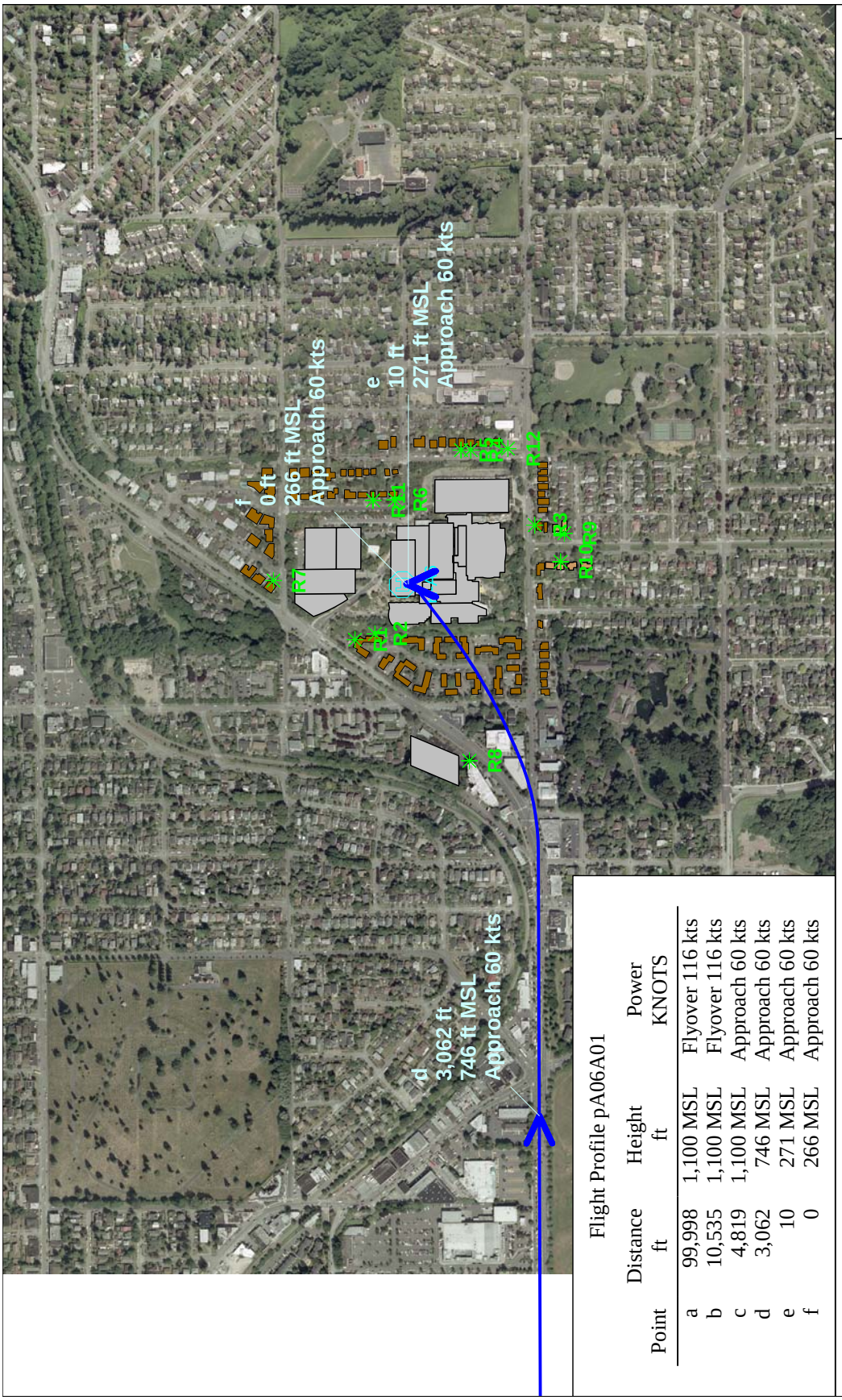
Alternative 3 Departure
Flight Profile pProD02
Flight Track ProD02 - Proposed Departure B

Scale in Feet 1:8,080 (1 inch = 673 feet)



Flight Profile pProD03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	290 MSL	Takeoff 60 kts
d	1,000	770 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



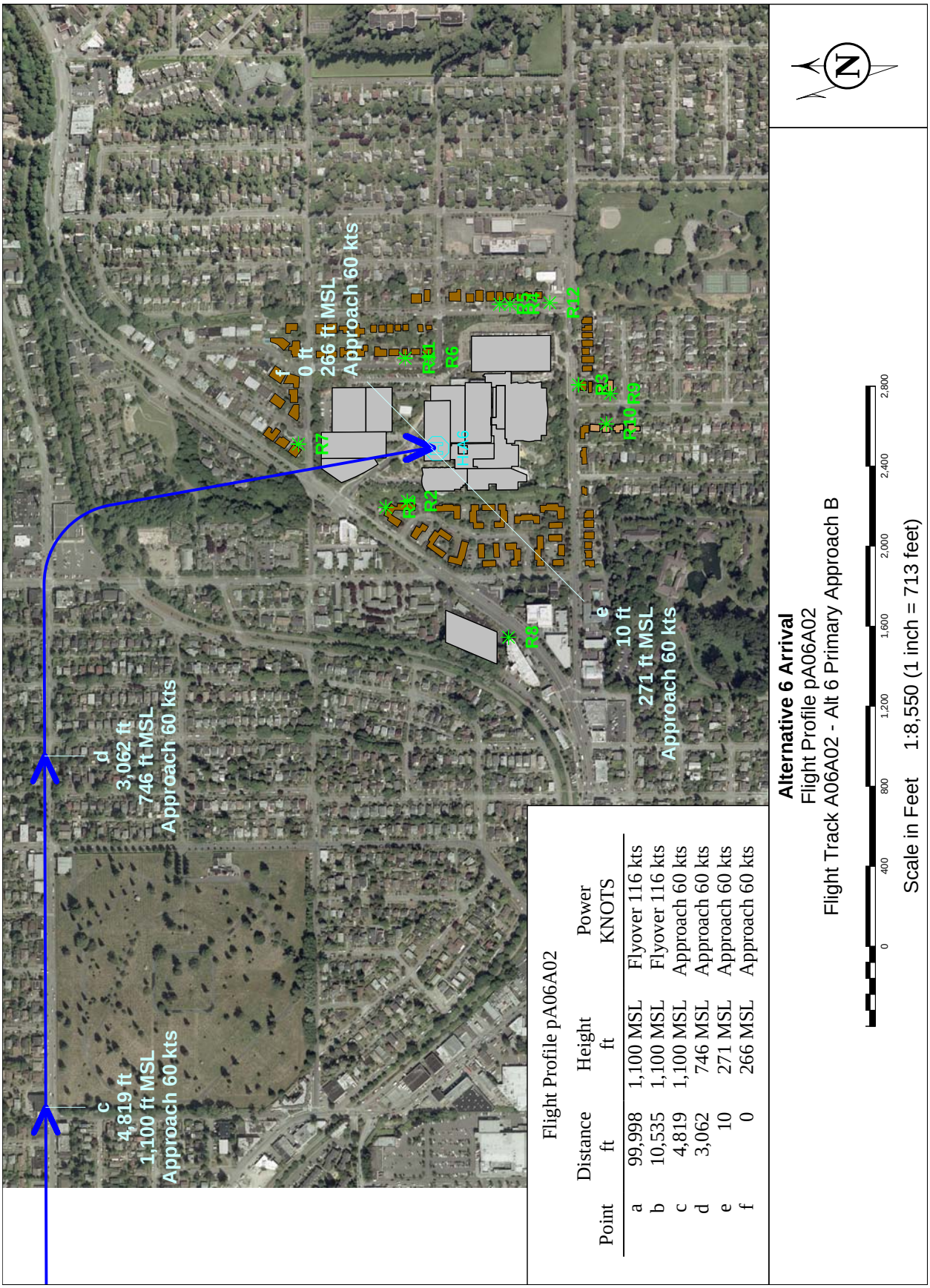
Flight Profile pA06A01

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	746 MSL	Approach 60 kts
e	10	271 MSL	Approach 60 kts
f	0	266 MSL	Approach 60 kts

Alternative 6 Arrival
Flight Profile pA06A01
Flight Track A06A01 - Alt 6 Primary Approach A

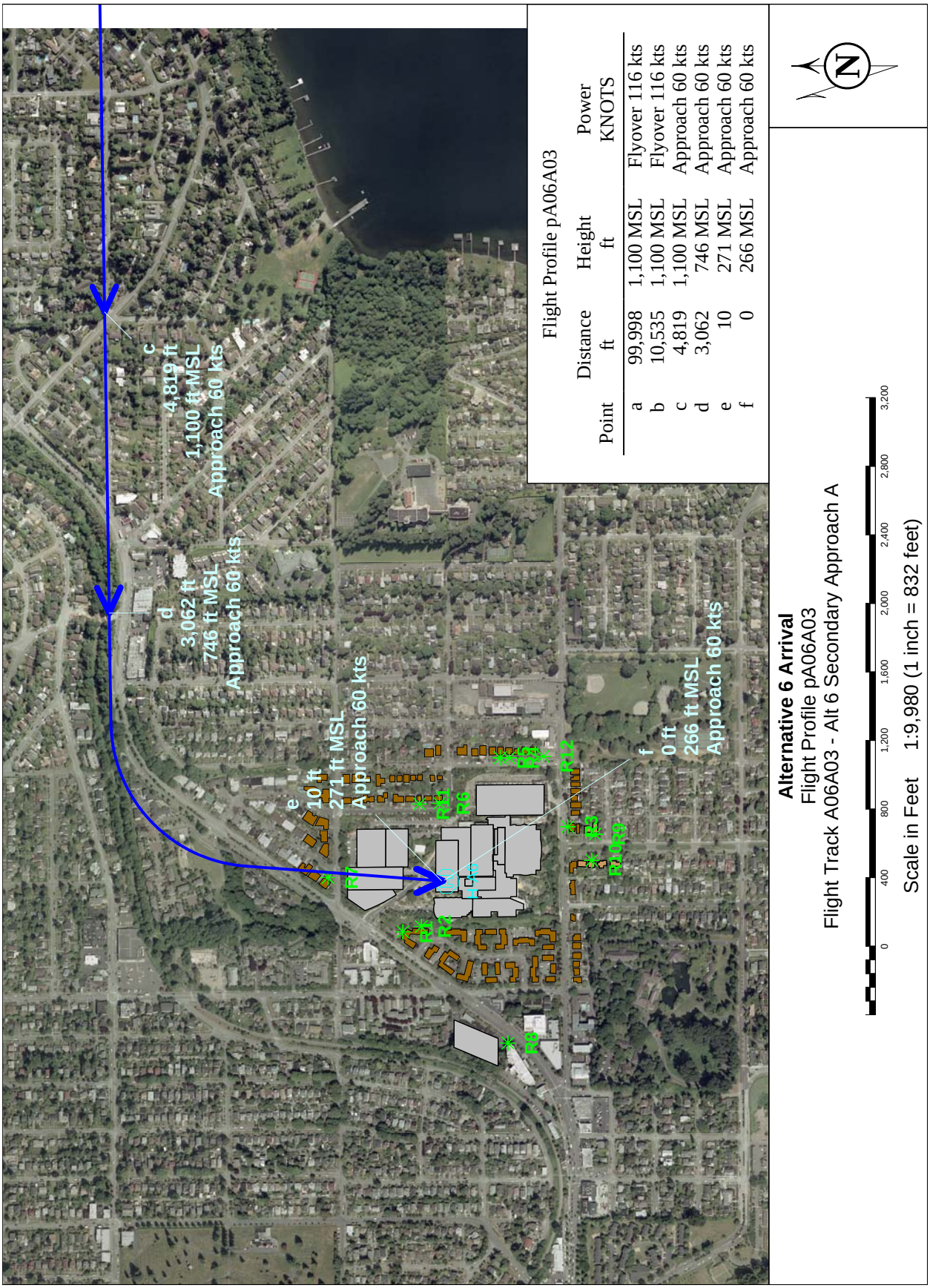
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

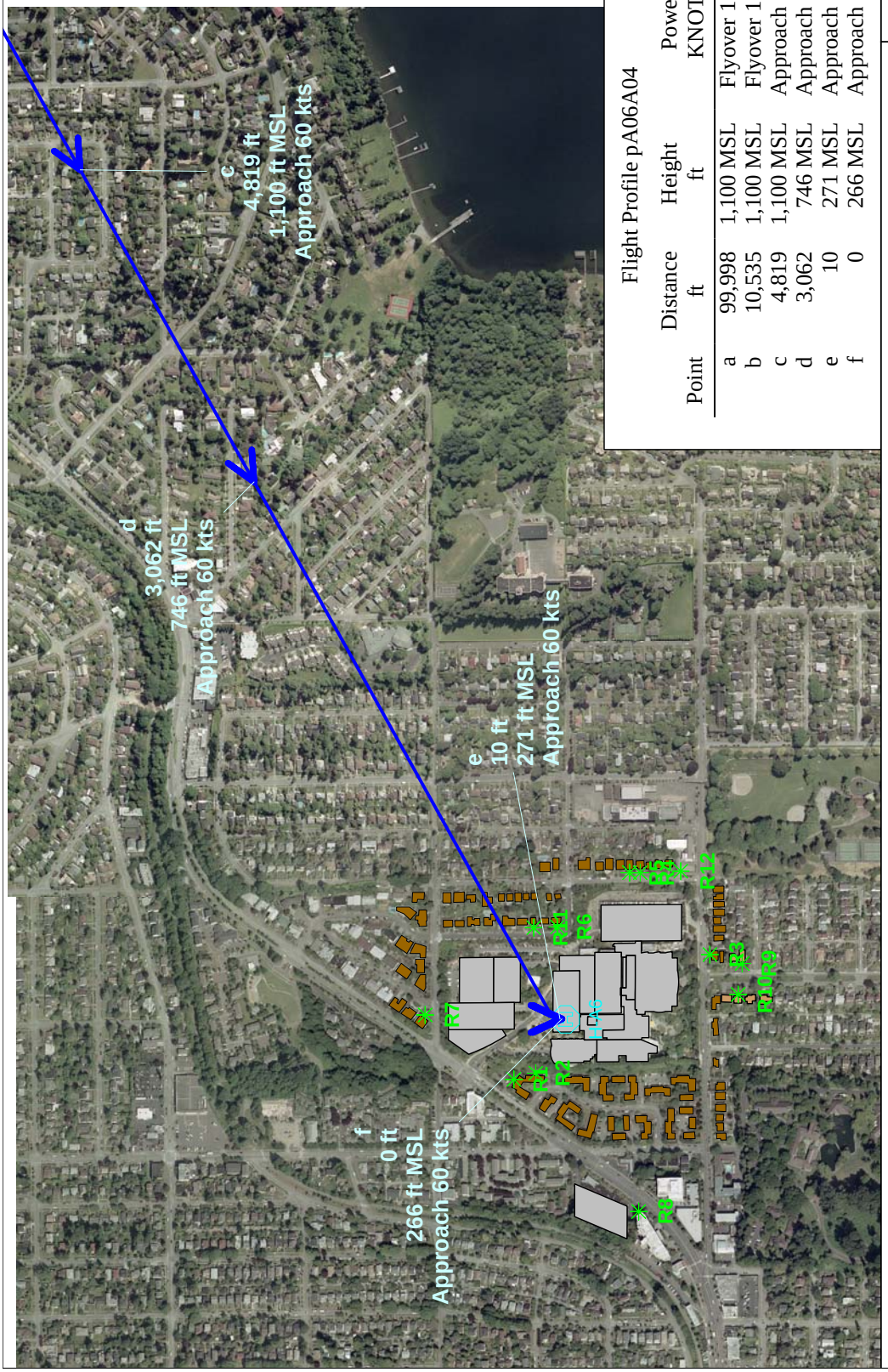
Scale in Feet 1:9,960 (1 inch = 830 feet)



Flight Profile pA06A02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	746 MSL	Approach 60 kts
e	10	271 MSL	Approach 60 kts
f	0	266 MSL	Approach 60 kts


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
746 ft MSL
Approach 60 kts
e
10 ft
271 ft MSL
Approach 60 kts
f
0 ft
266 ft MSL
Approach 60 kts
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
Flight Profile pA06A03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 746 MSL | Approach 60 kts
e | 10 | 271 MSL | Approach 60 kts
f | 0 | 266 MSL | Approach 60 kts
N
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Alternative 6 Arrival
Flight Profile pA06A03
Flight Track A06A03 - Alt 6 Secondary Approach A
Scale in Feet 1:9,980 (1 inch = 832 feet)



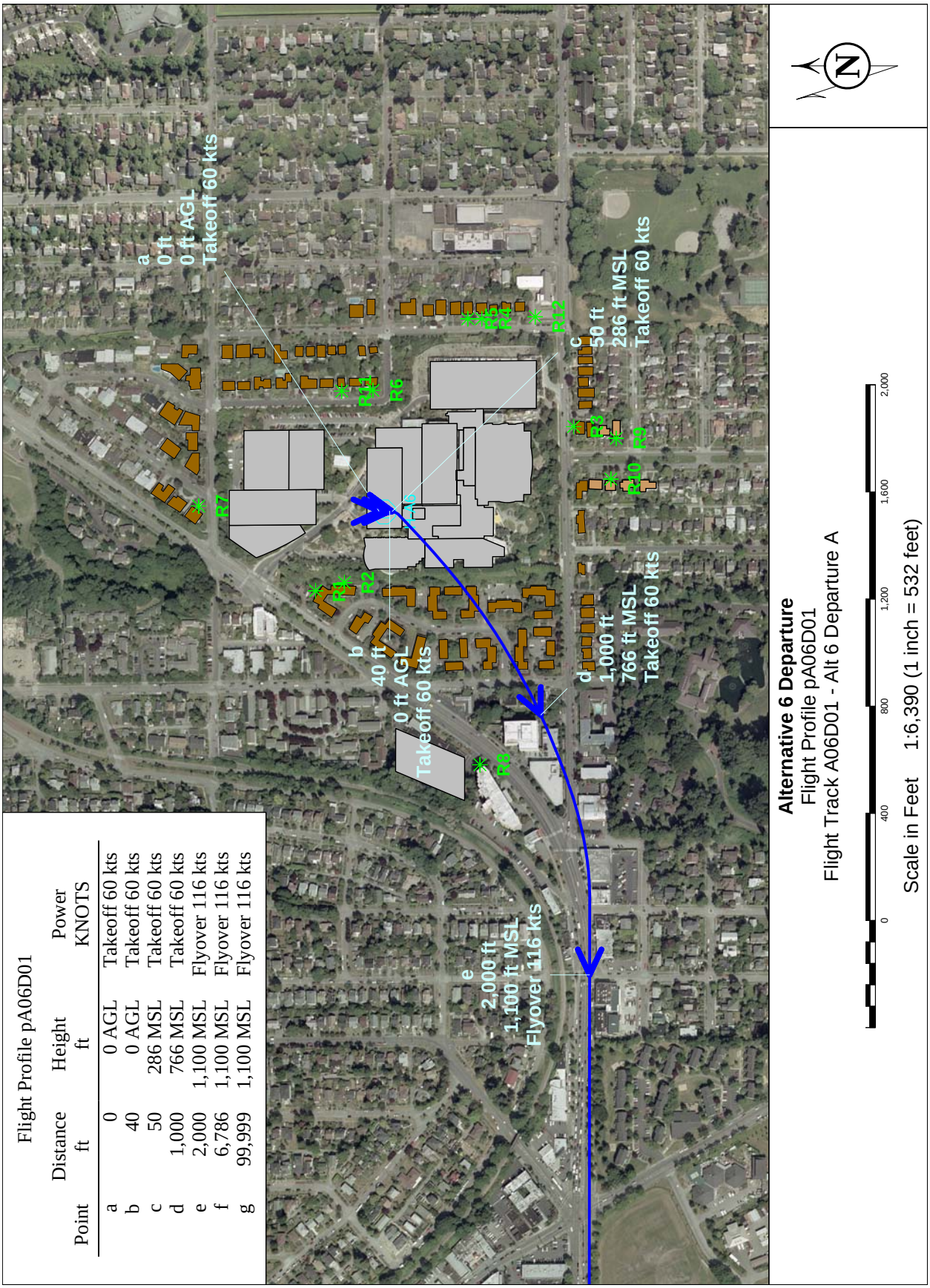
Flight Profile pA06A04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	746 MSL	Approach 60 kts
e	10	271 MSL	Approach 60 kts
f	0	266 MSL	Approach 60 kts

Alternative 6 Arrival
Flight Profile pA06A04
Flight Track A06A04 - Alt 6 Secondary Approach B

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

Scale in Feet 1:9,640 (1 inch = 803 feet)

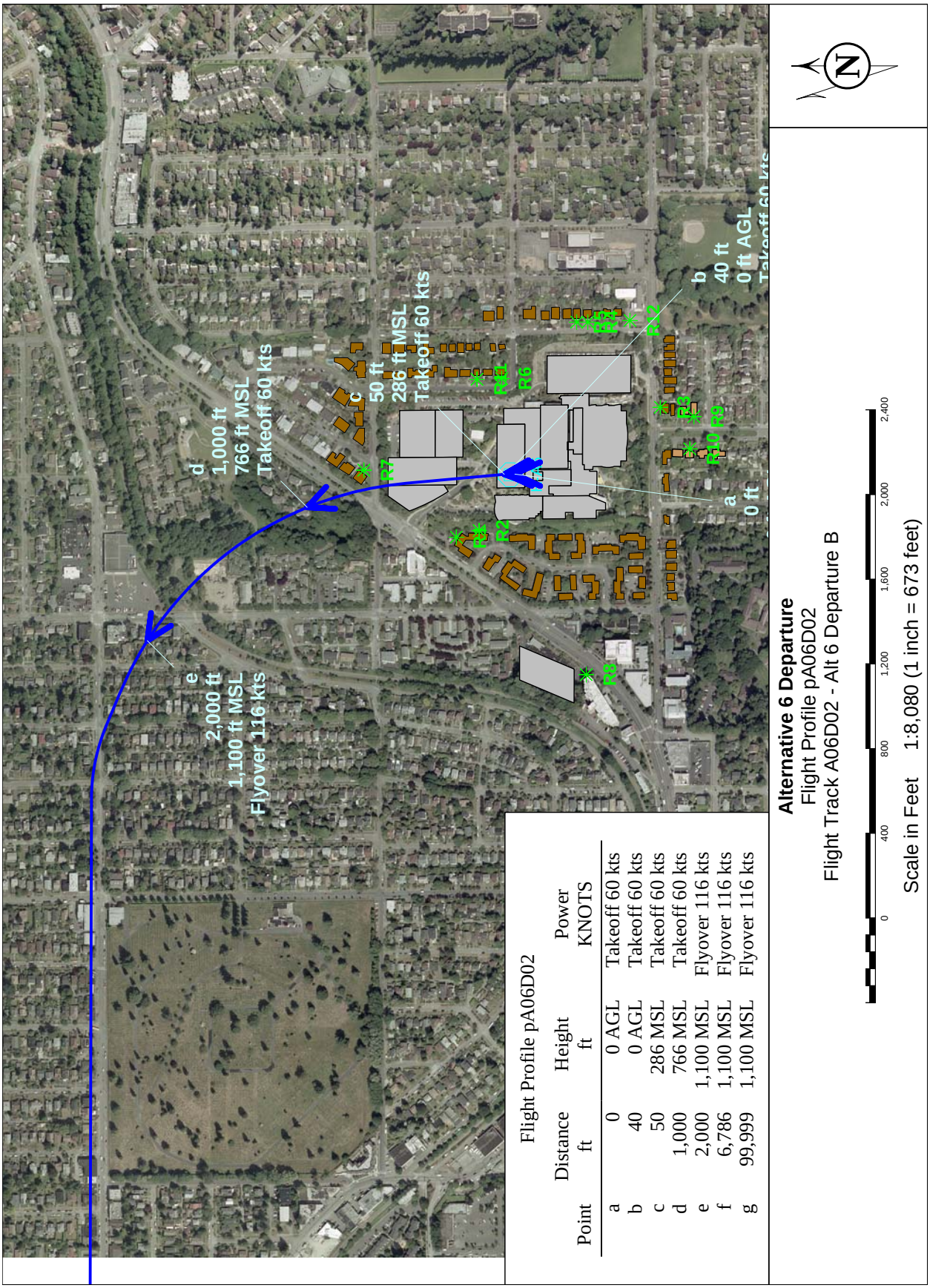


Flight Profile pA06D01

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	286 MSL	Takeoff 60 kts
d	1,000	766 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 6 Departure
Flight Profile pA06D01
Flight Track A06D01 - Alt 6 Departure A

