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An approach to land use planning near small airports

Robert A. Pazera
The University of Montana

AN APPROACH TO LAND USE PLANNING

NEAR SMALL AIRPORTS

By

Robert A. Pazera

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Dean, Graduate School

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PREFACE

This work should be used as a reference and guide for land use planning near small airports. The intended beneficiary should be the person responsible for devising and administering land use plans for areas near airports. This work deals primarily with the planning needs of small municipal and privately-owned airports encompassed within the following general aviation airport classifications:

General Utility..These airports can accommodate small aircraft up to 12,500 lbs. Most of these airports have only a single runway.

Basic Utility....Ninety-five percent of total annual operations at these airports involve aircraft under 12,500 lbs.; however, these facilities are capable of handling larger craft up to 60,000 lbs.

Basic Transport..These airports handle general operations characterized by a broad mix of aircraft use, including business jet operations, handling aircraft up to 60,000 lbs.[1]

General aviation facilities constitute the majority of airports in the United States. In Arizona, all but five of seventy-one incorporated towns operate their own municipal facility; of these, sixty-six qualify as a general aviation class. The Phoenix Metropolitan Area alone hosts eleven public and ten private airports rated for general aviation use.

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[1]Federal Aviation Administration. Advisory Circular "General Aviation Airports, Basic and General Transport." Section 150/5300-6 (Washington, D.C.)., p. 3.

The importance of planning is punctuated by the unique needs and characteristics of airport operations, the wide area impacted by airport operations, and the ability of airports to create or accelerate nearby development. Planning ensures compatibility between long-term land use and aviation by balancing land use and airport needs while eliminating damaging impacts on land use or airport safety. A successful plan will regulate development before development occurs and will allow for airport expansion. Such a plan is regulatory and involves public intervention in land use decisions, but it can be used positively to pattern land uses in a way that will be economically beneficial to the airport and community. Without such a tool, land uses which hamper or are hurt by airport operations may develop in adjacent areas.

Literature providing planning instructions for small airports is scant. This scarcity hurts communities not knowing how to initiate planning but wanting to protect airport-area land uses from the negative impacts of operations and vice versa. In order to help fill the gap, this paper provides fundamental information and guidance in formulating an airport environs plan. It is organized into three parts, presenting in sequence the three basic steps of airport environs planning. Part I discusses airport-related characteristics which impact land use. Land use impacts resulting from aircraft noise, airspace needs, and accident potential are introduced. This first section, then, provides a brief survey of fundamental airport and land-use relationships to readers lacking a background in the topic. Part II relates a series of tasks necessary for the development of an airport area plan, ordered largely on ideas cultivated during my work experiences with airport environs planning for the Arizona Cities of Chandler and Kingman. This section guides the reader in formulating land use recommendations based upon an assessment of a given airport. Part III involves plan implementation; its emphasis is placed on defining strategies and techniques traditional to land use planning. The main intent of this final section is to indicate implementation techniques consistent with different planning approaches. These choices offer considerable flexibility in addressing a number of different land use problems involving small airports. In the case of larger airports designated for the air-carrier and commuter services of passenger jets, planners should obtain specialized consultation for an airport environs plan. Although the basic relationships of airport characteristics and proper land use planning are the same for large airports as they are for the general aviation classes, it is beyond the scope of this work to provide the sophisticated guidance needed to plan for the severe noise and hazard problems of large airports.

In summary, this paper enables the reader to understand airport and land use relationships sufficiently well to make generally informed land use plans. It is not a final authority for those faced with an airport planning task, nor is it an exhaustive analysis of any single aviation issue. Many planning insights and questions reside in the field and reflect the uniqueness of a particular community. They must be worked out in the field. This work indicates the range of general possibilities involving airports and refers the reader to useful, more detailed materials and sources listed in the bibliography.

TABLE OF CONTENTS

PREFACE . . . . ii.

INTRODUCTION: THE NEED FOR AIRPORT ENVIRONS LAND USE PLANNING. 1

Primary Airport Planning Considerations 1
Recognition of Airport Growth Potential 3
The Value of Planning 5

PART I: AIRPORT CHARACTERISTICS AFFECTING LAND USE 7

Airspace Clearance Needs. 7
Airspace Requirements and Land Use Implications . . . 11
Accident Potential. 14
Land Use Implications 16
Aircraft Noise. 17
Land Use Issues 21
Land Use Recommendations. 24

PART II: PLANNING TASKS AND PLAN PREPARATION 29

Task 1: General Information Gathering. 30
Task 2: Flight Surfaces Location 32
Task 3: Land Use Issues Identification 36
-- Obstructions (36) -- Accidents (38) -- Noise (38)
Task 4: Airport Projections for Noise Etimations . . 38
Task 5: Establishing Noise Contours. 41
Task 6: Formulating Land Use Recommendations 46
Task 7: Synthesizing an Overall Impact Map 47
Task 8: Community Participation. 50
Task 9: The Draft Plan 51

PART III: IMPLEMENTATION METHODS 54

Types of Land Use Controls. 54
Traditional Zoning Districts. 55
Creating an Airport Zoning District 55
Subdivision Controls. 59
Easements and Covenants 59
Transfer of Development Rights. 60
Property Acquisition. 61
Building Modifications. 62

SUMMARY 66

GLOSSARY OF TERMS 69

SELECTED REFERENCES 71

ILLUSTRATIONS

Figure Page

1. Airport Imaginary Surfaces: based on F.A.R. 77 criteria....................................8

2. Overhead View of Airport Imaginary Surfaces.........10

3. Land Use Guidance Zones: Mohave County Airport.....23

4. Dimensions for Primary and Clear Zone Surfaces by Runway Type...33

5. Dimensions for Approach Surfaces by Runway Type.....34

6. Dimensions for Transitional, Horitzontal, & Conical Surfaces by Runway Type......................35

7. Overall Impact Sketch: Mohave County Airport.......48

LIST OF TABLES

Page

1. Common Land Use Obstructions............................13

2. Airport Safety Compatibility Criteria................15

3. Land Use Guidance Zones...........................25-26

INTRODUCTION: THE NEED FOR AIRPORT ENVIRONS LAND USE PLANNING

Cities and towns need to recognize and foster the planning of their airport environs. Airport operations impinge on areas beyond their boundaries, a phenomenon leading to potential conflicts between aviation operations and nearby land uses. Airport byproducts including noise, accident potential, and airspace requirements constitute important determinants for nearby land uses. Additionally, the very existence of airports can initiate or accelerate nearby development. Balancing both aviation and land use interests to achieve their mutual compatibility requires foresight and careful planning. Cities can ensure harmonious aviation and land use relationships by implementing an airport environs plan, the earlier, the better. Such a plan, through regulation of land uses, protects airport-area developments from adverse impacts while allowing airport operations to continue and freely expand without controversy. Although airport-related land use planning traditionally has addressed the major problems of noise and land use impacts of large, metropolitan airports, small airports deserve planning attention as well. A complete framework for successful small airport environs planning begins with a recognition of the need and advantages of planning.

Primary Airport Planning Considerations

The need for planning can be understood through an examination of airport and land use relationships. Most land use problems stem from three factors common to all airports: noise, hazard (accident) potential, and airspace requirements for clearances. These problems result from moving aircraft, primarily during takeoff or landing, and can extend well beyond airport boundaries.

Aircraft noise constitutes an annoyance near many airports. Activities sensitive to aircraft noise, including residences, hospitals, and schools, should be located away from noise exposed areas. Even though small airports create less noise than their larger counterparts, noise generated by smaller, piston-powered aircraft and business jets is significant enough to warrant planning attention. In planning, consideration of noise impacts should be based on projected future airport operations and projected increases in air travel. Noise, however, represents just one problem. Small airports also require unobstructed flightpaths and planning for potential accidents.

Aircraft accident potential and clearance needs, common to all airports, align with predetermined flight surface paths and altitudes for takeoff or landing. These flight surfaces must be free of land use obstructions to prevent collisions. Another requirement is that lands beneath flight surfaces should not incorporate uses that impede aircraft communications. For example, particulates suspended in the air that reduce visibility or bright lights and reflections that disorient pilots must be avoided. These sub-flight surface areas also represent potential crash zones; an airport environs plan must emphasize the land use sensitivities of flight surfaces and regulate land uses below to protect flight paths and restrict concentrations of people from potential crash areas. Because noise, flight surfaces, and accident potential extend well beyond airport boundaries, land use controls should precede development in order to prevent conflicts. Planning should anticipate future airport growth and land use development possibilities.

Recognition of Airport Growth

Recognition of planning needs near airports also involves an understanding of airport growth potential. Failure to plan because an airport is remotely located or surrounded temporarily by undeveloped land reflects a decision blind to the dynamics of airport economies. Airports can influence or accelerate the growth of nearby areas, which in turn may further accelerate airport operations, as demonstrated by the following points:

> Airports demand auxiliary services such as fueling, repair, storage, and rental/sales of aircraft. Airport employees and pilots can support food services, light retail, personal and business services, and nearby lodging. In essence, airports can become active commercial and employment centers.

> Industries using air transportation for shipping or executive travel like to be near airports. Industry near airports can influence creation of industrial parks, commercial and housing activities for employees, and

increased air-travel demand. Industries may even contribute to or pay for airport improvements further expanding airport operations.[2]

Airports like to locate in areas with natural characteristics supportive of development such as good soils, gently sloping terrain, and stable geology. Other types of development may find these conditions attractive, also.

Airports create their own infrastructure system of sewer and water services which surrounding lands eventually tie in to. Airports need good ground transportation links with population centers, and these links may become developing corridors, especially with the extension of utilities.

Small airports near major commuter airports may experience increased general-aviation activity because of limited capacity of the larger airport. For example, Phoenix Sky Harbor Airport serves an international market and city of 1,000,000 people but is expected to reach its small craft capacity by 1990; it is expected that the eleven publically-operated smaller municipal airports in the area will begin to absorb general aviation spillover from the major port.[3]

Planners who understand the growth potential of airports can anticipate and prevent conflicts before the latter become obvious. The crucial point to be understood is that planning

[2]A recent study of municipal airports with industrial parks in the Phoenix, Arizona metropolitan area affirms the impor tance of airports in industrial expansion. Perhaps the most interesting finding in the study was that only 30 percent of industrial tenants choosing locations in the five targeted airports have any direct use of the airport facility. When asked why they chose an airport location, many of the tenants cited low land costs, access to ready infrastructure, and overall appeal of the airport location in explaining their decision. Source: "An Investigation of Airports in the Phoenix Area," Mountain West Research-Southwest Inc., 1985, p. 90.

[3]United States Department of Housing and Development, "Major Airports and Their Effects on Regional Planning." Superintendent of Documents, U.S. Government Printing Office, (Washington, D.C. 1984) Stock Number 2300-00264., p. 5-7.

choices and flexibility are greatest before development occurs nearby. A long wait, doing nothing, defeats the purpose of an airport environs plan, which is a preventative tool. Early recognition of the need for planning also depends on an understanding of the potential consequences of not planning.

The Value of Planning: Examining the Consequences of Not Planning

Community airports contribute to a city's well-being. Cities have vested interests in promoting their airports as transportation and development hubs as well as in protecting the airport's surrounding environs. The benefits of successful planning can best be understood through examining some potential consequences of not planning. Failure to plan can result in harmful physical, economic, and social impacts on a community.

Physical impacts resulting from obstructed airspace and development in crash areas can involve death, injury, and property damages. Airports cannot operate safely if obstructions impede a pilot's maneuvering or communication requirements, or if development proliferates in hazardous areas. Noise impacts over residential areas can trigger a cycle of neighborhood annoyance, complaints, property value deterioration, and legal action possibly resulting in court actions ordering airports to take corrective actions. Corrective actions include relocation of residents, building renovations, and curtailment of airport operations, all of which can be costly to a community.

Economic impacts, including the cost of correction actions to abate noise problems, can involve long-term consequences. Land use conflicts can limit an airport's ability to expand. Airports which cannot freely continue or expand operations can be a liability to a city's transportation opportunities and economic development; industries which rely on unlimited air transportation might avoid restricted airports. Airports also jeopardize their Federal and State financial assistance without measures designed to minimize or negate land use and aviation conflicts.

Resulting social impacts include public dissatisfaction with airport operation and management, negative perception of local government, and feelings of neglect or helplessness. Community airports should be a civic focal point representing progress and welfare. Certainly, public dissatisfaction with their airport further impedes the ability of that airport to fulfill its community obligations and expectations.

The benefits of planning, therefore, are defined by the elimination of aviation and land use conflicts. This provides long-term freedom and opportunity for transportation and land use evolution. Once recognition of the need for planning becomes apparent, planners should be ready to follow through with other planning steps. The first step, covered in Part I, involves an understanding of the physical needs of airports and their effects on surrounding areas.

