SECRETARY OF THE ARMY
WASHINGTON

FEB 1 2 2018

The Honorable William M. "Mac" Thornberry
Chairman
Committee on Armed Services
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

Based on discussions with congressional members and staff and with stakeholders in the Department of Defense and the Federal Government, the report addresses the current corridors and historical data on traffic (frequency, altitudes, and restrictions). The report also addresses previous National Environmental Policy Act mitigation efforts in place for noise abatement; recommendations to further mitigate the noise; and recommendations to receive, track, and analyze complaints from citizens on an ongoing basis.

Thank you for your continued support of Army programs and our Soldiers.

Sincerely,

Mark T. Esper

Mark T. Esper

Enclosure

SECRETARY OF THE ARMY
WASHINGTON

FEB 12 2018

The Honorable Adam Smith
Ranking Member
Committee on Armed Services
U.S. House of Representatives
Washington, DC 20515

Dear Representative Smith:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

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SECRETARY OF THE ARMY
WASHINGTON

FEB 1 2 2018

The Honorable John McCain
Chairman
Committee on Armed Services
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

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SECRETARY OF THE ARMY
WASHINGTON

FEB 1 2 2018

The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate
Washington, DC 20510

Dear Senator Reed:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

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SECRETARY OF THE ARMY
WASHINGTON

FEB 12 2018

The Honorable Thad Cochran
Chairman
Committee on Appropriations
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

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SECRETARY OF THE ARMY
WASHINGTON

FEB 12 2018

The Honorable Patrick J. Leahy
Vice Chairman
Committee on Appropriations
United States Senate
Washington, DC 20510

Dear Senator Leahy:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

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Enclosure

SECRETARY OF THE ARMY
WASHINGTON

FEB 12 2018

The Honorable Rodney P. Frelinghuysen
Chairman
Committee on Appropriations
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

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Enclosure

SECRETARY OF THE ARMY
WASHINGTON

FEB 1 2 2018

The Honorable Nita M. Lowey
Ranking Member
Committee on Appropriations
U.S. House of Representatives
Washington, DC 20515

Dear Representative Lowey:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

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Enclosure

SECRETARY OF THE ARMY
WASHINGTON

FEB 1 2 2018

The Honorable Michael R. Pence
President of the Senate
United States Senate
Washington, DC 20510

Dear Mr. President:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

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Enclosure

SECRETARY OF THE ARMY
WASHINGTON

FEB 1 2 2018

The Honorable Paul D. Ryan
Speaker of the House
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Speaker:

I am pleased to submit the enclosed report to Congress titled "Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals" in response to the National Defense Authorization Act (NDAA) for Fiscal Year 2017, Public Law 114-328, Section 1073.

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Enclosure

HEADQUARTERS,
DEPARTMENT OF THE ARMY

Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals

REPORT TO CONGRESS

HEADQUARTERS, DEPARTMENT OF THE ARMY

2018

The estimated cost of this report for the Department of Defense is approximately $29,000 in Fiscal Years 2017 - 2018. This includes $18 in expenses and $29,000 in DoD labor.

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Report on the Effects of Military Helicopter Noise on National Capital Region Communities and Individuals

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TABLE OF ANNEXES

I. Purpose

This report is provided in response to Fiscal Year 2017 National Defense Authorization Act (NDAA), Public Law 114-328, Section 1073 which requires a report on the effects of military helicopter noise on National Capital Region (NCR) communities and individuals.

II. Original Reporting Requirement as Written in NDAA

SEC. 1073. STUDY ON MILITARY HELICOPTER NOISE.

(a) IN GENERAL.—The Secretary of Defense, in coordination with the Administrator of the Federal Aviation Administration, shall—

(1) Conduct a study on the effects of military helicopter noise on National Capital Region communities and individuals; and

(2) Develop recommendations for the reduction of the effects of military helicopter noise on individuals, structures, and property values in the National Capital Region.

(b) FOCUS.—in conducting the study under subsection (a), the Secretary and the Administrator shall focus on air traffic control, airspace design, airspace management, and types of aircraft to address helicopter noise problems and shall take into account the needs of law enforcement, emergency, and military operations.

(c) CONSIDERATION OF VIEWS.—in conducting the study under subsection (a), the Secretary shall consider the views of representatives of—

(1) Members of the Armed Forces;

(2) Law enforcement agencies;

(3) Community stakeholders, including residents and local government officials; and

(4) Organizations with interest in reducing military helicopter noise.

(d) REPORT.—

(1) IN GENERAL.—Not later than 90 days after the date of the enactment of this Act, the Secretary shall submit to Congress a report on the results of the study conducted under subsection (a).

(2) AVAILABILITY TO THE PUBLIC.—The Secretary shall make the report required under paragraph (1) publicly available.

III. Report Contents

After the passage of the NDAA there were subsequent discussions between the Army (acting on behalf of DoD) and the congressional committee regarding the report requirements. Based on those discussions, the Army is required to provide a report by January 31, 2018 addressing:

- Overview of current corridors, historical data on traffic (frequency, altitudes, and restrictions)

- Previous National Environmental Policy Act (NEPA) mitigation efforts in place for noise abatement
- List of constructive solutions/recommendations to further mitigate noise
- Recommendations for DoD to receive, track, and analyze complaints from citizens on an ongoing basis

IV. Helicopter Operators

The different organizations known to operate helicopters in the NCR, highlighting the complex and congested airspace, include:

- The Army Aviation Brigade, United States Army
- Marine Helicopter Squadron One (HMX1), United States Marine Corps
- The 1st Helicopter Squadron, United States Air Force
- District of Columbia Army National Guard
- The United States Coast Guard
- The United States Park Police
- The United States Capitol Police
- The United States Border Patrol
- The Federal Bureau of Investigation
- The Metropolitan Washington Police Department
- Virginia State Police
- Maryland State Police
- Fairfax County Police
- Prince George's County Police
- Department of Energy
- Charter helicopter companies (e.g., Monumental Helicopters)
- FOX5 Television
- ABC7 Television
- NBC4 Television
- MedStar
- American Helicopter – Helicopter Flight School

V. Background

According to Title 49 United States Code, Section 40103, the Federal Aviation Administration (FAA) has broad authority to regulate the safe and efficient use of the navigable airspace and issue air traffic rules and regulations to govern the flight of aircraft. This includes military aircraft.

The airspace inside the NCR is one of the busiest and most restrictive in the United States. In response to September 11, 2001, the FAA, in consultation with the Department of Homeland Security (DHS), the Department of Defense (DoD), and other Federal agencies, implemented a 25 nautical-mile (NM) radius Temporary Flight Restriction (TFR) area, extending from the surface to 18,000 feet around Washington, DC. In 2009, the FAA established the 30 NM Washington, DC metropolitan area Special Flight Rules Area (SFRA) and the 15 NM DC Flight Restricted Zone (FRZ) centered on Ronald Reagan Washington National Airport (DCA). The SFRA and the FRZ extends from the surface to 18,000 feet. There are two prohibited flight zones, P-56A and P56B, within the FRZ where all aircraft operations are forbidden. P-56A and P-56B incorporate the airspace around White House, the U.S. Capitol Building, and the Naval Observatory to an altitude of 18,000 feet. Both prohibited areas are depicted on the Washington inset in annex D, map 2.

The DoD possesses helicopters which operate and train inside the NCR supporting multiple missions to include continuity of operations, defense support of civil authorities, executive transport, and other activities as directed. These helicopter operations are necessary to enable the DHS and the DoD to effectively execute their respective constitutional and congressionally mandated duties to secure, protect, and defend the United States. While carrying out these missions, DoD must comply with FAA-dictated flight restrictions.

VI. Overview of Current Corridors, Historical Data on Traffic (Frequency, Altitudes, and Restrictions)

The NCR as described in the National Capital Planning Act of 1952 (Title 40, United States Code, Section 8702) is defined as Arlington, Fairfax, Prince William, and Loudoun counties in Virginia; and Montgomery and Prince George Counties in Maryland; the District of Columbia and all the cities in Virginia and Maryland in the geographic area encompassed by the outer boundary of the NCR counties.

Inside the NCR there are three “Class B” airports so designated as the Nation’s busiest airports based on the number of flights. These three airports are Dulles International Airport (IAD), Baltimore-Washington International Airport (BWI) (includes the greater Washington D.C Metropolitan area, the outer suburbs and the NCR), and Ronald Reagan Washington National Airport (DCA). Class B airports have protected airspace which takes priority over other aircraft operations. However, in the case of the NCR, the three Class B airports overlap and encroach on each other’s airspace. In addition to these three major airports, there are also three military airfields (Joint Base Andrews (ADW), Joint Base Anacostia-Bolling Heliport (BOF), and Fort Belvoir’s Davison Army Airfield (DAAF)) which reside in the NCR. Lastly, in addition to those six airfields, there are three other “minor” airfields known collectively as the “Maryland Three Airports” (College Park Airport (CGS), Potomac Airfield (VKX), and Washington Executive/Hyde Field (W32)). Air traffic control personnel don’t differentiate between fixed wing aircraft and helicopters under their control. Within the NCR, Reagan National Airport averages about 800 aircraft operations a day (mainly fixed wing), Dulles Airport averages 820 (mainly fixed wing), Joint Base Andrews averages 190 (mainly helicopter), and Davison AAF averages 115 operations a day (mainly helicopter).

The air traffic control tower at Ronald Reagan Washington National Airport controls helicopters operating within the Baltimore-Washington airspace. The helicopters are subject to extensive monitoring and are limited in their routing choices. The Baltimore-Washington map is found at annex D, map 1. A magnified view is provided in annex D, map 2. Where possible, the FAA has made maximum use of routes over the Potomac River and the Anacostia River and major roads such as I-95 and I-495 to restrict helicopters from flying over populated areas. The FAA is challenged by the flight profiles of large commercial passenger jets and relatively small helicopters. The routes provide for the safe and expeditious flow of helicopters through the Class B airspace by mandating both maximum altitudes and flight path. The routes provide ATC with a predictable and repeatable route structure.

The FAA assigns helicopters the lower airspace from the surface up to as high as 1300 feet Mean Sea Level (MSL). Altitude restrictions are based on relative height above sea-level, not the ground. A helicopter is assigned a maximum altitude to avoid collisions and wake turbulence produced by large aircraft. Since the assigned maximum altitude is given in MSL this generally results in the aircraft's actual height above the ground being lower than the MSL. These mandatory altitudes are depicted on the maps referenced above (see annex D, maps 1 and 2). For example, if an aircraft is at its maximum legal altitude of 1300 MSL in "Zone 2" but is flying over parts of Northwest DC where the surface elevation is 400 feet MSL, the aircraft itself may only be 900 feet Above Ground Level (AGL) (see annex D, map 3, for pictorial representation).

VII. Previous National Environmental Policy Act Mitigation Efforts in Place for Noise Abatement

There are no previously conducted NEPA studies or noise abatement mitigation efforts in-place within the NCR. However, there is a NEPA study currently underway for Davison Army Airfield. It is linked to the Fort Belvoir area development plan and focuses on the noise contours surrounding Davison Army Airfield. The NEPA environmental analysis will result in an environmental impact statement (EIS). In compliance with the NEPA, there will be a public comment opportunity on the EIS. The study results are expected in the summer of 2018. Three non-NEPA NCR military noise studies were completed and are included as annexes (see annex A, plans 1–3).

Included in the annexes is a Joint Base Andrews Air Installations Compatible Use Zones (AICUZ) study. Similar to the NEPA study, AICUZ studies are conducted when there are anticipated changes to the relative noise footprint and for development planning. A study was conducted in 2007 (see annex A, plan 4). A new AICUZ study was completed in 2017 and will be released in the spring of 2018. Helicopter pad and local pattern operations have changed little since the 2007 AICUZ. These changes did not increase the noise footprint for residential areas near Joint Base Andrews.

VIII. List of Constructive Solutions/Recommendations to Further Mitigate Noise

Under the direction of the NDAA, the FAA and DoD are working on the mitigation of military helicopter aviation noise in the NCR.

FAA: The FAA created a "Noise Complaint Initiative" that is responsive to the public while applying the best use of FAA resources. The FAA established a cross-agency team responsible for addressing noise complaints. The team gathered data on complaints, assessed current processes, and recommended process improvements. Some of the ideas being implemented include:

- Development of a webpage to better educate the public on FAA initiatives to address aircraft noise.
- Development of a Noise Portal and noise complaint repository to improve FAA internal coordination.
- The FAA conducted a test of the Noise Complaint Initiative in the Eastern Service Center which concluded in September 2017. The test was designed to ensure the FAA can properly conduct internal coordination and provide responses to the public. The data is being analyzed. If successful, the test will be expanded to the Central and Western Service Centers for further testing.

The FAA Noise Complaint Initiative will lead to improved understanding of noise effects on citizens. Additionally, it will inform future noise mitigation efforts resulting in a more efficient and consistent response to the public, and provide an effective means to evaluate trends and identify areas of concerns.

DoD: The DoD has no jurisdictional authority over non-military helicopters using NCR airspace. Non-DoD agencies are subject to the same FAA regulations; however DoD cannot direct their compliance. The Army Aviation Brigade, Marine Corps HMX1, and the 1st Helicopter Squadron are committed to reducing helicopter noise in the NCR and have engaged non-military organizations to share "best practices" to minimize noise impact. Military leaders are working to better recognize the noise impact on the surrounding community. Whenever possible, DoD plans its operations and training to minimize the noise impact. Avoidance of noise-sensitive areas, if practical, is preferable to overflight at higher altitudes.

It is DoD policy for pilots to exercise leadership, discipline, and the highest level of safety in efforts to minimize aircraft noise. It is Army, Air Force, and Marine policy to follow FAA-approved routes unless emergencies or air traffic control directs otherwise. Each Service has its own regulations regarding avoidance of Noise Sensitive Areas. All Services avoid charted Wildlife Refuge and National Recreation Areas by 2,000 feet Above Ground Level (AGL). Minimum altitude varies from 500 feet AGL to 2,000 feet AGL depending on how populated an area is unless a conflict with Federal Aviation Regulations, air traffic control clearances, or instructions dictates a lower altitude. When lower altitudes are deemed necessary to ensure safe operation, then consideration is given to minimize aircraft noise while operating at low altitudes. The Army Aviation Brigade, Marine Corps HMX1, and the 1st Helicopter Squadron have policies and procedures to ensure they fly the maximum altitude commensurate with the mission being flown in accordance with the Baltimore-Washington Helicopter Route Chart. This concept is anecdotally referred to in military parlance as the "Fly Friendly" policy and, in regards to Army aircraft, is codified in its Army Regulation 95-1(Flight Regulations): “Traffic pattern altitudes at Army airfields for airplanes should be set at 1,500 feet AGL. Helicopter traffic pattern altitudes should be at least 700 feet AGL. Installation and/or garrison commanders may set different altitudes based on noise abatement, fly-friendly policies, or other safety considerations. These will be displayed in flight operations and provided to the U.S. Army Aeronautical Services Agency (USAASA) for publication in the DoD and/or U.S. Government Flight Information Publications (FLIP).” These mitigation efforts are normally reinforced through the use of local standing operating procedures (SOP) (see annex C).

DoD Instruction 4165.57 (Air Installations Compatible Use Zones (AICUZ)) is a program designed to educate airport, heliport, and seaport personnel. The AICUZ Program is designed to promote the health, safety, and welfare of persons in the vicinity of and on air installations by minimizing aircraft noise and safety impacts without degrading flight safety and mission requirements; and promotes long-term compatible land use on and in the vicinity of air installations.

Some of the steps DoD has taken to “Fly Friendly” in the NCR include:

- Helicopter use of the Pentagon helipad is limited to only DoD-directed exercises and three and four star executive travel (and their civilian equivalents). There was an average of 40 operations per month in the last year.

- HMX-1 abides by FAA regulations unless their operational requirements, in support of the President of the United States, dictate otherwise. HMX-1 maximizes the use of published FAA routes. It also minimizes the use of the MV-22 Osprey tilt-rotor aircraft within the beltway.

- To reduce traffic in the Newington and Fort Belvoir area, operational units established a traffic pattern on the southwest side of the Davison Army Airfield. Units are required to split helicopter traffic between the original northeast pattern and the new southwest pattern to reduce overflight of Newington, VA (see annex D, map 4).

- Davison Army Airfield published Notices to Airmen (NOTAMS) directing rotary-wing traffic to fly runway heading until reaching I-95 and achieve traffic pattern altitude prior to turning downwind over populated areas or transitioning to the FAA helicopter routes. All aircrews using DAAF are required to read and comply with these published NOTAMS.

- All United States Army Military District of Washington (USAMDW) aircrews fly the highest allowable published altitudes on helicopter routes unless an emergency, weather, or ATC directs a lower altitude.

- All USAMDW aircrews are prohibited from conducting flights off the published helicopter routes unless unique mission requirements, emergencies, weather or ATC require deviation.

- USAMDW policy limits the hours of night training to Monday-Saturday, 8:00 am – 10:00 pm and Sunday, 12:00 pm – 10:00 PM. During daylight savings, the hours are extended until 11:00 pm, Monday – Friday.

- Aircrews operating out of Joint Base Andrews are also provided with immediate and semi-annual noise-reduction updates through Flight Crew Bulletins (semi-annual) and Flight Crew Information Files (immediately published guidance). This information includes:
    a. Amplifying information for Davison Army Airfield noise sensitive areas.
    b. Guidance on the use of airspace between Manassas Airport and Dulles International Airport.
    c. Guidance regarding flight restrictions at the airfield in College Park, Maryland.
    d. Avoidance of noise sensitive housing areas in the vicinity of landing zones on government property at remote sites near Davidsonville and College Park, MD and Paris, VA.

- Helicopter landing zones are surveyed every 6 months. The surveys include instructions explaining noise abatement requirements with either specific flight path or ground track recommendations. More detail can be found in annex B.

The Army Aviation Brigade, 1st Helicopter Squadron, and Marine Corps HMX1 remain engaged with the local community and elected officials. Representatives from USAMDW, Air Force District of Washington, and Marine Corps HMX1 attended a town hall meeting concerning helicopter noise on December 10, 2016 and attended a public forum hosted by REP Beyer on January 16, 2018. USAMDW also participated in the federal Quiet Skies caucus attended by REP Beyer and hosted by REP Holmes-Norton. Additionally, affected communities will be notified when abnormal operations will occur (contingency alerts, exercises).

IX. Recommendations for DoD to Receive, Track, and Analyze Complaints from Citizens on an Ongoing Basis

DoD should pursue the following actions to further mitigate helicopter noise and to receive, track, and analyze complaints from citizens in the NCR on an ongoing basis:

- Develop a noise inquiry website based off of Reagan National and Dulles International Airport's websites. The site should be linked to USAMDW's, Air Force District of Washington's, and the Marine Corps' HMX1's organizational websites. The website should: (1) provide a form to collect inquiry information; (2) geo-tag the location of the inquiry to an exportable map; (3) export information to an Excel spreadsheet; and (4) send an email response to the individual making the inquiry. By creating this repository, mitigation efforts can be directed toward concentrated areas of inquiries.

- Establish a DoD-led monthly helicopter noise abatement working group to collect, correlate, and identify trends associated with helicopter noise within the NCR. The working group will recommend procedural and systematic changes to mitigate the impact of helicopter noise on the community while sustaining aircrew readiness, training, and mission support.

TABLE OF ANNEXES

Annex A. Installation Operational Noise Management Plans

Listing of Plans in this Annex:

Plan 1. Installation Operation Noise Management Plan for the Pentagon Heliport, Arlington, Virginia

Plan 2. Operational Noise Consultation No. 52-EN-0DRM-11, Operational Noise Contours, Davison Army Airfield, Fort Belvoir, Virginia, 7 September 2010

Plan 3. 2017 Airport Cooperative Research Program (ACRP) Research Report 181: "Assessing Community Annoyance of Helicopter Noise."

Plan 4. Air Installations Compatibility Use Zones (AICUZ)

Annex A. Plan 1. Installation Operation Noise Management Plan for the Pentagon Heliport, Arlington, Virginia

INSTALLATION OPERATIONAL NOISE MANAGEMENT PLAN

FOR THE

PENTAGON HELIPORT

ARLINGTON, VIRGINIA

WASHINGTON HEADQUARTERS SERVICE

JANUARY 2009

Abbreviations and Acronyms

AAF	Army Airfield
AFB	Air Force Base
APZ	Accident Potential Zone
AR	Army Regulation
ARNG	Army National Guard
ATC	Air Traffic Control
CFR	Code of Federal Regulations
CZ	Clear Zone
DA	U.S. Department of the Army
dB	decibel
dBA	A-weighted decibels
DCA	Airport code for Ronald Reagan Washington National Airport
DNL	Day-Night Average Sound Level
DoD	Department of Defense
FAA	Federal Aviation Administration
Hz	Hertz
ICUZ	Installation Compatible Use Zone
IENMP	Installation Environmental Noise Management Plan
IFR	Instrument Flight Rules
IONMP	Installation Operational Noise Management Plan
LUPZ	Land Use Planning Zone
MDW	Military District of Washington
NAS	Naval Air Station
NEPA	National Environmental Policy Act
NLR	Noise Level Reduction
NMCC	National Military Command Center
PFPA	Pentagon Force Protection Agency
RDF	Remote Delivery Facility
SEL	Sound Exposure Level
SVFR	Special Visual Flight Rules
UFC	United Facilities Criteria
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAF	U.S. Air Force
USEPA	United States Environmental Protection Agency
USMC	U.S. Marine Corps
VFR	visual flight rules
WHS	Washington Headquarters Service
ZOI	Zone of Influence

Washington Headquarters Services
Defense Facilities Directorate
Engineering and Technical Services Division
Safety and Environmental Management Branch

Installation Operational Noise Management Plan

for the

Pentagon Heliport

Arlington, Virginia

[Signature here]
Approval Authority: Director, Washington Headquarters Services

This document is authorized by the Director of the Washington Headquarters Services and is maintained by the DFD/ETSD Safety and Environmental Management Branch.

INSTALLATION OPERATIONAL NOISE MANAGEMENT PLAN
FOR THE
PENTAGON HELIPORT, ARLINGTON, VIRGINIA

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1.0 INTRODUCTION

One of the goals of the Department of Defense (DoD) is to plan, initiate, and carry out actions and programs designed to minimize adverse impacts from their actions upon the quality of the human environment, but do so without impairing the DoD's mission. In keeping with this goal, the U.S. Army established the Installation Operational Noise Management Plan (IONMP) as the framework for the control of noise produced by U.S. Army activities at a specific installation. The intent in developing an IONMP for the Pentagon Heliport is to have a guidance document that can assist heliport personnel and the community regarding Pentagon Heliport operations and related noise impacts.

As cited in the Noise Control Act of 1972, the U.S. Congress found "that inadequately controlled noise presents a growing danger to the health and welfare of the Nation's population, particularly in urban areas" (42 United States Code 4901–4918). Noise is defined as "unwanted sound" by the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). The successful implementation of an IONMP carries out the obligation of the U.S. Department of the Army (DA) under the Noise Control Act, the Quiet Communities Act, and Army Regulation (AR) 200-1, *Environmental Protection and Enhancement* (USACHPPM 2005). Chapter 14 of AR 200-1, *Environmental Noise Management Program*, is provided as **Attachment A** of this IONMP. An IONMP provides a methodology for analyzing exposure to noise and safety hazards associated with military operations and provides land use guidelines for achieving compatibility between the DA and the surrounding communities. The DA has an obligation to U.S. citizens to recommend uses of land around its installations that will protect citizens from noise and other hazards and protect the public's investment in the installation.

1.1 Purpose and Objectives

The Army program, with the use of the IONMP, addresses all the sources of noise from Army installations, including aircraft (fixed-wing and helicopters), weapons fire, and ordnance use. Fixed-wing operations, weapons fire, and ordnance use do not occur at the Pentagon Heliport, and are therefore not discussed in this plan.

This IONMP assesses the noise and safety environment associated with helicopter operations at the Pentagon Heliport and provides a plan to manage this environment through proper land use planning and installation awareness. A key component of an IONMP is the Installation Compatible Use Zone (ICUZ) Program (see **Section 3.2.2**). The purpose of the ICUZ component is to identify land areas within the environs of military airfields that are exposed to generally unacceptable levels of aircraft-related noise and various levels of potential for aircraft accidents. After that information has been established, the IONMP then recommends uses for the land lying within these areas that are compatible with the needs of the civilian community and the DoD. The objectives of this IONMP are as follows:

- Educate the military and civilian communities and improve communications between them.
- Assess the compatibility of the noise environment with existing and proposed land use surrounding the Pentagon Heliport.

- Mitigate the noise environment, where feasible, to increase land use compatibility.
- Use noise abatement procedures to minimize the exposure of residential areas to noise, while ensuring the safety of the Pentagon Heliport flight and ground operations.

1.2 Operational Noise

1.2.1 History of Noise Controversy

The advent of jet aircraft in the 1950s resulted in a significant increase in the noise levels around commercial airports that led to an intense outcry from the public. This public outcry caused Congress to revise the Federal Aid to Airports Act to make Federal aid contingent upon implementation of programs to resolve noise problems with surrounding neighborhoods. Subsequently, Congress passed the Noise Control Act of 1972 and the Quiet Communities Act of 1978. Under these laws, airports carried out noise control measures such as the outright purchase of adjoining land, working with local communities to ensure zoning that would permit only compatible uses, development of procedures for including noise information in the consumer disclosure documents provided when real estate is sold, altering aircraft run-up procedures and locations, and changing aircraft approach and takeoff patterns. At the present time, the Federal Aviation Administration (FAA) has specific requirements for community involvement in airport planning.

The Federal Aid to Airports Act exempted military aircraft from these noise control measures, as did portions of the Noise Control Act of 1972. However, the Noise Control Act and the Quiet Communities Act contains language outlining the responsibilities of Federal agencies in protecting the public from unreasonable noise impacts. Specifically, these laws state that:

> *Federal agencies shall, to the fullest extent consistent with their authority under Federal laws administered by them, carry out the programs within their control in such a manner as to....promote an environment for all Americans free from noise that jeopardizes their health and welfare.*

To comply with the intent of Congress, the DoD provided guidance to military departments regarding the compatible uses of public and private lands in the vicinity of military airfields. DoD Instruction 4165.57 provides the following (DoD 1977):

- Defined restrictions on the uses and heights of natural and man-made objects in the vicinity of air installations
- Defined restrictions on land use in the vicinity of air installations to ensure compatibility with the characteristics, including noise, of military operations
- Provided policy as to the extent of the U.S. Government's interest in retaining or acquiring real property to protect the operational capability of active military airfields.

As a matter of general policy, the military departments were instructed to work toward achieving compatibility between air installations and the neighboring civilian communities through a compatible land use planning and control process conducted by the local civilian community.

Based on the DoD guidance, the DA developed its Installation Noise Management Program to consider noise from all sources of military activities, not just military airfields. The DA's program (U.S. Army 2007) is designed to:

- Control environmental noise to protect the health and welfare of military personnel and their dependents, DA civilian employees, and members of the public on lands adjacent to Army, Army Reserve, and Army National Guard (ARNG) installations.
- Reduce community annoyance from environmental noise, to the extent feasible, consistent with Army, Army Reserve, and ARNG training and materiel testing activities.
- Actively engage local communities in land use planning in areas subject to high levels of operational noise and a high potential for noise complaints.

1.2.2 The Threat to Military Installations

Military installations have long been synonymous with expanding communities, influencing the creation of new communities, and increasing the activity of its civilian sector. This expansion, while beneficial to the communities, can cause strain on the boundaries of the military installation and adversely affect the military's ability to support training and maintain an adequate level of readiness for its units. As noise impacts from military activities increase on the civilian communities, both litigation and political pressures could also increase, which could result in an adverse impact on the installation's mission. When civilian communities experience an increase in noise impacts, not only does the number of complaints to the installation's commander increase, but the number of complaints to members of Congress also increases. In the past, adverse public reaction has caused some military installations to close and others to limit their operations.

One of the best examples of an adverse impact on a mission as a result of encroachment occurred at the Naval Air Station (NAS) in Los Alamitos, California. When it was established during World War II, the NAS was situated in a rural area. After the postwar expansion of southern California, residential property surrounded Los Alamitos NAS. As a result, the Navy could no longer routinely fly jet aircraft onto this airfield. Today, the airfield serves the needs of the California ARNG, which, compared to the Navy, operates aircraft that have lower noise levels. Another example occurred at Fort Belvoir, Virginia. In this case, the size of explosives that were used in Combat Engineer field training at Fort Belvoir, a DA installation, was severely restricted. This made it necessary to move portions of the training to less urbanized areas at Fort A.P. Hill, Virginia, and Fort Leonard Wood, Missouri. In another example, limitations were placed on the types of weapons that could be fired at Fort Dix, New Jersey, as well as the number of times that weapons could be fired (U.S. Army undated). In all of these examples, the limitations upon operational activities resulted in a loss of installation capabilities to support essential training, and forced the movement of the training missions to other installations.

1.2.3 Contending with the Threat

The consequences of ignoring the conflicts between noise generated on military installations and the desires of the adjacent civilian community can be critical. If the DoD fails to respond to the concerns of the civilian community, the ill-will produced by such an approach is quite likely to result in an unwillingness within the civilian community to work with the DoD to regulate land use. The community's animosity can result in political pressure or lawsuits, which can force unilateral concessions on the part of the DoD without any reciprocal concessions from the community.

To prevent the conflicts between military operations and the civilian community from escalating, it is necessary for the DoD to work with local communities to prevent incompatible land use, and to take reasonable steps on the installation to protect the community from adverse noise impacts. Since the regulation of land use on property adjacent to the installation is the responsibility of the local communities, the DoD cannot solve these problems unilaterally. Rather, the DoD must work with local communities to establish controls that will prevent noise problems from growing.

1.2.4 Stages of the Installation Operational Noise Management Plan Process

The following paragraphs provide the stages of the IONMP process.

Stage 1: Quantify the installation's noise environment. The primary means of assessing operational noise is through computer simulations. Computer-generated noise contours can be overlaid on land use maps and incorporated into the installation's master plan and National Environmental Policy Act (NEPA) documentation.

Stage 2: Identify noise-impacted areas. During this stage noise contours are overlaid on a map of the installation vicinity to determine areas that are currently or potentially impacted by the installation's noise-producing activities.

Stage 3: Identify existing and potential incompatible land uses. Using the noise zone overlays, current and future land uses are examined to identify those land areas that are or will be incompatible with noise generated by installation activities. This stage requires coordination between the installation and civilian communities if incompatible land uses that are identified by the IONMP are to be resolved.

Stage 4: Identify alternative actions to mitigate or minimize noise impacts. The purpose of this stage is to generate a variety of alternative actions that could be implemented by either the installation or the community to minimize noise impacts. Similar to Stage 3, this stage also requires coordination between the installation and the civilian communities.

Stage 5: Evaluate alternative actions. During this stage the impact of each alternative action must be evaluated.

Stage 6: Develop agreements with local communities and agencies. At this stage, good-faith efforts should be made to negotiate agreements with local communities and agencies that affect or will be affected by the commitments made as a result of the IONMP.

Stage 7: Submit agreements for review by decisionmakers. All agreements must be ratified by the installation commander and elected bodies within the civilian communities.

Stage 8: Publish final IONMP and implement agreements. The final IONMP must be made available to the public and contain all elements of the IONMP process, including the agreement reached between the installation and the civilian communities. These agreements will be implemented during this stage. If exceptions with respect to timing should arise, they must be defined to avoid conflicts.

Stage 9: Update and review. At this stage, procedures should be established to monitor the agreements and the effectiveness of the actions taken. Established procedures for monitoring the agreements are essential to ensure that problems are identified and solved in a cooperative manner. At this stage, it is essential to examine the impact of changes in DA training doctrine and modern weapons technology.

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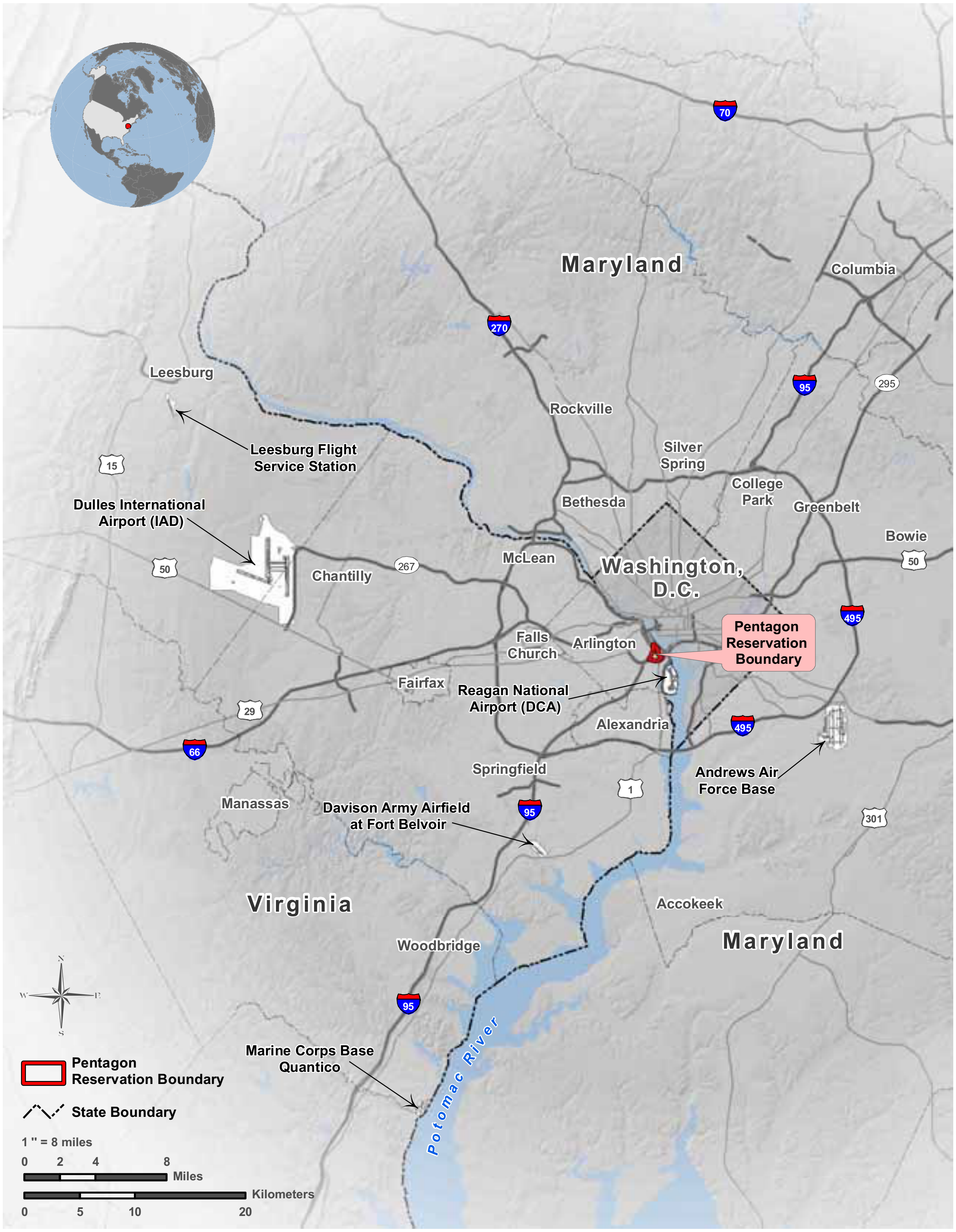
2.0 HELIPORT DESCRIPTION AND FLYING OPERATIONS

The Pentagon Reservation, including the Pentagon building, heliport, and associated facilities is situated between Arlington National Cemetery to the west, the Potomac River to the east, and Interstate 395 to the south as shown on **Figure 2-1**. Since completion of the Pentagon Reservation in Arlington County, Virginia on 15 January 1943 (DoD 2008a), the Pentagon has served as the headquarters of the United States DoD.

The Pentagon Heliport is a joint-use facility between the DoD and the DoD components (Army, Navy, Air Force, and Marine Corps) located at the Pentagon Reservation. The Pentagon Heliport is used only for helicopter (rotary-wing aircraft) operations. No fixed-wing operations are conducted. The Pentagon does not have any based helicopters; therefore, all flights are transient.

The Pentagon Heliport facilities as shown on **Figure 2-2** include the following:

- ***Helipad (pentagon-shaped):***
  - Width at widest point: 156 feet (47.5 meters)
  - Width at narrowest point: 97 feet (29.6 meters)
  - Length: 148 feet (45.1 meters)
  - Weight restrictions. 75,000 lbs (maximum estimated) (DoD 2004).
- ***Heliport elevation.*** The Pentagon Heliport is situated on the roof of the Remote Delivery Facility (RDF) with the helipad at the northern end. The RDF roof is an elevated surface; the established heliport elevation is 40 feet (12.2 meters) above mean sea level (AirNav 2008). The RDF is a 250,000-square-foot shipping and receiving facility adjoining the Pentagon building to the north. The RDF improves the physical security of the Pentagon by providing a secure consolidated location for receiving and screening thousands of items shipped to the building each day (WHS 2008).
- ***ATC tower.*** The Pentagon Heliport ATC tower is northwest of the Pentagon mall terrace entrance and southwest of the helipad. The ATC tower is 745 feet (227.1 meters) from the center of the helipad. There is a landscaped area between the helipad and the ATC tower that blocks part of the line of sight. As a result, the helipad cannot be seen from the tower.
- ***Helicopter parking areas.*** Four grass aircraft parking pads are present at the Pentagon Heliport. Each parking pad is 75 feet (22.3 meters) wide by 84 feet (25.6 meters) long with 14 feet (4.3 meters) of pavement between each pad. Two of the parking pads, one closest to the Pentagon Heliport and one closest to the Pentagon building, are closed.
- ***Taxiways.*** There are no hard-surfaced taxiways on the heliport. Helicopters wishing to occupy parking areas shall do so by means of taxing while in the air to a grass parking pad predetermined by the ATC tower.
- ***Fire Station.*** The fire station that accommodates the fire truck from Fort Myer is southeast of the ATC tower and west of the Pentagon Mall Terrace Entrance.
- ***Emergency response personnel trailer.*** The trailer is northeast of the fire station and west of the Pentagon Mall Terrace Entrance.



Source: ESRI StreetMap USA 2005

Figure 2-1. Pentagon Reservation Vicinity Map

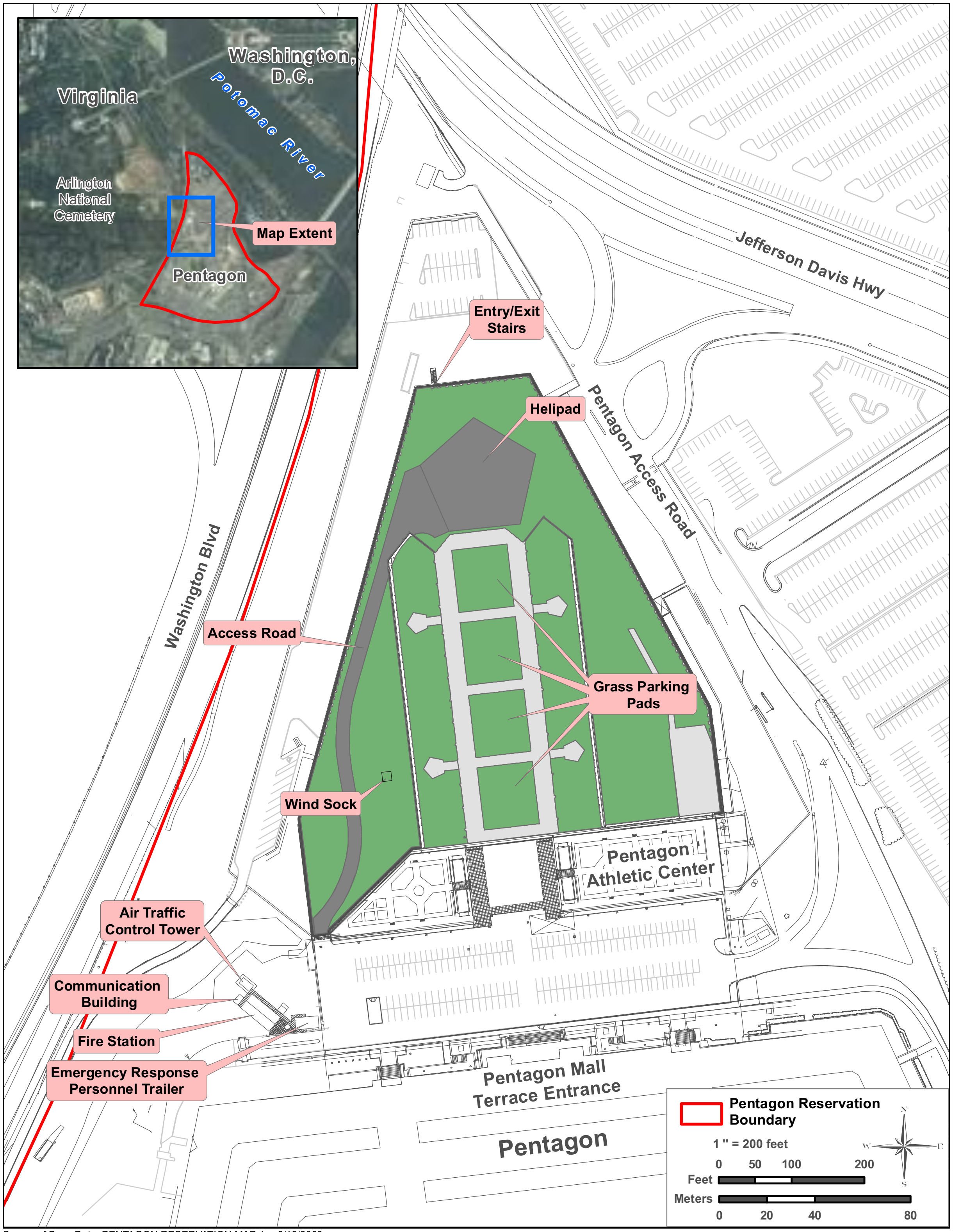


Figure 2-2. Pentagon Heliport Map

2.1 Pentagon Reservation and Heliport History

The Pentagon building was originally built to provide a consolidated space for an expanding staff of Army personnel in 1941. At that time, personnel were scattered among 17 buildings in Washington, D.C., with others in Fort Myer and Alexandria, Virginia. The Pentagon building was completed on 15 January 1943. With its construction, 17 buildings that were managed by the War Department were consolidated into one facility (DoD 2008a).

The Defense Authorization Act of Fiscal Year 1991 transferred control of the Pentagon Reservation from the Administrator of General Services to the Secretary of Defense. In 1992, the Pentagon became a national historic landmark. The Pentagon Reservation has been altered over the years; today the Pentagon Reservation consists of 583 acres (DoD 2008a).

On 11 September 2001, as part of the terrorist attack on the United States, a hijacked commercial airliner struck the western side of the Pentagon building close to the heliport that existed at that time. To commemorate this historic tragedy, a Pentagon Memorial was constructed on a 1.9 acre parcel of land adjacent to the Pentagon and within view of the impact zone. The Pentagon Memorial is situated approximately 40 feet south of the previous helipad (USACE 2002). The Pentagon Memorial was opened to the public on 11 September 2008 (Pentagon Memorial Fund 2008). Officials anticipate up to 2 million visitors to the memorial each year (USAF 2008).

The Pentagon building was renovated after the 11 September 2001 attack; renovations included repairing the damage caused by the plane crash. The Pentagon Reservation is currently undergoing additional renovations that include removal of hazardous materials, replacement of building systems, addition of new elevators and escalators to improve vertical circulation, and installation of new security and telecommunications systems. Additionally, sustainable design measures and force protection initiatives prompted by the 11 September 2001 terrorist attack have been successfully integrated into the design of the Pentagon building (DoD 2008b).

The current Pentagon Heliport is situated on the roof of the RDF with the helipad at the northern end. Before construction of the RDF could begin, the Mall Extension parking lot needed to be removed, and demolition was completed in June 1999 (Global Security 2008). The roof of the facility was landscaped and was intended for ceremonial activities. Landscaping of the RDF roof was completed in the summer of 2001 (WHS 2008). After the attack on 11 September 2001 destroyed the helipad on the western side of the Pentagon building, the helipad was relocated to the northern end of the RDF roof.

2.2 Mission

The mission of the Pentagon Heliport is to coordinate visual flight rules (VFR), instrument flight rules (IFR), and special visual flight rules (SVFR) control with the ATC tower of Ronald Reagan Washington National Airport (airport identification as DCA), as necessary for the safe, orderly, and expeditious flow of air traffic (DoD 2004).

Distinguished passengers of the code equivalent to a Lieutenant General or higher, Senior Executive Service employees, members of congress, and the President of the United States utilize the Pentagon Heliport. The Pentagon Heliport is also the landing site for ranking foreign diplomats and Heads of State (DoD 2004).

2.3 Pentagon Reservation and Heliport Command

The Pentagon Reservation is the headquarters for DoD, which includes the Secretary of Defense, Joint Chiefs of Staff, the U.S. Army, U.S. Air Force (USAF), U.S. Navy, and U.S. Marine Corps (USMC). The mission of the DoD is to provide the military forces needed to deter war and to protect the security of our country. Additionally, the Pentagon is home to several DoD tenants, including the Pentagon Force Protection Agency (PFPA) (USAF 2008). The PFPA is a civilian Defense Agency within the DoD charged with protecting and safeguarding the occupants, visitors, and infrastructure of the Pentagon, Navy Annex, and other assigned Pentagon facilities (PFPA 2008).

The Pentagon Heliport (including the ATC tower) is controlled by Washington Headquarters Services (WHS) with the Defense Facilities Directorate providing operational and maintenance support. The U.S. Army, Military District of Washington (MDW) is responsible for the operational control of the Pentagon Heliport. The Tower Chief, ATC Division, is responsible for the direct supervision of the Pentagon ATC tower. Transportation and Travel in Crystal City, Virginia, is the approval authority for flights into the Pentagon Heliport. The ATC tower at DCA provides for the operational services for the heliport and serves as the coordinator for aircraft arriving and departing from the heliport. Leesburg Flight Service Station provides flight services for Army aircraft (DoD 2004).

The Commander, 12th Aviation Battalion, Davison Army Airfield (AAF) at Fort Belvoir, Virginia, provides ATC personnel as required for the operations at the Pentagon Heliport (DoD 2004). The 12th Aviation Battalion is a tenant unit at Fort Belvoir, which is an MDW installation (MDW 2005).

2.4 Flying Activity

To describe the relationship between aircraft operations and land use, it is necessary to fully understand the exact nature of flying activities. An inventory has been made of such information for the transient helicopters that use the Pentagon Heliport, which includes where the helicopters fly, how they fly, and how often they fly. Military flying at the Pentagon Heliport is counted in terms of operations. An operation consists of one arrival or one departure.

Normal operating hours for the Pentagon Heliport ATC tower are 7:30 a.m. to 5:30 p.m., Monday through Friday, excluding holidays. Arrivals and departures at the Pentagon Heliport before and after normal operating hours are restricted to mission-essential codes approved by Transportation and Travel, Crystal City, Virginia.