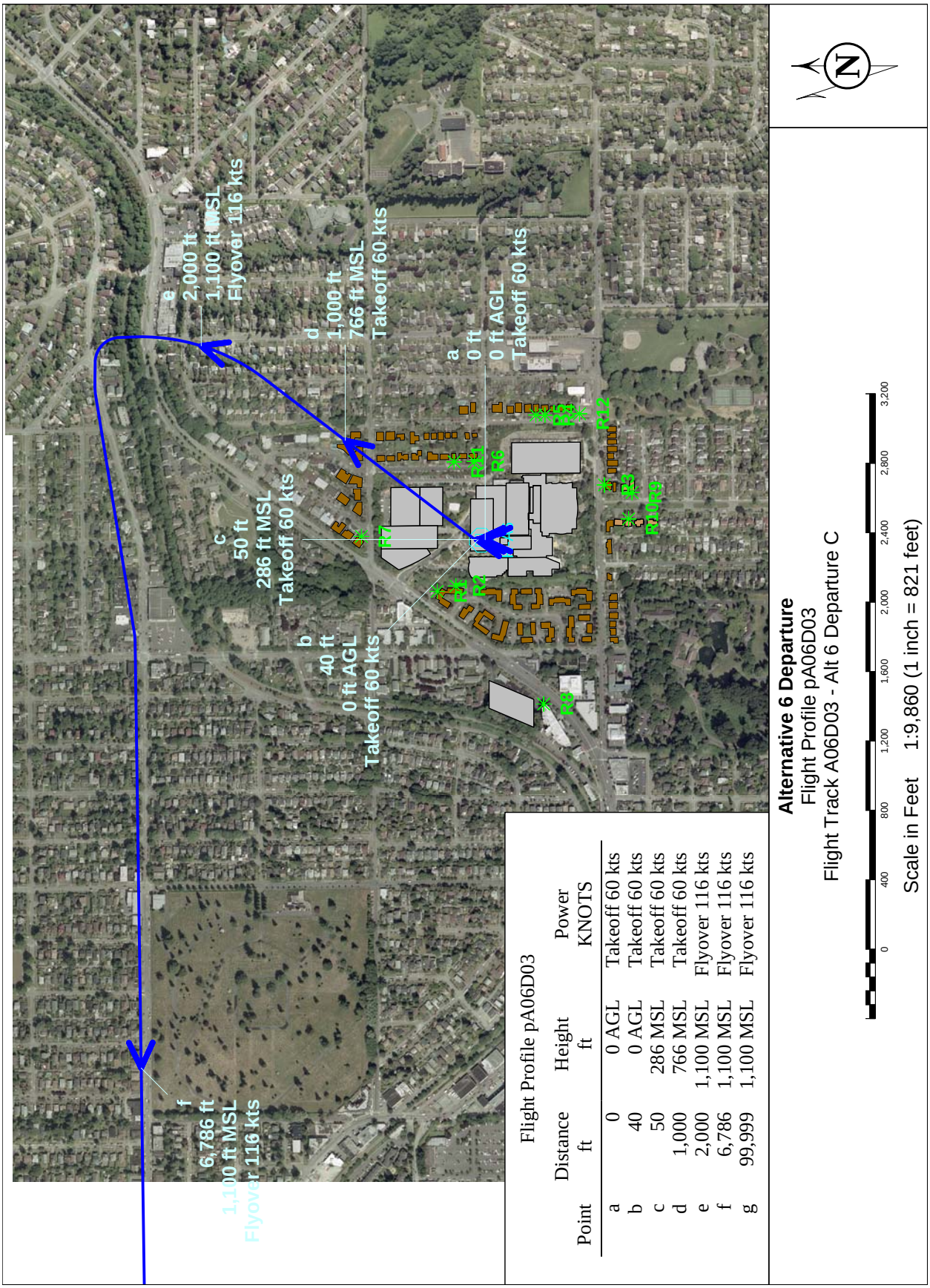
Scale in Feet 1:6,390 (1 inch = 532 feet)



Flight Profile pA06D02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	286 MSL	Takeoff 60 kts
d	1,000	766 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

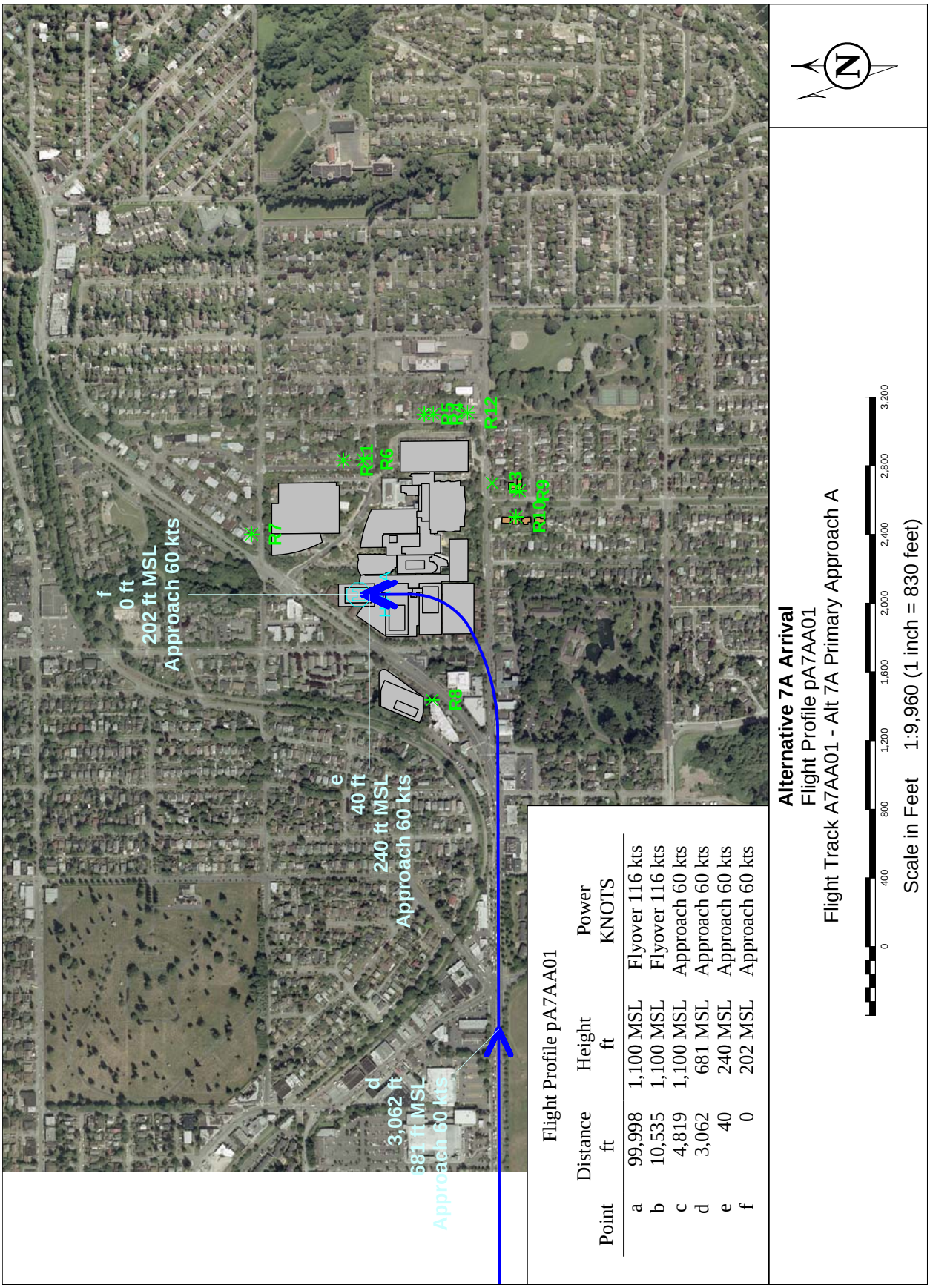
Alternative 6 Departure
Flight Profile pA06D02
Flight Track A06D02 - Alt 6 Departure B



Flight Profile pA06D03

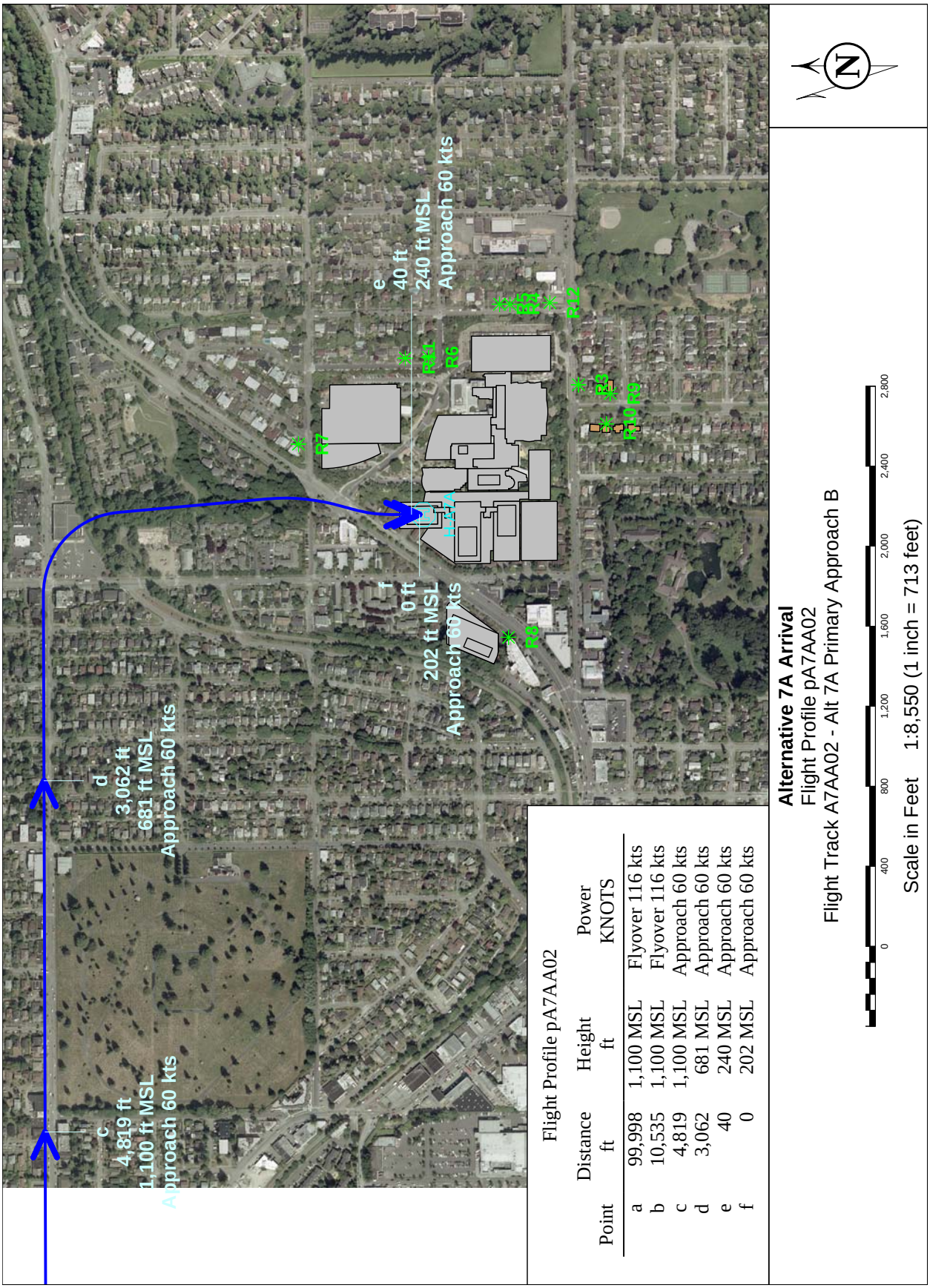
Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	50	286 MSL	Takeoff 60 kts
d	1,000	766 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 6 Departure
Flight Profile pA06D03
Flight Track A06D03 - Alt 6 Departure C



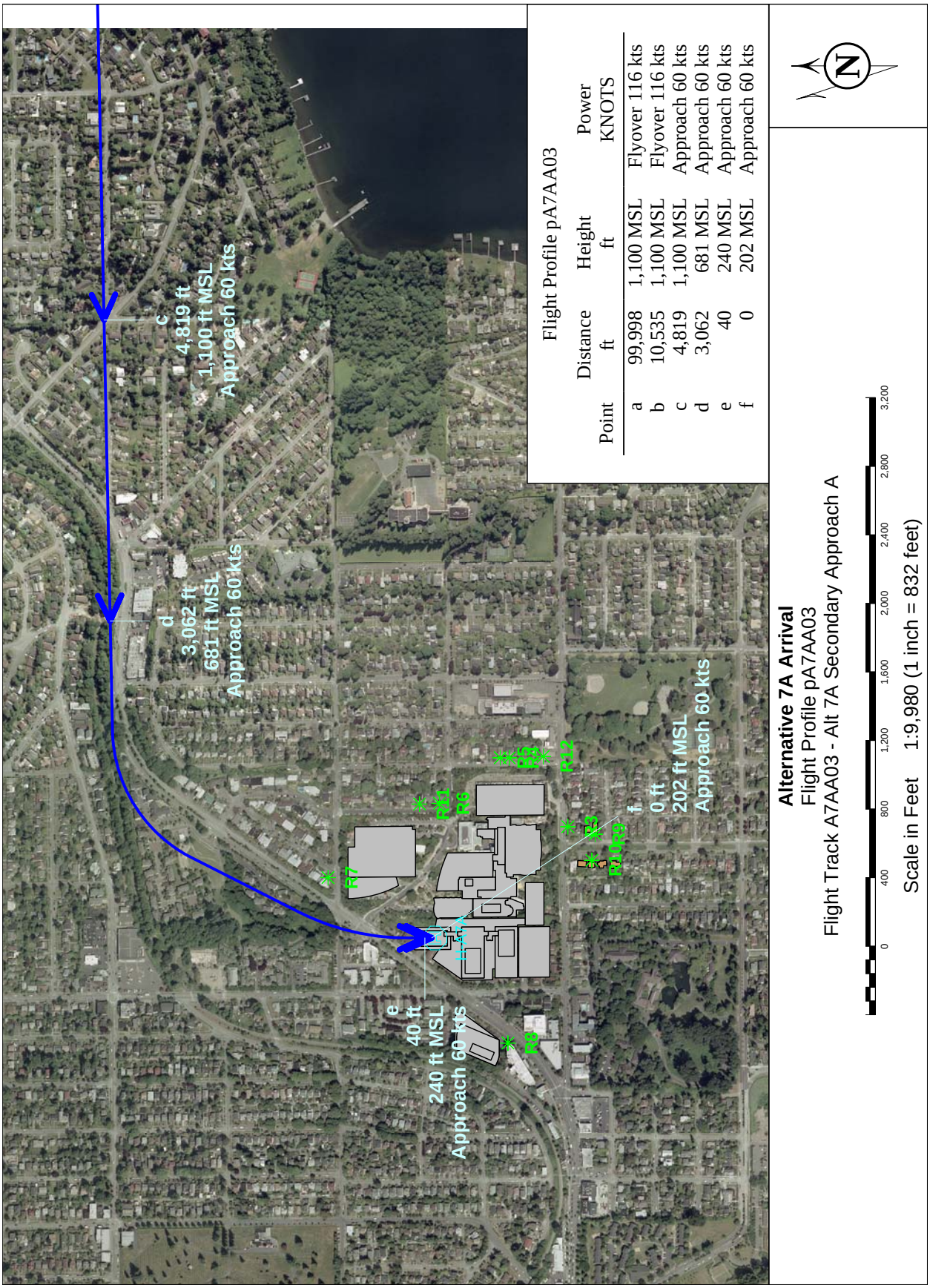
Flight Profile pA7AA01

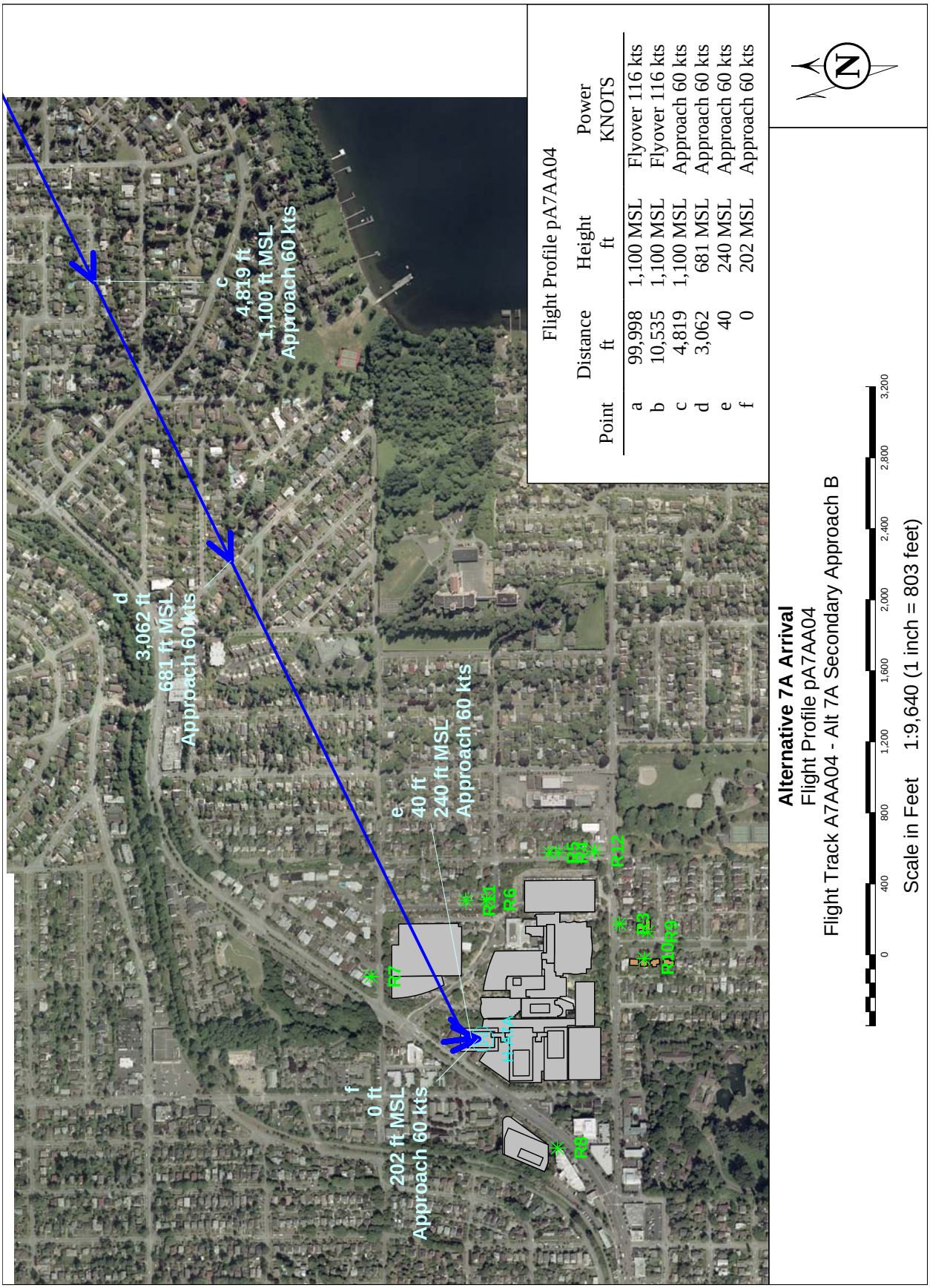
Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	40	240 MSL	Approach 60 kts
f	0	202 MSL	Approach 60 kts



Flight Profile pA7AA02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	40	240 MSL	Approach 60 kts
f	0	202 MSL	Approach 60 kts

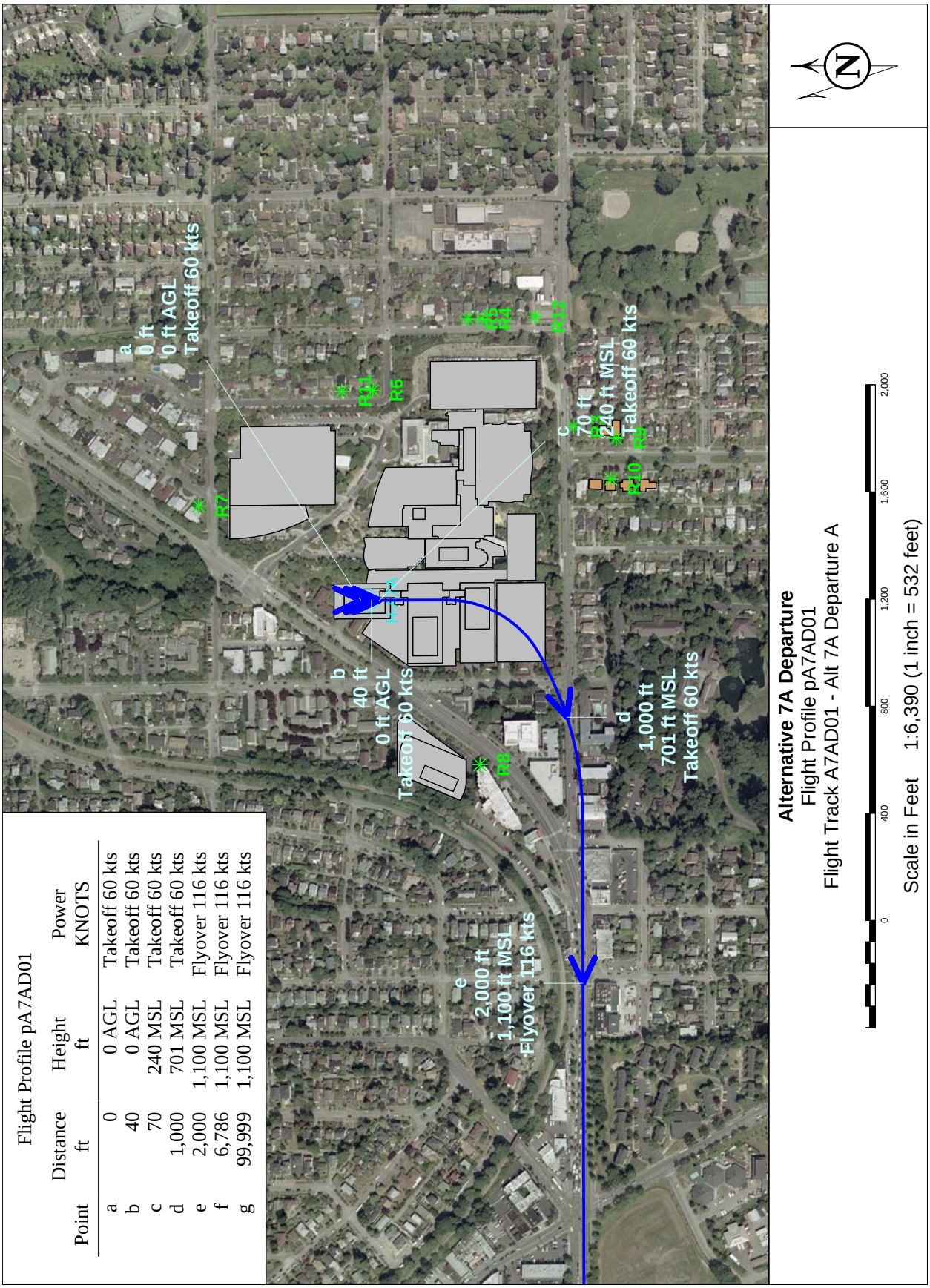

c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
681 ft MSL
Approach 60 kts
e
40 ft
240 ft MSL
Approach 60 kts
f
0 ft
202 ft MSL
Approach 60 kts
R7
R11
R6
R5
R4
R12
R3
R10
R9
R8
Flight Profile pA7AA03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 681 MSL | Approach 60 kts
e | 40 | 240 MSL | Approach 60 kts
f | 0 | 202 MSL | Approach 60 kts
N
Alternative 7A Arrival
Flight Profile pA7AA03
Flight Track A7AA03 - Alt 7A Secondary Approach A
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,980 (1 inch = 832 feet)



Flight Profile pA7AA04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	40	240 MSL	Approach 60 kts
f	0	202 MSL	Approach 60 kts

