CHAPTER 9

Establishing Airport Safety Compatibility Policies

OVERVIEW

Compared to noise compatibility issues, the need to address the safety aspects of interactions between airports and surrounding land uses is largely a forgotten compatibility planning topic. Perhaps this is because aircraft noise is experienced daily, but off-airport accidents are rare. Except for regulations on airspace obstructions and clearance requirements in the immediate vicinity of runways, there are few formal federal or state standards addressing safety compatibility concerns. This *Handbook* provides the most comprehensive guidance known to be available.

This chapter expands upon the safety and airspace protection concepts outlined in Chapter 3. It analyzes the accident data presented in Chapter 8 and assesses how this data and other factors can be applied to the development of safety compatibility policies for inclusion in compatibility plans prepared by airport land use commissions. Major sections address:

- The nature of airport land use safety compatibility concerns;
- The foundations of safety compatibility policies;
- Fundamental risk concepts;
- Geographic patterns of aircraft accidents;
- Development of safety compatibility policies for individual airports; and
- Airspace obstructions and other hazards to flight.

Most of the discussion in this chapter deals with the development of safety compatibility zones and associated criteria aimed at limiting the consequences which aircraft accidents can have upon people and property near airports. The need for establishment of safety compatibility zones does not imply that airports are unsafe. Neither does it suggest that existing land uses near airports are necessarily unsafe. Indeed, aircraft accidents in the vicinity of airports are very infrequent occurrences and, historically, very few people on the ground have been seriously or fatally injured as a result of such accidents. Safety, though, is a relative concept. More can almost always be done to enhance safety. The important questions to be answered are: what is an acceptable level of safety; and what is the cost of attaining that level? Central to the assessment of these issues is the concept of risk. This topic is explored in a major section of this chapter.

Beyond the fundamental concept of risk, the specific issue addressed in this chapter is what restrictions should be placed on development of land uses near airports in response to the potential occurrence of aircraft accidents. It is not sufficient to rely solely upon Federal Aviation Administration guidance for this purpose. The focus of FAA standards is on the safe operation of aircraft, not on land use planning (the federal government has no direct authority over local land uses in any case). Also, it is misguided to argue that restrictions beyond those defined by the FAA are unnecessary given the historically infrequent occurrence of accidents resulting in serious consequences to people on the ground. To a significant extent, the good record with regard to harm that has come to people and property near airports can be attributed to the existence of compatible land uses near airports. As airport environs become more intensively urbanized, the likelihood of more severe accident consequences can only increase. Thus, if the utility of airports and the safety of the general public are both to be protected, decision makers will need to be more aware of and more responsive to safety-related compatibility concerns.

The discussion and guidance presented in this chapter is concerned with aircraft accidents, not deliberate acts.

The final sections of the chapter present guidelines which airport land use commissions, together with the counties and cities which have jurisdiction over airport area land uses, can use as the basis for establishing safety compatibility policies for areas around airports. No pretense is made that the suggested guidelines represent an ideal or absolute level of safety or land use compatibility. Rather, they are intended to represent a multi-faceted balance: a balance between the need for protection of airports and the public and the necessity for, or inevitability of, some amount of development near most airports; and also a balance between the benefits which airports provide and the risks which they present. In this regard, an assessment in the 1952 *Report of the President's Airport Commission* (the Doolittle Commission)—a document which provided the foundation for addressing airport land use safety compatibility—says it well and remains valid today:

> "Absolute safety for the individual is an ideal which has ever been sought but never attained. Because man does not have full control over his environment, the very function of living has inherent hazards which become more pronounced as the scheme of living grows more complex. Thus, since absolute safety is a theoretical concept, one can speak only of relative risk."

SAFETY CONCERNS

Safety is a factor in the interaction between airports and nearby land uses in three distinct ways:

- Protecting people and property on the ground;
- Minimizing injury to aircraft occupants; and
- Preventing creation of hazards to flight.

Each of these concerns needs to be addressed in airport land use compatibility plans. The nature of each concern can be summarized as noted here. More detailed evaluation of each concern is the objective of the remainder of this chapter.

Protecting People and Property on the Ground

Protecting people and property on the ground from the potential consequences of near-airport aircraft accidents is a fundamental land use compatibility planning objective. To accomplish this, some form of restrictions on land use are essential. Land use characteristics are the most important factors to consider in developing safety compatibility criteria. The potential severity of an off-airport aircraft accident is highly dependent upon the nature of the land use at the accident site. For the purposes of evaluating the relative risks presented by different land uses, three characteristics are most important:

Even when safety compatibility criteria are formatted in terms of a detailed list of land uses, usage intensity is generally the basic factor upon which the acceptability or unacceptability of each use is judged.

- **Intensity of Use**—The most direct means of limiting the potential consequences of an off-airport accident is to limit the intensity of use. Intensity of use is measured in terms of the number of people which the development can attract per acre. This metric serves as a common denominator among various types of nonresidential uses. Except for certain especially risk-sensitive uses, as noted below, the degree of safety compatibility is usually considered the same for any two land uses having similar usage intensities.

Even when safety compatibility criteria are formatted in terms of a detailed list of land uses, usage intensity is generally the basic factor upon which the acceptability or unacceptability of each use is judged.

- **Residential versus Nonresidential Function**—Residential land uses are typically measured in dwelling units per acre rather than people per acre. This is principally a practical measure to simplify implementation. However, residential uses are also normally afforded a comparatively higher degree of protection than nonresidential ones. That is, for a given location, higher occupancy levels are permitted for nonresidential uses than for residential uses.

- **Sensitive Uses**—Certain other types of land uses are also commonly regarded as requiring special protection from hazards such as potential aircraft accidents. These uses fall into two categories:
  - *Low Effective Mobility Occupancies:* Society normally seeks a high degree of protection for certain groups of people, especially children and the infirm. A common element among these groups is inability—either because of inexperience or physical limitations—to move out of harm's way. Among the types of land uses which are regarded as particularly risk sensitive are elementary and secondary schools, day care centers, hospitals, and nursing homes.
  - *Hazardous Materials:* Functions, such as aboveground storage of large quantities of flammable materials or other hazardous substances which could substantially contribute to the severity of an aircraft accident if they were to be involved in one.

A limit of no more than 6,000 gallons is suggested. Tanks larger than this size must meet more stringent requirements under the Uniform Fire Code as well.

Minimizing Injury to Aircraft Occupants

In accidents involving an aircraft that is out of control as it descends, the character of the land uses below are not likely to have a significant effect on the survivability of the crash. However, as noted in Chapter 8, some aircraft mishaps involve situations in which the aircraft is descending, often without power, but otherwise under control. If the aircraft has sufficient altitude, the pilot has some choice as to where to attempt an emergency landing. Under these circumstances, the pilot of a disabled aircraft will, if possible, direct the aircraft toward some form of open land when an off-airport emergency landing is inevitable.

This propensity forms the premise behind the primary form of land use control intended to minimize the severity of injury to aircraft occupants in the event of an off-airport emergency landing. Specifically, some amount of useful open land should be preserved in the vicinity of airports. This concept is largely limited to airports that serve small aircraft.

Preventing Creation of Hazards to Flight

Unlike the preceding land use characteristics which can only affect the consequences of an aircraft accident (for better or worse), hazards to flight can be the cause of an accident. Hazards to flight fall into three basic categories:

- Obstructions to the airspace required for flight to, from, and around an airport;
- Wildlife hazards; and
- Other forms of interference with safe flight, navigation, or communication.