Helicopters arrive and depart from the Pentagon Heliport to various locations (as shown on **Figure 1-1**), including Davison AAF at Fort Belvoir, Virginia; Andrews Air Force Base (AFB) Maryland; and Quantico Marine Corps Base, Virginia. The breakdown of operations by military branch is provided in **Table 2-1**. As shown, the vast majority (approximately 70 percent) of all operations at the Pentagon Heliport are conducted by the Army.

Table 2-1. Pentagon Heliport Operations by Military Branch

Branch	Percentage of Operations Performed
Army	70.35
Navy	0.37
USAF	20.07
USMC	9.21
Total	**100**

The ATC tower at DCA serves as the coordinator for aircraft arriving and departing from the Pentagon Heliport. Helicopters are under ATC control at DCA until they are in close proximity (approximately 1 to 2 nautical miles) to the heliport, at which time ATC control is transferred to the tower at the Pentagon Heliport. Helicopters typically use four main flight tracks as they approach or depart from the Pentagon Heliport, as shown on **Figure 2-3**. The four main flight tracks and the percentage that they are used include the following:

- Approximately 33 percent of helicopters use the southern flight track. This flight track follows the Potomac River south past Bolling AFB towards Fort Washington, Maryland.
- Approximately 25 percent of helicopters use the northeastern flight track. This flight track follows the Anacostia River towards Greenbelt, Maryland.
- Approximately 25 percent of helicopters use the southwestern flight track. This flight track follows Interstate 395 towards Springfield.
- Approximately 17 percent of helicopters use the northwestern flight track. This flight track follows the Potomac River northwest past Theodore Roosevelt Island into Maryland.

Once ATC control is transferred to the tower at the Pentagon Heliport, helicopters typically arrive and depart from the heliport in two directions, the northwest and northeast. Approximately 60 percent of helicopters arrive and depart to the northwest and approximately 40 percent to the northeast. This restriction is due partly to air navigation obstructions at the Pentagon Heliport, which include the following (DoD 2004):

- The ATC tower cab southwest of the helipad
- The tree line west of the helipad
- The Pentagon Athletic Center south of the heliport
- The Pentagon building south of the Pentagon Athletic Center
- The wind sock southwest of the helipad.

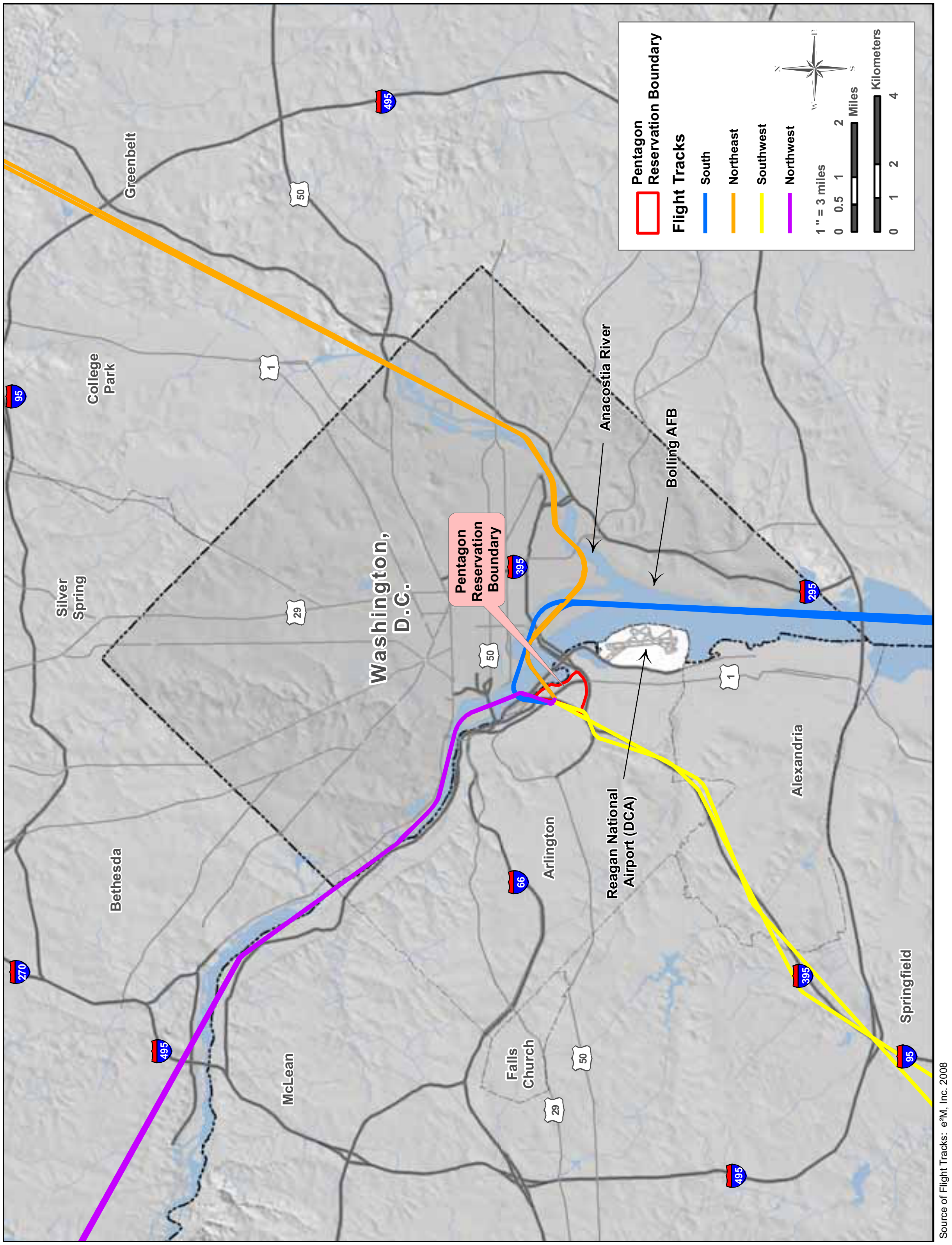


Figure 2-3. Flight Tracks for the Pentagon Heliport

The DoD-approved NOISEMAP software program (Version 7.3) was used to generate the noise contours presented in this IONMP that depict the noise associated with helicopters using the Pentagon Heliport. See **Section 3.2.3** for more information on the noise contours for the Pentagon Heliport. The NOISEMAP software program includes a specific set of aircraft for use in the noise analysis of an airfield or heliport. Several of the helicopters that access the Pentagon Heliport are not included in the NOISEMAP software program; therefore, a substitution using comparable aircraft was made. Daily operations at the Pentagon Heliport by military branch, helicopter type, and flight track are provided in **Table 2-2**.

Table 2-2. Daily Operations at the Pentagon Heliport

Military Branch	Helicopter	Substitute Helicopter	Percentage of Daily Operations	Flight Track				
				South	***Northeast***	***Southwest***	***Northwest***	***Total***
Army	UH-60	--	60	0.369	0.280	0.280	0.190	1.119
	H-72	UH-1	30	0.185	0.140	0.140	0.095	0.560
	UH-1	--	10	0.061	0.047	0.047	0.032	0.187
	Subtotal		*100*	*0.615*	*0.467*	*0.467*	*0.317*	*1.866*
Navy	H-3	CH-3C	100	0.003	0.002	0.002	0.002	0.009
	Subtotal		*100*	*0.003*	*0.002*	*0.002*	*0.002*	*0.009*
USAF	UH-1	--	100	0.175	0.133	0.133	0.090	0.531
	Subtotal		*100*	*0.175*	*0.133*	*0.133*	*0.090*	*0.531*
USMC	H-3	CH-3C	47.5	0.038	0.029	0.029	0.020	0.116
	UH-60	--	47.5	0.038	0.029	0.029	0.020	0.116
	V-22	--	5	0.004	0.003	0.003	0.002	0.012
	Subtotal		*100*	*0.080*	*0.061*	*0.061*	*0.042*	*0.244*
Total				**0.873**	**0.663**	**0.663**	**0.451**	**2.650**

As shown in **Table 2-2**, there is an average of 2.65 operations per day at the Pentagon Heliport. This includes both arrivals and departures. As discussed previously, operations during normal operating hours at the Pentagon Heliport are conducted Monday through Friday, excluding holidays. Multiplying 5 flying days per week times 52 weeks per year equates to 260 flying days per year. Multiplying 260 flying days per year times 2.65 operations per day equates to 689 operations flown at the Pentagon Heliport per year.

As discussed in **Section 2.3**, normal hours of operations for the ATC tower are from 7:30 a.m. to 5:30 p.m. As discussed in **Section 3.2**, the noise metric used to estimate impacts incorporates a "penalty" for nighttime noise events to account for increased annoyance. For purposes of noise assessment, night hours under the IONMP are considered those hours between 10:00 p.m. and 7:00 a.m. Day operations occur from 7:00 a.m. to 10:00 p.m. Approximately 4 night operations are conducted at the Pentagon Heliport per year, which is 0.58 percent of the 689 total operations conducted per year.

3.0 LAND USE CONSTRAINTS AND COMPATIBILITY GUIDELINES

The DoD develops the IONMP for military airfields. Using such plans, DoD works to protect aircraft operational capabilities at its installations and to assist local government officials in protecting and promoting the public health, safety, and quality of life. The goal is to promote compatible land use development around military airfields by providing information on aircraft noise exposure and accident potential.

An IONMP describes three basic types of constraints that affect, or result from, flight operations. The first constraint involves areas that the FAA and DoD have identified for height limitations. DoD obstruction criteria are based upon those contained in 14 Code of Federal Regulations (CFR), Part 77, *Objects Affecting Navigable Airspace*. These obstruction criteria are defined for all military airfields regardless of the current flying mission. The height restrictions are to prevent man-made structures from creating an obstruction that could prevent aircraft from accessing airports or pose an accident hazard. Aircraft approach and depart from airports on a diagonal line that gets farther from the ground as distance from the airport increases. The height obstruction criteria reflect this principle, and permit the placement of taller structures as distance from the airport increases.

The second constraint involves noise contours associated with aircraft operations. Using the NOISEMAP program, DoD produces noise contours showing the noise exposure levels generated by military aircraft, and for the Pentagon Heliport for helicopter operations. NOISEMAP is used to visually create continuous contours that connect the points of the same noise exposure level, in much the same way as ground contours on a topographic map visually represent lines of equal elevation. These noise contours are drawn in 5 A-weighted decibel (dBA) increments from the airfield, ranging from a Day-Night Average A-weighted Sound Level (DNL) of 60 dBA up to 80 dBA, and are overlaid on a map of the airport vicinity. The area encompassed by a noise contour is known as a noise zone. This makes noise zones uniquely suited as a tool for making important zoning and land use decisions based on noise exposure. The metric expressing Sound Exposure Level (SEL), on the other hand, is a measure of the total sound exposure of an event compressed into a 1-second time interval. This metric is most often used when comparing single noise events, such as noise from a single aircraft departure and by their nature, reflect higher dBA levels than the DNL metric. Additional information on noise methodology is contained in **Attachment B** of this report.

The third constraint involves Accident Potential Zones (APZs) based on statistical analyses of past DoD aircraft accidents. DoD analyses have determined that the areas immediately beyond the ends of runways and along the approach and departure flight paths have significant potential for aircraft accidents. Based on this analysis, DoD developed three zones that have high relative potential for accidents: Clear Zones (CZs) and APZs I and II. APZ II is not applicable to heliports per United Facilities Criteria (UFC) 3-260-01, *Airfield and Heliport Planning and Design* (DoD 2008c).

3.1 Airspace Area Controlled for Height Restrictions

Airspace areas controlled for height restrictions result from the application criteria for height and obstruction clearance given in 14 CFR Part 77. UFC 3-260-01 applies to all DoD military facilities in the United States. UFC 3-260-01 stipulates that modifications to existing facilities and construction of new facilities must consider navigable airspace, and could require that a Notice of Proposed Construction or Alteration be submitted to the FAA. The FAA's height obstruction criteria are outlined in FAA Advisory Circular 150/5300-13, which classifies an obstruction to air navigation as an object of greater height than any of the heights or surfaces presented in 14 CFR Part 77.

The standards in 14 CFR Part 77 stipulate that the area surrounding a landing surface must be kept clear of objects that might damage an aircraft and therefore is bounded by imaginary airspace control surfaces that are defined in detail in the 2009 *Airfield Management Plan for the Pentagon Heliport, Arlington, Virginia*. The purpose of these imaginary airspace control surfaces is to provide a planning tool to graphically depict airspace management concepts in a way that can enhance the safety and efficiency of aircraft operations. These regulations can prevent the construction of structures whose height could compromise the ability of aircraft to land safely, particularly in adverse weather conditions or during military training operations.

Although the FAA sets airspace height restrictions, the FAA does not have the authority to control airspace heights. Therefore, in order to protect the health, safety, and welfare of populations around airfields, the local communities must enforce the height restriction guidelines established by the FAA. This is particularly important for DoD airfields. The FAA can influence civilian airports through funding matters. However, the FAA does not provide funds to DoD airfields; consequently, it is imperative that local communities around DoD airfields enforce the restrictions set for airspace heights.

3.2 Noise Contours

Noise and sound share the same physical aspects, but noise is considered a disturbance while sound is defined as an auditory effect. Noise is defined as any sound that is undesirable because it interferes with communication, is intense enough to damage hearing, or is otherwise annoying. Noise can be intermittent or continuous, steady or impulsive, and can involve any number of sources and frequencies. It can be readily identifiable or generally nondescript. Human response to increased sound levels varies according to the source type, characteristics of the sound source, distance between source and receptor, receptor sensitivity, and time of day. How an individual responds to the sound source will determine if the sound is viewed as music to one's ears or as annoying noise. Affected receptors are specific (i.e., schools, churches, or hospitals) or broad areas (e.g., nature preserves or designated districts) in which occasional or persistent sensitivity to noise above ambient levels exists.

The normal human ear can hear frequencies from about 20 Hertz (Hz) to about 20,000 Hz. It is most sensitive to sounds in the 1,000 to 4,000 Hz range. When measuring community response to noise, it is common to adjust the frequency content of the measured sound to correspond to the frequency sensitivity of the human ear. This adjustment is called A-weighting. Sound levels that have been so adjusted are referred to as A-weighted sound levels.

Cumulative noise levels, resulting from multiple single events, are used to characterize effects from aircraft operations. The cumulative DNL is expressed in dBA and presented in the form of noise contours. The DNL metric is calculated using the computerized noise model called NOISEMAP. This noise metric incorporates a "penalty" for nighttime noise events to account for increased annoyance. DNL is the energy-averaged sound level measured over a 24-hour period, with a 10-dBA penalty assigned to noise events occurring between 10:00 p.m. and 7:00 a.m. DNL values are obtained by averaging sound exposure level values over a given 24-hour period.

DNL is a time-averaged noise metric, which takes into account both the noise levels of 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. For an example of this characteristic using an aircraft flyover, consider a case in which one flyover occurs during daytime hours creating a sound level of 100 dBA for 1 second. The DNL for this 24-hour period would be 50.6 dBA. If there were 30 flyovers at 100 dBA for 1 second each, the DNL for this 24-hour period would be 65.5 dBA. 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 events. This is the basic concept of a time-averaged sound metric, and specifically the DNL. The actual sound levels that a person hears fluctuate throughout the 24-hour period. DNL is the preferred noise metric of the FAA, U.S. Department of Housing and Urban Development, U.S. Environmental Protection Agency (USEPA), and the DoD for determining land use compatibility in the airport environment.

3.2.1 Installation Compatible Use Zone Program

In January 1983, the Army established the ICUZ Program to protect the mission of the installations as well as the public (USACHPPM 2005). The ICUZ Program is an integral part of an IONMP. The goal of the ICUZ Program was to identify noise-impacted areas so that the public, as well as government officials working with the Army, can develop solutions to problems in a cooperative manner, thereby minimizing noise impacts through effective land use planning and control. The purpose of the ICUZ Program component of the IONMP is to identify land areas that are exposed to generally unacceptable levels of noise and aircraft accident potential. After that information has been established, the IONMP then recommends uses for the land lying within these areas that are compatible with the needs of the civilian community and the Army.

Army installation commanders establish and maintain active programs to achieve the maximum feasible compatibility between the noise environment and noise-sensitive land uses, both off and on the installation. The ICUZ Program requires that all appropriate governmental bodies and citizens are fully informed whenever ICUZ or other planning matters affecting the installation are under consideration. This includes a positive and continuous effort designed as follows:

- Provide information, criteria, and guidelines to Federal, state, regional, and local planning bodies, civic associations, and similar groups.
- Inform such groups of the requirements of the operational activity, noise exposure, aircraft accident potential, and ICUZ plans.
- Describe the noise reduction measures, which are or could be used.
- Ensure that all reasonable, economical, and practical measures are taken to reduce or control the impact of noise-producing or hazardous activities so as to minimize the exposure of populated areas. This must be done without jeopardizing the safety or effectiveness of military operations.

Through the ICUZ Program, noise zones have been established based on what noise-sensitive land uses should be permitted given the common noise levels found there. Some land uses, such as schools, residences, medical facilities, and churches, are more sensitive to noise than other uses of land, such as industrial or agricultural. The land use planning guidelines factor in those and other variables, such as use and building construction, in order to create lists of compatible uses for each noise zone.

There are four noise zones, which include the land use planning zone (LUPZ) discussed later in this section, Noise Zone I, Noise Zone II, and Noise Zone III. These zones are projected using computer models (for detailed information please see **Attachment B**). **Table 3-1** provides a quick reference for these zones, noise levels, and percent of the population likely to be annoyed. The extent of the noise exposure levels resulting from helicopter operations at the Pentagon Heliport will be depicted graphically later in this section.

Table 3-1. Land Use Planning Guidelines

Noise Zone	Percent of Population Highly Annoyed	Aviation DNL Noise Limit in dBA
LUPZ	≥ 9	60–65
Noise Zone I	< 15	< 65
Noise Zone II	15–39	65–75
Noise Zone III	39+	75+

Source: USACHPPM 2005 and U.S. Army 2007

Notes:

(a) Although local conditions regarding the need for housing might require noise-sensitive land uses in Noise Zone II, on or off installation, this type of land use is strongly discouraged. The absence of viable alternative development options should be determined and an evaluation should be conducted locally prior to local approvals indicating that a demonstrated community need for the noise-sensitive land use would not be met if development were prohibited in Noise Zone II.

(b) Where the community determines that these uses must be allowed, measures to achieve outdoor and indoor Noise Level Reduction (NLR) of at least 25 dB to 30 decibels (dB) in Noise Zone II, from aviation noise, should be incorporated into building codes and be in individual approvals.

(c) Normal permanent construction can be expected to provide a NLR of 20 dB, for aircraft noise, thus the reduction requirements are often stated as 5, 10, or 15 dB over standard construction and normally assume mechanical ventilation, upgraded Sound Transmission Class ratings in windows and doors, and closed windows year round.

(d) NLR criteria will not eliminate outdoor noise problems. However, building location and site planning, and design and use of berms and barriers can help mitigate outdoor noise exposure NLR, particularly from ground level aircraft sources.

Noise Zone I. Noise Zone I includes all areas around a noise source where the DNL is less than 65 dBA for aircraft activity. This area is usually acceptable for all types of land use activities, and is acceptable for noise sensitive land uses such as housing, schools, churches, and medical facilities (USACHPPM 2005).

Noise Zone II. Noise Zone II consists of an area where the DNL is between 65 and 75 dBA for aircraft activity. Land within Noise Zone II should normally be limited to activities such as industrial, manufacturing, transportation, and resource production. However, if the community determines that land in Noise Zone II must be used for residential purposes, then noise level reduction (NLR) features of 25 to 30 decibels (dB) should be incorporated into the design and construction of new buildings.

Noise Zone III. Noise Zone III consists of the area around the noise source where the DNL is greater than 75 dBA for aircraft activity. The noise levels within Noise Zone III are considered so severe that noise-sensitive land uses should not be considered therein.

3.2.2 Land Use Planning Zone

In order to provide a planning tool that can be used to account for days of higher than average operations and possible adverse reactions, the Army established the LUPZ. By setting the LUPZ between a DNL of 60 to 65 dBA for aircraft activity, the variability in the noise environment can be accounted for. The LUPZ shows where levels of annoyance usually associated with Noise Zone II can be found during periods of increased operations. The LUPZ provides the installation with a means to predict possible complaints, and meet the public demand for a description of what will exist during a period of increased operations. The LUPZ can provide the installation with an adequate buffer for land use planning, and could potentially reduce future conflicts between noise producing activities and the civilian community if recommendations regarding noise-sensitive land uses within the LUPZ are implemented by local municipalities.

The LUPZ is more of a predictor of annoyance rather than a predictor of complaints. Analyses of noise complaints received by the Army have shown that short-term increases in DNL, not the long-term average, result in additional complaints (Luz et al. 1983). In the absence of regulatory noise exposure standards, complaints have become the standard. To USACHPPM's knowledge, there are no instances when a state or Federal regulatory authority has come to the Army with a Notice of Violation for noise. At the same time, there are many instances when Army commanders have voluntarily curtailed activities to reduce noise complaints. Through a formal IONMP, Army installations try to prevent complaints through self-monitoring of operations and partnering with land use planning efforts by local government. The use of the LUPZ provides the local community additional information to make more informed land use decisions.

3.2.3 Noise Contours at the Pentagon Heliport

The ambient noise environment around the Pentagon is dominated by vehicle traffic, the surrounding commercial and industrial facilities, and airport operations at DCA. Ambient noise levels on a daily basis in a noisy urban environment are typically 65 dBA and can reach 80 dBA in a downtown major metropolitan area (FHWA 1980). The Pentagon Heliport, and the area north and west of the heliport, is within the DNL of 65 to 69 dBA noise zone from aircraft operations associated with DCA. Operations at the Pentagon Heliport by themselves do not generate enough noise to produce a DNL of 60 dBA, which has been established by USACHPPM as a land use planning threshold. In effect, when modeled alone, helicopter operations at the Pentagon Heliport do not produce a DNL of even 50 dBA. Consequently, noise levels associated with helicopter operations at the Pentagon Heliport are considerably lower than the ambient noise environment surrounding the Pentagon.

While cumulative noise metrics (i.e., DNL) are better for showing the noise exposure from multiple events, SEL is more useful for showing the effects of a single event. Noise-sensitive receptors for use in this analysis were chosen around the heliport to estimate SELs in areas adjacent to the airfield from helicopter operations at the Pentagon Heliport. The SEL value at the columbarium at Arlington National Cemetery, west of the heliport, is 90.7 dBA. The SEL value at Lyndon B. Johnson Memorial Grove, east of the heliport, is 90.1 dBA.

If in the future, noise generated by Pentagon Heliport operations were to increase, this IONMP would be updated and a comprehensive discussion of land use compatibility within the noise contours would be provided.

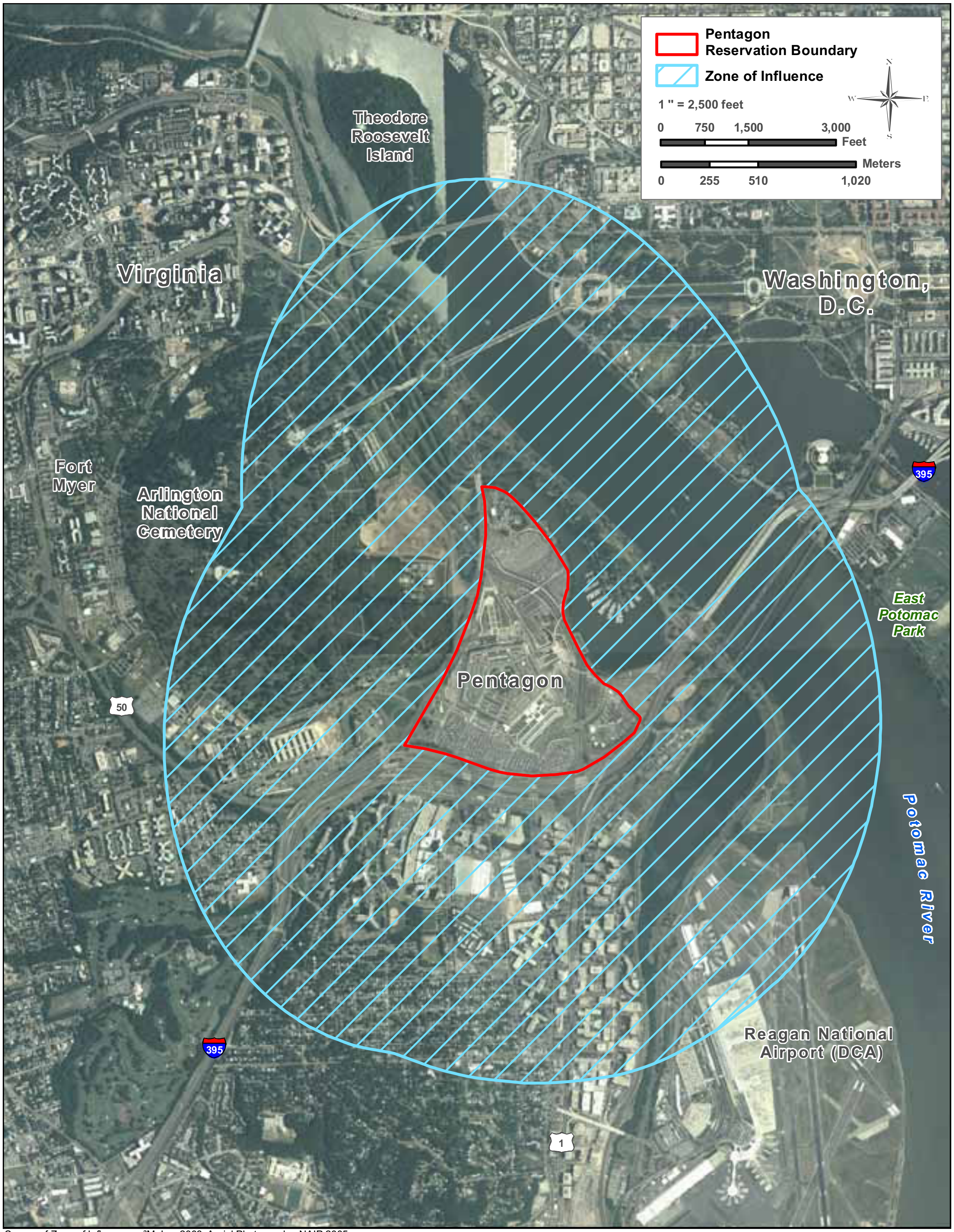
3.2.4 Disclosure of Installation Activity and Noise

To protect the Pentagon Heliport's mission, areas within a 1-mile buffer (adjacent to the reservation boundary that are not already contained within a noise zone) should be included in a Zone of Influence (ZOI). Local communities should disclose to existing and potential landowners within the ZOI and the LUPZ the existence of the Pentagon Heliport and its activities. This would provide the residents with an understanding of the Pentagon Heliport's mission and purpose. Thus, informing the community of the installation's existence reduces citizen concerns and misunderstandings related to noise from unknown installation activities. The ZOI for the Pentagon Heliport is shown in **Figure 3-1**. Disclosure of the existence of the reservation should be mandatory for any property located within the ZOI.

3.3 Helipad Accident Potential Zones

DoD analysis has determined that the areas along the approach and departure flight paths of aircraft (including helicopters) have significant potential for aircraft accidents. Based on this analysis, DoD developed three zones for runways that have high relative potential for accidents. APZs for heliports are provided in UFC 3-260-01, *Airfield and Heliport Planning and Design* and are shown on **Figure 3-2**.

The APZs for a helipad include the CZ and APZ I. The CZ and APZ I are areas on the ground, located under the helicopter approach-departure surface. Please see the 2009 *Airfield Management Plan for the Pentagon Heliport, Arlington, Virginia* for a description of the imaginary surfaces for a heliport that includes the approach-departure surface. Military airfields have an APZ II, the third zone for runways that have high relative potential for accidents, however APZ II criteria are not applicable for helicopter facilities (DoD 2008c). Land use within the APZs for the Pentagon Heliport is discussed in **Section 4.1.3**.



Source of Zone of Influence: e²M, Inc. 2008; Aerial Photography: NAIP 2005.

Figure 3-1. Disclosure Area for the Zone of Influence at the Pentagon Heliport

Source of Accident Potential Zones, Primary Surface: e²M, Inc. 2008; Aerial Photography: NAIP 2005.

Figure 3-2. Clear Zones and Accident Potential Zones at the Pentagon Heliport

The CZ is 300 feet wide by 400 feet long (91.4 meters by 91.4 meters). The CZ should be free of obstructions, both natural and manmade, and should be either owned or protected under a long term lease. The length of APZ I is 300 feet wide by 800 feet long (45.7 meters by 243.8 meters). There are no grading requirements for APZ I.

3.4 Army Land Use Policy and Its Application at the Pentagon Heliport

It is the Army's policy to manage lands, facilities, and resources effectively. This requires a dual focus of maximizing mission effectiveness while conserving resources and preserving the quality of the human and natural environment.

Compliance with the laws, regulations, executive orders, and guidelines that are applicable to current operations and to restoration of sites contaminated by previous activities, is fundamental to attaining DA goals associated with environmental protection and conservation of natural resources. In this respect, the DA has designated the achievement of the following goals, applicable in land use planning, as an integral part of the overall Army mission:

- Demonstrate leadership in environmental protection and improvement.
- Minimize adverse environmental and health impacts while maximizing readiness and strategic preparedness.
- Ensure that consideration of the environment is an integral part of Army decisionmaking.
- Initiate aggressive action to comply with all applicable Federal, state, regional, and local environmental quality laws.
- Restore lands and waters damaged through past waste disposal activities.

3.5 Land Use Compatibility Guidelines

With an overview of the Pentagon Reservation's land, airspace, and facility requirements, the rationale behind the Army's efforts (through the IONMP and the ICUZ Program component of the IONMP) to achieve compatibility between military operations and private property interests should be more apparent. Land use guidelines are meant to ensure compatibility with the noise environment while allowing maximum beneficial use of contiguous property. The Army has an obligation to the communities around the Pentagon Heliport and the citizens of the United States to identify ways to protect both the people in adjacent areas and the public investment in the installation. As a result of this obligation, the Army has established recommended land use compatibility guidelines in relation to noise zones and CZs and APZs to determine if land uses surrounding an installation are recommended in the those environs.

To establish land use compatibility for noise zones, the type of land use is compared to the Federal Interagency Committee on Urban Noise document *Guidelines for Considering Noise in Land Use Planning and Control* (see **Attachment C**) (FICUN 1980). In addition, the type of land use is also compared to the "land use planning guidelines" table presented in the 2005 USACHPPM *Operational Noise Management Handbook*, which is shown in this IONMP as **Table 3-1**. In order to establish land use compatibility for airfield CZs and APZs, the type of land use is compared to the "DoD Air Installations Compatible Use Zones Suggested Land Use Compatibility in Accident Potential Zones" table presented as Appendix B, Section 3 of UFC 3-260-1, *Airfield and Heliport Planning and Design* (DoD 2008c). This table is also presented in this IONMP as **Attachment C**.

4.0 LAND USE ANALYSIS

Land use planning and control is a dynamic, rather than a static, process. The specific characteristics of land use determinants will always reflect, to some degree, the changing conditions of the economic, social, and physical environment of a community, as well as changing public concern. The planning process accommodates this fluidity in that decisions are normally not based on boundary lines, but rather on more generalized area designations.

Computer technology enables the Pentagon Heliport to more precisely display its noise contours for land use planning purposes. This same technology allows the installation a means to communicate the extent to which the Pentagon Heliport's region of impact extends into the surrounding communities.

4.1 Current Land Use

4.1.1 Land Use in the Vicinity of the Pentagon Reservation

As shown in **Figure 4-1**, the Pentagon Reservation is bounded by Route 27 (Washington Boulevard) to the west, the Potomac Lagoon to the east, and Interstate 395 to the south. The boundaries of the Pentagon Heliport are Route 27 to the west, Route 110 (Jefferson Davis Highway) to the east, and the Pentagon Athletic Center to the south (DoD 2004). The vast majority of the land within the Pentagon Reservation boundary composes of the Pentagon building and its associated facilities, which includes the RDF north of the Mall Terrace Entrance, several large aboveground parking lots, and accessory buildings. Two industrial areas are present within the reservation boundary: the first is north of the Pentagon building at the intersection of Route 27 and Boundary Channel Drive, the second is southeast of the Pentagon building. No other types of land use such as residential or commercial are present within the reservation boundary.

The Pentagon Heliport is approximately 1.1 miles northeast of the closest runway end at DCA. West of the Pentagon Reservation boundary across Route 27 is Arlington National Cemetery, which extends west for approximately 1 mile. North of the Pentagon Reservation boundary is George Washington Memorial Parkway and its surrounding recreational land, which includes the Lady Bird Johnson Park and the Lyndon B. Johnson Memorial Grove. The Potomac River borders the Parkway to the north, east, and south. The Fashion Centre at Pentagon City, a commercial land use, is present south of Interstate 395 between Army Navy Drive and 15th Street South. In the same area, east of the Fashion Centre to the Potomac River, are multiple commercial and residential parcels that include several large hotels and apartment complexes. The closest residential area to Pentagon Heliport is the Post Apartment Homes, situated directly across South Joyce Street from the Fashion Centre, approximately 0.80 miles southwest of the heliport. Directly south of the Fashion Centre across 15th Street South is Virginia Highlands Park, a recreational land use. South of Virginia Highlands Park, approximately 1.14 miles southwest of the heliport, is a large residential area that consists of single family homes in the Virginia Highlands and Addison Heights communities.

Source of Aerial Photography: NAIP 2005.

Figure 4-1. Land Use in the Vicinity of the Pentagon Reservation

4.1.2 Noise Contours

As previously discussed, helicopter operations at the Pentagon Heliport do not generate enough noise by themselves to produce a DNL of 60 dBA, which has been established by USACHPPM as a land use planning threshold.

4.1.3 Accident Potential Zones

As shown on **Figure 3-2**, land in the northeastern CZ and APZ I are within the reservation boundary. Approximately 52 percent (approximately 1.4 acres) of land in the northeastern CZ consists of transportation land use that includes Route 110 (and its access ramps) and the Pentagon Access Road. The remaining 48 percent (approximately 1.3 acres) of the land in the northeastern CZ includes the eastern edge of the heliport and the right-of-way for Route 110. Approximately 0.1 acres (approximately 2 percent) of land in the northeastern APZ I consists of transportation (the northern edge of Route 110); the remaining 98 percent (approximately 5.4 acres) includes a large parking lot that is used by Pentagon personnel.

Approximately 25 percent of the land in the northwestern CZ and all of northwestern APZ I extend outside the reservation boundary. Land uses in the northwestern CZ include approximately 0.7 acres of reservation property, 0.8 acres of transportation (Route 27 and its access ramps), and 1.3 acres of Arlington National Cemetery. Land in the northwestern APZ I (approximately 5.5 acres) is completely within Arlington National Cemetery and encompasses the northeastern corner of the Columbarium (a structure of vaults lined with recesses for cremated remains). None of the land in the Pentagon Heliport APZs encompasses residential, commercial, or industrial land use.

4.2 Additional Hazards to Aircraft Navigation

In addition to the Pentagon Heliport CZs and APZs, another aviation safety issue consists of the intrusion of structural or natural impediments into the airspace required to conduct flying operations. These impediments are called obstructions, and obstructions can include existing and proposed man-made objects, objects of natural growth, and terrain. Examples of man-made obstructions could include communication towers, wind turbines, buildings, bridges, or cranes. If these objects were to be constructed within the airspace for the Pentagon Heliport, they would present an air navigation hazard that would need to be avoided by helicopters for safety reasons. Improper siting of these objects could result in a change of flight procedures such as rerouting air traffic corridors and routes and altering departure and landing procedures and traffic patterns. These alterations could result in an increase in noise levels on the local community. Local governments should ensure that internal planning review processes effectively limit potential land development that could impede air traffic within the Pentagon Heliport environs.

In addition to physical obstructions that can be erected within the airspace, there are other uses that can create conditions hazardous to aircraft operations, such as the following:

- Activities that release substances into the air, such as steam, dust, or smoke, which can impair the visibility of aircrew members. Some examples of such activities are industrial plants, refineries, quarries, and sand or gravel pits.

- Objects that produce light emissions, either direct or indirect (reflective), which could interfere with the vision of aircrew members. Some examples include high-intensity strobe lights, extensive areas of glass such as those found in many modern office buildings, and highly reflective artificial surfaces.
- Activities that produce emissions capable of interfering with aircraft communications or navigational systems.
- Activities that tend to attract birds or waterfowl, particularly in large numbers. Such activities include the operation of sanitary landfills; the maintenance of feeding stations; and growing certain types of vegetation, such as grain and cornfields.

4.3 Incompatible Land Uses

The DoD established recommended land use guidelines in relation to APZs and noise zones in order to determine if land uses surrounding an installation were recommended in the IONMP environs. In order to establish land use compatibility, the type of land use is compared to the DoD recommended guidelines in relation to APZs and noise zones (see **Table 3-1** and **Attachment C**). Land uses are defined as compatible, potentially compatible, or incompatible. Compatible refers to those land uses and related structures that are recommended within the IONMP environs without restriction. Incompatible refers to those land uses and related structures that are not recommended within the IONMP environs and should be prohibited. Potentially incompatible refers to land uses and related structures that are generally recommended within the IONMP environs, with certain restrictions. Restrictions can include limits on densities of people and structures, requirements that NLR measures be incorporated into the design and construction of structures, or the use of berms and barriers. Please see the notes for **Table 3-1** as well as **Attachment C** for limitations on land use compatibility.

4.3.1 Noise Contours

As discussed in **Section 3.3.1**, Noise Zone I includes all areas around a noise source in which the DNL is less than 65 dBA for aircraft activity. The area encompassed by Noise Zone I is usually acceptable for all types of land use activities including noise-sensitive land uses such as housing, schools, churches, and medical facilities. Operations at the Pentagon Heliport by themselves do not generate enough noise to produce a DNL of 60 dBA. Consequently, the land use surrounding the Pentagon is compatible with the noise levels from helicopter operations at the Pentagon Heliport. However, as previously mentioned, the ambient noise environment around the Pentagon is dominated by vehicle traffic, the surrounding commercial and industrial facilities, and airport operations at DCA. The Pentagon Heliport, and the area north and west of the heliport, is within the DNL of 65 to 69 dBA noise zone from aircraft operations associated with DCA. This analysis does not account for noise levels from these operations.

Municipalities should consider that noise contours are not static, but fluctuate depending on aircraft activities. A change in the areas encompassed by the noise contours could result from increased operations tempo, such as an increase in the number of aircraft operations. If in the future, noise generated by Pentagon Heliport operations were to increase, this IONMP would be updated and a comprehensive discussion of land use compatibility within the noise contours would be provided.

4.3.2 Accident Potential Zones

As shown on **Figure 3-2**, land in the northeastern CZ and APZ I are within the reservation boundary and are therefore considered compatible. Approximately 0.7 acres (approximately 25 percent) of the land in the northwestern CZ is within the reservation boundary and is therefore considered compatible. The area includes a portion of the RDF and a tree line. Approximately 0.8 acres (approximately 29 percent) of land in the northwestern CZ consists of transportation, which includes Route 27 and its access ramps. As shown in **Attachment C**, highways are considered a compatible use in CZs as long as they are not situated in the graded area. The CZ at the Pentagon Heliport is not graded; therefore the transportation land within the northwestern CZ is considered compatible. The remaining 46 percent (approximately 1.3 acres) of the land in the northwestern CZ consists of cemetery use (Arlington National Cemetery), which is considered an incompatible use within a CZ. All of the land in the northwestern APZ I consists of cemetery land, which is considered compatible in APZ I with the exclusion of chapels. The Columbarium is not considered a chapel; therefore all of land in the northwestern APZ I (approximately 5.5 acres) is considered compatible.

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5.0 DoD, Army, and Community Responsibilities

The responsibilities of the DoD, Army, and civilian communities with respect to this IONMP will be covered in this section. It is the responsibility of the local and state governments as they represent the civilian community to integrate noise considerations and safety of humans and property into the land use planning process. The Pentagon Heliport Commander/Manager should be mindful of the noise considerations important to civilians. It is through this joint process of both civilian and military involvement that responsible noise management can occur.

If the military and the civilian communities neglect their responsibilities to each other, a variety of problems ranging from complaints to legal action could ensue and disrupt the relationship between the military and civilian communities. Recommendations to achieve compatibility between the needs of the civilian community and the Pentagon Heliport's mission are provided in this section.

As discussed in **Section 3.2.3**, the 2008 noise contours at the Pentagon Heliport are classified as Noise Zone I. Operations at the Pentagon Heliport do not create enough noise by themselves to reach the 60 dBA threshold required for the LUPZ; therefore land use planning and controls are not required for this area. If in the future, noise generated by Pentagon Heliport operations were to increase, this IONMP would be updated and the Army and the civilian communities' responsibilities with respect to the following topics would be included in this section:

- Noise implications.
- DoD and Army responsibilities for noise impact reduction, such as the Fly Neighborly Program, aircraft control procedures, and changes to the airspace corridor/route system.
- DoD and Army responsibilities for participation with local communities with respect to noise, which could include noise education and awareness, noise complaint management, compliance with noise reduction regulations, and noise mitigation.

5.1 Safety Implications

The analysis of the safety impacts shows that portions of the land in the northwestern CZ and all of the northwestern APZ I at the Pentagon Heliport extend off the Pentagon Reservation (see **Section 4.1.3**). The safety of both military pilots and the surrounding communities is a priority to the Pentagon Heliport.

5.2 Responsibility for Safety of Operations

The Army Safety Program was established to provide a safe and healthful environment for all Army personnel and others exposed to Army operations. This includes civilians who live in the vicinity of, or work on, military installations. Facets of the Army Safety Program pertinent to this report include the safety of training and operational activities conducted by Army aircraft at the Pentagon Heliport. The following are objectives of the program:

- Preventing injury due to Army operations.

- Detecting and eliminating causes of preventable, inadvertent damage to property both on and off the military reservation, which could result from military activities.
- Preventing accidents.
- Complying with Federal statutes dealing with the safety of people, property, or the environment.

The DoD has designated safety zones of fixed dimensions at its airfields and ranges to protect the safety of Army training and allied activities. These safety zones provide a means for identifying areas within the environs where an accident, injury, or problem is likely to take place. Please see **Section 3.3** for more information on the APZs for the Pentagon Heliport.

5.3 Recommendations

It cannot be emphasized enough that, in providing these recommendations, neither the Army nor anyone at the Pentagon Heliport has any desire to impact privately owned land values. However, when the development that has occurred around the Pentagon Heliport is considered, it becomes apparent what actions are appropriate to guide the future development of the surrounding or adjoining private property. The following recommendations are offered in a spirit of mutual cooperation.

5.3.1 General Recommendations

General recommendations are provided for consideration by the elected officials of the counties; cities and towns within these counties; civic, social, and business organizations; and the concerned citizens. As discussed in the introduction to **Section 5**, if, in the future, noise generated by Pentagon Heliport operations were to increase, this IONMP would be updated and this section would be modified to include recommendations with respect to operational noise. Authorities at the Pentagon Heliport, DoD, and the DA are available to provide additional information and advice regarding specific details.

1. County and municipal governments should provide a means for informing individuals, companies, and corporations of the safety hazards to humans and property generated by military activities in the areas adjacent to the Pentagon Heliport.
2. County and municipal governments should consider incorporation of statements into legal documents (e.g., deeds, subdivision plats, and comprehensive plans) that will inform property owners or buyers of the nature and extent of safety hazards generated by the Pentagon Heliport's mission-essential activities.
3. County and municipal governments should provide advisory services, either directly or via library reference, to those persons wishing to build in the vicinity of an aviation facility. In the case of aviation safety zones, information regarding the existence of these zones and the precise locations should be made available.
4. Local governments are encouraged to support efforts by authorities at the Pentagon Heliport in obtaining memorandums of agreement or understanding to address land use issues identified in this report.

5. Comprehensive Land Use Plans, initiated by any county or municipal government, should be coordinated with the Pentagon Heliport to develop recommendations for land use compatibility in areas adjacent to its facilities. Land use compatibility should be established in each area impacted by operations at the Pentagon Heliport.

5.3.2 Specific Recommendations

The following specific recommendations are provided to promote the orderly use and development of land for purposes that are compatible with the Pentagon Heliport's mission requirements and the needs and concerns of the surrounding civilian community. While many of the recommended techniques could result in additional design and construction costs, it can be assumed that Federal and state environmental protection legislation will continue to mandate more stringent measures to enhance the safety of humans and protection of property in the near future.

5.3.2.1 Pentagon Heliport

Public record. The Pentagon Heliport should distribute or present this IONMP to the county and municipal governments and ensure that it is filed in the office of official records to become a matter of public record.

Education program. The Pentagon Heliport should continue to educate its personnel in various techniques needed to minimize safety concerns from their operations. In addition, the Pentagon Heliport should educate the communities surrounding its facilities on its mission and what it is doing to reduce and minimize the negative impacts of its mission on the community.

5.3.2.2 Local Jurisdictions

Coordination between the Pentagon Heliport and local governments is essential if the Pentagon Heliport is to continue to use their facilities without restrictions. Recommendations to the local governments include the following:

- All jurisdictions should adopt a disclosure for those areas within the 1 mile (1.6 kilometer) ZOI adjacent to the Pentagon Heliport boundary.
- Local governments should continue to inform the Pentagon Heliport of planning and zoning actions that have the capacity to affect Pentagon Heliport operations.

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6.0 REFERENCES

AirNav 2008 — AirNav. 2008. "KJPN Pentagon Army Heliport, Washington, District of Columbia, USA." Federal Aviation Administration (FAA) information effective 31 July 2008. Available online: <*http://www.airnav.com/airport/KJPN*>. Accessed 28 August 2008.

DoD 1977 — Department of Defense (DoD). 1977. *Air Installations Compatible Use Zones*. DoD Instruction 4165.57. 8 November 1977.

DoD 2004 — DoD. 2004. *JPN Facility Training Manual (FTM)*.

DoD 2008a — DoD. 2008. "The Pentagon – Facts and Figures: Land Area and Cost." Available online: <*http://pentagon.afis.osd.mil/facts-area.html*>. Accessed 27 August 2008.

DoD 2008b — DoD. 2008. "The Pentagon: History, Ongoing Renovation." Available online: <*http://pentagon.afis.osd.mil/renovation.html*>. Accessed 2 September 2008.

DoD 2008c — DoD. 2008. *Airfield and Heliport Planning and Design.* United Facilities Criteria (UFC) 3-260-01. Prepared by Air Force Civil Engineer Support Agency, U.S. Army Corps of Engineers, and Naval Facilities Engineering Command. 17 November 2008.

FICUN 1980 — Federal Interagency Committee on Urban Noise (FICUN). 1980. *Guidelines for Considering Noise in Land Use Planning and Control.* June 1980.

FHWA 1980 — Federal Highway Administration (FHWA). 1980. *Noise Fundamentals Training Document Highway Noise Measurement.* September 1980.

Global Security 2008 — Global Security. 2008. "The Pentagon." Available online: <*http://www.globalsecurity.org/military/facility/pentagon.htm*>. Accessed 18 September 2008.