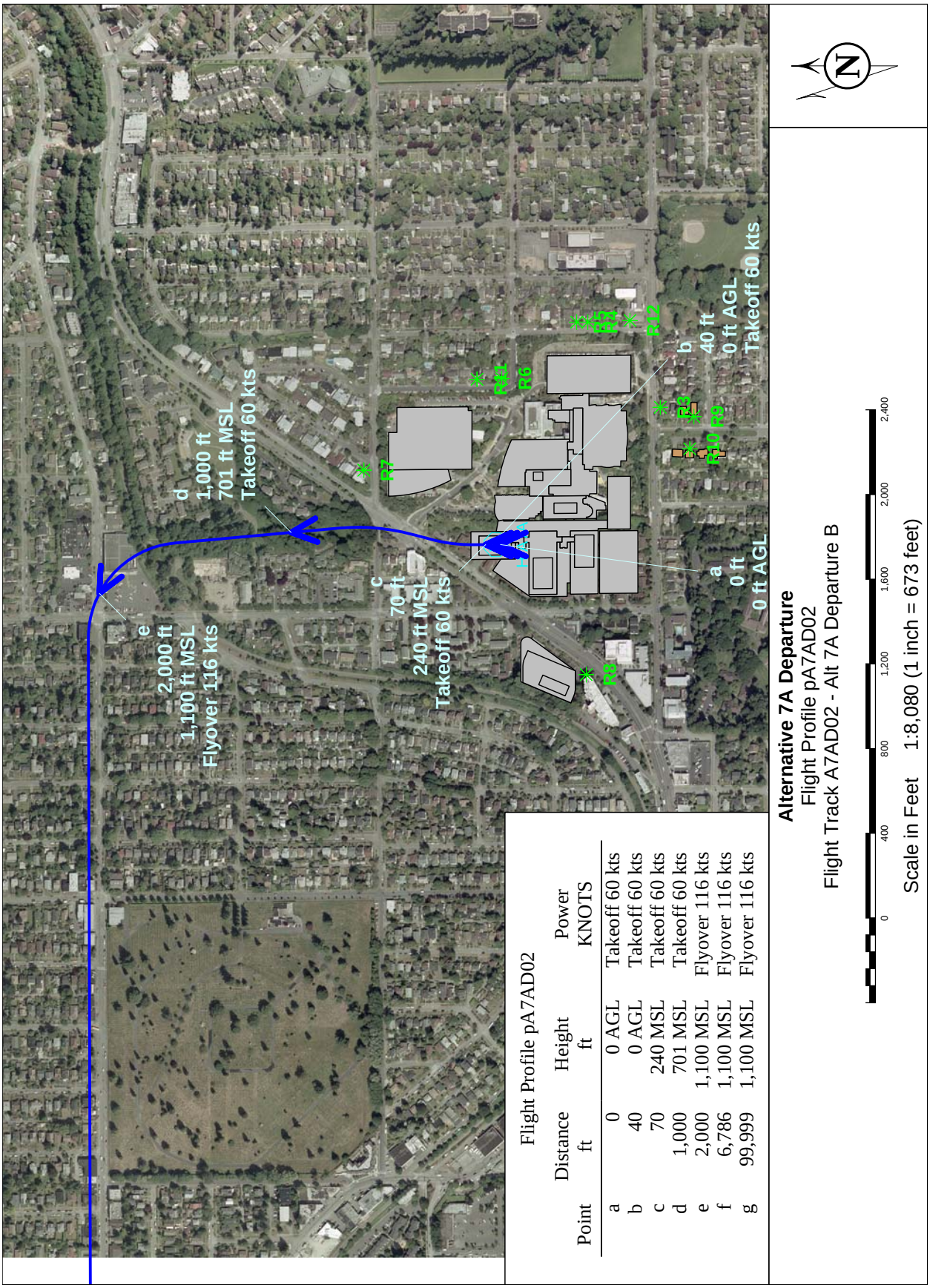
Alternative 7A Arrival
Flight Profile pA7AA04
Flight Track A7AA04 - Alt 7A Secondary Approach B



Flight Profile pA7AD01

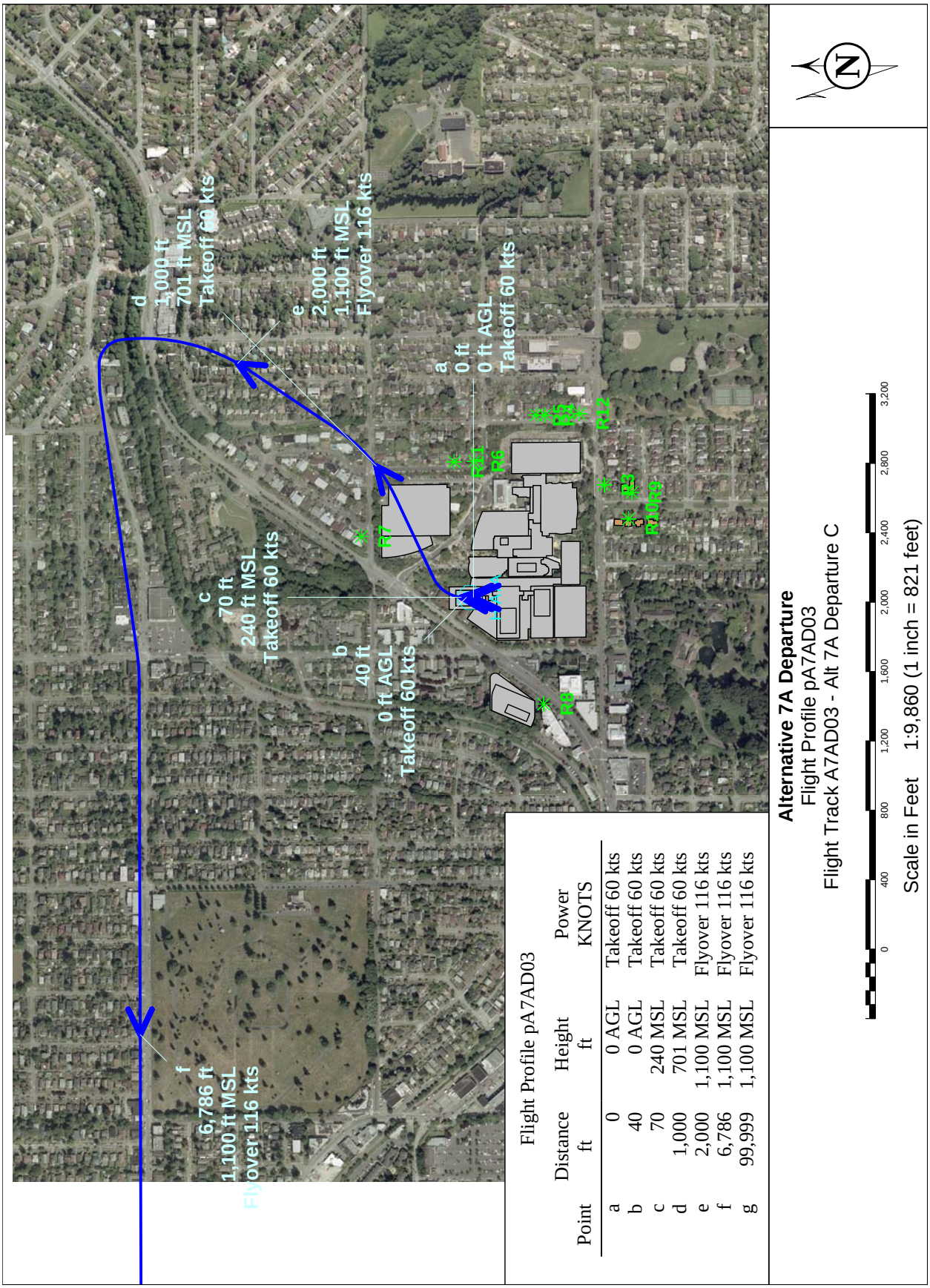
Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	240 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 7A Departure
Flight Profile pA7AD01
Flight Track A7AD01 - Alt 7A Departure A



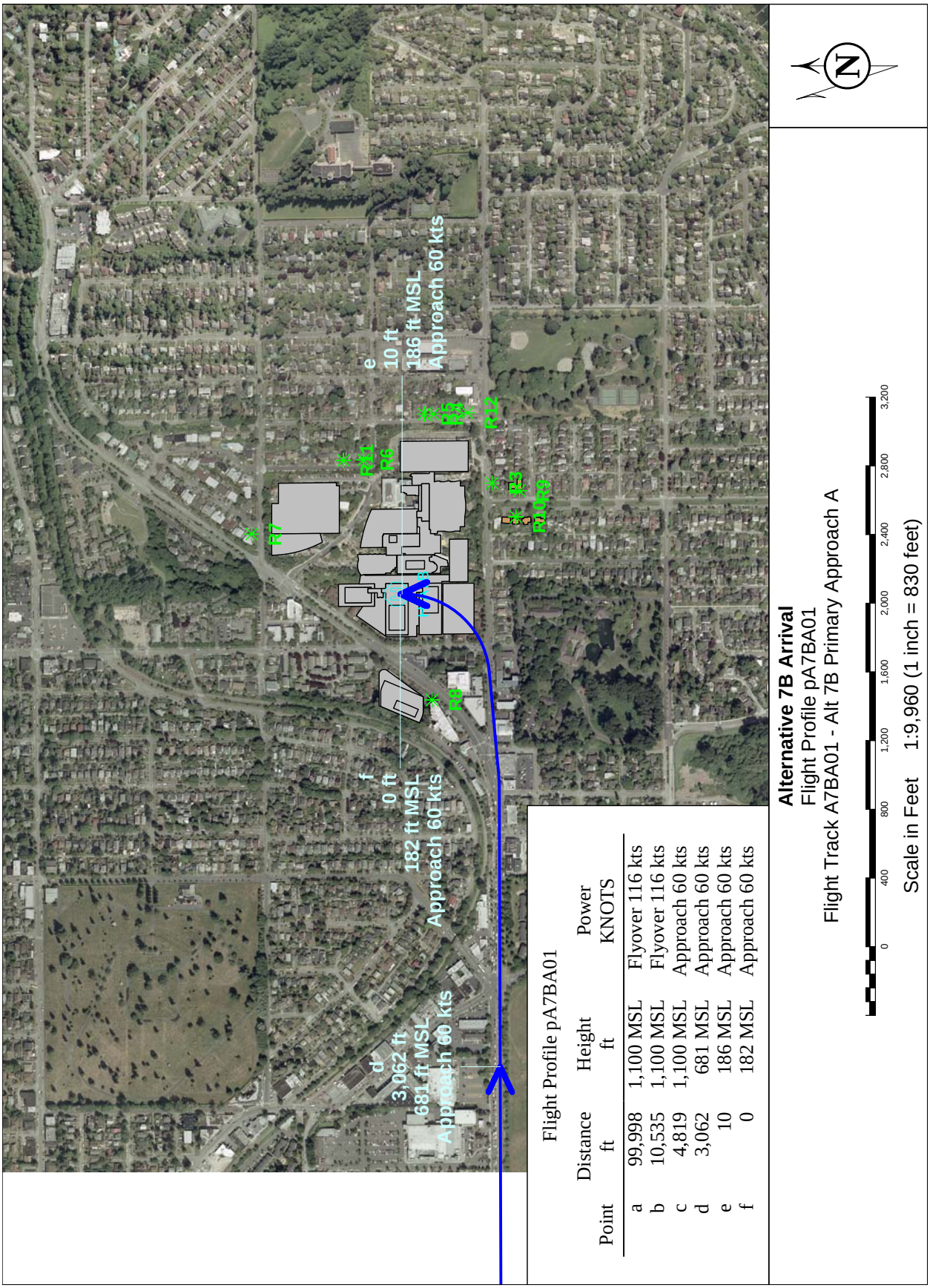
Flight Profile pA7AD02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	240 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



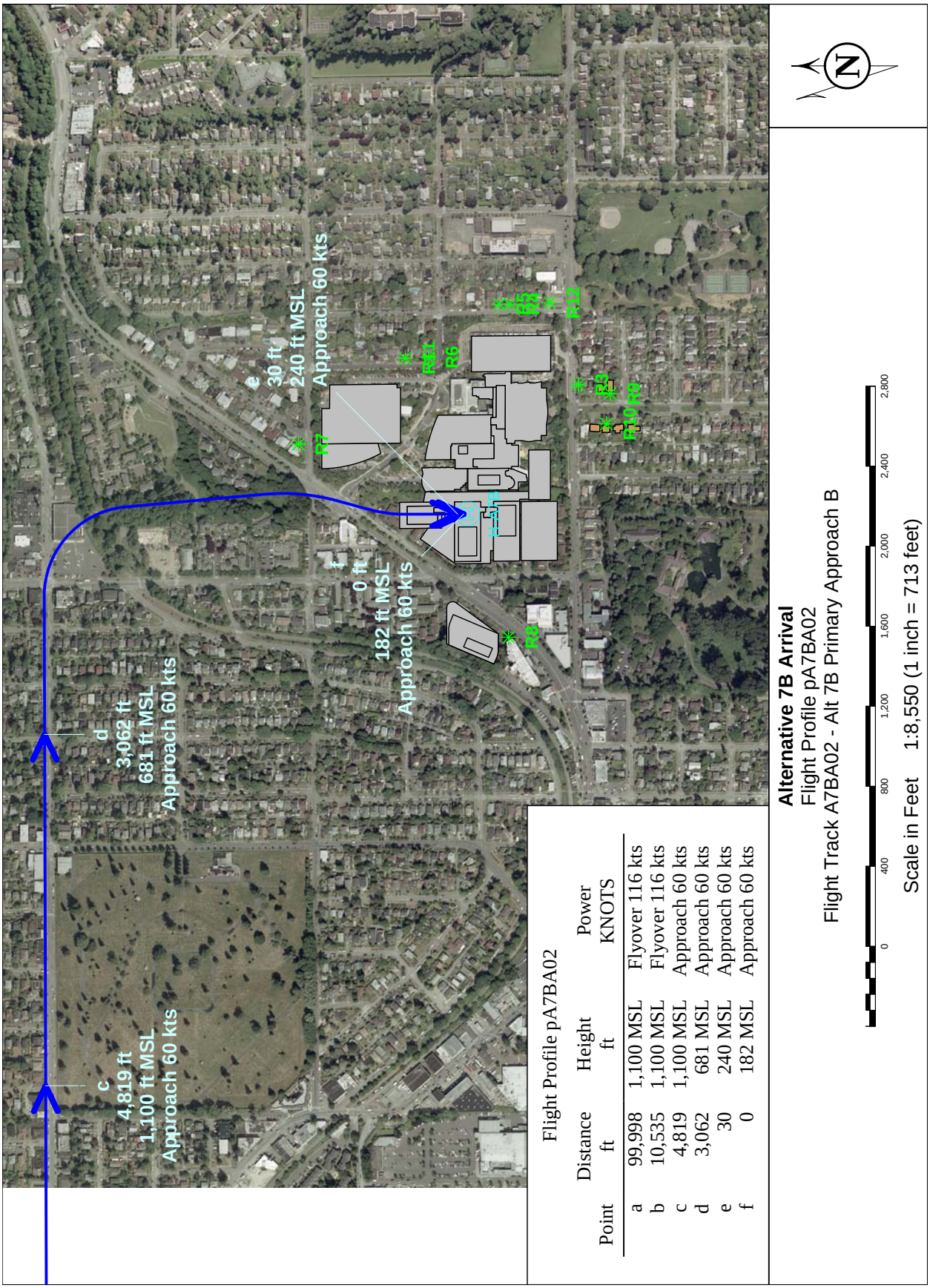
Flight Profile pA7AD03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	240 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



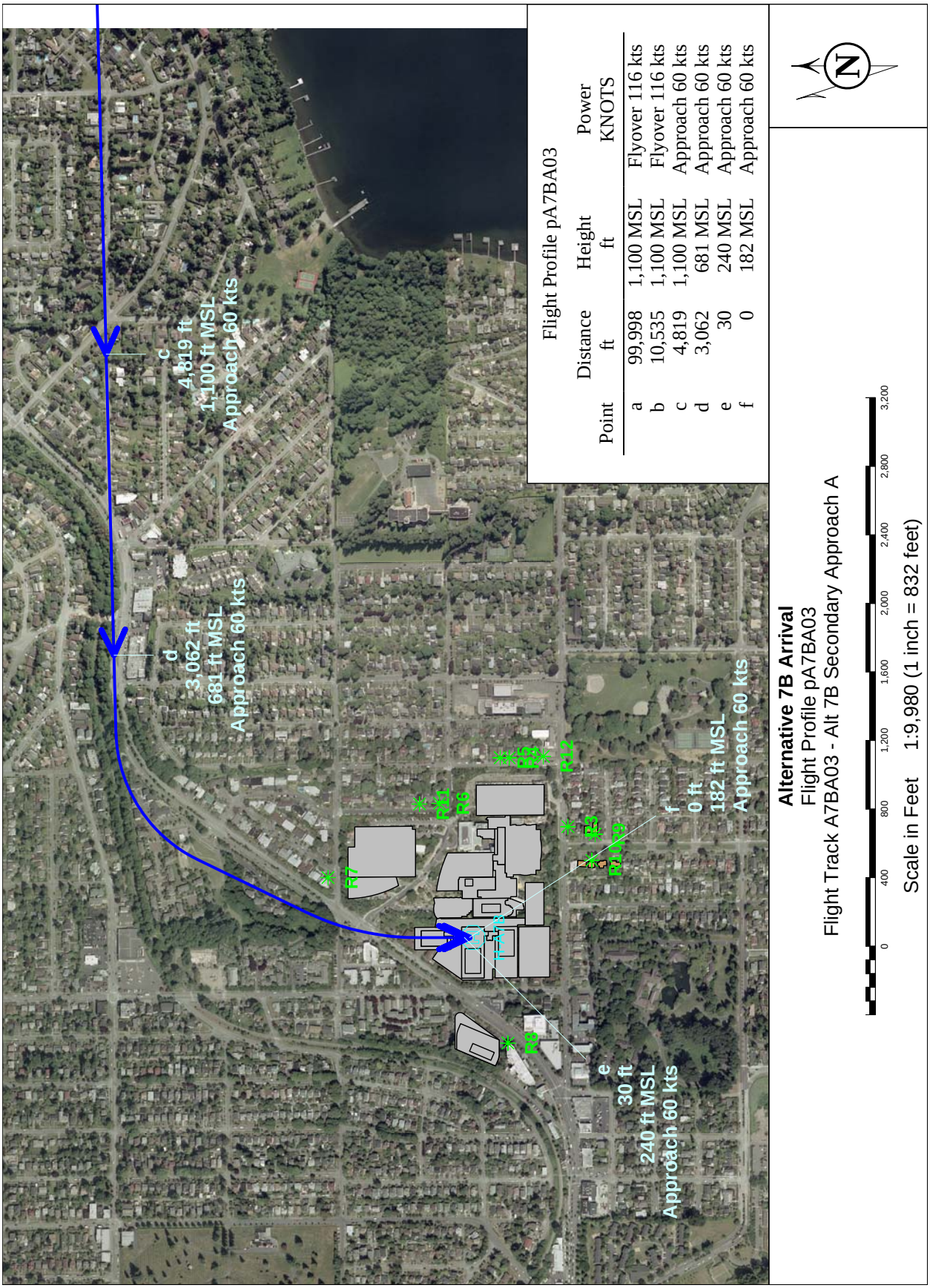
Flight Profile pA7BA01

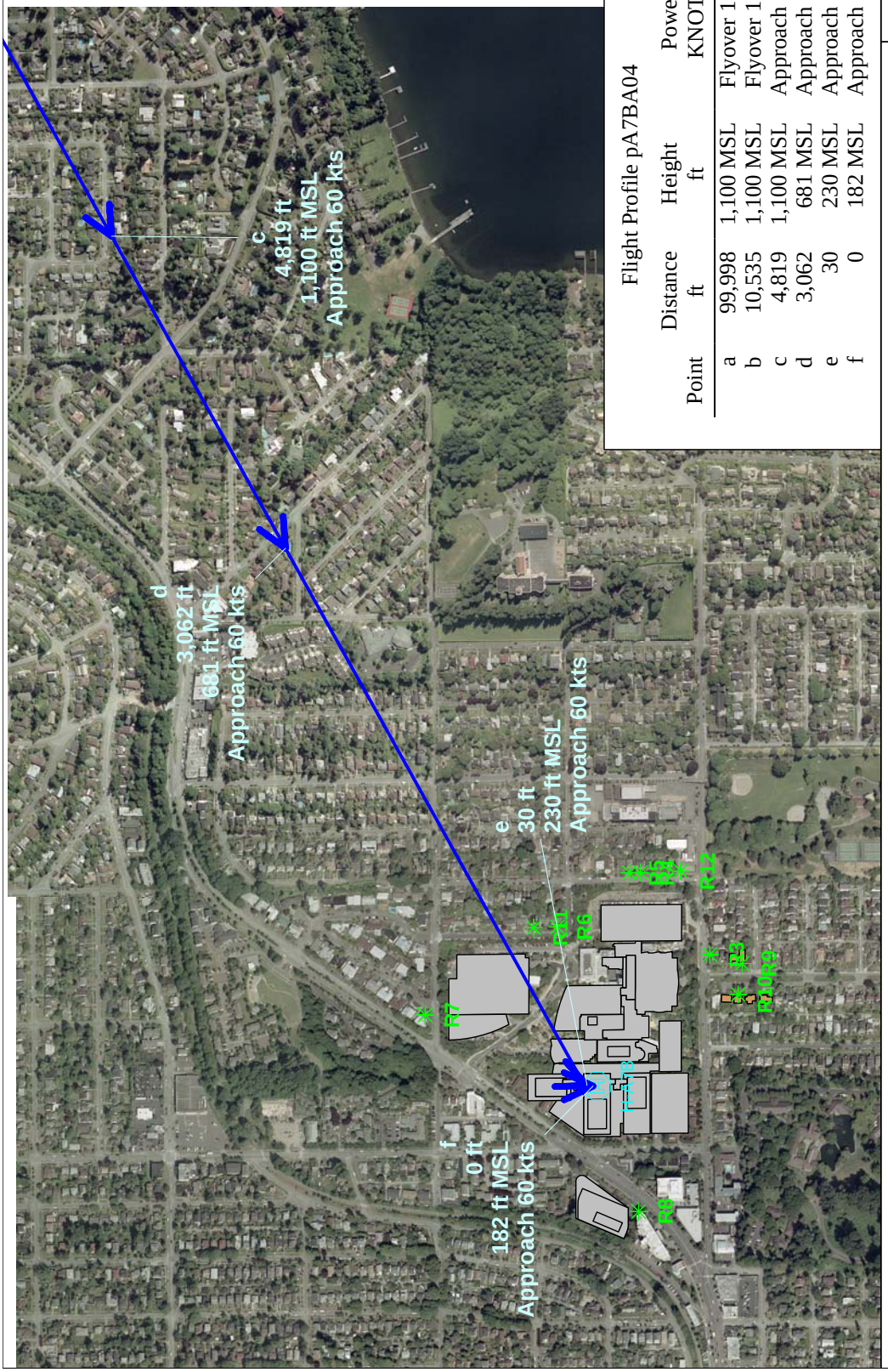
Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	10	186 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts



Flight Profile pA7BA02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	30	240 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
681 ft MSL
Approach 60 kts
e
30 ft
240 ft MSL
Approach 60 kts
f
0 ft
182 ft MSL
Approach 60 kts
R7
R11
R6
R5
R4
R12
R3
R10
R9
R8
Flight Profile pA7BA03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 681 MSL | Approach 60 kts
e | 30 | 240 MSL | Approach 60 kts
f | 0 | 182 MSL | Approach 60 kts
N
Alternative 7B Arrival
Flight Profile pA7BA03
Flight Track A7BA03 - Alt 7B Secondary Approach A
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,980 (1 inch = 832 feet)

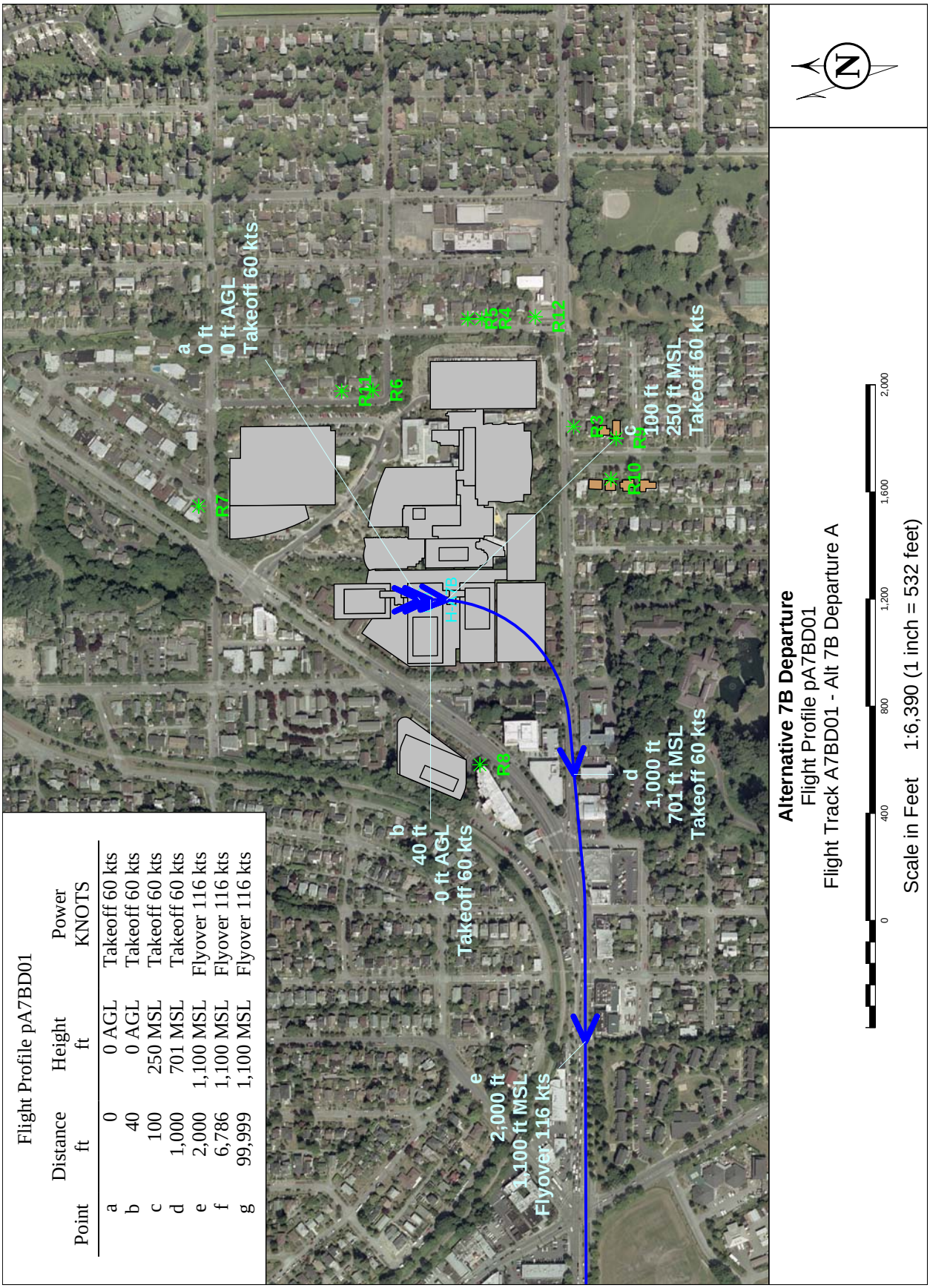


Flight Profile pA7BA04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	30	230 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts

Alternative 7B Arrival
Flight Profile pA7BA04
Flight Track A7BA04 - Alt 7B Secondary Approach B

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,640 (1 inch = 803 feet)

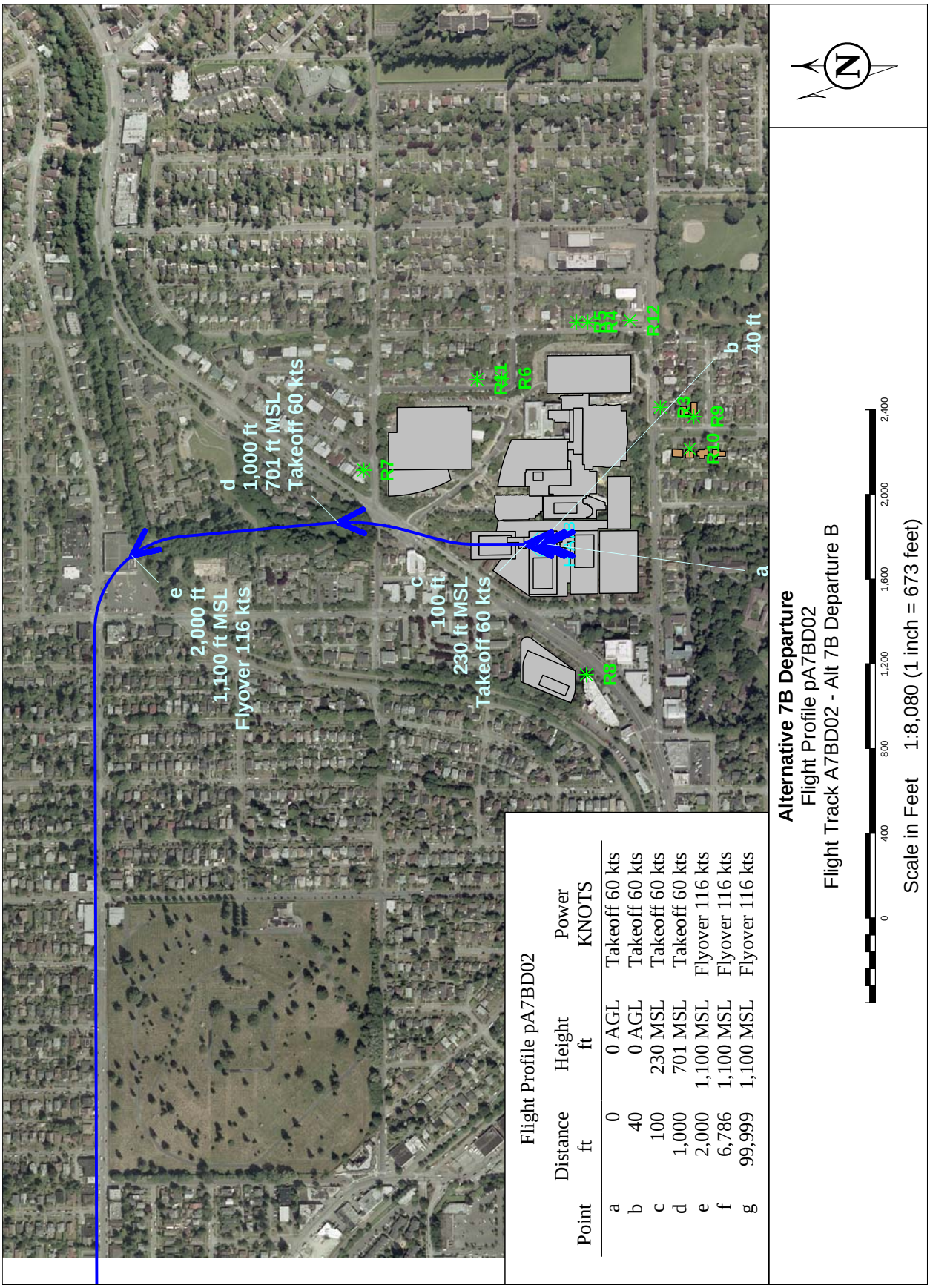


Flight Profile pA7BD01

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	100	250 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 7B Departure
Flight Profile pA7BD01
Flight Track A7BD01 - Alt 7B Departure A

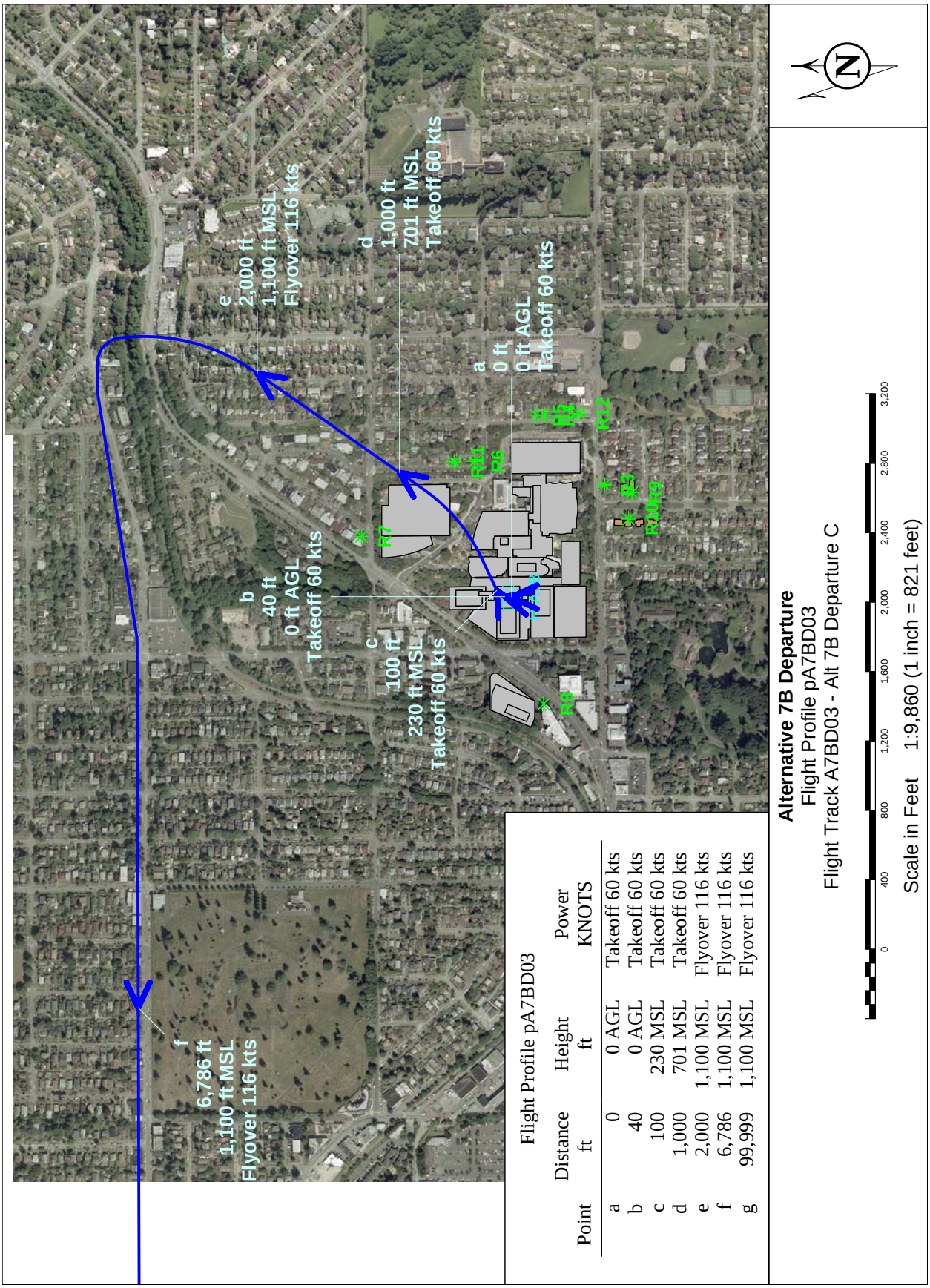
Scale in Feet 1:6,390 (1 inch = 532 feet)



Flight Profile pA7BD02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	100	230 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

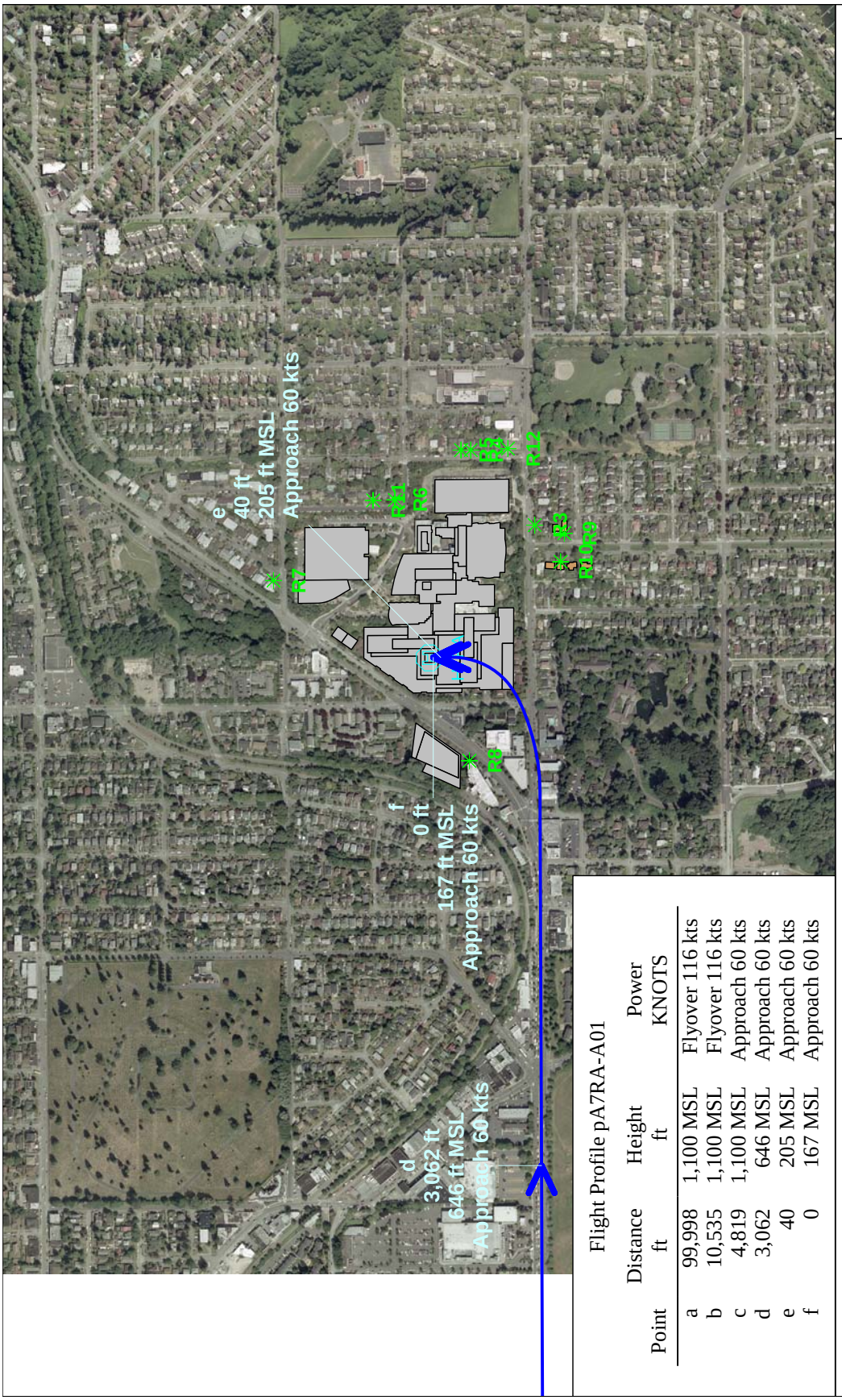
Alternative 7B Departure
Flight Profile pA7BD02
Flight Track A7BD02 - Alt 7B Departure B



Flight Profile pA7BD03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	100	230 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 7B Departure
Flight Profile pA7BD03
Flight Track A7BD03 - Alt 7B Departure C



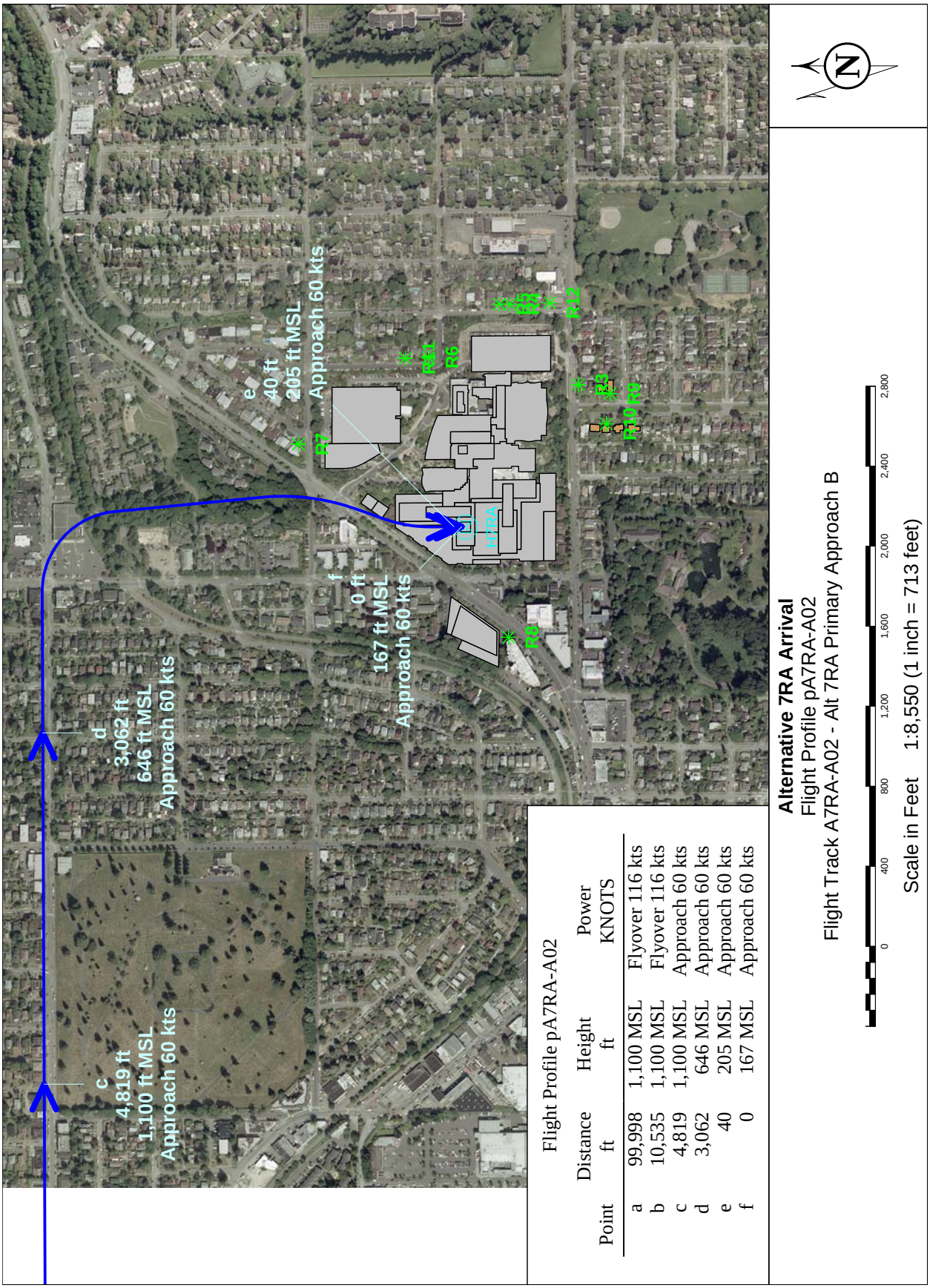
Flight Profile pA7RA-A01

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	646 MSL	Approach 60 kts
e	40	205 MSL	Approach 60 kts
f	0	167 MSL	Approach 60 kts

Alternative 7RA Arrival
Flight Profile pA7RA-A01
Flight Track A7RA-A01 - Alt 7RA Primary Approach A

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

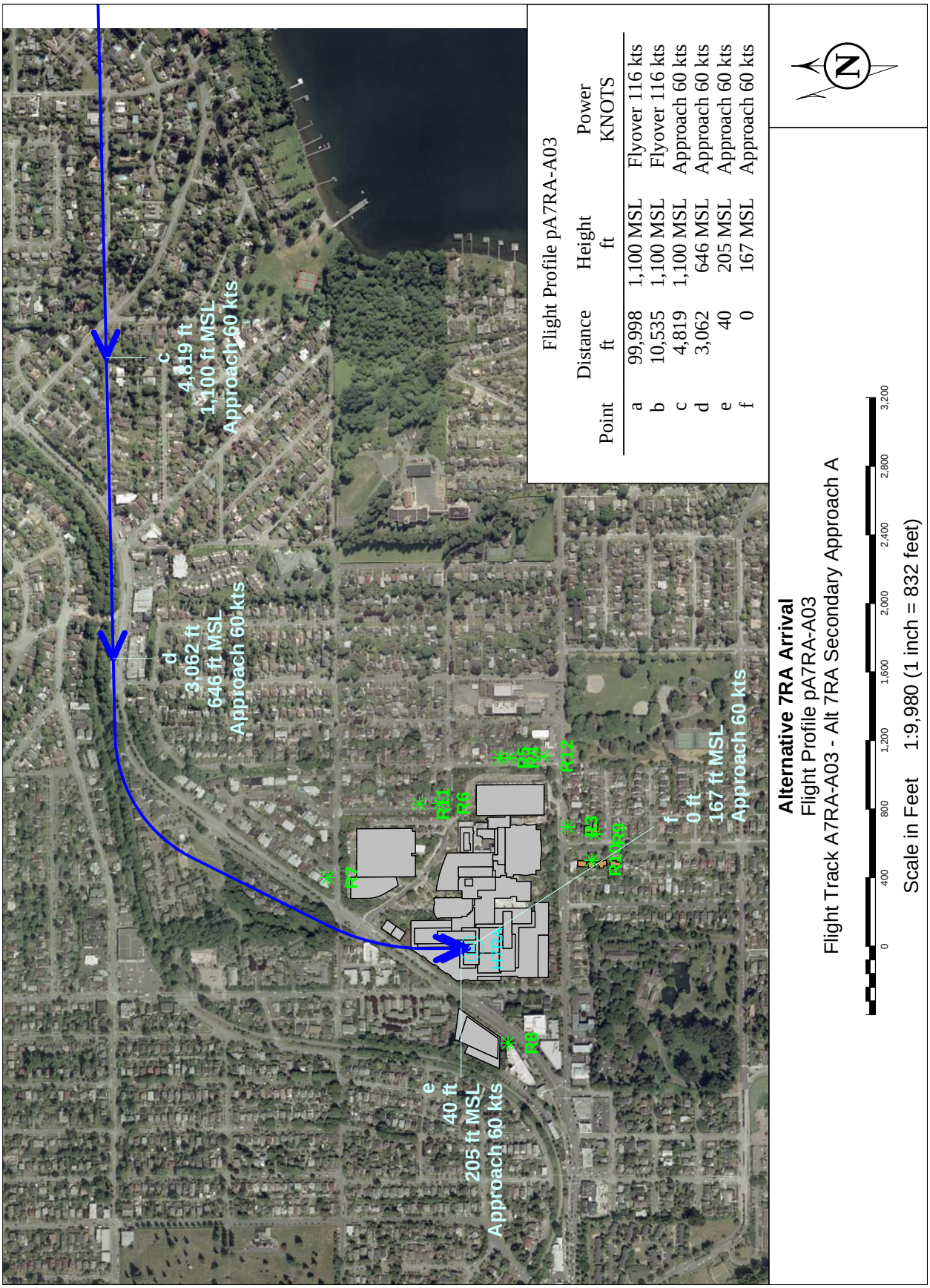
Scale in Feet 1:9,960 (1 inch = 830 feet)

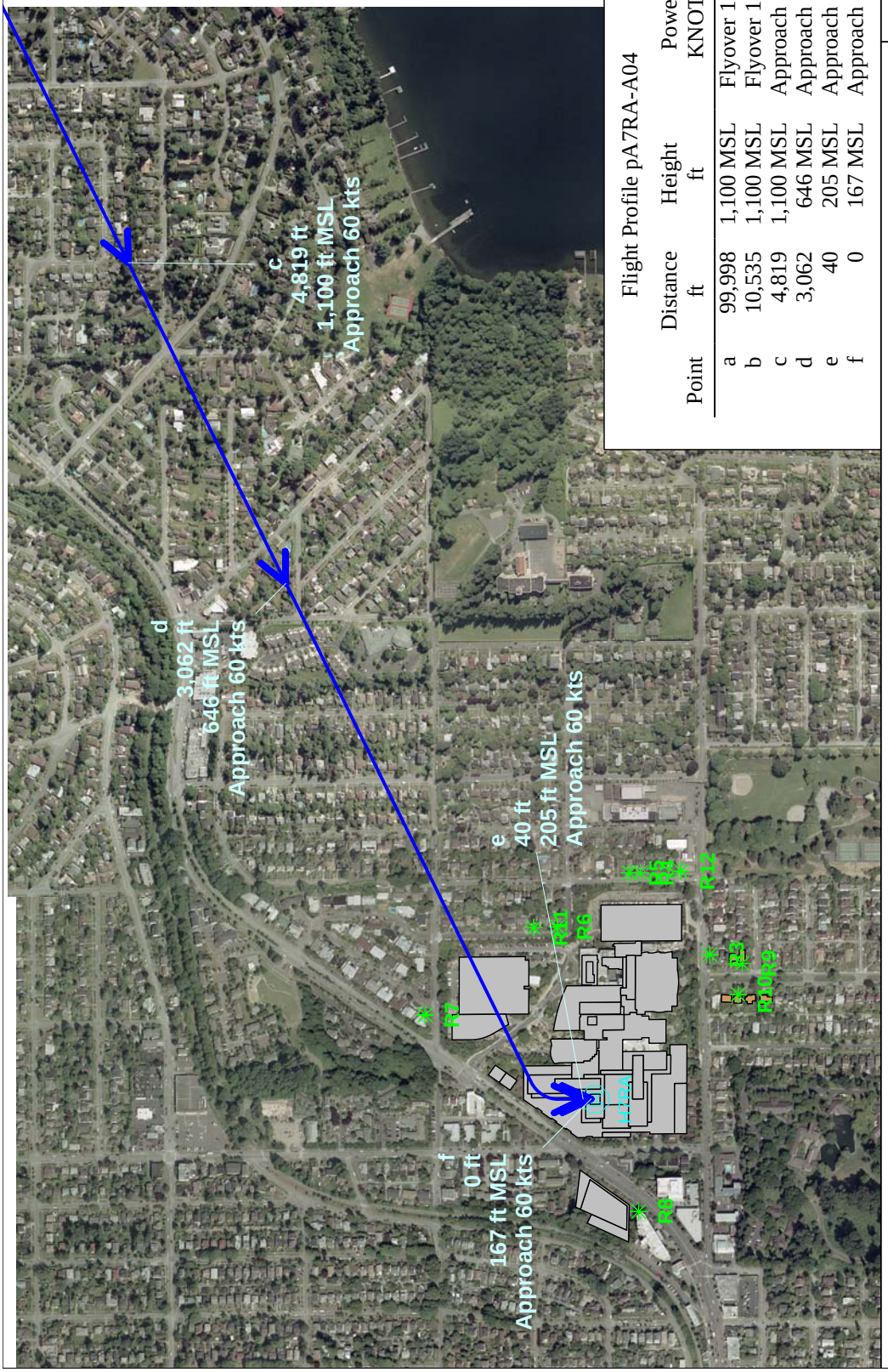


Flight Profile pA7RA-A02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	646 MSL	Approach 60 kts
e	40	205 MSL	Approach 60 kts
f	0	167 MSL	Approach 60 kts