SAFETY POLICY FOUNDATIONS

In order for ALUCs and local land use jurisdictions to address the preceding compatibility concerns, an assessment of safety standards and guidelines set by federal and state agencies is essential. Unlike the case with noise, though, few federal and state laws, regulations, or policies address the issue of safety-related land use compatibility around airports. Only the guidelines prepared by the Department of Defense for military air bases are comprehensive in their approach. This section summarizes significant criteria which federal and state agencies have developed.

Federal Aviation Administration

Property acquisition for approach protection purposes is eligible for FAA grant funding.

Land use safety compatibility guidance from the Federal Aviation Administration (FAA) is limited to the immediate vicinity of the runway, the runway protection zones at each end of the runway, and the protection of navigable airspace. The lack of FAA land use compatibility criteria for other portions of the airport environment is often cited by land use development proponents as an argument that further controls on land use are unnecessary. What must be remembered, however, is that the FAA criteria apply only to property controlled by the airport proprietor. The FAA has no authority over off-airport land uses—its role is with regard to the safety of aircraft operations. The FAA's only leverage for promoting compatible land use planning is through the grant assurances which airport proprietors must sign in order to obtain federal funding for airport improvements. State and local agencies are free to set more stringent land use compatibility policies as they see fit.

Runway Vicinity

The emphasis in FAA safety criteria is upon the runway surface and the areas immediately adjoining it. Standards are established which specify ground surface gradients for areas adjacent to runways and the acceptable location and height of aeronautical equipment placed nearby. These areas normally are encompassed within airport boundaries.

These standards are set forth in an FAA Advisory Circular entitled *Airport Design* (AC 150/5300-13).

Runway Protection Zones

Runway protection zones (RPZs) are trapezoidal-shaped areas located at ground level beyond each end of a runway. The dimensions of RPZs vary depending upon:

- The type of landing approach available at the airport (visual, non-precision, or precision); and
- Characteristics of the critical aircraft operating at the airport (weight and approach speed).

Runway protection zones (previously called clear zones) date from a recommendation in the 1952 *Report of the President's Airport Commission*. See Chapter 8 for additional information.

Ideally, each runway protection zone should be entirely clear of all objects. The FAA's *Airport Design* advisory circular strongly recommends that airports own this property outright or, when this is impractical, to obtain easements sufficient to control the land use. Acquisition of this property is eligible for FAA grants (except at some small airports which are not part of the national airport system). Even on portions of the RPZs not under airport control, the FAA recommends that churches, schools, hospitals, office buildings, shopping centers, and other places of public assembly, as well as fuel storage facilities, be prohibited. Automobile parking is considered acceptable only on the outer edges of RPZs (outside the extended object free area).

Beyond the runway protection zones, the FAA has no specific safety-related land use guidance other than airspace protection. However, additional property can also potentially be acquired with federal grants if necessary to restrict the use of the land to activities and purposes compatible with normal airport operations. In general, this property must be situated in the approach zones within a distance of 5,000 feet from the runway primary surface. Exposure to high levels of noise can also be the basis for FAA funding of property acquisition.

Airspace Protection

Part 77 of the Federal Aviation Regulations (FAR), *Objects Affecting Navigable Airspace*, establishes standards for determining obstructions to navigable airspace and the effects of such obstructions on the safe and efficient use of that airspace. The regulations require that the FAA be notified of proposed construction or alteration of objects—whether permanent, temporary, or of natural growth—if those objects would be of a height which exceeds the FAR Part 77 criteria. The height limits are defined in terms of imaginary surfaces in the airspace extending about two to three miles around airport runways and approximately 9.5 miles from the ends of runways having a precision instrument approach.

Excerpts from FAR Part 77 are contained in Appendix B.

It is essential to emphasize that FAA aeronautical studies are concerned only with airspace hazards, not with hazards to people and property on the ground. An FAA determination of "no hazard" says nothing about whether proposed construction is compatible with airport activity in terms of safety and noise.

As described below, the California State Public Utilities Code gives the Division of Aeronautics and local governments authority to prevent hazards to air navigation.

Also, under state laws, an airport's permit to operate could be restricted, suspended, or revoked because of objects deemed by the FAA to be hazards to air navigation.

When notified of a proposed construction, the FAA conducts an aeronautical study to determine whether the object would constitute an airspace hazard. Simply because an object would exceed an airport's airspace surfaces established in accordance with FAR Part 77 criteria does not mean that the object would be considered a hazard. Various factors, including the extent to which an object is shielded by nearby taller objects, are taken into account. The FAA may recommend marking and lighting of obstructions.

The FAA has no authority to remove or to prevent construction or growth of objects deemed to be obstructions. Local governments having jurisdiction over land use are typically responsible for establishing height limitation ordinances which prevent new, and enable removal of existing, obstructions to the FAR Part 77 surfaces. Federal action in response to new airspace obstructions is primarily limited to three possibilities:

- For airports with instrument approaches, an obstruction could necessitate modification to one or more of the approach procedures (particularly greater visibility and/or cloud ceiling minimums) or even require elimination of an approach procedure.
- Airfield changes such as displacement of a landing threshold could be required (especially at airports certificated for commercial air carrier service).
- The owner of an airport could be found in noncompliance with the conditions agreed to upon receipt of airport development or property acquisition grant funds and could become ineligible for future grants (or, in extreme cases, be required to repay part of a previous grant).

Additional guidelines regarding protection of airport airspace are set forth in other FAA documents. In general, these criteria specify that no use of land or water anywhere within the boundaries encompassed by FAR Part 77 should be allowed if it could endanger or interfere with the landing, take off, or maneuvering of an aircraft at an airport (FAA–1987). Specific characteristics to be avoided include:

- Creation of electrical interference with navigational signals or radio communication between the airport and aircraft;
- Lighting which is difficult to distinguish from airport lighting;
- Glare in the eyes of pilots using the airport;
- Smoke or other impairments to visibility in the airport vicinity; and
- Uses which attract birds and create bird strike hazards.

Bird strike and other forms of wildlife hazard have become a major concern internationally. In the United States and Canada, reduction and management of wildlife hazards are of particular concern. With regard to bird strike hazards, the FAA specifically considers waste disposal sites (sanitary landfills) to be incompatible land uses if located within 10,000 feet of a runway used by turbine-powered aircraft or 5,000 feet of other runways. Any waste disposal site located within five statute miles of an airport is also deemed incompatible if it results in a hazardous movement of birds across a runway or aircraft approach and departure paths. Caution should be exercised with regard to certain other land uses—including golf courses and some agricultural crops—in these locations to ensure that wildlife hazards do not result (FAA–1997). Additionally, Federal statutes (49 U.S.C. §44718(d)) now prohibit new "municipal solid waste landfills" within six miles of airports that (1) receive FAA grants and (2) primarily serve general aviation aircraft and scheduled air carrier operations using aircraft with less than 60 passenger seats. A landfill can only be built within six miles of this class of airports if the FAA concludes that it would have no adverse effect on aviation safety (FAA–2000b).

U.S. Department of Defense

Safety compatibility criteria for military air bases are set forth through the Air Installations Compatible Use Zones (AICUZ) program (DOD–1977). The objective of this program is to encourage compatible uses of public and private lands in the vicinity of military airfields through the local communities' comprehensive planning process.