Luz et al. 1983 — Luz, G.A. and N.D. Lewis. 1983. *Problems in Using the C-weighted Day-Night Level to Assess Military Blast Noise Environments*. Presented at the 97th Meeting of the Acoustical Society of America, Cambridge, Massachusetts.

MDW 2005 — Military District of Washington (MDW). 2005. "Davison Army Airfield Factsheet." Available online: <*http://www.mdw.army.mil/content/anmviewer.asp?a=86&z=6*>. Accessed 4 September 2008.

Pentagon Memorial Fund 2008	Pentagon Memorial Fund. 2008. "Pentagon Memorial Construction Nears September Completion." Available online: <*http://www.pentagonmemorial.net/home.aspx*>. Accessed 2 September 2008.
PFPA 2008	Pentagon Force Protection Agency (PFPA). 2008. "About the PFPA." Available online: <*http://www.pfpa.mil/index2.html*>. Accessed 28 August 2008.
U.S. Army undated	U.S. Army. Undated. *U.S. Army Training and Doctrine Command, Installation Compatible Use Zone Training Course.* Page 1-2.
U.S. Army 2007	U.S. Army. 2007. *Environmental Protection and Enhancement.* Army Regulation (AR) 200-1. Headquarters, Department of the Army, Washington, DC. 13 December 2007.
USACE 2002	U.S. Army Corps of Engineers (USACE). 2002. "Pentagon Memorial Location Plan." June 2002. Available online: <*http://memorial.pentagon.mil/files/location_plan.pdf*>. Accessed 12 September 2002.
USACHPPM 2005	U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM). 2005. "Environmental Noise Management: An Orientation Handbook for Army Facilities." November 2005. Available online: <*http://chppm-www.apgea.army.mil/dehe/morenoise/noisemanual.aspx*>. Accessed 29 May 2007.
USAF 2008	U.S. Air Force (USAF). 2008. "Pentagon Force Protection Agency Braces for Tourists." Available online: <*http://www.af.mil/news/story.asp?id=123109952*>. Accessed 25 August 2008.
WHS 2008	Washington Headquarters Service (WHS). 2008. "Remote Delivery Facility." Available online: <*http://renovation.pentagon.mil/projects-RDF.htm*>. Accessed 10 September 2008.

ATTACHMENT A

ARMY REGULATION 200-1, ENVIRONMENTAL PROTECTION AND ENHANCEMENT, CHAPTER 14

Army Regulation 200–1

Environmental Quality

Environmental Protection and Enhancement

Headquarters
Department of the Army
Washington, DC
13 December 2007

UNCLASSIFIED

SUMMARY of CHANGE

AR 200–1
Environmental Protection and Enhancement

This administrative revision, dated 13 December 2007--

o Updates the policy regarding Army Program Guidance Memorandum (para 15-1).

o Corrects typographical errors throughout the publication.

Headquarters
Department of the Army
Washington, DC
13 December 2007

***Army Regulation 200–1**

Effective 27 December 2007

Environmental Quality

Environmental Protection and Enhancement

By Order of the Secretary of the Army:

GEORGE W. CASEY, JR.
General, United States Army
Chief of Staff

Official:

JOYCE E. MORROW
Administrative Assistant to the Secretary of the Army

History. This publication is an administrative revision. The portions affected by this administrative revision are listed in the summary of change.

Summary. This regulation covers environmental protection and enhancement and provides the framework for the Army Environmental Management System.

Applicability. This regulation addresses environmental responsibilities of all Army organizations and agencies. Specifically, this regulation applies to—
(a) Active Army, Army National Guard/Army National Guard of the United States, and United States Army Reserve.
(b) Tenants, contractors, and lessees performing functions on real property under jurisdiction of the Department of the Army (for example, Army and Air Force Exchange Service (AAFES), Defense Commissary Agency (DECA)).
(c) Activities and operations under the purview of the Army even when performed off of installations.
(d) Formerly used defense sites (FUDS) and other excess properties managed by the Army. As used throughout this regulation, the term Army National Guard includes the Army National Guard of the United States.

Installations and facilities in foreign countries will comply with requirements of this regulation that specifically prescribe overseas requirements.

Contracts to operate Government-owned facilities will reference this regulation and will designate by specific citation the applicable provisions.

This regulation does not apply to civil works (CW) functions under the jurisdiction of the U.S. Army Corps of Engineers (USACE).

The terms "Army environmental programs" and "Army Environmental Program" must be read in context. All Army organizations, regardless of their organizational level or chain of command, have environmental responsibilities as part of their functions; these environmental responsibilities must be incorporated into the planning, programming, budgeting, and execution of their respective missions. The Assistant Chief of Staff for Installation Management, working through the Director of Environmental Programs (see Responsibilities, para 1–13x), has specific and more narrowly defined responsibilities that are planned, programmed, budgeted, and executed via assigned accounts. These accounts resource specifically prescribed and focused environmental efforts. Each organization must program and fund its environmental activities from the appropriate account of the proponent's operating budget, not necessarily an environmental account. Being mindful of the context in which requirements are articulated will help define the scope of the "program" being addressed and will preclude inappropriate resourcing decisions or expectations.

Proponent and exception authority. The proponent of this regulation is the Assistant Chief of Staff for Installation Management. The proponent has the authority to approve exceptions or waivers to this regulation that are consistent with law and regulations. The proponent may delegate this approval authority, in writing, to a division chief within the proponent agency or its direct reporting unit or field operating agency, in the grade of colonel or the civilian equivalent. Activities may request a waiver to this regulation by providing justification that includes a full analysis of the expected benefits and must include formal review by the activity's senior legal officer. All waiver requests will be endorsed by the commander or senior leader of the requesting activity and forwarded through their higher headquarters to the policy proponent. Refer to AR 25–30 for specific guidance.

Army management control process. This regulation contains management control provisions and identifies key management controls that must be evaluated.

Supplementation. Supplementation of this regulation and establishment of command or local forms are prohibited without prior approval from Assistant Chief of Staff for Installation Management, 600 Army Pentagon, Washington, DC 20310–0600.

Suggested improvements. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) through the chain of command to HQDA, DAIM–ED, 600 Army Pentagon, Washington, DC 20310–0600.

Distribution. This publication is available in electronic media only and is intended for command levels C, D, and E for the Active Army, the Army National Guard/Army National Guard of the United States and the United States Army Reserve.

*This regulation supersedes AR 200–1, dated 28 August 2007.

UNCLASSIFIED

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Glossary

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13–4. Major program goals

The Army goal for EQT is to enable mission readiness through the development and exploitation of technology that provides sustainable installations, training lands, and weapons systems.

13–5. Major requirements

a. Identify and document user requirements and invest in high priority environmental requirements providing validated solutions to the end-user for qualification, production, or fielding.

b. Leverage other DOD and Congressionally-directed initiatives to help resolve Army environmental requirements.

c. Use the EQT requirements to prioritize the Army funded efforts at the NDCEE.

Chapter 14
Operational Noise

14–1. Policy

a. Evaluate and document the impact of noise produced by ongoing and proposed Army actions/activities and minimize annoyance to humans to the extent practicable.

b. Develop installation noise management plans as appropriate.

c. Reduce noise to acceptable levels in on-post noise sensitive locations (for example, medical treatment, education, family housing) through appropriate land use planning and/or architectural and engineering controls.

d. Monitor, record, archive and address operational noise complaints.

e. Develop and procure weapons systems and other military combat equipment (for example, electrical generators, etc.) that produce less noise, when consistent with operational requirements. Measure the noise emitted by all combat equipment and weapons systems to be used in training before deployed to units.

f. Procure commercially manufactured products, or those adapted for general military use that produce less noise, and comply with regulatory noise emissions standards.

g. Acquire property only as a last resort to resolve off-post noise issues.

h. Manage operational noise issues and community relations to maintain sustainable testing and training capabilities and prevent encroachment.

14–2. Legal and other requirements

Property and tort law; Noise Control Act of 1972, Quiet Communities Act of 1978; AR 95–1; AR 210–20; AR 350–19; and applicable State and local laws.

14–3. Major program goals

a. Control operational noise to protect the health and welfare of people, on- and off- post, impacted by all Army-produced noise, including on- and off-post noise sources.

b. Reduce community annoyance from operational noise to the extent feasible, consistent with Army training and materiel testing mission requirements.

c. Actively engage local communities in land use planning in areas subject to high levels of operational noise and a high potential for noise complaints.

14–4. Program requirements

a. Noise descriptors (metrics) appropriate for determination of compatible land use, and assessment procedures will be based on the best available scientific information.

(1) The day-night level (DNL) is the primary descriptor for military noise, except small arms, see table 14–1. The DNL is the time weighted energy average sound level with a 10-decibel (dB) penalty added to the nighttime levels (2200 to 0700 hours). The DNL noise metric may be further defined, as appropriate, by the installation with a specific, designated time period (for example, annual average DNL, average busy month DNL). The typical assessment period over which the noise energy is averaged is 250 days for Active Army installations and 104 days for Army Reserve and National Guard installations. The use of average busy month DNL is appropriate when the OPTEMPO is significantly different during certain peak periods of the year. For future land use planning and encroachment assessment purposes, a reasonable annual growth factor in activity (for example, 10 or 15 percent) may be assumed.

(2) Supplemental metrics, such as single event noise data (for example, Peak, PK 15(met) or CSEL), may be employed where appropriate to provide additional information on the effects of noise from test and training ranges. A-weighted maximum noise levels will be used to assess aviation low level military training routes (MTRs) and/or flight tracks.

(3) The use of average noise levels over a protracted time period generally does not adequately assess the probability of community noise complaints. Assess the risk of noise complaints from large caliber impulsive noise

resulting from testing and training activities, ex. armor, artillery, mortars and demolition activities, in terms of a single event metric, either peak sound pressure level (PK 15(met)) or C-weighted sound exposure level (CSEL). The metric PK 15(met) accounts for statistical variation in received single event peak noise level that is due to weather. It is the calculated peak noise level, without frequency weighting, expected to be exceeded by 15 percent of all events that might occur. If there are multiple weapon types fired from one location, or multiple firing locations, the single event level used should be the loudest level that occurs at each receiver location.

(4) Assess noise from small arms ranges using a single event metric, either PK 15(met) or A-weighted sound exposure level (ASEL).

(5) Use the land use planning zone (LUPZ) contour to better predict noise impacts when levels of operations at airfields or large caliber weapons ranges are above average.

(6) Use available DOD noise assessment software as the primary means of operational noise assessment.

(7) Prepare noise maps showing noise zones and limits as defined in tables 14–1 and 14–2.

(8) Manage noise-sensitive land uses, such as housing, schools, and medical facilities as being acceptable within the LUPZ and noise zone I, normally not recommended in noise zone II, and not recommended in noise zone III. These noise zones are defined in table 14–1.

(9) Single event noise limits in table 14–2 correspond to areas of low to high risk of noise complaints from large caliber weapons and weapons systems. These should be used to supplement the noise zones defined in table 14–1 for land use decisions. Noise sensitive land uses are discouraged in areas where PK 15(met) is between 115 and 130 dB; medium risk of complaints. Noise sensitive land uses are strongly discouraged in areas equal to or greater than PK 15(met) = 130 dB; high risk of noise complaints. For infrequent noise events, installations should determine if land use compatibility within these areas is necessary for mission protection. In the case of infrequent noise events, such as the detonation of explosives, the installation should communicate with the public.

(10) Transportation and industrial noise will be assessed on a case by case basis using appropriate noise metrics, including U.S. Department of Transportation guidelines.

b. Address issues concerning building vibration and rattle due to weapons blast through the appropriate subject matter experts and legal counsel.

c. Address noise impacts on domestic animals and wildlife, as required, through the study of each species' response or a surrogate response to noise. The noise levels set forth herein apply to humans only and do not apply to domestic animals or wildlife.

Table 14–1
Noise Limits for Noise Zones

Noise zone	Noise limits (dB)	Noise limits (dB)	Noise limits (dB)
	Aviation ADNL	Impulsive CDNL	Small arms — PK 15(met)
LUPZ	60 - 65	57 - 62	N/A
I	< 65	< 62	<87
II	65 - 75	62 - 70	87 - 104
III	>75	>70	>104

Legend for Table 14-1:
dB=decibel
LUPZ=land use planning zone
ADNL=A-weighted day-night levels
CDNL=C-weighted day-night levels
PK 15(met)=Single event peak level exceeded by 15 percent of events
<=less than
>=greater than
N/A=Not Applicable

Table 14–2
Risk of Noise Complaints by Level of Noise

Risk of Noise complaints	Large caliber weapons noise limits (dB) PK 15(met)
Low	< 115
Medium	115 - 130
High	130 - 140
Risk of physiological damage to unprotected human ears and structural damage claims	> 140

Legend for Table 14-2:
dB = decibel
PK 15(met) = Single event peak level exceeded by 15 percent of events

Notes:
[1] Although local conditions regarding the need for housing may require noise-sensitive land uses in Noise Zone II, on or off post, this type of land use is strongly discouraged. The absence of viable alternative development options should be determined and an evaluation should be conducted locally prior to local approvals indicating that a demonstrated community need for the noise-sensitive land use would not be met if development were prohibited in Noise Zone II.
[2] Where the community determines that these uses must be allowed, measures to achieve an outdoor to indoor noise level reduction (NLR) of at least 25 dB to 30 dB in Noise Zone II, from small arms and aviation noise, should be incorporated into building codes and be in individual approvals. The NLR for communities subject to large caliber weapons and weapons system noise is lacking scientific studies to accomplish the recommended NLR. For this reason it is strongly discouraged that noise-sensitive land uses be allowed in Noise Zone II from large caliber weapons.
[3] Normal permanent construction can be expected to provide a NLR of 20 dB, for aircraft and small arms, thus the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation, upgraded Sound Transmission Class (STC) ratings in windows and doors and closed windows year round. Additional consideration should be given to modifying NLR levels based on peak noise levels or vibrations.
[4] NLR criteria will not eliminate outdoor noise problems. However, building location and site planning, and design and use of berms and barriers, can help mitigate outdoor noise exposure NLR particularly from ground level aircraft sources. Barriers are generally not effective in noise reduction for large arms such as artillery and armor, large explosions, or from high-level aircraft sources.

Chapter 15
Program Management and Operation

15–1. Structure and resourcing

a. Army Environmental Funding Policy.

(1) Army organizations are responsible for addressing environmental requirements for activities under their purview to ensure timely compliance with legal mandates, and for sustaining environmental stewardship.

(2) Environmental requirements must be funded from the appropriate account of the proponent who has the responsibility for the action, not necessarily the Installations Program Evaluation Group (II PEG) environmental program accounts.

b. Programming and budgeting. Commensurate with their responsibilities, Army organizations (to include tenants) will plan, program, budget, and execute resources to:

(1) Mitigate actual or imminent health and environmental hazards.

(2) Comply with Federal, State and local statutes, regulations, agreements, and other judgments, applicable executive orders (EOs), Final Governing Standards (FGS), and legally-binding international agreements at overseas installations.

(3) Sustain the quality and continued availability of lands for essential operations, training, and testing by protecting natural and cultural resources.

(4) Maintain an adequately trained and staffed organization for environmental monitoring and program management.

(5) Employ cost-effective pollution prevention and reuse/recycle-based solutions in all mission areas as the preferred approach for meeting compliance requirements, reducing operating costs, and maintaining environmental stewardship.

(6) Focus environmental quality technology (EQT) research and innovative applications to achieve program goals and reduce program costs.

(7) Address environmental quality costs associated with weapons system life cycle within the context and requirements of the life cycle cost estimate, and adequately assess these costs in the acquisition milestone review process.

c. Investment strategy. Army organizations will make prudent investments in environmental initiatives that support mission accomplishment, enhance readiness, reduce future funding needs, prevent or mitigate pollution, improve compliance, and reduce the overall cost of compliance with applicable environmental requirements.

d. Payment of fines and penalties for environmental violations. Fines, penalties, and supplemental environmental project (SEP) costs will be paid by the organization against which the fine or penalty has been assessed, using applicable Army appropriations unless otherwise required by law. Payment of fines and penalties will be charged to the

ATTACHMENT B

DESCRIPTION OF THE NOISE ENVIRONMENT, NOISE EVALUATORS, AND NOISE CONTOUR PROCEDURES

Attachment B

Description of the Noise Environment, Noise Evaluators, and Noise Contour Procedures

B.1 Introduction

Noise is defined as unwanted sound. Sound is the variation of air pressure above a mean (atmospheric) pressure. These changes in the atmospheric pressure [100,000 Pascals (14.7 pounds per square inch)] vary from approximately 0.0006 Pascals for a whisper at 2 meters to 1,000 Pascals for firing an M16 rifle at the firer's ear. Because of this large range of sound pressure and the fact that the human ear responds more closely to a logarithmic scale rather than a linear scale, sound pressure level is defined as 20 times the common logarithm of the ratio of the sound pressure to the reference pressure (0.00002 Pascal). The sound pressure level is measured in decibels (dB). For example, if the sound pressure doubles from 0.2 to 0.4 Pascals, the level increases by 6 dB from 80 to 86 dB.

A characteristic of operational noise is that it is not steady, but varies in amplitude from one moment to the next. To account for these variations in the sound pressure level with time, and to assess operational noise in a consistent and practical manner, a statistical approach has been used to reduce the time-varying levels to single numbers. For Federal agencies, the currently accepted single-number evaluators are the equivalent sound level (LEQ) and the day-night average sound level (DNL). The predominant rating scale now in use in California for land use compatibility assessment is the Community Noise Equivalent Level (CNEL).

An essential concept in understanding operational noise problems is the noise source, path, and receiver relationship. Noise emanates from a source, travels along a path, and is perceived by the receiver. The end effect of noise on the receiver can be considered the focal point of the entire system. Before a noise problem can be resolved, however, the nature and intensity of the noise must be quantified. Because of the different types of noise (e.g., fixed- and rotary-wing aircraft flyovers, ground run-up, and explosive detonations) there are differences in the way the sound levels are measured.

In operational noise, the sound pressure level is usually measured using one of the frequency networks of the sound level meter. Since the human ear is more sensitive to sounds of 1,000 Hertz and above than to sounds of 125 Hertz and below, it is appropriate to apply a weighting function to the noise spectrum to approximate the response of the human ear. The A-weighting frequency network of the sound level meter de-emphasizes the lower frequency portion of the noise spectrum to approximate the human ear's response to the noise. This A-weighting frequency response is specified by an American National Standards Institute (ANSI) standard (ANSI 1983). In a wide variety of published studies, the A-weighting of the frequency content of the noise signal has been found to have an excellent correlation with the human subjective judgment of annoyance of the noise. The sound pressure levels measured using the A-weighting networks are expressed as dBA. To assess the additional annoyance caused by low frequency vibration of structures, the C-weighting network is used to evaluate the impulsive noise from all weapons larger than small arms. This weighting is also specified by the standard. The sound pressure levels measured using the C-weighting networks are expressed as dBC.

B.2 History of Noise Evaluators

Before the mid 1970s, every organization had its own set of preferred operational noise evaluators. This resulted in a wide variety of evaluators. Since each evaluator was developed for a specific purpose, a noise environment measured with one evaluator could not be compared with an environment measured using another evaluator. In carrying out its responsibilities under the Noise Control Act of 1972 (Public Law [PL] 92-574), the U.S. Environmental Protection Agency (USEPA) recommended the adoption of a single operational noise evaluator, the LEQ, and its 24-hour version, DNL. The Department of Defense, along with most U.S. Government agencies followed the USEPA recommendation. The DNL is the most widely accepted descriptor for operational noise (FAA 1990) because of the following characteristics:

- The DNL is a measurable quantity
- The DNL is simple to understand and use by planners and the public who are not familiar with acoustics or acoustical theory
- The DNL provides a simple method to compare the effectiveness of alternative scenarios
- The DNL is a "figure of merit" for noise impacts that is based on communities' reactions to operational noise
- The DNL is the best measure of noise exposure to identify significant impacts on the quality of the human environment
- By Federal interagency agreement, the DNL is the best descriptor of all noise sources for land use compatibility planning
- The DNL is the only metric backed by a substantial body of scientific survey data on the reactions of people to noise.

In recommending the DNL, USEPA noted that most noise environments are characterized by repetitive behavior from day to day, with some variation imposed by differences between weekday and weekend activity, as well as seasonal variation. To account for these variations, an annual average is used. Since annoyance is caused by long-term dissatisfaction with the noise environment, the annual average is an excellent predictor of the average community annoyance when there is not a large variation in the day-to-day or season-to-season DNL. The annual DNL is not a good predictor of noise complaints, since complaints represent the person's immediate dissatisfaction with the noise environment. Currently, there are no guidelines for judging the land use compatibility for single noise events. Although much of the early work on annoyance was done on single events, each study was designed differently and the results cannot be combined in a systematic fashion to form a statistically valid sample. Most of these studies were either done inside a laboratory or, if done outdoors, in controlled settings. Only recently has equipment become available that would allow subjects to register their annoyance if single events are experienced during their routine activities. There is not enough of this information available to support setting standards on single events.

For impulsive noise, the Department of the Army (DA) uses the C-weighted DNL (CDNL). The use of C-weighting is based on the findings of the National Academy of Sciences Committee on Hearing, Bioacoustics and Biomechanics (CHABA) (CHABA 1981). Studies have been performed by the U.S. Army Construction Engineering Research Laboratory (USACERL) (U.S. Army 1984) to define the average annoyance as a function of the C-weighted DNL. The ANSI (ANSI 1986) has endorsed this method for predicting the annoyance caused by impulsive noise.

Research with real explosions, small arms fire, and truck noise (Schomer 1994) confirms what previous research had already found. Annoyance from impulsive noise does not increase at the same rate as annoyance from continuous noise. It increases twice as fast. That is, if an increase in the continuous noise level causes the annoyance to double, the same increase in the impulsive noise level will cause the annoyance to increase fourfold. At a sound exposure level (SEL) of 103 dB, the annoyance from continuous and impulsive noise is equal. ANSI has, in fact, recommended a methodology to adjust the calculation of CDNL to incorporate the accentuated loudness function associated with weapons noise (ANSI 1996). However, the collective experience of experts at USACERL and U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) has shown the correction to be extremely sensitive to assumptions about the highest events in a statistical distribution of blast events.

B.3 LEQ/DNL/CNEL Noise Evaluators

The LEQ is defined as the equivalent steady state sound level which, in a stated period of time, would contain the same acoustic energy as the time-varying sound during the same period. The LEQ is an energy average. The energy average puts more emphasis on the higher sound pressure levels than the arithmetic average. The LEQ is usually computed for a 1-minute, 10-minute, 30-minute, 1-hour, 8-hour, or 24-hour segment of operational noise.

To assess the added annoyance of operational noise during the nighttime hours (10 p.m. to 7 a.m.), the DNL is used. The DNL is the 24-hour LEQ, with a 10 dB penalty added to the nighttime levels. By using the LEQ and DNL, the three important determinants of noise annoyance can be described by using a single number. The three determinants are the intensity of the noise event, the duration of the noise event, and the number of times the noise event takes place. Numerous laboratory and field studies have confirmed that the tradeoff between intensity, duration, and number is adequately described by averaging the total acoustical energy.

B.4 Noise Contours

Noise contours for single event noise sources, such as small arms noise or general-purpose bombing, are generated using the peak sound pressure level (PK 15[met]). See **Section B.4.4** for more information on PK15(met).

Noise contours for continuous noise sources, such as aircraft or vehicles, are generated using A-weight DNL (ADNL). Noise contours for impulsive noise, such as large arms noise, are generated using CDNL. The contours are computed by averaging over the time period of interest, the acoustical energy from the operations of the set of noise sources of interest. The averaging period is usually a busy day, a training cycle, or a year. The contours, representing the boundaries between the noise zones, are constructed by connecting points of equal acoustical energy. For example, the contours for an airfield are computed by averaging at many points the acoustical energy arriving at these points from aircraft operations. A 10 dB penalty is added to all nighttime operations. The contours for the airfield are constructed by connecting all points having a total acoustical energy equal to 65 dBA and connecting all points equal to 75 dBA.

B.4.1 Impulsive Noise

The noise simulation program used to assess heavy weapons noise is BNOISE2. This model is an upgrade of MicroBNOISE (U.S. Army 1986). BNOISE2 models the noise from the muzzle blast, the explosive detonation at impact, and the bow shock caused by the round going down range. The effects of terrain on the sound propagation are also included. The BNOISE2 program requires operational data concerning the type of weapons fired from each range or firing point, including demolitions; the number and type of rounds fired from each weapon; the location of targets for each range or firing point; and the amount of propellant used to reach the target.

B.4.2 Aircraft Noise

The noise contours for aircraft activity in the vicinity of airfields are generated using the NOISEMAP computer program. This program was developed for the U.S. Air Force (USAF) by Wyle Laboratories (USAF 1990a). The required inputs to the program are the location of the flight tracks and the number of each type of aircraft using each flight track. The BASEOPS program (USAF 1990b) is used to enter these data into the NOISEMAP input file. The NMPLOT program is used to plot the contours and to transfer the contour points to a geographical information system (GIS) data layer. The noise zones for the Nap of the Earth (NOE) routes are generated using the HELOSLICE computer program. The HELOSLICE is a simplified version of the NOISEMAP computer program. It was developed to predict the noise from operations at remote landing areas and from NOE routes. The required inputs to this model include the number and type of aircraft using each area and the altitude of the aircraft at the point of interest. The noise contours for the corridors by low-flying subsonic jet aircraft are generated using ROUTEMAP (USAF 1988). The ROUTEMAP is a model developed for the USAF by Wyle Laboratories used for predicting noise exposure from aircraft operations on military training routes. The inputs to the model are the altitude, power setting, speed, and number of operations by aircraft type for a 1-month period. The ROUTEMAP model computes and plots the LEQ, the A-weighted DNL, the onset rate-adjusted monthly day-night level (DNMRL), and the probability of high annoyance. These levels are computed for distances perpendicular to the corridor.

B.4.3 Small Arms Noise

The noise simulation program used to assess small arms weapon noise is the Small Arms Range Noise Assessment Model (SARNAM). SARNAM was developed at the USACERL for the Operational Noise Program at USACHPPM. It incorporates the latest available information on weapons noise source models (including directivity and spectrum), sound propagation, effects of noise mitigation and safety structures (walls, berms, ricochet barriers), and community response protocols for small arms noise.

SARNAM uses a more suitable noise metric than has been previously used for small arms in the United States. It includes an extensive selection of weapons in the source library, can handle multiple ranges of various types, and is designed to maximize user productivity. The graphical output shows noise contours and range boundaries and can also display installation features.

B.4.4 Single Events

PK15(met) accounts for statistical variation in received single event peak noise levels due to weather. It is the calculated peak noise level, without frequency weighting, expected to be exceeded by 15 percent of all events that might occur. This "85 percent solution" gives the installation and the community a means to consider the areas impacted by training noise without putting stipulations on land that would only receive high sound levels under infrequent weather conditions that greatly favor sound propagation. If there are multiple weapon types fired from one location, or multiple firing locations, the single event level used should be the loudest noise level that occurs at each receiver location. PK15(met) does not take the duration or the number of events into consideration. Noise from small arms ranges will be assessed using the peak unweighted sound level until the international standard procedure currently being developed is approved (U.S. Army 1997).

B.4.5 Noise-Level Reduction

The Department of Defense has published two guides on reducing noise through architectural mitigation. The first, *Guidelines for Sound Insulation of Residences Exposed to Aircraft Operations* (U.S. Navy 2005), was sponsored by the Department of the Navy, Naval Facilities Engineering Command, by Wyle Laboratories in April 2005. This document provides in-depth, state-of-the-art noise level reduction guidelines. The second, *Expedient Methods for Rattle-Proofing Certain Housing Components* (Schomer et al. 1987), was prepared by the USACERL. This report is more limited in its scope. Rather than being a guide on how to reduce the transmission of explosive noise heard inside a house, it analyzes several different building elements to identify individual components contributing to rattle. Eliminating rattle is important because people exposed to the sound of large guns tend to complain about the rattling rather than the sound.

B.4.6 References

ANSI 1983	American National Standards Institute (ANSI). 1983. *American National Standard Specifications for Sound Level Meters.* S1.4-1983.
ANSI 1986	ANSI. 1986. *American National Standard method for Assessment of High-Energy Impulsive Sounds with Respect to Residential Communities.* S12.4-1986.
ANSI 1996	ANSI. 1996. *Quantities and Procedures for Description and Measurement of Environmental Sound—Part 4: Noise Assessment and Prediction of Long-Term Community Response*. S12.9-1996/Part 4.
CHABA 1981	National Academy of Sciences Committee on Hearing, Bioacoustics and Biomechanics (CHABA). 1981. *Working Group 84 Report, Assessment of Community Response to High-Energy Impulsive Sounds.*
FAA 1990	Federal Aviation Administration (FAA). 1990. *Day Night Average Sound Level (DNL), The Descriptor of Choice for Airport Noise Assessment.*
Public Law 92-574	Public Law 92-574. 1972. *Noise Control Act of 1972.* 92nd U.S. Congress.
Schomer et.al. 1987	Schomer, Paul. D., PhD. 1987. "The role of Helicopter Noise-Induced Vibration and Rattle in Human Response." *Journal of the Acoustical Society of America*, 81(4). April 1987.
Schomer 1994	Schomer, Paul. D., PhD. 1994. "Human and Community Response to Military Sounds: Results from Field-Laboratory Tests of Small Arms, Tracked Vehicles, and Blast Sounds." *Noise Control Engineering Journal*, 42(2), 71-84. March–April 1994.
USAF 1988	U.S. Air Force (USAF). 1988. *ROUTEMAP Model for Predicting Noise Exposure from Aircraft Operations on Military Training Routes*. Report No. AARML-TR-88-060.
USAF 1990a	USAF. 1990. *Air Force Procedure for Predicting Aircraft Noise Around Airbases: Noise Exposure Model (NOISEMAP) User's Manual*. Report No. AARML-TR-90-011
USAF 1990b	USAF. 1990. *Air Force Procedure for Predicting Aircraft Noise Around Airbases: Airbase Operations Program (BASEOPS) Description*. Report No. AARML-TR-90-012.
U.S. Army 1984	U.S. Army. 1984. *Community Reaction to Impulsive Noise: A 10 Year Research Summary*. USACERL Technical Report N-167.
U.S. Army 1986	U.S. Army. 1986. *MicroBNOISE: A User's Manual*. USACERL Technical Report No. N86/12.

U.S. Army 1997 U.S. Army. 1997. *Army Regulation 200-1, Environmental Protection and Enhancement.*

U.S. Navy 2005 U.S. Navy. 2005. "Guidelines for Sound Insulation of Residences Exposed to Aircraft Operations." April 2005. Available online: <*http://www.wylelabs.com/content/global/documents/WSI.pdf*>.

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ATTACHMENT C

GUIDELINES FOR COMPATIBLE LAND USE

June 1980

GUIDELINES FOR CONSIDERING NOISE IN LAND USE PLANNING AND CONTROL

U.S. Department of Transportation

Federal Interagency Committee on Urban Noise

GUIDELINES FOR CONSIDERING NOISE IN LAND USE PLANNING AND CONTROL

June 1980

Federal Interagency Committee on Urban Noise

FEDERAL
INTERAGENCY COMMITTEE
ON URBAN NOISE

To all local government officials and others interested in noise/land use concerns:

In his Environmental Message to Congress in August, 1979, President Carter announced a new Urban Noise Initiative to reduce urban noise. The Federal Interagency Committee on Urban Noise was thereby established to coordinate various programs, including an interagency program designed "to encourage noise sensitive development, such as housing, to be located away from major noise sources." As a first step in that program, the Committee is pleased to make available this document which presents a broad consolidation of Federal guidance on the incorporation of noise considerations in local development planning and site review operations. We hope that it will facilitate improved communication among all levels of government on noise compatible land use and that you will find it useful in addressing noise/land use concerns in your community.

Douglas Costle
Administrator
U.S. Environmental Protection Agency

Neil Goldschmidt
Secretary
U.S. Department of Transportation

Moon Landrieu
Secretary
U.S. Department of Housing and Urban Development

Robert B. Pirie, Jr.
Assistant Secretary of Defense (Manpower, Reserve Affairs & Logistics)
U.S. Department of Defense

Max Cleland
Administrator
Veterans Administration

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INTRODUCTION

In recent years noise has become a recognized factor in the community planning process. Some significant advancements are being made in the reduction of noise at its source; however, noise cannot be eliminated completely. Local, state, and Federal agencies, in recognition of this fact, have developed guidelines and procedures to deal with noise in the community land use planning process.

A number of Federal agencies have published policies and/or guidance on noise and land use. These agencies have done this for several different reasons: to carry out public law mandates to protect the public health and welfare and provide for environmental enhancement; to serve as the basis for grant approvals; and to integrate the consideration of noise into the overall comprehensive planning and interagency/intergovernmental coordination process.

Because the purposes and uses of these policy and guidance packages are often different, they can appear to be inconsistent and incomparable. This situation may have inhibited state and local planning and decision making with respect to noise and land use and, thus, inhibited consideration of noise in various Federal-grant-in-aid programs.

The purpose of this document is to put the various Federal agency policy and guidance packages into perspective. Although this document does not replace the individual Federal agency material, it can serve as the departure point for dealing with each agency's programs and facilitate the consideration of noise in all land use planning and interagency /intergovernmental coordination processes.

Although several of these Federal programs include noise standards or guidelines as part of their eligibility and performance criteria, the primary responsibility for integrating noise considerations into the planning process rests with local government which generally has exclusive control over actual land development. Noise, like soil conditions, physiographic features, seismic stablility, floodplains and other considerations, is a valid land use determinant. Scientific evidence clearly points to noise as not simply a nuisance but an important health and welfare concern.

The purpose of considering noise in the land use planning process is not to prevent development but rather to encourage development that is compatible with various noise levels. The objective is to guide noise sensitive land uses away from the noise and encourage non-sensitive land uses where there is noise. Where this is not possible, measures should be included in development projects to reduce the effects of the noise.

Section 1 presents consolidated Federal agency land use compatibility guidelines. Section 2 overviews techniques by which the guidelines can be implemented. Section 3 briefly overviews the major Federal agency noise control policies and programs. The Appendices contain brief descriptions of environmental noise descriptors and annotated bibliographies of selected Federal documents.

Section 1. LAND USE COMPATIBILITY GUIDELINES

This section contains two tables. Table 1 classifies noise levels into a set of noise zones according to the most commonly used environmental noise descriptors. Noise zones are identified in order of increasing noise level by the letters "A" through "D". The descriptors are discussed in Appendix A. The Day-Night Average Sound Level (DNL)[1] descriptor can be used for all noise sources. The Equivalent Sound Level (L_{eq}) is included because some highway noise data can be expected to be in terms of an equivalent sound level for the highway "design hour" — see Table 1 for description of when L_{eq} (design hour) is equivalent to DNL for planning purposes. The L_{eq} descriptor itself is not unique to highways and can be applied to any noise source. The Noise Exposure Forecast (NEF) descriptor is used for aircraft noise only and is being superceded by DNL. The Community Noise Equivalent Level (CNEL) descriptor (for the state of California) uses values similar to DNL. Older descriptors unique to airport noise environments, such as the Composite Noise Rating (CNR), may be encountered. For general comparison purposes L_{dn} 65 = NEF 30 = CNR 100, L_{dn} 75 = NEF 40 = CNR 115.

Table 2 contains suggested land use compatibility guidelines. The table arrays land uses[2] on the left with the noise zones of Table 1 across the top. Land use compatibility is expressed as being "compatible", "incompatible" and "compatible with restrictions." The system as presented in the table is comprised of two digit categories identifying land use activity in the most generalized way (e.g. "10 Residential"). Within some of the two-digit categories here are sub-categories identifying activity in greater detail. Compatibility as expressed in this table represents a consolidation of existing Federal agency guidelines. This table serves as a point of departure in making several kinds of determinations, including whether various land uses should be allowed at particular sites based upon the noise levels at those sites. Detailed planning should be based on the procedures and specific general planning guidance found in appropriate Federal agency documents (Appendix B) as well as the needs, desires and site characteristics of the particular community. Another input to the

[1]Day-Night Average Sound Level is abbreviated as DNL and symbolized mathematically as L_{dn} (e.g., L_{dn} 65, L_{dn} 75, etc.).

[2]Land uses are here categorized according to the standard land use activity categories found in the *Standard Land Use Coding Manual*, Housing and Home Finance Agency (now Department of Housing and Urban Development) and Bureau of Public Roads (now Department of Transportation/Federal Highway Administration), 1965.

planning process is the statement of public health and welfare goals in EPA's "Levels" Document. The levels can be used by individual communities to incorporate public health and welfare goals into the planning process. These levels do not *in themselves,* however, form the sole basis for appropriate land use actions because they do not consider cost, feasibility, the noise levels from any particular source, or the development needs of the community and do include an adequate margin of safety. They should be considered by all communities in their planning, including those who now enjoy quiet and wish to preserve it, as well as those which are relatively noisy and wish to mitigate the problem.

TABLE 1. NOISE ZONE CLASSIFICATION

Noise Zone	Noise Exposure Class	Noise Descriptor			HUD Noise Standards
		DNL[1] Day-Night Average Sound Level	**L_{eq}(hour)[3] Equivalent Sound Level**	**NEF[4] Noise Exposure Forecast**	
A	Minimal Exposure	Not Exceeding 55	Not Exceeding 55	Not Exceeding 20	"Acceptable"
B	Moderate Exposure	Above 55[2] But Not Exceeding 65	Above 55 But Not Exceeding 65	Above 25 But Not Exceeding 30	
C-1	Significant Exposure	Above 65 Not Exceeding 70	Above 65 Not Exceeding 70	Above 30 But Not Exceeding 35	"Normally Unacceptable"[5]
C-2		Above 70 But Not Exceeding 75	Above 70 But Not Exceeding 75	Above 35 But Not Exceeding 40	
D-1	Severe Exposure	Above 75 But Not Exceeding 80	Above 40 But Not Exceeding 80	Not Exceeding 45	"Unacceptable"
D-2		Above 80 But Not Exceeding 85	Above 80 But Not Exceeding 85	Above 45 But Not Exceeding 50	
D-3		Above 85	Above 85	Above 50	

[1]CNEL — Community Noise Equivalent Level (California only) uses the same values.

[2]HUD, DOT and EPA recognize L_{dn} = 55 dB as a goal for outdoors in residential areas in protecting the public health and welfare with an adequate margin of safety (Reference: EPA "Levels" Document.) However, it is not a *regulatory* goal. It is a level defined by a negotiated scientific consensus without concern for economic and technological feasibility or the needs and desires of any particular community.

[3]The Federal Highway Administration (FHWA) noise policy uses this descriptor as an alternative to L_{10} (noise level exceeded ten percent of the time) in connection with its policy for highway noise mitigation. The L_{eq} (design hour) is equivalent to DNL for planning purposes under the following conditions: 1) heavy trucks equal ten percent of total traffic flow in vehicles per 24 hours; 2) traffic between 10 p.m. and 7 a.m. does not exceed fifteen percent of the average daily traffic flow in vehicles per 24 hours. Under these conditions DNL equals L_{10} - 3 decibels.

[4]For use in airport environs only; is now being superceded by DNL.

[5]The HUD Noise Regulation allows a certain amount of flexibility for non-acoustic benefits in zone C-1. Attenuation requirements can be waived for projects meeting special requirements.

TABLE 2. SUGGESTED LAND USE COMPATIBILITY GUIDELINES

Land Use		Noise Zones/DNL Levels in L_{dn}						
SLUCM No.	**Name**	**A 0-55**	**B 55-65**	**C-1 65-70**	**C-2 70-75**	**D-1 75-80**	**D-2 80-85**	**D-3 85+**
10	**Residential**							
11	Household units.							
11.11	Single units — detached	Y	Y*	25[1]	30[1]	N	N	N
11.12	Single units — semidetached	Y	Y*	25[1]	30[1]	N	N	N
11.13	Single units — attached row	Y	Y*	25[1]	30[1]	N	N	N
11.21	Two units — side-by-side	Y	Y*	25[1]	30[1]	N	N	N
11.22	Two Units — one above the other	Y	Y*	25[1]	30[1]	N	N	N
11.31	Apartments — walk up	Y	Y*	25[1]	30[1]	N	N	N
11.32	Apartments — elevator	Y	Y*	25[1]	30[1]	N	N	N
12	Group quarters	Y	Y*	25[1]	30[1]	N	N	N
13	Residential hotels	Y	Y*	25[1]	30[1]	N	N	N
14	Mobile home parks or courts	Y	Y*	N	N	N	N	N
15	Transient lodgings	Y	Y*	25[1]	30[1]	35[1]	N	N
16	Other residential	Y	Y*	25[1]	30[1]	N	N	N
20	**Manufacturing**							
21	Food and kindred products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
22	Textile mill products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
23	Apparel and other finished products made from fabrics, leather, and similar materials — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
24	Lumber and wood products (except furniture) — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
25	Furniture and fixtures — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
26	Paper and allied products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
27	Printing, publishing, and allied industries	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
28	Chemicals and allied products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
29	Petroleum refining and related industries	Y	Y	Y	Y[2]	Y[3]	Y[4]	N

*The designation of these uses as "compatible" in this zone reflects individual Federal agencies' consideration of general cost and feasibility factors as well as past community experiences and program objectives. Localities, when evaluating the application of these guidelines to specific situations, may have different concerns or goals to consider. For an indication of possible community reaction in residential environments at various levels of cumulative noise, Table D-1 in Appendix D should be consulted.

NOTES FOR TABLE 2

1. a) Although local conditions may require residential use, it is discouraged in C-1 and strongly discouraged in C-2. The absence of viable alternative development options should be determined and an evaluation indicating that a demonstrated community need for residential use would not be met if development were prohibited in these zones should be conducted prior to approvals.

   b) Where the community determines that residential uses must be allowed, measures to achieve outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB (Zone C-1) and 30 dB (Zone C-2) should be incorporated into building codes and be considered in individual approvals. Normal construction can be expected to provide a NLR of 20 dB, thus the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation and closed windows year round. Additional consideration should be given to modifying NLR levels based on peak noise levels.

   c) NLR criteria will not eliminate outdoor noise problems. However, building location and site planning, design and use of berms and barriers can help mitigate outdoor noise exposure particularly from ground level sources. *Measures that reduce noise at a site should be used wherever practical in preference to measures which only protect interior spaces.*

2. Measures to achieve NLR of 25 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

3. Measures to achieve NLR of 30 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

4. Measures to achieve NLR of 35 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

KEY TO TABLE 2

SLUCM	Standard Land Use Coding Manual
Y (Yes)	Land Use and related structures compatible without restrictions.
N (No)	Land Use and related structures are not compatible and should be prohibited.
NLR (Noise Level Reduction)	Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.
Y^x (Yes with restrictions)	Land Use and related structures generally compatible; see notes 2 through 4.
25, 30, or 35	Land Use and related structures generally compatible; measures to achieve NLR of 25, 30 or 35 must be incorporated into design and construction of structure.
25*, 30* or 35*	Land Use generally compatible with NLR; however, measures to achieve an overall do not necessarily solve noise difficulties and additional evaluation is warranted.

TABLE 2. SUGGESTED LAND USE COMPATIBILITY GUIDELINES (continued)

Land Use		Noise Zones/DNL Levels in L_{dn}						
SLUCM No.	Name	A 0-55	B 55-65	C-1 65-70	C-2 70-75	D-1 75-80	D-2 80-85	D-3 85+
30	**Manufacturing (cont'd)**							
31	Rubber and misc. plastic products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
32	Stone, clay and glass products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
33	Primary metal industries	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
34	Fabricated metal products — manufacturing.	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
35	Professional, scientific, and controlling instruments; photographic and optical goods; watches and clocks — manufacturing	Y	Y	Y	25	30	N	N
39	Miscellaneous manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	
40	**Transportation, communication and utilities**							
41	Railroad, rapid rail transit and street railway transportation	Y	Y	Y	Y[2]	Y[3]	Y[4]	Y
42	Motor vehicle transportation	Y	Y	Y	Y[2]	Y[3]	Y[4]	Y
43	Aircraft transportation	Y	Y	Y	Y[2]	Y[3]	Y[4]	Y
44	Marine craft transportation	Y	Y	Y	Y[2]	Y[3]	Y[4]	Y
45	Highway and street right-of-way	Y	Y	Y	Y[2]	Y[3]	Y[4]	Y
46	Automobile parking	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
47	Communication	Y	Y	Y	25[5]	30[5]	N	N
48	Utilities	Y	Y	Y	Y[2]	Y[3]	Y[4]	Y
49	Other transportation, communication and utilities	Y	Y	Y	25[5]	30[5]	N	N
50	**Trade**							
51	Wholesale trade	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
52	Retail trade — building materials, hardware and farm equipment	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
53	Retail trade — general merchandise	Y	Y	Y	25	30	N	N
54	Retail trade — food	Y	Y	Y	25	30	N	N
55	Retail trade — automotive, marine craft, aircraft and accessories	Y	Y	Y	25	30	N	N
56	Retail trade — apparel and accessories	Y	Y	Y	25	30	N	N
57	Retail trade — furniture, home furnishings and equipment	Y	Y	Y	25	30	N	N
58	Retail trade — eating and drinking establishments	Y	Y	Y	25	30	N	N
59	Other retail trade	Y	Y	Y	25	30	N	N

NOTES FOR TABLE 2

2. Measures to achieve NLR of 25 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

3. Measures to achieve NLR of 30 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

4. Measures to achieve NLR of 35 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

5. If noise sensitive use indicated NLR; if not use is compatible.

KEY TO TABLE 2

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Y^X (Yes with restrictions)	Land Use and related structures generally compatible; see notes 2 through 4.
25, 30, or 35	Land Use and related structures generally compatible; measures to achieve NLR of 25, 30 or 35 must be incorporated into design and construction of structure.
25*, 30* or 35*	Land Use generally compatible with NLR; however, measures to achieve an overall noise reduction do not necessarily solve noise difficulties and additional evaluation is warranted.