Alternative 7RA Arrival
Flight Profile pA7RA-A02
Flight Track A7RA-A02 - Alt 7RA Primary Approach B


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
646 ft MSL
Approach 60 kts
e
40 ft
205 ft MSL
Approach 60 kts
f
0 ft
167 ft MSL
Approach 60 kts
R7
R11
R6
R5
R4
R12
R3
R2
R1
R10
R8
Flight Profile pA7RA-A03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 646 MSL | Approach 60 kts
e | 40 | 205 MSL | Approach 60 kts
f | 0 | 167 MSL | Approach 60 kts
N
Alternative 7RA Arrival
Flight Profile pA7RA-A03
Flight Track A7RA-A03 - Alt 7RA Secondary Approach A
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,980 (1 inch = 832 feet)



Flight Profile pA7RA-A04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	646 MSL	Approach 60 kts
e	40	205 MSL	Approach 60 kts
f	0	167 MSL	Approach 60 kts

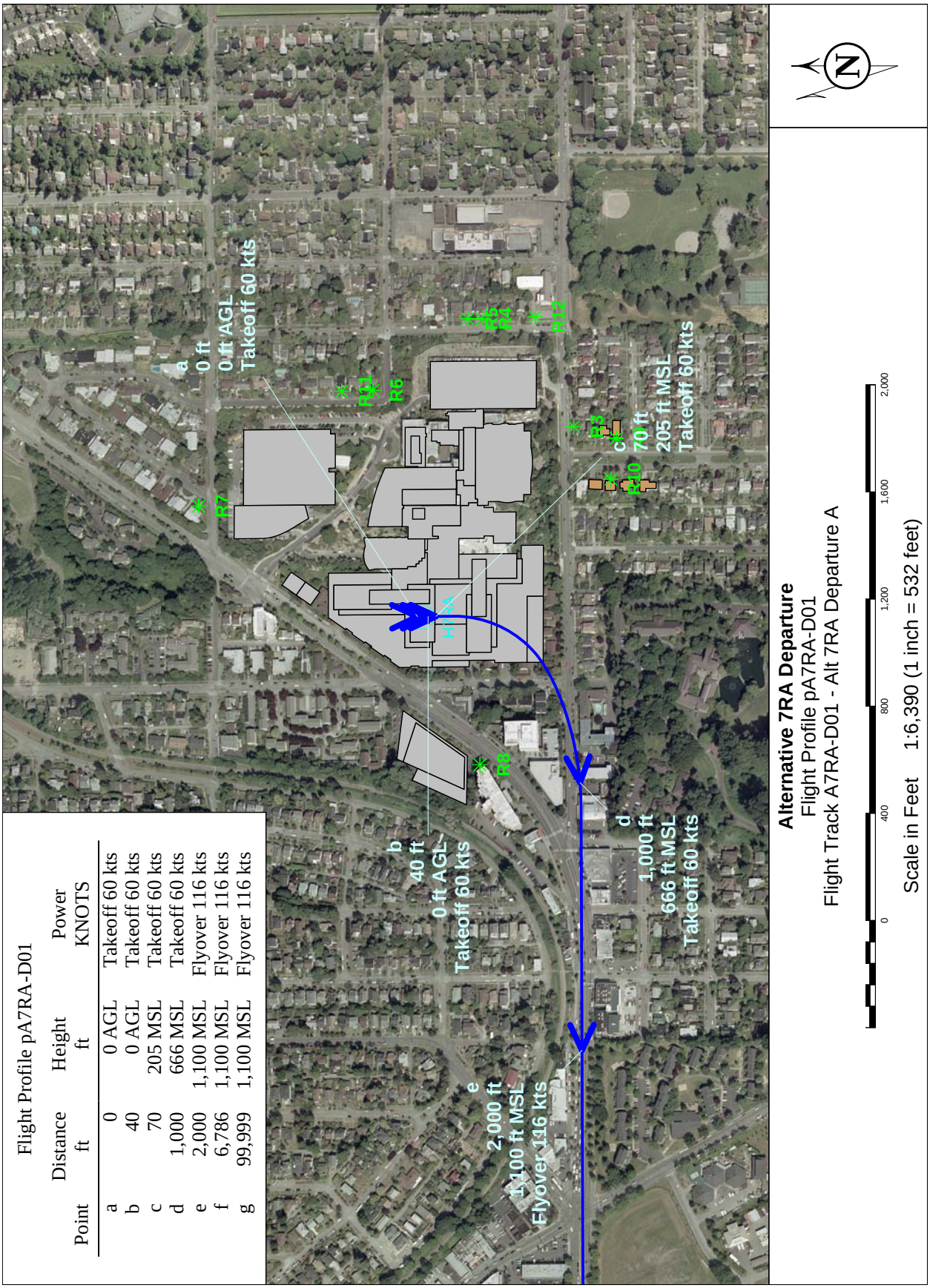
Alternative 7RA Arrival
Flight Profile pA7RA-A04
Flight Track A7RA-A04 - Alt 7RA Secondary Approach B

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

Scale in Feet 1:9,640 (1 inch = 803 feet)

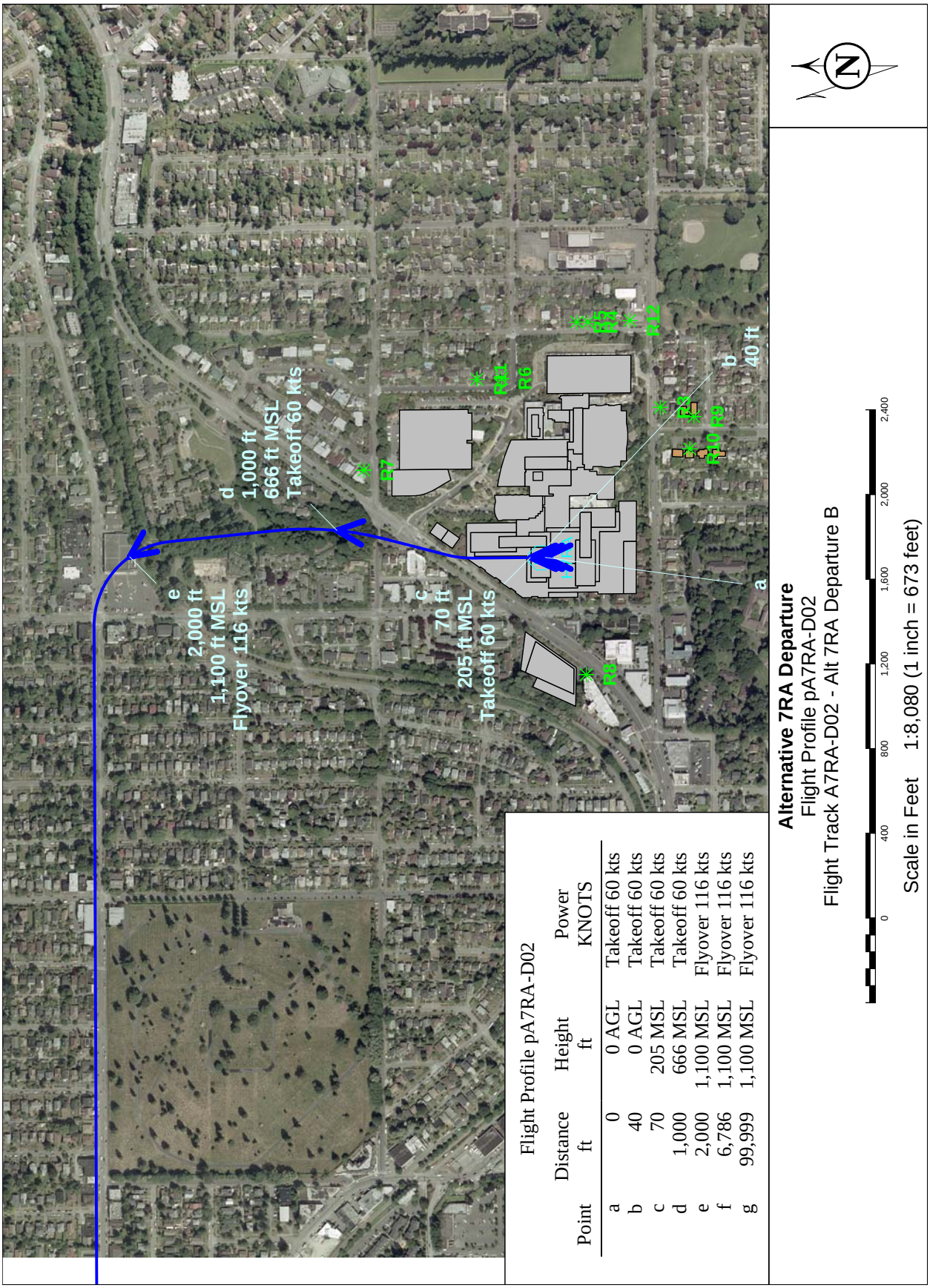
Flight Profile pA7RA-D01

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	205 MSL	Takeoff 60 kts
d	1,000	666 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



Alternative 7RA Departure
Flight Profile pA7RA-D01
Flight Track A7RA-D01 - Alt 7RA Departure A

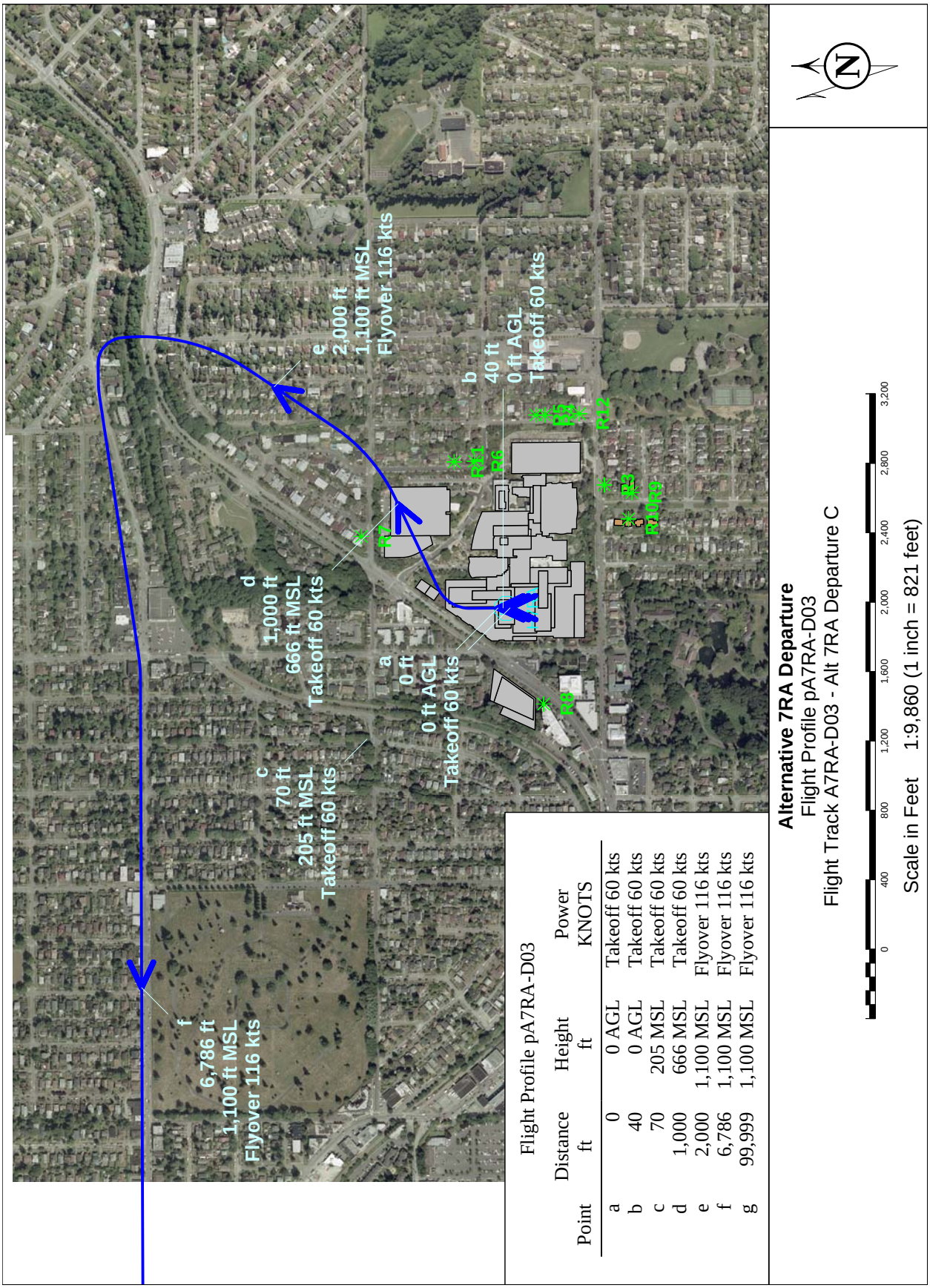
Scale in Feet 1:6,390 (1 inch = 532 feet)



Flight Profile pA7RA-D02

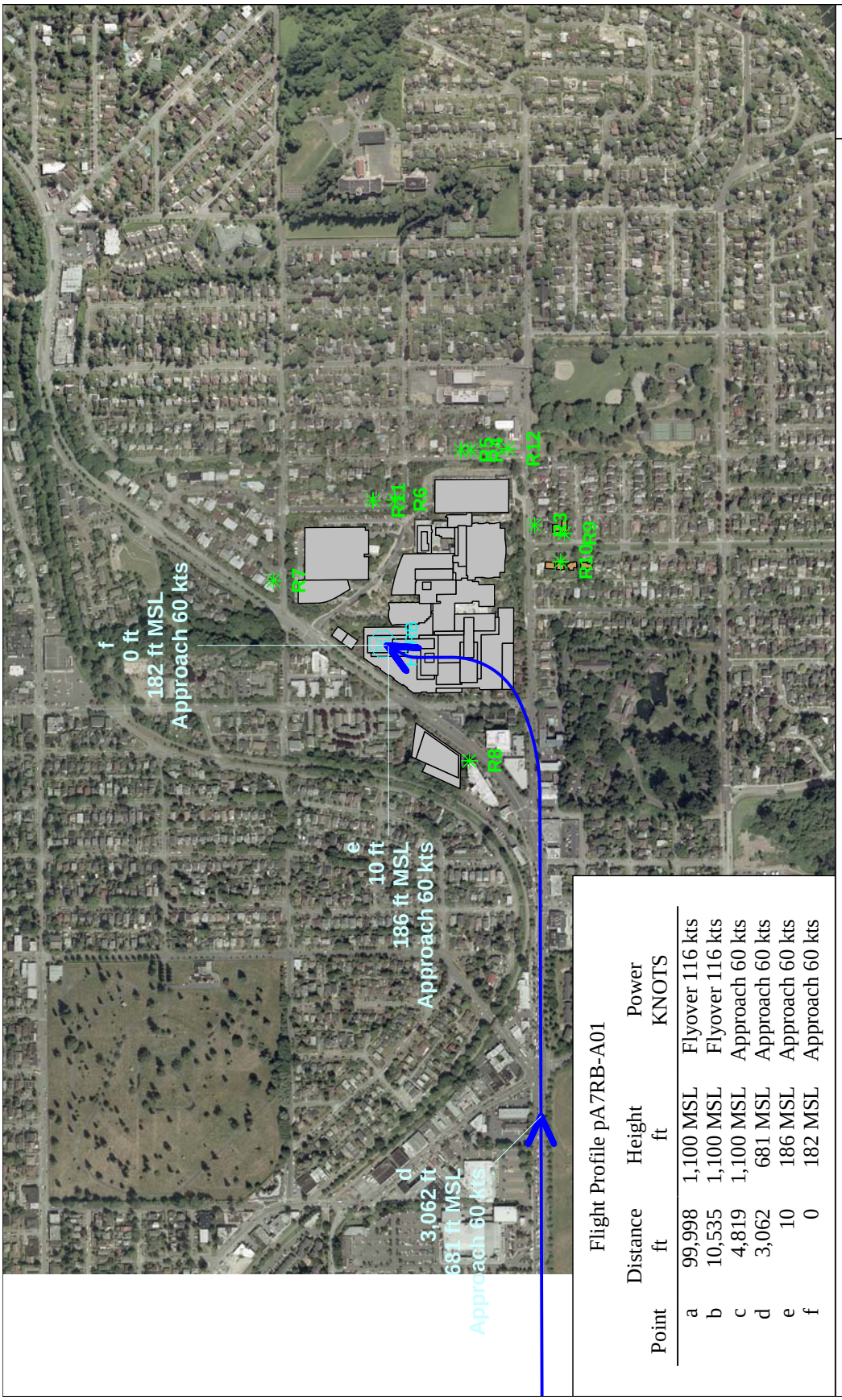
Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	205 MSL	Takeoff 60 kts
d	1,000	666 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 7RA Departure
Flight Profile pA7RA-D02
Flight Track A7RA-D02 - Alt 7RA Departure B



Flight Profile pA7RA-D03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	205 MSL	Takeoff 60 kts
d	1,000	666 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



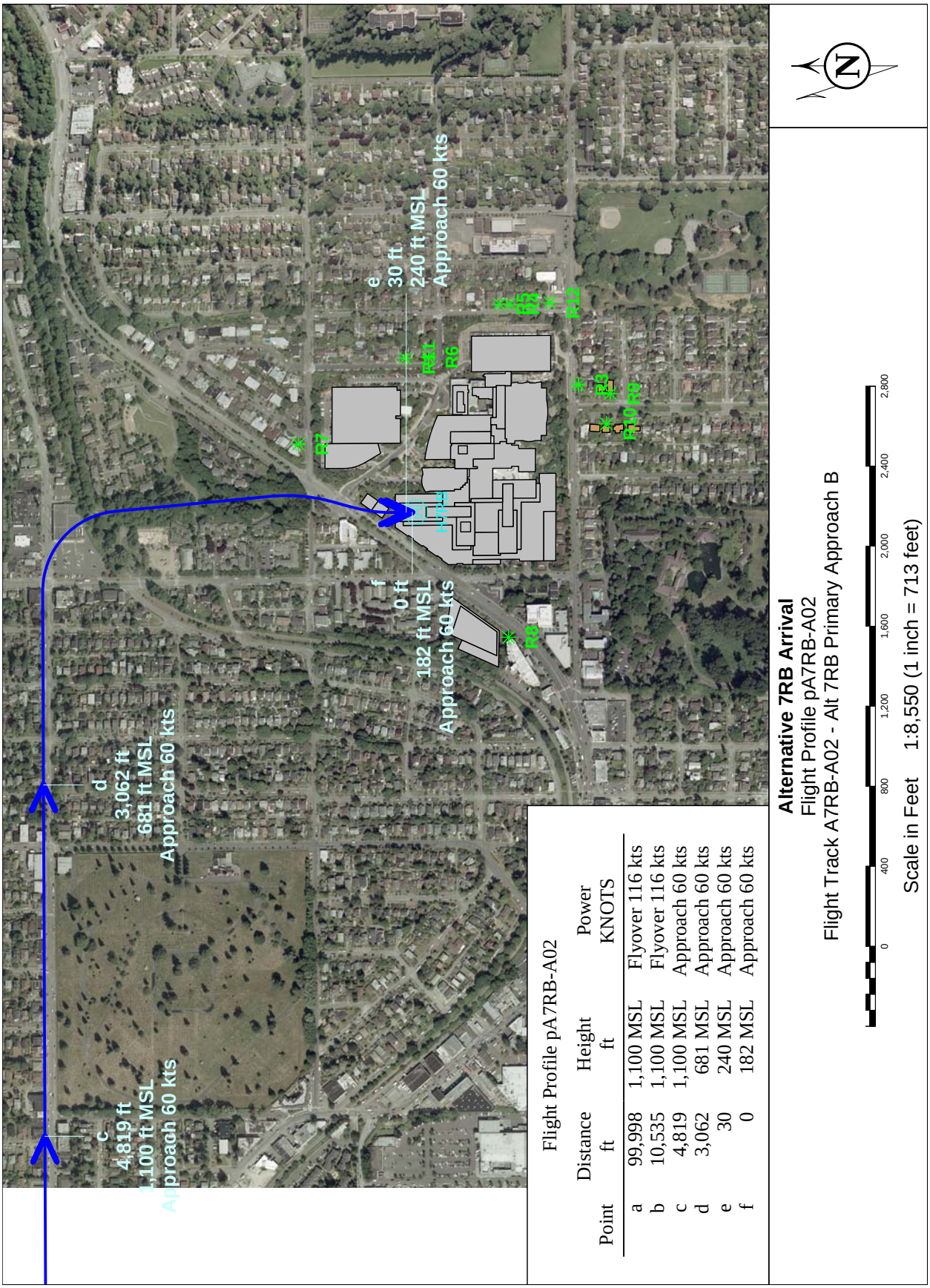
Flight Profile pA7RB-A01

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	10	186 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts

Alternative 7RB Arrival
Flight Profile pA7RB-A01
Flight Track A7RB-A01 - Alt 7RB Primary Approach A

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

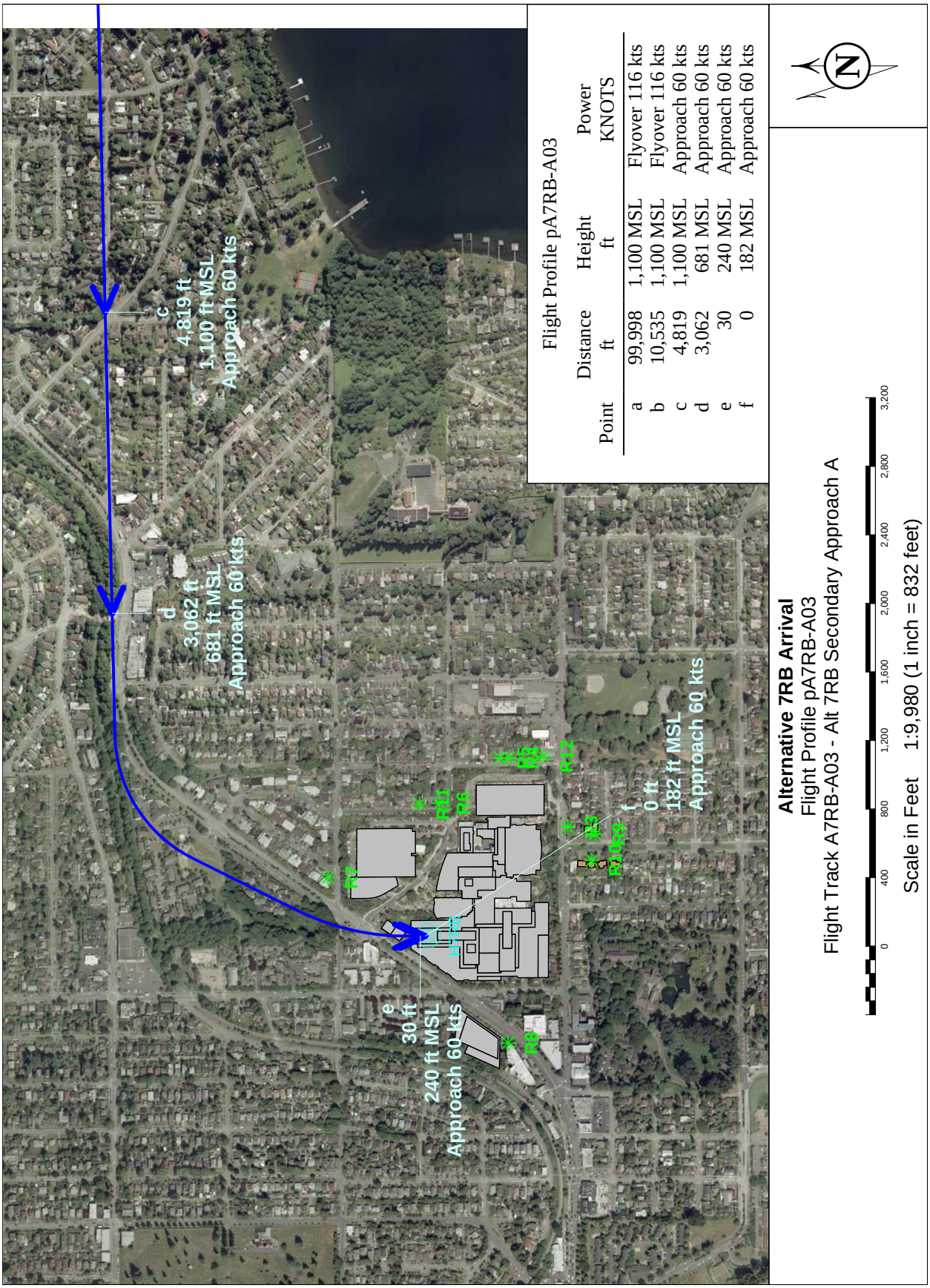
Scale in Feet 1:9,960 (1 inch = 830 feet)