PART I: AIRPORT CHARACTERISTICS AFFECTING LAND USE

Certain characteristics common to flying aircraft affect land uses over wide areas beyond airport boundaries. These characteristics, which entail airspace clearances, accident potential, and aircraft noise, impact land uses primarily under or near flightpaths. Each characteristic has unique land use implications; therefore, determining cumulative land use impacts requires an examination of all airport-related land use determinants near the facility. Since land use impacts relate to the location of flying aircraft, one needs to locate flightpaths, and this requires an understanding of basic airport operating rules. Flightpaths do not occur randomly but are the consequences of federal restrictions regardless of airport class.

Airspace Clearance Needs

The dimensional requirements for aircraft flightpaths are defined by the Federal Aviation Regulation (F.A.R.), Part 77, which guide flightpaths along a system of imaginary surfaces.[4] Fig. 1., p. 8, illustrates an isometric view of these surfaces as they relate to a runway. Each surface defines a different part of the flight spectrum -- all aircraft patterns for takeoff, landing, approaching and circling at

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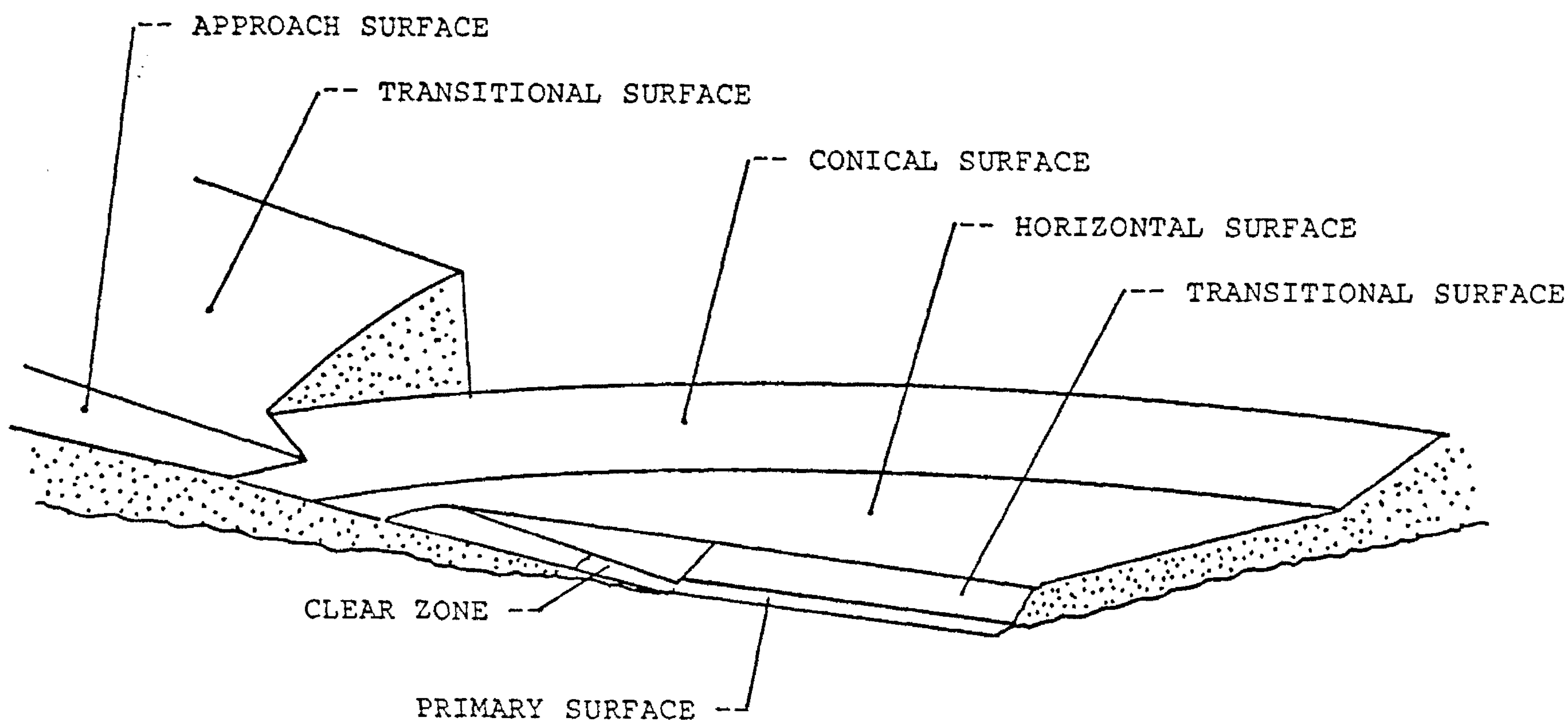
[4] Federal Aviation Administration. Federal Aviation Regulation, Part 77. "Objects Affecting Navigable Airspace" Section 77.25-Civil Airport Imaginary Surfaces (Washington, D.C. 1975), 170 pp.

FIGURE 1

AIRPORT IMAGINARY SURFACES
Based on FAR 77 Criteria

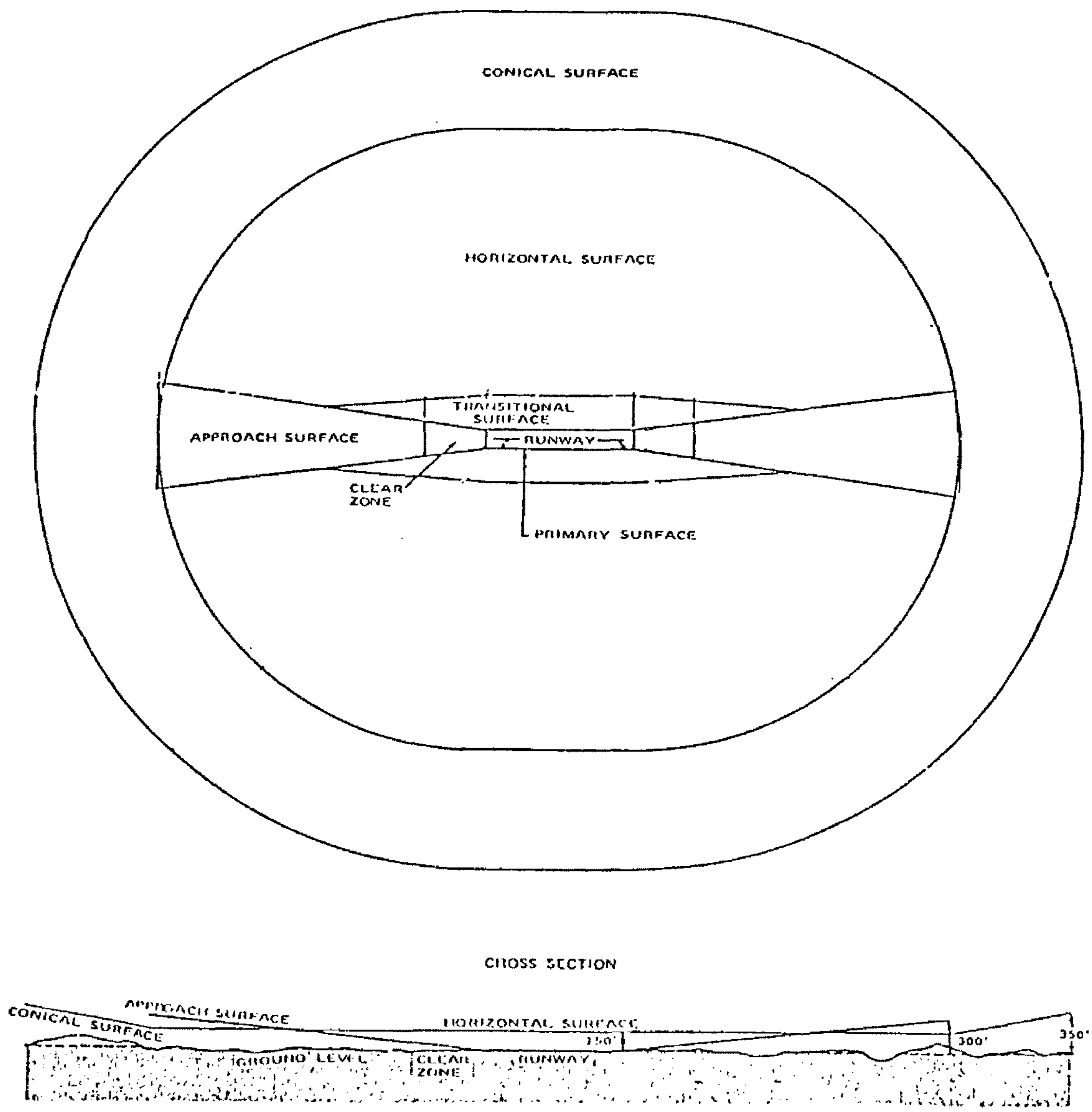


(See Glossary of Terms, pp. 69-70 for Definitions) airports follow the horizontal and vertical dimensions of these prescribed flight surfaces. Lands located beneath flight surfaces are commonly referred to as flight surface zones. The essential land use issues related to airspace requirements involve land use encroachment into flight surfaces or phenomena in flight surface zones which distract pilot communications. The quality of these mutual aviation and land use incompatibilities varies with the class of flight surface.

Fig. 2., p. 10, depicts the horizontal arrangement of flight surfaces around a runway. All surfaces have specific clearances and important land use implications. The primary surface covers the runway and runway shoulders and protects aircraft on the ground; the clear zone surface extends beyond the ends of runways marking an aircraft's initial takeoff or final landing at a point fifty feet above the runway; the approach surface marks a transition where planes are making their final landing approach or initial takeoff climb; the horizontal surface lies above the airport at a height of 150 feet providing a minimum buffer elevation for circling and flyover; the conical surface extends beyond the horizontal surface and provides elevation guidance for planes moving into landing position or leading out towards cruising altitude; transitional surfaces link the primary surface with the horizontal surface and the approach surface with the horizontal and conical surfaces, thereby providing elevation transition between surfaces. The basic geometric configuration of

FIGURE 2

OVERHEAD VIEW OF
AIRPORT IMAGINARY SURFACES



(See Glossary of Terms, pp. 69-70 for Definitions) flight surfaces is fixed for all airports, although dimensions for the primary, clear zone, and approach surfaces vary with runway class.[5] Flight surface types closest to ground such as primary, clear zone and approach surfaces are most affected by obstacles such as poles, trees, and buildings; however, higher surfaces such as horizontal or conical surfaces may be affected by high towers, high-tension powerlines, and buildings exceeding 150 feet in height. Certain land uses in zones under or near approach surfaces, because of light or radio emissions, can interfere with pilot communications. Land use implications can be identified by examining the needs of each surface class. By recognizing and avoiding problematic land uses, compatible land uses can be identified.

Airspace Requirements and Land Use Implications

Flight surfaces demand unobstructed airspace. Obstructions result from objects encroaching above minimum flight surface elevations. Each surface has set elevations, marking the absolute clearance thresholds which govern land uses or object heights. Surfaces closest to the runway are near ground elevation; therefore encroachment can result from short objects. Primary and clear zone surfaces involve flight modes with little margin for maneuvering error or deviation; these sur-

[5]Dimensions vary because different runway classes handle aircraft with different maneuvering and performance requirements; some places need more space beyond runways to maneuver, some require less. Refer to Figures 4, 5, and 6, pp. 33-35, for flight surface dimensions by runway type.

faces should be completely free of all objects, including fences, markers, roads, and topographical irregularities. Airports usually purchase the ground under these surfaces to ensure complete control of land uses. Surfaces extending beyond the immediate airport area, but with relatively low elevations such as the approach, transitional, and horizontal surfaces, are subject to encroachment by common uses such as buildings, towers, trees and antennas. These surfaces are also sensitive to uses which may impinge on pilot communications.

Some land uses can interfere with aircraft maneuvering without blocking flight surfaces. These create conditions that interfere with or distract a pilot's visual and radio communication with the airport. Land uses that interfere with communication include those producing smoke, reflective glare, lights, and radio emissions. Lights shining upward at night can affect a pilot's ability to identify clearly lit runway and approach area markings. Land uses emitting smoke or reflective glare can cause a pilot to be visually distracted at a critical time. Uses involving electronics may emit radio waves that affect an aircraft's controls or radio communications. Additionally, bird attractors such as lagoons, sewage treatment plants, and landfills may bring bird flocks into the path of moving planes. Table 1, p. 13, summarizes interfering land use characteristics due to height and their potential obstructions to different flight surfaces. This table can be combined with Table 2, p. 15, which relates land

TABLE 1.: Common Land Use Obstructions

Surface Type	Land Use Restrictions
Primary Surfaces.	These should be owned by the airport. Primary surfaces should be free of all objects and have a level surface.
Clear Zones	These surfaces should be under airport ownership; clear zones should be free of all objects, including parked aircraft, cars and pedestrian ways. Terrain should be shaped to be level if mounds outcrops, or boulders exist. Trees should be removed. Normally, ground cover and shrub plants are acceptable.
Approach Surfaces	These usually extend well beyond airport boundaries. neight restrictions for land use are necessary to ensure that poles, towers, buildings, and building appurtenances do not encroach into the surface.
Transitional Surfaces . .	The sensitive areas next to runways should be under airport ownership. Otherwise, height restrictions to keep object elevations below these surfaces are necessary.
Horizontal Surfaces . . .	Land uses with heights in excess of 150 feet should be prohibited; these types of uses include high tension utility towers, multistory buildings, and radio transmission towers.
Conical Surfaces.	Usually no need for height restriction unless local codes permit heights in excess of 100-150 feet; otherwise, height limitations should be applied.