TABLE 2. SUGGESTED LAND USE COMPATIBILITY GUIDELINES (continued)

Land Use		Noise Zones/DNL Levels in L_{dn}						
SLUCM No.	Name	A 0-55	B 55-65	C-1 65-70	C-2 70-75	D-1 75-80	D-2 80-85	D-3 85+
60	**Services**							
61	Finance, insurance and real estate services	Y	Y	Y	25	30	N	N
62	Personal services	Y	Y	Y	25	30	N	N
62.4	Cemeteries	Y	Y	Y	Y^{2}	Y^{3}	$Y^{4,11}$	$Y^{6,11}$
63	Business services	Y	Y	Y	25	30	N	N
64	Repair services	Y	Y	Y	Y^{2}	Y^{3}	Y^{4}	N
65	Professional services	Y	Y	Y	25	30	N	N
65.1	Hospitals, nursing homes	Y	Y*	25*	30*	N	N	N
65.1	Other medical facilities	Y	Y	Y	25	30	N	N
66	Contract construction services	Y	Y	Y	25	30	N	N
67	Governmental services	Y	Y*	Y*	25*	30*	N	N
68	Educational services	Y	Y*	25*	30*	N	N	N
69	Miscellaneous services	Y	Y	Y	25	30	N	N
70	**Cultural, entertainment and recreational**							
71	Cultural activities (including churches)	Y	Y*	25*	30*	N	N	N
71.2	Nature exhibits	Y	Y*	Y*	N	N	N	N
72	Public assembly	Y	Y	Y	N	N	N	N
72.1	Auditoriums, concert halls	Y	Y	25	30	N	N	N
72.11	Outdoor music shells, amphitheaters	Y	Y*	N	N	N	N	N
72.2	Outdoor sports arenas, spectator sports	Y	Y	Y^{7}	Y^{7}	N	N	N
73	Amusements	Y	Y	Y	Y	N	N	N
74	Recreational activities (incl. golf courses, riding stables, water recreation)	Y	Y*	Y*	25*	30*	N	N
75	Resorts and group camps	Y	Y*	Y*	Y*	N	N	N
76	Parks	Y	Y*	Y*	Y*	N	N	N
79	Other cultural, entertainment and recreation	Y	Y*	Y*	Y*	N	N	N
80	**Resource production and extraction**							
81	Agriculture (except livestock)	Y	Y	Y^{8}	Y^{9}	Y^{10}	$Y^{10,11}$	$Y^{10,11}$
81.5 to 81.7	Livestock farming and animal breeding	Y	Y	Y^{8}	Y^{9}	N	N	N
82	Agricultural related activities	Y	Y	Y^{8}	Y^{9}	Y^{10}	$Y^{10,11}$	$Y^{10,11}$
83	Forestry activities and related services	Y	Y	Y^{8}	Y^{9}	Y^{10}	$Y^{10,11}$	$Y^{10,11}$
84	Fishing activities and related services	Y	Y	Y	Y	Y	Y	Y
85	Mining activities and related services	Y	Y	Y	Y	Y	Y	Y
89	Other resource production and extraction	Y	Y	Y	Y	Y	Y	Y

*The designation of these uses as "compatible" in this zone reflects individual Federal agencies' consideration of cost and feasibility factors as well as program objectives. Localities, when evaluating the application of these guidelines to specific situations, may have different concerns or goals to consider. For an indication of possible community reaction in residential environments at various levels of cumulative noise, Table D-1 in Appendix D should be consulted.

NOTES FOR TABLE 2

2. Measures to achieve NLR of 25 must be incorporated into the design and construction of portions of these buildings where the public is received, office ares. noise sensitive areas or where the normal noise level is low.

3. Measures to achieve NLR of 30 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

4. Measures to achieve NLR of 35 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

6. No buildings.

7. Land use compatible provided special sound reinforcement systems are installed.

8. Residential buildings require a NLR of 25.

9. Residential buildings require a NLR of 30.

10. Residential buildings not permitted.

1 Land use not recommended, but if community decides use is necessary, hearing protection devices should be worn by personnel.

KEY TO TABLE 2

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25*, 30* or 35*	Land Use generally compatible with NLR; however, measures to achieve an overall noise reduction do not necessarily solve noise difficulties and additional evaluation is warranted.

UFC 3-260-01
17 NOVEMBER 2008

UNIFIED FACILITIES CRITERIA (UFC)

AIRFIELD AND HELIPORT PLANNING AND DESIGN

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U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY (Preparing Activity)

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-260-01, dated 1 November 2001.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA). Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCESA) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 3-260-01
Superseding: UFC 3-260-01, dated 1 November 2001

Description of Changes: This update to UFC 3-260-01:

- Updates and adds references to associated design manuals and publications with related standards and criteria
- Clarifies: the application of criteria to airfields and facilities constructed under previous standards; the aircraft wheel load design requirements for drainage structures in shoulder areas and the graded area of clear zones; pavement types and surface smoothness criteria near arresting system cables; information on limited use helipads
- Adds: a requirement to file FAA Form 7460-2 for project completion; a requirement for USAF activities to develop a construction phasing plan for all projects; new aircraft mission-design series to runway classification by aircraft type; new Air Force aircraft arresting systems; information on siting criteria for fire hydrants when required adjacent to aprons; an allowance for service roads controlled by ATC within the graded area of clear zone; specific wheel load requirements for the paved portion of runway overruns and shoulder areas; Service-specific AICUZ guidelines; a new Navy and Marine Corps requirement for transverse slope requirements near aircraft arresting system cables; criteria for runway and taxiway intersection fillets; new tables and figures; information on Navy/Marine Corps exemptions from waivers
- Revises criteria for: longitudinal grades of runway and shoulders; transverse grade of runway, paved shoulder, unpaved shoulder, and area to be graded; runway lateral clearance zones; mandatory frangibility zone; rate of longitudinal grade change per 30 meters for fixed-wing taxiways; grade of area between taxiway shoulder and taxiway clearance line on fixed-wing taxiways; taxiway intersections; paved shoulders on USAF runways with a paved surface wider than the minimum needed for the mission; fixed-wing aprons; warm-up pads; siting warm-up pads, other aprons, hot cargo spots, and taxiways to these facilities; siting access roads and parking areas for access roads; siting compass calibration pads; siting of hazardous cargo pads; hangar access aprons; landing zones; rotary-wing landing lanes; aircraft clearances inside hangars; waiver processing procedures; compatible use zones; jet blast requirements and blast resistant pavement; Air Force tie-downs and static ground; Air Force airfield support facilities; airfield construction projects; establishing the building restriction line at USAF bases
- Revises: Navy/Marine Corps aircraft dimensions

Reasons for Changes:

- Response to AFSAS Mishap ID 305221, F-15C, Class A, Landing Mishap, Final Evaluation, 20020903FTFA315A, Recommendations 3 & 4
- Response to HQ ACC/A7OI request that grade allowances be aligned with FAA criteria
- Response to COE recommendations based on current construction techniques
- Response to C-32A Class A Mishap, 20060601, Recommendation 7
- Response to NAVFAC ECO recommendations
- Response to AFSAS mishap ID 305955, F-15E, Class C, 05022003001C, Recommendation 5.1
- Improvement to readability of figures and addition of information via new tables and figures

Impact: There are negligible cost impacts; however, these benefits should be realized:

- Increased aircraft safety during runway construction projects
- Reduced costs for providing paved shoulders on runways wider than 46 meters
- Reduced costs for grading runway shoulders
- Improved waiver processing guidelines

Non-Unification Issues: Due to differences in mission, aircraft, tactics, mishap potential and mishap rates for specific aircraft, not all criteria within this UFC are unified. The primary elements of criteria that are not unified are clear zone and accident potential zone (APZ) shapes and sizes, separation distances between runways and taxiways, and size and implementation dates for certain protected air space elements. Maintaining these differences allows the Services to avoid costs associated with non-mission-driven changes in airfield configuration and mapping, and acquisition of real property or avigation easements.

- Planning: The processes vary among the Services due to differing organizational structures and are delineated in separate Service-specific directives.
- Clear zone and APZ shapes and sizes: These areas are different for each Service and class of runway because they are based on the types of aircraft that use the runways and Service-specific accident potential.
- Distances between fixed and rotary wing runways: The distance is greater for Air Force and Navy/Marine Corps runways due to the frequency of operations by high-performance aircraft.
- Increased width of landing lanes for Navy/Marine Corps: The width is increased to prevent rotor wash damage to landing lane shoulders and subsequent potential foreign object damage (FOD) from large rotary wing aircraft.
- Lesser width of Class A taxiways on Navy/Marine Corps: No new Navy/Marine Corps Class A facilities have been constructed since World War II. The Navy will unify their criteria but must defer until the next UFC update to allow for a thorough evaluation.
- No Navy/Marine Corps requirement for paved shoulders on Class A taxiways: Same rationale as for the width of Class A taxiways above.
- Reduced site distance for Air Force taxiways: Enables the Army and Navy/Marine Corps to operate with uncontrolled taxiways.
- Increased clearance from taxiway centerlines to fixed or mobile obstacles: The Air Force routinely operates C-5 aircraft on all Air Force airfields. Use of the reduced clearances slows taxi speeds and hinders expedient operations.
- Reduced distance between taxiway and parallel taxiway centerlines on Army airfields: The Army does not routinely simultaneously operate numerous wide-body aircraft on a single airfield.
- Different Air Force and Navy/Marine Corps intersection geometry: The differences are in the methods for widening the pavement prior to intersections.
- Tow way width differences: The Navy/Marine Corps base tow way width on three general aircraft types; the Air Force and Army base tow way width on mission aircraft.
- Clearance from tow way centerline to fixed or mobile obstacles: The Navy/Marine Corps require distance be based on tow way type; the Air Force and Army require clearance be based on mission aircraft.
- Vertical clearance from tow way pavement surface to fixed or mobile obstacles: The Navy/Marine Corps require distance be based on tow way type; the Air Force and Army require clearance be based on mission aircraft.
- Differences in apron spacing for parking aircraft: The Navy/Marine Corps apron spacing requirements are developed for each aircraft in the inventory. Air Force and Army requirements are based on aircraft wingspan.
- Differences in Air Force and Army apron clearance distance: The Army requires a 38-meter (125-foot) clearance distance for all Class B aircraft aprons. This distance is sufficient to accommodate C-5 aircraft. The Air Force formerly used the same criteria but recently began basing the required distance on the most demanding aircraft that uses the apron. This is because all aprons will not accommodate C-5 aircraft.
- Differences in apron layout for rotary wing aircraft: Formerly, Air Force and Army rotary wing criteria were slightly different. The Air Force has adopted Army rotary wing criteria as optional and will standardize these criteria in the next revision of AFH 32-1084, *Facility Requirements*.

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FIGURES

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SECTION 3 DOD AIR INSTALLATIONS COMPATIBLE USE ZONES
SUGGESTED LAND USE COMPATIBILITY IN ACCIDENT POTENTIAL ZONES [1]

SLUC M* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
10	***Residential***				
11	Household units				
11.11	Single units: detached	N	N	Y[2]	Maximum density of 1–2 Du/Ac
11.12	Single units: semidetached	N	N	N	
11.13	Single units: attached row	N	N	N	
11.21	Two units: side-by-side	N	N	N	
11.22	Two units: one above the other	N	N	N	
11.31	Apartments: walk-up	N	N	N	
11.32	Apartment: elevator	N	N	N	
12	Group quarters	N	N	N	
13	Residential hotels	N	N	N	
14	Mobile home parks or courts	N	N	N	

SLUCM* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
15	Transient lodgings	N	N	N	
16	Other residential	N	N	N	
20	***Manufacturing*** [3]				
21	Food & kindred products; manufacturing	N	N	Y	Maximum FAR 0.56 IN APZ II
22	Textile mill products; manufacturing	N	N	Y	Same as above
23	Apparel and other finished products; products made from fabrics, leather and similar materials; manufacturing	N	N	N	
24	Lumber and wood products	N	Y	Y	Maximum FAR of 0.28 in APZ I & FAR of 0.56 in APZ II
25	Furniture and fixtures; manufacturing	N	Y	Y	Same as above
26	Paper and allied products; manufacturing	N	Y	Y	Same as above

SLUCM* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
27	Printing, publishing, and allied industries	N	Y	Y	Same as above
28	Chemicals and allied products; manufacturing	N	N	N	
29	Petroleum refining and related industries	N	N	N	
30	***Manufacturing[3] (continued)***				
31	Rubber and misc. plastic products; manufacturing	N	N	N	
32	Stone, clay and glass products; manufacturing	N	N	Y	Maximum FAR 0.56 in APZ II
33	Primary metal products; manufacturing	N	N	Y	Same as above
34	Fabricated metal products; manufacturing	N	N	Y	Same as above

SLUCM* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
35	Professional scientific, and controlling instruments; photographic and optical goods; watches and clocks	N	N	N	
39	Miscellaneous manufacturing	N	Y	Y	Maximum FAR of 0.28 in APZ I & FAR of 0.56 in APZ II
40	***Transportation, communication and utilities [3,4].***				See Note 3 below
41	Railroad, rapid rail transit, and street railway transportation	N	Y[5]	Y	Same as above
42	Motor vehicle transportation	N	Y[5]	Y	Same as above
43	Aircraft transportation	N	Y[5]	Y	Same as above
44	Marine craft transportation	N	Y[5]	Y	Same as above
45	Highway and street right-of-way	N	Y[5]	Y	Same as above
46	Automobile parking	N	Y[5]	Y	Same as above

SLUCM* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
47	Communication	N	Y[5]	Y	Same as above
48	Utilities	N	Y[5]	Y	Same as above
48.5	Solid waste disposal (landfills, incinerators, etc.)	N	N	N	
49	Other transportation, communication and utilities	N	Y[5]	Y	Same as above
50	***Trade***				
51	Wholesale trade	N	Y	Y	Maximum FAR of 0.28 in APZ I. Maximum FAR of 0.56 in APZ II
52	Retail trade – building materials, hardware and farm equipment	N	Y	Y	Maximum FAR of 0.14 in APZ I & 0.28 in APZ II
53	Retail trade – general merchandise	N	N	Y	Maximum FAR of 0.14.
54	Retail trade - food	N	N	Y	Maximum FARs of 0.24

SLUCM* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
55	Retail trade – automotive, marine craft, aircraft and accessories	N	Y	Y	Maximum FAR of 0.14 in APZ I & 0.28 in APZ II
56	Retail trade – apparel and accessories	N	N	Y	Maximum FAR 0.28
57	Retail trade – furniture, home, furnishings and equipment	N	N	Y	Same as above
58	Retail trade – eating and drinking establishments	N	N	N	
59	Other retail trade	N	N	Y	Maximum FAR of 0.22
60	***Services*** [6]				
61	Finance, insurance and real estate services	N	N	Y	Maximum FARs of 0.22 for "General Office/Office park"
62	Personal services	N	N	Y	Office uses only. Maximum FAR of 0.22
62.4	Cemeteries	N	Y[7]	Y[7]	

SLUCM* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
63	Business services	N	Y	Y	Max. FARs of 0.11 APZ I; 0.22 in APZ II
63.7	Warehousing and storage services	N	Y	Y	Maximum FAR of 1.0
64	Repair services	N	Y	Y	Max. FARs of 0.11 APZ I; 0.22 in APZ II
65	Professional services	N	N	Y	Max. FARs of 0.22
65.1	Hospitals, nursing homes	N	N	N	
65.16	Other medical facilities	N	N	N	
66	Contract construction services	N	Y	Y	Max. FARs of 0.11 APZ I; 0.22 in APZ II
67	Government services	N	N	Y	Max FAR of 0.22
68	Educational services	N	N	N	
69	Miscellaneous	N	N	Y	Max. FAR of 0.22
70	***Cultural, Entertainment and Recreational***				

SLUC M* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
71	Cultural activities	N	N	N	
71.2	Nature exhibits	N	Y[8]	Y[8]	
72	Public assembly	N	N	N	
72.1	Auditoriums, concert halls	N	N	N	
72.11	Outdoor music shells, amphitheaters	N	N	N	
72.2	Outdoor sports arenas, spectator sports	N	N	N	
73	Amusements	N	N	Y	
74	Recreational activities (including golf courses, riding stables, water recreation)	N	Y[8]	Y[8]	No club house
75	Resorts and group camps	N	N	N	
76	Parks	N	Y[8]	Y[8]	Same as 74
79	Other cultural, entertainment and recreation	N	Y[8]	Y[8]	Same as 74

SLUCM* No.	Land Use Name	Clear Zone Recommendation	APZ-I Recommendation	APZ-II Recommendation	Density Recommendation
80	***Resource production and extraction***				
81	Agriculture[9] (except live stock)	Y[4]	Y	Y	
81.5, 81.7	Livestock farming and breeding	N	Y[10]	Y[10]	
82	Agriculture-related activities (processing and husbandry services)	N	Y	Y	Max FAR of 0.28; no activity which produces smoke, glare, or involves explosives
83	Forestry activities [11]	N	Y	Y	Same as above
84	Fishing activities [12]	N[12]	Y	Y	Same as above
85	Mining activities[13]	N	Y	Y	Same as above
89	Other resource production or extraction	N	Y	Y	Same as above
90	***Other***				
91	Undeveloped land	Y	Y	Y	
93	Water areas	N[14]	N[14]	N[14]	

B3-1 **LEGEND.** The following legend refers to the preceding table.

*Standard Land Use Coding Manual (SLUCM), U.S. Department of Transportation

Y (Yes) - Land uses and related structures are normally compatible without restriction.

N (No) – Land use and related structures are not normally compatible and should be prohibited.

Y^x – (Yes with restrictions) The land uses and related structures are generally compatible; see notes indicated by the superscript.

N^x – (No with exceptions) See notes indicated by the superscript.

FAR – Floor Area Ratio. A floor area ratio is the ratio between the square feet of floor area of the building and the site area. It is customarily used to measure non-residential intensities.

Du/Ac – Dwelling Units per Acre. This is customarily used to measure residential densities.

B3-2 **NOTES.** The following notes refer to the preceding table.

1. A "Yes" or a "No" designation for compatible land use is to be used only for general comparison. Within each, uses exist where further evaluation may be needed in each category as to whether it is clearly compatible, normally compatible, or not compatible due to the variation of densities of people and structures. In order to assist installations and local governments, general suggestions as to floor/area ratios are provided as a guide to density in some categories. In general, land use restrictions which limit commercial, services, or industrial buildings or structure occupants to 25 per acre in APZ I and 50 per acre in APZ II are the range of occupancy levels considered to be low density. Outside events should normally be limited to assemblies of not more than 25 people per acre in APZ I, and maximum assemblies of 50 people per acre in APZ II. Recommended FARs are calculated using standard parking generation rates for various land uses, vehicle occupancy rates, and desired density in APZ I and II.

2. The suggested maximum density for detached single family housing is 1 to 2 Du/Ac. In a planned unit development (PUD) of single-family detached units, this density could possibly be increased slightly, where the amount of open space is significant and the amount of surface area covered by structures does not exceed 20% of the PUD total area.

3. Other factors to be considered: labor intensity, structural coverage, explosive characteristics, air pollution, electronic interference with aircraft, height of structures, and potential glare to pilots.

4. No structures (except airfield lighting and navigational aids necessary for the safe operation of the airfield when there are no other siting options), buildings or above-ground utility/communications lines should normally be located in clear zone areas on or off the installation. The clear zone is subject to severe restrictions.

5. No passenger terminals and no major aboveground transmission lines in APZ I.

6. Low-intensity office uses only. Ancillary uses such as meeting places, auditoriums, etc., are not recommended. See recommended FARs.

7. No chapels are allowed within APZ I or APZ II.

8. Facilities must be low-intensity; club houses, meeting places, auditoriums, large classes, etc., are not recommended.

9. Excludes feedlots and intensive animal husbandry (see SLUCM 81.5, 81.7). Activities that attract concentrations of birds, creating a hazard to aircraft operations, should be excluded.

10. Includes feedlots and intensive animal husbandry.

11. Lumber and timber products removed due to establishment, expansion, or maintenance of clear zones will be disposed of in accordance with appropriate DOD Natural Resources Instructions.

12. Controlled hunting and fishing may be permitted for the purpose of wildlife management.

13. Surface mining operations that could create retention ponds that may attract waterfowl and present bird aircraft strike hazards (BASH) or operations that produce dust and/or light emissions that could impact pilot vision are not compatible.

14. Naturally occurring water features (e.g., rivers, lakes, streams, wetlands) are pre-existing, non-conforming land uses. Naturally occurring water features that attract waterfowl present a potential BASH. Actions to expand naturally occurring water features should not be encouraged.

B3-3 **REFERENCES.** Refer to the following documents for the latest guidance on air installation land use compatibility guidelines. Also, refer to paragraph 3-11 and Table 3-5 for additional information on the graded area of clear zones.

B3-3.1 **DOD**. DODI 4165.57 provides the DOD policy for Service AICUZ program management.

B3-3.2 **Air Force**. Air Force land use guidelines are provided in AFI 32-7063 and AFH 32-7084.

B3-3.3 **Navy and Marine Corps**. For Navy and Marine Corps installations, see OPNAVINST 11010.36B.

Annex A. Plan 2. Operational Noise Consultation No. 52-EN-0DRM-11, Operational Noise Contours, Davison Army Airfield, Fort Belvoir, Virginia, 7 September 2010

DEPARTMENT OF THE ARMY
US ARMY INSTITUTE OF PUBLIC HEALTH
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MD 21010-5403

MCHB-IP-EON

30 NOV 2010

MEMORANDUM FOR Environmental and Natural Resources Division (Mr. Christopher McQuale), Directorate of Public Works, 9430 Jackson Loop, Fort Belvoir, VA 22060-5116

SUBJECT: Operational Noise Consultation, 52-EN-0DRM-11, Operational Noise Contours for Davison Army Airfield, Fort Belvoir, VA, 7 September 2010

1. We are enclosing 2 copies of the consultation.

2. Please contact us if this consultation or any of our services did not meet your needs or expectations.

3. The point of contact is Ms. Kristy Broska, Environmental Protection Specialist or Ms. Catherine Stewart, Program Manager, Operational Noise, Army Institute of Public Health, at DSN 584-3829, Commercial (410) 436-3829, or email: kristy.broska@us.army.mil or catherine.stewart@us.army.mil.

FOR THE DIRECTOR:

Encl

William J. Bettin
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Portfolio Director, Environmental Health Engineering

CF:
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PHCR-NORTH, (MAJ McCowin)

U.S. ARMY PUBLIC HEALTH COMMAND (Provisional)
5158 Blackhawk Road, Aberdeen Proving Ground, Maryland 21010-5403

OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0DRM-11
OPERATIONAL NOISE CONTOURS
DAVISON ARMY AIRFIELD
FORT BELVOIR, VIRGINIA
7 SEPTEMBER 2010

Distribution authorized to U.S. Government agencies only; protection of privileged information evaluating another command; Sep 10. Other requests for this document shall be referred to Environmental and Natural Resources Division, Directorate of Public Works (Mr. Christopher McQuale), 9430 Jackson Loop, Fort Belvoir, VA 22060-5116

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EXECUTIVE SUMMARY
OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0DRM-11
OPERATIONAL NOISE CONTOURS
DAVISON ARMY AIRFIELD
FORT BELVOIR, VIRGINIA
7 SEPTEMBER 2010

1. PURPOSE. To address the noise impacts of the aviation activity at the Davison Army Airfield (DAAF).

2. CONCLUSIONS.

a. The operations at DAAF generate a Land Use Planning Zone (60-65 decibel (dB) A-weighted Day Night average Noise Level (ADNL) noise contour that extends along the approach and departure route to the airfield. The Zone II (65-75 dB ADNL) noise contour extends beyond the northwestern boundary extending to Interstate 95. Based on available imagery, the area within the Noise Zone II contour is "industrial" and there are no non-recommended land uses therein. The on-post Noise Zone II contour extends into an undeveloped area.

b. The ADNL contours indicate that annual average noise levels from the aviation activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

c. The proposed relocation of the hangers, apron, and taxiways would not change the operational noise contours.

3. RECOMMENDATIONS. The DAAF should continue to use the noise management program to reduce the potential for noise complaints, caused by day-to-day operations through a responsive noise complaint procedure, and taking actions that are appropriate to guide future development of those properties adjacent to its boundaries.

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OPERATIONAL NOISE CONSULTATION
NO. 52-EN-0DRM-11
OPERATIONAL NOISE CONTOURS
DAVISON ARMY AIRFIELD
FORT BELVOIR, VIRGINIA
07 SEPTEMBER 2010

1. REFERENCES.

a. A list of the references used in this consultation is in Appendix A. A glossary of terms and abbreviations used are in Appendix B. Appendix C provides guidelines for discussing noise contour maps.

b. Appendix D contains background information on noise, noise evaluation, and contouring. Appendix E summarizes the regulatory requirements.

2. AUTHORITY. The Army Environmental Command, Aberdeen Proving Ground, MD funded this consultation under MIPR number MIPR10006555 to support Operational Noise Programs at multiple sites.

3. PURPOSE.

a. To address the noise impacts of the aviation activity at the Davison Army Airfield (DAAF).

b. To address the proposed relocation of structures that are within 500 feet of the runway and any noise impacts there forth.

c. An Installation Operational Noise Management Plan (IONMP) is required "as appropriate" by Army Regulation (AR) 200-1. Since the operational noise-producing activities at Fort Belvoir are limited to the aircraft operations at DAAF, this consultation was developed in lieu of an IONMP. The consultation summarizes the key points in the IONMP specific to Fort Belvoir's noise management needs.

4. GENERAL.

a. The DAAF is located on the northwest side of Fort Belvoir. The airfield is home to the 12th Aviation Battalion under the US Army Air Operations Group Military District of Washington (MDW); the headquarters of the Army's fixed-wing Operational Support Airlift Agency (OSAA); the US Army Aviation Forces Command DC National Guard; and the US Army Air Systems Division for Night Vision.

b. The OSAA's mission is to provide high priority, scheduled and short notice air transport of passengers, and cargo for the Army and Department of Defense (DOD).

c. The 12th Aviation Battalion is MDW's aviation support unit. It is made up of three helicopter companies.[1] The battalion operates helicopters in support of training and contingencies for the Old Guard and other MDW units. The battalion provides airlift to the highest levels of the Army and DOD.

5. AIRFIELD NOISE CONTOURING PROCEDURES.

a. The noise simulation program used to assess annual aircraft noise is NoiseMap/Baseops (U.S. Air Force 2005a). The NoiseMap/Baseops program requires operational data concerning type of aircraft, altitude, flight tracks, and number of operations.

b. Per AR 200-1, the metric used to address aviation noise requirements is the A-weighted Day-Night average Level (ADNL). Noise-sensitive land uses, such as housing, schools, and medical facilities are acceptable within the Land Use Planning Zone (LUPZ) (60-65 decibel [dB] ADNL) and the Noise Zone I (< 65 dB ADNL); normally not recommend in Noise Zone II (65–75 dB ADNL); and not recommended in Noise Zone III (> 75 dB ADNL).

6. AIRFIELD AVIATION ACTIVITY.

a. The DAAF is a 24-hour facility, however, the bulk of the traffic is during the hours the control tower is open. The airfield operates approximately 250 days per year; the normal operating hours at the control tower are Monday–Friday (0600–2130 hours).

[1] http://www.globalsecurity.org/military/agency/army/12avn-bn.htm

b. From Sep 09 to Aug10, the DAAF airfield reported 48,327 operations. The number and type of aircraft operations varies from day to day and month to month. The average daily movements on the airfield is 192. The number of movements is based upon aircraft that utilized the airfield, not aircraft just passing through the DAAF airspace.

c. The primary aircraft utilizing the airfield are the UH-60 Blackhawk and the Beechcraft Super King Air (BE-20).

d. Other common aircraft utilizing the airfield include the Cessna Citation (500/560); the Short Sherpa (SH-33); the CH-46 Seaknight; and the UH-72 Lakota. See Appendix F for a visual reference to the primary types of aircraft utilized. Additionally, other aircraft models may infrequently use the airfield. However, these occasional operations have only a negligible impact on the noise environment.

e. Table 1 lists the average daily aviation activity.

TABLE 1. AVERAGE DAILY AVIATION ACTIVITY.

	Daytime Operations (0700 – 2200 hours)	**Nighttime Operations (2200 – 0700 hours)**
BE-20	51	0
C-500	3	0
C-560	7	0
CH-46	4	0
SH-33	7	0
UH-60	106	0
UH-72	14	0

Note: An operation is defined as either an arrival or a departure or a closed traffic pattern.

7. AIRFIELD NOISE EXPOSURE RESULTS.

a. Figure 1 contains the noise contours for the operations at DAAF. The operations generate a LUPZ (60-65 dB ADNL) noise contour that extends along the approach and departure routes to the airfield. The Zone II (65-75 dB ADNL) noise contour extends beyond the northwestern boundary, extending to Interstate 95. Based on available aerial imagery, the area within the Noise Zone II contour is "industrial" and there are no non-recommended land uses therein. The on-post Noise Zone II contour extends into an undeveloped area.

b. The operations at the DAAF do not generate noise levels above 75 dB ADNL (Zone III).

FIGURE 1. DAVISON ARMY AIRFIELD OPERATIONAL NOISE CONTOURS

8. AVIATION ANNOYANCE POTENTIAL.

a. Although the aviation activity does not generate noise contours that indicate incompatible land use, there is still the potential that individual aircraft overflights could annoy people and possibly generate complaints.

b. Scandinavian Studies (Rylander 1974 and Rylander 1988) have found that a good predictor of annoyance at airfields with 50 to 200 operations per day is the maximum level of the 3 loudest events. The SELCalc2 Program (U.S. Air Force 2005b) was used to calculate the maximum A-weighted (dBA) noise levels for the loudest and/or most common aircraft at the DAAF. The levels are listed in Table 2. These maximum levels are compared with the levels listed in Table 3 to determine the percent of the population that would consider itself highly annoyed. While annoyance levels may be lower at flight corridors with fewer than 50 operations per day, it is a tool in providing some indication of the percent of people who might be annoyed.

TABLE 2. MAXIMUM NOISE LEVELS OF AIRCRAFT.

Slant Distance (feet)	Maximum Level, dBA					
	BE-20	CH-46	C-500/C-560	SH-33	UH-60	UH-72
500	79	85	84	85	80	75
1,000	73	78	77	79	73	69
1,500	69	74	73	75	69	65
2,000	67	72	69	72	66	62

TABLE 3. PERCENTAGE OF POPULATION HIGHLY ANNOYED FROM AIRCRAFT NOISE. (Rylander 1974)

Maximum, dBA	Highly Annoyed
90	35%
85	28%
80	20%
75	13%
70	5%

c. Tables 4 and 5 indicate the percent of population that would consider itself highly annoyed correlated with maximum noise levels for the most common aircraft overflights at DAAF. The correlation is based on the Rylander studies which investigated airfields with 50 to 200 operations per day.

TABLE 4. ROTARY WING AIRCRAFT OVERFLIGHT ANNOYANCE POTENTIAL[1].

Source	Ground Track Distance[2]	dBA Maximum[3]	Population Highly Annoyed[4]
CH-46–500' AGL	0'	85	28%
	1320' (1/4 mile)	74	11%
	1760' (1/3 mile)	71	7%
	2640' (1/2 mile)	67	1%
CH-46–1000' AGL	0'	78	17%
	1320' (1/4 mile)	73	10%
	1760' (1/3 mile)	71	7%
	2640' (1/2 mile)	67	1%
UH-60–500' AGL	0'	80	20%
	1320' (1/4 mile)	69	4%
	1760' (1/3 mile)	66	<1%
UH-60–1000' AGL	0'	73	10%
	1320' (1/4 mile)	68	2%
	1760' (1/3 mile)	65	<1%
UH-72–500' AGL	0'	75	13%
	1320' (1/4 mile)	70	5%
	1760' (1/3 mile)	65	<1%
UH-72–1000' AGL	0'	69	4%
	1320' (1/4 mile)	67	1%
	1760' (1/3 mile)	63	<1%

[1] Percent annoyance shown is based upon 50 to 200 overflights per day. (Rylander 1974)
[2] Distance between receiver and the point on Earth at which the aircraft is directly overhead.
[3] Obtained via SELCalc2 Program (U.S. Air Force 2005b)
[4] Calculated percentage based upon regression using the known values in Table 3.

TABLE 5. FIXED WING AIRCRAFT OVERFLIGHT ANNOYANCE POTENTIAL[1].

Source	Ground Track Distance[2]	dBA Maximum[3]	Population Highly Annoyed[4]
BE-20–500' AGL	0'	79	19%
	1320' (1/4 mile)	69	4%
	1760' (1/3 mile)	66	<1%
BE-20–1000' AGL	0'	73	10%
	1320' (1/4 mile)	68	2%
	1760' (1/3 mile)	66	<1%
C-500/C-560– 500' AGL	0'	84	26%
	1320' (1/4 mile)	72	8%
	1760' (1/3 mile)	69	4%
C-500/C-560– 1000' AGL	0'	77	16%
	1320' (1/4 mile)	71	7%
	1760' (1/3 mile)	69	4%
SH-33–500' AGL	0'	85	28%
	1320' (1/4 mile)	75	13%
	1760' (1/3 mile)	72	8%
	2640' (1/2 mile)	67	1%
SH-33–1000' AGL	0'	79	19%
	1320' (1/4 mile)	74	11%
	1760' (1/3 mile)	71	7%
	2640' (1/2 mile)	68	2%

1 Percent annoyance shown is based upon 50 to 200 overflights per day. (Rylander 1974)
2 Distance between receiver and the point on Earth at which the aircraft is directly overhead.
3 Obtained via SELCalc2 Program (U.S. Air Force 2005b)
4 Calculated percentage based upon regression using the known values in Table 3.

d. Also based on Rylander's results, Figure 2 provides a graphical depiction of the data presented in Table 4 for the percent of population annoyed by a UH-60 overflight. The figure shows that the levels are based on the receivers being located directly under the UH-60 at 200 feet Above Ground Level (AGL).

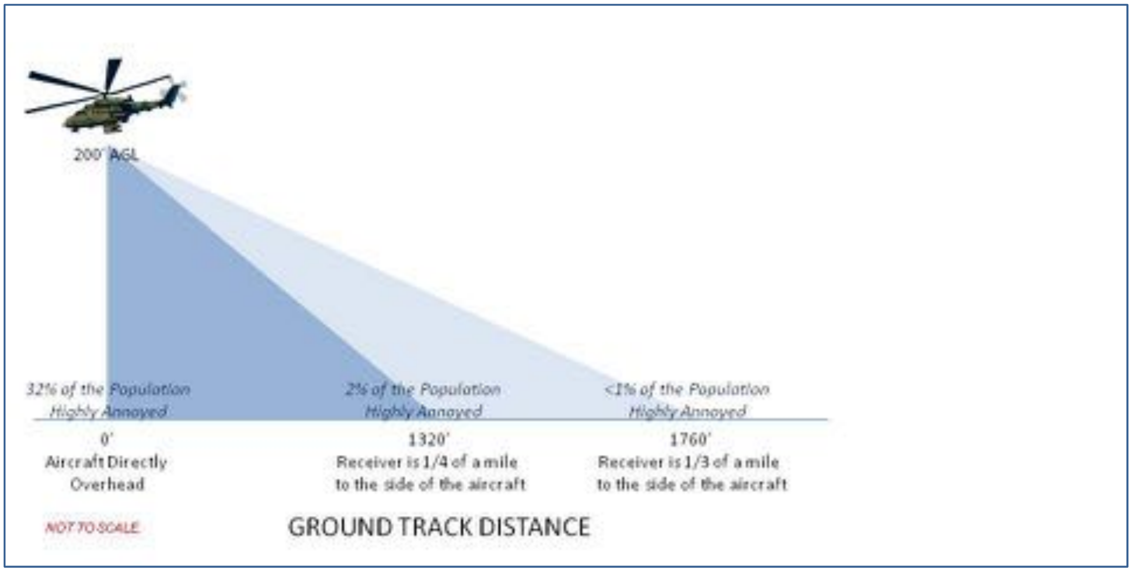

FIGURE 2. UH-60 OVERFLIGHT ANNOYANCE POTENTIAL
(More than 50 Daily Overflights).

e. There is a potential that aircraft utilizing the DAAF airfield may cause annoyance to those living near the flight tracks (Figure 3). Flight tracks that are just passing through the DAAF airspace are not shown. Though the Rylander studies did not develop a correlation between annoyance and complaint risk, a reasonable assumption would be that those who complain are annoyed.

9. COMPLAINT PROCEDURES.

a. A noise complaint procedure is required by AR 200-1 (U.S. Army 2007) to log and investigate all complaints. An effective procedure enables Fort Belvoir to maintain a good relationship with the surrounding communities. In accordance with AR 200-1, the following noise complaint Standard Operating Procedure is in place at Fort Belvoir:

- *Complaints are received by the Fort Belvoir Public Affairs Office. A Noise Complaint Questionnaire is completed for all noise complaints received.*
- *Complaints are routed to the activity responsible for the complaint.*
- *Complaints are investigated and the complainant is contacted without delay.*
- *The complainant is made aware of the unit mission and informed that every effort will be made to correct the problem, mission permitting.*

b. Currently, the aviation activity at the DAAF generates 1 to 2 noise complaints per year.

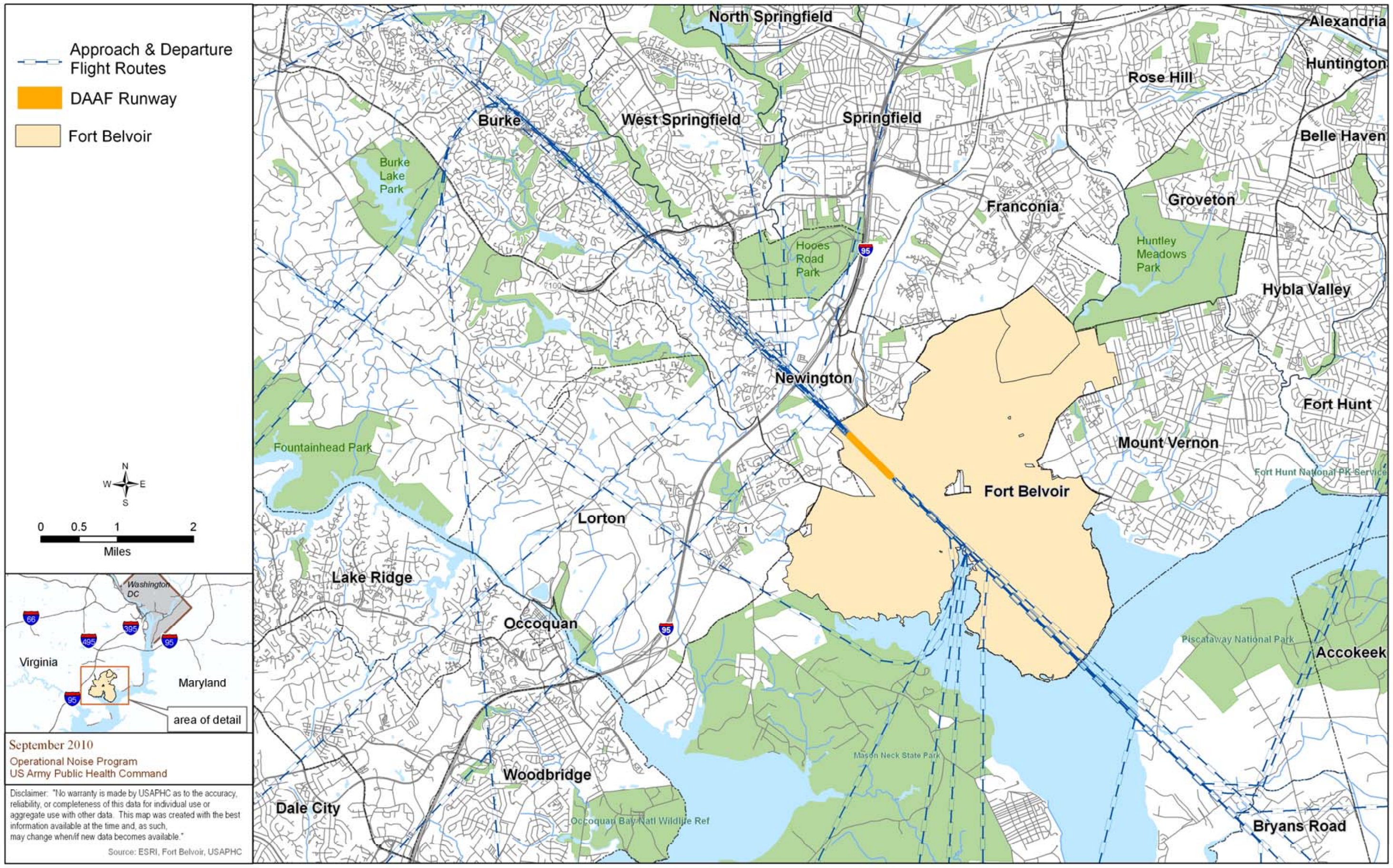

FIGURE 3. APPROACH AND DEPARTURE ROUTES DAVISON ARMY

10. NOISE ABATEMENT PROCEDURES.

a. The DAAF area has residential land uses adjacent to its western boundary. To mitigate noise impacts on surrounding neighbors, DAAF has several noise abatement procedures in place:

- Fly-Neighborly Areas (Figure 4):
  - A noise-sensitive area located near State Route 7100 and Telegraph Road in Newington.
  - Minimum Altitude Restrictions: Parts of the main post area of Fort Belvoir (including the hospital, housing areas).

- Run-up Restrictions: Aircraft run-ups are only conducted on the run-up areas prior to 0800 and after 2200 (Figure 5).
  - Fixed-wing engine run-ups and maintenance operational checks will only be accomplished in the Runway 32 or Runway 14 run-up areas.
  - DC ARNG may also use their ramp for run-ups.
  - Runway 14 run-up area will be used as the primary run-up area for noise abatement concerns.

- Closed Traffic Pattern Restrictions (Figure 6):
  - Flights limited to Monday–Saturday, 0800-2200 hours, and Sunday 1200-2200 hours.

b. Though there are residential areas nearby, DAAF receives few noise complaints. The flight patterns and altitudes over the residential areas fly at the highest altitude that meets both the mission requirements and the noise abatement procedures. Another reason for the low number of complaints is that the airfield is just south of a major highway so the ambient noise levels are already high in the area. Additionally, there are other much larger and more frequent aircraft (commercial aviation) in the airspace.

c. Sufficient measures to mitigate the effects of aircraft noise are currently in place at DAAF, including departure and arrival procedures and the establishment of no-fly areas. However, there is always the possibility that an individual overflight could lead to a complaint. Therefore, DAAF officials depend upon the goodwill and cooperation of the civilian sector to promote public support for and understanding of the DAAF mission requirements. The DAAF should continue implementing fly-neighborly programs that adjust aircraft training times and routes to lower the impact on the community to the greatest extent possible given mission requirements.

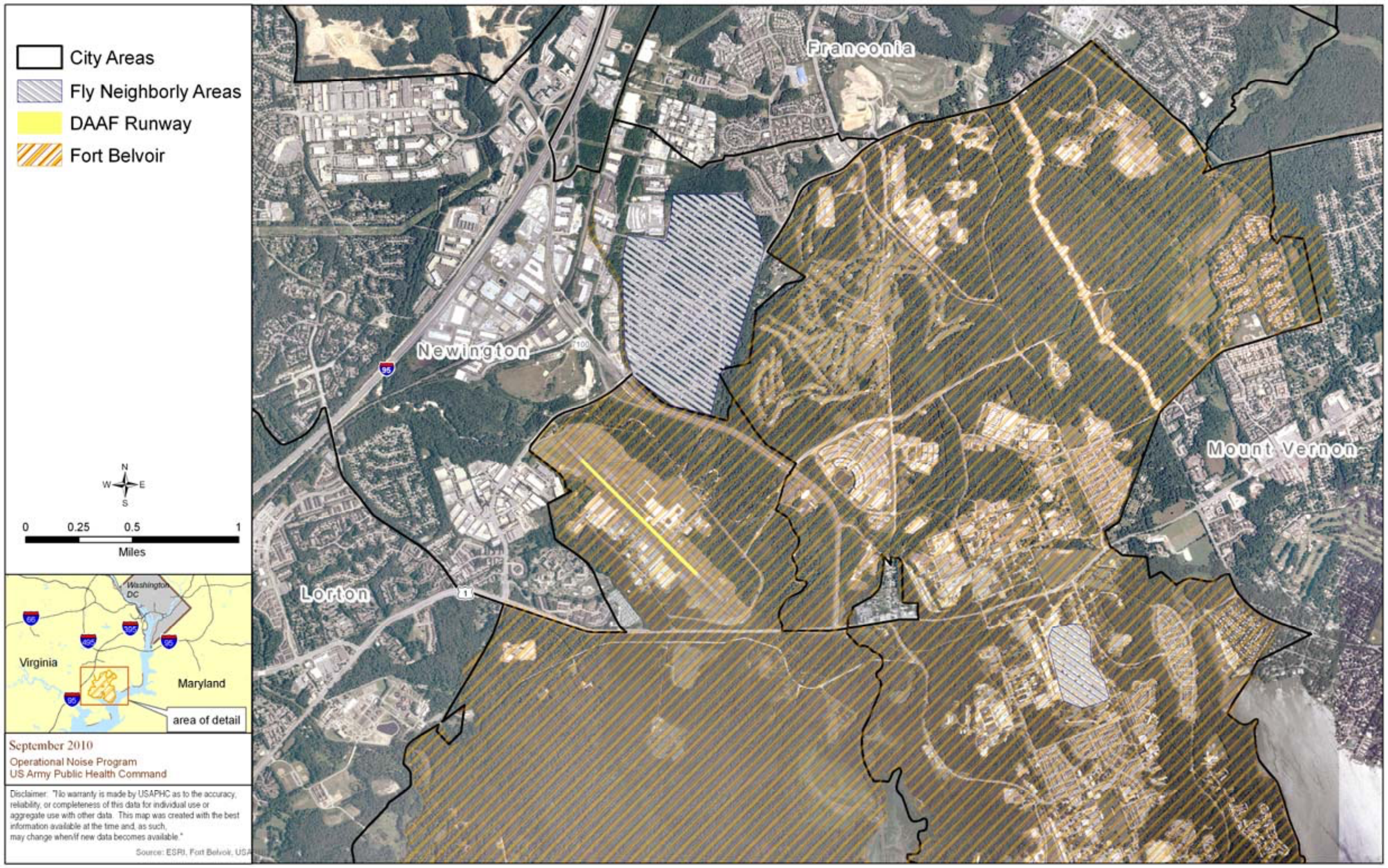

FIGURE 4. DAVISON ARMY AIRFIELD FLY-NEIGHBORLY AREAS

FIGURE 5. DAVISON ARMY AIRFIELD RUN-UP AREAS

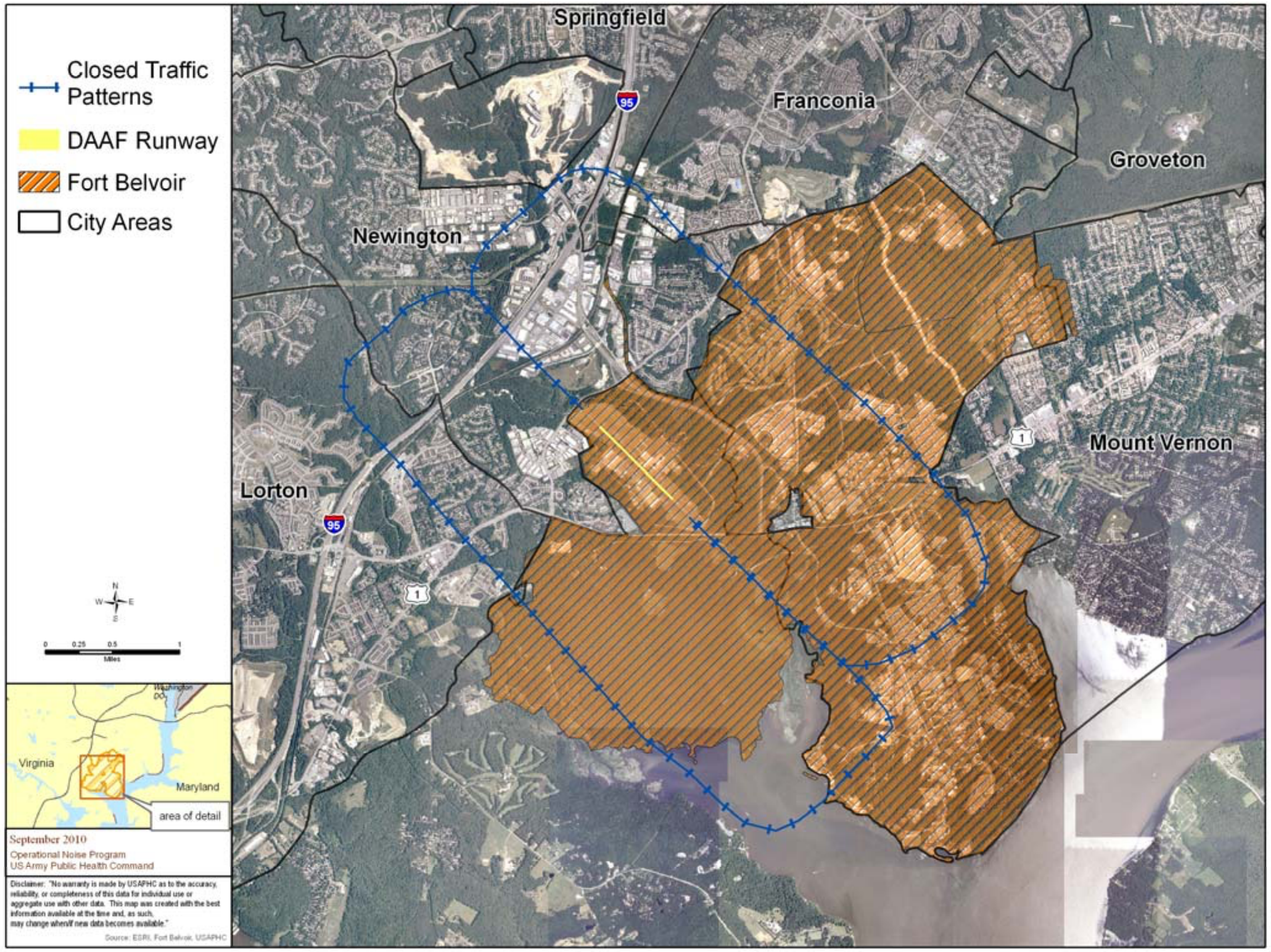

FIGURE 6. CLOSED TRAFFIC PATTERNS - DAVISON ARMY AIRFIELD

11. PROPOSED AVIATION CONSTRUCTION.

a. To comply with the airfield safety standards set forth in the Unified Facilities Criteria (UFC) Airfield and Heliport Planning and Design, DAAF is required to relocate structures that are within 500 feet of the runway.

b. Multiple structures do not meet UFC obstruction clearances (5 aircraft hangers, the DAAF Base Operation Complex, and 2 headquarters buildings). The relocation of these structures will result in rerouting the airfield road (Britten Drive) and construction and/or extension of apron, ramps, and taxiways.

c. The proposed relocation of the hangers, apron, and taxiways would not change the operational noise contours. The noise from the aircraft on the apron, taxiways, ramps are acoustically insignificant. The primary noise generating areas at DAAF are the runway and the run-up areas.