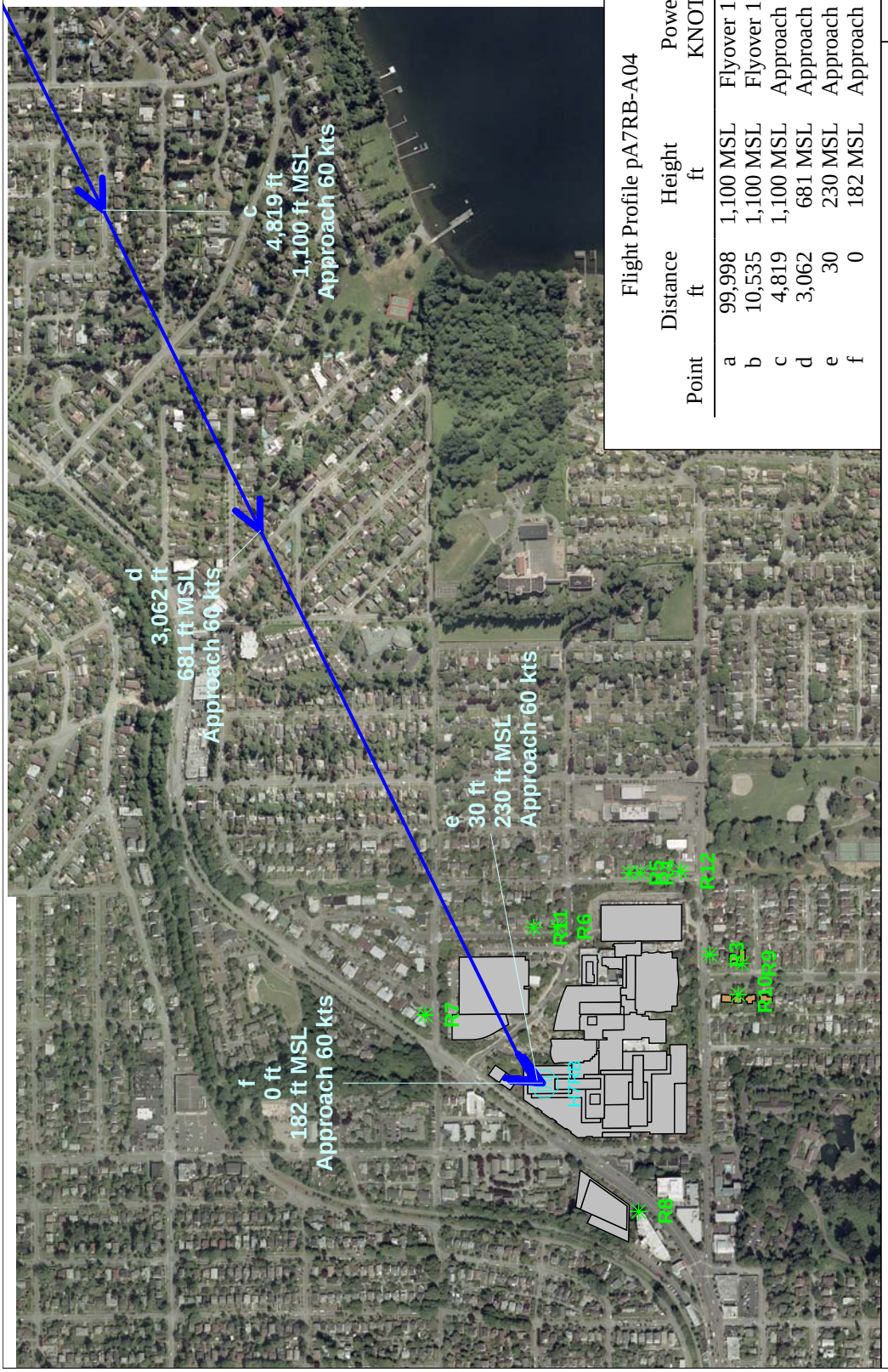


Flight Profile pA7RB-A02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	30	240 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts

Alternative 7RB Arrival
Flight Profile pA7RB-A02
Flight Track A7RB-A02 - Alt 7RB Primary Approach B


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
681 ft MSL
Approach 60 kts
e
30 ft
240 ft MSL
Approach 60 kts
f
0 ft
182 ft MSL
Approach 60 kts
R7
R11
R6
R5
R4
R12
R3
R10
R9
R8
A7RB
Flight Profile pA7RB-A03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 681 MSL | Approach 60 kts
e | 30 | 240 MSL | Approach 60 kts
f | 0 | 182 MSL | Approach 60 kts
N
Alternative 7RB Arrival
Flight Profile pA7RB-A03
Flight Track A7RB-A03 - Alt 7RB Secondary Approach A
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,980 (1 inch = 832 feet)



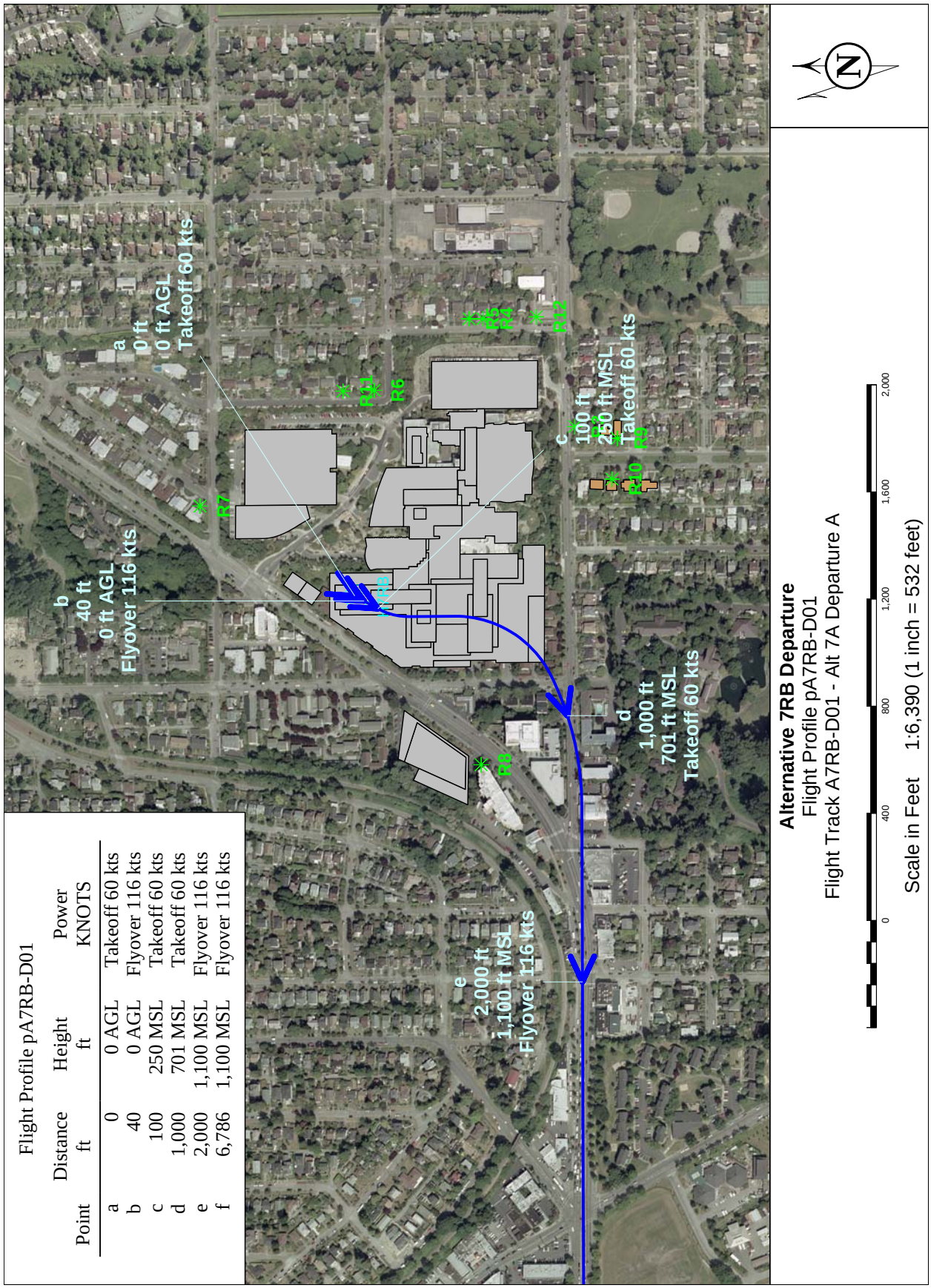
Flight Profile pA7RB-A04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	30	230 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts

Alternative 7RB Arrival
Flight Profile pA7RB-A04
Flight Track A7RB-A04 - Alt 7RB Secondary Approach B

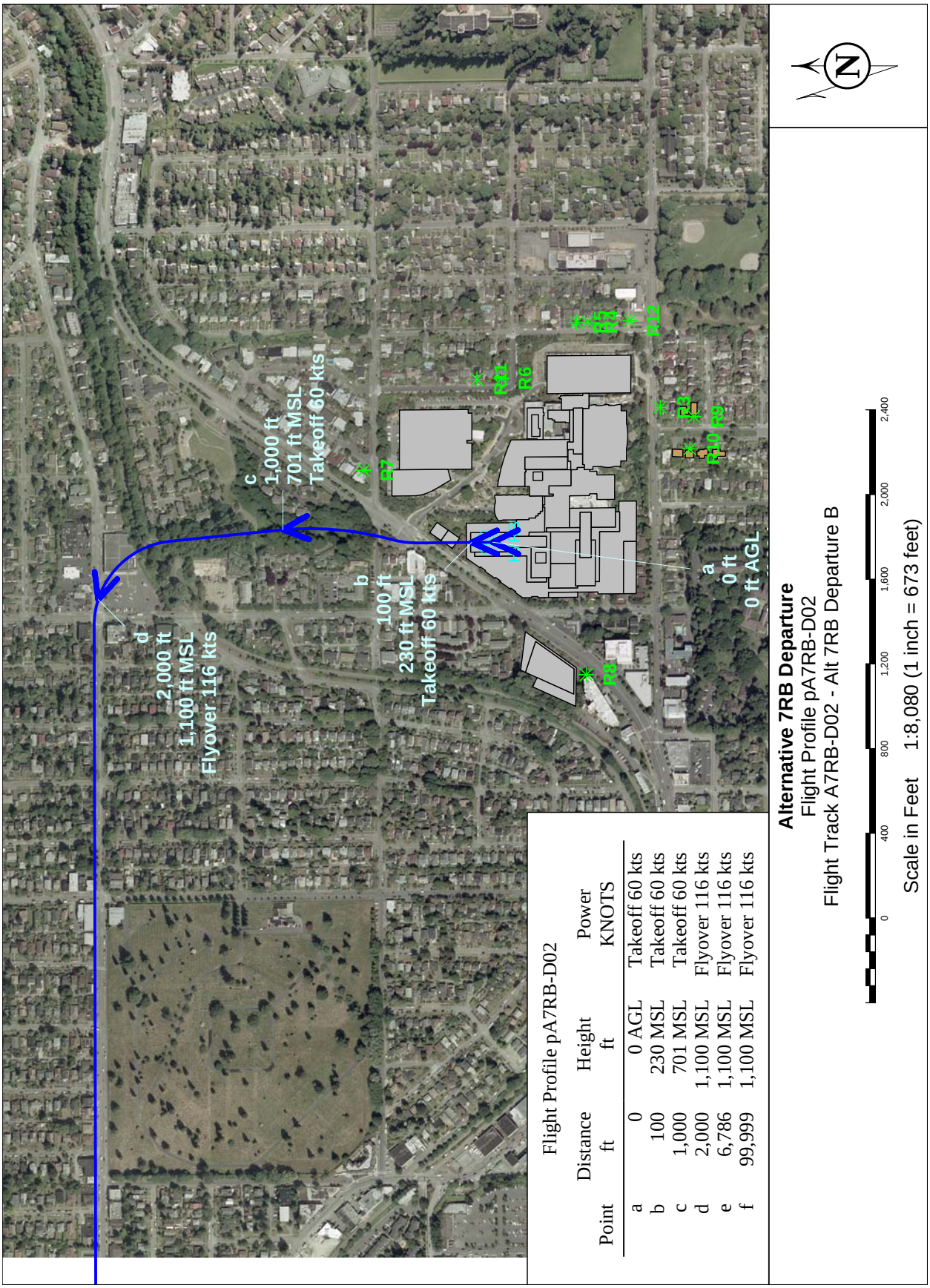
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

Scale in Feet 1:9,640 (1 inch = 803 feet)



Flight Profile pA7RB-D01

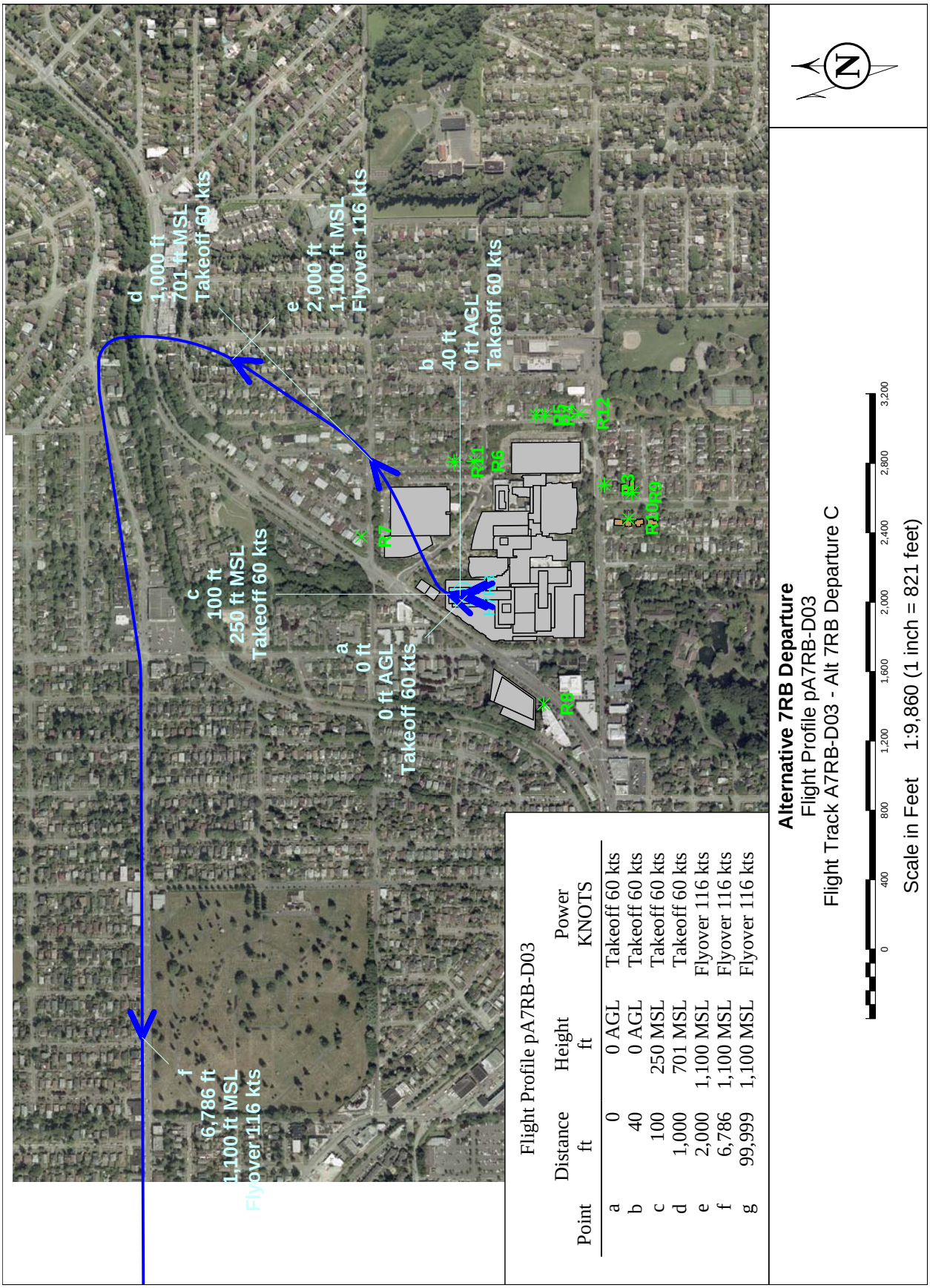
Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Flyover 116 kts
c	100	250 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts



Flight Profile pA7RB-D02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	100	230 MSL	Takeoff 60 kts
c	1,000	701 MSL	Takeoff 60 kts
d	2,000	1,100 MSL	Flyover 116 kts
e	6,786	1,100 MSL	Flyover 116 kts
f	99,999	1,100 MSL	Flyover 116 kts

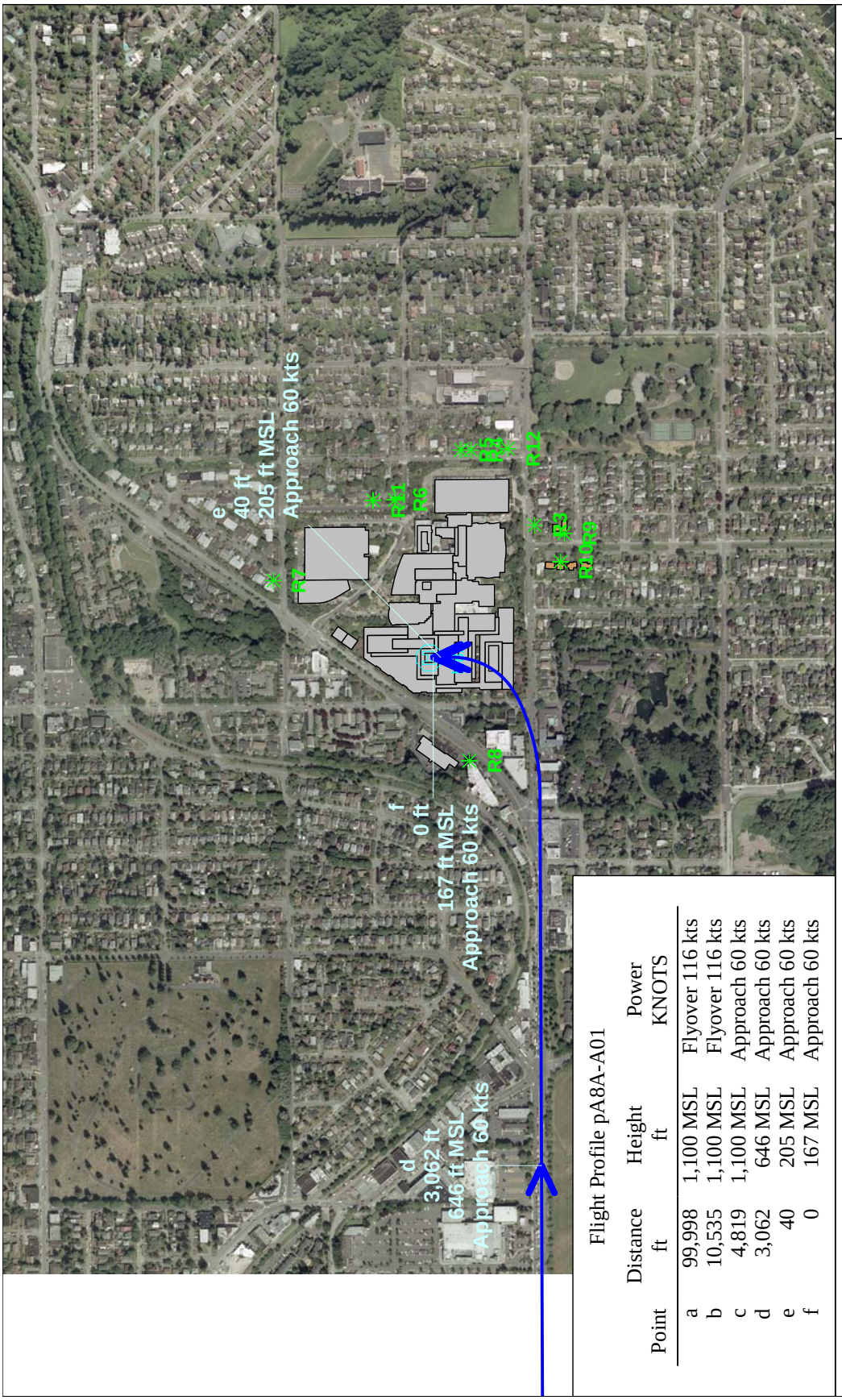
Alternative 7RB Departure
Flight Profile pA7RB-D02
Flight Track A7RB-D02 - Alt 7RB Departure B



Flight Profile pA7RB-D03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	100	250 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 7RB Departure
Flight Profile pA7RB-D03
Flight Track A7RB-D03 - Alt 7RB Departure C



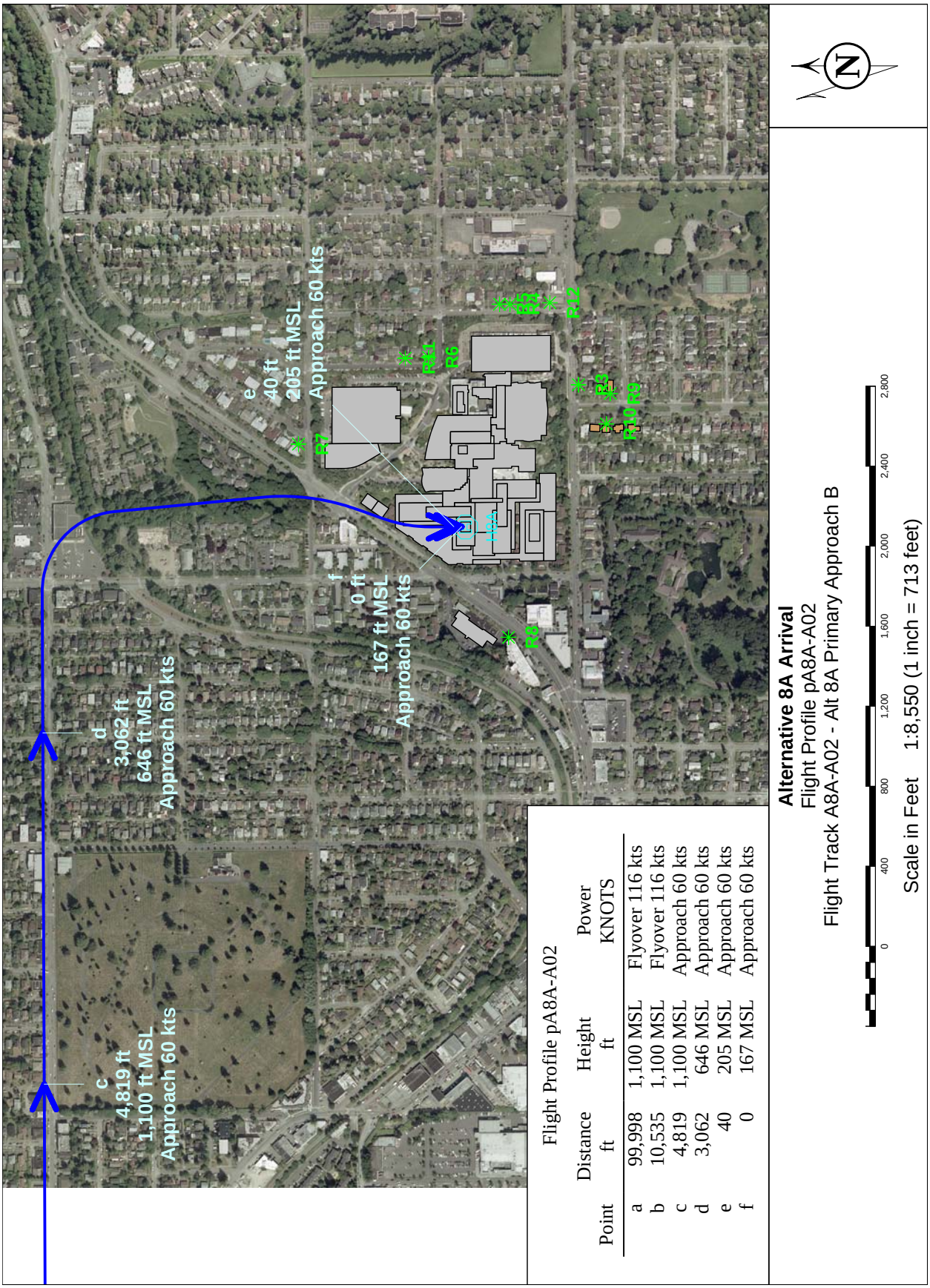
Flight Profile pA8A-A01

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	646 MSL	Approach 60 kts
e	40	205 MSL	Approach 60 kts
f	0	167 MSL	Approach 60 kts

Alternative 8A Arrival
Flight Profile pA8A-A01
Flight Track A8A-A01 - Alt 8A Primary Approach A