With respect to safety, AICUZ standards establish three accident potential zones (APZs) beyond each end of a military airfield runway. The innermost zone—the clear zone—is either trapezoidal in shape (at Navy bases) or rectangular (at Air Force bases). Two additional zones—designated APZ I and APZ II—lie beyond the clear zone. The alignment of these zones may be altered to follow the primary flight tracks. The clear zone length is typically 3,000 feet. Other dimensions vary depending upon the type of aircraft and/or number of aircraft operations on the runway. For most military runways, though, the APZs are 3,000 feet wide and have lengths of 5,000 feet for APZ I and 7,000 feet for APZ II, for a total of 15,000 feet from the runway end.

As noted in Chapter 8, these dimensions were developed based upon a study of where military aircraft accidents have occurred in the past.

Within each zone, the compatibility or incompatibility of possible land uses is specified. For example, residential uses are considered incompatible in the clear zone and APZ I and compatible only at low densities in APZ II. Retail land uses are unacceptable in the clear zone and may or may not be compatible in APZ I and II depending upon on the intensity of use.

State of California

Statutes

As is true at the federal level, California state laws—and regulations as well—provide few specifics with respect to airport land use safety compatibility. The guidance which is available is found in two primary locations:

Note that other parts of state law—the Government Code and the Public Resources Code, in particular—establish various requirements for compatibility planning and the review of development near airports, but do not set specific compatibility criteria.

➤ **State Aeronautics Act**—The Aeronautics Act (Public Utilities Code, Section 21001 et seq.) provides for the right of flight over private property, unless conducted in a dangerous manner or at altitudes below those prescribed by federal authority (Section 21403(a)). No use shall be made of the airspace above a property which would interfere with the right of flight, including established approaches to a runway (Section 21402). The act also gives the State Department of Transportation and local governments the authority to protect the airspace defined by FAR Part 77 criteria. The act prohibits any person from constructing any structure or permitting any natural growth of a height which would constitute a hazard to air navigation as defined in FAR Part 77 unless the department issues a permit (Public Utilities Code, Section 21659). The permit is not required if the FAA has determined that the structure or growth does not constitute a hazard to air navigation or would not create an unsafe condition for air navigation. Typically this has been interpreted to mean that no penetrations of FAR Part 77 imaginary surfaces is permitted without a finding by the FAA that the object would not constitute a hazard to air navigation.

- **State Education Code**—The State Education Code (Section 17215) requires that, before acquiring title to property for a new school site situated within two miles of an airport runway, a school district must notify the Department of Education. The Department of Education then notifies the Department of Transportation which is required to investigate the site and prepare a written report. If the Department of Transportation report does not favor acquisition of the site for a school, no state or local funds can be used for site acquisition or building construction on that site.

  Another section of the Education Code (Section 81033) establishes similar requirements for community college sites.

Department of Transportation Guidelines

DEPT. OF TRANSPORTATION GUIDANCE
See the Summary section for a discussion of how the "be guided by" requirement should be interpreted.

In 1994, a section was added to the Aeronautics Act to require that: "An airport land use commission that formulates, adopts or amends a comprehensive airport land use plan shall be guided by … the Airport Land Use Planning Handbook published by the Division of Aeronautics of the Department of Transportation" (Public Utilities Code, Section 21674.7).

The addition of this statute changed the role of the *Handbook* from a useful reference document to one that must be used as guidance in the development of ALUC policies. This is particularly important in the development of safety compatibility policies, because very little guidance is otherwise available for civilian airports.

RISK CONCEPTS

Maintaining a high degree of safety as lands near airports are developed is clearly an important planning objective. Frequently, planners face issues that have a potential for compromising safety and look for guidance on how best to proceed. Established federal and state regulations are among the resources often examined. However, from the preceding review, the narrow focus of official federal and state airport land use safety compatibility policies is apparent. Particularly lacking is guidance regarding protection of people and property on the ground in the event of aircraft accidents in the vicinity of airports. To adequately address this concern, ALUCs and local land use jurisdictions need to go beyond the basic policy foundations.

This task is not simple. While the basic concerns are clear, the extent to which the use of land around airports should be restricted in response to these concerns is not as evident. Defining appropriate safety compatibility policies based upon the available aircraft accident data thus represents a major challenge. To attempt this task, requires an understanding of the concepts of *risk*.

Experts in the field of risk have done extensive amounts of research on the topic in general and on certain types of risks in particular. However, very little of this research is specifically concerned with the risks to people and property on the ground in the environs of airports. Even so, there is much of relevance to airport land use compatibility issues that can be gleaned from these broader analyses. Toward that end, the first portion of this section examines risk concepts as they concern hazards in general; the latter portion then focuses on how these concepts can specifically be applied to airport land use compatibility planning.

In simple terms, risk can be defined as "the chance of injury, damage, or loss." More technically, risk is "the potential for realization of unwanted, adverse consequences to human life, health, property, or the environment" (Society for Risk Analysis). In mathematical terms, risk equals the probability of occurrence of an unwanted event times the adverse consequences. Risk can be considered as the inverse of safety; the latter being defined as "relative protection from adverse consequences."

The discussion here focuses on risks which have two common characteristics. First, the associated activities are physical in nature (as opposed to being strictly financial, for example). Secondly, the adverse consequences of concern are measured in terms of a specific event (rather than the incremental effects of prolonged exposure). These both are characteristics common to aircraft accident risks.

Risk Assessment

The assessment of risks and determination of appropriate actions to be taken in response to those risks is a complex and often imprecise process. Some elements of risk can be quantitatively measured and delineated. Risk assessment done in this way is often referred to as technical risk assessment, probabilistic risk assessment, or quantitative risk assessment. These forms of risk assessment are generally equivalent and are most useful for comparing various alternatives in a decision problem, such as, for example, which of two engineering solutions or land use plans has the lower risk.

Most risks, though, also have equally significant qualitative components. Moreover, subjective judgment plays an especially important role in formulation of responses to risks. These characteristics exist even for risks involving only one individual or a small group of people, but are particularly evident when the effects extend to large segments of a community or to society as a whole. Risk assessment that is done from a qualitative perspective is useful in determining why and how risks differ in ways that are not captured or represented by their quantitative or statistical characteristics. This type of risk assessment also helps with understanding what makes some risks appear acceptable and others unacceptable even though they do not differ appreciably in quantitative terms.

Measurement of Risk

The beginning point for any efforts to develop public policies to address most risks is to measure the extent to which a particular risk exists. Risk measurement or analysis is concerned with the question of what might happen.

As noted in the definition above, the two fundamental components of risk measurement are frequency and consequences. *Frequency* measures when or how often an adverse event might occur. The *consequences* component describes what the effects of such an event might be (in terms of fatalities, injuries, property damage, service interruption, etc.).

For most risks involving physical hazards (and certainly those related to airport area land uses), it is useful to consider a third component. Accident frequency can be thought of not just in terms of how often accidents occur, but also in terms of their *distribution*. The distribution component of risk identifies where or for whom there is an exposure to accidents (geographically or to certain segments of the population).

While the frequency and distribution components of risk are measured in quantitative (even if sometimes only relative or rank order) terms, the consequences of accidents can have important qualitative characteristics. Depending upon the perspective taken with respect to the potential consequences of accidents, the overall risk can be measured with respect to three fundamentally different metrics.