12. CONCLUSIONS.

a. The ADNL noise contours indicate that annual average noise levels from the aviation activity are compatible with the surrounding environment. Yet, there is potential for individual events to cause annoyance and possibly generate noise complaints.

b. There is a potential that aircraft utilizing the DAAF airspace may annoy those living near the flight tracks.

c. The proposed relocation of the hangers, apron, and taxiways would not change the operational noise contours.

13. RECOMMENDATIONS.

a. Since the DAAF receives few noise complaints annually, the recommendations at this time are limited to the following:

DAAF should continue to build its noise management program to:

- Prevent detrimental effects on the mission.
- Carry on the good-neighbor relationship with surrounding communities.
- Monitor both the noise environment and any proposed land use changes surrounding the installation.
- Continue implementing fly-neighborly programs that adjust aircraft training times and routes to lower the impact on the community to the greatest extent possible given mission requirements.

b. The DAAF should continue to reduce the potential for noise complaints through a responsive noise complaint procedure, and through taking actions that are appropriate to guide future development of those properties adjacent to its boundaries.

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APPENDIX A

REFERENCES

1. Rylander, et. al., 1974, "Re-Analysis of Aircraft Noise Annoyance Data Against the dBA Peak Concept", Journal of Sound and Vibration, Volume 36, pages 399 - 406.

2. Rylander and Bjorkman, 1988, "Maximum Noise Levels as Indicators of Biological Effects", Journal of Sound and Vibration, Volume 127, pages 555 - 563.

3. The U.S. Air Force, 2005a, NOISEMAP/BASEOPS, Wright-Patterson Air Force Base, OH.

4. The U.S. Air Force, 2005b, SELcalc2 Noise Model, Wright-Patterson Air Force Base, OH.

5. The U.S. Army, 2007, Army Regulation 200-1, Environmental Protection and Enhancement, Chapter 14 Operational Noise.

APPENDIX B

GLOSSARY OF TERMS, ACRONYMS & ABBREVIATIONS

B-1. GLOSSARY OF TERMS.

Above Ground Level–distance of the aircraft above the ground.

A-weighted Sound Level–the ear does not respond equally to sounds of all frequencies, but is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound pressure level of a noise containing a wide range of frequencies in a manner approximating the response of the ear, it is necessary to reduce, or weight, the effects of the low and high frequencies with respect to the medium frequencies. Thus, the low and high frequencies are de-emphasized with the A-weighting. The A-scale sound level is a quantity, in decibels, read from a standard sound-level meter with A-weighting circuitry. The A-scale weighting discriminates against the lower frequencies according to a relationship approximating the auditory sensitivity of the human ear. The A-scale sound level measures approximately the relative "noisiness" or "annoyance" of many common sounds.

Average Sound Level–the mean-squared sound exposure level of all events occurring in a stated time interval, plus ten times the common logarithm of the quotient formed by the number of events in the time interval, divided by the duration of the time interval in seconds.

Day-Night Average Sound Level (DNL)–the 24-hour average frequency-weighted sound level, in decibels, from midnight to midnight, obtained after addition of 10 decibels to sound levels in the night from midnight up to 7 a.m. and from 10 p.m. to midnight (0000 up to 0700 and 2200 up to 2400 hours).

Decibels (dB)–a logarithmic sound pressure unit of measure.

Ground Track Distance–the distance between the receiver and the point on the Earth at which the aircraft is directly overhead.

Noise–any sound without value.

Slant Distance–the line of sight distance between the receiver and the aircraft. The slant distance is the hypotenuse of the triangle represented by the altitude AGL of the aircraft and the distance between the receiver and the aircraft's ground track distance.

B-2. GLOSSARY OF ACRONYMS AND ABBREVIATIONS.

AGL	Above Ground Level
ADNL	A-weighted average Day Night Level
DAAF	Davison Army Airfield
dB	Decibels
dBA	Decibels, A-weighted
DNL	Day Night average Level
MAX	Maximum sound level

APPENDIX C

GUIDELINES FOR DISCUSSING NOISE CONTOUR MAPS

C.1 INTRODUCTION

Noise contour maps are the best way to show where noise is likely to go and at what intensity. Though much effort has been put into the creation of the computer programs that generate the noise contours, putting a highly variable concept onto a 2-dimensional piece of paper is a precarious science. Often, people viewing a noise contour map erroneously assume that the simplicity of the medium (i.e., the piece of paper) equates to the relative difficulty of the subject. The fact is, all of the intricacies of sound cannot be completely and accurately be portrayed in such a simplistic manner, but noise contour maps are the best way available and are quite effective if explained properly.

Note: If one is going to be charged with explaining noise contours (or any other potentially controversial subject) to the public on a regular basis, it is advised that the individual take a class in risk communication.

C.2 PREPARATION

Preparation is the primary ingredient needed to get any message across to an audience. Logically, one must first understand the message themselves before they can expect to credibly deliver it to anyone else.

It is not required that an individual be an expert on every aspect of the creation of the map. But, the concept of credibility (which will be a recurring theme in this Section) depends upon the presenter being knowledgeable and trustworthy. Proper preparations should include:

- Knowing inside and out the meaning of a particular set of contours (i.e., what the noise contours <u>do</u> say, and what they <u>do not</u> say).

- Familiarizing oneself with the basics of sound, how it travels, what effects that travel, and the relationship between sound and annoyance.

- Familiarizing oneself with the computer modeling and Geographic Information System (GIS) applications used to create the contours and maps.

- Learning about the concerns and/or biases of the audience.

Establishing credibility allows for the audience to trust your facts and helps bridge the gap in understanding that skepticism can create.

C.3 MEANING OF THE CONTOURS

A primary source of misunderstanding is how the contours are "interpreted." In reality, the contours are a stark picture of what is happening based on the parameters that have been input into the models, not an artist's rendition. Consequently, there is only one way to "read" the contours. Interpretation becomes a factor only when members of the audience are deciding if what the contours say is a good or a bad thing.

C.3.1 WHAT NOISE CONTOURS *CAN* TELL US

Noise contours are best at advising people of the approximate distribution of the noise coming from a particular source; in this case, military installations. Accordingly, if a person feels that there may be a chance that they are noise-sensitive, the contour map can give that individual an idea of where it might not be best for he/she to live.

Also, noise contours are excellent for making comparisons between the noises generated under one set of circumstances to those generated under another. This is especially useful when deciding such things as under what weather conditions it is best to train, whether a proposed location would work well for a new range, or to what degree troop deployments/reassignments will impact the surrounding areas.

C.3.2 WHAT NOISE CONTOURS *CANNOT* TELL US (WITH CERTAINTY)

Anyone explaining noise contours should first and foremost be aware that the noise levels do not stop at the line on the map. Most contours are averages of some sort and these averages are necessary because the infinite number of physical and meteorological variables at any given location would require an equally infinite number of maps to show them all. Thus, contours are representations of what someone is likely to experience under a given set of circumstances, and they cannot say that it is too loud for an assisted living center on one side of the road but not the other.

Also, it must be pointed out that contours change (sometimes often) due to weather, training schedules, deployments, technologies, etc. And, though what is shown on a map has a built in level of conservatism, it by no means suggests that things will never be louder or quieter at a given location.

Furthermore, contours cannot say whether or not the amount of noise shown to be in a particular area is going to be bothersome; this is up to individuals to decide and is a product of many variables. For instance, a relatively modest sound level at a house that is located next to a busy street is likely to be accepted quite differently than the same sound level at a house located on a canyon ridge all by itself.

Noise contours deal only with noise generalities and cannot reliably give information beyond noise (e.g., predict that houses "here" are worth more or less than houses over "there").

C.4 THE BASICS OF SOUND AND ANNOYANCE

Explaining the limits of the noise contours inevitably generates questions regarding why it is so difficult to pin down exactly where noise is going to travel and at what levels. The answer is that the propagation of sound and human perceptions of sound are dependent on so many variables that it impossible to cement exactly what will irritate a particular person.

The physical propagation of sound is affected by weather, terrain, distance, barriers, and the nature of the sound itself (i.e., different frequencies have different travel characteristics). In fact, weather has a profound effect on the degree to which a sound "lands" at a particular location, and that is of course a variable that can literally change from hour-to-hour. Appendix D gives a more in-depth description of the science of sound.

Human perception is even more challenging to account for on a single map. From county to county, ZIP code to ZIP code, and house to house, people's ideas of when a sound becomes noise can differ markedly. These differences in perception can attributed to such varied sources as:

- The physical state of the individual's hearing ability (i.e., is the individual's hearing health good or bad?)
- Past experiences (i.e., could the individual have experienced trauma in the past that makes them particularly sensitive to loud or sharp sounds?)
- Attitude toward the noise source (i.e., does the receiver dislike the military?)
- General temperament (i.e., is the individual "jumpy?")

By understanding the relationship between the physical behavior of sound and some of the human variables that can turn a sound into a noise, we can paint a clearer picture to an audience about how they can each use the noise contours to make the decisions that best suit their individual situations.

C.5 COMPUTER MODELS AND GIS

It is also difficult to explain with any validity what the noise contours mean if one knows nothing about the process that created them.

The specific process of creating noise contours varies by what is creating the noise and, accordingly, which model is used to make the picture. But, the general idea is that pertinent information (such as the item making the noise, its location, the direction of fire/travel, weather conditions, etc.) is entered into the appropriate computer model, the model outputs a picture based on the noise metric specified, and then that picture is imported into a GIS program so that a map can be created.

However, while the computer models used by the military are some of the best available, they do have important limitations. First, no matter how sophisticated, no model can take into account every terrain variable at a given location unless models were specifically developed for every installation (which would cost an enormous amount, if it were even possible). Second, the databases of noise producers in the models are representative of the military's equipment, but may not contain individual specifications for every variety of a particular piece of equipment.

So, taken together, these two limitations further prevent the resolution of the noise contours from reaching the "street level," and they advance the idea that noise sensitive persons must take into consideration all available information before making a choice that may conflict with an existing noise environment (such as buying a home next to a highway or military installation).

In summary, taking the time to explain how the models work will draw an audience's expectations more toward what the computer models can actually provide.

C.6 AUDIENCE

While it has been mentioned previously that the information on a noise contour map is absolute and not necessarily up to interpretation, the type of audience to whom one is presenting noise contour information has an enormous impact on exactly how that information should be presented. For example, the social atmosphere created by a group of installation commanders is likely to be far different than the atmosphere in a meeting of developers and county planners.

So, most audiences are going to be biased in one way or another. But, when the interests of a particular group are at odds with the interests of the military, a hostile atmosphere could be the product. Here, it must be remembered that these things are rarely personal—most of the time the individuals do not dislike the presenter or the government, they are simply concerned about their business or livelihoods.

In all cases, the best practice is to keep a professional appearance and demeanor, and stick to the facts. The presenter should answer only the questions she/he knows, and jot down the questions she/he does not know with the promise that the participant will be contacted with the answer in a timely manner. Additionally, while it is best to keep the atmosphere light, it is important that an audience is comfortable that their concerns are being taken seriously.

C.7 CONCLUSION

By and large, people are either apathetic or fearful of things they do not understand, neither of which is good when it comes to issues involving noise.

On the one hand, the military does not want citizens or installation personnel not caring about issues of noise, because this eliminates the interest that is required to solve problems proactively. On the other hand, fearful individuals tend to overreact and further complicate a situation. The ideal state is one where an informed and concerned military does everything it can to mitigate noise impacts while still performing its Constitutionally-charged mission, and an informed and concerned public makes land use decisions that are compatible with that noise environment.

To that end, the way in which noise contours are presented (and to whom) can go a long way toward a state where installations and the public work together to each other's mutual benefit.

Remember: in risk communication, one has successfully conveyed the seriousness of a situation when they have raised the alarm of the Unconcerned, and calmed the Overly-concerned to the rational level of awareness that the particular situation deserves.

APPENDIX D

DESCRIPTION OF NOISE, NOISE EVALUATION, AND CONTOURING

D.1 INTRODUCTION

Military noise comes from a variety of sources and is a concern for a number of reasons. Of course big guns make big sounds, but the noise made by everything from generators to trucks to machine shop tools must be considered as well. For the military, issues involving noise can be broken down into two components: hearing conservation as it pertains to the physical damage to the ear caused by sound, and operational noise as it relates to complaints and encroachment.

The first involves the exposure to noise by individuals who are performing their duties. Since loud sounds are known to cause immediate and/or cumulative hearing damage, the military must be constantly monitoring the noise exposure of its employees and soldiers, both in day-to-day and combat situations.

The second (and the focus of this piece) centers upon the problems caused when military sounds irritate the public—whether through poor decisions by installation personnel, or through or increasing encroachment around a once-remote installation.

In order to understand how military sounds become a problem, it is important to understand the science of sound, and what happens when a sound becomes a noise.

D.2 WHAT IS NOISE?

Noise is simply unwanted sound. So, in the context of hard science, there is no difference between the two. However, whether something is a "sound" or a "noise" has a great influence over the military's everyday planning and policy decisions as it tries to fulfill its Constitutionally-charged duty to protect the citizens if the United States of America.

In short, sound isn't noise until someone says it is; and when it is, it needs attention.

D.3 THE FUNDAMENTALS OF SOUND AND ACOUSTICS

Sound is a physical phenomenon created by minute variations about a mean pressure (or *vibrations*) that travel through a medium such as air or water. This variation in pressure takes the form of waves and, under ideal conditions, these waves travel evenly away from the source much like the ripples created when a pebble is dropped into calm water.

However, life on earth is rarely so perfect and the travel of these waves is always being influenced by variables such as temperature, terrain, and barriers. Add to those physical influences the fact that our human experience of audible sounds depends on the pattern of vibrations form the source, the way our hearing mechanism interprets these vibrations, and how our personalities affect how we feel about those vibrations, and one can begin to grasp the complexity of issues involving sound and noise.

The field of science that deals with all of these variables as well as the production, control, reception, effects, and propagation is called *acoustics*.

D.3.1 THE CHARACTERISTICS OF SOUND

As an object moves back and forth in the atmosphere, it collides with the surrounding air particles creating a pressure disturbance. As those air particles collide with adjacent air particles, the pressure disturbance begins to spread away from the source of vibration. At the ear, this disturbance generates a vibration in the eardrum that is transmitted via a network of bones to the cochlea, which then converts the vibration into an electrical signal that the brain can interpret.

A sound is measured by gauging the alternate *compression* ("bunching") and *rarefaction* ("spreading") of the acoustic pressure disturbance above and below the normal atmospheric pressure, and is quantified in units called *Pascals* (Pa). Normal atmospheric pressure at sea level is 100,000 Pa, and sound waves generally travel at approximately 1,100 feet (335 meters) per second through air. For reference, the variation about this atmospheric pressure can be a little as 0.0006 Pa (or 60μPa) for a whisper at 2 meters, to 1,000 Pa for an M16 rifle shot at the firer's ear.

As with all waves, the energy and effects of a sound are dependent upon the sound wave's *frequency* and *wavelength*. Frequency is the number of compressions of rarefactions per unit of time. Wavelength is the distance between successive compressions or successive rarefactions (see Figure D-1).

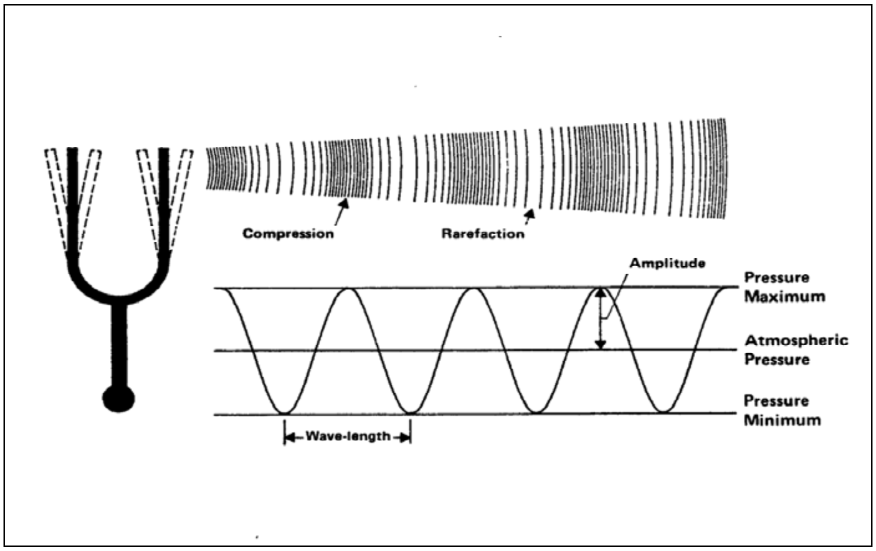

Figure D-1 Acoustics of a Pure Tone

Of course, sounds can bring us important information and/or pleasure. But, whether or not that is the case is dependent on two things: the content of the sound and the predisposition of the receiver to the sound.

When a sound brings neither pleasure nor information, it is safe to call it a noise.

D.3.1.1 SOUND CONTENT AND HUMAN HEARING

The content of a sound is determined by three defining characteristics:

(1) its spectral or frequency content;
(2) its loudness or intensity; and
(3) its time pattern

But, the importance of each of these is also dependent upon the innate response of a human ear that's primary function was to keep people alive, not critique M-16 fire.

D.3.1.1.1 SPECTRUM AND FREQUENCY

Sound frequency is measured in terms of cycles-per-second or Hertz (Hz). The normal human ear can detect sounds ranging from about 20 Hz to 20,000 Hz (for reference, the average dog's hearing range is approximately 20-45,000 Hz). However, not all sounds in this wide range are heard equally well; the human ear is most sensitive to frequencies in the 1,000 to 4,000 Hz range.

As mentioned earlier, a vibrating object produces a sound wave with a characteristic frequency (a *tone*). But, there are no pure tones in the natural soundscape. Instead, any given sound found in nature is actually comprised of a complex combination of individual frequency components produced by the many different vibrational and oscillatory modes of the sound source. The total of all of these individual frequency components is known as a sound's *spectrum*, and knowledge of a sound's spectrum is a key in any attempt to mitigate the sound.

D.3.1.1.2 LOUDNESS AND DECIBELS

The concept of *volume* (i.e., relative loudness or quite) is fundamentally about the level of sound pressure hitting the eardrum. Historically (and for obvious reasons), the first scientists to seriously study the ear's response to sound pressure were telephone engineers. These scientists soon discovered that the human ear responds to a very broad range of pressures and subsequently invented a logarithmic scale using the *decibel* (dB) as its unit of measurement.

The scale is zeroed at the beginning of human hearing (20μPa) and, since the scale is logarithmic, each one dB increase is a 10x increase in pressure (see Figure D-2).

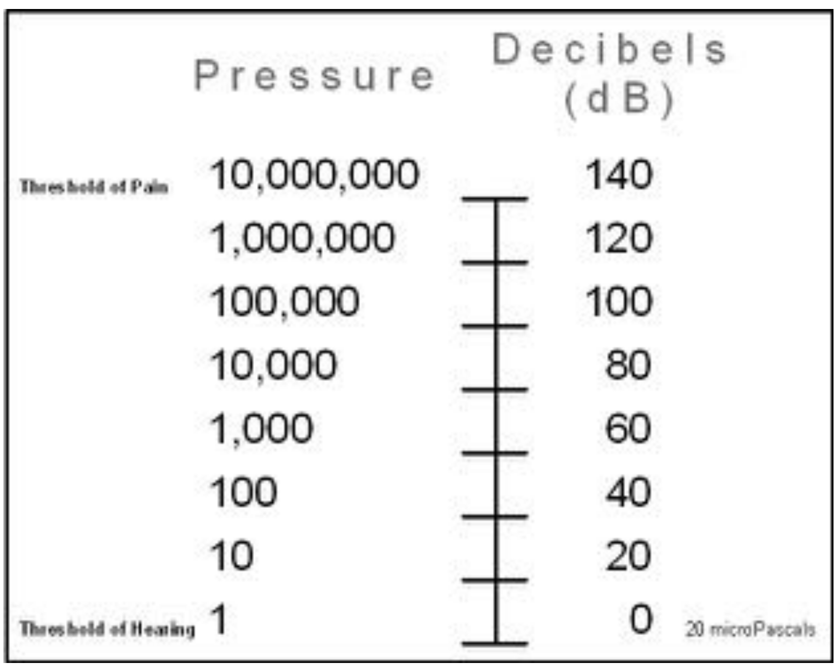

Figure D-2 Relationship between Sound Pressure and Decibels

For humans, the upper tolerable limit of loudness before hearing damage occurs depends on the frequency and duration of the sound. For example, a 20 millisecond rifle shot at a 140 dB level can damage the hearing in some unprotected ears. But a howitzer shot at 140 dB, with its lower frequency (i.e., it's not as "sharp" as the rifle shot), is far less likely to cause hearing damage. Alternately, a passing sound at 120 dB is enough to cause only discomfort, while several minutes of such exposure can cause damage. And, moving further down the scale, one could tolerate as much as 8 hours of 85 dB before damage becomes a possibility.

Though laboratory studies have demonstrated a greater acuity, for practical purposes it takes a plus-or-minus three dB change in pressure (roughly a doubling or halving of energy) for a person to notice a difference across most audible frequencies.

But, because of the logarithmic nature of the decibel, dBs do not add directly. To get an exact answer, the root pressures of the sounds to be added must be combined and then converted to decibels using the following formula:

Pressure (dB) = 10 log (<u>Measured Pressure/20 microPascals)</u>

Table D-1 shows the short cuts to dB addition, but these are only to be used for quick approximations.

When Two Levels Differ By:	Add the Following to the Higher Value:
0 to 1 dB	3
2 to 3 dB	2
4 to 9 dB	1
10 or more dB	0

Table D-1 Shortcuts to Decibel Addition

D.3.1.1.3 VIBRATION

Often hand-in-hand with the discussion of loudness comes the phenomena of *vibration*. Vibration in the context of military training is caused by the impact of lower frequency sound waves on unsecured objects. In fact, there are situations where vibration can be the primary irritant to the public, because the sound making the vibration is too low for the human ear to hear. Thus, a citizen may have little idea that training operations are occurring at all until a picture falls off of the wall.

Vibration issues can largely be abated by appropriate construction techniques (e.g., heavy outer walls, suitable duct design, sealing of cracks, etc.) and prescient site planning. Additionally, while many citizens are fearful that vibration may damage their homes, the threshold for damage to even a poorly constructed house is far greater than the tolerance of the occupants is likely to be.

A list of "dos" and "don'ts" is published in an Army Construction Engineering Research Laboratory (CERL) report, Expedient Methods for Rattle-Proofing Certain Housing Components, and that report (or additional information on vibration in general) can be obtained from CERL or USAPHC.

D.3.1.1.4 TIME PATTERNS

Time patterns are extremely important to the discussion of sound because it is so important in predicting annoyance.

Sound can be classified into four basic categories that define its basic time pattern:

(1) *Ambient.* Ambient sound is the ever-present collection of background sounds at any given place. Ambient sound can be strictly natural such as frogs and cicadas in the deep woods, strictly mechanical such as street noise in a busy city, or a combination of both like that which is found in the suburbs. It is important to consider the existing ambient soundscape because what exists already has much to do with how annoying people will find a new sound. For example, the hum of a generator will be much better tolerated by those already living in an area of high mechanized ambient noise than those living in the far woods.

(2) *Steady-state*. Steady-state sound is a sound of consistent level and spectral content such as that which originates from ventilation or mechanical systems that operate more or less continuously. From a military perspective, generators and aircraft run-up sounds are the most prominent steady-state sounds and, as a rule, the longer a steady-state sound persists, the more annoyed people will be.

(3) *Transient Sound*. Transient sound has a clearly defined beginning and end, rising above the background and then fading back into it. Transient sounds are typically associated with "moving" sound sources such an aircraft overflight or a single vehicle driving by, and they usually last for only a few minutes at the most. The annoyance caused by transient sounds is dependent upon both the maximum level and the duration.

(4) *Impulsive Sound.* Impulsive sound is of short duration (typically less than one second) high intensity, abrupt onset, rapid decay, and often a fast-changing spectral composition. It is characteristically associated with such sources as explosions, impacts, the discharge of firearms, the passage of supersonic aircraft (sonic booms), and many industrial processes. Impulsive sound can be particularly annoying because of the "startle factor" where the receiver has no warning that exposure to a loud sound is imminent.

The temporal aspect of a sound is important when it comes to predicting annoyance. Even a sound that is barely audible can be extremely irritating if it is continuous and is occurring at an inconvenient time (such as bedtime).

D.4 NOISE EVALUATION AND METRICS

There is little disagreement about the fact that noise must be regulated to some degree in order to maintain the quality of life for the public at large. However, noise is one of those things where everyone seems to know it when they hear it, but it has been historically difficult to define in words or numbers. This has been particularly irksome to lawmakers, because any laws regulating noise must be clearly understood to both producers and receivers in order to be effective. Consequently, over the past 30 years a wide variety of acoustic measures and rating scales have been developed for the purpose of quantifying the sound generated by particular sources.

To date there is no perfect way to quantify noise for every circumstance and condition, but there are ways to assign meaningful numbers to sounds so that they can be compared from situation to situation.

D.4.1 WEIGHTING

As stated above, due to the natural response of the human ear, the perception of loudness is not consistent across frequencies. For instance, at any sound pressure less than 90 dB, a 1000 Hz tone would sound louder than a 100 Hz tone. While this is a bit of an oversimplification, essentially, as the frequency drops, it takes more pressure (volume) to maintain the same sense of "loudness."

Accordingly, weighting scales have been developed so that the intensity of a sound (or noise) can be equalized and brought in line with the actual human perception. The weighting scales that concern operational noise are the A-scale (A-weighting) and the C-scale (C-weighting), both specified by an American National Standards Institute standard (ANSI, 1983). Figure D-3 shows the relationship between the two scales.

A-weighting

The *A-weighting* of decibels (dBA) was designed to work primarily with higher frequency sounds. In military noise, this would encompass such sounds as those from generators, aircraft, maneuver drills, and general transportation.

C-weighting

The *C-weighting* of decibels (dBC) is used for intense signals containing low frequency sound energy like those that emanate from large gun blasts, sonic booms, and detonations.

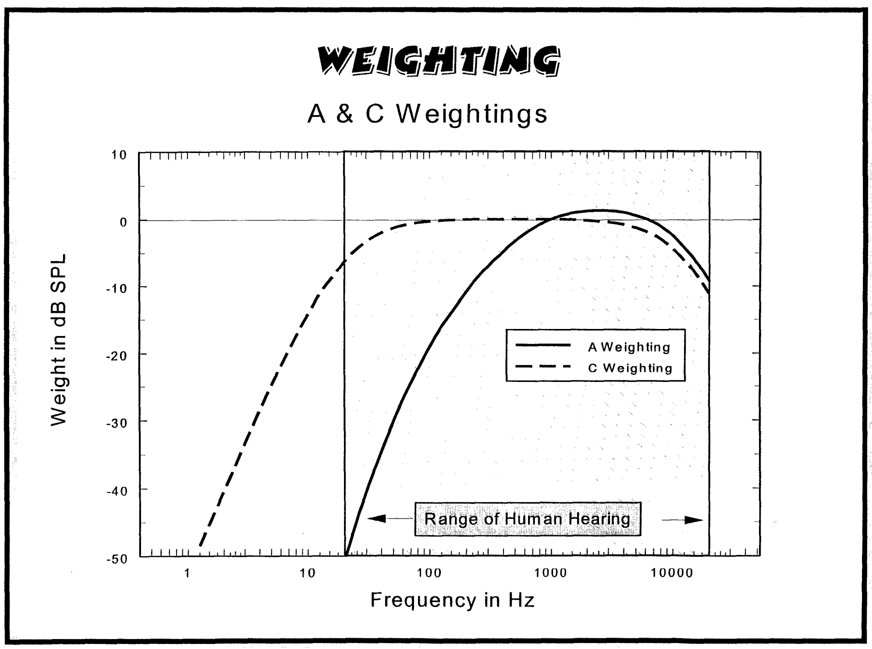

Figure D-3 A- and C- Weighting Scales

D.4.2 NOISE METRICS

The weighting scales are only one part of noise evaluation. In order to get a proper idea of the overall effect of noise, one must combine the weighting scales with the effects of a sound's time pattern to get a meaningful, all-encompassing cumulative noise measurement that can be used to compare noise exposure across a variety of situations.

Here, too, there are several choices of metrics depending on the noise environment to be measured and exactly for what the data is to be used. Many countries have their own standard metrics, but the U.S. military is concerned primarily with the following:

- Equivalent Sound Level (L_{eq})
- Day-Night Level (DNL)
- Sound Exposure Level (SEL)
- PK15(met)
- Unweighted Peak

D.4.2.1 EQUIVALENT SOUND LEVEL (L_{eq})

Since annoyance increases with the number of times an intrusive sound is experienced during a given period of time, the L_{eq} is a way of capturing the annoyance of a number of intrusions by "averaging" acoustical energy over a prescribed time period. The time period can be any length, but it is usually taken in some meaningful block of time such as an 8-hour L_{eq} for an office or a 24-hour L_{eq} for a residence. Figure D-4 illustrates how the daily variation of traffic noise can be summarized in terms of a single 24-hour L_{eq} value.

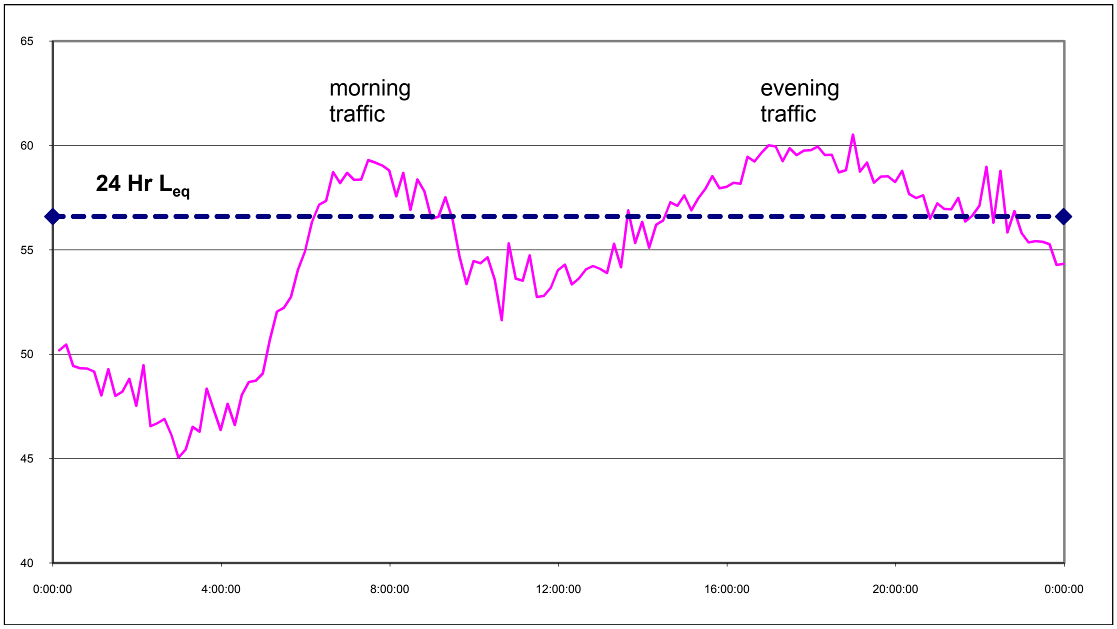

Figure D-4 Equivalent Noise Level (L_{eq})

D.4.2.2 DAY-NIGHT LEVEL (DNL)

The DNL is an average like the L_{eq} but with a 10dB "penalty" inflicted on sounds occurring between the hours of 10:00 p.m. and 7:00 a.m. (a particularly intrusive time when people are usually sleeping). As discussed above, the DNL may be A-weighted (ADNL) or C-weighted (CDNL) depending on the noise being measured. This average is calculated over any specified amount of time, but usually it is 250 training days for active military and 104 days for National Guard sites.

Also, within the DNL, there is a further penalty known as the *onset rate penalty*. For people living along aircraft flight routes, it was found that the DNL was underestimating their annoyance. So, this penalty (known as the L_{DNmr}) is used by the U.S. Air Force to take into account the sudden onset and sporadic nature of these sounds.

D.4.2.3 SOUND EXPOSURE LEVEL (SEL)

Since, prolonged, low-intensity events can be just as annoying as short, high-intensity events, the SEL is a way of capturing the annoyance of both variables in terms of a single number. It is the total energy of a sound event normalized to a specific amount of time (e.g., one second) so that sounds of different durations may be compared directly. Put another way, the SEL represents all the acoustic energy of an event as if it occurred within a one second period.

D.4.2.4 PK15(met)

PK15(met) is the peak sound level, factoring in the statistical variations caused by weather, that is likely to be exceeded only 15% of the time (i.e., 85% certainty that sound will be within this range). This metric exists only in modeling—one cannot take a PK15(met) measurement on the ground—and it is used for land use planning with small arms and as additional information for large arms and other impulsive sounds. It has gained popularity for military applications in recent years because it is a metric that works very well at showing just how loud things are likely to get at a particular location. Unfortunately, PK15(met) does not take duration or incidence into consideration, so it cannot tell how often things will be that loud.

D.4.2.5 UNWEIGHTED PEAK

One of the simplest ways to measure sound is through the use of unweighted peak (dBP). This is the peak, single event sound level on the ground, without any particular certainty—such as with the 85% certainty built into the PK15(met) above. This is a real-time measurement that is affected by everything from the weather to the length of the grass. As such, it is highly variable.

D.4.3 A BRIEF HISTORY OF NOISE EVALUATION IN THE U.S. GOVERNMENT

Before the 1970's, every organization had its own preferred set of noise evaluators (or metrics). Since each noise evaluator was developed for a specific purpose, data from one noise evaluator could not be reliably compared to that of another.

However, the field moved toward standardization when, in carrying out its responsibilities under the Noise Control Act of 1972 (PL 92-574 1972), the U.S. Environmental Protection Agency (EPA) recommended the adoption of the LEQ (and its 24-hour cousin, the DNL).

In recommending the DNL, the EPA noted that most noise environments are characterized by repetitive behavior from day-to-day, with some variation imposed by differences between weekday and weekend activity, and seasonal fluctuations. Consequently, the DNL's annual average accounts for this variation and complements the fact that annoyance is generally caused by long-term dissatisfaction with the noise environment. It must be kept in mind, though, that the DNL is not an effective predictor of complaints, because complaints tend to represent an individual's immediate dissatisfaction with the noise environment, not a general annoyance.

So, the acceptance of the DNL helped to predict annoyance (and general disruption patterns), but it could not fully address the issue of complaint prediction. Consistent prediction of complaints, it has been found, is much more achievable when dealing with peak noise levels rather than averages. As a result, in 2004, the U.S. Army Construction Engineering Research Laboratory and (USACERL) and USAPHC together helped to usher in the PK15(met) evaluator as a means to predict complaint potential and supplement the information given by the DNL figures.

D.5 NOISE CONTOURING

The various metrics described above produce numbers that can be compared to one another. But, it is difficult to make a number meaningful to someone interested in where the noise is going. To that end, the idea of noise contouring on maps was born.

Contours on a map are made by connecting points of equal values. Most commonly, points of equal elevation are connected to form the contour lines most typically found on topographical maps. But, points of many other themes can be detected to give a visual representation of the extent or degree of something. So, for noise, computer programs have been developed that model the genesis and propagation of sound from particular sources, and then connect points of equal decibel value to show areas where a particular sound intensity can be expected.

Unlike topographic contours, noise contours are not intended to be precise delineation of the noise zones. Meteorology and the receiver's perception of the source, etc. can influence the level or impact of noise. Noise contours do not clearly divide noise zones with one side of the line compatible and the other side incompatible.

For instance, Figure D-5 is an example of a map showing peak noise contours. The operator of the computer model may plot whatever values she/he wishes to show, but this example shows the 130 dBP line (red) and the 115 dBP line (blue). While the lines will never be absolutely exact (due to the nature of sound, they can fluctuate quite a bit as conditions change), what this map in effect says is that all of the area inside of the blue line will start at 115 dB and grow louder as it gets closer to the red 130 dB line. And similarly, once at the red 130 dB line, the sound level will grow louder still all the way to the source.

This is eminently useful because it shows both the installations and the public not only where the sound/noise is going, but at what levels. With that, installations, local governments, and individuals can use these maps to make informed choices based on their temperaments, tolerances, and philosophies concerning noise.

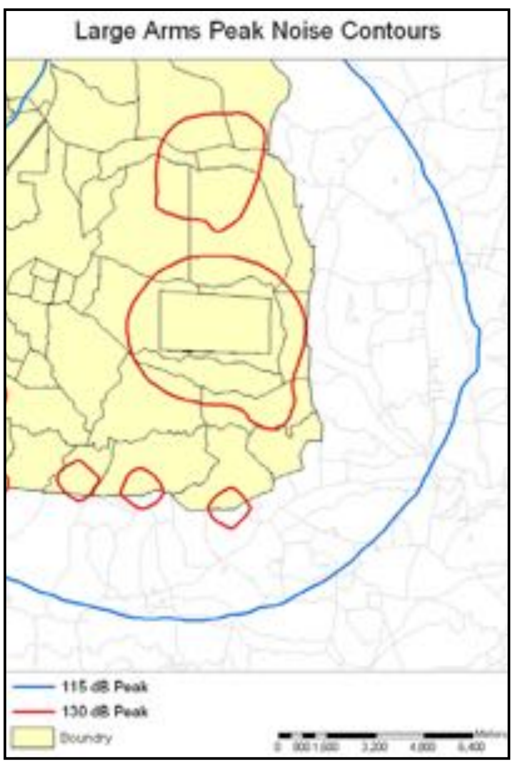

Figure D-5 Example of a Map Showing Peak Noise Contours

D.5.1 COMPUTER PROGRAMS

The relatively simple looking output of a map showing noise contour lines is actually the result of some comparatively complicated computer programs. In fact, most of these programs are in perpetual states of evolution as new data become available and advances in computing power allow for more variables to be factored into creating the final contour.

Table D-2 lists the most popular noise mapping programs and some of their preferred usage characteristics.

Model	Timeframe	Characteristic	Source	Use
NOISEMAP	Long-term	Transient	Fixed-wing aircraft	Airbase noise exposure, AICUZ
Rotorcraft Noise Model	Long-term & single events	Transient	Helicopters and tiltrotors	Airbase noise exposure, AICUZ, range noise
ROUTEMAP	Long-term	Transient	Fixed-wing	MTRs
MR_NMAP	Long-term & single missions	Transient	Fixed-wing	MOA, MTR, Special uses ranges
BNOISE2	Long-term & single events	Impulse	OD & large guns	Ranges and OD pits
SARNAM	Long-term & single events	Impulse/transient	Small arms	Firing range
MENU11	Single event	Transients	Fixed wing	Ground run up noise levels
NMSIM	Single event	Transients	Fixed wing	Subsonic aircraft operations
PCBOOM3	Single event	Impulse	Fixed wing	Sonic boom analysis
TNM	Long-term	Transient	Road traffic	Highway and road noise exposure
RWNM	Long-term	Transient	Trains and guided rail vehicles	Rail operations, yard and tracks

Table D-2 Noise Models and Their Uses

Operational Noise Consultation No. 52-EN-0DRM -11, 7 Sep 10

Regarding the contours featured in Operational Noise Plans created by USAPHC:

Small arms noise contours are generated by the Small Arms Range Noise Assessment Model (SARNAM). This model incorporates the latest available information on weapons noise source models (including directivity and spectrum), sound propagation, effects of noise mitigation and safety structures (walls, berms, ricochet barriers, etc.), and community response protocols for small arms noise. It also includes an extensive selection of weapons in the source library, can handle multiple ranges of various types, and is designed to maximize user productivity.

Blast noise (i.e., explosions and large arms) contours are generated by the BNOISE2 program. It accounts for spectrum and directivity of both muzzle blast and projectile sonic boom while also considering issues of propagation including land/water boundaries and terrain.

Aircraft noise contours are generated by NOISEMAP with inputs of aircraft type, altitude, power setting, speed, and number of operations.

All of the computer models work in generally the same fashion. The weapon type and number of rounds fired is combined with various geographic and atmospheric data (location, direction of fire, weather, etc.). The user then defines which contours he/she wishes to see, the program calculates how far the sound will travel under those conditions, and the resulting contours are then overlaid onto a conventional map of the area.

In spite of the research invested and the intricacies of the programs, it must be said that the outputs of the modeling programs are not always exactly what may be found "on the ground" at any given moment. The problem lies not with the calculations or algorithms, but with the number of variables that practical and computing considerations limit the user to inputting. Put another way, there are far too many variables on the ground (even down to how long the grass is) to ever truly simulate the natural world.

So, when done properly, the contours produced can be relied upon to paint a clear picture of the general noise environment of an area, and show information that is of the integrity needed to make prudent planning and zoning decisions.

Additional information on noise models or contouring procedures can be obtained from the USAPHC's Operational Noise Group.

D.5.2 WHAT EFFECTS CONTOUR SHAPES?

In an ideal world (for acousticians, anyway), all noise contours would be perfect circles because the noise would travel from the source at the same speed and intensity in every direction. But, the geology, geography, climatology, and physics of our planet create an environment where external forces are acting on sound waves the second they are created. Those waves may be directed by the nature of the source, reflected by a wall, refracted by some mountains, attenuated by winds, intensified by atmospheric conditions, or absorbed entirely by a thick coniferous forest.

All of these situations then ply that theoretically perfect circle, stretching it in some places (e.g., pushing through a mountain gap), and smashing it in others (such as in the direction against a heavy breeze).

D.6 CONCLUSION

The science of measuring and modeling unwanted sounds is constantly evolving, just like the relationships between military installations and the communities that surround them. As defense spending continues to drive innovation and support a large sector of our nation's economy, the weapons are getting more powerful and louder, and population pressures are increasing around once-remote installations.

But, while evolving relationships always pose new challenges, they also always pose new opportunities. Understanding the way sound behaves and utilizing the noise monitoring and modeling tools available are critical to making proper land use decisions in and around installations, so that the installations and the surrounding communities continue to thrive in each other's presence.

APPENDIX E

REGULATORY REQUIREMENTS

ARMY REGULATION 200-1 NOISE SECTION (2007)

Chapter 14
Operational Noise

14–1. Policy

a. Evaluate and document the impact of noise produced by ongoing and proposed Army actions/activities and minimize annoyance to humans to the extent practicable.

b. Develop installation noise management plans as appropriate.

c. Reduce noise to acceptable levels in on-post noise sensitive locations (for example, medical treatment, education, family housing) through appropriate land use planning and/or architectural and engineering controls.

d. Monitor, record, archive and address operational noise complaints.

e. Develop and procure weapons systems and other military combat equipment (for example, electrical generators, etc.) that produce less noise, when consistent with operational requirements. Measure the noise emitted by all combat equipment and weapons systems to be used in training before deployed to units.

f. Procure commercially manufactured products, or those adapted for general military use that produce less noise, and comply with regulatory noise emissions standards.

g. Acquire property only as a last resort to resolve off-post noise issues.

h. Manage operational noise issues and community relations to maintain sustainable testing and training capabilities and prevent encroachment.

14–2. Legal and other requirements

Property and tort law; Noise Control Act of 1972; Quiet Communities Act of 1978; AR 95–1; AR 210–20; AR 350–19; and applicable State and local laws.

14–3. Major program goals

a. Control operational noise to protect the health and welfare of people, on- and off- post, impacted by all Army-produced noise, including on- and off-post noise sources.

b. Reduce community annoyance from operational noise to the extent feasible, consistent with Army training and materiel testing mission requirements.

c. Actively engage local communities in land use planning in areas subject to high levels of operational noise and a high potential for noise complaints.

14–4. Program requirements

a. Noise descriptors (metrics) appropriate for determination of compatible land use, and assessment procedures will be based on the best available scientific information.