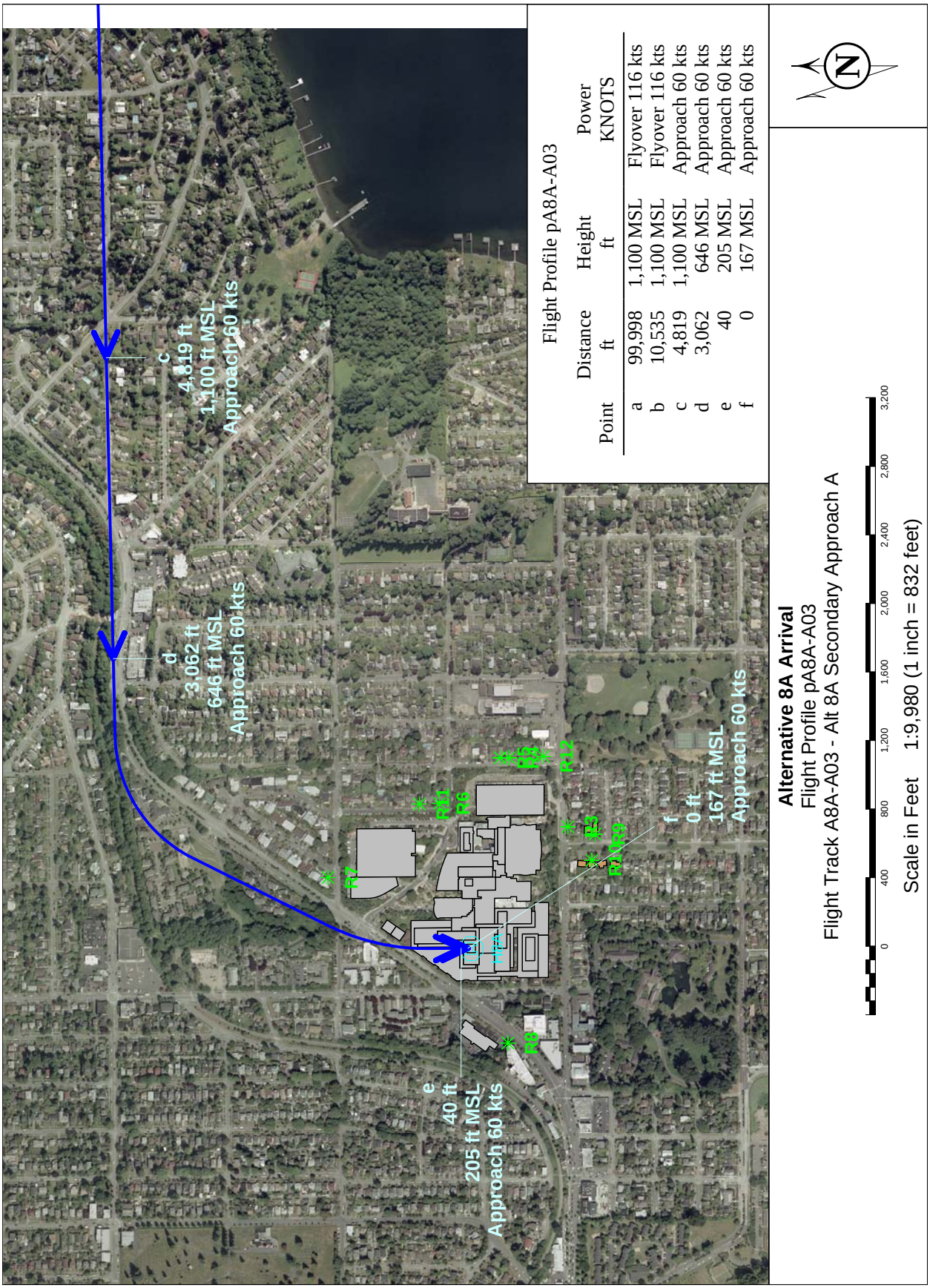
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

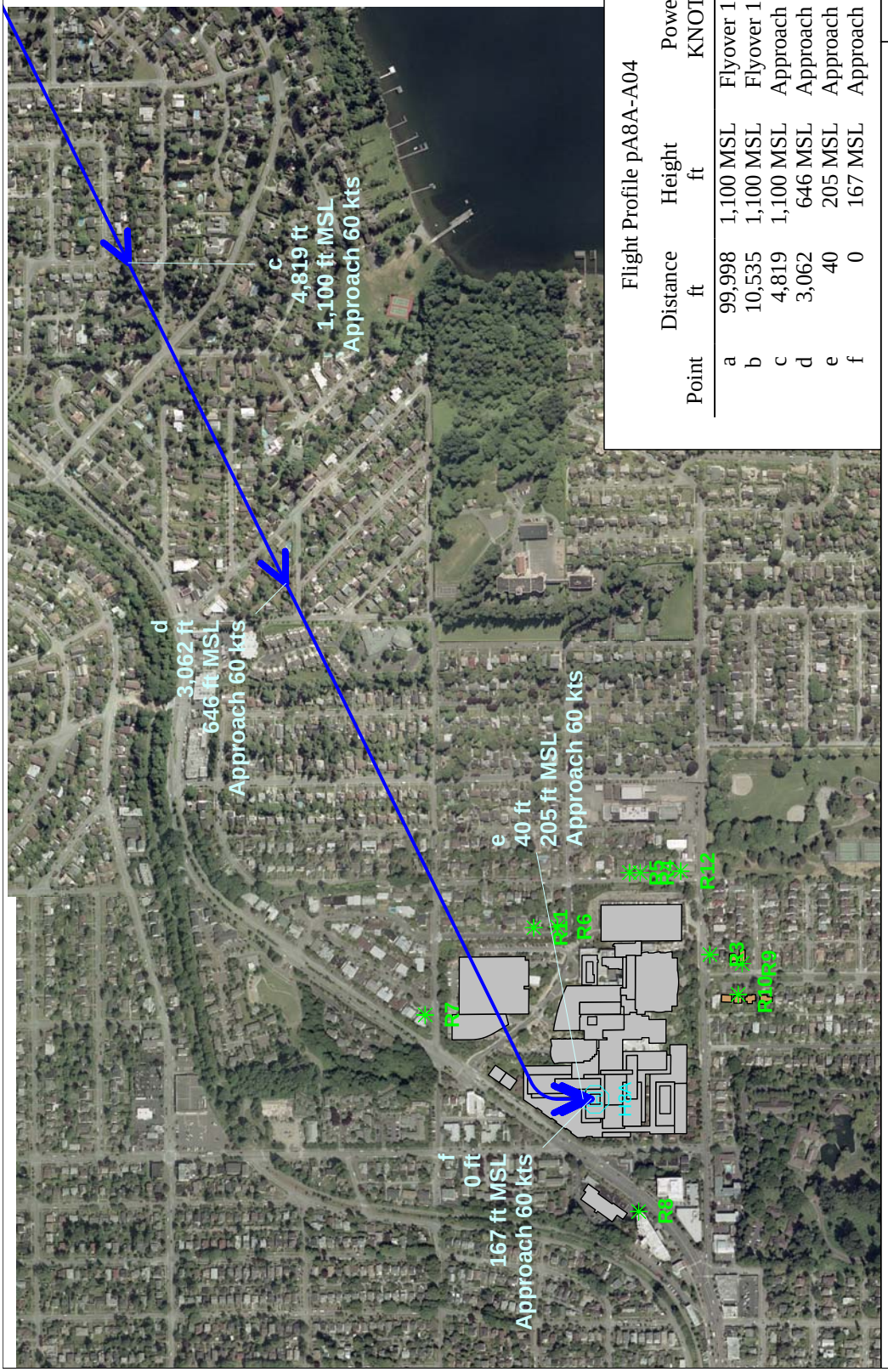
Scale in Feet 1:9,960 (1 inch = 830 feet)



Flight Profile pA8A-A02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	646 MSL	Approach 60 kts
e	40	205 MSL	Approach 60 kts
f	0	167 MSL	Approach 60 kts


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
646 ft MSL
Approach 60 kts
e
40 ft
205 ft MSL
Approach 60 kts
f
0 ft
167 ft MSL
Approach 60 kts
R7
R11
R6
R5
R4
R12
R3
R2
R1
R8
Flight Profile pA8A-A03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 646 MSL | Approach 60 kts
e | 40 | 205 MSL | Approach 60 kts
f | 0 | 167 MSL | Approach 60 kts
N
Alternative 8A Arrival
Flight Profile pA8A-A03
Flight Track A8A-A03 - Alt 8A Secondary Approach A
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,980 (1 inch = 832 feet)



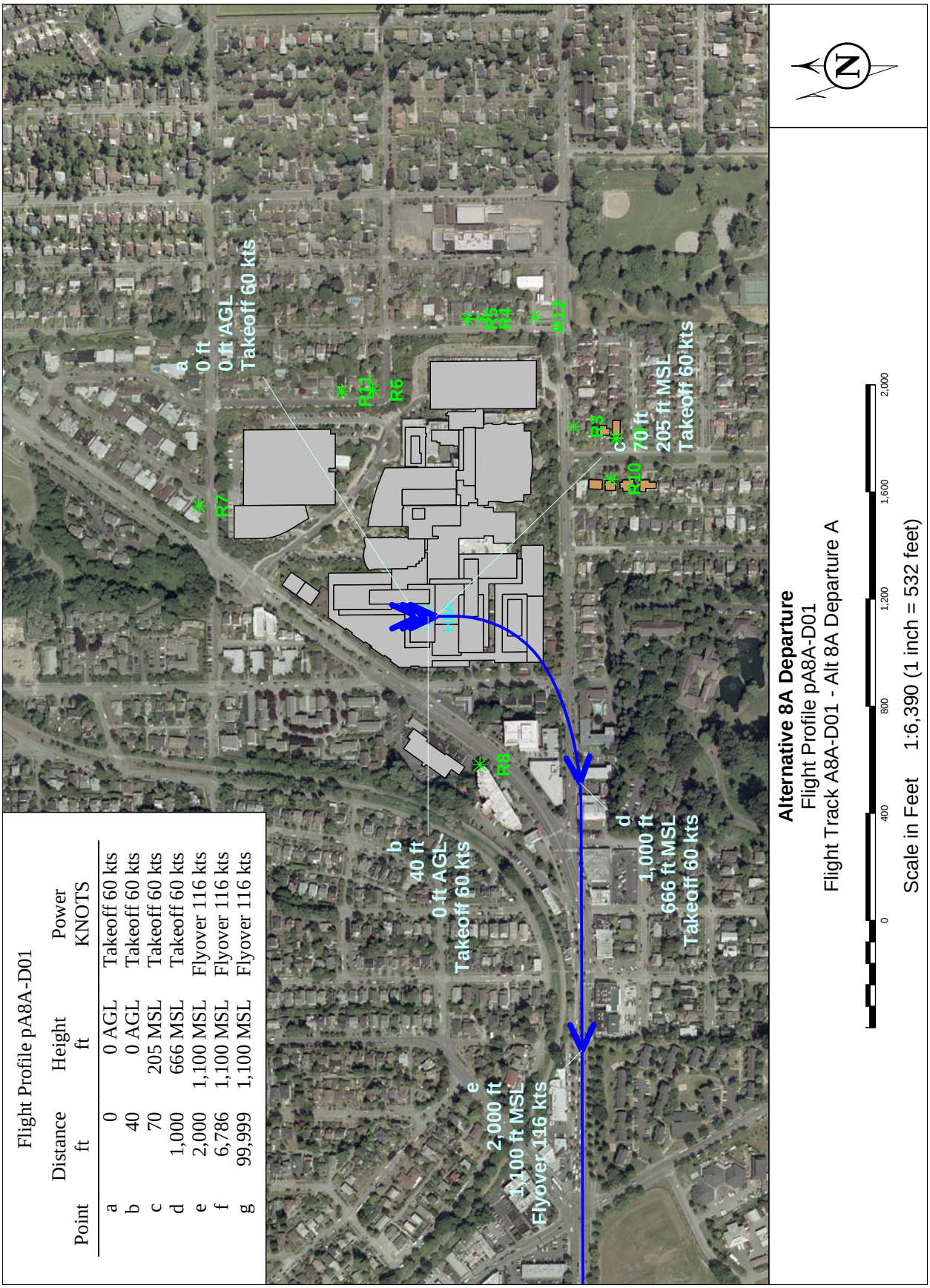
Flight Profile pA8A-A04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	646 MSL	Approach 60 kts
e	40	205 MSL	Approach 60 kts
f	0	167 MSL	Approach 60 kts

Alternative 8A Arrival
Flight Profile pA8A-A04
Flight Track A8A-A04 - Alt 8A Secondary Approach B

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

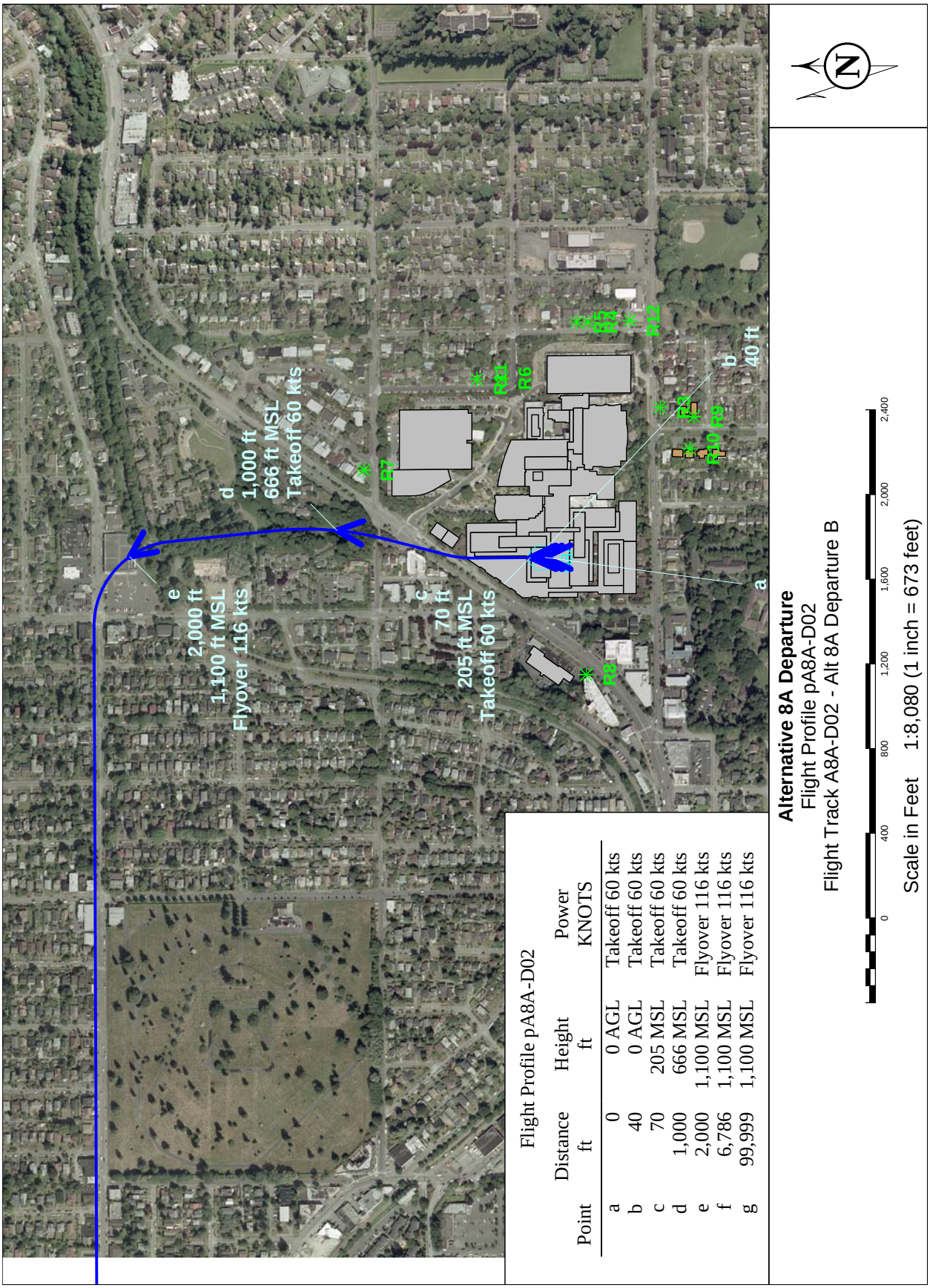
Scale in Feet 1:9,640 (1 inch = 803 feet)



Flight Profile pA8A-D01

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	205 MSL	Takeoff 60 kts
d	1,000	666 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

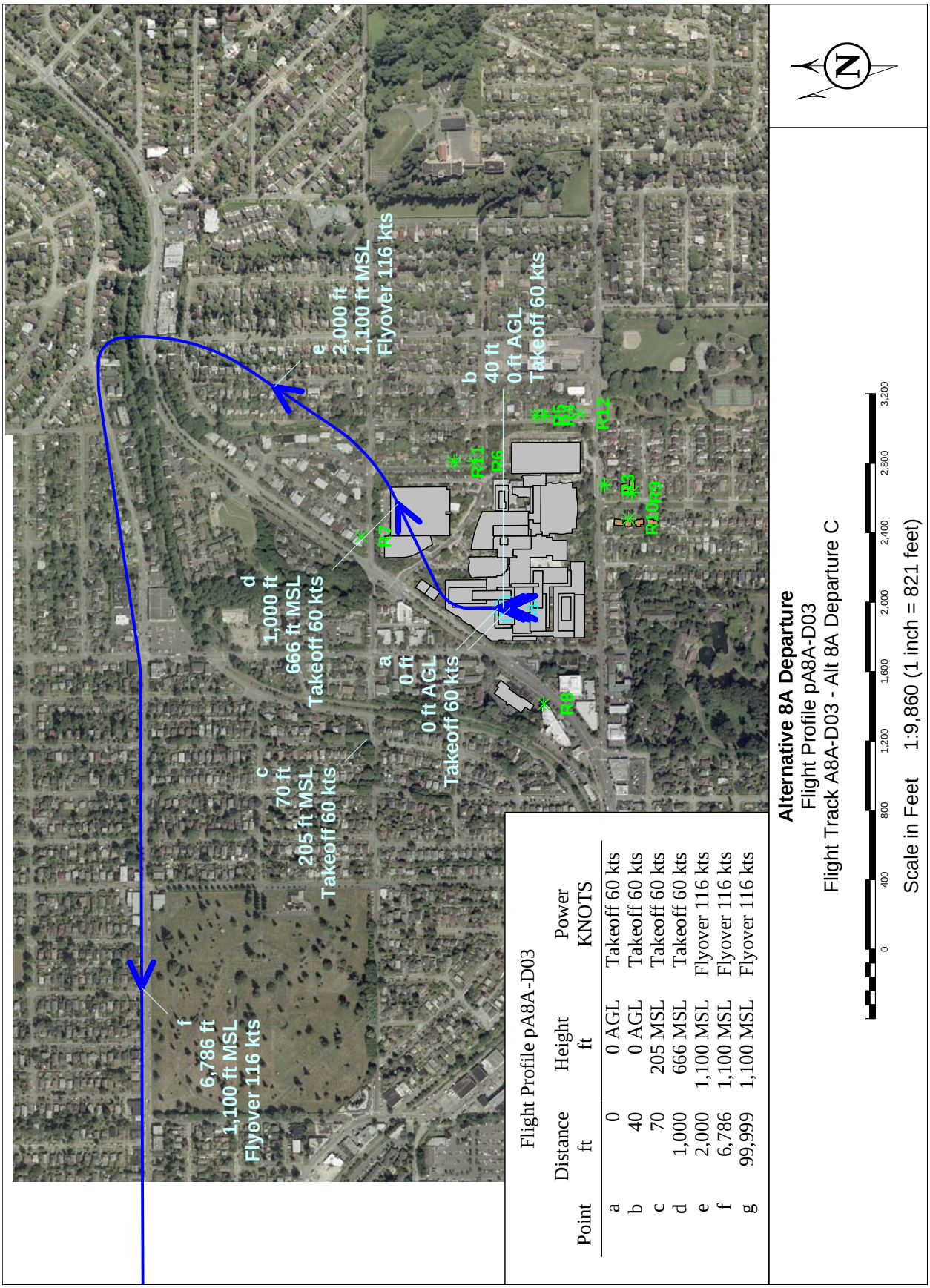
Alternative 8A Departure
Flight Profile pA8A-D01
Flight Track A8A-D01 - Alt 8A Departure A



Flight Profile pA8A-D02

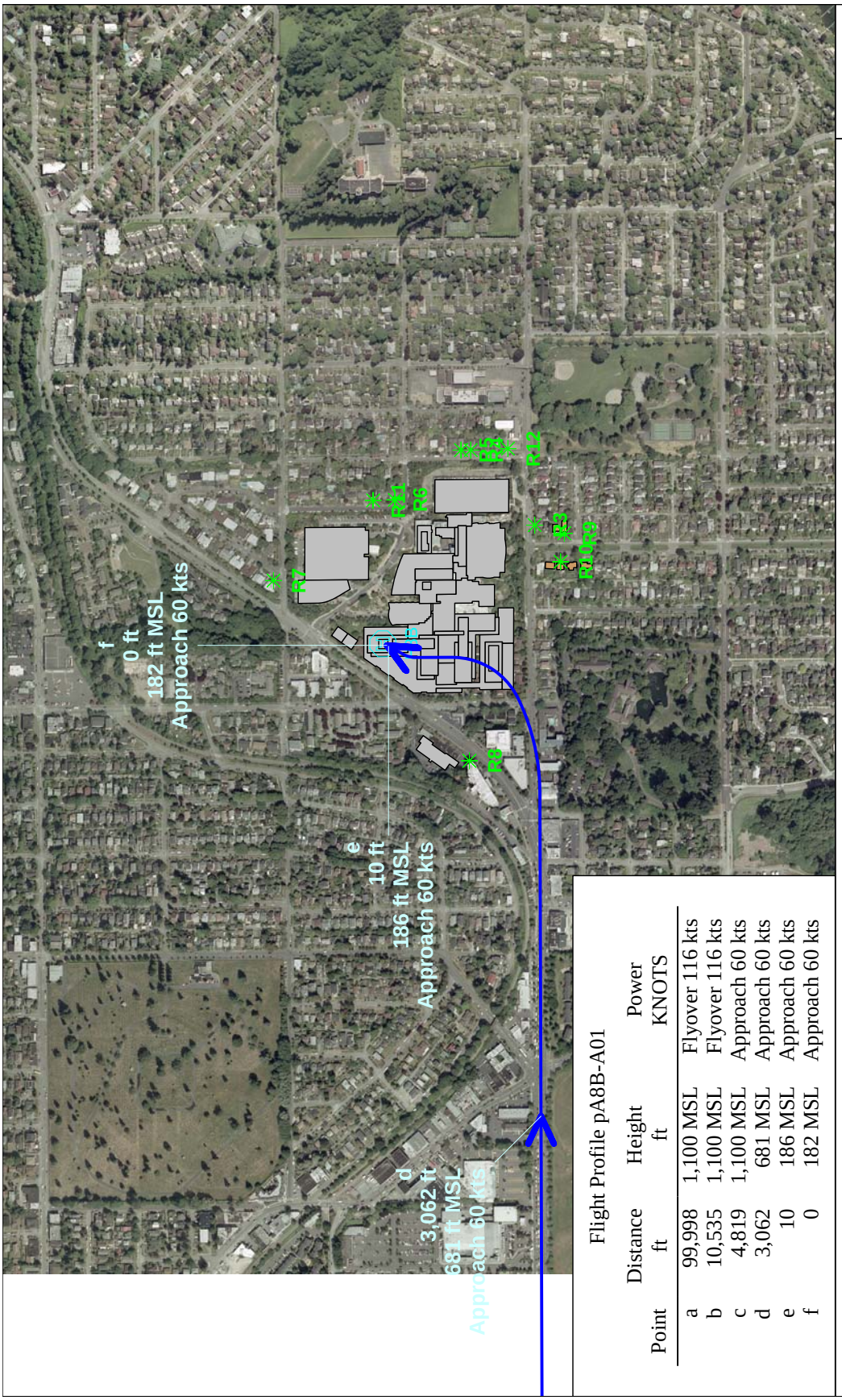
Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	205 MSL	Takeoff 60 kts
d	1,000	666 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 8A Departure
Flight Profile pA8A-D02
Flight Track A8A-D02 - Alt 8A Departure B



Flight Profile pA8A-D03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	70	205 MSL	Takeoff 60 kts
d	1,000	666 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