- **Accident Risk**—Most basic among these metrics is the accident risk rate (sometimes also referred to as crash or failure risk). This number simply measures the annual number of events predicted to occur within a specified unit of area. The consequences component is held constant—that is, the potential consequences are assumed to be the same regardless of where and how often the accidents might occur. The number of general aviation accidents projected to take place in the U.S. in a year is an example of accident risk. By combining the projected accident rate data with historical data on accident locations, the probability of an accident occurring in a given location can be calculated. With respect to aircraft accidents, the resulting information can be presented in the form of contours defining locations having the same probability of accident occurrence.
- **Individual Risk**—The individual risk rate changes the focus from events to people. Individual risk thus takes into account both the frequency of accidents as measured by the accident risk and the severity or consequences of the accident. Typically, only the most serious consequences to an individual are considered—the risk of death—although sometimes serious injuries are also taken into account. The risk is usually calculated on the basis of a person exposed to the hazard on a constant basis, 24 hours per day, 365 days per year.
- **Societal Risk**—The most broadly based form of risk metric is societal or collective risk. Societal risks are concerned with consequences that are wider than the the discrete effects on individuals. Repercussions of certain events go beyond the immediate casualties and damage to the extent of provoking socio-political response. The need to avoid these types of

accidents or events may thus be greater than statistical measurements would suggest. Indeed, societal risk often takes into account non-quantitative elements and can particularly be influenced by public perceptions.

Regardless of the precision to which a risk can be measured, a factor to be recognized is that even scientific measures of risk are inherently subjective in one respect. Scientists and experts typically measure risk in terms of mortality rates or probability of harm. There are many ways in which this information can be portrayed, however. This choice can affect how the data is judged. For example, in the context of transportation, the chance of someone being killed in an accident can be measured relative to total population (deaths per million population), passenger-miles for the transportation mode, or the number of trips. The way in which the data is numerically presented also makes a difference: 1 death per *x* people versus *y* deaths per million people. The point is that there is no right or wrong frame of reference—no universal set of characteristics—for measuring risk.

Risk Perceptions

While measurement of risks provides essential input to the making of public policy, it is not the only consideration. In our society, decisions about how to respond to many risks—particularly ones affecting many people or whole communities—are not the sole purview of experts. Moreover, such decisions are not based simply on technical analyses and data. The public's *perception* of risks plays a major role as well. Perception is a key component in any assessment of societal risk.

To those experts or others who evaluate risk in a strictly quantitative manner, public perceptions may seem to be irrational or even ignorant. While some component of public reaction may be attributable to these human qualities, other more definable factors are also apparent. Studies have shown that risks are usually perceived to be high when factors such as the following are prevalent:

- The general public has limited understanding of how the technology or system operates;
- After a failure in the technology or system, no one, including experts in the field, seems to know and understand the cause (as opposed to events for which the cause is clear);
- The possible consequences of the hazard evoke feelings of dread, especially concerns about death;
- The possible consequences seem unbounded (in magnitude or persistence over time) or are believed to be potentially catastrophic;
- The activity is not under one's own control (the risks are not affected by one's own skills);
- The risk exposure is not on a voluntary basis (the exposure cannot readily be reduced by changes in one's lifestyle);
- The hazard is unnatural (not an act of nature);
- The potential personal or societal benefits to be gained from the activity involved appear to be minimal or nonexistent;

- The distribution of risks and benefits among groups or geographically is inequitable;
- The groups at risk include children, elderly, the infirm, or others regarded as having comparatively little control over their own lives; and/or
- Highly negative imagery about the technology or system is widespread in the media (especially pictures on television and in newspapers).

To a significant extent, the manner in which people judge the importance of these factors depends upon our attitudes toward the underlying technology or system. Our attitudes, in turn, have their basis in social values. These judgments are inherently subjective—there are no right or wrong responses. Thus, at least from the perspective of social science, risk is not an objective concept. Danger is real, but there is no such thing as real risk—risk is socially constructed.

Because of these subjective elements, risk perceptions are frequently not consistent with statistical expectations. Risks are often misjudged, sometimes overestimated and sometimes underestimated. Moreover, judgments about the facts associated with risks may be held with unfounded confidence. As a consequence, technical risk analyses and statistics prepared by experts often do little to change people's attitudes and perceptions. Even news that studies of a potential risk are being conducted can add to public concerns. The rapidity with which information—both accurate and inaccurate—is transmitted today further adds to the challenge of placing risks in a proper perspective within society as a whole.

Another factor which affects how a risk is perceived is the scale on which the risk is measured. Experts typically measure risk in terms of fatalities. To most people, though, riskiness means more than the number of deaths per year. The manner in which the presence of the risk affects one's daily life also influences how the risk is viewed.

Even when annual fatalities is the accepted risk measure, statistically equivalent risks may be perceived differently. For example, a technology or system on which one accident with 100 fatalities has occurred is likely to be judged more risky than a system which has experienced 100 accidents having one fatality each. In effect, there is a penalty function which gives added weight to events with large consequences. On the other hand, our familiarity with particular technologies or systems can also affect how their associated risks are perceived. The apparent seriousness of an unfortunate event is determined in part by what the event signals or portends—what its potential social impact may be. An accident on an unfamiliar system, even if small in size, may be viewed as a harbinger of more catastrophic events and thus deemed to be worse than a large accident on a familiar system.

A final, not often acknowledged, element of risk perception is hindsight. Knowing that something has happened increases its perceived inevitability. What is more, not only do such occurrences seem in retrospect to have been inevitable, the judgment often is that they should have been anticipated in advance. "On the other hand, perhaps the handwriting on the wall was written in ink visible in hindsight alone" (Fischhoff–1975).

As one author summarized the topic: "…there is wisdom as well as error in public attitudes and perceptions. Lay people sometimes lack certain information about hazards. However, their basic conceptualization of risk is much richer than that of the experts and reflects legitimate concerns that are typically omitted from expert risk assessments" (Slovic–1987).

Risk Comparisons

Another approach to risk assessment is to compare a new or uncertain risk with risks which are better known and understood. Both the general public and risk experts engage in making these comparisons. Although such comparisons must be made with caution, they can be informative.

One situation in which risk comparisons can be useful is with respect to infrequently occurring events. For frequent events, risks can be measured with a great deal of precision. However, the probability of events which take place infrequently—even though they may be of high consequence—is very difficult to predict with any high degree of statistical accuracy. For many technologies, the very success of hazard reduction efforts has led to relatively few events from which to calculate the level of risk.

In general, observed data cannot lead to confident estimates of extremely rare events. The probability of events with 50-to-100-year intervals can be estimated with a reasonable degree of confidence, but not those with 10,000-year intervals. In such situations, an alternative approach is to measure risk levels in a relative rather than probabilistic manner. Experts in a particular technology often can identify the locations or circumstances which present higher-than-usual risks, even if they cannot estimate the probability of an event.

The danger of risk comparisons is that differences among risks can be oversimplified if both the quantitative and qualitative attributes are not considered. The general public may overlook important measurable factors. On the other hand, experts may gauge the acceptability of risk solely in terms of the probability of fatalities or other loss, but ignore the *context* within which the risk occurs. Context helps us to gain perspective on the size and scope of a risk and to determine what response may be appropriate.

It is because of the difference in context that comparisons between the chance of a person on the ground being injured or killed as a result of an aircraft accident and the chance of a similar result from being struck by lightening are not valid. Hazards from technological and natural events are not perceived the same.