(1) The day-night level (DNL) is the primary descriptor for military noise, except small arms, see table 14–1. The DNL is the time weighted energy average sound level with a 10-decibel (dB) penalty added to the nighttime levels (2200 to 0700 hours). The DNL noise metric may be further defined, as appropriate, by the installation with a specific, designated time period (for example, annual average DNL, average busy month DNL). The typical assessment period over which the noise energy is averaged is 250 days for Active Army installations and 104 days for Army Reserve and National Guard installations. The use of average busy month DNL is appropriate when the OPTEMPO is significantly different during certain peak periods of the year. For future land use planning and encroachment assessment purposes, a reasonable annual growth factor in activity (for example, 10 or 15 percent) may be assumed.

(2) Supplemental metrics, such as single event noise data (for example, Peak, PK 15(met) or CSEL), may be employed where appropriate to provide additional information on the effects of noise from test and training ranges. A-weighted maximum noise levels will be used to assess aviation low level military training routes (MTRs) and/or flight tracks.

(3) The use of average noise levels over a protracted time period generally does not adequately assess the probability of community noise complaints. Assess the risk of noise complaints from large caliber impulsive noise

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resulting from testing and training activities, ex. armor, artillery, mortars and demolition activities, in terms of a single event metric, either peak sound pressure level (PK 15(met)) or C-weighted sound exposure level (CSEL). The metric PK 15(met) accounts for statistical variation in received single event peak noise level that is due to weather. It is the calculated peak noise level, without frequency weighting, expected to be exceeded by 15 percent of all events that might occur. If there are multiple weapon types fired from one location, or multiple firing locations, the single event level used should be the loudest level that occurs at each receiver location.

(4) Assess noise from small arms ranges using a single event metric, either PK 15(met) or A-weighted sound exposure level (ASEL).

(5) Use the land use planning zone (LUPZ) contour to better predict noise impacts when levels of operations at airfields or large caliber weapons ranges are above average.

(6) Use available DOD noise assessment software as the primary means of operational noise assessment.

(7) Prepare noise maps showing noise zones and limits as defined in tables 14–1 and 14–2.

(8) Manage noise-sensitive land uses, such as housing, schools, and medical facilities as being acceptable within the LUPZ and noise zone I, normally not recommended in noise zone II, and not recommended in noise zone III. These noise zones are defined in table 14–1.

(9) Single event noise limits in table 14–2 correspond to areas of low to high risk of noise complaints from large caliber weapons and weapons systems. These should be used to supplement the noise zones defined in table 14–1 for land use decisions. Noise sensitive land uses are discouraged in areas where PK 15(met) is between 115 and 130 dB; medium risk of complaints. Noise sensitive land uses are strongly discouraged in areas equal to or greater than PK 15(met) = 130 dB; high risk of noise complaints. For infrequent noise events, installations should determine if land use compatibility within these areas is necessary for mission protection. In the case of infrequent noise events, such as the detonation of explosives, the installation should communicate with the public.

(10) Transportation and industrial noise will be assessed on a case by case basis using appropriate noise metrics, including U.S. Department of Transportation guidelines.

b. Address issues concerning building vibration and rattle due to weapons blast through the appropriate subject matter experts and legal counsel.

c. Address noise impacts on domestic animals and wildlife, as required, through the study of each species' response or a surrogate response to noise. The noise levels set forth herein apply to humans only and do not apply to domestic animals or wildlife.

Table 14–1
Noise Limits for Noise Zones

Noise zone	Noise limits (dB)	Noise limits (dB)	Noise limits (dB)
	Aviation ADNL	Impulsive CDNL	Small arms — PK 15(met)
LUPZ	60 - 65	57 - 62	N/A
I	< 65	< 62	<87
II	65 - 75	62 - 70	87 - 104
III	>75	>70	>104

Legend for Table 14-1:
dB=decibel
LUPZ=land use planning zone
ADNL=A-weighted day-night levels
CDNL=C-weighted day-night levels
PK 15(met)=Single event peak level exceeded by 15 percent of events
<=less than
>=greater than
N/A=Not Applicable

Table 14–2
Risk of Noise Complaints by Level of Noise

Risk of Noise complaints	Large caliber weapons noise limits (dB) PK 15(met)
Low	< 115
Medium	115 - 130
High	130 - 140
Risk of physiological damage to unprotected human ears and structural damage claims	> 140

Legend for Table 14-2:
dB = decibel
PK 15(met) = Single event peak level exceeded by 15 percent of events

Notes:

[1] Although local conditions regarding the need for housing may require noise-sensitive land uses in Noise Zone II, on or off post, this type of land use is strongly discouraged. The absence of viable alternative development options should be determined and an evaluation should be conducted locally prior to local approvals indicating that a demonstrated community need for the noise-sensitive land use would not be met if development were prohibited in Noise Zone II.

[2] Where the community determines that these uses must be allowed, measures to achieve an outdoor to indoor noise level reduction (NLR) of at least 25 dB to 30 dB in Noise Zone II, from small arms and aviation noise, should be incorporated into building codes and be in individual approvals. The NLR for communities subject to large caliber weapons and weapons system noise is lacking scientific studies to accomplish the recommended NLR. For this reason it is strongly discouraged that noise-sensitive land uses be allowed in Noise Zone II from large caliber weapons.

[3] Normal permanent construction can be expected to provide a NLR of 20 dB, for aircraft and small arms, thus the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation, upgraded Sound Transmission Class (STC) ratings in windows and doors and closed windows year round. Additional consideration should be given to modifying NLR levels based on peak noise levels or vibrations.

[4] NLR criteria will not eliminate outdoor noise problems. However, building location and site planning, and design and use of berms and barriers, can help mitigate outdoor noise exposure NLR particularly from ground level aircraft sources. Barriers are generally not effective in noise reduction for large arms such as artillery and armor, large explosions, or from high-level aircraft sources.

DEPARTMENT OF DEFENSE INSTRUCTION ON NOISE PROGRAMS

Department of Defense

INSTRUCTION

NUMBER 4715.13
November 15, 2005

USD(AT&L)

SUBJECT: DoD Noise Program

References: (a) DoD Directive 5134.1, "Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L))," December 9, 2005
(b) DoD Directive 5124.2, "Under Secretary of Defense for Personnel and Readiness (USD(P&R))," October 31, 1994
(c) DoD Instruction 4165.57, "Air Installations Compatible Use Zones," November 8, 1977
(d) DoD Directive 5000.1, "The Defense Acquisition System," May 12, 2003
(e) through (g), see enclosure 1

1. PURPOSE

Under the authority of reference (a) and in conformance with reference (b), this Instruction establishes policy and assigns responsibilities for a coordinated DoD noise program. It also provides for establishment of a DoD Noise Working Group (DNWG).

2. APPLICABILITY

This Instruction applies to the Office of the Secretary of Defense, the Military Departments, the Chairman of the Joint Chiefs of Staff, the Combatant Commands, the Office of the Inspector General of the Department of Defense, the Defense Agencies, the DoD Field Activities, and all other organizational entities within the Department of Defense (hereafter referred to collectively as the "DoD Components").

3. DEFINITION

Noise. For the purposes of this Instruction, noise is defined as unwanted sound generated from the operation of military weapons or weapons systems (e.g., aircraft, small arms, tank guns, artillery, missiles, bombs, rockets, mortars, and explosives) that affects either people, animals (domestic or wild), or structures on or in areas in proximity of a military installation;

1

occupational noise exposure and underwater sound associated with ship testing and training activities are specifically excluded from this definition.

4. POLICY

The DoD noise program shall:

4.1. Reduce adverse effects from the noise associated with military test and training operations consistent with maintaining military readiness.

4.2. Consider the adverse effects of noise from military weapons or weapons systems on the ability to test, train, and operate weapons systems during the development of Initial Capabilities Documents, Capability Development Documents, Capability Production Documents and Capstone Requirements Documents and throughout the Joint Capabilities Integration and Development System and associated acquisition processes.

4.3. Integrate, without degrading mission capabilities, noise management techniques and principles into installation, operational range, and operating area plans and programs and incorporate into Air Installation Compatible Use Zone and Joint Land Use Study program efforts (reference (c) and DoD Instruction 3030.3 (reference (g)).

4.4. Promote scientific research and the use of sound scientific methods and validated noise data as the basis for and the establishment of noise program guidance.

4.5. Promote the development of initiatives to educate and train DoD military, civilian and contractor personnel, and the public on noise issues.

4.6. Leverage resources to the maximum extent possible by ensuring the coordination of DoD noise program initiatives among the Department of Defense and other Federal Agencies.

4.7. Promote outreach with entities affected by noise generated from the operation of military weapons and weapons systems.

5. RESPONSIBILITIES

5.1. The Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) shall:

5.1.1. Provide policy, guidance, oversight, and representation for the DoD noise program.

5.1.2. Establish noise policy and guidance that fully addresses military readiness considerations and ensures noise impacts are considered in the development, acquisition, and fielding of weapons and weapons systems, in coordination with the Under Secretary of Defense for Personnel and Readiness and the Director of Operational Test and Evaluation.

5.1.3. Review USD(AT&L) DoD Directives 4165.57 and 5000.1 (references (c) and (d)) and DoD Instruction 4715.9 (reference (e)), and supporting references for consistency, revision, and elimination of duplicative requirements.

5.2. The Deputy Under Secretary of Defense for Installations and Environment (DUSD(I&E)), under the USD(AT&L), shall:

5.2.1. Develop and promulgate goals and objectives for the DoD noise program and establish metrics to evaluate progress toward meeting those goals and objectives.

5.2.2. Develop DoD noise program guidance and establish requirements and priorities for use in DoD Component planning, programming, and budgeting, in consultation with the DoD Components.

5.2.3. Consult with the Military Departments on their various installation compatible land use and noise management programs through the DNWG and the Range Sustainment Working Integrated Product Team process.

5.2.4. Establish, support, and provide guidance to a DNWG that includes representatives from the Military Departments. The DNWG shall:

5.2.4.1. Evaluate and advise the DUSD(I&E) and the DoD Components on noise-related issues that have a bearing on the Department of Defense's ability to carry out its assigned mission requirements.

5.2.4.2. Coordinate and provide recommendations on technical and policy issues concerning noise associated with military testing and training activities and the impacts of such noise.

5.2.4.3. Represent DUSD(I&E) at meetings of the Federal Interagency Committee on Aviation Noise and maintain liaison with other Federal and State Agencies, nongovernmental organizations, professional organizations, educational institutions, and industries having similar interests or responsibilities.

5.3 The Under Secretary of Defense for Personnel and Readiness shall:

5.3.1. Coordinate on all policy and guidance issued by the USD(AT&L) regarding the DoD noise program to ensure the policy and guidance fully address military readiness considerations.

5.3.2. Review DoD Directive 3200.15 (reference (f)) and supporting issuances for consistency, revision, and elimination of duplicative requirements.

5.4. The Director of Operational Test and Evaluation shall coordinate on all policy and guidance issued by USD(AT&L) regarding the DoD noise program to ensure the policy and guidance fully consider impacts on testing and evaluation and the operations of the Major Range and Test Facility Base within the Department.

5.5. The Heads of the DoD Components shall:

5.5.1. Provide management support, resources, and professionally qualified staff sufficient to ensure effective implementation of the DoD noise program at all organizational levels.

5.5.2. Provide representatives to the DNWG.

5.5.3. Analyze current and future test and training needs to support effective planning, programming, budgeting, and execution of DoD noise program requirements.

5.6. The Chairman of the Joint Chiefs of Staff shall ensure the impacts of noise emissions on the ability to train and operate are considered during the Joint Capabilities Integration and Development System process.

6. EFFECTIVE DATE

This Instruction is effective immediately.

NOV 15 2005

Kenneth J. Krieg
Under Secretary of Defense
For Acquisition, Technology, and Logistics

Enclosures - 1
E1. References, continued

APPENDIX F

PRIMARY AIRCRAFT UTILIZING DAVISON ARMY AIRFIELD

For reference, Figures F-1 through F-7 shows examples of the primary types of rotary-wing and fixed-wing aircraft utilizing the Davison Army Airfield at Fort Belvoir.

Figure F-1 Example of a UH-60 Black Hawk

The UH-60 Black Hawk is a medium-lift utility or assault helicopter. The Black Hawk series of aircraft can perform a wide array of missions, including the tactical transport of troops, electronic warfare, and aero-medical evacuation.

Figure F-2 Example of a BE-20 Super King Air

Several BE-20 variants are used by the U.S. Air Force, U.S. Army, and the U.S. Navy. These aircraft are used for various duties, including embassy support, medical evacuation, passenger and light cargo. Some models are used by the U.S. military under the designation C-12.

Figure F-3 Example of a Cessna Citation (500)

The Cessna 500 Citation I is a turbofan-powered small-sized business jet suitable for operations from shorter airfields. These aircraft are used for passenger transport.

Figure F-4 Example of a Cessna Citation (560)

The Cessna Citation V (Model 560) is a turbofan-powered small-to-medium sized business jet. These aircraft are primarily used for passenger transport. Some models are used by the U.S. military under the designation UC-35.

Figure F-5. Example of a CH-46 Seaknight

The CH-46 Sea-Knight is a medium-lift tandem rotor transport helicopter, used by the U.S. Marine Corps to provide all-weather, day-or-night assault transport of combat troops, supplies and equipment.

Figure F-6 Example of a SH-33 Shorts Sherpa

The SH-33 Short Sherpa is a light cargo twin-engine turboprop aircraft used for a variety of cargo, airdrops and aeromedical evacuation. Some models are used by the U.S. military under the designation C-23.

Figure F-7 Example of a UH-72 Lakota

The UH-72 Lakota is a twin-engine helicopter with a single, four-bladed main rotor. The UH-72 is a militarized version of the Eurocopter EC145. The UH-72 is intended to be a Light Utility Helicopter and is designed to take on a range of missions, from general support and medical evacuation (MEDEVAC) to personnel recovery and counter-narcotics operations.

Plan 3. 2017 Airport Cooperative Research Program (ACRP) Research Report 181: "Assessing Community Annoyance of Helicopter Noise."

Air Cooperative Research Program (ACRP) Research Report 181 explores community annoyance of helicopter noise. It describes a protocol for conducting a large-scale community survey.

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This PDF is available at http://nap.edu/24948

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Assessing Community Annoyance of Helicopter Noise

DETAILS

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP RESEARCH REPORT 181

Assessing Community Annoyance of Helicopter Noise

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). ACRP carries out applied research on problems that are shared by airport operating agencies and not being adequately addressed by existing federal research programs. ACRP is modeled after the successful National Cooperative Highway Research Program (NCHRP) and Transit Cooperative Research Program (TCRP). ACRP undertakes research and other technical activities in various airport subject areas, including design, construction, legal, maintenance, operations, safety, policy, planning, human resources, and administration. ACRP provides a forum where airport operators can cooperatively address common operational problems.

ACRP was authorized in December 2003 as part of the Vision 100—Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academy of Sciences formally initiating the program.

ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

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ACRP RESEARCH REPORT 181

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FOREWORD

By Joseph D. Navarrete
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ACRP Research Report 181 explores what is currently known about community annoyance of helicopter noise. It describes a protocol for conducting a large-scale community survey to quantify annoyance due to civil helicopter noise and presents the results of a test of the protocol which also helped improve understanding of the roles of acoustic and non-acoustic factors that influence community annoyance to civil helicopter noise. The report should be of particular interest to airport industry practitioners, community planners, and researchers who desire a better understanding of the factors affecting community annoyance with helicopter noise and possible differences between helicopter noise impacts and fixed-wing aircraft noise impacts.

Helicopter noise differs from fixed-wing aircraft noise in many ways. Helicopter operations and routes are more variable than those of fixed-wing aircraft and often occur at lower altitudes. In addition, the frequency content, sound level onset, decay rates, and overall duration of helicopter noise differ from those of fixed-wing aircraft. These differences may be associated with differences in how humans react to helicopter noise versus fixed-wing aircraft noise. There also may be factors affecting community response to helicopter noise, including audibility, safety, and privacy concerns. Although a 2004 FAA Report to Congress (*Nonmilitary Helicopter Urban Noise Study*) recommended that "additional development of models for characterizing the human response to helicopter noise should be pursued," to date, no such work had been undertaken. Research was therefore needed to better understand the factors affecting community annoyance to helicopter noise.

The research team, led by Landrum & Brown, began with a literature review. A set of hypotheses was developed from the review to explore whether helicopter noise was more annoying than noise from fixed-wing aircraft at comparable sound levels, and, if so, what factors might contribute to that greater annoyance. Also explored was how possible differences might be accounted for when predicting helicopter noise impacts. The team then developed a research protocol that included a large-scale social survey, noise monitoring, and noise modeling. The team next implemented the protocol in an effort to validate the approach and, if possible, obtain results to confirm their hypotheses. The surveys were conducted via telephone (both landline and wireless) in Long Beach, California; Las Vegas, Nevada; and Washington, D.C. About 2,300 respondents were interviewed. Survey results were analyzed and correlated to the noise monitor data and noise modeling output to draw conclusions.

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In addition to the literature review, the report provides a detailed description of the research protocol and rationale, detailed survey results, and summary conclusions. While the project validated the protocol for conducting a large-scale study on community annoyance to helicopter noise, it could not conclusively identify any notable difference between community annoyance with light civil helicopter noise and the noise generated by fixed-wing aircraft at comparable sound exposure levels, nor could it conclusively identify any non-acoustic factors that might affect an individual's perception of helicopter noise.

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SUMMARY

Assessing Community Annoyance of Helicopter Noise

This report presents the findings of a study of the annoyance of helicopter and fixed-wing aircraft noise. This study developed and tested a series of hypotheses intended to determine whether helicopter noise is more annoying than fixed-wing noise. The request for proposal (RFP) cited a general lack of understanding of the relationship between helicopter noise and community response. In a 2004, FAA Report to Congress titled "Nonmilitary Helicopter Urban Noise Study," it was suggested that "additional development of models for characterizing the human response to helicopter noise be pursued." The RFP further raised the question of whether the assumed "excess" annoyance of helicopter noise was more appropriately attributed to purely acoustic factors, to nonacoustic factors, or to a combination of the two.

The study began with a review of the technical literature that identified annoyance as the primary noise effect of concern, distinguishing between the direct annoyance of airborne noise and the indirect annoyance of secondary emissions (vibration and rattling sounds) that may be induced in residences by helicopters. The review included an annotated bibliography of a score of prior publications on the annoyance of helicopter noise as well as tutorials on the nature and aerodynamic origins of helicopter noise emissions. It also included an analysis of the correlations among noise metrics commonly used as predictors of community response and a description of a systematic approach to accounting for nonacoustic influences on the annoyance of helicopter noise.

The literature review found inconclusive evidence from prior laboratory and field studies concerning half a dozen hypotheses about the origins of annoyance due to helicopter noise. The main point of agreement was that helicopter noise is much more variable and complex than fixed-wing aircraft noise. The main point of disagreement was the degree to which main rotor impulsive noise controls the annoyance of helicopter noise. Overall, the reviewed laboratory and field studies revealed little systematic, rigorous, or theory-based understanding of the annoyance of helicopter noise. Seven hypotheses were formed from the literature review about the origins of the annoyance of helicopter noise.

In simplified form, the hypotheses were:

1. The prevalence of annoyance due to helicopter noise exposure in a community is greater than that associated with comparable levels of exposure to noise produced by fixed-wing aircraft;
2. The prevalence of annoyance due to helicopter noise is most usefully predicted in units of A-weighted cumulative exposure;
3. The prevalence of annoyance due to helicopter noise is strongly influenced by its impulsive character, and thus requires an impulsiveness "correction" to A-weighted cumulative exposure;
4. The prevalence of annoyance due to helicopter noise is strongly influenced by indoor secondary emissions (rattle and vibration) due to its low-frequency content;

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5. The prevalence of annoyance due to helicopter noise is appreciably influenced by non-acoustic factors;
6. The prevalence of annoyance due to helicopter noise is more usefully attributed to proximity to helicopter flight paths than to helicopter noise emissions per se; and
7. Complaints lodged about helicopter noise are more reliable predictors of the prevalence of annoyance than measures of exposure to helicopter noise or proximity to helicopter flight paths.

Telephone interviews were conducted with residents of three urban areas about their annoyance with exposure to helicopter noise. The interviewing sites were among those with the greatest concentrations of civil helicopter traffic in the United States. The range of helicopter-only cumulative noise exposure levels expressed in day-night average sound level (DNL) across the interviewing sites nonetheless ranged from about 27 dB $\leq L_{dn} \leq$ 53 dB.

A questionnaire consisting of 15 items was created to collect information relevant to these hypotheses in largely residential neighborhoods near three airports supporting fixed-wing and helicopter operations: Long Beach, CA [Long Beach Airport (LGB)]; Las Vegas, NV [McCarran International Airport (LAS)]; and Washington, D.C. [Ronald Reagan Washington National Airport (DCA)]. Interviewing sites were selected primarily for their substantial exposure—by civil aviation standards—to helicopter noise. A range of helicopter noise exposure levels was sought at each site, and when possible, a range of fixed-wing aircraft noise exposure as well. Because the primary site selection criterion was exposure to large numbers of daily civil helicopter flight operations, only one of the three interviewing sites (DCA) was exposed to appreciable levels of noise exposure produced by fixed-wing flight noise.

Modeling of these helicopter operations was undertaken to estimate the helicopter noise exposure. Representative random samples of both landline and wireless telephone-subscribing households at each site were then compiled into a sampling frame by first identifying geographic areas in proximity to helicopter flight tracks with similar noise exposure, and then by identifying households within them. Home addresses of wireless telephone subscribers were inferred from their billing addresses, or from address information associated with the wireless number in other proprietary databases.

Computer-assisted, live-agent telephone interviewing was then conducted over a period of at least 1 week in each of the neighborhoods. A total of 2,372 respondents completed the interview: 1,189 in Long Beach, 741 in Las Vegas, and 442 in Washington, D.C.

Field measurements to confirm the noise exposure predictions were conducted for a week prior to the start of interviewing and during interviewing at LGB and at LAS. Time series of sound pressure levels were collected at 1-second intervals, along with A-weighted 1-second equivalent continuous noise level (L_{eq}), C-weighted 1-second L_{eq}, and 1-second L_{eq} in each of the one-third octave bands from 6 Hz to 20 kHz. Both A-weighted and C-weighted 1-second time histories of L_{eq} values were also recorded. Due to high levels of fixed-wing aircraft noise in Washington, D.C., helicopter noise exposure levels were estimated by noise modeling alone. Helicopter flight operations at DCA were highly constrained by higher altitude fixed-wing approach and departure flight paths, and high-quality radar flight track information was available during the interviewing period.

All of the neighborhoods in which interviewing was conducted had stable residential populations. Large majorities of respondents in Long Beach and Las Vegas described their neighborhoods as quiet. Nearly half of the respondents in Washington did as well. However, nearly a quarter of the respondents in Long Beach described their neighborhood as noisy, and nearly a third of the respondents in Washington described their neighborhood as "quiet, except for aircraft noise."

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Only small minorities of respondents reported noticing helicopters more than a few times a day at any of the three study sites even though the number of flights per day at one site was nearly 10 times the number of flights at the other two sites. The mean level of exposure to helicopter noise of respondents who were annoyed in any degree by it was 44 dB. The mean level of exposure to helicopter noise of respondents who were *not* annoyed in any degree was 42 dB. The difference in exposure levels of respondents who were and were not annoyed in any degree by helicopter noise was unlikely to have arisen by chance alone, but accounted for very little variance in the relationship between noise exposure and annoyance. Likewise, a weak but statistically significant relationship between exposure to helicopter noise and high annoyance (self-description by respondents as "very" or "extremely" annoyed by helicopter noise) was observed in the Long Beach interviewing area. No statistically significant relationship between helicopter noise levels and annoyance due to in-home vibration and rattling was observed at any of the three study areas.

Less than 3% of all respondents reported that they had ever registered complaints about helicopter noise. Among the 1,937 respondents who reported no annoyance with helicopter noise, 1.3% registered complaints; of the 330 respondents who reported at least slight annoyance by helicopter, 9.4% registered complaints. No statistically significant difference was observed in the helicopter-only DNL for respondents who did and did not complain.

At two of the three interviewing sites (Las Vegas and Washington), the prevalence of high annoyance with helicopter noise was statistically distinguishable from zero, but varied little with DNL. At the remaining site (Long Beach), the prevalence of high annoyance with helicopter noise was also non-zero and invariant with DNL at low exposure levels, but increased modestly at levels exceeding about $L_{dn} = 45$ dB.

The prevalence of annoyance with helicopter noise was not strongly related to noise exposure levels over the range of helicopter-only DNL values that were available for study. The present study could not determine whether respondents in the same communities differed in tolerance for fixed- and rotary-wing aircraft, because sites with comparable exposures to the two types of aircraft noise were not found. At the one interviewing site (Washington, D.C.) at which residents were exposed to both forms of aircraft noise, noise due to fixed-wing operations generated significantly higher annoyance, but the fixed-wing noise exposure was also considerably greater than noise exposure due to helicopter operations.

The majority of survey respondents were exposed to helicopter-only DNL values between roughly 30 and 45 dB. These absolute levels of exposure to helicopter noise were low with respect to typical urban noise exposure, so that most of the observed prevalence rates of high annoyance with helicopter noise were correspondingly low as well. It was observed that individuals highly annoyed by fixed-wing aircraft noise were fifteen times more likely to be highly annoyed by helicopter noise than those not highly annoyed by fixed-wing aircraft noise.

The relatively low levels of exposure to helicopter noise (with respect to other sources of cumulative urban noise exposure) are believed to be responsible for a general absence of strong helicopter noise effects in the current data set. The findings of the present study do not support construction of useful dosage-response relationships between exposure to helicopter-only noise and the prevalence of high annoyance. It also does not appear that further surveys along typical civil helicopter routes would prove to be any more useful in developing a dosage-response relationship. Additional study in communities with much higher helicopter DNL exposure values, such as around military facilities, might support development of a more definitive dosage-response relationship. However, such a relationship would be applicable primarily to heavy military helicopters whose impulsive noise signatures are more prominent than those of lighter civil helicopters.

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Introduction

ACRP's RFP for Project 02-48 cited a general lack of understanding of the relationship between helicopter noise and community response and that in 2004, an FAA Report to Congress, "Nonmilitary Helicopter Urban Noise Study," recommended that "additional development of models for characterizing the human response to helicopter noise should be pursued." The solicitation raised the question of whether the assumed "excess" annoyance of helicopter noise was more usefully attributed to purely acoustic factors, or to nonacoustic factors, or to a combination of the two. This report presents the findings of a social survey on the annoyance of aircraft noise that was intended to seek evidence of the reasonableness of the underlying assumption of the RFP.

Chapter 1 reviews the technical literature on the annoyance of helicopter noise to aid in the design of questionnaire items and other aspects of field surveys regarding opinions about the annoyance of helicopter noise.

Chapter 2 develops hypotheses for field testing about the annoyance of exposure to helicopter noise. Not all hypotheses were testable at all sites, since individual site characteristics limited types and amounts of helicopter and fixed-wing aircraft noise exposure available for analysis.

Chapter 3 discusses criteria used to select survey sites, and identifies sites that satisfied selection criteria. The chapter also describes the questionnaire that was developed, along with the purposes that individual questionnaire items served in testing the hypothesis developed in Chapter 4.

Chapter 4 describes noise measurement and social survey methods and implementation.

Chapter 5 presents the analysis of survey findings including an interpretation of the results.

Chapter 6 provides conclusions and discussion.

Appendix A is a short tutorial on the sources and nature of helicopter noise emissions, and an analysis of the correlations among noise metrics commonly used as predictors of community response.

Appendix B is an annotated bibliography of relevant studies of the annoyance of helicopter noise, in both laboratory and field settings. It is intended as an interpretive guide to the technical literature on the annoyance of helicopter noise. The annotation focuses on the issue of the "excess" annoyance of rotary-wing aircraft noise, and on examining hypotheses of potential interest for empirical tests in the field study phase of ACRP Project 02-48.

Appendix C summarizes a modern approach to accounting for the potential excess annoyance of helicopter noise. The approach concentrates on estimating the *net* effect of all of the many potential nonacoustic factors on the prevalence of annoyance judgments in communities, rather than identifying individual factors.

Appendix D describes the noise measurement protocol for this study.

Superscripts in the text refer to Endnotes located at the end of this document.

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CHAPTER 1

Literature Review

1.1 Introduction

The literature review performed by the research team initially identifies prior design and analysis approaches used for research on community response to aircraft noise. Review of these prior design and anaylsis approaches then leads to a discussion of hypotheses that merit consideration in field studies.[1] The review then identifies annoyance as the primary noise effect of concern and distinguishes between the direct annoyance of airborne noise and the indirect annoyance of secondary emissions (vibration and rattling sounds) that may be induced by helicopter acoustic emissions. A recent increase in concern with helicopter noise complaints is then discussed.

The next topics addressed are the potential influences of nonacoustic factors in community response to helicopters and the usefulness of laboratory and field findings about helicopter annoyance. The review concludes with a summary of prior findings.

1.2 Understanding of Helicopter Noise Versus Fixed-Wing Aircraft Noise

Community reaction to helicopter noise has been less studied and less well understood than community reaction to fixed-wing aircraft noise for a variety of reasons. Most obviously, exposure to helicopter noise remains a more geographically limited problem than exposure to fixed-wing aircraft noise, and affects far fewer people. For example, out of a total of 232,567 active aircraft in the domestic U.S. fleet of commercial and general aviation aircraft, only 11,245 are helicopters (FAA 2011). Despite the smaller numbers of people affected by exposure to helicopter noise than by exposure to noise from fixed-wing aircraft, helicopter noise can nonetheless be distinctive and highly annoying.

As described in Appendix A, noise emissions of helicopters are more complex, variable, and unpredictable than those of fixed-wing aircraft. (The appendix provides a brief tutorial on the sources and characteristics of helicopter noise in various flight regimes.) Helicopter noise emissions vary not only with flight regime, orientation with respect to the flight path, and speed, but also with manner of operation. A fixed-wing aircraft flyover characteristically produces a simple and familiar "haystack" temporal pattern. Fixed-wing aircraft noise increases more or less monotonically as an aircraft flies toward an observer, reaches a peak at about the time that the aircraft is directly overhead, and then monotonically decreases as it flies away from the observer. In areas within a few miles of runway ends, high-speed, fixed-wing aircraft usually follow predictable paths and distribute their noise emissions symmetrically with respect to the flight path.

In contrast, the spatial distribution of helicopter noise is more complex than that of fixed-wing aircraft because of source directivity, dependence of emissions on flight regime, and the

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operational flexibility of rotary-wing flight. High-speed impulsive (HSI) helicopter noise is concentrated in the plane of the rotor disk and in the direction of forward flight. Blade-vortex interaction (BVI) noise ("blade slap") is also impulsive sounding and is concentrated forward and downward, along the helicopter's flight path. Broadband emissions of rotary-wing aircraft are typically greater on the side of the aircraft with the counter-torque rotor. Helicopters may approach and depart a landing pad at low speeds, and to and from more than one direction. The flexibility of rotary-wing flight also means that the time pattern of helicopter noise intrusions is less predictable than that of fixed-wing aircraft. Helicopters typically operate at lower altitudes than fixed-wing aircraft and can orbit a location on the ground or hover in place for prolonged periods. These flight characteristics can render individual helicopter operations more audible, for longer periods of time, than fixed-wing aircraft overflights in urban ambient noise environments. Further, the low-frequency noise emissions of helicopters can excite more indoor rattle and vibration in residences than fixed-wing aircraft in flight at greater altitudes.

For all of these reasons, helicopter noise is often thought to be more annoying on a per-event basis than fixed-wing aircraft noise of comparable sound level. It is also commonly believed that the repetitive impulsive nature of helicopter noise is its most annoying characteristic. Neither of these interpretations is necessarily correct, nor the complete story. In particular, it remains unclear whether the supposed "excess" annoyance of helicopter noise (vis-à-vis that of fixed-wing aircraft noise) is acoustic or nonacoustic in origin.

1.3 Noise Effects of Concern

1.3.1 Annoyance

The Federal Interagency Committee on Noise (FICON) (1992) considers annoyance an attitude (that is, a covert mental process) as its preferred general indication of adverse aircraft noise impacts. In this context, annoyance is gauged by the self-reporting of opinions in community-wide social surveys, in response to questions such as "While you've been at home over the last (day/week/year), have you been not at all, slightly, moderately, very, or extremely annoyed by aircraft noise?" Schultz (1978) and his successors have produced several quantitative dosage-response relationships to predict the prevalence of a consequential degree of aircraft noise-induced annoyance attributable to cumulative noise exposure. Nearly all of the field studies from which such relationships have been inferred have dealt with annoyance produced by fixed- rather than rotary-wing aircraft operations.

Most dosage-response relationships attempt to predict the prevalence of aircraft noise-induced annoyance in communities from a single independent variable—cumulative noise exposure—as estimated either by direct measurement or by noise modeling. Such relationships account for less than half of the variance in the association between noise exposure and annoyance. Only in recent years has a practical, quantitative method emerged for incorporating an additional variable into predictions of annoyance prevalence rates. As described in Appendix C, the second predictor variable is the sum total of community-specific, *nonacoustic* influences on annoyance.[2]

Even if it is assumed that the annoyance of exposure to noise produced by helicopters is best understood in entirely acoustic terms, a further question remains: is that annoyance produced solely by the airborne acoustic energy that helicopters produce or by secondary emissions (rattling noises and vibration) induced by helicopter noise in residences.

1.3.2 Direct Annoyance of Airborne Noise Created by Helicopters

Figure 1-1 compares three dosage-response relationships between cumulative aircraft noise exposure and the prevalence of aircraft noise-induced annoyance in average communities.

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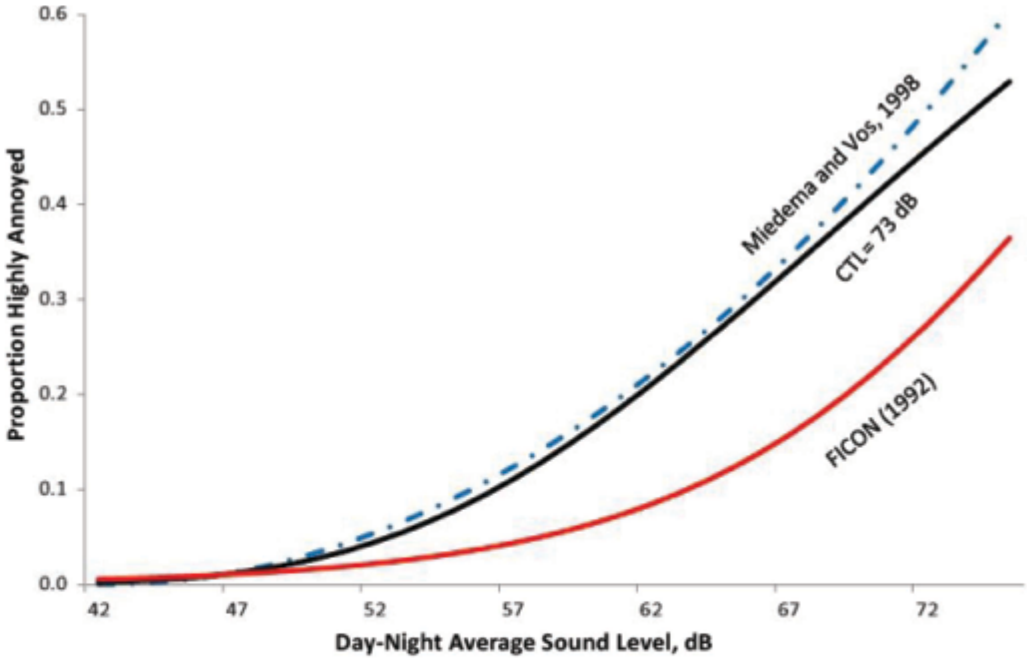

Figure 1-1. Comparison of revised ISO Standard 1996-1 dosage-response curves with earlier FICON curve.

The solid black line, the community tolerance level (CTL) relationship, is the one recommended in the 2016 revision of International Standards Organization (ISO) Standard 1996-1.[3] (Appendix C provides additional detail about the methods described in the latest revision of the ISO Standard.) If helicopter noise is more annoying, decibel-for-decibel, than fixed-wing aircraft noise, the CTL curve seen in Figure 1-1 (developed for fixed-wing aircraft) will be shifted toward the left side of the graph.

Figure 1-2 illustrates a family of dosage-response relationships corresponding to increases in the annoyance of helicopter noise exposure by amounts ranging from 3 to 10 dB. For example, if helicopter noise proves to be 3 dB more annoying than fixed-wing aircraft noise, analyses of survey data may be expected to produce a dosage-response relationship similar to the dashed curve to the left of the one seen in Figure 1-1. Note that the curves in Figure 1-2 differ both in positions on the abscissa, and in their slopes, for reasons discussed in Appendix C. The shapes of the curves are identical no matter where they are horizontally. However, the horizontal position affects the slope of a given curve at a particular dose (i.e., DNL value), and hence the rate at which annoyance grows with increasing dose at that level.

1.3.3 Annoyance Due to Secondary Emissions

The primary structural resonance in conventional wood frame construction for single-family detached dwellings is typically in the 10–25 Hz frequency region, the same frequency region as the fundamental (one per revolution) frequency of the main rotor system of many helicopters. This means that helicopter operations can easily induce noticeable vibration in homes near helipads and flight paths. Even modest levels of structural vibration, which might escape direct notice, can cause lightweight or suspended architectural elements (windows, doors, bric-a-brac on shelves, pictures on walls, crockery in cupboards, HVAC ducts, and other household paraphernalia) to

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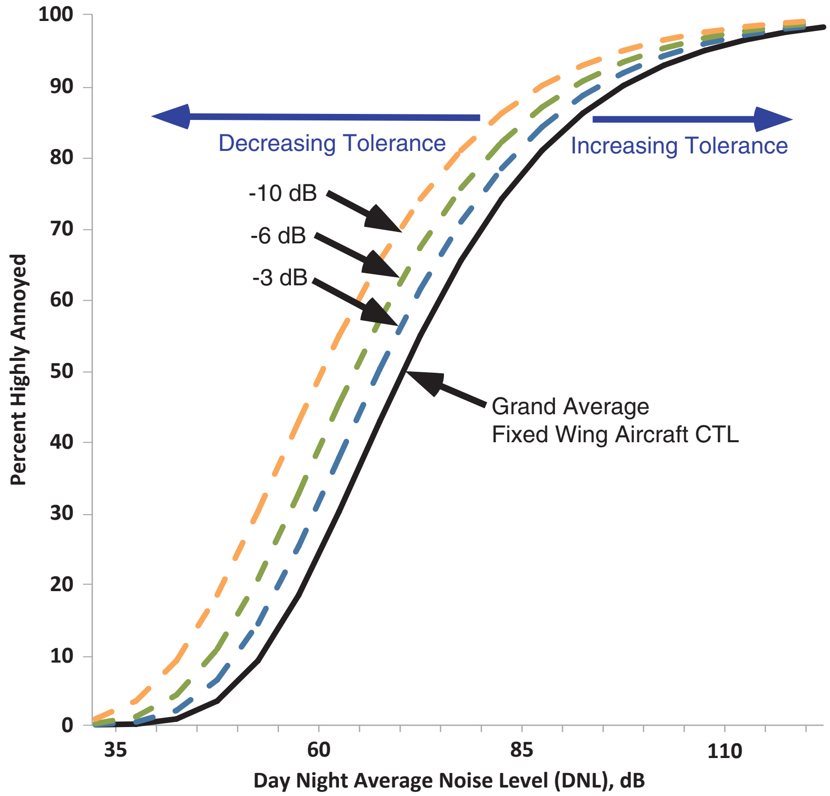

Figure 1-2. Family of hypothetical dosage-response curves for differing levels of community sensitivity.

rattle audibly. Such rattling noises can be annoying in their own right, whether or not accompanied by noticeable vibration, or by audible helicopter noise.

Figure 1-3, adapted from Fidell et al. (2002a), shows a relationship between the prevalence of annoyance due to aircraft noise-induced rattle and a single-event measure of low-frequency noise level. The measure, known as low frequency sound level (LFSL), is the sum of the sound exposure levels in the six one-third octave bands between 25 and 80 Hz.

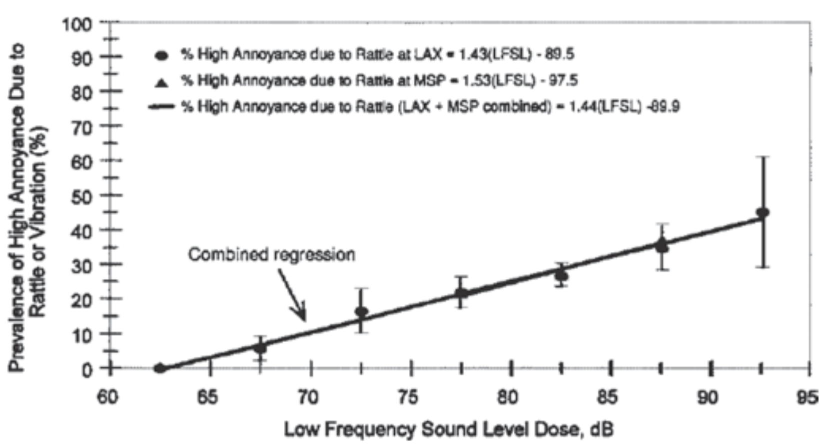

Figure 1-3. Relationship between LFSL and the prevalence of high annoyance with rattle. (Note: the % high annoyance due to rattle at MSP appears at 87.5 dB on the graph.)

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1.3.4 Complaints

In July of 2013, the Washington, D.C., Court of Appeals found that helicopter noise could adversely affect a residential population at an A-weighted cumulative noise level more than 20 dB lower than FAA's customary criterion of "significant" noise impact (L_{dn} = 65 dB). The court ruled in Helicopter Association International, Inc. *v*. Federal Aviation Administration, Case No. 12-1335 (C.A. D.C., Jul. 12, 2013) that the FAA was justified in mandating compulsory compliance with an offshore flight route for helicopters,[4] even when the noise created by helicopter operations did not exceed L_{dn} = 45 dB at affected residences. The ruling seems to rely solely on a high number of noise complaints rather than any specific acoustic measure. Complaints, a behavior, are not the same quantity as annoyance, an attitude. A recent study has made some progress in suggesting a potential relation between the behavior and the attitude (Fidell et al. 2012). Note that the referenced study made a clear distinction between numbers of complaints, number of complainers and segregating complainers by numbers of complaints. Except for the most prolific complainers, a common pattern was observed leading to the conclusion that tracking the number of non-prolific complainers *may* provide an indication of community attitudes about noise. This is a topic about which more, and very possibly quite productive, research could be done.

The court's ruling implies an A-weighted difference on the order of 20 dB between the annoyance of helicopter and fixed-wing aircraft noise. Conventional analyses, such as those identified by ISO 1996 and discussed in Appendix C, however, "penalize" helicopter noise by less than 10 dB in an attempt to equalize predictions of the annoyance of rotary- and fixed-wing noise. The order of magnitude difference between the findings of the Court of Appeals and current (acoustically driven) noise impact evaluation methods suggests that metrics sensitive to acoustic factors alone may not be fully capable of predicting community response to helicopter noise.

1.4 Noise Metrics Useful for Quantifying Helicopter Noise

Two frequency weighting networks and families of noise metrics are commonly employed in the U.S. to express sound levels of both fixed- and rotary-wing aircraft. For aircraft noise certification purposes, the FAA has required frequency weighting, called the tone-corrected perceived noise level, abbreviated PNL(T), developed in the 1950s. For predicting and assessing environmental impacts of aircraft noise exposure, the FAA endorses the A-weighting network, developed in the 1930s.[5] Each metric supports a family of single-event and cumulative exposure metrics to deal with exposure that varies from instantaneous through annual time frames.[6]

Concern about noise metrics appropriate for predicting the annoyance of exposure to rotary-wing aircraft noise has peaked several times since the 1950s. As discussed in Appendix B, a 1982 literature review by Molino (1982) compares the findings of 34 earlier analyses of the annoyance of helicopter noise, the earliest of which date to the 1960s (cf. Crosse et al. 1960, Niese 1961, Robinson et al. 1961, and Pearsons 1967). The findings of these early studies are neither consistent nor definitive. These and other studies (e.g., Powell, 1981) do not fully support Molino's conclusion that there is "no need to measure helicopter noise any differently from other aircraft noise."

The common belief that rotary-wing aircraft noise causes more annoyance on a decibel-for-decibel basis than fixed-wing aircraft noise has led to the practice of imposing decibel-denominated "penalties" on A-weighted (but not PNL-weighted) measures of helicopter noise for purposes of assessing environmental impacts of helicopter noise. This may be an expedient way of accommodating the supposed excess annoyance of helicopter noise, but is not necessarily the most systematic or defensible way.

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The tactic of assigning penalties treats the assumed excess of annoyance of helicopter noise as a simple problem of measurement, while ignoring the underlying causes of the supposed excess annoyance. Since the evidence supporting the assumption of excess annoyance is not definitive, the issue may not simply be one of physical measurement, however. The supposed excess could be attributable to operational factors (the characteristic shorter slant ranges and relatively longer duration of helicopter operations *vis-à-vis* fixed-wing aircraft operations) rather than inherent differences in noise-induced annoyance. The supposed excess could also be attributable to entirely nonacoustic factors. Although a good deal has been learned since Molino's 1982 review about the mechanisms that generate rotary-wing aircraft noise in different flight regimes, it is only recently that systematic means have become available to focus more closely on potential nonacoustic factors that influence annoyance judgments (Appendix C provides greater detail about these means).

To the extent that excess annoyance of helicopter noise is attributable to the annoyance of rattle and vibration (to which A-weighted noise metrics are insensitive), A-weighted noise metrics are unlikely to adequately predict the overall annoyance of helicopter overflights of residential populations, if the helicopter noise has strong low-frequency components as is the case for heavy military aircraft.

1.5 Nonacoustic Contributions to Community Reaction to Helicopter Noise

FAA (2004) summarized many operational, situational, and other nonacoustic factors that contribute to adverse community response to helicopter noise. These include low flight altitudes; long hover durations; times, numbers, and frequencies of operations; fear of crashes; and attitudes of misfeasance and malfeasance. Most of these factors similarly affect the annoyance of fixed-wing aircraft, but to lesser degrees. Perceptions of the necessity for flight operations can differ greatly for a range of rotary-wing missions. The necessity of medical evacuation, search and rescue, law enforcement, firefighting, and some heavy lift construction missions is widely acknowledged. The necessity for other rotary-wing flight operations is less apparent.

For example, large fixed-wing aircraft are self-evidently the most efficient mode of public transportation for regularly scheduled, long-haul carriage of hundreds of passengers per flight. As such, their necessity is generally taken for granted. In contrast, short-haul private transportation of individuals by helicopter is widely viewed as a luxurious choice (or "a rich man's toy," in the words of FAA's 2004 Report to Congress) rather than a practical necessity. Similarly, the limited ground visibility from fixed-wing airplanes and high flight speeds and altitudes pose little threat to domestic privacy. Helicopters hovering over residences are a different matter. Few would consider long duration hovering to permit paparazzi to photograph private events to be truly necessary.