(Source: Mohave County, Department of Planning and Zoning. "Mohave County Airport Environs Compatibility Study" 1983.)

use characteristics with pilot communication needs, to comprehensively bridge flight surface requirements with land use recommendations.

One can understand the mechanics of flight surfaces by visualizing the three-dimensional aspects of flying airplanes. These visualizations fortify one's understanding of other land use determinants such as accident or hazard potential and noise, determinants which closely align with flight-path locations. An understanding of flight surfaces is requisite to assessing an airport's airspace requirements, discussed under "Part II: Planning Tasks," and community implementation of land use plans designed to protect airspace discussed in "Part III: Implementation Methods." Closely related to the clear zone and approach surfaces are areas where higher risks of accident potentially threaten land uses.

Accident Potential

In addition to obstructions and distractions to safe flight caused by inappropriate land uses, planners need to be aware of crash or hazard threats to people beneath certain flight surfaces. The Federal Aviation Administration finds that sixty percent of all airplane crashes and emergency landings occur in areas within 5,000 feet of runway ends.[6] Under normal circumstances, most aircraft are following approach or

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[6] Mohave County, Department of Planning and Zoning. "Mohave County Airport Environs Compatibility Study" (Kingman, AZ), 1983, p. 29.

TABLE 2
AIRPORT SAFETY COMPATIBILITY CRITERIA

CRITERIA - SAFETY ZONES 1/

LAND USE CHARACTERISTICS	Clear Zone	Approach Zone 2/ 3/	Transitional Zone 3/	Beneath Flight Track	Horizontal and Concical Zones
Distracting Lights and Glare	--	--	-	-	0
Source of Smoke	--	--	--	-	0
Source of Electronic Interference	--	--	--	--	--
Attractor of Birds	--	--	--	-	-
Permanent Sructures	--	+	++	++	++

INTERPRETATION

++ CLEARLY ACCEPTABLE:
No hazards result when the land use characteristic oc within the specified zone.

\+ NORMALLY ACCEPTABLE:
Safety is a consideration but, unless unusual conditions are involved, no hazards will result.

C CONDITIONALLY ACCEPTABLE:
Hazards are associated with the location of the land use characteristic in the given zone, but mitigation measures are available which may make the relationship between them acceptable.

\- NORMALLY UNACCEPTABLE:
The land use characteristic should generally be avoided in the specified zone because of the significant hazards which will result.

-- CLEARLY UNACCEPTABLE:
Unless strong overriding circumstances prevail, the land use characteristics should not be permitted within the indicated safety zone. Within the extended runway safety area of a clear zone, exceptions are not permissible under any circumstances.

DEFINITIONS

Distracting Lights and Glare: Any nonairport light which can be mistaken for airport lights. Any source of glare directed toward an operating aircraft.
Source of Smoke: Any substantial generator of smoke whether from a permanent use or temporary source.
Source of Electronic Interference: Any source which disrupts radio communications or navigational signals.
Attractor of Birds: Any land use characteristic, especially including sanitary landfills, which increases the likelihood of aircraft colliding with birds.
Permanent Structures: Any building, sign, or other structure not required for airport operation. (Note: the height of structures must meet the criteria set forth in the airspace policies.)

NOTES AND CONDITIONS

1/ Where zones overlap, the more strictive criterion applies.

2/ For the purpose of assessing safety compatibility, only the inner 10,000 feet of a precision instrument runway approach zone need be considered.

3/ Where the affected land is lower than the runway elevation, less restrictive criteria may be acceptable.

clear zone surfaces within 5,000 feet of landing or takeoff. Therefore, knowledge of the location of areas beneath clear zones and approach surfaces becomes paramount in locating potential crash sites. While cities cannot prevent crashes, they can reduce the chances of catastrophy by widely dispersing people in accident prone areas.

Chandler, Arizona, has located and mapped accident-prone areas near its community airport by scribing an arc with a radius of 5,000 feet from the two ends of the primary runway and interconnecting these arcs with tangents. Buildings that concentrate people such as stadiums, motels, and restaurants can be placed within this area only upon determination that such uses do not locate directly under clear zone or approach surface flightpaths. Mohave County, Arizona, defines accident potential areas by using the width dimensions of approach surfaces and clear zones for a distance of 5,000 feet beyond their runways. People-oriented land uses are prohibitted from such accident-prone areas. Common sense and prudence help eliminate the types of uses that could suffer great damage from locating in accident-prone areas.

Land Use Implications

If an aircraft experiences mechanical trouble during takeoff or landing, a pilot will try to maintain flight, or, if unable to do so, will attempt to ground the craft in an open area. However, precise control of a plane under these or other circumstances, such as those caused by weather or collision, may be impossible; therefore, areas beyond runways are best left free of land uses attracting many people. Residences, schools, churches, stadiums, concert halls/auditoriums, and hospitals exemplify uses which should locate away from hazardous areas. Commerical uses such as restaurants, hotels, factories, and offices, more common to airport areas, should also be kept out of accident-prone areas. Recreational uses such as parks and golf courses are compatible with potential crash areas; although people-oriented, these uses do not concentrate large groups in small parcels.

Communities should understand the importance of keeping large groups of people out of potential accident zones. These communities, in addition, can make their own judgement as to what is acceptably safe for particularly sensitive uses, such as schools and churches in other areas. The fear or threat of crash, even if the risk is extremely low, in areas outside of flightpaths may justify stricter community location standards for some uses. Fortunately, from the standpoint of safety, most uses sensitive to the risk of crash are also sensitive to noise, another common airport by-product and land use determinant. Like accidents, noise hurts people.

Aircraft Noise

Aircraft noise is transmitted quickly over a wide area beneath flightpaths. Noise severity depends on the number, type, and loudness of occurrences over a given area. Since these variables differ for each airport, the extent of potential noise problems will differ by community also. Commonly, small airports generate noise levels much lower than large airports having jet aircraft and a greater number of operations. However, airport environs plans for small airports must always incorporate a study of noise expected from future expansion. Because certain noise levels impact various land use classes, land use decisions should reflect a scenario combining future airport and nearby development activity. The basic mechanics and consequences of airport noise can be approached through an understanding of noise sources and transmission, measurement techniques, noise level descriptors, and land use sensitivities to various noise levels.

Noise Sources and Transmission

Jet-propelled aircraft have two primary sources of noise: a thrust of jet exhaust creating an intensive, highly directive roar, especially upon takeoff, and an internal engine noise causing a high frequency "whine," especially upon landing. Although not so noisy, prop-driven craft generate noise from three sources simultaneously -- blade-slap against air, airflow past the blades, and internal engine noise. All airplanes generate most noise upon takeoff at maximum engine power and on braking after landing. As aircraft take off or land, sound waves spread out and are loudest downward along flightpaths. On the ground, the perceived loudness of aircraft is greatest directly under flightpaths just beyond runway ends; noise decreases as one moves away from the flightpath or as aircraft achieve greater altitude over the ground. The degree of loudness can reflect one's sensitivity to a single occurrence or to a multitude of occurrences over a long period. Noise affects people, and their tolerance and response to it depends largely on the types of activity associated with different land uses.

Noise Description and Measurement

Aircraft noise impacts on land use activities can be approximated by measuring and describing noise and predicting human responses to it in various land use settings. Predicting each person's response is impossible given the individuality of beliefs, attitudes, and values. Similarly, measuring noise by describing or comparing particular noise occurrences evokes different personal perceptions but fails to provide a consistent means of defining a cumulative noise situation, which takes into account the number, timing, loudness, and duration of noise occurrences over an extended period such as six months or a year. Over the past twenty-five years, researchers have studied trends and have developed methods which reasonably correlate community annoyance with cumulative noise descriptors or measurements. These measurements quantify and integrate factors identified by research to cause varying degrees of community response, the response being tied to percentages of people sharing common complaints and degrees of annoyance to documented noise levels.

Two methods of noise measurement are commonly utilized in airport environs planning today: the Noise Exposure Forecast (NEF) and the Day-Night Average Sound Level (ldn). The Noise Exposure Forecast was developed by the Federal Aviation Administration to quantify noise over a 24 hour period taking into account the loudness, frequency, duration, and timing (night or day) of each occurrence or flight over a given area. These integrated variables, different for each airport, are translated into numerical ratings used to predict levels of community annoyance. These ratings are largely based on the findings of the "Wilson Committee" appointed by the British Government to investigate existing noise impacts on land uses near London's Heathrow Airport.[7] This committee interviewed households in different noise-exposed areas and determined percentages of the population disturbed in various activities, including sleep, relaxation, conversation, and television viewing. The study identified similarities among percentages of those annoyed with particular levels of aircraft flyovers, noting time, duration, loudness and frequency of each noise event. Areas near Heathrow Airport sharing common individual responses were categorized by numerical ratings. Now these ratings are utilized in the NEF method to locate groundpoints having equal noise exposure. Such points are connected with contours, and within these lines

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[7] Federal Aviation Administration, U. S. Department of Transportation. "Impact of Noise on People." U. S. Government Printing Office (Washington, D.C. 1977), p. 7.

predictions of community response to noise are projected.[8] In a similar manner, The Day-Night Average Sound Level (ldn) was developed by the Environmental Protection Agency also to associate aircraft-noise conditions with anticipated community impacts and annoyance. The ldn method takes into account the same aircraft noise characteristics as the NEF and relates these conditions to the findings of the "Wilson Committee" and to more recent studies examining complaints from those in the workplace about noise near major airports. Like the NEF method, the ldn assigns numerical values to common noise-exposed areas and connects identical values with contours. Also, both indexes take into account nighttime occurrences. Ldn and NEF values are calculated using different methods but are consistent and interchangeable when used to assess land use impacts. The advantage of one over the other has not been determined as yet by research.

Land Use Issues

The Land Use Guidance (LUG) has been developed by the Federal Aviation Administration to determine aircraft noise impacts on land use.[9] The LUG translates NEF and ldn indexes into land use guidance zones with defined levels of noise exposure. The noise exposure descriptions are linked to the probability of provoking community annoyance and com-

[8] Ibid., p. 8.

[9] Ibid., p. 12.

plaints based on those used to establish NEF and ldn values, as follows:

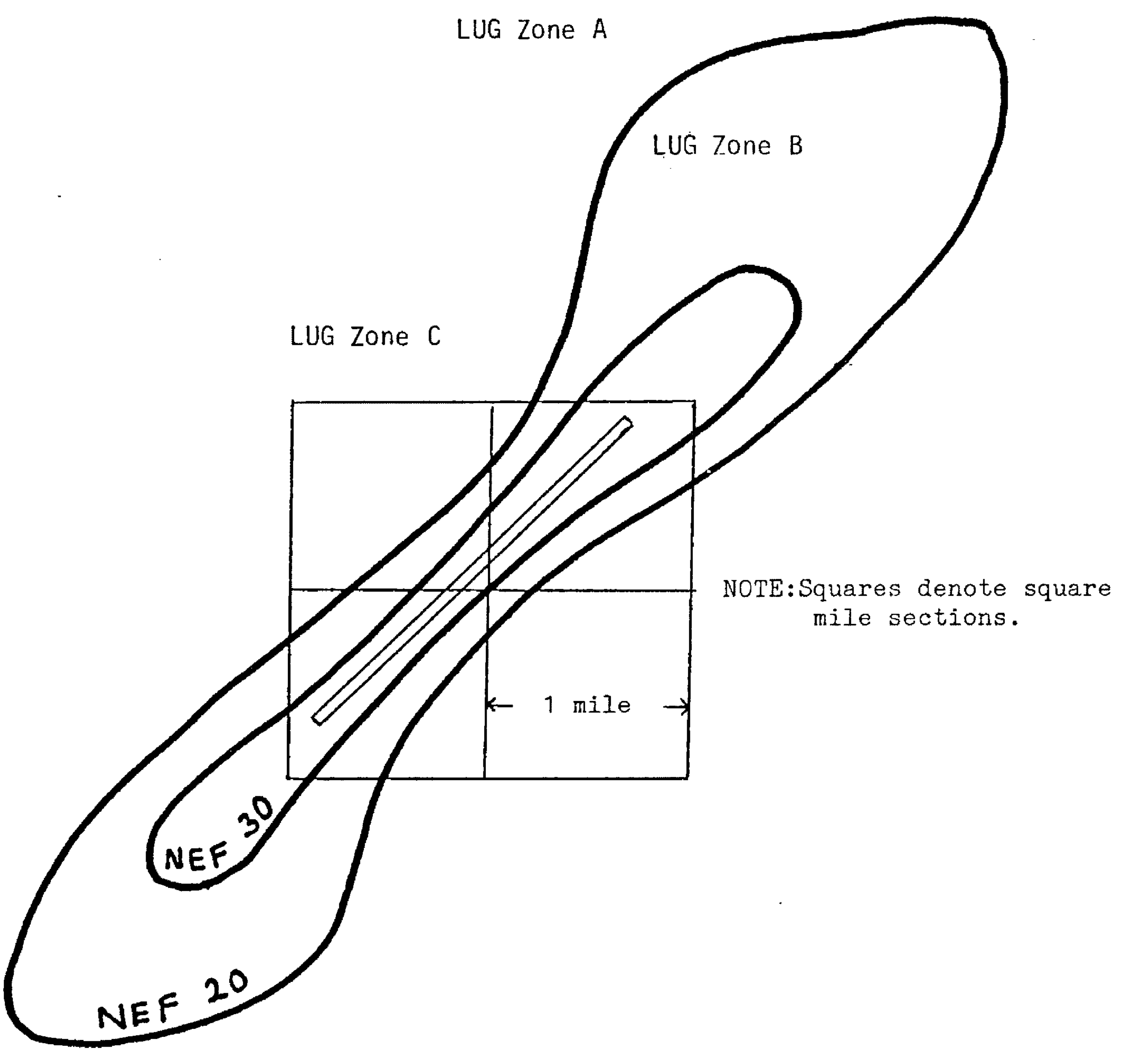
	NEF Range	ldn Range
Zone A - Minimal Exposure	0 - 20	0 - 55
Zone B - Moderate Exposure	20 - 30	55 - 65
Zone C - Significant Exposure	30 - 40	65 - 75
Zone D - Severe Exposure	40 & Higher	75 & Higher

Fig. 3, p. 23, based on NEF contours calculated for the Mohave County (AZ) Community Airport depicts the separation of zones by noise contours. Zone A falls outside of the NEF 20 contour signifying places with minimal aircraft noise exposure. This exposure area does not explicitly mean the total absence of aircraft noise, but indicates that noises, if any, do not cause significant human annoyance or complaints. Areas delineated by Zone B will experience noise levels likely to cause complaints from residents. Ollerhead (1967) found in his interviews in the Netherlands that twenty percent and forty percent of those interviewed lost sleep and felt annoyed, respectively.[10] The Environmental Protection Agency defines the NEF range of 20 - 30 to be potentially disruptive to some everyday activities such as relaxation and sleep; suitable land use controls should be applied to areas in this zone. Most cities with airport-area plans, including

[10]Ibid., p. 8.

FIGURE 3

LAND USE GUIDANCE ZONES
MOHAVE COUNTY AIRPORT



Source: Mohave County Department of Planning. "Mohave County Airport Environs Study" 1983 p. 28.

Yuma, Chandler, and Kingman, AZ, prohibit residential and institutional development in Zone B. Chandler also prohibits from Zone B motels, hotels, and commercial services such as banks, offices, and government buildings.[11]

Zone C represents areas with significant exposure and substantial land use restrictions. This Zone reflects a noise level rare near small airports except directly over runways. As a hypothetical example, a NEF 40 contour would occur 5,000 feet beyond a runway with 100 daily jet operations.[12] Most land uses except agriculture and manufacturing should be restricted from Zone C. Zone D is not associated with small airports.

Land Use Recommendations

The land use matrix in Table 3, pp. 25-26, identifies common land use restrictions applied to land use guidance Zones A, B, and C. These restrictions are consistent with the Environmental Protection Agency's findings on land use noise sensitivities and are endorsed by the Arizona Department of Transportation for its municipal airport plans. These recommendations are based on many noise studies over the past twenty years and are defensible in a court of law; however,

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[11] City of Chandler, Department of Planning. "Chandler Airport Impact Ordinance." BRW, Inc. 1985., Article XXX, pp. 4-5.

[12] Each of these 100 operations would generate approximately 95 decibels dba, equivalent to the sound of a motorcycle accelerating at a 50 foot distance from the point of reception.

TABLE 3: LAND USE RESTRICTIONS FOR LUG ZONES

CODE	LAND USE RESTRICTIONS
	No Restrictions
1	The land use or activity is permitted; however, the level of noise within the principally permitted structures must be reduced by the developer of this land use activity, in accordance with Chapter 35 Sound Transmission Control of UBC 1979 Edition.
2	The land use or activity is permitted; however, the level of noise within principally permitted structures shall not exceed 45 ldn.
3	The land use or activity is permitted; however, the level of noise within principally permitted structures shall not exceed 45 ldn.
4	The land use or activity is permitted when the level of noise does not exceed 45 ldn within the principally permitted structure, unless 45 ldn is exceeded by self generated noise.
5	Uses within this category are not permitted.

	USE	LUG ZONE A	B	C
RESIDENTIAL	Single family, duplex, multi-family	1,2	5	5
	Mobile homes, parks or courts			
	Other Residential	1,2	5	5
PUBLIC FACILITIES	Educational facilities	1,2	5	5
	Religious facilities, libraries, museums, galleries, clubs, and lodges	1,2	5	5
	Outdoor sport events, entertainment and public assembly, except amphitheaters	1,2	5	5
	Indoor recreation, amusements, athletic clubs, gyms, and spectator events		1,3	
	Neighborhood parks			5
	Community and regional parks			5
	Outdoor recreation: tennis, golf courses, riding trails, etc.			5
	Cemeteries			

TABLE 3. (Continued)

	USE	LUG ZONE A	B	C
COMMERCIAL	Hotels/Motels	1,2	5	5
	Hospitals and other health care services	1,2	5	5
	Services: finance, real estate, insurance, professional, and government offices	1,2	5	5
	Retail sales: building materials, farm equipment, automotive, marine, mobile homes, recreational vehicles and accessories		1,3	5
	Restaurants, eating and drinking establishments		1,3	5
	Retail sales: general merchandise, food, drugs, apparel, etc.		1,3	5
	Personal services: barber and beauty shops, laundry and dry cleaning, etc.		1,3	5
	Automobile service stations		1,3	4
	Repair services			4
INDUSTRIAL	Processing of food, wood and paper products; printing and publishing, warehouses, wholesale and storage activities			4
	Refining, manufacturing and storage of chemicals, petroleum and related products, manufacturing and assembly of electronic components, etc.			4
	Manufacturing of stone, clay, glass, leather, gravel and metal products; construction and salvage yards; natural resource extraction and processing, agricultural, mills and gins			
AGRICULTURE	Animal husbandry; livestock, farming, breeding and feeding; plant nurseries (excluding retail sales)			
	Farming (except livestock)			
MISCELLANEOUS	Transportation terminals, utility and communication facilities			
	Vehicle Parking			
	Signs			

communities may adopt stricter measures. For example, many Arizona cities, including Chandler, permit residential and institutional land uses in Zone A (0-55 ldn) only if Noise Reduction Levels (NRL) are incorporated into building construction to reduce interior noise levels.[13] Cities may also restrict extremely sensitive land uses such as hospitals, libraries, and auditoriums from areas within Zone A that experience "noticeable" noise levels. These areas can be located by measuring the sound levels[14] of individual occurrences and recording decibel levels at various points in Zone A. It is important to realize that the quality of sound experienced in the different land use guidance zones varies depending on the frequency, duration, timing, and intensity of noise occurrences; for example, the NEF 20 - 30, LUG Zone B can result from many flights producing moderate levels of perceived noise or fewer operations producing more severe levels. Accurate land use recommendations rely on accurate placement of noise contours. Like other determinants, accurate placement of noise contours depends on accurately assessing an airport's level of future operations activity.

Land uses and airports share a common reality: their successful coexistence depends on planning to assure that

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[13] Part III: "Implementation Methods," p. 62, discusses techniques used to employ NRL.

[14] Zone A qualifies as no or minimal exposure; however, areas in Zone A may be subject to noticeable levels of noise or may experience several very loud occurrences daily.

land uses are suited to airport-related constraints or impacts. Failing to plan for aircraft clearances, accidents, or noise can result in dire consequences, endangering those on the ground, pilots, or both. The magnitude of airport-related impacts varies from airport to airport; however, planning for compatible land uses should reflect each airport's projected maximum growth potential.

Because airports affect land uses over an extremely wide area, planners need to identify correctly the extent of each airport-related impact and address all land use implications comprehensively. It does little good to pay heed to noise impacts but ignore accident potential or needed airspace around airports. With a good understanding of each impact's affect on land uses, one can begin formulating an airport-environs plan. Plan formulation involves an assessment of airport operations, a listing of existing and potential land use impacts, and recommendations for compatible land uses. Part II lists and explains tasks which will systematically guide one through this planning process.

PART II: PLANNING TASKS AND PLAN PREPARATION

The success of an airport environs plan depends on the completeness and accuracy of plan information. Complete and accurate information can be systematically gathered by the undertaking and completion of a series of tasks individually designed to relate specific phenomenon to a set of land use recommendations. These tasks should be completed in their presented order, beginning with those designed to get planners generally acquainted with their work, proceeding with those tasks designed to provide specialized information on pertinent airport-related impacts, and culminating with those tasks designed to enable planners to address these impacts with land use recommendations. The tasks are:

TASK	DESCRIPTION
1:	General Information Gathering
2:	Flight Surfaces Location
3:	Land Use Issues Identification a. Obstruction analysis, b. Accident danger, c. Assessing noise
4:	Airport Projections for Noise Estimations a. Demand, b. Airfield capabilities, c. External contraints
5:	Establishing Noise Contours
6:	Formulating Land Use Recommendations
7:	Synthesizing an Overall Impact Map
8:	Community Participation
9:	The Draft Plan

The first task presented involves one's gathering of information and assistance available from other agencies empowered to assist municipalities to plan; tasks 2 through 7 enable planners to assess their airport's present and future clearance, accident and noise characteristics, and link these assessments with land use recommendations; task 8 involves public input and the relationship of community needs with land use planning; task 9 directs planners to present land use recommendations in the form of a draft plan. Perhaps the most important task, however, is the first one presented. This task enables planners to build a general information base which orients them to a variety of airport-related topics. Such an overview provides a base from which to direct specialized tasks later on.

TASK 1: General Information Gathering

Planners should become cognizant of the public agencies and organizations available to assist a community's efforts toward airport environs planning; the bibliographical literature dealing with airport noise, flight surfaces, airport zoning ordinances, and other topics of planning interest are available from Federal agencies such as the Environmental Protection Agency, Department of Housing and Urban Development, Air Force, and Federal Aviation Administration, State agencies such as one's own State transportation department, and local agencies such as other municipalities and airports that already have airport environs plans. Oftentimes, the airport manager can provide information on airport operations, projections, and capital improvement plans for the airport. Local and regional airlines, nearby military bases, and private pilot associations or flying clubs can help planners assess local flight conditions. Manpower assistance is sometimes available, and such assistance was provided by the State Department of Transportation in directing the Mohave County Airport Environs Compatibility Study (1983) and various other plans for Arizona municipalities. Planners should spend much time with this task since an accurate planning assessment of a particular airport depends on one's command of current information on the topic, and an awareness of how other cities have planned, especially in common situations. From task 1, planners can proceed with specialized tasks leading to a comprehensive airport assessment and set of land use recommendations.

Airport Assessment

The character of one's airport determines the extent of airspace needs, hazard potential, and noise impacts; therefore, reliable information on physical layout and proposed improvements, existing and anticipated operations, and aircraft mix allows one to define and map areas impacted by airspace clearances, potential accidents, and noise. This information must be obtained from informed sources or agencies, or calculated as part of the airport environs plan. Alignments and types of runways will define locations of flightpaths and flight surfaces dimensions used to determine areas sensitive to obstructions or accidents. Flightpath locations and number of aircraft operations will define noise contours used to determine land use impacts. Such impacts correspond with recommended land uses. Tasks 2-7, pp. 32-50, provide information required to complete the assessment.

TASK 2: Flight Surfaces Location

Flight surfaces defined by FAR 77 can best be located by obtaining the flight surfaces map from the airport or State transportation department. This map will show existing runways and flight surfaces dimensions consistent with the existing and proposed runway class. If this map is not available, FAR 77 surfaces can be mapped using the following information:

1. Location, length, class, and planned improvements or extensions of all runways. This information is available from the airport. There are five basic runway classes; each class defines capability of a runway to support various aircraft types. (See Glossary, pp. 69-70, for runway definitions.)