Responding to Risks

Ultimately, the decisions we—as individuals or as a society—make in response to hazards come down to a question of our tolerance for or acceptance of the risks which are known or believed to be involved. This is not a question which can be answered in an absolute sense, however. Society's allocation of resources must be taken into account. It is always possible to reduce risk, but the cost of doing so increases as the risk becomes smaller.

One approach risk experts have taken to this question is to divide the risk spectrum into three regions separated by two key boundary lines (Figure 9A):

- The upper boundary line is the threshold of intolerable risk. Risks exceeding this threshold must be reduced below the line regardless of cost. From an individual perspective, these are risks which are not tolerable regardless of the amount of money offered in compensation.
- The lower boundary line is the threshold of acceptable risk. Risks below this level merge into the background risks of life and require no action. We generally do not concern ourselves with these risks as we go about our daily lives.

The three risk levels thus might be described as:

- Intolerable risks;
- Significant but tolerable risks; and
- Acceptable risks.

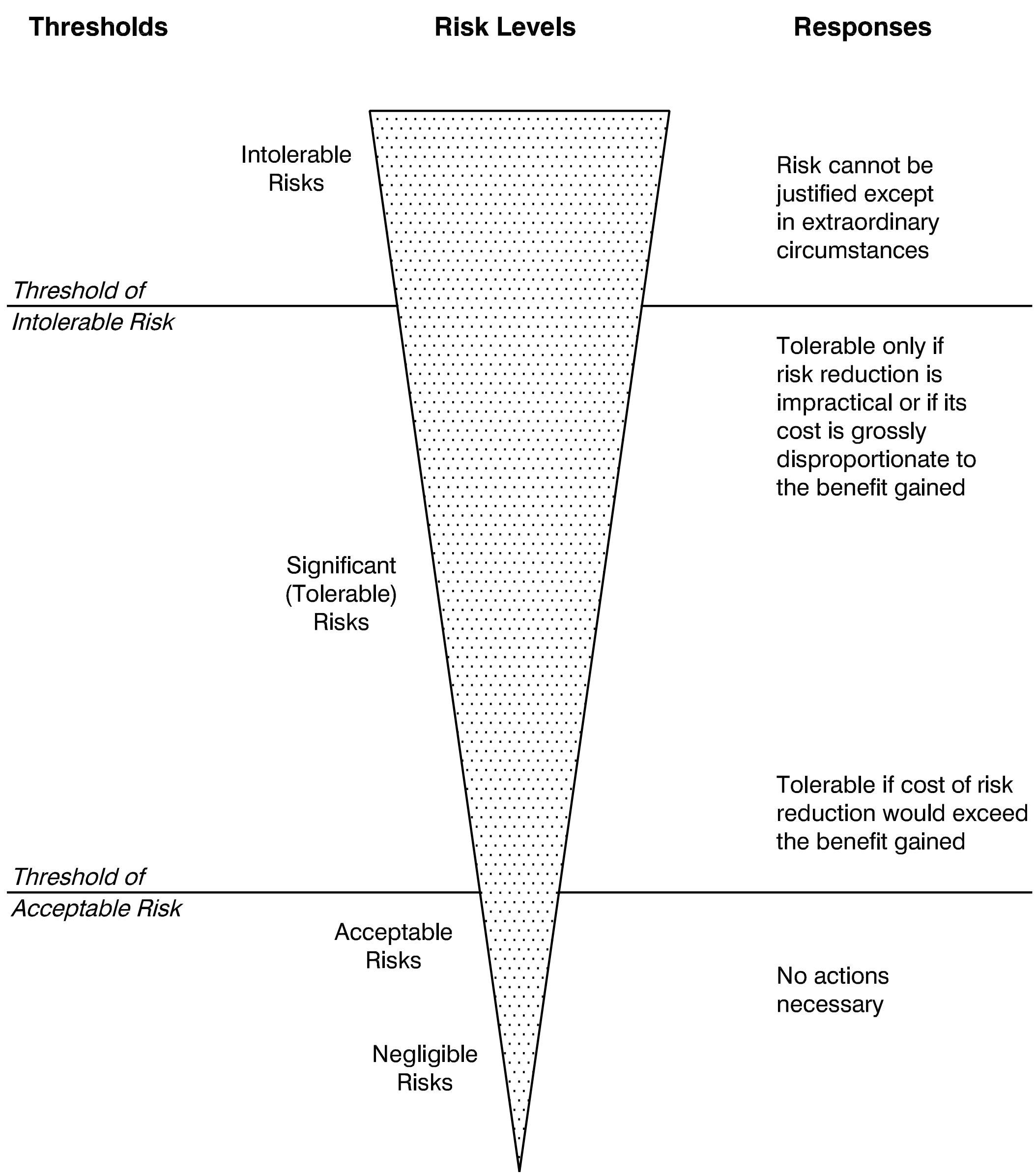
Given this categorization, the next question which might be asked is where any specific risk falls within the overall spectrum.

Judging Risk Acceptability

As indicated earlier, accident risks can be assessed as a combination of the anticipated *frequency* of occurrence at any given location and the potential magnitude of adverse *consequences*. One qualitative method of judging risk acceptability thus is to divide the full range of frequencies and consequences into discrete increments and then evaluate the implications of each possible combination of the two components. The result will be a matrix such as the one shown below. The matrix illustrates the conceptual relationship between accident frequency, potential consequences, and judgments as to the overall risk acceptability. Frequency is calculated in terms of the number of events within a specific time period and location. Consequences are typically defined in terms of injuries, particularly fatalities and serious (life-threatening) injuries. Property damage can also be included, however.

Conceptual Relationship of Risk Components

		Potential Consequences				
		Negligible	*Minor*	*Major*	*Severe*	*Disastrous*
Anticipated Frequency of Occurrence	*Frequent*					
	Occasional					
	Uncommon					
	Rare					
	Extraordinary					
Legend		Acceptable Risk		Significant Risk		Intolerable Risk



Source: Based upon diagram in National Air Traffic Services Ltd., London (1997)

FIGURE 9A

Risk Acceptability Framework

This matrix suggests a variety of possible risk responses. For example:

- Risks which have negligible consequences do not warrant specific action regardless of how frequently the events occur. Even minor consequences do not make the risk significant unless the frequency is such as to be almost predictable.
- Activities with potentially major adverse consequences generally necessitate investigation into possible risk reduction measures unless the events rarely occur.
- A combination of relatively frequent occurrence and potentially high consequences means that action to reduce the risks to a tolerable level must be taken.
- While potentially disastrous consequences are always significant and the risk reduction measures need to be evaluated, action still may not be warranted when the events are rare or extraordinary.

Several additional points regarding this matrix are worth noting. First is that it pertains only to risks for which exposure is *involuntary*. People generally accept higher risks when they engage in an activity voluntarily and have a high degree of self control over its outcome. Greater risks also are tolerated when more *benefit* is to be gained from the activity. Thus, the public tends to accept higher risks from voluntary activities (such as driving a car) than from equally beneficial involuntary risks (food preservatives, for example). Another factor in judgment of risk acceptability is public perception. As a result, for certain risks, adjustments to the matrix may be necessary to reflect the influences noted earlier as having an effect on risk perception.

One further point is that both individual and collective risks are relevant to the assessment of acceptability. For some activities or circumstances, individual risk may be low either because accidents are rare or because the likelihood of severe consequences (death or serious injury) is minimal even if more minor mishaps are comparatively common. Nevertheless, even when measurable individual risk is low, governmental regulations to prevent some harm may be warranted simply because a large number of people are exposed.