Likewise, fixed-wing aircraft in the vicinity of airports necessarily approach and depart runways on flight paths corresponding to runway alignments. The motivation and necessity for non-emergency (e.g., air tour), small rotorcraft operations are not as apparent. Given their flexibility of flight, why must helicopters approach a particular house so closely on their way to and from landing pads? Why must multiple news gathering helicopters orbit the same traffic accident?

1.6 Laboratory Versus Field Studies of Helicopter Annoyance

Studies of the annoyance of rotary-wing aircraft noise have been conducted under both laboratory and field conditions. Laboratory studies offer greater precision of control over listening conditions than field studies, but lack the residential context of field studies. It is also difficult to

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accurately reproduce recorded or helicopter-like synthetic sounds under laboratory conditions while also preserving crest factor (ratio of peak value to average value of sound wave—important with impulsive noise), phase relationships (whether two sound waves are synchronized or shifted in time), low frequency, and other dynamics of rotorcraft noise emissions. On the other hand, while field studies provide the appropriate residential context for annoyance judgments, they lack the precision of control over acoustic conditions of laboratory studies.

It follows that questions about potential nonacoustic influences on the "excess" annoyance of helicopter noise are not readily answered in laboratory studies and that questions about the detailed acoustic origin of excess annoyance are not readily answered in field settings.

1.7 Summary of Findings of Literature Review

This literature review was conducted to identify pragmatically useful—that is, testable and relevant—hypotheses about the origins of annoyance with exposure to helicopter noise as a preliminary aid to the design of subsequent field research. The current review, as well as prior literature reviews such as those conducted by Molino (1982), Ollerhead (1985), and FAA (2004) document research undertaken in the last half-century to quantify and predict the individual and community annoyance of rotary-wing aircraft noise.

Whether conducted under laboratory or field conditions, much of this research was intended, directly or indirectly, to inform decisions about aircraft noise regulatory policy. Understandably, the early research sought out low-hanging fruit: "magic bullet" noise metrics; non-systematic (*ad hoc*, regression-based) dosage-response relationships; evidence that demographic and socio-economic factors could account for non-trivial amounts of variance in a predictively useful manner, and so on. The reviewed literature provided little systematic, rigorous, or theory-based understanding of the annoyance of helicopter noise.

Given what has been learned over the decades, some of the earlier exploratory research goals, hypotheses tested, study designs, and analysis approaches are not as relevant or appropriate today as they once may have been. For example, individual-level analyses intended to identify covariates that might arguably improve prediction of helicopter annoyance prevalence rates are now outdated. Individual differences such as demographic (sex, age, gender, nationality, etc.) account for relatively little variance in the relationship between noise exposure and annoyance, and are of little practical regulatory utility. Attitudinal differences (fear, suspected malfeasance, sense of necessity, etc.) as measured on a community-wide basis have significant effects on annoyance. Systematic means have recently become available for efficiently taking into consideration the net effects, rather than individual influences, of all of the nonacoustic factors that may affect the annoyance of helicopter noise exposure.

The findings of individual studies on the annoyance of helicopter noise disagree about as often as they agree. The main point of agreement in the technical literature is that helicopter noise is much more variable and complex than fixed-wing aircraft noise. This variability and complexity make it more difficult to accurately and credibly model helicopter noise exposure (other than under idealized conditions[7]), particularly in the vicinity of helipads. It follows, in turn, that predictions of the prevalence of annoyance of exposure to helicopter noise are likely to be more uncertain than predictions of the annoyance of exposure to fixed-wing aircraft noise.

A main point of disagreement is the degree to which main rotor impulsive noise controls the annoyance of helicopter noise. Many believe that impulsiveness "corrections" are appropriate for predicting the annoyance of exposure to helicopter noise; others believe that conventional A-weighted noise measurements suffice for predicting the annoyance of helicopter noise.

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Table 1-1 summarizes the laboratory (controlled listening) and field (social survey) evidence for and against hypotheses about the origins of the supposed excess annoyance of helicopter noise. (Annotation is provided in Appendix B for only some of the cited sources.) The empty cells in Table 1-1 reflect the incomplete nature of understanding of the origins of annoyance with helicopter noise.

Some of the implications of the findings of this literature review for the design of field studies include the following:

- Neighborhood opinions about the annoyance of helicopter noise and fixed-wing aircraft noise exposure are likely to differ for nonacoustic reasons. Unless analytic means are employed to account for such community-specific differences, it may not be possible to reliably identify differences in opinions about fixed- and rotary-wing annoyance per se.

Table 1-1. Evidence relevant to hypotheses about the annoyance of rotary-wing noise exposure.

HYPOTHESIS	EVIDENCE OR ASSERTION CONSISTENT WITH HYPOTHESIS	MARGINAL OR INCONCLUSIVE EVIDENCE OR ASSERTION	EVIDENCE INCONSISTENT WITH HYPOTHESIS
Decibel for decibel, rotary-wing aircraft noise is more annoying than fixed-wing aircraft noise	No reliable, large-scale comparisons reported in peer-reviewed field studies	More (2011); several other controlled-listening tests, which may not have controlled for confounding factors; tone-corrected effective perceived noise level [EPNL(T)] is a less consistent predictor of annoyance for rotary- than fixed-wing aircraft noise (Ollerhead 1982)	Ollerhead, 1982 (2 dB average effect in effective perceived noise level, in direction opposite to predicted direction)
Main rotor impulsive noise controls the annoyance of helicopter noise (and hence requires an impulsive noise "correction" to A-weighted measurements)	Sternfeld and Doyle (1978); Man-Acoustics & Noise, Inc. (1976); Lawton (1976); Wright and Damongeot (1977); Galanter et al. (1977); Klump and Schmidt (1978)	Fields and Powell (1987) (weak evidence at best); More (2011); Schomer and Wagner (1996); Magliozzi et al. (1975); Munch and King (1974)	Patterson et al. 1977; Powell 1981; Ollerhead 1982—also ICAO, 1981 [no impulse correction needed for EPNL(T); effect of impulsiveness is confounded with level and duration]; Passchier-Vermeer, 1994; Ohshima and Yamada, 1993; Gjestland, 1994; Bisio et al., 1999
A-weighted noise measurements are inadequate for predicting the annoyance of rotary-wing aircraft noise	Patterson et al. (1977); Schomer et al. (1991); Schomer and Neathammer (1987); Sternfeld et al. (1995); Edwards, (2002); Ollerhead (1982)	More (2011)	Molino, 1982
The annoyance of helicopter noise is strongly influenced by nonacoustic factors	Leverton (2014); Ollerhead (1982); FAA (2004); Atkins et al. (1983)		
Situational and operational factors account for much of the annoyance of helicopter noise	Ollerhead and Jones (1994); FAA (2004) Anecdotal evidence from popular press		
Cumulative noise metrics usefully predict the annoyance of exposure to helicopter noise	Fields and Powell (1987) ("broad consistency"); Atkins et al. (1983)		
Secondary emissions (rattle) induced by helicopter noise strongly influence its annoyance	Schomer and Neathammer (1987)		
The annoyance of helicopter noise is strongly influenced by its noticeability rather than its level per se	Schomer and Wagner (1996)		
Annoyance is better predicted by time-integrated proximity to flight tracks than by acoustic measures			

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- The flexibility of low-speed, rotary-wing flight lends itself to much more complex flight paths than those of fixed-wing aircraft. These complex flight paths cause the helicopter to accelerate/decelerate along the flight path and can dramatically change blade vortex interaction (BVI) impulsive noise level. The directivity of helicopter noise emissions further complicates noise exposure predictions based on flight tracks alone. Selecting sites with comprehensive flight track radar coverage and using sections of level flight rather than climbing and descending segments, the aircraft performance information will aid prediction, measurement, and interpretation of helicopter noise exposure, minimizing the uncertainty of the dosage portion of the dosage-response analysis. In other words, differences of as little as 2 or 3 dB between the annoyance of rotary- and fixed-wing aircraft may be difficult to discern on the basis of social surveys undertaken in a limited number of communities.
- Extensive efforts to confirm the utility of impulsive noise adjustments have yielded contradictory and inconclusive results.
- Correlation analyses have shown that most of the noise metrics commonly used to quantify helicopter noise are so highly correlated with one another that no one metric differs meaningfully from others in its ability to predict the prevalence of annoyance of helicopter noise (Mestre et al. 2011).
- Operational factors can also affect the annoyance of helicopter noise, but their effects may or may not be accounted for by integrated energy noise metrics.
- Questions about potential nonacoustic influences on the "excess" annoyance of helicopter noise are not readily answered in laboratory studies, while questions about the detailed acoustic origin of excess annoyance are not readily answered in field settings.

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CHAPTER 2

Development of Hypotheses

2.1 Introduction

The literature review contained in Appendix B, and described in Chapter 1, identified hypotheses about the absolute and relative annoyances of fixed- and rotary-wing aircraft and examined the published evidence in favor of and contrary to the various hypotheses. Much of the historical evidence about these hypotheses proved to be either contradictory or ambiguous. As a practical matter, the hypotheses may be expressed in terms of the ability of various factors to explain variance in the relationship between helicopter noise exposure and the prevalence of a consequential degree of annoyance in communities. The nine hypotheses described in Table 1-1 were summarized and restated in seven hypotheses that were tested in this study. The nonacoustic hypotheses (general nonacoustic, noticeability, and situational awareness) were combined into one, and A-weighted and cumulative hypotheses were considered in combination.

Loosely stated in simplified form, the hypotheses are:

1. The prevalence of annoyance due to helicopter noise in a community is greater than that associated with comparable levels of exposure to noise produced by fixed-wing aircraft;
2. The prevalence of annoyance due to helicopter noise is most appropriately predicted in units of A-weighted cumulative exposure;
3. The prevalence of annoyance due to helicopter noise is strongly influenced by its impulsive character, and thus requires an impulsiveness “correction” to A-weighted cumulative exposure (cumulative helicopter noise exposure corrections may be different for different helicopters at different exposure points on the ground);
4. The prevalence of annoyance due to helicopter noise is strongly influenced by indoor secondary emissions (rattle and vibration) due to its low-frequency content;
5. The prevalence of annoyance due to helicopter noise is appreciably influenced by nonacoustic factors;
6. The prevalence of annoyance due to helicopter noise is appreciably influenced by proximity to helicopter flight paths; and
7. Complaints lodged about helicopter noise are more reliable predictors of the prevalence of annoyance than measures of exposure to helicopter noise or proximity to helicopter flight paths.

The following sections describe some of the factors that complicate the testing of these hypotheses. These issues are discussed next in considerable detail, including the nature and relative amounts of exposure to fixed- and rotary-wing aircraft noise, population and sample

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size requirements, methods for quantifying nonacoustic influences on annoyance, magnitudes of expected effects, site selection criteria, and content and method of questionnaire administration.

2.2 Factors Complicating Hypothesis Testing

Both general and site-specific factors complicate hypothesis testing and interpretations of social survey findings. For example, some of the hypotheses are not mutually exclusive. It is possible that an impulsiveness correction may improve the ability of A-weighted measurements to predict the prevalence of annoyance created by helicopters, at least in flight regimes that produce conspicuous blade slap. It is also possible, however, that audible blade slap, rattle, and vibration are sufficiently correlated with one another that any of these factors could provide equally plausible explanations. Likewise, simple proximity to helicopter flight paths is highly correlated with most measures of noise exposure, even if the predominant cause of annoyance (e.g., fear of a crash) is not necessarily audible airborne sound.

In the abstract, the field research techniques that can produce evidence in favor or contrary to these hypotheses are clear. Opinion surveys can be conducted with representative samples of people in neighborhoods exposed to varying amounts of helicopter (and potentially fixed-wing) noise. Field measurements of aircraft noise exposure can be made prior to and during the interviewing process, in areas with large residential populations living within geographically distinct areas with well-defined boundaries with homogenous exposure to noise produced by similar amounts of rotary- and fixed-wing aircraft operations, little seasonal variability, and a wide range of aircraft types and exposure levels.

Many factors can reduce the reliability and generalizability of social survey findings, compromise the ability to make confirming field measurements of actual noise exposure, increase interviewing costs, or make it difficult to delineate geographic areas eligible for interview. The following are among the factors that complicate or even preclude conduct of a social survey of relative reactions to fixed- and rotary-wing noise exposure at any site:

- Geographic disparities between areas with high helicopter noise exposure and areas with sufficiently large residential populations;
- Greatly disparate amounts of noise exposure due to fixed- and rotary-wing aircraft operations;
- Narrow ranges of exposure levels created by helicopter noise[8];
- Small numbers of operations in particular flight modes (cruise, hover, rapid ascent and/or descent, taxiing, etc.);
- Insufficient numbers of respondents to yield a sample large enough to document small differences in annoyance prevalence rates;
- Unavailability of reliable radar/transponder information about actual rotorcraft flight paths;
- Unreliability of noise modeling due to variability, complexity, seasonality, or sketchy knowledge of operations;
- Excessively high ambient neighborhood noise levels;
- Unavailability of complaint records; and
- Large proportions of non-English speaking residents (for reasons of cost).

The consequence of all of these complications is that few sites are likely to be appropriate for testing all hypotheses. In particular, it may not be possible to test many of the other hypotheses if priority in site selection is given to a direct test of the basic hypothesis that helicopter noise is more annoying than fixed-wing aircraft noise. A major goal of site selection is to identify a set of sites that allows testing for as many hypotheses as feasible.

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2.3 Some General Constraints on Hypothesis Testing

2.3.1 Geographic Disparities Between Areas with High Helicopter Noise Exposure and Areas with Sufficiently Large Residential Populations

Helicopter noise exposure levels are generally greatest in geographic areas near terminal operating areas and in close proximity to flight routes. Good land use and flight route planning tend to minimize residential populations in such areas. Thus, to avoid overflights of residential areas, helipads are often located near shorelines, and approach and departure routes to them often overfly bodies of water rather than residential neighborhoods. Heliports are also often located in commercial and industrial areas with relatively few residences as well as in very high-density business districts with elevated ambient noise levels and urban canyons.

The net effect of good planning practice is to minimize the exposure of residential areas with low ambient noise levels to very high levels of helicopter noise exposure. This, in turn, makes it difficult to identify interviewing sites in which opinions about effects of high levels of helicopter noise can be solicited from suitably large numbers of households.

2.3.2 Disparate Exposures to Fixed- and Rotary-Wing Aircraft Operations

Areas of high exposure to fixed-wing aircraft noise are concentrated around runway ends and in approach and departure corridors along extended runway centerlines. For air traffic safety reasons, these are precisely the areas from which helicopter operations are excluded. It was difficult to locate interviewing sites with high levels of exposure to *both* fixed- and rotary-wing aircraft noise.

It may be less difficult to locate residential areas exposed to intermediate or low levels of both types of aircraft noise, but these are unlikely to be areas in which the greatest differences in the annoyance of rotary- and fixed-wing aircraft noise are likely to be observed. Smaller differences between the annoyance of the two types of aircraft noise require larger sample sizes to discern, and hence, larger residential populations from which to draw such samples.

By definition, the areal extents of low-density residential areas (i.e., those with low outdoor ambient noise levels) are greater than those of high-population density areas. Aircraft noise levels across these greater areas are likely to vary considerably, perhaps by ± 10 dB or more.[9] In turn, this implies that sub-populations in low-population density areas with similar noise exposure levels may be quite small. It may therefore be impractical to stratify samples in low-population density areas into geographic zones within narrow exposure ranges (say, ± 1.5 dB).

If it is not possible to identify large enough sample strata with reasonably homogeneous noise exposure that span a wide enough exposure range, it will be necessary to model exposure levels of individual survey respondents. Because nominal integrated noise model (INM) flight tracks are often assumption-based rather than empirical, credible inferences of helicopter noise exposure levels may be limited to those at sites for which high-quality radar data are available. In practice, this may restrict interviewing sites to those near major airports with good radar coverage. INM was used because the study began before the Aviation Environmental Design Tool (AEDT) was released. INM Version 7.0d and AEDT Version 2b make identical noise predictions in any event.

2.3.3 Narrow Ranges of Exposure Levels Created by Helicopter Noise and/or Small Numbers of Operations in Particular Flight Modes

A narrow range in exposure levels within a given community implies that the *shape* of the dosage-response curve cannot be well defined empirically, regardless of the number of

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respondents.[10] While the findings of this study will be analyzed in part with respect to a fixed-shape dosage-response curve that translates laterally depending on local community tolerance to aircraft noise sources, it is highly desirable to verify the fixed-shape assumption within communities. A narrow exposure range can preclude this possibility.

Furthermore, helicopter sound level emissions can differ markedly between flight modes (in addition to differences in helicopter types). These flight modes can change rapidly along a flight corridor. For example, if a helicopter is descending rapidly, then the BVI may create significant amounts of blade slap, which can affect both its A-weighted sound level as well as any impulsiveness adjustments. On the other hand, if the aircraft goes into a very shallow decent or level flight, blade slap can cease very quickly. Consistency of operation along any given flight corridor would benefit site selection, but such consistency cannot be expected from one flight to the next at sites with differing types of helicopters and modes of operation. Of greatest concern is the ability to estimate when high sound level modes of operation occur, since even a small percentage of high sound level events may control annoyance responses.

2.3.4 Unavailability of Reliable Radar Flight Performance Information About Actual Rotorcraft Flight Paths and Procedures

Reliable radar information is essential for modeling noise levels over the interviewing area. Helicopters almost always operate as visual flight rules (VFR) flights, and hence do not usually file flight plans or transmit a unique transponder code. Helicopter radar tracks must therefore be distinguished from fixed-wing aircraft radar tracks based on unique level flight segments at low altitude, origin or destination at specific heliport locations, or tracks within a known and exclusive helicopter corridor.

A test program is in progress in Los Angeles in which VFR helicopter flights will not use 1200 as their squawk code, but will be assigned unique helicopter codes. This simplifies identification of helicopter tracks. Radar data is a regularly acquired data set at airports with modern airport noise monitoring systems. It is also possible to obtain radar data from FAA. Radar data will be available only within reasonable distances of aircraft surveillance radar (ASR) sites that will be located near airports, and for which no terrain or building obstructions intervene between the ASR sensor and the helicopter paths. Because helicopter tracks are lower and farther from the airport than those of fixed-wing aircraft, this may limit survey sites to those near (within 20 nm and without obstructions) ASR sites. Although helicopter tracks can be distinguished from fixed-wing aircraft tracks by speed, the study sites selected all had programs in place for unique helicopter squawk codes. As noted later, LAS and DCA also assign unique call signs to helicopters.

2.3.5 Questionable Reliability of Noise Modeling Due to Operational Variability, Complexity, Seasonality, or Sketchy Knowledge of Operations

INM-based noise modeling for civil airports is conventionally conducted on an "average annual day" basis. If helicopter flight activity at a potential interviewing site is concentrated in one season of the year, but interviewing is conducted in a different season, standard noise modeling contours may not work well for stratifying samples by noise exposure. Such noise modeling errors could bias observed dosage-response relationships. Likewise, as with any model, generalizations and simplifications are made regarding flight paths.

Noise modeling at the block or individual residence level is preferable for estimating respondents' noise doses. The modeling procedure can also be adjusted to reflect sound

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level measurements made at various sites within the interviewing area. Hence, the combined uncertainty in both measurements and modeling will be reflected in the computed doses. Dose uncertainty is ultimately determined by the less reliable form of estimation, whether measurement or modeling. Selection of interviewing sites should be based in part on the complexity of operations to estimate the size of a difference in exposure that can be attributed to aircraft type. All of these considerations underscore the need to measure, model, and ask attitudinal questions about identical time frames to maximize the strength of association between dose and response.

2.3.6 Excessively High Ambient Neighborhood Noise Levels

Excessively high ambient sound levels in the vicinity of heliports pose several complications for present purposes. In extreme cases, such as heliports in very high population density areas, or in areas with high levels of highway traffic noise, extraneous noise sources may mask the noise of some helicopter operations. High ambient noise levels also complicate estimation of individual noise event levels, and thus may influence differing attitudes toward aircraft noise in urban, suburban and rural areas. Since low-frequency noise level measurements are susceptible to large pseudo-noise artifacts in windy conditions (such as wind interacting with the microphone), one criterion for survey site selection may be typical wind speeds. Areas expected to have high wind speeds and high turbulence levels were avoided. Nonetheless, two unseasonable weather fronts moved through Long Beach during the field data collection period.

2.3.7 Unavailability of Complaint Records

Many airports collect detailed complaint records. This may not be true at all heliports. Availability of complaint records was considered in site selection.

2.3.8 Large Proportions of Residents Ineligible or Unavailable for Interview

Unless the expense of translating the survey instrument (questionnaire) into other languages is affordable, response rates may be low in areas with large proportions of non-English speakers. A highly transient population (for example, of students, as in the vicinity of a helicopter-served hospital or at a major university) can also be difficult to contact.

2.4 Discussion of Potential Tests of Hypotheses

Several of the hypotheses summarized in Table 1-1 can be tested via analyses of responses to individual questionnaire items about the annoyance of aircraft noise. Several other hypotheses are testable by comparing responses across sites chosen for the present study, or by less direct means described below. The suggested form of closed response category annoyance items is:

> "While you've been at home during (*time period of interest*), have you been bothered or annoyed by (*noise source*)?"

and if yes,

> "Would you say that you've been slightly, moderately, very, or extremely annoyed by aircraft noise while you've been at home during (*time period of interest*)?"

The time period of interest can be either (or both) the week prior to interview—during which extensive empirical noise measurements were made at field sites—or the year prior

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to interview, over which exposure estimates may be made from modeling of annual average day exposure.

Hypothesis 1: Decibel for decibel, rotary-wing aircraft noise is more annoying than fixed-wing aircraft noise.

The most basic of the hypotheses holds that exposure to noise produced by rotary-wing aircraft is more annoying than exposure to an equivalent amount of noise produced by fixed-wing aircraft. The hypothesis does not specify *why* one type of aircraft noise may be more annoying than another—for example, because of spectral differences in emissions, indoor vibration or rattle excited by rotary-wing aircraft, greater noticeability of helicopter noise in some ambient noise environments, and so forth. Thus, even if the hypothesis can be empirically confirmed, it would not necessarily yield enough understanding to be useful for improved explanatory, regulatory, or policy purposes.

As discussed in Section 1.2 in general terms, and Appendix A in greater detail, the complex and varied nature of rotary-wing operations can make it difficult to fully test this hypothesis. Helicopter noise may vary relatively little from fixed-wing aircraft noise at some locations and in some flight regimes (e.g., at off-track, long-range, sideline locations during straight and level cruise) but can vary greatly from that of fixed-wing aircraft in other flight regimes (e.g., in duration, level, audibility, predictability, and impulsiveness during low-altitude maneuvering). The most useful tests of this hypothesis must be able to characterize not just exposure levels, but also the nature of helicopter noise emissions. It may be necessary to test this hypothesis at more than one site, since no one site may include all of the helicopter flight regimes of potential interest.

The most direct test of this hypothesis would compare the annoyance judgments of the same interview respondents to very similar levels of fixed- and rotary-wing aircraft noise. If it is possible to conduct interviews at sites with sufficient numbers of respondents who are exposed to comparable levels of fixed- and rotary-wing aircraft noise, the general form of questionnaire items that could test this hypothesis would be:

> "While you were at home last week, did helicopter noise bother or annoy you?"
>
> "Would you say you were not at all, slightly, moderately, very, or extremely annoyed by noise from helicopters while you were at home last week?"
>
> "While you were at home last week, did noise from aircraft *other* than helicopters bother or annoy you?"
>
> "Would you say you were not at all, slightly, moderately, very, or extremely annoyed by noise from aircraft other than helicopters while you were at home last week?"

It could also be helpful to include a questionnaire item seeking a direct comparison of the annoyance of fixed- and rotary-wing aircraft noise, of the general form as follows:

> "While you were at home last week, were you annoyed more greatly by noise made by helicopters or noise made by other types of aircraft?"

As noted earlier, it may not be possible to identify sites at which sufficient numbers of eligible respondents are exposed to similar amounts of *both* forms of aircraft noise. A less direct test of the hypothesis is still possible if this should prove to be the case. The opinions of respondents about helicopter noise could be compared with the opinions about fixed-wing aircraft noise of 75,000 respondents to prior surveys about the annoyance of aircraft noise (Fidell et al. 2011). Annoyance prevalence rates measured in the planned study could then be compared with previously measured annoyance prevalence rates at as many as hundreds of sites with similar noise exposure levels at which respondents had been queried about their annoyance with exposure to fixed-wing aircraft noise.

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Hypothesis 2: The prevalence of annoyance due to rotary-wing noise is most appropriately predicted in units of A-weighted cumulative exposure.

No specific questionnaire items are required to test this hypothesis. The utility of the A-weighting network for predicting the annoyance of helicopter noise can be gauged instead via simple calculations of variance accounted for in the relationship between various measures of noise exposure and the prevalence of a consequential degree of annoyance at interviewing sites. All that is required is that noise measurements accompanying interviewing be conducted in such a manner that alternative frequency weightings and other adjustments can be calculated. This can be accomplished by capturing raw acoustic waveforms and post-processing them with reference to radar-confirmed helicopter flight operations.

As in the case of testing Hypothesis 1, a fully generalizable test of Hypothesis 2 requires both social and acoustic measurements of helicopter noise produced in varying flight regimes.

Hypotheses 3 and 4: Main rotor impulsive noise controls the annoyance of helicopter noise (and hence requires an impulsive noise "correction" to A-weighted measurements); the prevalence of annoyance due to helicopter noise is strongly influenced by indoor secondary emissions (rattle and vibration) due to its low-frequency content.

Hypotheses 3 and 4 are most appropriately tested at sites exposed to considerable amounts of BVI (or "blade slap") noise. Due to the highly directional nature of blade slap noise, this constraint may limit testing of these hypotheses to sites exposed to landing noise in the immediate vicinity of helipads, or to cruise noise in the direction of flight and directly beneath helicopter flight paths.

Questionnaire items of interest for testing Hypothesis 3 require a "yes" response to a prior question about annoyance with helicopter noise.[11] Respondents who report some degree of annoyance with helicopter noise can then be asked questions of the form:

> "Have you been not at all, slightly, moderately, very, or extremely annoyed by repeated pounding or slapping noises made by helicopter rotors?"
>
> "Have you been not at all, slightly, moderately, very, or extremely annoyed by droning noises made by helicopters?"
>
> "Have you been slightly, moderately, very, or extremely annoyed by whining noises made by helicopters?"
>
> "What sort of helicopter noise annoys you most?"

Questionnaire items of interest for testing Hypothesis 4 also require a "yes" response to a prior question about annoyance with helicopter noise. Respondents who express some degree of annoyance with helicopter noise can then be asked previously tested (Fidell et al., 1999, 2002a) questions of the form:

> "Do helicopters make vibrations or rattling sounds in your home?"
>
> "Are you bothered or annoyed by these vibrations or rattling sounds in your home?"
>
> "Would you say that you are slightly annoyed, moderately annoyed, very annoyed, or extremely annoyed by vibrations or rattling sounds in your home?"
>
> "About how often do you notice vibrations or rattling sounds in your home made by helicopters?"

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Hypothesis 5: The prevalence of annoyance due to helicopter noise is heavily influenced by nonacoustic factors.

The most direct test of this hypothesis would require soliciting annoyance judgments from respondents in two or more communities with very similar helicopter noise exposure but very different tolerances for helicopter noise. It is not yet apparent whether such pairs of communities can be found.

An alternative test of this hypothesis could be conducted, however, with reference to the database of observations of annoyance prevalence rates for fixed-wing aircraft in more than 500 communities worldwide. The survey instrument itself would not need any items other than the customary ones described in the discussion of Hypothesis 1.

Hypothesis 6: The prevalence of annoyance due to helicopter noise is heavily influenced by proximity to helicopter flight paths.

This hypothesis is most readily tested at sites along well-defined and heavily trafficked helicopter routes. Geographic information system (GIS) methods can be used to estimate how long helicopters flew within varying distances of respondents' homes over the course of the week prior to interview. Since proximity to flight paths and noise exposure levels are highly correlated, it would be necessary to conduct ancillary GIS-based analyses of complaint rates to distinguish between exposure and proximity as determinants of annoyance and complaints, such as those described below.

Figure 2-1 and Figure 2-2 show spatial complaint densities in the vicinity of Seattle-Tacoma International Airport (SEA) before and after the opening of a new runway. Both the numbers and westward shift of complaints are consistent with a small but abrupt shift in aircraft noise

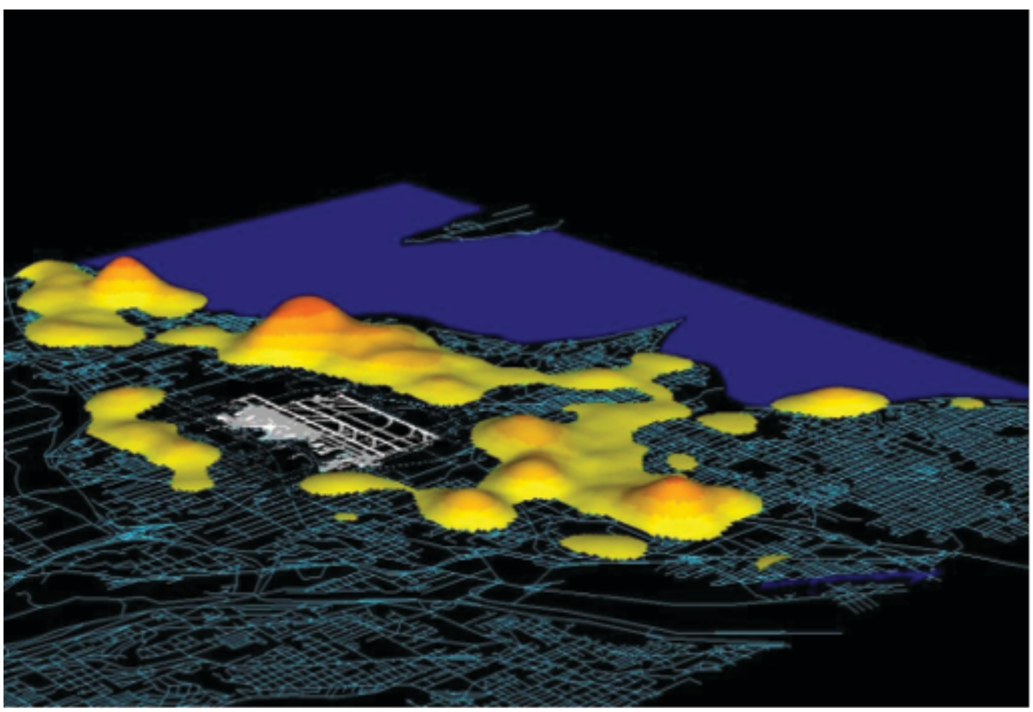

Figure 2-1. Three-dimensional spatial density representation (viewed obliquely) of complaints in 12 months prior to the start of operations on third runway.

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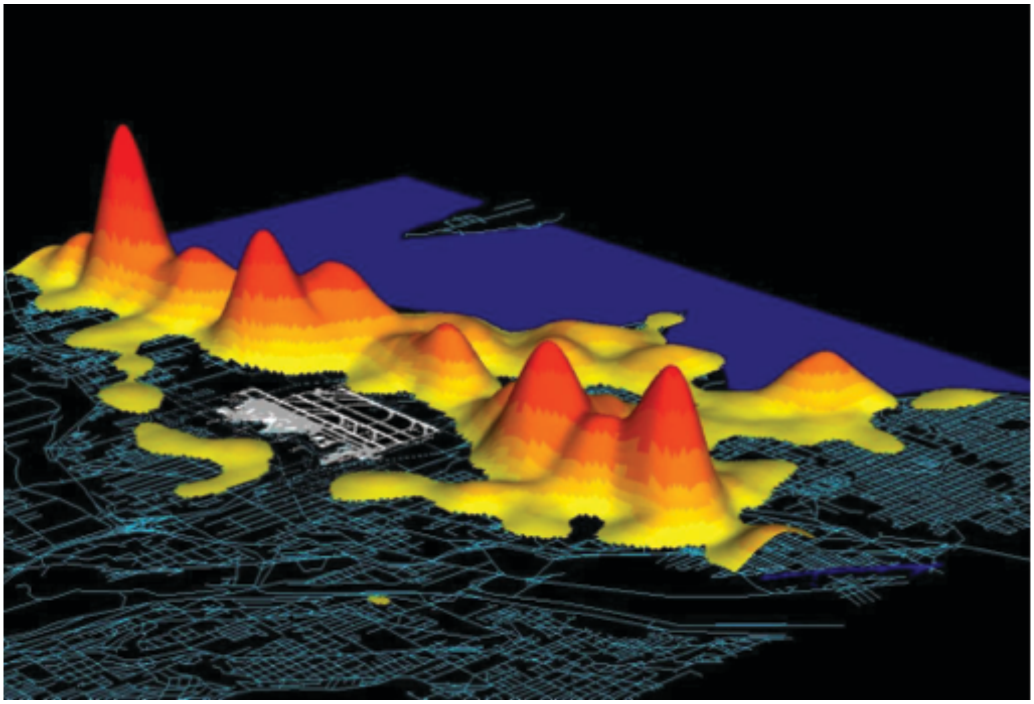

Figure 2-2. Three-dimensional spatial density representation (viewed obliquely) of complaints in 12 months following the start of operations on third runway.

exposure levels in the immediate vicinity of the airport. Actual changes in the geographic distribution of complaints were closely contained in the vicinity of changes in flight paths associated with the runway opening. The actual change in DNL was minor. Even though the change received widespread media coverage, the pattern of changes in complaints could not be attributed to the media coverage per se. Rather than reflecting a community-wide response to media coverage, the changes in spatial density of complaints were limited to the vicinity of changed flight tracks.

Hypothesis 7: Complaints lodged about helicopter noise are more reliable predictors of the prevalence of annoyance than measures of exposure to helicopter noise or proximity to helicopter flight paths.

One or more questionnaire items inquiring whether social survey respondents had lodged single or multiple complaints about helicopter noise might be a useful predictor of the prevalence of annoyance with helicopter noise. It is conceivable that responses to such items might predict actual annoyance prevalence rates as well as measures of exposure, per se, or measures of proximity to helicopter flight paths.

If access is available to helicopter noise complaints at airports with appreciable numbers of helicopter operations, it might be possible to compare empirical measurements of annoyance prevalence rates with total numbers of complaints and numbers of complaints per complainant, in the manner described by Fidell et al. (2012). The latter reference demonstrated that the number of complaints per complainant at half a dozen airports closely followed a power law relationship known as Zipf's Law.

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CHAPTER 3

Site Selection and Opinion Survey Methods

3.1 Introduction

This chapter describes site selection and measurement methods. Section 3.2 discusses the survey site selection process. Criteria used to assess the suitability of survey sites are presented along with the sites considered and a recommendation for survey sites for the study. Section 3.3 describes the questionnaire along with discussions of its form and organization as well as of interviewing methods.

Section 3.4 is a general discussion of the role of sample size in social survey design. Noise measurement methods are described in Section 3.7, along with specific discussion of sample size concerns.

3.2 Survey Site Evaluation

3.2.1 Overview of Survey Site Selection Process

Survey site selection is complicated by the fact that there is no such thing as generic "helicopter noise." Acoustic emissions of helicopters vary much more with flight regime than do those of fixed-wing aircraft. Sites exposed to sideline noise from straight and level flight have considerably different acoustical experiences than those near landing pads that can experience prominent blade slap from steeply descending helicopters. Sites on either side of the flight path can experience different acoustical exposures due to the directionality of BVI impulsive noise and tail rotor noise. Some sites may be exposed to relatively short overflights, while others may experience prolonged exposures from hovering, orbiting, or otherwise maneuvering helicopters. The selected sites should provide as wide a range of aircraft noise exposures as possible.

The primary consideration for survey sites is that the residents must be exposed to appreciable amounts of civil helicopter noise and, where possible, fixed-wing aircraft noise. If only a small portion of an exposed population is annoyed by aircraft noise, or is only slightly annoyed by it, then unreasonably large numbers of interviews may be necessary to demonstrate that population proportions of annoyance differ significantly from zero. Further, it may not be possible to perform a credible dosage-response analysis if annoyance prevalence rates are low.

As a generality, a large number of survey responses over as wide a range of helicopter flight regimes and nonmilitary noise levels is preferred. To maximize the potential for responses, thousands of households should be eligible for interviews at a site. Further, individual sites should be exposed to as great a variety of aircraft types as possible. If a site is overflown only by a small number of aircraft types, such as a small tour helicopter or a large military rotorcraft, it may be difficult to generalize any findings beyond those aircraft types.

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One of the primary goals of the project is to determine the relative annoyance of exposure to rotary- and fixed-wing aircraft. Residents eligible for interview would ideally be exposed to noise from both forms of aircraft, if possible. Further, the magnitude of residential noise exposure levels of the two forms of aircraft noise should be roughly comparable to support straightforward analyses and inferences.

In addition to the characteristics described above, the survey sites should preferably lack any features that preclude or complicate collection and processing of interview and acoustic information. For example, unambiguous aircraft noise exposure measurements require that non-aircraft noise levels at measurement sites not approach or exceed aircraft noise levels. To facilitate valid measurement of cumulative (average annual day) exposure metrics, aircraft operations should have little seasonal variability. Neighborhoods with large proportions of non-English speaking households can increase the cost and complexity of administering questionnaires. Detailed radar data and helicopter performance state data will be needed to provide an accurate basis for noise modeling.

The following sections describe the site selection process. The primary, secondary, and survey optimization criteria used to select sites are discussed in Section 3.2.2. Section 3.2.3 presents the locations that were considered and discusses sites that satisfy the primary survey site criterion. A comparison of the potential survey sites relative to the selection criteria is presented in Section 3.2.4. Finally, Section 3.2.5 presents the recommended sites along with a discussion of the rationale for selecting them.

3.2.2 Survey Site Selection Criteria

Selection of survey sites was accomplished in several steps. The primary criterion—sufficient civil helicopter overflights of residential neighborhoods—was used to develop an initial list of potentially acceptable sites. Secondary criteria were used to evaluate the acceptability of these potential sites to provide high quality data required for the analysis. Sites that were clearly unable to meet the secondary criteria were not considered further. The sites that were at least minimally acceptable were then compared and summarized in Table 3-1.

The primary criterion for selection of survey sites was sufficient rotary-wing aircraft overflight of residential land. Four general types of areas were believed likely to satisfy the primary selection criterion: those near commercial airports, neighborhoods near military airfields that are also exposed to noise from civil aircraft operations, neighborhoods near hospitals, and areas near civil heliports.

3.2.2.1 Secondary Criteria for Selecting Interviewing Sites

Secondary criteria were used to further appraise the sites satisfying the primary criterion. Table 3-1 contains a list of the secondary criteria along with their relative importance and a summary discussion of each. The following paragraphs discuss secondary selection criteria in greater detail.

The first of the secondary site selection criteria is the absence of any conditions that would unnecessarily increase the cost or complexity of data collection. Increased sampling, interviewing, and acoustic measurement costs required for sites outside the contiguous 48 states were considered unjustifiable.

While noise measurements were made concurrently with interviewing, noise modeling was required to quantify noise exposures at each site. The noise measurements were used to validate and improve the accuracy of modeled noise levels. Reliable radar data for aircraft operations in the week before and during interviewing was also needed and acquired.

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Table 3-1. Secondary criteria for site selection, ranked by importance.

CRITERION	IMPORTANCE	DISCUSSION
Survey Feasibility/Cost	Very High	Survey sites must be suitable for both noise measurement and interviewing. Higher costs for sites outside the continental United States are not justifiable.
Availability of Radar Data and Performance State Data	Very High	Radar data is essential for accurate and meaningful noise modeling. Performance state will be based on noise model profiles.
Aircraft Noise Exposure Levels	High	Low noise exposures are likely to produce small annoyance prevalence rates and require larger sample sizes.
Background Noise Levels	High	Aircraft noise should not be masked by other community sources.
Fleet Mix	Moderate	Small variability in the fleet of aircraft limits the generalizability of the findings.
Seasonality	Moderate	Highly seasonal operations may result in misleading cumulative (average annual day) exposure metrics and constrain schedules.
Availability of Complaint Records	Moderate	Complaint information can be helpful for analytic purposes. (A recent D.C. Court of Appeals ruling on regulation of helicopter noise was largely based on complaints.)
Predominant Language	Moderate	Neighborhoods with predominantly non-English speaking households increase complexity and cost of social surveys.

The noise exposure levels from aircraft overflights must engender measureable annoyance prevalence rates. Both the absolute level of the exposure from single overflights and numbers of overflights are important. In addition, each site must have sufficient aircraft noise exposure to result in an annoyance prevalence rate that can be detected by a reasonable number of interviews.

Similarly, background noise levels (those due to non-aircraft noise sources) must not be so great that they mask single-event aircraft noise levels. Readily generalizable findings of the social survey require exposure to a variety of aircraft types and flight regimes. Sites with little variability in types of aircraft overflights were thus undesirable.

Sites with high seasonal variability in aircraft operations and noise exposures were also undesirable. Such sites would result in misleading cumulative (annual average day) noise exposure metrics. Further, high seasonal variability could unreasonably constrain interviewing schedules. Likewise, special events such as parades and large sporting events with extensive helicopter activity provide only short exposures and are not the focus of this study.

3.2.2.2 Optimizing Social Survey Design

Potential survey sites that satisfied both the primary and secondary selection criteria were then compared with respect to criteria for optimizing the design of the social survey. These criteria are listed in Table 3-2 along with their relative importance and a brief summary.

3.2.3 Sites Considered

The primary criterion for selection of interviewing sites was sufficient rotary-wing aircraft overflights of populated areas. Areas that satisfy this basic requirement are typically found around civil airports, military airfields, heliports, and hospitals. Table 3-3 lists facilities that satisfy the primary criterion.

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Table 3-2. Survey optimization criteria by importance.

CRITERION	IMPORTANCE	RATIONALE FOR CRITERION
Mix of Exposure Levels	Very High	Wider range of noise exposures provides more defensible, credible, and generalizable dose-effect relationships.
Mix of Helicopter Type and Operational Regimes	High	Helicopter noise is highly variable in character and dependent on both helicopter type and flight regime. The greater the range in these factors, the more generalizable the results.
Mix of rotary-wing and fixed-wing aircraft	High	Sites exposed to both fixed-wing and helicopter overflights will allow for a direct comparison of annoyance rates.
Relative rotary-wing and fixed-wing exposure levels	Moderate/High	Smaller disparities between rotary- and fixed-wing aircraft noise exposures simplify study design and reduce the need for statistical measures to compensate for large disparities.
Use of unique transponder (XPNDR) Codes	Moderate	The use of unique XPNDR codes facilitates identification of aircraft type.

3.2.3.1 Civil Airports

Figures 3-1 through Figure 3-4 show published helicopter routes for Van Nuys Airport, Torrance Airport, Long Beach Airport, and Las Vegas Airport. Actual helicopter routes for Las Vegas, derived from radar tracking, are shown in Figure 3-5. The Long Beach and Las Vegas figures also show residential land uses (red-shaded) in the areas around the airport. Published helicopter routes in the region around Reagan National Airport are shown in Figure 3-6.

Heliports reviewed include the numerous heliports in the Washington, D.C., area, Manhattan, New York, and Paulus Hook, New Jersey. Figure 3-6 and Figure 3-7 show heliports and published helicopter routes in the Washington, D.C., area. Figure 3-7 shows the Georgetown/Northern Arlington area in detail. This area of D.C. is exposed to helicopter operations over the river as well as fixed-wing aircraft from DCA that also fly over the river, albeit at higher altitudes. Residential land uses are shaded in red. Mixed-use land uses that include residential uses are shaded in orange. Figure 3-8 shows radar tracks for aircraft operations in this area. The aircraft altitudes are shown to distinguish helicopter operations from fixed-wing aircraft approaching and departing from Reagan National Airport. Aircraft at altitudes below 600 feet in Figure 3-8 are helicopters, while those above 600 feet are fixed-wing aircraft.

Table 3-3. Initial list of sites considered.

CIVIL AIRPORTS	MILITARY FIELDS	HOSPITALS*	HELIPORTS
Van Nuys, CA (VNY) Long Beach, CA (LGB) Torrance, CA (TOR) Las Vegas, NV (LAS) Reagan National, D.C. (DCA) Anchorage, AK (ANC) Kahului, Maui, HI (OGG) Hilo, Hawaii, HI (ITO) Lihue, Kauai, HI (LIH)	Camp Pendleton MCAB, CA Miramar MCAS, CA Ft. Rucker, AL Ft. Eustis, VA Edgewood Arsenal, MD 29 Palms MCB (Joshua Tree), CA	San Francisco General, CA UCLA Medical Center, CA Massachusetts General, MA	Manhattan, NY East 34th Street, NY MetLife Building, NY West 30th St., NY Paulus Hook (Jersey City), NJ Hamptons, NY Boston Harbor, MA Washington, D.C., heliports

*Additional hospitals with helicopter noise issues were reviewed for consideration but excluded because they had less than one flight per day on average. The three hospitals noted have near-daily operations

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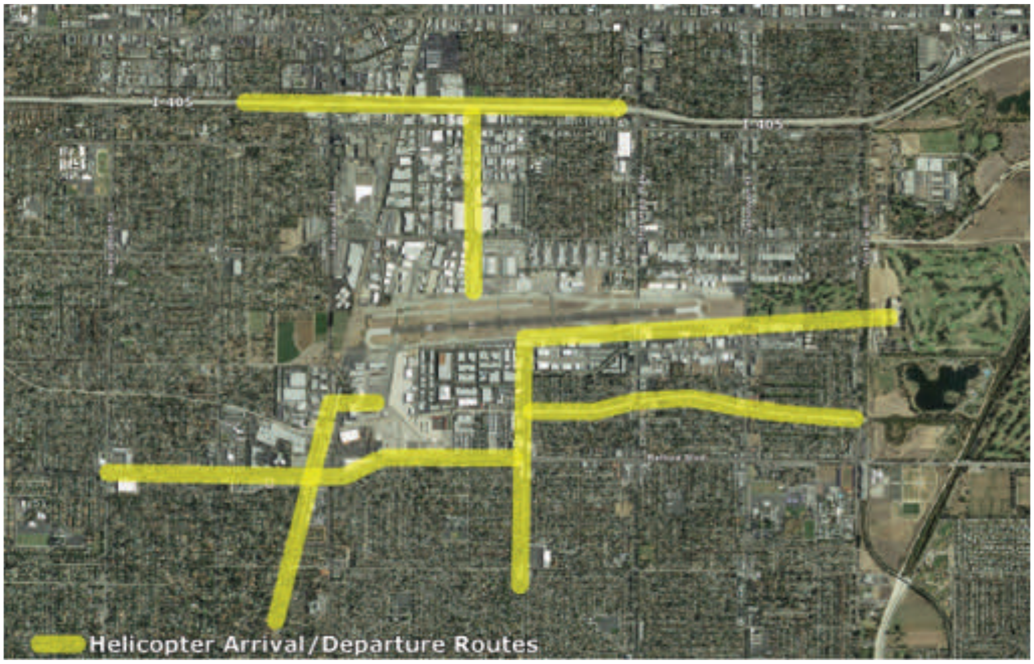

Figure 3-1. Van Nuys Airport.