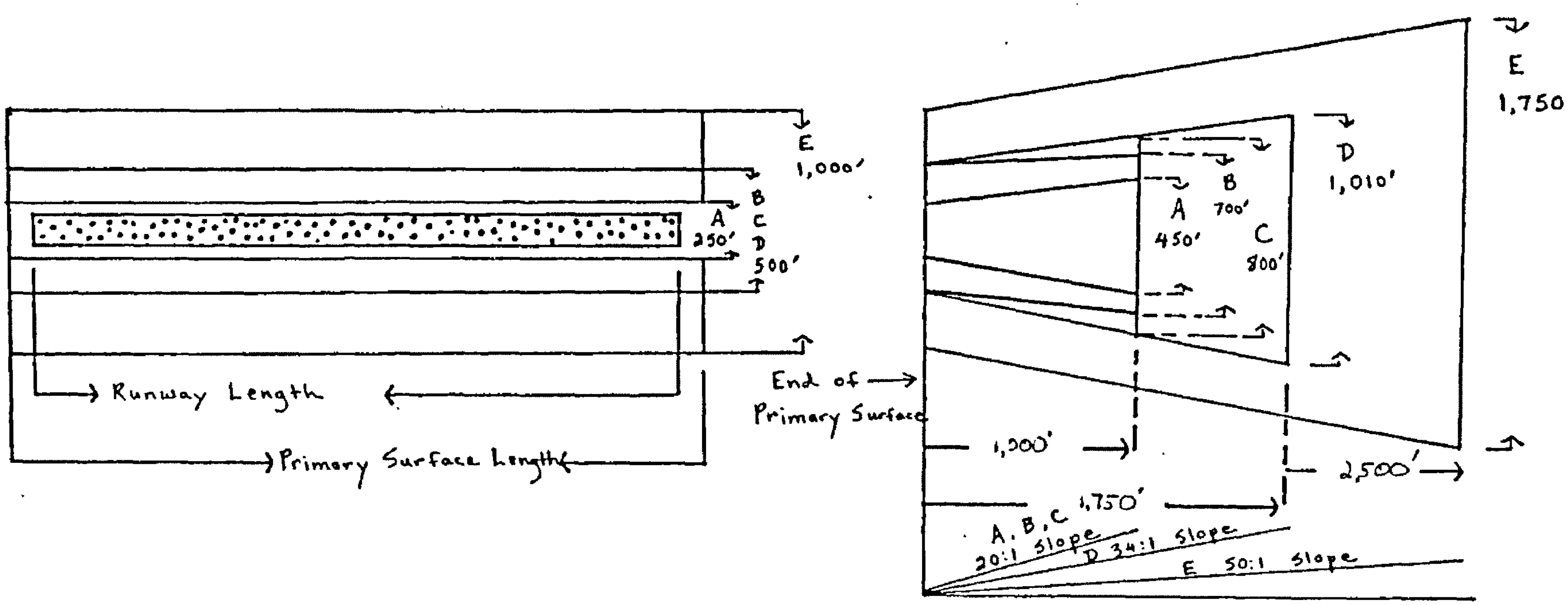
2. Dimensions of critical flight surfaces. Figures 4, 5, and 6, pp. 33-35, respectively, depict flight surface dimensions by runway type for the flight surfaces. The primary, clear zone, and approach surfaces are the most susceptible to common land use obstructions and also define flightpath alignment and accident-prone areas.

3. Topographical maps for the airport area. These maps, such as those made by the United States Geological Survey, show elevation contours and are used to define distance relationship between flight surfaces and ground elevations under the surfaces.[15]

[15] Arizona Department of Transportation, Aviation Division. "Arizona Airport Obstruction Zone Analysis." Phoenix. 1979, pp. 16-20.

FIGURE 4

Dimensions for Primary and Clear Zone Surfaces by Runway Type

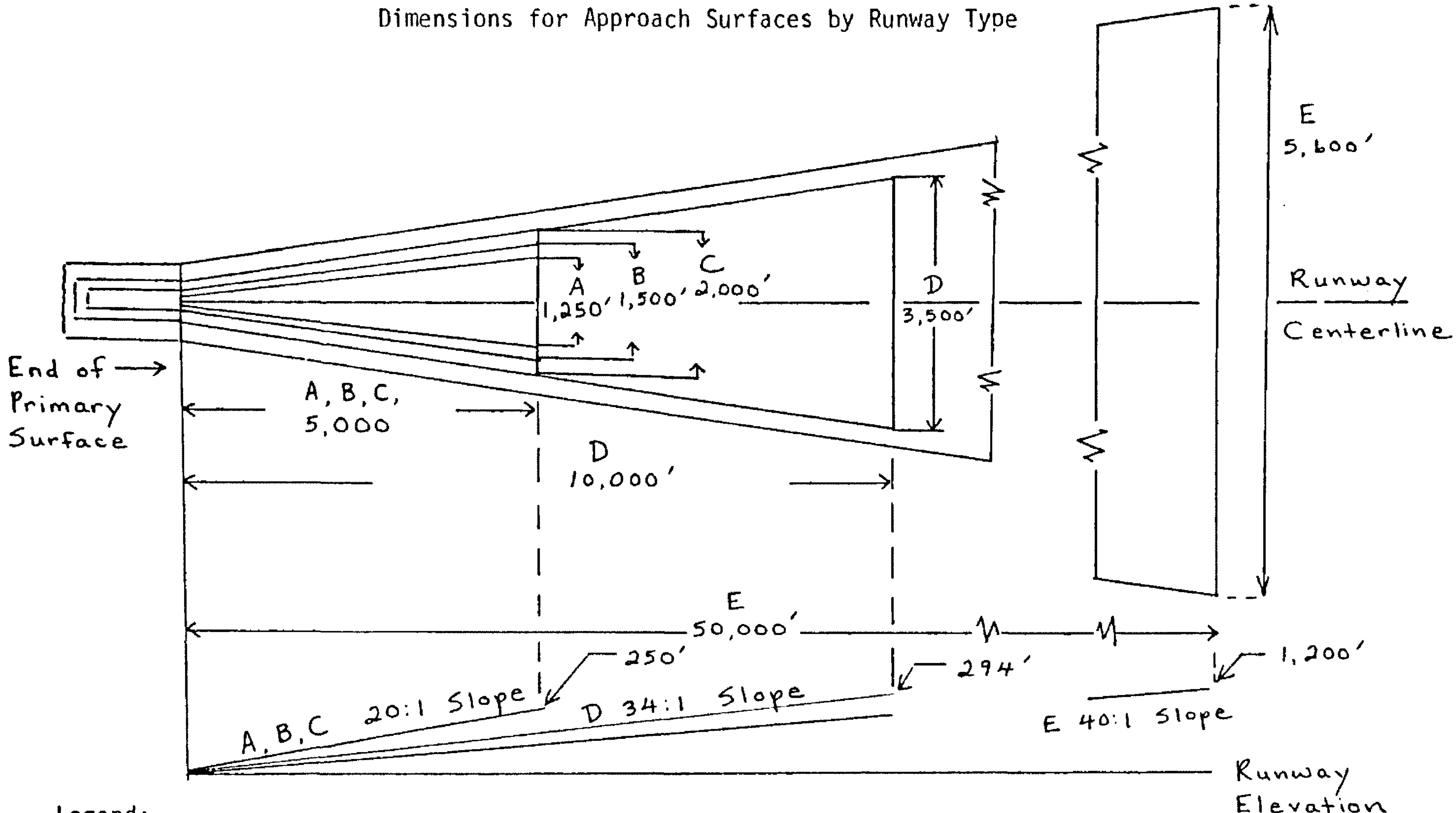


A: Visual Approach, Utility Runway
B: Visual Approach, Larger than Utility Runway
C: Non-precision Instrument Approach, Utility Runway
D: Non-precision Instrument Approach, Larger than Utility Runway
E: Precision Instrument Approach, Larger than Utility Runway

Source for Figures 4,5,&6: Arizona Department of Transportation. Aviation Division. "Arizona Airport Obstruction Zone Analysis". Phoenix. 1979.

FIGURE 5

Dimensions for Approach Surfaces by Runway Type

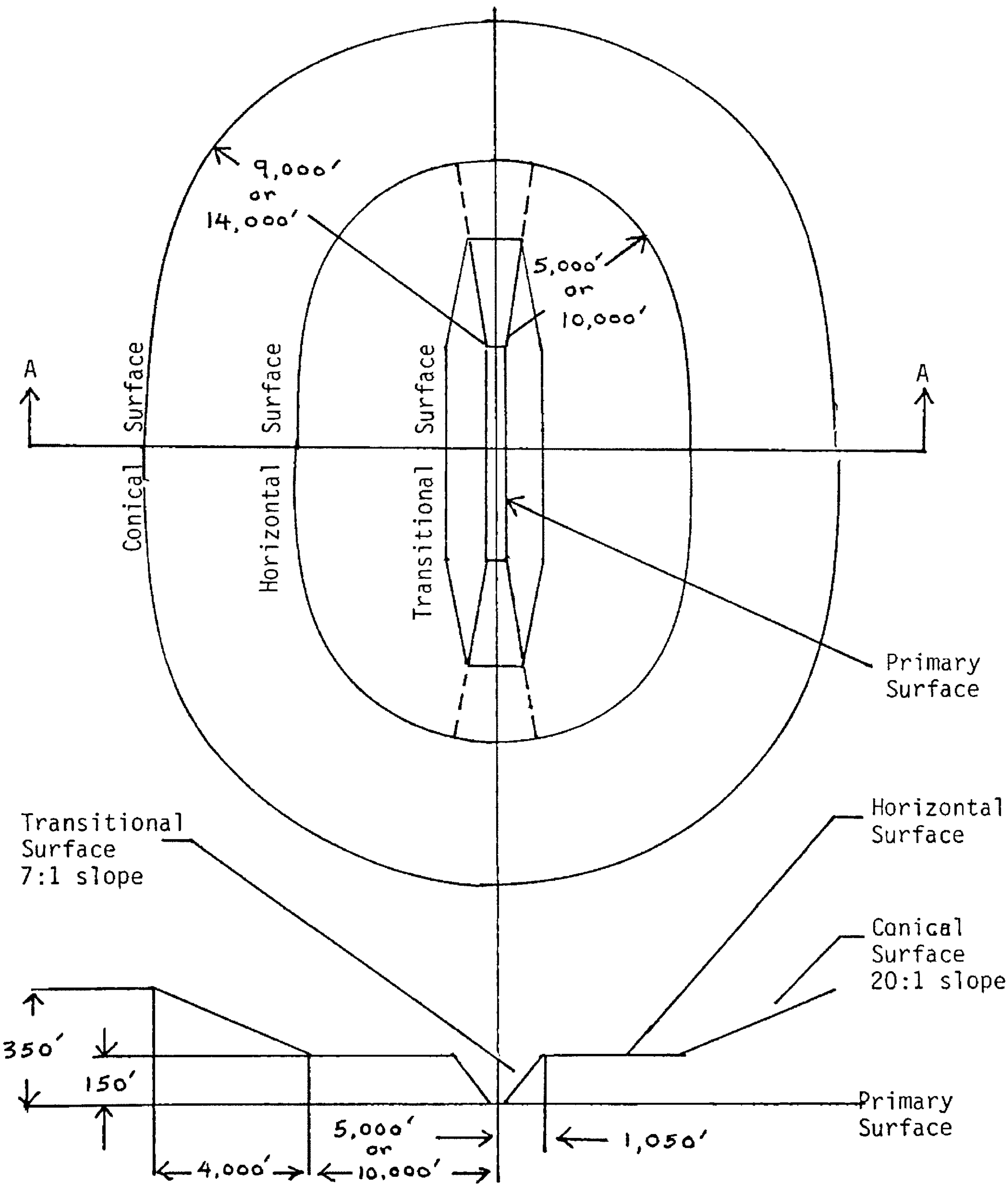


Legend:

A: Visual Approach, Utility Runway
B: Visual Approach, Larger than Utility Runway
C: Non-precision Instrument Approach, Utility Runway
D: Non-precision Instrument Approach, Larger than Utility Runway
E: Precision Instrument Approach, Larger than Utility Runway

FIGURE 6

Dimensions for Transitional, Horizontal, and Conical Surfaces by Runway Type



SECTION A-A

Runway alignments and dimensions should be drawn directly on topographical maps. Then, using the information provided by Figures 4, 5 and 6, flight surface dimensions and slopes can be put on the maps. The ground elevation contours and flight surface dimensons together will define the distance separating the ground from the surface, becoming the reference by which maximum land use heights can be set.

TASK 3: Land Use Issues Identification

Airspace and ground areas subject to different accident potentials can be determined from flight surface dimensions. Airspace needs and land use issues should be examined through an obstructional analysis, devoted to aircraft maneuvering and communication requirements. The potential severity of accidents can be evaluated by mapping ground points beneath clear zone and approach surfaces and listing those land uses involving concentrations of people as unsuitable for these locations. Another crucial determinant, noise, can be assessed by compiling the amount and quality of airport operations. Once analyzed, these determinants should be combined to produce an overall impact map.