Lastly, no attempt to quantify either the frequency or consequences components of the matrix has been made here. Such a step may be possible although the ranges would vary depending upon the type of risk involved. Again, the only intent of the matrix is to illustrate the conceptual relationships among risk components and risk acceptability.

Of interest, though, is that—despite the variability in how frequency and consequences would need to be quantified depending upon the hazard involved—the combination of the two components have a quantifiably consistent relationship to acceptability regardless of the type of risk. That is, the measured level of risk which defines the boundaries between intolerable, significant, and acceptable risks has been found to remain relatively constant across a wide range of hazards. To be specific:

- The upper limit of tolerability for involuntary risks has been concluded to be on the order of one death per 10,000 people, or 10^{-4} chance of death to an individual, per year. Risks exceeding this level essentially mandate government intervention.
- Society also seems to have achieved a general consensus that governmental action to protect public health and safety is usually warranted if a hazard results in an annual death rate of more than 1:100,000 (10^{-5}).
- Risks as low as 1:1,000,000 (10^{-6}) per year are also commonly of sufficient concern to justify further investigation into possible actions.
- Lower levels of risk generally do not merit an explicit response unless the risk presents broader societal implications or is widely perceived in a manner which heightens its significance.

To emphasize the point, these numbers refer to risks to which people are exposed on an involuntary basis. As indicated above, people will accept a much greater risk when the exposure is on a voluntary basis. Indeed, risk researchers have concluded that acceptance of voluntary risks is roughly 1,000 times greater than for equally beneficial involuntary risks (Fischhoff–1979).

Weighing Responses to Risks

Risks which fall into the middle (significant) range—ones which are tolerable, but not particularly acceptable—represent the greatest challenge for determining appropriate responses. Intolerable risks must be dealt with in all cases and acceptable risks require no action. The mid-level risks, while significant, may or may not warrant a response depending upon the circumstances. In general, the objective in dealing with these risks is to make them as low as reasonably practical.

The 1952 *Report of the President's Airport Commission* comments on this topic that: "…'calculated risk' is an American concept which gives mobility to the whole social structure. The phrase simply means a willingness to embark deliberately on a course of action which offers prospective rewards outweighing its estimated dangers."

Various approaches have been devised as means of evaluating actions to be taken in response to the mid-range risks. Perhaps most common are cost-benefit analyses. The difficulty with cost-benefit analyses, though, is that they necessitate having data which is both meaningful and can be quantified. This often requires judgments—determining the value of human life, for example.

A further consideration is that a safety measure that seems appropriate on a cost-benefit basis may not be reasonable in a cost-effectiveness sense. That is, even if the benefits outweigh the costs, other measures may be available which could achieve greater benefits for the same cost or the same benefits for less cost. The range of possible safety measures thus generally also needs to be evaluated on a cost-effectiveness scale. The objective of cost-effectiveness analyses is to help set priorities among different risk reduction measures so as to achieve maximum safety for the amount spent. Cost-effectiveness analyses also can help to sort out the interactions among hazards. A risk reduction measure which may not manifest the highest benefit-cost ratio with respect to one particular hazard, may nevertheless be the most overall cost-effective measure because it can reduce multiple risks.

Another factor to be considered in cost-benefit or cost-effectiveness analyses of risk reduction measures is who bears the costs and who attains the benefits. For most risks which affect a large number of people, costs and benefits are seldom distributed equally. Governments, particularly the federal government, are usually better able to bear the costs of risk reduction measures than are private individuals or businesses, but even governments must balance the investment against the benefits. Economic feasibility has further implications where the costs are to be borne privately. When government-imposed measures are not affordable, the rules may be circumvented and enforcement can then become a problem.

Determining appropriate responses to risks associated with events which are extraordinarily rare but potentially catastrophic presents a particularly difficult test. An example of this type of hazard is a volcanic eruption. One study of this risk pondered whether anything at all should be done to protect against such an event given its extreme rarity (William Spangle and Associates–1987). On the other hand, the report notes that "the potential for a major catastrophe which could be averted begs for some kind of public response." As for where to strike the balance between acceptable risk and affordable protection, the report concludes:

> "Do what you can, politically and fiscally, to reduce the exposure and provide for effective emergency response and that becomes, by definition, acceptable risk. An official who proposes to go farther than his constituents want will find out quickly what the limits are."

Lastly, it is important to recognize that, whether accurate or not, public perceptions about risks play an influential role in determining the priorities of legislative and regulatory bodies. These entities, in turn, must exercise their own judgments about both the quantified risk data and the public perceptions of the risks. The amounts spent to reduce various types of risk can thus vary greatly and with little apparent rationality when viewed in light of the measured risks. For example, U.S. society has spent some 75 times as much to prevent each death due to environmental toxin exposure as it has to prevent each death from transportation accidents (Tengs–1994).

One risk expert sums up this tendency toward inconsistency by noting that good analysis may be insightful, but need not be conclusive. "Uncertainty about facts and values in a disorderly social world means the various decision making approaches must be viewed as tools rather than ends in themselves." Thus, perhaps "the best we can hope for is some intelligent muddling through" (Fischhoff–1979).

Putting Airport Land Use Risks into Perspective

From a risk reduction perspective, a fundamental objective of airport land use compatibility planning is to minimize the consequences of aircraft accidents when they happen.

Assessing and responding to the risks which aircraft accidents pose for land uses around airports is a difficult process. Compared to aircraft noise, there is little data from which to work—risks cannot simply be measured with a "risk level" meter. Even if better data were available, the problem would remain as to how to determine appropriate responses. Again, there is relatively little with which to compare. A variety of studies address the topic of accident-related risks. Most of these studies focus on evaluating actions which can be taken to reduce the frequency with which the accidents occur. With land use compatibility planning around airports, however, reducing the frequency of accidents is not the objective—except for airspace obstructions, land uses have little effect on whether aircraft accidents occur. Rather, the purpose is to minimize the consequences of accidents when they happen.

Measuring the Risk

Conceptually, calculation of the risks associated with potential aircraft accidents near airports is easy. The risk consists of a combination of the three earlier described components: frequency, consequences, and distribution. The difficulty, though, lies in the fact that each of these components is complex to measure particularly with regard to any single airport. Errors and inaccuracies can easily be introduced into the equation. The following are some insights into factors which affect measurement of each of these components.

➤ **Frequency of Occurrence**—While the historical number of aircraft accidents nationwide has varied to some extent from year to year, future trends can nevertheless be predicted with a fair degree of accuracy. Even with respect to specific classes of aviation (air carrier, general aviation, military) or types of aircraft (business jets, helicopters, etc.), the frequency of accident occurrence is fairly constant and predictable. The difficulty with prediction arises when the focus is on a single airport rather than nationwide data. Even for busy airports, the frequency of occurrence may be once per some multiple number of years. As discussed earlier, predictions become less certain as the number of events becomes less frequent. A further complication with measuring frequency of occurrence lies in defining the types of events that are of interest. Clearly, accidents are the most significant events for airport land use planning purposes, but lesser mishaps are also relevant. Even though aircraft sometimes successfully land off airport—and thus the event is not treated as an accident—the potential exists that any such occurrence could have more serious consequences.