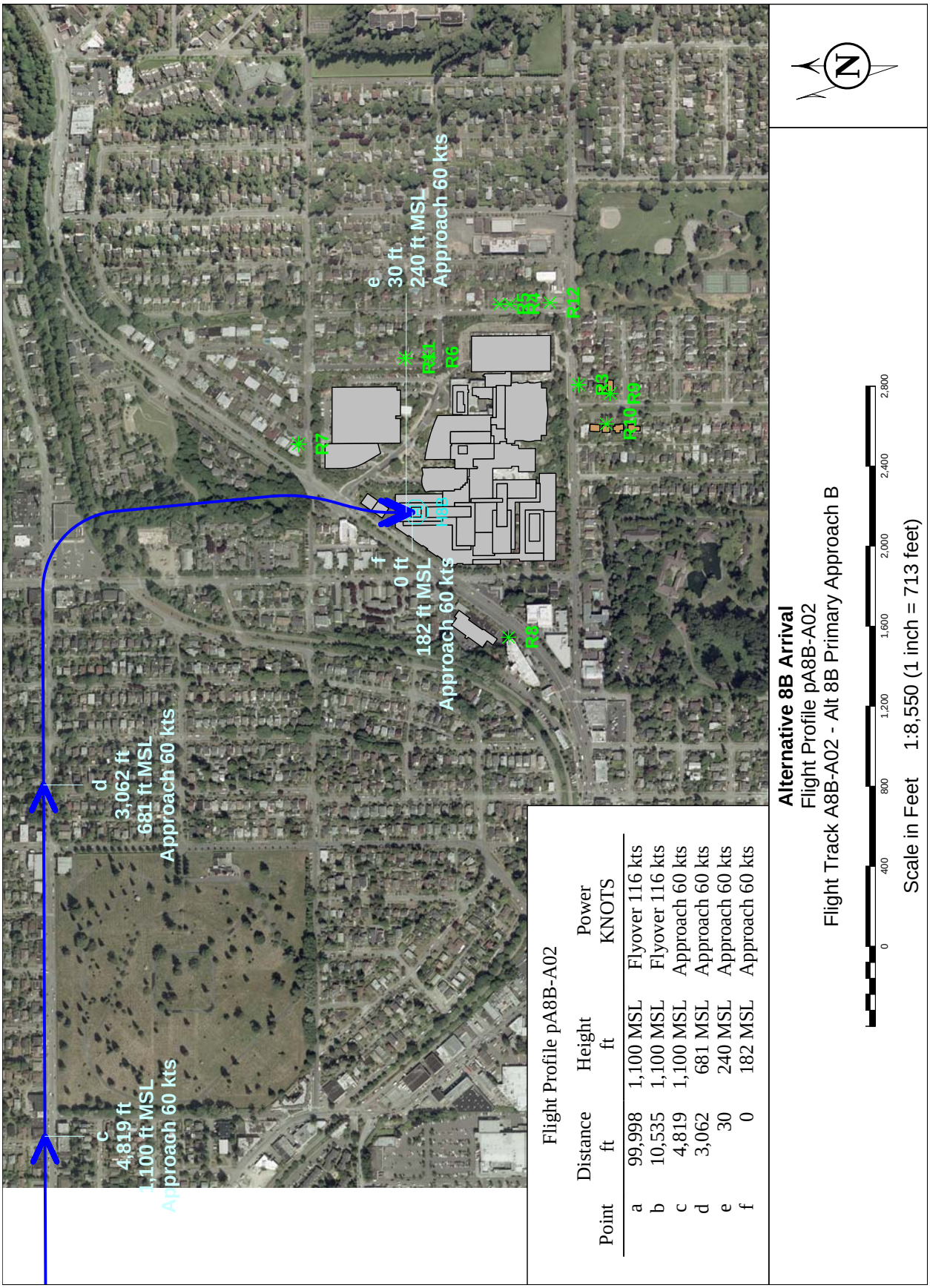


Flight Profile pA8B-A01

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	10	186 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts

Alternative 8B Arrival
Flight Profile pA8B-A01
Flight Track A8B-A01 - Alt 8B Primary Approach A

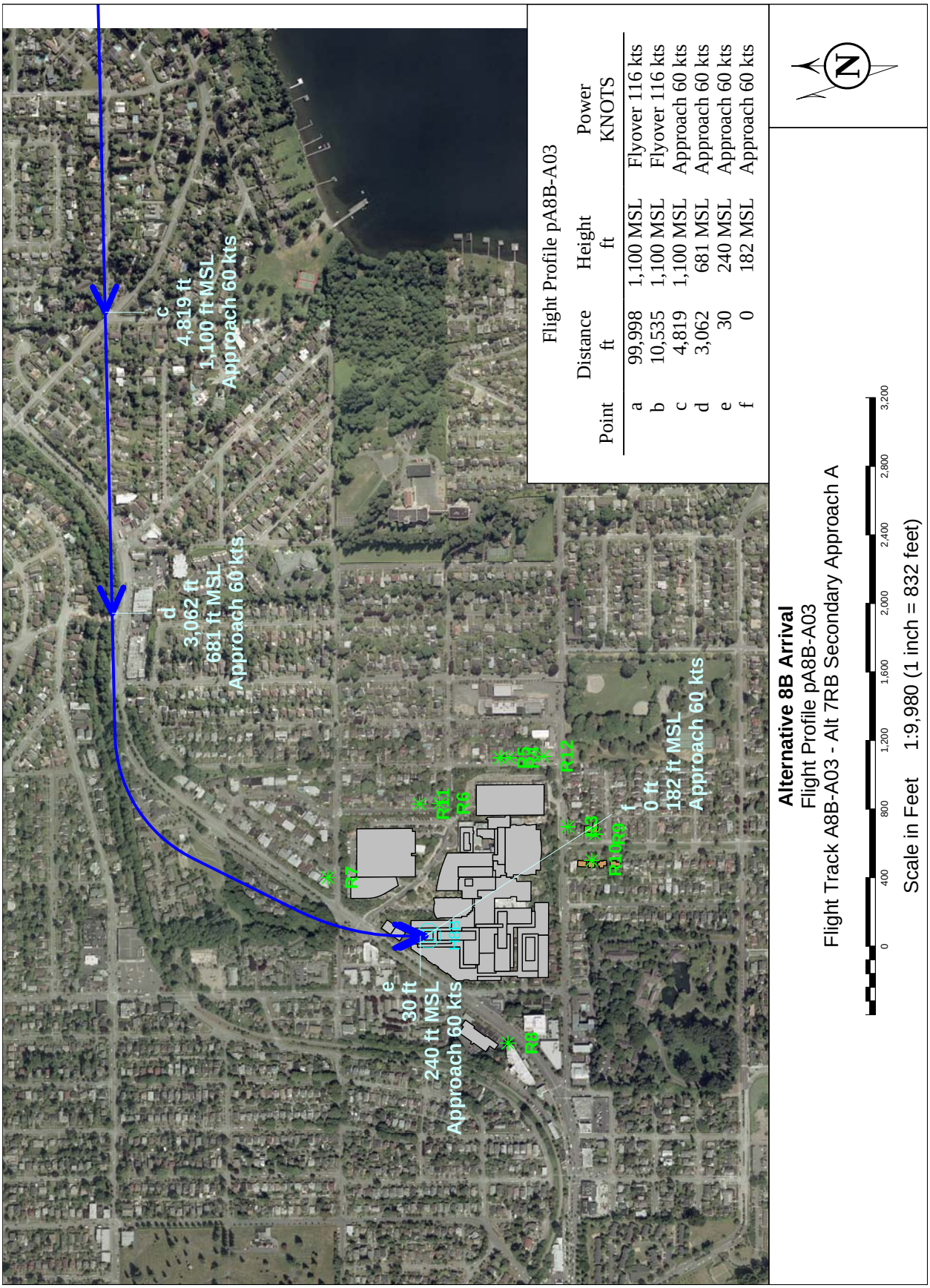
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,960 (1 inch = 830 feet)

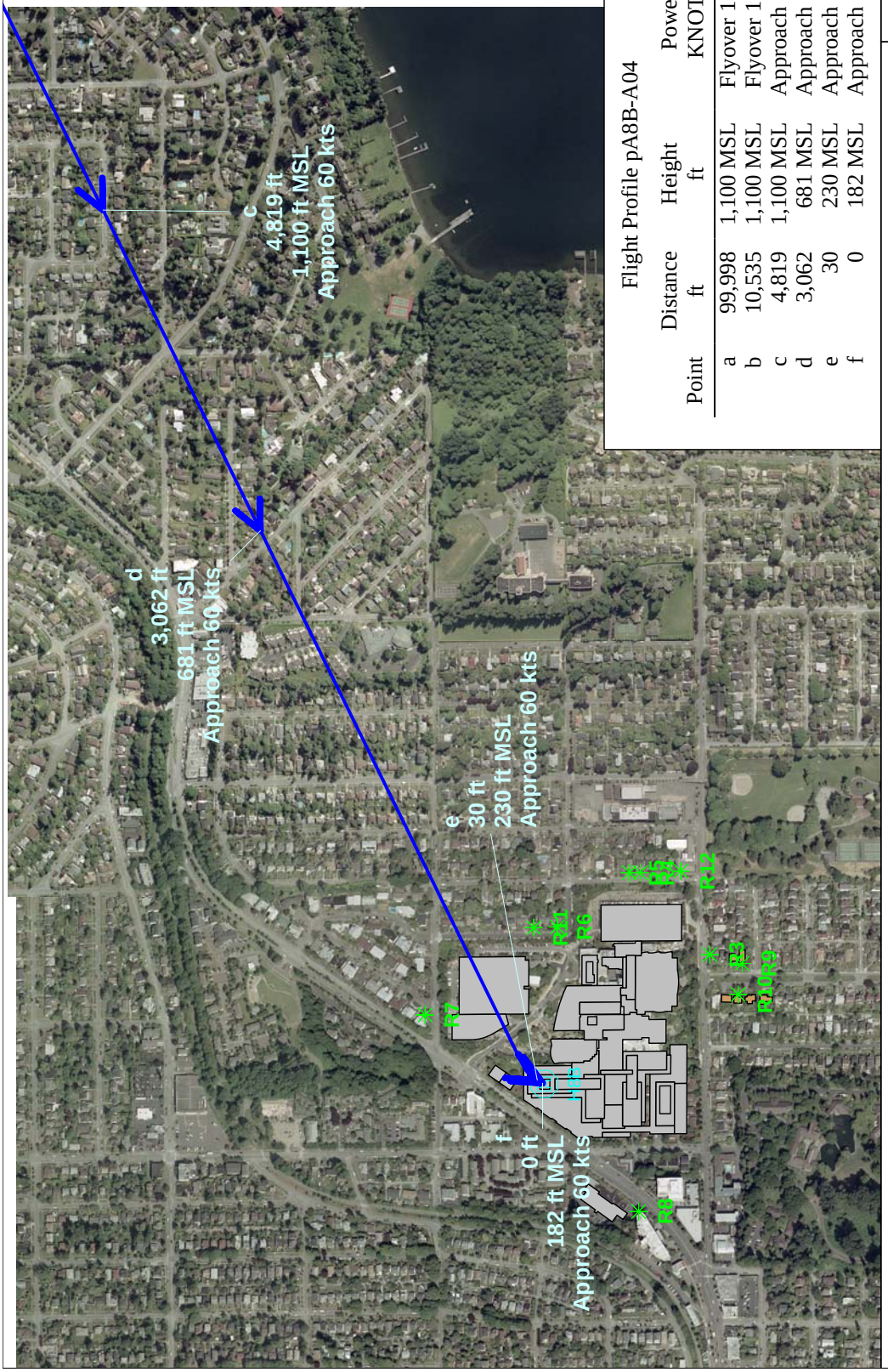


Flight Profile pA8B-A02

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	30	240 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts

Alternative 8B Arrival
Flight Profile pA8B-A02
Flight Track A8B-A02 - Alt 8B Primary Approach B


c
4,819 ft
1,100 ft MSL
Approach 60 kts
d
3,062 ft
681 ft MSL
Approach 60 kts
e
30 ft
240 ft MSL
Approach 60 kts
f
0 ft
182 ft MSL
Approach 60 kts
R7
R11
R6
R8
R12
R3
R10
R9
Flight Profile pA8B-A03
Point | Distance ft | Height ft | Power KNOTS
a | 99,998 | 1,100 MSL | Flyover 116 kts
b | 10,535 | 1,100 MSL | Flyover 116 kts
c | 4,819 | 1,100 MSL | Approach 60 kts
d | 3,062 | 681 MSL | Approach 60 kts
e | 30 | 240 MSL | Approach 60 kts
f | 0 | 182 MSL | Approach 60 kts
N
Alternative 8B Arrival
Flight Profile pA8B-A03
Flight Track A8B-A03 - Alt 7RB Secondary Approach A
0 400 800 1,200 1,600 2,000 2,400 2,800 3,200
Scale in Feet 1:9,980 (1 inch = 832 feet)



Flight Profile pA8B-A04

Point	Distance ft	Height ft	Power KNOTS
a	99,998	1,100 MSL	Flyover 116 kts
b	10,535	1,100 MSL	Flyover 116 kts
c	4,819	1,100 MSL	Approach 60 kts
d	3,062	681 MSL	Approach 60 kts
e	30	230 MSL	Approach 60 kts
f	0	182 MSL	Approach 60 kts

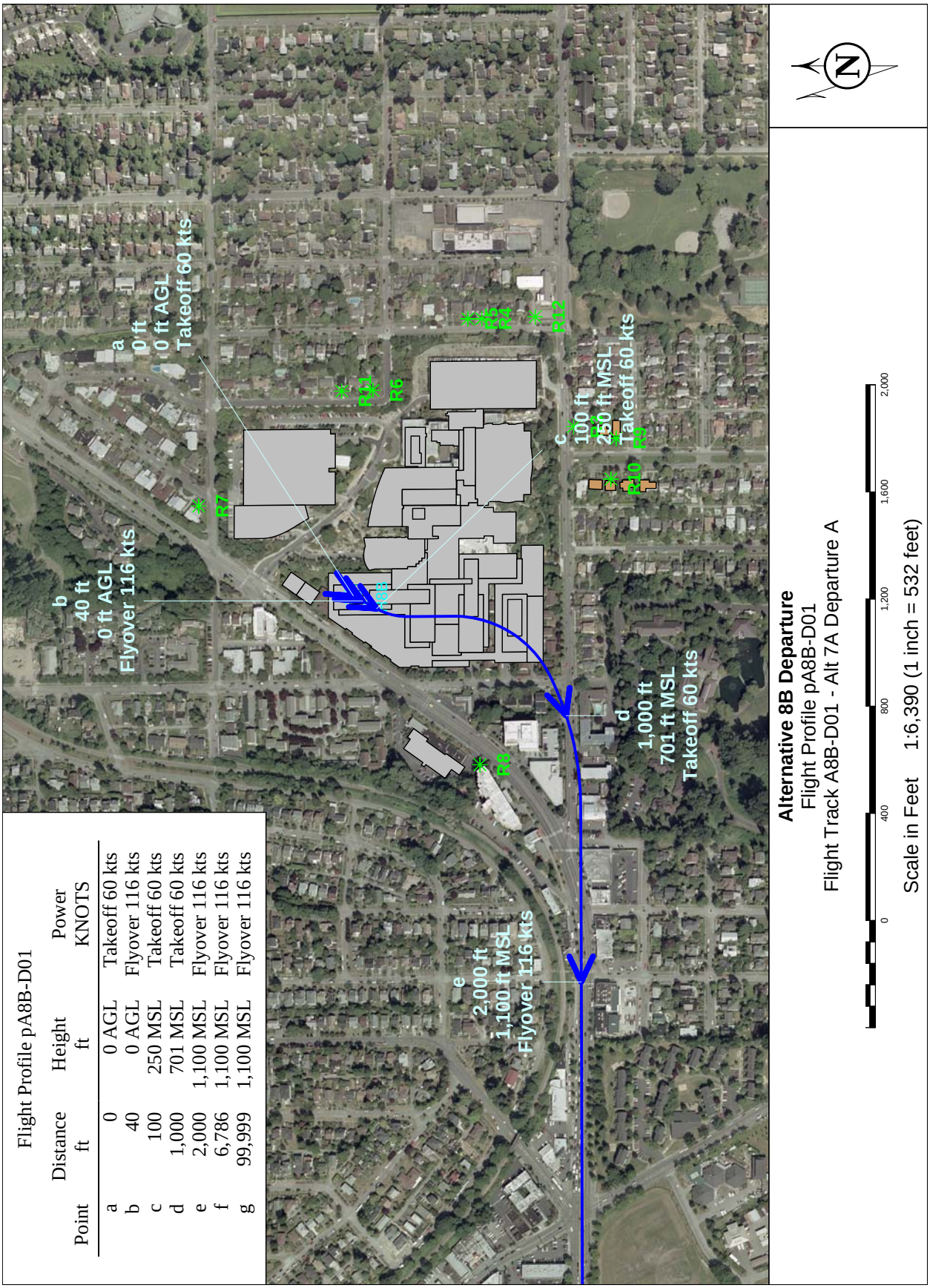
Alternative 8B Arrival
Flight Profile pA8B-A04
Flight Track A8B-A04 - Alt 7RB Secondary Approach B

0 400 800 1,200 1,600 2,000 2,400 2,800 3,200

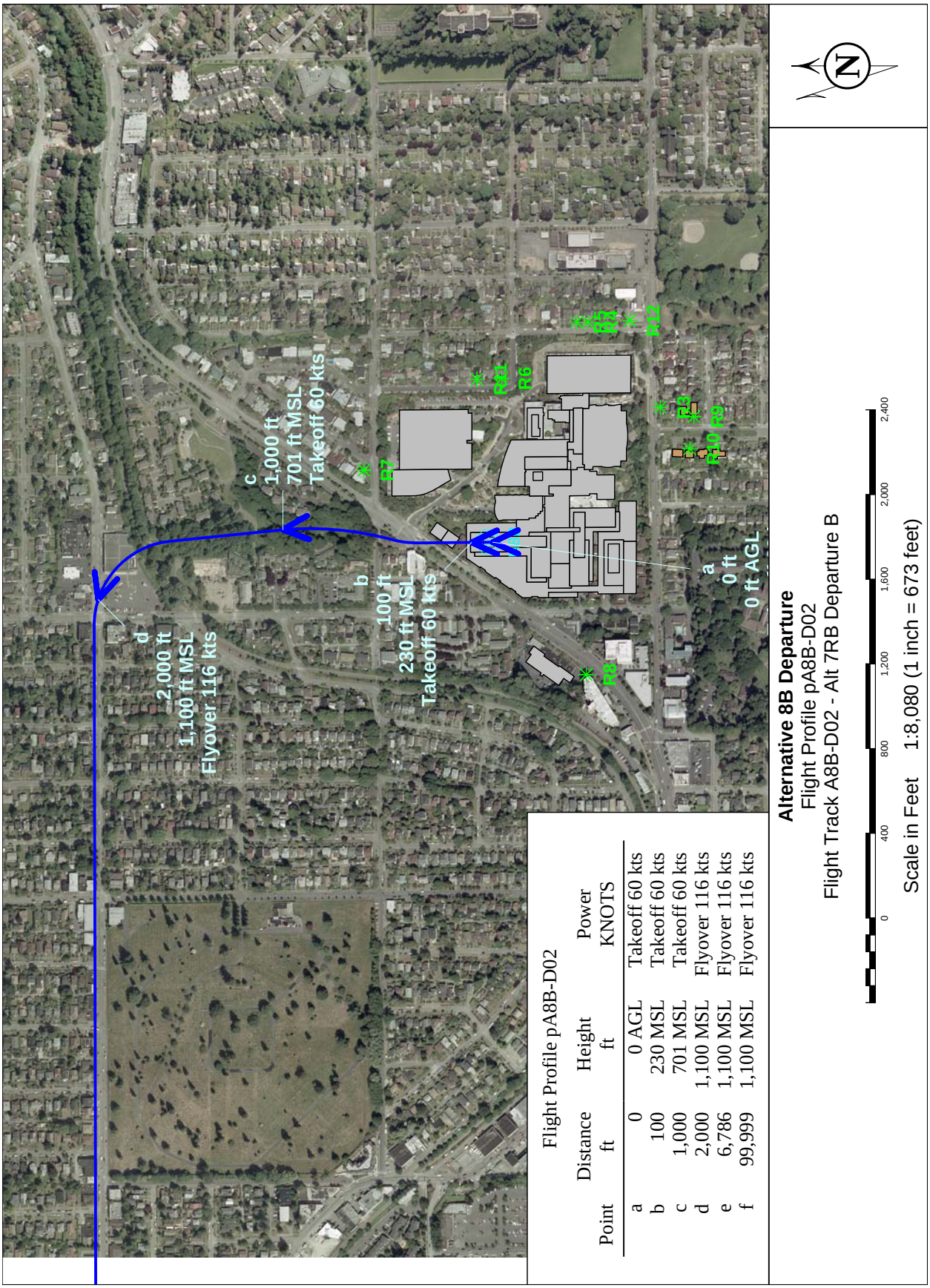
Scale in Feet 1:9,640 (1 inch = 803 feet)

Flight Profile pA8B-D01

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Flyover 116 kts
c	100	250 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts



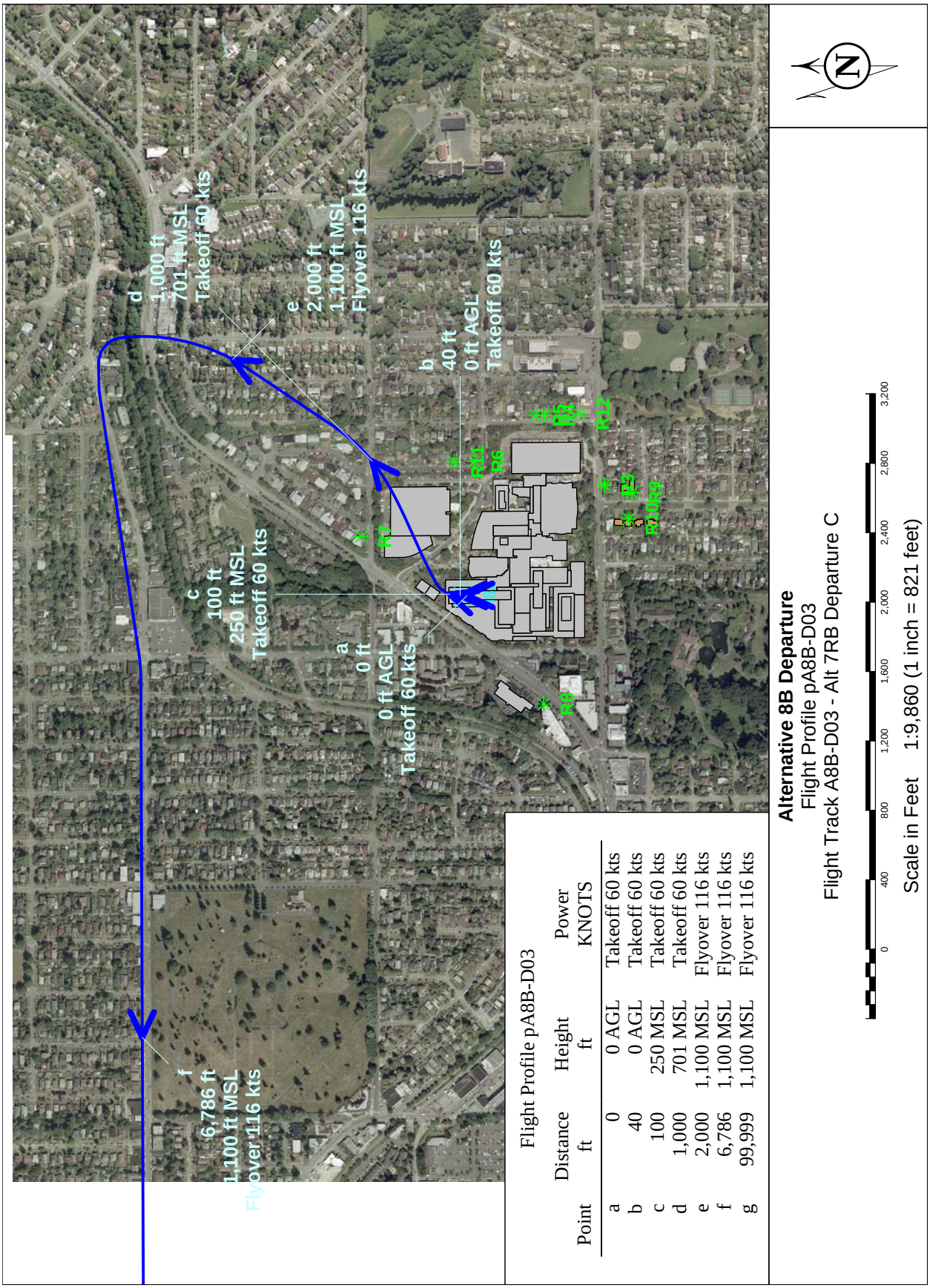
Alternative 8B Departure
Flight Profile pA8B-D01
Flight Track A8B-D01 - Alt 7A Departure A



Flight Profile pA8B-D02

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	100	230 MSL	Takeoff 60 kts
c	1,000	701 MSL	Takeoff 60 kts
d	2,000	1,100 MSL	Flyover 116 kts
e	6,786	1,100 MSL	Flyover 116 kts
f	99,999	1,100 MSL	Flyover 116 kts

Alternative 8B Departure
Flight Profile pA8B-D02
Flight Track A8B-D02 - Alt 7RB Departure B



Flight Profile pA8B-D03

Point	Distance ft	Height ft	Power KNOTS
a	0	0 AGL	Takeoff 60 kts
b	40	0 AGL	Takeoff 60 kts
c	100	250 MSL	Takeoff 60 kts
d	1,000	701 MSL	Takeoff 60 kts
e	2,000	1,100 MSL	Flyover 116 kts
f	6,786	1,100 MSL	Flyover 116 kts
g	99,999	1,100 MSL	Flyover 116 kts

Alternative 8B Departure
Flight Profile pA8B-D03
Flight Track A8B-D03 - Alt 7RB Departure C