A. Obstructional Analysis

Overall land use height limitations can be assessed by using the distance between the ground and flight surface at any given location. Common obstructions for each surface type are listed in Table 1, pp. 13-14. Height limitations and a listing of common obstructions should be noted for each surface. Conflicts should also be noted for existing land uses or topographical variations.[16] Many of the existing or potential flight surface encroachments result from natural or incidential uses such as trees, power poles, fences, and boulders.

The land use matrix in Table 2, p. 15, identifies land uses which may hinder aircraft communication by producing glare, particulates, or radio interference under flight surfaces. Potential land use conflicts resulting from these interferences should be noted for each flightpath. The potential conflicts are combined with the height restrictions for each flight surface to produce a comprehensive obstruction analysis. The results will constitute one source element in an overall impact map. This map, identifying land use restrictions by

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[16] Flight surface elevations are relative to the mean runway elevation. Changes in ground elevation outside of airports affect land use height limitations. For example, if an area located beneath a horizontal surface is seventy-five feet above the mean runway elevation, then the distance separating the ground and the horizontal surface is only seventy-five feet. The Kingman (Arizona) Municipal Airport lies in an alluvial valley bordered by the Cerbat and Hulapai Mountains, respectively to the west and south. The airport's horizontal surface is actually lower in elevation than several of the surrounding foothill areas. Although pilots will avoid natural flight surface encroachments, planners should make sure existing problems are not compounded. In Kingman's case, land use regulations prohibit installation of radio, television, or microwave transmission or relay towers on surfaces penetrating the horizontal surface. These restrictions were advised since radio towers are commonly installed on hilltops.

area, will also assess accident hazard potentials and noise impacts.

B. Accident Dangers

Areas below clear zone and approach surfaces are exposed to high risks posed by crashes and missed landings. Excluded land uses are those which attract concentrations of people such as schools, hospitals, office buildings, and stadiums. Clear zone and approach surface dimensions are commonly used to define accident-prone areas. However, a community can expand this area if it desires. A complete listing of all people-oriented uses to be kept out of accident-prone areas should be made. This will be added to the obstructional analysis and noise assessment in compiling the overall impact map.

C. Assessing Noise

Although noise impacts enter into the compilation of an overall impact map, their assessment is involved and requires considerable description. In consequence, noise assessment is presented as three separate tasks. These tasks involve task 4, making noise projections for airports; task 5, establishing noise contours; and task 6, formulating land use recommendations.

TASK 4: Airport Projections for Noise Estimations

The easiest way to accomplish this task is to obtain already-prepared projections, often obtainable from the airport operator or the State's Department of Transportation.

Projections normally are part of an airport's capital improvements plan and State-prepared aviation forecasts. If projections are unavailable, planners must estimate future activity. If the airport is at maximum capacity with no anticipated expansion, then projections are unnecessary and existing flight conditions will suffice for a noise assessment. Existing or projected operations need to include total annual operations, average daily operations by aircraft type, and average nightly (10:00 p.m. to 7:00 a.m.) operations by aircraft type. Approximate projections for each can be based on three related analyses: A. air service demand, B. airport capabilities, and C. external constraints and opportunities.

A. Demand for services involves two general aviation user classes:

> Fixed Base Operations -- these are usually small aircraft under 12,500 lbs. based permanently at the airport. Includes government planes, business planes, crop dusters and craft used for leisure and personal use. May include small jets, and propeller-driven craft above 12,500 lbs.
>
> Itinerant Operations -- these are stop and go operations. They can be on a regular schedule such as express freight and occasional commuter travel. Unscheduled operations include visitation, touch and go operations, flying lessons, fueling and/or overnight rest stops. Itinerant operations for small airports can be significant in or near resort areas, industrial areas, or large cities. These may include aircraft of all sizes up to the maximum permitted at the airport.[17]

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[17]Johannesen and Girand, Consulting Engineers, "Master Plan Report for Mohave County Airport." Oct. 24, 1984. (Kingman, AZ), pp. 6-8, pp. 33-35.

The demand for fixed base operations usually is associated with market area population, employment, and income. Demand for itinerant operations also relates to employment and population, but is primarily influenced by types of industries in the area, location of established air routes near the airport, and the community's role as a destination point for recreational activity. Projections of fixed base and itinerant operations can be tied to population and employment projections for the airport's market area.

B. Airfield capabilities may dictate levels of air service and operations. Runway capabilities are determined by their length, thickness, and classification. Fixed-base operators are limited in number by the extent of hangar and tie-down storage. Itinerant operations can be limited in number by the type or amount of fueling and servicing facilities. If the airport's physical facilities are unable to expand, then it is likely that operations will become fixed. Planners should consult the airport's facility master plan, its capital improvement program, and the potential availability of government financial assistance to help assess the airport's future.

C. External constraints may affect the operations of a small airport. An airport's operations may be curtailed because larger, better equipped airports nearby are more attractive to the general aviation public. Airspace conflicts with other airports may also restrict operations to certain levels below airfield capacity or market demands. In contrast, external opportunities may suddenly cause a small airport's operation to increase. For example, an airport located in the general vicinity of an overcrowded airport may be asked to handle some general aviation spillover, thereby increasing its operations.

Projections of airport operations can be derived from other estimated factors such as population, employment, and income estimations along with various qualifiers including type of expected economic development, the role of aviation for future local transportation needs, and other suppositions about the future. The noise contours depicted in Figure 3 were based upon projected airport improvements and operations for Mohave County by the year 2000. Total operations were computed by taking known ratios of fixed based and intinerant operations to current population and applying these ratios to approved 2000 population figures. This is a simple but valid method which assumes that air operations are a function of population. Operation numbers per aircraft type were calculated for the year 2000 by using present-day proportions applied to the projected annual estimated total.

TASK 5: Establishing Noise Contours

Land use guidance zones contained between noise contours delineate areas with potential conflicts expected for different levels of airport activity. Like other plan information, noise contours may be obtained from the airport or State transportation department. If contours are unavailable, NEF or ldn contours can be generated by using computer models.[18] If outside or professional assistance in computing noise contours is not possible, then approximate NEF and ldn contours can be calculated using a mathematical model developed by the Department of Housing and Urban Development.[19] This model allows one to calculate NEF or ldn values at various points beyond runway ends using aircraft operations numbers, type, and time of day. The noise contours shown in Figure 3, p. 23, were based on this simplified method using the following airport information projected for the year 2000:

Aircraft Type	Average Daily Operations	Average Nightly Operations
One and Two Engine Propellor under 12,500 lbs.	150	15
Two Engine Turbo Prop under 12,500 lbs.	20	5
Business Jet	4	0

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[18]Information on how to calculate NEF contours can be found in E. D. Bishop and A. P. Hays; Bolt, Beranek, and Newman, Inc. Developing Noise Exposure Contours for General Aviation Airports (FAA - AS-75-1). December 1975. Information on how to calculate ldn contours can be found in Environmental Protection Aency, Calculation of Day-Night Levels (ldn) Resulting from Civil Aircraft Operations (AW-471). January 1977.

[19]U.S. Department of Housing and Urban Development, "Aircraft Noise Impact, Planning Guidelines for Local Agencies" by Wilsey and Ham, Report TE/NA-472 U.S. Government Printing Office, Washington, D.C. 1972, pp. 207-210.

Also incorporated into the model are the EPNL (Effective Perceived Noise Level) values for each aircraft class. The EPNL quantifies the perceived loudness of individual noise occurrences taking into account duration, intensity, and frequency of a noise signal. EPNL values are published for all aircraft types for various points along their flightpaths and are expressed in decibels (dba).[20] The simplified model provided for the calculation of NEF values, as follows:

$$NEF = EPNL + 10 \log [N(day) + 16.67\ N(night)] - 88$$

where: NEF = Noise Exposure Forecast along a flight path

EPNL = Noise level of a particular airplane produced along a given flight path

N(day) = Number of day operations

N(night) = Number of night operations

In order to illustrate, this equation will be applied to projections for The Kingman Airport. A series of steps, A through E, will be followed:

STEP A

The first step separates projected operations by time and type.

Aircraft Type	EPNL (decibels)	Day Operations	Night Operations
Business Jet	110	4	0
2-Engine turboprop under 12,500 lbs.	93	20	5
2-Engine propellor under 12,500 lbs.	90	150	15

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[20] U.S. Department of Transportation, Federal Aviation Administration, "Certificated Airplane Noise Levels." Advisory Circular No. 36-1B, Washington, D.C. December 5, 1977, 11 pp.

STEP B

The second step weights the number of night operations by 16.67 and adds this figure to the number of day operations.

Business Jet

Night operations	=	0
x 16.67	=	0
+ Day operations	=	4
Total	=	4

2-Engine Turboprop

Night operations	=	5
x 16.67	=	83.35
+ Day operations	=	20
Total	=	103.35

2-Engine Light Craft

Night operations	=	15
x 16.67	=	250.05
+ Day operations	=	50
Total	=	400.05

STEP C

The third step weights the number of operations by multiplying the logarithm of the total number of each aircraft by 10.

a.	Business Jet	10(log 4)	= 6.02
b.	2-Engine turboprop under 12,500 lbs.	10(log 103.35)	= 20.14
c.	2-Engine propellor under 12,500 lbs.	10(log 400.05)	= 26.02

STEP D

The above figures are then added to the EPNL rating for a given point by aircraft type and the normalizing constant (88) is subtracted to identify the NEF for each aircraft type.

a. 6.02 + 110 = 116.02 (-88) = 28.02 NEF

b. 20.14 + 93 = 113.14 (-88) = 25.14 NEF

c. 26.02 + 90 = 116.02 (-88) = 28.02 NEF

STEP E

Total NEF is figured by using this formula.

$$NEF = 10 \log \left[\text{anti log } \frac{28.02}{10} + \text{anti log } \frac{25.14}{10} + \text{anti log } \frac{28.02}{10}\right]$$

$$= 10 \log [633.8 + 326.5 + 630.9] = 10 \log 1591.2$$

$$= 32 \text{ NEF}$$

The EPNL values assigned for each aircraft type represent perceived noise levels in decibels one would hear standing at a location 5,500 feet beyond the runway; therefore, the calculated NEF 32 would be plotted at the identical distance. The EPNL ratings follow FAA-published EPNL contours for each aircraft class.[21] Given these contours, planners can determine EPNL values for each aircraft type at any given point and plot total NEF values to complete noise contours; although this exercise is best left to the computer, approximate contours can be drawn using this model. Noise impacts can also be roughly estimated on the basis of airport type. General Utility airports, limited to planes under 12,500 lbs., handle smaller one and two-engine, propeller-driven craft such as those made by Piper, Cessna, and Beech, the quietest type of aircraft. Basic Utility airports can accommodate larger planes such as those in the two-engine turboprop and business jet class, although these planes usually constitute no more than five percent of annual operations.

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[21] Ibid, 11 pp.

EPNL levels for these aircraft exceed the smaller classes by up to 40 decibels, each 10-decibel increase representing a doubling of noise. Basic Transport airports handle all kinds of aircraft and potentially are the noisest type of general aviation airport. If contours cannot be calculated for a particular airport, then noise-impacted areas may be estimated by using the type of airport as a general guide, as follows:

Airport Class	Noise Impact Area Extension Beyond Runways	Impact Area Width
General Utility	1/2 - 1 Mile	1/2 Mile
Basic Utility	1 - 1 1/2 Miles	1/2 Mile
Basic Transport	1 1/2 - 2 Miles	3/4 Mile

Although not as precise as calculated noise contours, approximated contours reflect the fact that aircraft noise will occur along flightpaths near an airport. These areas can expect noise levels similar to those in LUG Zone B.