➤ **Potential Consequences**—The consequences of an aircraft accident on land uses near an airport can basically be described in terms of the number of people killed or injured and the size and value of the property damaged. However, as described in Chapter 8, the consequences of any particular accident depends upon numerous variables involving the aircraft characteristics, the manner of its descent, and the nature of the terrain and land uses at the site. Because of the wide range of each of these variables, the outcome is highly uncertain. Therefore, even though the vast majority of near-airport aircraft accidents do not result in serious land use consequences, the emphasis in any analysis needs to be on the potential consequences—that is, on what could happen. Moreover, in terms of airport land use compatibility planning, the issue is what could happen if incompatible development is allowed to occur.

An important point to realize with respect to near-airport aircraft accidents is that the consequences have historically most often been minimal because of the extent of undeveloped or low-intensity uses near many airports. Allowing more intensive nearby development can only increase the frequency with which more severe consequences occur.

- **Spatial Distribution**—Although not huge by many standards, the aircraft accident data described in Chapter 8 is sufficient to enable the spatial distribution of accidents to be well defined for each category of airport (air carrier, general aviation, and military). This distribution is broadly applicable to most airports within each category. Nevertheless, to more accurately predict where future accidents are most likely to occur at a particular airport, the physical characteristics and usage patterns of the airport need to be considered. The risks will generally be most concentrated along the flight routes which aircraft use most frequently.

To summarize measurable airport land use risks in the context of the preceding discussion of risk concepts, near-airport aircraft accidents are events which occur infrequently, but have potentially high consequences. Moreover, despite the relative rarity of the events, the spatial distribution of aircraft accidents near airports can be delineated quite well as indicated by the data presented in Chapter 8 and the potential consequences can be directly related to the characteristics of land use in the areas of concern.

Risk Perceptions and Comparisons

Proponents of land use development near airports sometimes attempt to quantitatively assess the risks of an aircraft accident and then dismiss the risk on the basis of comparison with other types of risks. Caution should be exercised in the preparation and review of such analyses.

One factor to be recognized is that, while the spatial distribution of aircraft accidents is quite predictable close to the ends of runways, it is less so at greater distances. This is particularly true for general aviation airports because their aircraft flight tracks are comparatively more spread out than at major air carrier airports. Analyses thus need to be done with respect to relatively broad-scale areas. Otherwise, by defining a sufficiently small site of interest, the accident probability can be calculated as near zero (the probability of an accident occurring somewhere in the airport vicinity is much greater than the probability of an accident occurring on a particular one-acre site).

Several studies have sought to take the step of broadly quantifying the individual risk which aircraft accidents represent for people on the ground. The results from two of these studies (NATS–1997; Shutt Moen Associates–1999) are useful in putting airport land use risks into a context with other types of risks.

- The level of individual risk for a given location near an airport is dependent to a significant extent upon the number of aircraft operations and to a lesser degree upon the type of aircraft. The greater potential consequences of a large air carrier aircraft accident compared to that of a small general aviation aircraft is balanced by the fact that the larger aircraft have fewer accidents per a given number of operations.
- Not surprisingly, the data shows the highest level of risk occurs immediately beyond the runway ends. These risks are on the order of 1:10,000

(10^{-4}) per year and are typically contained within the limits of the an airport's runway protection zones (RPZs).

- ➤ The extent of risks at the 1:100,000 (10^{-5}) level is more dependent upon the volume of aircraft operations on a runway, but generally is within an area immediately surrounding the RPZs.
- ➤ The 1:1,000,000 (10^{-6}) risk level, although also dependent upon aircraft operations numbers, is much more extensive. Even for a moderately busy general aviation airport, risks of this magnitude can extend two miles from the runway. For major air carrier airports, the distance is greater, but the risk is more concentrated along the extended runway centerline than is the case at general aviation airports. The risk tends to be more dispersed for general aviation airports because aircraft follow more varied flight tracks than do larger aircraft.
- ➤ Nationwide, the annual risk of an aircraft accident causing fatal injury to an individual on the ground, but not on an airport, was found to be 1:1,700,000 (6×10^{-8}) for the 1975-85 period (Goldstein–1992).

Another consideration with regard to comparisons between airport land use and other risks is that subjective characteristics must be similar. In the context of the previously mentioned factors which influence public perceptions, the risks of off-airport aircraft accidents can be characterized as:

- Not voluntary except to the extent that people choose to live near an airport;
- Not controllable as a function of the individual's skills;
- Generally not well understood;
- Including consequences which are unpredictable;
- Not an act of nature;
- Giving no advance warning of an impending event; and
- Usually not balanced by potential personal benefits of the activity.

Because of these factors, comparisons with the chance of fatal injury as an occupant in an automobile accident or from being stuck by lightening, for example, are not directly relevant to the issue of airport land use compatibility planning.

Responding to the Risk

Regardless of the method used to assess the risks, a decision still must be made as to what the public-policy response should be. The basic question to be asked is *how much risk is acceptable?* As discussed earlier in this chapter, acceptability can be evaluated as a function of the frequency and consequences of undesirable events. The chart on page 9-14 is helpful in showing the conceptual relationship between these two components. When applying this chart to the defining of safety compatibility criteria, though, two factors should be kept in mind:

- ➤ To be of value to airport land use compatibility planning, the frequency scale needs to be considered primarily in terms of the relative concentration of aircraft accidents near airport runways. If the scale is set relative to the wide range of physical risks, then aviation-related risks to land uses near airports would probably all fall in the rare category.

- For most airports, the risks to nearby land uses are dominated by the consequences side of the risk equation. Even a small airplane could cause major to severe harm if it were to strike an exposed, densely populated site. Only in essentially unoccupied locations such as range lands or wilderness areas can the potential consequences to people on the ground be considered negligible or minor.

As also indicated in the earlier discussion of risk concepts, the acceptability of a risk is not the only consideration in the establishment of public policy in response to that risk. An additional question to be weighed is *how much protection can society afford to provide?* Or, to put the issue another way, *how safe is safe enough?*

To answer these questions, the benefit-cost ratio of the risk reduction measures must be taken into account. When an airport is situated in a rural area, well away from development pressures, the cost—to the landowner, the community, and the airport—for a high degree of protection may be low. Important land use development can usually be redirected toward areas where the prospects of an aircraft accident are minimal. At the other end of the spectrum, the need for developable land around urban area airports typically is such that avoidance of only very risky forms of development—those in the most accident-prone locations or ones which greatly increase the potential severity—may be affordable. It is for this reason that some ALUCs allow infill development to occur in established urban areas even though the development would typically not conform to compatibility criteria.

Also an element of any cost-benefit evaluation of acceptable land uses near airports is that the outcome is different for existing development than it is for proposed new construction. While the benefits of having compatible land uses are the same whether development already exists or not, the cost of eliminating incompatible uses is usually much greater than the cost of avoiding it in the first place. Safety compatibility policies developed for use in Great Britain acknowledge this distinction (NATS–1997). Specifically, the British policy is:

- To eliminate existing incompatible development, if any, within areas where the individual risk exceeds 1:10,000 (10^{-4}).
- Except for low-intensity nonresidential uses, new development should be avoided in locations where the risk exceeds 1:100,000 (10^{-5}). However, existing development—other than highly risk-sensitive uses such as schools, hospitals, and places of assembly—can remain.
- In locations where the risk level is less than 1:100,000 (10^{-5}), the only necessary restrictions on new development are to avoid schools, hospitals, and places of assembly.