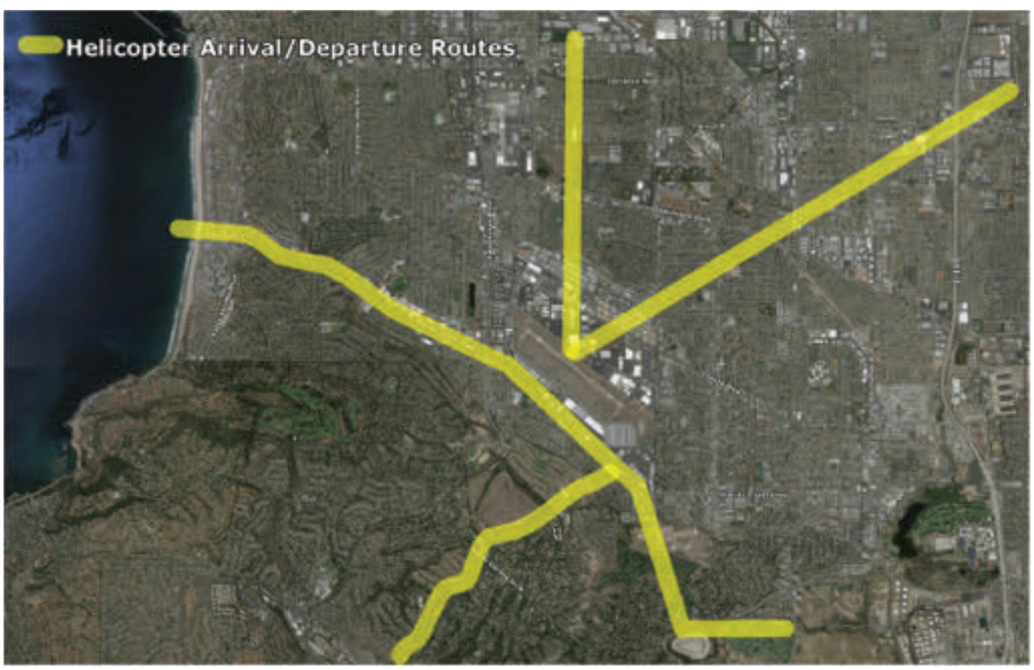

Figure 3-2. Torrance Airport.

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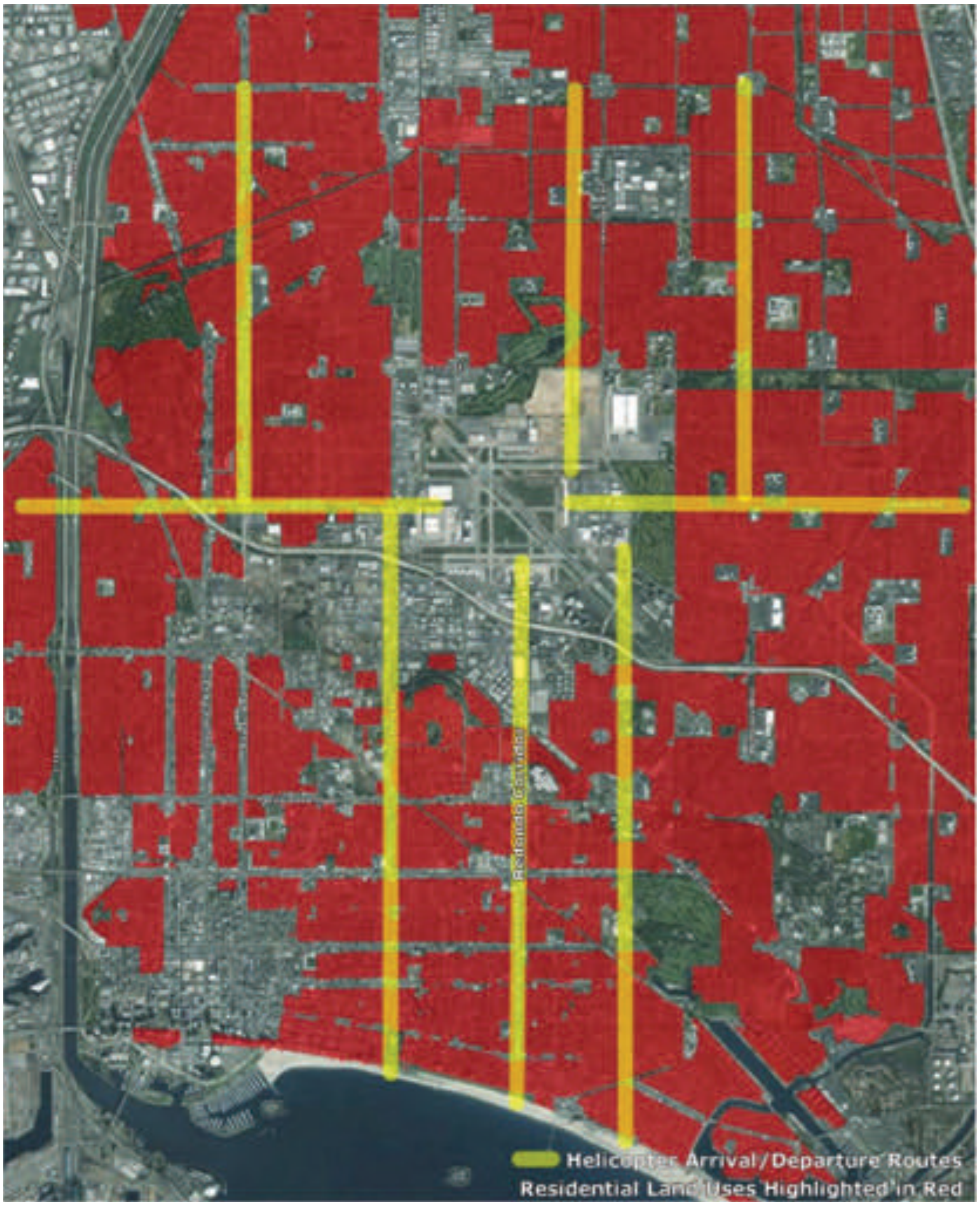

Figure 3-3. Long Beach Airport.

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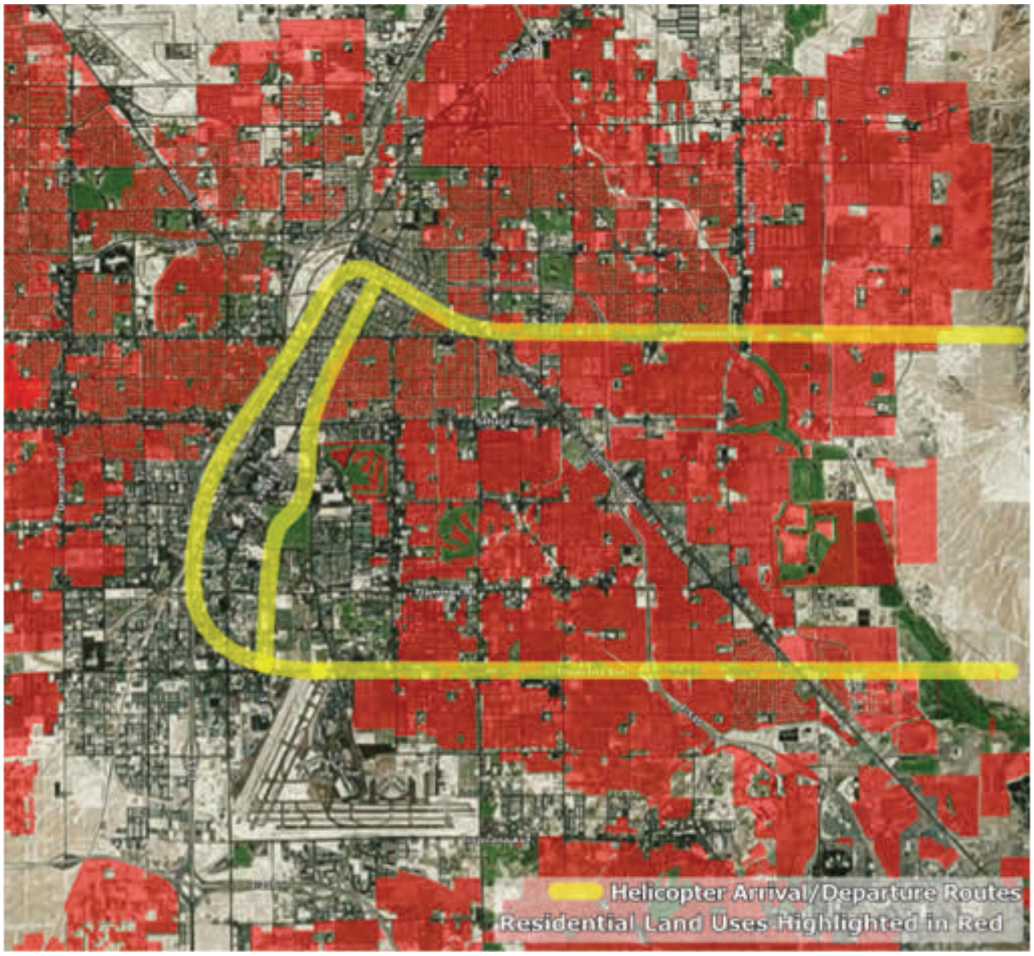

Figure 3-4. Las Vegas International Airport.

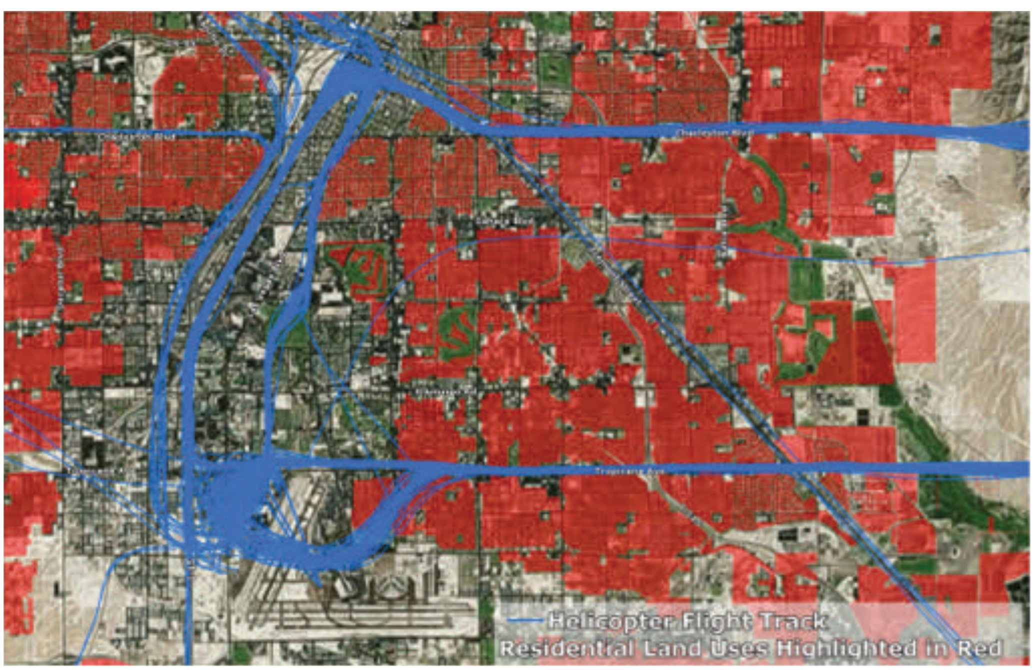

Figure 3-5. Las Vegas helicopter radar tracks.

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Figure 3-6. Greater Washington, D.C., helicopter routes.

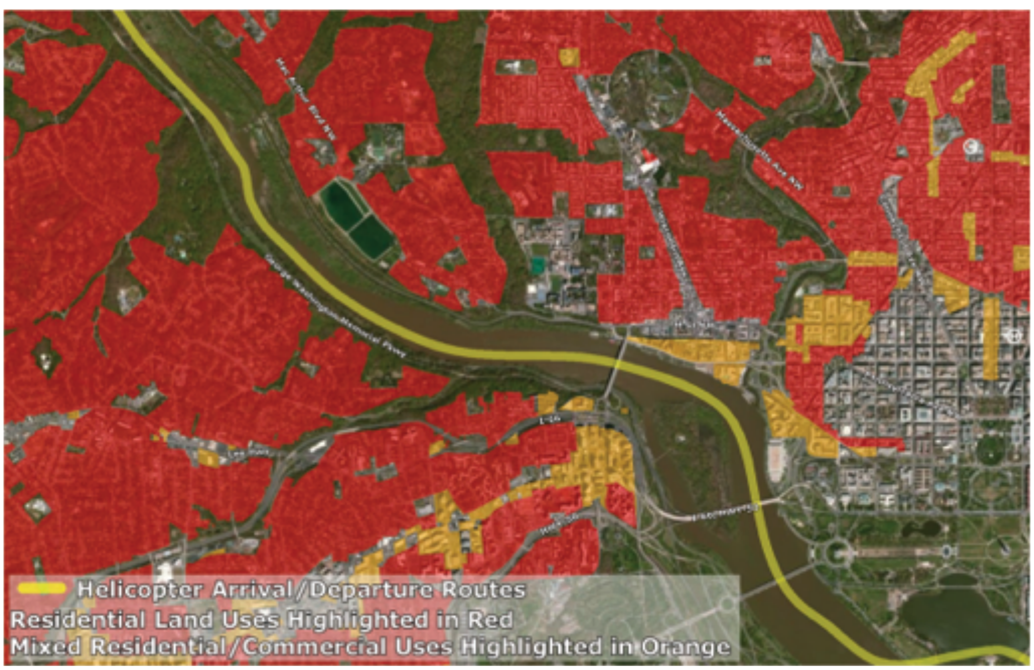

Figure 3-7. Georgetown, Washington D.C.

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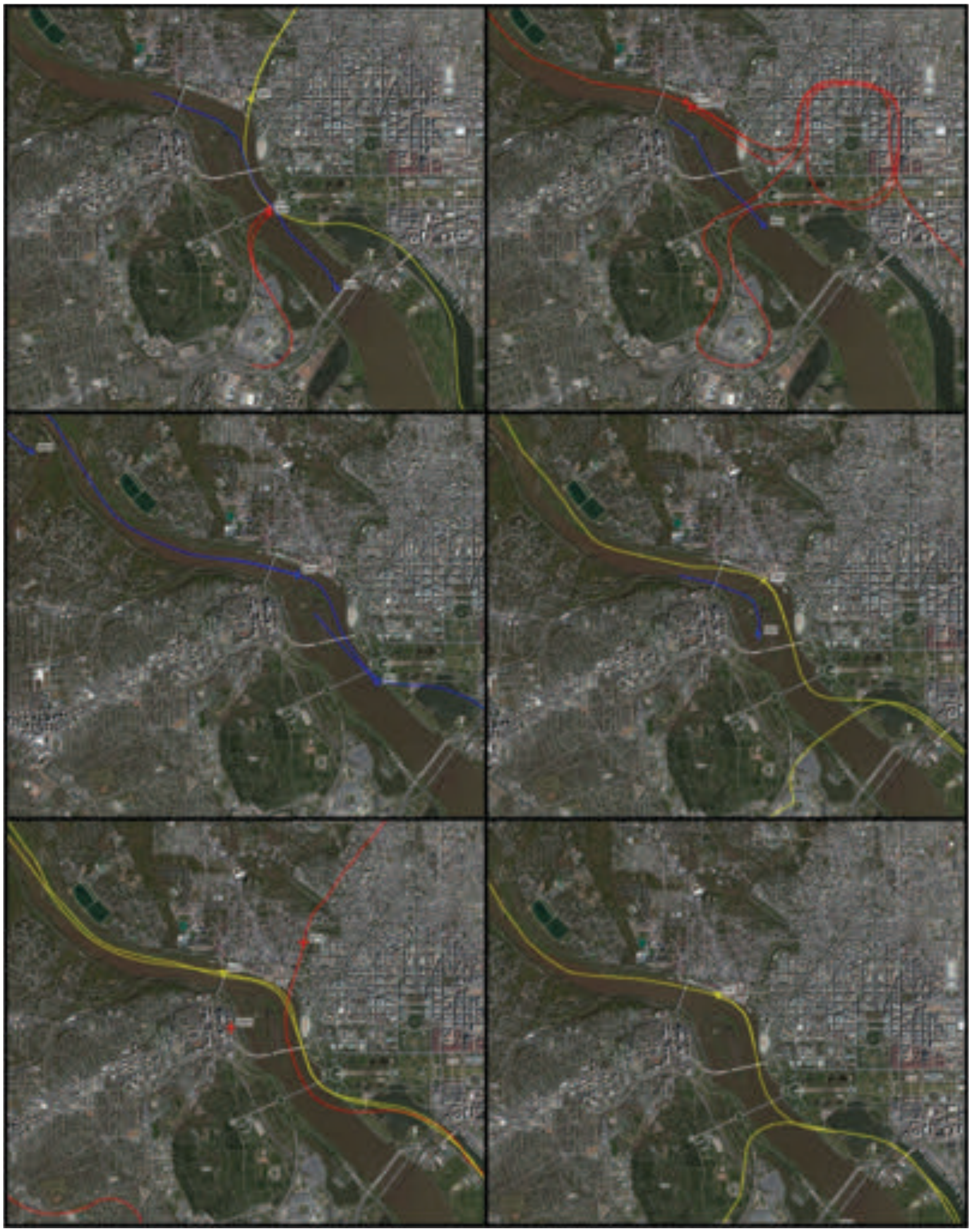

Figure 3-8. Georgetown, Washington, D.C., radar flight tracks.

Figure 3-9 and Figure 3-10 show the published helicopter routes and nearby land uses in the immediate vicinity of the Manhattan and Paulus Hook helistops. Residential land uses are shaded in red. Mixed-use land uses that include residential uses are shaded in orange.

3.2.4 Site Evaluation

Table 3-4 summarizes the considered sites' characteristics relative to the selection criteria. The type of facility is presented along with information relevant to the primary, secondary, and

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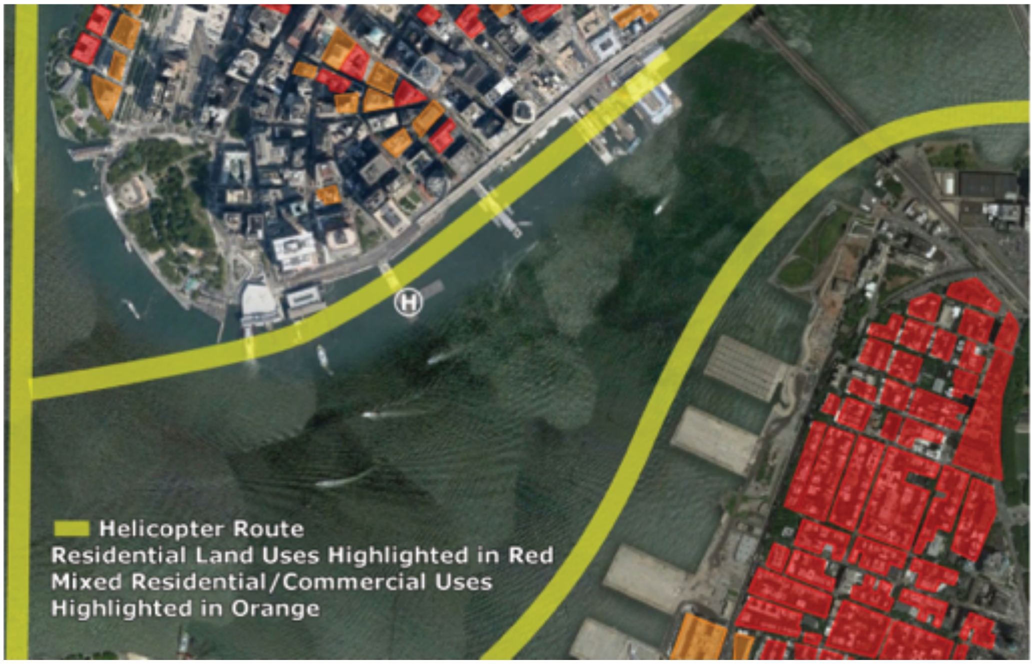

Figure 3-9. Manhattan heliport.

Figure 3-10. Paulus Hook heliport.

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Table 3-4. Survey site evaluation summary matrix.

		PRIMARY CRITERIA		SECONDARY CRITERIA		OPTIMIZATION CRITERIA		
SITE	FACILITY TYPE	NUMBER OF DAILY OPERATIONS	RESIDENTIAL OVERFLIGHTS	RADAR TRACK AVAILABILITY	BACKGROUND NOISE	MIX OF AIRCRAFT TYPE	UNIQUE XPNDR CODE	RECOMMENDED FOR FURTHER CONSIDERATION
Van Nuys, CA (VNY)	Airport	Unknown	Yes	Yes	Acceptable	Good	Yes	Yes
Long Beach, CA (LGB)	Airport	34	Yes	Yes	Acceptable	Good	Yes	Yes
Reagan National, D.C. (DCA)	Airport	~35	Yes	Yes	Acceptable	Excellent	Yes	Yes
Las Vegas, NV (LAS)	Airport	237	Yes	Yes	Acceptable	Very Good	Yes	Yes
Kahului, Maui, HI (OGG)[1]	Airport	Unknown	Yes	Yes	Acceptable	Poor	No	No
Hilo, Hawaii, HI (ITO)[1]	Airport	Unknown	Yes	Yes	Acceptable	Poor	No	No
Lihue, Kauai, HI (LIH)[1]	Airport	Unknown	Yes	Yes	Acceptable	Poor	No	No
Anchorage, AK (ANC)[1]	Airport	Unknown	Yes	Yes	Acceptable	Poor	No	No
Torrance, CA (TOR)	Airport	Unknown	Yes	Yes	Acceptable	Poor	Yes	Yes
Camp Pendleton MCB, CA	Military	Unknown	No	Unknown	Acceptable	Poor	No	No
Miramar MCAS, CA	Military	Unknown	Yes	Yes	Acceptable	Poor	No	No
Ft. Rucker, AL	Military	Unknown	Yes	Unknown	Acceptable	Poor	No	No
Ft. Eustis, VA	Military	Unknown	Yes	Unknown	Acceptable	Poor	No	No
Edgewood Arsenal, MD	Military	Unknown	Yes	Unknown	Acceptable	Poor	No	No
29 Palms MCB (Joshua Tree), CA	Military	Unknown	No	Unknown	Acceptable	Poor	No	No
San Francisco General[2]	Heliport	None	No	Yes	Excessive	Good	No	No
UCLA Medical Center	Heliport	Low	Yes	Yes	Excessive	Good	Yes	No
Massachusetts General	Heliport	Low	Yes	Yes	Excessive	Good	No	No
Manhattan	Heliport	Unknown	No		Excessive			No
East 34th Street	Heliport	Unknown	Yes		Excessive			No
MetLife Building	Heliport	Unknown	Yes		Excessive			No
Hamptons	Heliport	Unknown	Yes	No	Acceptable	Good	No	No
Paulus Hook (Jersey City)	Heliport	0[3]	No	n/a	Excessive	n/a	n/a	No
Boston Harbor	Heliport	Unknown	Yes		High			No

[1]Eliminated from consideration due to travel costs.
[2]Conditional Use Permit for heliport not approved.
[3]The helipad owner has recently ceased all operations at this facility. It is not known if, or when, they will resume.

optimization criteria. The table shows approximate number of daily helicopter operations, along with information about the presence or absence of overflights of residential neighborhoods. The availability of radar tracks and a characterization of the background noise levels in the vicinity of the site are also shown. A characterization of the mix of aircraft types at each location, and the use of unique XPNDR codes, is used to evaluate the optimization criteria. The final column of Table 3-4 indicates whether further consideration was warranted for each of the sites considered.

3.2.5 Site Recommendations

Site visits were conducted at Long Beach, Las Vegas, Washington, D.C., Van Nuys, and Torrance. Of these, Long Beach, Las Vegas, and Washington, D.C., were selected for the social surveys.

3.3 Questionnaire

The social survey was intended to test as many of the hypotheses as feasible, as described in Chapter 2 about the annoyance of helicopter noise at three interviewing sites. The hypotheses concern community reactions to various aspects of helicopter noise exposure and required detailed acoustic and aircraft position ("radar") information for testing. Some hypotheses required analyses of explicit questions about the nature of annoyance with helicopter noise. Other hypotheses

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could be evaluated simply by comparing dosage-effect relationships constructed with different noise metrics, or other variables, as independent (predictor) variables.

3.3.1 Form and Organization of Questionnaire

An ISO Technical Specification (15666:2003 "Acoustics—Assessment of noise annoyance by means of social and socio-acoustic surveys") offers general recommendations for the order and wording of transportation noise annoyance questionnaire items. The recommendations are intended to facilitate meta-analysis and interpretation of survey findings, not to further specific research goals.

All of the Technical Specification's recommendations are merely informative, and are qualified by provisions that they not conflict with survey goals. The ISO specification explicitly states, "specific requirements and protocols of some social and socio-acoustic studies may not permit the use of some or all of the present specifications. This Technical Specification in no way lessens the merit, value or validity of such research studies." The suggested organization of the present questionnaire follows that of many prior studies of the prevalence of annoyance with aircraft noise exposure in airport neighborhoods.

3.3.2 Questions for All Interviewing Sites

Table 3-5 shows the complete questionnaire. Instructions to interviewers that are not posed to respondents are shown in italic blue or red: questions posed to respondents are in black. The interview was introduced as a study of neighborhood living conditions, not as one of the annoyance of exposure to helicopter noise. This approach reduces the likelihood that respondents will either grant or refuse an interview, or bias their responses to questionnaire items, based on foreknowledge of the purpose of the study.

Item 1 was intended to confirm eligibility for interview. Respondents who did not confirm residence at the household street address (e.g., guests, relatives, household employees, etc.) were not eligible for interview, but were asked whether and when an adult resident would be available for interview. The response coding provides information for a test of a potential relationship between duration of residence and degree of annoyance with aircraft noise—an indirect measure of adaptation.

Items 2 and 3 were included for the sake of consistency with the introduction of the study as one of neighborhood living conditions. They also provided an opportunity, prior to any mention of noise-related concerns, for spontaneous mention of helicopter noise as the least-favored aspect of neighborhood living.

Items 4 and 4A introduced respondents to the closed category absolute judgment scale used in all subsequent items for expressing degrees of annoyance with noise exposure. Item 5 was the first explicit mention of noise as a neighborhood living condition of interest.

Items 6 and 6A sought information about the frequency of notice of helicopter noise in the week preceding interview. Items 7 and 7A inquired about the degree of annoyance of helicopter noise.

Several variant sets of questionnaire items could follow Item 7A, depending on the suitability of noise exposure and other site-specific circumstances. These included:

- Variant 1: Assessment of relative annoyance of exposure to fixed- and rotary-wing aircraft noise, intended for administration at sites exposed to both types of flight operations.
- Variant 2: Assessment of relative contributions of different aspects of helicopter noise for sites exposed to BVI ("blade slap"), thickness, blade-wake interaction, and ducted fan tail rotor noise, intended for administration at sites exposed to noise of diverse helicopter operations.

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Table 3-5. List of questionnaire items.

<table>
<tr><td>Item 1</td><td>How long have you lived at (street address)?</td></tr>
<tr><td colspan="2">Response/Coding Categories: don't live at this address (0, ask to speak with resident, schedule a callback, or terminate interview), less than 1 year (1), at least 1 year but less than 2 years (2), 2 to 5 years (3), 5 to 10 years (4), more than 10 years (5), don't know (6), refused (7)</td></tr>
<tr><td>Item 2</td><td>What do you like best about living conditions in your neighborhood?</td></tr>
<tr><td colspan="2">Record verbatim response (coding per optional post hoc content analysis)</td></tr>
<tr><td>Item 3</td><td>What do you like least about living conditions in your neighborhood?</td></tr>
<tr><td colspan="2">Record verbatim response, code as "aircraft noise-related" (1) or "non-aircraft noise-related" (2)</td></tr>
<tr><td>Item 4</td><td>Would you say that your neighborhood is quiet or noisy?</td></tr>
<tr><td colspan="2">Response/Coding Categories: quiet (0), quiet except for aircraft (of any kind) (1), noisy (2), don't know (5), refused (6), skipped (7)</td></tr>
<tr><td colspan="2">If respondent answers "noisy," ask Item 4A; if any other response to Item 4, ask Item 5 next</td></tr>
<tr><td>Item 4A</td><td>Would you say that your neighborhood is slightly, moderately, very , or extremely noisy?</td></tr>
<tr><td colspan="2">Response/Coding Categories: slightly (1), moderately (2), very (3), extremely (4), don't know (5), refused (6) , skipped (7)</td></tr>
<tr><td>Item 5</td><td>While you're at home, are you bothered or annoyed by street traffic noise in your neighborhood?</td></tr>
<tr><td colspan="2">Response/Coding Categories: no (0), yes (1), don't know (5), refused (6)</td></tr>
<tr><td colspan="2">If respondent answers yes to Item 5, ask Item 5A; if any other response to Item 5, ask Item 6 next</td></tr>
<tr><td>Item 5A</td><td>Would you say that you are slightly, moderately, very, or extremely annoyed by street traffic noise in your neighborhood?</td></tr>
<tr><td colspan="2">Response/Coding Categories: slightly (1), moderately (2), very (3), extremely (4), don't know (5), refused (6), skipped (7)</td></tr>
<tr><td>Item 6</td><td>While you were at home last week, did you notice noise made by helicopters?</td></tr>
<tr><td colspan="2">Response/Coding Categories: no (0), yes (1), don't know (5), refused (6)</td></tr>
<tr><td colspan="2">If respondent answers yes to Item 6, ask Item 6A; if any other response to Item 6, ask Item 7 next</td></tr>
<tr><td>Item 6A</td><td>About how often did you notice noise made by helicopters while you were at home last week? Would you say you noticed noise made by helicopters less than once a day, about once a day, a few times a day, or at least several times an hour while you were at home last week?</td></tr>
<tr><td colspan="2">Response/Coding Categories: less than once a day (1), a few times a day (2), several times or more per hour (3), don't know (5), refused (6), skipped (7)</td></tr>
<tr><td>Item 7</td><td>While you were at home last week, did noise made by helicopters bother or annoy you?</td></tr>
<tr><td colspan="2">Response/Coding Categories: no (0), yes (1), don't know (5), refused (6)</td></tr>
<tr><td colspan="2">If respondent answers yes to Item 7, ask Item 7A; if any other response to Item 7, ask Item 8 next</td></tr>
<tr><td>Item 7A</td><td>Would you say that you were slightly, moderately, very, or extremely annoyed by noise made by helicopters while you were at home last week?</td></tr>
<tr><td colspan="2">Response/Coding Categories: slightly (1), moderately (2), very (3), extremely (4), don't know (5), refused (6), skipped (7)</td></tr>
<tr><td>Item 8</td><td>While you were at home last week, did you notice noise made by aircraft other than helicopters?</td></tr>
<tr><td colspan="2">Response/Coding Categories: no (0), yes (1), don't know (5), refused (6)</td></tr>
<tr><td colspan="2">If respondent answers to Item 8, ask Item 8A; if any other response to Item 8, ask Item 9 next</td></tr>
<tr><td>Item 8A</td><td>About how often did you notice noise made by aircraft other than helicopters while you were at home last week? Would you say you noticed noise made by aircraft other than helicopters less than once a day, about once a day, a few times a day, or at least several times an hour?</td></tr>
<tr><td colspan="2">Response/Coding Categories: less than once a day (0), once a day (1), a few times a day (2), several times an hour or more (3), don't know (5), refused (6), skipped (7)</td></tr>
</table>

(continued on next page)

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Table 3-5. (Continued).

Item 9	While you were at home last week, did noise made by aircraft *other* than helicopters bother or annoy you?
Response/Coding Categories: no (0), not home last week (1), yes (2), don't know (5), refused (6)	
If respondent answers yes to Item 9, ask Item 9A; if any other response to Item 9, ask Item 10 next	
Item 9A	Would you say you were slightly, moderately, very, or extremely annoyed by noise made by aircraft *other* than helicopters while you were at home last week?
Response/Coding Categories: slightly (1), moderately (2), very (3), extremely (4), don't know (5), refused (6), skipped (7)	
Item 10:	While you were at home last week, did you notice repeated pounding or slapping noises made by helicopters?
Response/Coding Categories: no (0), not home last week (1), yes (2), don't know (5), refused (6)	
If respondent answers yes to Item 10, ask Item 10A; if any other response to Item 10, ask Item 11 next	
Item 10A	Would you say that you were slightly, moderately, very, or extremely annoyed by thumping or slapping noises made by helicopters while you were at home last week?
Response/Coding Categories: slightly (1), moderately (2), very (3), extremely (4), don't know (5), refused (6), skipped (7)	
Item 11	While you were at home last week, did you notice buzzing noises made by helicopters?
Response/Coding Categories: no (0), not home last week (1), yes (2), don't know (5), refused (6) don't know, refused	
If respondent answers yes to Item 11, ask Item 11A; if any other response to Item 11, ask Item 12 next	
Item 11A	Would you say you were not at all, slightly, moderately, very, or extremely annoyed by buzzing noises made by helicopters while you were at home last week?
Response/Coding Categories: slightly (1), moderately (2), very (3), extremely (4), don't know (5), refused (6), skipped (7)	
Item 12:	While you were at home last week, did you notice whining or tonal noises made by helicopters?
Response/Coding Categories: no (0), not home last week (1), yes (2), don't know (5), refused (6), skipped (7)	
If respondent answers yes to Item 12, ask Item 12A; if any other response to Item 12, ask Item 13 next	
Item 12A	Would you say you were not at all, slightly, moderately, very, or extremely annoyed by whining or tonal noises made by helicopters while you were at home last week?
Response/Coding Categories: slightly (1), moderately (2), very (3), extremely (4), don't know (5), refused (6), skipped (7)	
Item 13	Did helicopters make vibrations or rattling noises in your home last week?
Response/Coding Categories: no (0), not home last week (1), yes (2), don't know (5), refused (6), skipped (7)	
If yes to Item 13, ask Item 13A; if any other response to Item 13, ask Item 14 next	
Item 13A	Would you say that you are slightly, moderately, very, or extremely annoyed by vibrations or rattling noises in your home that are made by helicopters?
Response/Coding Categories: slightly (1), moderately (2), very (3), extremely (4), don't know (5), refused (6), skipped (7)	
Item 14	About how often do you notice vibrations or rattling noises in your home that are made by helicopters? Do you notice vibrations or rattling noises about once a week, once a day, or several times a day?
Response/Coding Categories: once a week or less (0), once a day (1), several times a day (2), don't know (5), refused (6), skipped (7)	
Item 15	Has any member of your household ever called or written to the airport to complain about noise made by helicopters?
Response/Coding Categories: no (0), yes (1), don't know (5), refused (6), skipped (7)	
If yes to Item 15, ask Item 15A; if any other response to Item 15, terminate interview	
Item 15A	About how many times has a member of your household complained about helicopter noise in the last year? Has someone in your household complained just once, a few times, or many times over the last year?
Response/Coding Categories: once (1), a few times (2), many times (3), don't know (5), refused (6), skipped (7)	

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- Variant 3: Assessment of annoyance due to secondary emissions (vibration and rattle) excited by BVI noise.
- Variant 4: Assessment of predictability of annoyance from complaint information, particularly for sites with reliable complaint databases.

3.4 Description of Questions

3.4.1 Questions for Direct Comparison of Relative Annoyance of Exposure to Fixed- and Rotary-Wing Noise

At sites for which it was possible to directly compare the relative annoyance of exposure to fixed- and rotary-wing aircraft, Items 8 and 9 follow the initial several items. Items 8 and 8A sought respondents' opinions about the frequency of notice of exposure to noise of fixed-wing aircraft operations. The term "aircraft other than helicopters" was preferred because it would be easier for some respondents to understand than "fixed-wing" aircraft. The wording and coding of these items parallel those of Items 6 and 6A. Likewise, Items 9 and 9A parallel Items 7 and 7A. The similarity of wording and coding of these items were intended to support comparisons of the frequency of notice and degree of annoyance of fixed- and rotary-wing aircraft noise.

3.4.2 Questions for Assessing Relative Annoyance of Exposure to Various Forms of Helicopter Noise

Items 10 through 12 were posed to respondents at sites exposed to noise from helicopter operations that generate more than one form of noise, and/or to operations of a mixed fleet of helicopters that includes some equipped with shrouded rotors (Fenestron) and some with open counter-torque rotors.

3.4.3 Questions for Assessing Annoyance of Helicopter-Induced Rattle and Vibration

Items 13 and 14 were posed to respondents at sites exposed to blade slap noise.

3.4.4 Questions for Assessing Relationship Between Helicopter Noise Complaints and Annoyance

Items 15 and 15A were intended to reveal potential relationships between helicopter annoyance prevalence and complaint rates, as well as potential relationships between helicopter complaint rates and noise exposure levels.

3.4.5 Target Population and Preparation of Sampling Frames

The survey was intended to provide unbiased information about the relative annoyance of exposure to nonmilitary, fixed- and rotary-wing aircraft noise in adult residential populations. In practice, the population of interest is confined to geographic areas within relatively short ranges of aircraft flight routes and civil helipads. Opinions of the general population exposed only to occasional overflights and/or to low levels of fixed- and rotary-wing aircraft noise were of secondary interest.

By definition, an unbiased sample of any target population requires that each member of the target population have an equal opportunity of contributing opinions to the survey. This means, among other things, that respondents cannot self-select for participation in the survey. It also means that inexpensive methods for compiling a sampling frame (an exhaustive and current

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enumeration of every person eligible for interview) are inappropriate for present purposes. These include constructing sampling frames from citywide voter registration, countywide tax assessor information, and other wide-area public records, not to mention random digit dialing of all numbers within a telephone exchange.

Reverse telephone directories were common sources of sampling frames in the era when landline telephone subscription was effectively universal. In recent years, rates of unlisted telephone numbers have become so high, and cell phone-only telephone subscription so widespread, that it has become difficult to rely on public information for such purposes.[12] The Telephone Consumer Protection Act of 1991, as amended, further complicates and increases the cost of telephone-based interviewing.

3.5 Potential Interviewing Methods

Three common methods of conducting interviews about opinions and reactions to aircraft noise exposure are by telephone, mail, and in person (face to face).[13] As summarized in Table 3-6, each method is characterized by unique sets of advantages and disadvantages. These must be balanced against study goals. The questionnaire was administered by telephone to a sample of landline and cell phone subscriber households located within areas defined by the vertices of

Table 3-6. Comparison of relative advantages and disadvantages of alternate interviewing methods.

Feature	PERSONAL (FACE TO FACE)	POSTAL	TELEPHONE
Interview Completion Rate	High	Low	Historically high; recently low
Relative Cost of Data Collection	High	Low to moderate, depending on follow-up methods for nonresponse	Intermediate (depends on sample incidence rate and numbers of callbacks)
Duration of Data Collection	Moderate (at least several days, dependent on field logistics)	Long (weeks), vulnerable to shifts in opinions due to external events (e.g., aircraft crashes, current events)	Short (several hours per day over the course of 3 or 4 days, depending on callback scheduling)
Efficiency of Data Collection (Cost per Interview, Including Data Entry)	Greatest in high population density settings	Independent of population density	Independent of population density
Common Limitations	High training costs, limited field supervision, costly to administer over wide areas	No knowledge of respondent identity; loss of control over order of questioning; biased toward more literate respondents	Questionable representation of younger, single, lower socioeconomic and less educated respondents, possible ethnic and racial biases
Most Appropriate for…	Administration of lengthy interviews to relatively small numbers of respondents in small, densely populated geographic areas about complex or sensitive matters	Settings in which duration, temporal specificity, confirmation of the identity of respondents, and supervision of the interviewing process is not critical	Representing residential response to noise exposure in large populations in short, well-defined time periods, with tight control over data collection
Difficulty of Constructing a Sampling Frame	Low (for example, field workers may be instructed to flip a coin or solicit interviews at every nth door or floor in an apartment building, or at every nth street address in an area of dense single-family detached dwellings)	Moderate (currency of sampling frame is difficult to maintain in high-turnover rental areas)	Moderate (workarounds required for high rates of unlisted telephone numbers and for cell phone-only users)
Interview Quality Control	Low (little effective real-time field supervision; slow tracking of response rates and callback success; difficulty in managing release of sub-samples and scheduling additional interviews)	None; lengthy delays in administration and tracking of survey progress	High (real-time supervision of interviewing possible; immediate tracking of sample incidence and refusal rates and scheduling of callbacks; possibility of conversion of refusals)
Knowledge of Respondent Identity	High	None	Intermediate
Control Over Order of Questioning	Complete	None	Complete

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polygons enclosing geographic areas with reasonably homogeneous aircraft noise exposure. The selection of telephone interviewing was based on the following factors:

1. The costs of making field measurements for prolonged periods to correspond with the period of questionnaire items ("While you've been at home during the past *week*. . . .");
2. The need to control the order of presentation of questionnaire items;
3. The lack of necessity for lengthy and/or sensitive personal information; and
4. Overall data collection costs, except possibly at some (urban, high-density residential) sites, at which in-person (face-to-face) interviewing might be cost-effective.

3.6 General Discussion of Sample Size Constraints

This section presents background information about the role of sample size in social survey design. A more specific discussion of sample sizes required to test the hypotheses of current interest is included in the mock data analysis section.

The size of the population exposed to rotary-wing aircraft noise is a basic issue affecting study design and site selection. Larger sample sizes reduce the uncertainty of estimates of annoyance prevalence of rates for a given cumulative sound level exposure. They also reduce uncertainty about equivalent shifts, in decibels, of the dose-response curve that reflect nonacoustic influences on annoyance prevalence rates. Smaller uncertainties, in turn, permit more reliable estimates of smaller differences in community tolerance to a noise source.

Smaller sample sizes have the opposite effect. A basic decision must be made before final site selection regarding the minimal magnitude of effect of current interest, since it may not be realistic to seek evidence of small differences in annoyance rates at some sites. As a generality, surprisingly few (50–100) interviews may suffice to detect large differences between the annoyance of exposure to fixed- and rotary-wing aircraft, while surprisingly many (several hundred, if not more) interviews may be needed to detect small differences.

In practice, the number of respondents and the size of expected differences in annoyance prevalence rates are the major factors affecting site selection. Annoyance prevalence rates may be expected to change by about 1% (near asymptotes of dosage-response relationships) to 3% (in the linear portion of dosage-response relationships) per decibel of noise exposure. If differences in annoyance prevalence rates between interviewing sites with exposures differing by only 3 to 5 dB must be detected, then 95% confidence intervals of about 2% to 3% are required.

About 200 to 300 completed interviews are usually sufficient to achieve such confidence intervals. Roughly estimated, about half of the households in a sampling frame are likely to have unlisted telephone numbers, or cannot be reached with reasonable numbers of callbacks. Another half of the eligible respondents with listed telephone numbers may refuse to grant interviews. Working backward from confidence intervals of the desired widths, several thousand households must be eligible for interview by address-based landline telephone at a given interviewing site.

Residential neighborhoods with uniform low-density housing (e.g., single-family detached dwellings on large lots) may therefore not be optimal as interviewing sites. Levels of exposure to helicopter noise may vary considerably across such sites, unless they extend for distances as great as miles parallel to well-defined helicopter flight corridors.

3.6.1 Size of Expected Differences in Annoyance Prevalence Rates due to Rotary- and Fixed-Wing Aircraft Noise

Figure 3-11 shows a set of dosage-response relationships between cumulative noise exposure levels and percentages of respondents describing themselves as highly annoyed by aircraft

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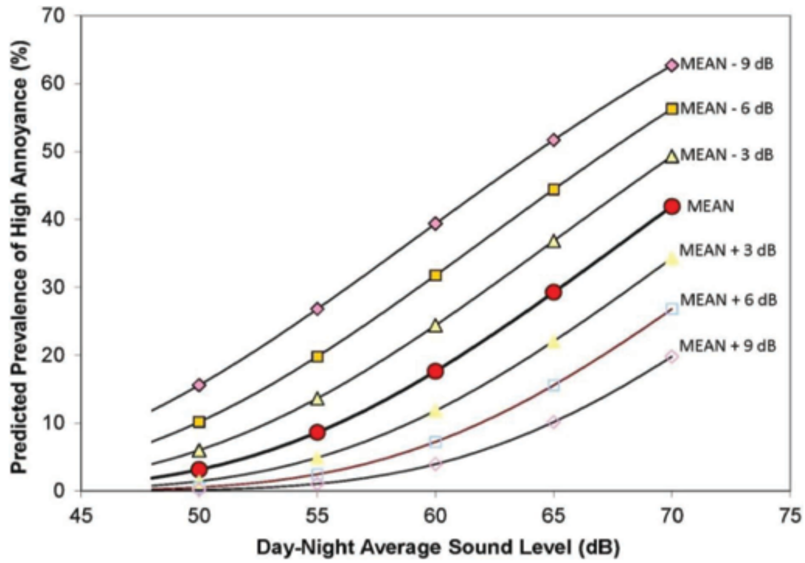

Figure 3-11. Hypothetical differences in annoyance prevalence rates in communities with greater or lesser degrees of tolerance for noise exposure due to fixed- and rotary-wing aircraft.

noise exposure. These curves are derived from the assumption that annoyance is most effectively predicted from the "effective" (duration-adjusted) loudness of noise exposure, as described by Fidell et al. (2011) and Schomer et al. (2012). The separations between dosage-response curves reflect varying degrees of community tolerance for noise exposure. For example, at a noise exposure level of $L_{dn} = 65$ dB in a community 6 dB less tolerant of helicopter than fixed-wing aircraft noise, an additional 15% of the population may be highly annoyed by helicopter noise than by fixed-wing aircraft noise.

The curve reflecting the grand mean of annoyance judgments made by 75,000 social survey respondents at about 540 interviewing sites is the one in the middle (shown with filled red circle plotting symbols). The other curves are for communities that are either more or less tolerant than average of aircraft noise exposure. If helicopter noise is truly more annoying than fixed-wing aircraft noise on a decibel-for-decibel basis, then the annoyance of helicopter noise should be displaced from the mean curve shown in Figure 3-11. The amount of displacement from the mean curve is a decibel-denominated measure of the size of the effect of differential tolerance for the noise of fixed- and rotary-wing aircraft noise.

3.6.2 General Examples of Sample Size Requirements

Figure 3-12 illustrates the effects of sample size (number of completed interviews) on the precision of estimation of the prevalence of high annoyance. Precision of measurement of a binomial proportion, such as the proportion of a population highly annoyed by rotary-wing aircraft noise, is expressed in Figure 3-12 in terms of the widths of confidence intervals constructed around observed proportions. For moderate or greater sample sizes, the upper bound of the 95% confidence interval is the observed proportion plus $1.96(pq/n)^{1/2}$, while the lower bound of the 95% confidence interval is the observed proportion minus $1.96(pq/n)^{1/2}$, where p is the percent highly annoyed, q is the percent not highly annoyed, and n is the number of completed interviews.[14]

Figure 3-12 shows that over the range of annoyance prevalence rates of present interest, confidence intervals for estimates of proportions of respondents highly annoyed are smaller than 1%,

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