TASK 6: Formulating Land Use Recommendations

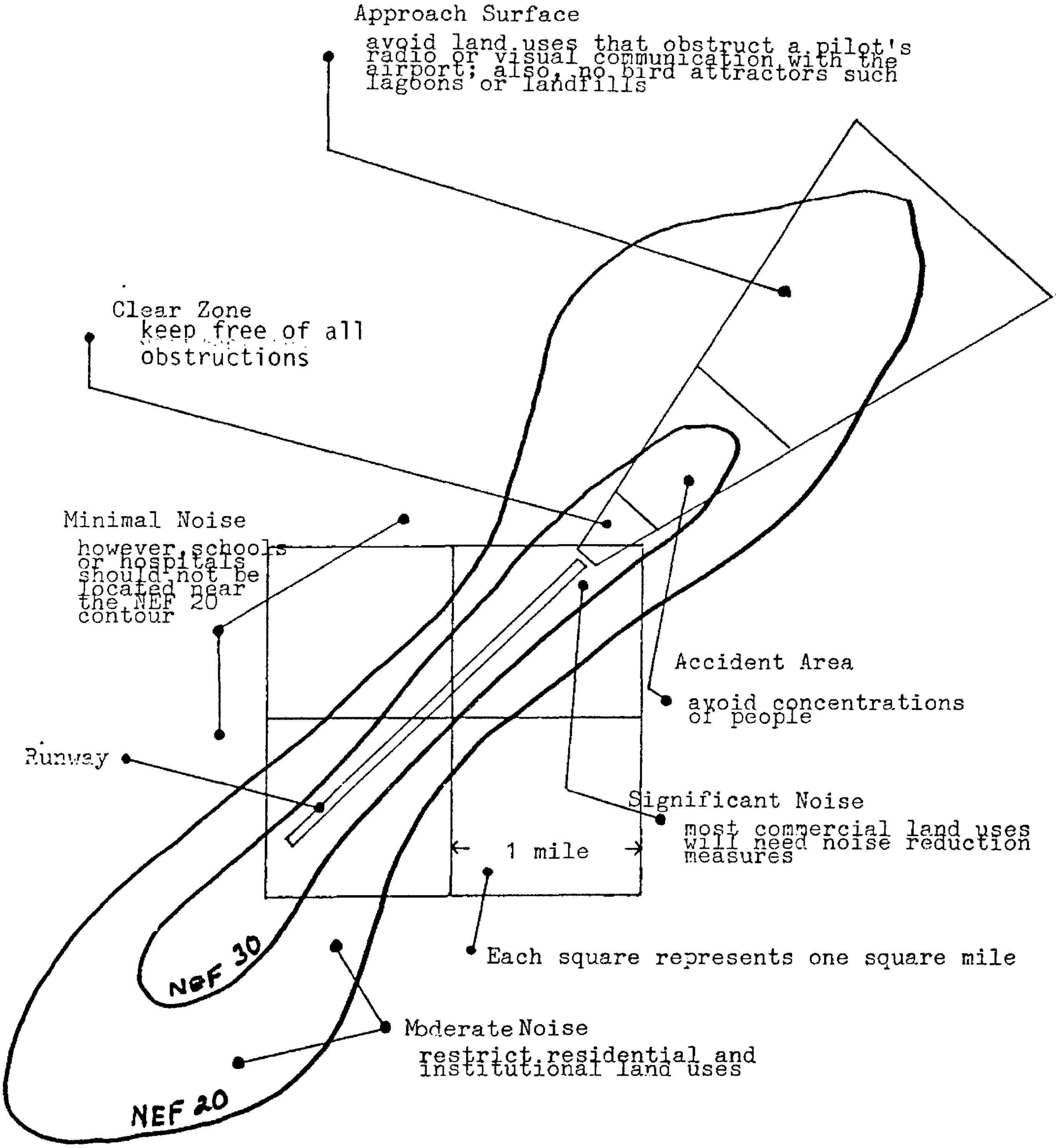
After noise contours and land use guidance zones are identified, planners can list restricted land uses in proximity to the airport. The Land Use Guidance (LUG) System recommends the land use restrictions appearing in Table 2 (pp. 25-26) for various noise exposed zones. These restrictions provide solid direction for land use recommendations which ensure mutual compatibility of future land uses and anticipated noise levels. If an airport assessment is based on the estimation, rather than on the calculations of noise impact areas, then planners may choose to simply restrict all noise-sensitive land uses from the estimated noise area. This approach is not so precise as one which mathematically delineate noise zones, but it is a much more intelligent alternative than to take no action at all. Additionally, cities can choose to require inherently noise-sensitive uses such as hospitals, schools, libraries, and auditoriums to locate well away of all aircraft noise influences, even including areas exposed to just occasional occurrences. The result of this choice is that it provides additional protection for extra-sensitive community uses, giving the community greater peace of mind. Noise impact zones should be added to the overall impact map.

TASK 7: Synthesizing an Overall Impact Map

Cumulative airport-related land use impacts can be illustrated by the noise contours, flight surfaces, and accident-prone areas delineated together on a single map. Fig. 7, p. 48, Mohave County Airport, provides an example combining the noise contours and the locations of accident and sensitive flight surface areas with the listings and locations of recommended land use restrictions. Such a map becomes the primary basis for eventual implementation of land use regulations. It permits one to visualize the proximity and geometry of impacted areas and realize that different re-

FIGURE 7

OVERALL IMPACT SKETCH:
MOHAVE COUNTY AIRPORT



Source: Mohave County Department of Planning. "Mohave County Airport Environs Study". 1983. p. 32.

strictions sometimes overlap. Airport-related land use determinants can be integrated with existing land use plans, or in the absence of such, can include comprehensive information on which to plan.

Integration of Airport-Related Impacts With Other Planning Criteria

An airport environs plan can complement a community's comprehensive plan by adding airport-related land use determinants, or it can take the role of a comprehensive plan by addressing other land use determinants when a community has failed to do so. Although it is not the purpose of this paper to list and discuss comprehensively non-airport land use determinants, examples do exist where cities have successfully integrated or combined airport-related impacts with other land use determinants to achieve comprehensive planning results. Additional land use impacts involve natural determinants, such as soils, slope, and drainage characteristics, and human determinants, such as land use design, extension of utilities, and transportation planning. The Scottsdale, Arizona, "Airport Area Plan" (1979) combines environmental land use determinants with airport related impacts to provide land use recommendations. A main goal of the plan is to preserve as much undisturbed desert as possible, and this has been accomplished by giving preservation status to those areas also severely impacted by accident potential or noise. The Mohave County, Arizona, "Airport Environs Compatibility

Plan" (1983), in addition to including environmental determinants, also addresses utility extensions and capital improvements, thereby providing a complete basis for land use recommendations. Kingman adopted this approach because its airport environs had no previous land use plan or policy. Chandler, Arizona, adopted an "Airport Impact Ordinance" (1984) containing a set of airport-related land use restrictions which were "added" to the City's existing general plan around the airport. None of these plans would have been adopted without first securing the involvement and trust of the public.

TASK 8: Community Participation

Plan preparation should involve some degree of community participation. Plan objectives, solutions, and implementation strategies are meaningful only if they provide benefits understood and agreed upon by the community. Public participation in the planning process, including plan preparation, not only gives the planner feedback on key issues and alternatives but in turn provides continuous information on plan progress to the community. Community participation in the planning process also helps ensure later community acceptance and support of the plan. Finally, community interest may actually motivate volunteers to assist the planner.

By way of illustration, the Mohave County, Arizona, "Airport Environs Compatibility Study" (1983) was initiated by a special task committee of citizens appointed by the local legislature. These individuals possessed varied professional perspectives including those of an engineer, lawyer, airline executive, and pilot. This committee defined the plan's goals and objectives and performed plan preparation tasks consistent with their backgrounds: the attorney researched the legal basis for airport planning; the engineer drew the noise contours; the pilot provided flight and other surface maps and a flyer's orientation; the airline executive prepared studies for projecting airport operations. Each committee member worked directly on the plan while representing the public. Each answered questions, informed affected landowners, and brought back their suggestions. Collectively, the committee gave local credibility to the planning process and assisted planners in assembling the document. In consequence, the plan was accepted by the community without issue. The planning document included the information and recommendations generated by completion of each task and formed the basis for later implementation of land use regulations in accordance with community goals.

TASK 9: The Draft Plan

Many states, including Arizona and California, require that city-governed land use regulations be consistent with a city's "General Plan." The information generated by completing the tasks discussed earlier in this section provide a system of base information, impact assessments, land use recommendations, and community goals which link recommendations to actual development. After these are incorporated as a draft plan, the document can be given to property owners, politicians, and public agencies for additional information or review. The document can be updated and amended as conditions dictate without losing sight of its overall purpose.

The airport assessment produced as a consequence of tasks 1 through 7 strives to determine all future airport-related determinants in order to link compatible land uses with the airport's ultimate potential; therefore, the plan should be implemented for a long-term period covering ten to twenty years. Plan updates should be scheduled to coincide with airport expansions. A general aviation facility can expand into a large airport as a consequence of commuter or large jet demand, improvement upgrades, and Federal reclassification to an air-career or commuter airport. In such instances, the plan should incorporate implementation methods based on the advice of professional consultants. Such an airport would fall beyond the scope of a general aviation facility, the subject of this paper.

The tasks reviewed in Part II enable one to analyze a particular airport and to formulate land use recommendations on the basis of airspace requirements, accident potential, and noise impacts. The suggested task organization gives the reader a strategy by which to map out a plan and to show the public the logic of the plan's findings and recommendations. But these recommendations need to be put to work. Part III discusses airport environs plan implementation and common techniques used by planners to effect desired land uses.

PART III: IMPLEMENTATION METHODS

An airport environs plan makes recommendations which balance airport and land use needs to insure their mutual compatibility. Land use controls are needed to implement these recommendations, the majority of such controls require public intervention through accepted techniques such as zoning laws or property easements. In addition, other regulatory techniques exist to implement plan objectives. Cities can select one or several to serve their purposes. It is important to realize that, if possible, land use regulations should be applied positively and creatively, not in a way which "locks up" land use potential, a condition which risks the loss of community and political support.

Types of Land Use Controls

Zoning laws represent the most common form of land use control. These laws regulate land uses by creating zoning districts and defining what uses can occur in these districts. Design and intensity guidelines regulating bulk, height, appearance, and lot coverage of allowed uses usually supplement the land use controls of each district. These districts can then be patterned throughout a community's area in a way consistent with planned recommended land use arrangements. Likewise, zoning can be used to impose land use patterns that respect airport-related needs and impacts. Zoning controls can be applied in various ways to meet community objectives:

1. Traditional Zoning Districts

Zoning is most commonly exercised by districts which allow integration of compatible or "like" uses inside district boundaries. Traditional districts classify land use into open space or agricultural, industrial, commercial, or residential areas. These general classifications can be further subdivided into specialized categories such as single family residences, neighborhood retail commerce, or heavy industry. Land use control can be applied effectively near airports by designating zoning districts which permit compatible uses and prohibit incompatible land uses in certain impacted areas. For example, districts permitting residences and institutions would not be located in noise-impacted areas. The use of zoning districts works best following a planned land use arrangement consistent with the location and quality of airport-related impacts. The major problem with using traditional districts is that they may be too broad or general to implement specific land use needs. For example, industrial districts may preclude noise-sensitive uses under flightpaths but permit factories producing smoke. Thus, other approaches to zoning may be needed to effect the plan.

2. Creating an Airport Zoning District

Some states, including Arizona and California, permit cities to establish zoning laws to effect specific land use and aviation compatibility. As opposed to traditional zoning districts, which permit many uses falling under a usually broad category, special districts can define a reduced range of permitted uses. For an airport environs plan, these uses can be defined in relation to identified impacted areas. The Kingman, Arizona plan was implemented by such a district which was extended over a six square-mile area earlier identified by airport-related impacts. This "Airport Development" (AD) Zone combines height and use restrictions respecting noise, flight surfaces, and accident potential, with wording as follows:

Airport Development Zone (AD)

Land Use:

Permitted Uses: Agricultural uses; open space - golf courses; resource conservation or study; cemeteries; riding stables and horse breeding farms; retail plan nurseries; creameries; public garages; car sales lots; storage within buildings (warehousing); aircraft maintenance yards; wholesale stores; manufacturing plants producing no noise, light, particulates, smoke, dust or glare; screened open storage areas.

Other Uses: Any other use which is construed to be a like use with above-listed uses excluding those which attract permanent large numbers or high concentrations of people, are noise sensitive, or which constitute a safety hazard to normal airport flight operations.

Uses Prohibited: All residential uses whether permanent or transient, including single family, multiple family, residential subdivisions, cooperatives, condominiums and mobile home parks; schools, churches, daycare centers, funeral homes, nursing homes, infirmaries, hospitals, orphanages, theatres, and private airstrips, sanitary landfills.

In addition, no use shall be allowed which:

a. Release into the air any substance which would impair visibility or otherwise interfere with the operation of aircraft.

b. Produce light emissions, either direct or indirect which might interfere with pilot vision.

c. Attract birds or water fowl in such numbers as would create a hazard to aircraft operations; i.e. sanitary landfills, sewage lagoons.

Height:

No use or structure within the AD zone shall exceed sixty (60) feet in height or shall encroach within any flight or airspace control surfaces established for aircraft approach, landing and maneuvering, as established by F.A.A.[22]

The AD Zone is tailored to the land use needs identified near the Kingman Airport and is consistent with the airport environs plan to combine open spaces with selected industries. There exist other variations of the special district.

Another variety of the special district is the floating or flexible zoning district used widely to promote mixed-use developments not usually possible under traditional zoning. Several cities in Arizona, including Chandler, employ a Planned Area District (PAD) which is not limited to a defined set of restrictions but which accommodates various combinations of land uses and restrictions. Chandler uses the PAD classification to achieve land uses complementary to the airport. Land near the Chandler Airport is zoned for agricultural uses. A developer proposing other types of land uses must submit to the City detailed development plans depicting land use arrangements by type, intensity, quality, and height. If these uses conform with the airport environs plan objectives, the land is zoned PAD and is restricted to the

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[22]Mohave County Development of Planning. "Mohave County Airport Environs Study," 1983, pp. 45-46.

City-approved development plan. This may be the best way to implement airport-related land use recommendations because its variations and restrictions are unlimited. Planners can virtually tailor land uses by their location within airport impacted areas. In situations where flexible zoning is impossible or limited by existing traditional zoning, a different variety of zoning, overlay zoning, may prove useful.

As implied by its name, overlay zoning establishes a second set of land use restrictions over already-zoned areas. This method supplements existing zoning by imposing additional use or height restrictions as needed. Although Chandler, Arizona relies on flexible zoning for new development near its airport, existing development and some undeveloped land carry traditional zoning classifications permissive of various land uses. Chandler has extended an overlay zone over already zoned property to limit building heights and the addition of residences which otherwise would be unconditionally permitted. Overlay zoning allows cities to add needed restrictions in airport-impacted areas without changing the underlying zoning.

Besides zoning, there exist other approaches to implementing an airport environs plan. They include subdivision controls, land use easements, transfer of development rights, land purchase, and use of building standards. These methods can supplement zoning or help effect plan implementation in the absence of zoning; they are discussed below.

Subdivision Controls

Many states have legislation giving cities the power to regulate the subdivison of land. In Arizona, cities require subdividers to record a map or plat depicting the location of roads, lots, and other improvements. The affected city then approves or denies the subdivision based upon its General Plan goals such as land capability, availability of utilities, or other determinants including those which are airport-related. Subdivision laws do not regulate land uses but limit the placement of roads and number of new lots. By restricting or prohibiting roadways and new lots, cities can help promote land uses that meet the goals of the airport environs plan. An example would be that of denying any residential subdivisions in noise-impacted areas.

Subdivision controls should be supplemented by zoning. If a city does not have zoning laws, then land uses should be regulated via other means. Easements and covenants represent additional means to achieve possible land uses.

Easements and Covenants

An easement is a limited right to use another's property. Negative easements give the holder the right to prevent things from happening on another's property; for example, cities can acquire, through purchase or dedication, easements over property which restrict obstacle heights or land use. These easements can be used to regulate land uses in clear zones or in areas beneath flightpaths not owned by the airport. In contrast, positive easements give the holder the right to use the property; for example, cities may acquire positive easements for the right to fly over property, create noise, or present endangerment. The property owner determines the cost of an easement in terms of how much the easement restricts his use or enjoyment of the property. Easements can be defined to implement any restriction needed in a given situation. A covenant is a promise from a property owner to maintain a property for certain purposes. Easements and covenants usually involve negotiation of public funds or other public resources. Another similar method of land use control which does not require public expenditures makes use of development rights.

Transfer of Development Rights

Some cities allow landowners to sell or transfer development rights to others. For example, a city can prevent development from occurring in severely impacted areas by permitting the landowner to sell his development rights as defined by zoning and transfer these rights to property located elsewhere. This method can effectively shift development potential away from airport-impacted areas. For example, if existing zoning under a flightpath allows for apartments, then a city can allow an owner to sell his right to build apartments to a purchaser who then can build apartments in another location properly zoned. In effect, the seller agrees not to develop his property for compensation equal to loss in property values. The seller and buyer both benefit from the transaction, and the city has achieved control over the development of the property in accordance with airport environs plan objectives. If property owners refuse or are unable to cooperate through easements, covenants, or development rights, then outright purchase or condemnation of property may be necessary.

Property Acquisition

Outright purchase of impacted areas is expensive but sometimes necessary. The most critical lands such as those beneath primary and clear zone flight surfaces should be under city or airport ownership. Cities should consider purchasing or condemning tracts of land beneath approach surfaces for public parks, golf courses, or other open spaces dedicated to public use. Cities also should consider land purchases near their airports for locating public facilities such as water tanks, vehicle storage yards, or other service uses compatible with airport-associated impacts. In addition, land can be acquired through dedication by property owners. For example, if someone seeks to develop land near an airport, dedicated land required for open space, drainage, or water storage can be concentrated in airport-impacted areas.

Building Modifications

The impacts of noise on people can be mitigated through structural modifications designed to noise-proof a building's interior. These modifications provide added protection for land uses, especially those on the airport premises such as offices, terminal areas, and cafeterias. The Land Use Guidance System (LUG) permits certain uses to locate in noise-impacted areas if the buildings incorporate various structural improvements to reduce interior noise levels. A survey of 60 hospitals and schools near six major U. S. airports concluded that normal building standards provide roughly a twenty decibel noise level reduction from exterior aircraft-noise levels.[23] (Perceived interior noise is one fourth as loud since each 10 decibel reduction halves the perceived loudness.) The Land Use Guidance Systems (LUG) permits hospitals, residences, and schools in noise areas not exceeding 60 ldn or 25 NEF if maximum interior noise levels do not exceed 45 decibels. Normal construction practices usually ensure this reduction. Commercial retail, offices, and services can comfortably locate in areas of moderate exposure (ldn 60-70 - NEF 25-35) if interior noise levels do not exceed 45 decibels, a needed interior noise reduction of 15-35 decibles. A 15 decibel reduction beyond standard in-

[23] U. S. Department of Transportation, Federal Aviation Administration. "The Feasibility, Practicality, and Cost of the Soundproofing of Schools, Hospitals, and Public Health Facilities Located Near Airports." Report to Congress by the Secretary of Transportation (Washington, D.C. 1977). p. i.

terior noise levels requires building modifications primarily consisting of replacement of normal windows with sealed, double pane windows, addition of insulation, and weatherstripping windows, doors, and vents. Modifications providing an additional 20-25 decibel reduction include sealing windows with wall materials, providing additional insulation, and installing 24-hour ventilation.[24] Buildings requiring noise level reductions should not be located in noise areas if alternative areas are available. Noise reduction is particularly useful for commercial and industrial office uses associated with airport operations or in business parks near the airport.

<u>Keeping Land Use Controls in a Positive Framework</u>

Effective plan implementation requires that land use controls be tied to positive goals. Hostile public intervention in the way land is used can defeat the plan if positive results are not clearly demonstrated. For example, zoning vast amounts of land for open spaces or industrial uses does little good if the land is unsuitable or unmarketable for these uses. Housing developments excluded from noise-exposed areas should be given alternative locations suited for residences, especially in order to meet the housing demands of airport or airport-industry employees. These types of regulations need realistic applications. The Cities of Scottsdale, Chandler, and Kingman, Arizona take an active and positive approach to

[24] Ibid, p. i.

land use regulations for their general aviation airports. All three cities have acquired extra land around their airports for lease to airport-related services and industries; all three cities provide economic incentives for industries to locate in these areas. This approach combines land use regulations that ensure airport compatibility with the economic progress of the community. Chandler's goal is to make its airport an employment center to be surrounded by complementary commercial uses. Non-impacted areas near the airport are intended for residential uses, shopping centers, and schools. Severely-impacted areas are reserved for parks, golf courses, and open areas for stormwater retention. This approach is comprehensive, positive, and realistic, and is supported by the community as a long-term commitment.

Ideally, recommendations in an airport environs plan should be implemented prior to land use development. The techniques discussed in this Part represent different means to accomplish plan objectives and have been successfully utilized by other communities. Cities may find it advantageous to use a combination of techniques to implement their planning; for example, severely impacted areas within or near clear zones should be kept open through land or easement acquisition, whereas less impacted areas can be devoted to compatible land uses by means of various zoning techniques. In addition, overall development trends near airports can be affected by regulation of street designs or utility extensions. However, the effectiveness of any of these techniques depends on a community's commitment to stand by its plan as well as the statutory municipal planning limitations of a particular state.

SUMMARY

The importance of planning for aiports is magnified by considering the consequences of not planning. Failure to keep flightpaths free of obstructions and to protect people from accidents or noise threatens the safe juxtaposition of the airport and nearby land uses, a condition which is damaging and potentially irreversible. Small airports require effective planning, particularly since they can accelerate development near their peripheries. Since planning alternatives range most freely and are easiest to implement prior to development of the airport area, the immediacy of early planning is crucial. Given the right information, a plan can be formulated expeditiously.

The information provided to the reader in Part I lists and discusses airport operations and their fundamental characteristics having land use implications. All airports have specific flight surfaces, accident-prone areas, and aircraft noise. Each of these characteristics requires appropriate land use regulation to ensure mutual airport and land use compatibility. The type and severity of detrimental impacts depend on the airport's physical capabilities and schedule of operations. Given these characteristics and their land use implications, planners can proceed. Such information is obtained through an airport analysis involving the series of tasks listed and discussed in Part II. This series guides

the user in conducting an airport analysis, in identifying the nature and extent of land use impacts, and in formulating informal land use recommendations. Each task is intended to permit those without previous exposure to airport environs planning to meet each challenge successfully. The first task involves general information gathering and solicitation of assistance from government agencies. Other tasks are designed primarily to enable the user to identify types of airports and to assess the future growth of a particular airport. The quality of airport operations determines directly the quality of land use impacts, and some additional tasks facilitate these determinations. Once suitable land use recommendations are formulated, the final tasks provide for plan implementation. Part III provides alternatives for this effort.

Part III involves traditional implementation techniques used in land use planning. Planners can rely on a single method, or they can combine methods to achieve desired results. The primary goal of any plan should be to sustain itself and the public trust through community political, economic, and social changes. The techniques discussed can be successfully matched with a city's financial resources and existing general plans. These techniques dictate land use arrangements which provide perpetual harmony with the airport, thereby putting to rest possible obstructions to airport operations or threats to community safety. The crucial point, however, relates to the immediacy of planning since an airport environs plan works only when implemented prior to airport-area improvements and land use development.

GLOSSARY OF TERMS

APPROACH SURFACE; A surface longitudinally centered on the extended runway centerline, extending outward and upward from the end of the primary surface and at the same slope as the approach zone height limitation slope set forth in Section II of this Ordinance. In plan, the perimeter of the approach surface coincides with the perimeter of the approach zone.

CONICAL SURFACE; A surface extending outward and upward from the periphery of the horizontal surface at a slope of 20 to 1 for a horizontal distance of 4,000 feet.

HORIZONTAL SURFACE; A horizontal plane 150 feet above the established airport elevation, the perimeter of which in plan coincides with the perimeter of the horizontal zone.

LARGER THAN UTILITY RUNWAY; A runway that is constructed for and intended to be used by propeller driven aircraft of greater than 12,500 pounds maximum gross weight and jet powered aircraft.

NONPRECISION INSTRUMENT RUNWAY; A runway having an existing instrument approach procedure utilizing air navigation facilities with only horizontal guidance, or area type navigation equipment, for which a straight-in nonprecision instrument approach procedure has been approved or planned.

PRECISION INSTRUMENT RUNWAY; A runway having an existing instrument approach procedure utilizing an Instrument Landing System (I.L.S.) or a Precision Approach Radar (P.A.R.). It also means a runway for which a precision approach system is planned and is so indicated on an approved airport layout plan or any other planning document.

PRIMARY SURFACE; This surface defines the limits of the obstruction clearance requirements in the immediate vicinity of the landing area. The primary surface comprises surfaces of the runways, runway shoulders, and lateral safety zones. The length of the primary surface is the same as the runway length. The width of the primary surface is 2,000 feet (1,000 feet each side of the runway centerline). However, at established bases where substantial construction has taken place in accordance with previous lateral clearance criteria the 2,000 foot width may be reduced to the former criteria.

RUNWAY CLEAR ZONE; A trapezoidal area at ground level under the control of the airport authorities for the purpose of protecting the safety of approaches and keeping the area clear of congregation of people. The runway clear zone begins at the end of each primary surface and is symmetrically centered upon the extended runway centerline. Clear zone slope extends upward to the Approach Zone at a point 50 feet above elevation runway.

TRANSITIONAL SURFACES; These surfaces extend outward at 90 degree angles to the runway centerline and the runway centerline extended at a slope of seven (7) feet horizontally for each foot vertically from the sides of the primary and approach surfaces to where they intersect the horizontal and conical surfaces. Transitional surfaces for those portions of the precision approach surfaces, which project through and beyond the limits of the conical surface, extend a distance of 5,000 feet measured horizontally from the edge of the approach surface and at 90 degree angles to the extended runway centerline.

UTILITY RUNWAY; A runway that is constructed for and intended to be used by propeller driven aircraft of 12,500 pounds maximum gross weight and less.

VISUAL APPROACH RUNWAY; A visual runway is a runway intended solely for the operation of aircraft using visual approach procedures.

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