The Geography of Risk: Identifying Accident Location Patterns

A primary element in establishment of safety compatibility policies is knowing where aircraft accidents pose risks to land uses near airports. Of course, the fact that accidents have historically occurred in certain locations is no guarantee that they will happen in precisely those places in the future, especially at any one airport. Nevertheless, it is reasonable to predict that the broad areas within which significant numbers of accidents have taken place in the past will be where most accidents will also occur in the future.

A glance at the aircraft accident distribution patterns presented in Chapter 8 gives a good indication of where accidents are most likely to occur in relationship to a runway. In the form presented, however, the accident patterns are not easily usable for defining appropriate land use safety compatibility criteria. Doing so would be equivalent to attempting to set noise compatibility policies by using noise data for a series of discrete geographic points. An essential first step thus is to aggregate the accident location data into a more functional format. This process is described below.

Accident Distribution Contours

One approach to identifying accident location patterns is to group the accident data points according to their relative degrees of geographic concentration. A particularly illustrative perspective on the distribution of accidents near runways is the three-dimensional view shown in Figure 9B. The vertical dimension to the graph represents the number of accident sites within each of the cells in the grid (the grid spacing used was 300 feet by 300 feet). The approach end of the runway is at the center of the graph and the runway extends up and to the right from there. Clearly evident is the concentration of accident sites—primarily arrivals—near the runway's approach end. The second hump lies along the runway and its extended centerline and is mostly comprised of departure accidents. (Note that this chart is derived from the accident database contained in the 1993 *Handbook*. Although smaller in size than the current database, the locational distribution of accident sites is similar to that of the present, expanded database.)

While informative in a visual sense, the three-dimensional chart is not very useful for analytical purposes. More valuable is to depict the data in the form of a set of accident distribution contours.

Figures 9C through 9J portray contours for various subsets of the general aviation aircraft accident location data from Chapter 8. (No comparable analyses of air carrier and military aircraft accidents have been conducted.) Any number of contours can be defined. In this case, the contours divide the accident data sets into five equal groups of 20% each. The contours encompass the most highly concentrated 20%, 40%, 60%, and 80% of the data points. The remaining 20% occur beyond the outermost contour, including some points beyond the limits of the diagrams. The contours are irregular in shape. No attempt has been made to create geometric shapes.

The accident distribution contours depict where an aircraft accident is most likely to happen when one occurs. Because these contours do not take into account either the accident frequency over time or the consequences of the accidents, they technically are not risk contours.

(Various computer programs potentially can be used to create contours from scattered, individual *x/y* data points such as those represented by the accident location data. The results may vary depending upon the type of program used and the assumptions applied to measuring the degree to which a group of points is concentrated. The contours shown here were developed using geographic information system software to count the number of other points within a certain radius of each specific point, then ranking the results.)

All Runway Lengths

Figure 9B depicts the accident distribution contours for all general aviation arrival accidents in the database; Figure 9C shows the contours for departure accidents. In both instances, all runway lengths are represented. Several geometric patterns are evident from a look at the two graphs:

➤ **Arrival Accident Patterns**

(The zero/zero point on the axes is the landing end of the runway.)

- Arrival accident sites tend to be located close to the extended runway centerline.
- Some 40% fall within a narrow strip, approximately 500 feet wide and extending some 2,000 feet from the runway end.
- Over 80% of the arrival accident sites are concentrated within just 2,000 feet laterally from the extended runway centerline, but extending outward to approximately 11,000 feet (about 2.0 miles) of the runway end.

➤ **Departure Accident Patterns**

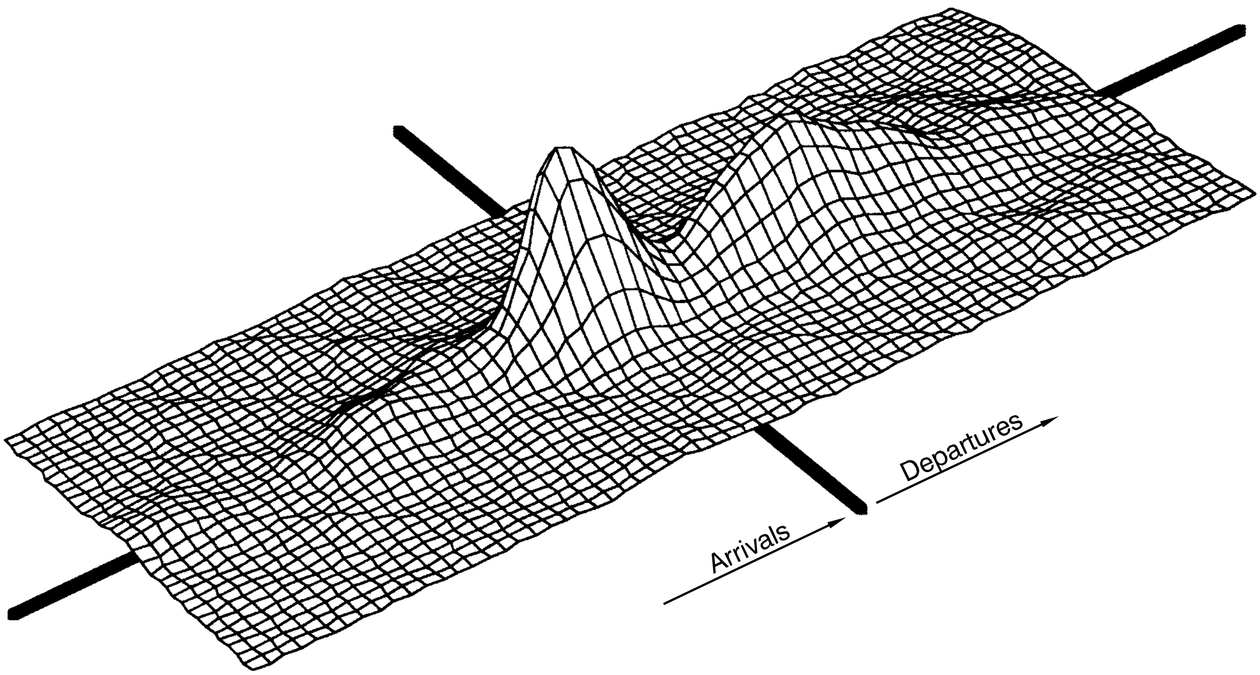
(The zero/zero point on the axes is the takeoff end of the runway.)

- Departure accident sites also tend to be clustered near the runway end, but are not as concentrated close to the runway centerline as are the arrival accident sites.
- The most tightly bunched 40% of the points lie within an area 1,500 feet wide, extending approximately 2,000 feet beyond the runway end, but also adjacent to the edges of the runway.
- The 80% contour extends some 6,000 feet beyond the runway end plus along the sides of the runway and spreads laterally approximately 2,000 feet from the runway centerline.
- Two factors account for the substantial number of departure accident sites lateral to the runway. (1) As defined for the purposes of the database, departing aircraft which crash while attempting to return to the runway are counted as departure accidents unless the aircraft became established in the traffic pattern or on final approach. (2) On long runways, aircraft may begin to turn before reaching the far end of the runway.

Another variable for which an accident location pattern diagram is included in Appendix F is for single-sided traffic patterns. Intuitively, the distribution of accidents at airports with a pattern on only one side can be expected to differ from that at airports with dual traffic patterns. However, as discussed in Chapter 8, the information in the database is insufficient to adequately assess the differences.

Variations by Runway Length

From the data and discussions in Chapter 8, it is evident that the patterns of general aviation aircraft accident locations near runways differ substantially depending upon characteristics of the runway and aircraft involved in

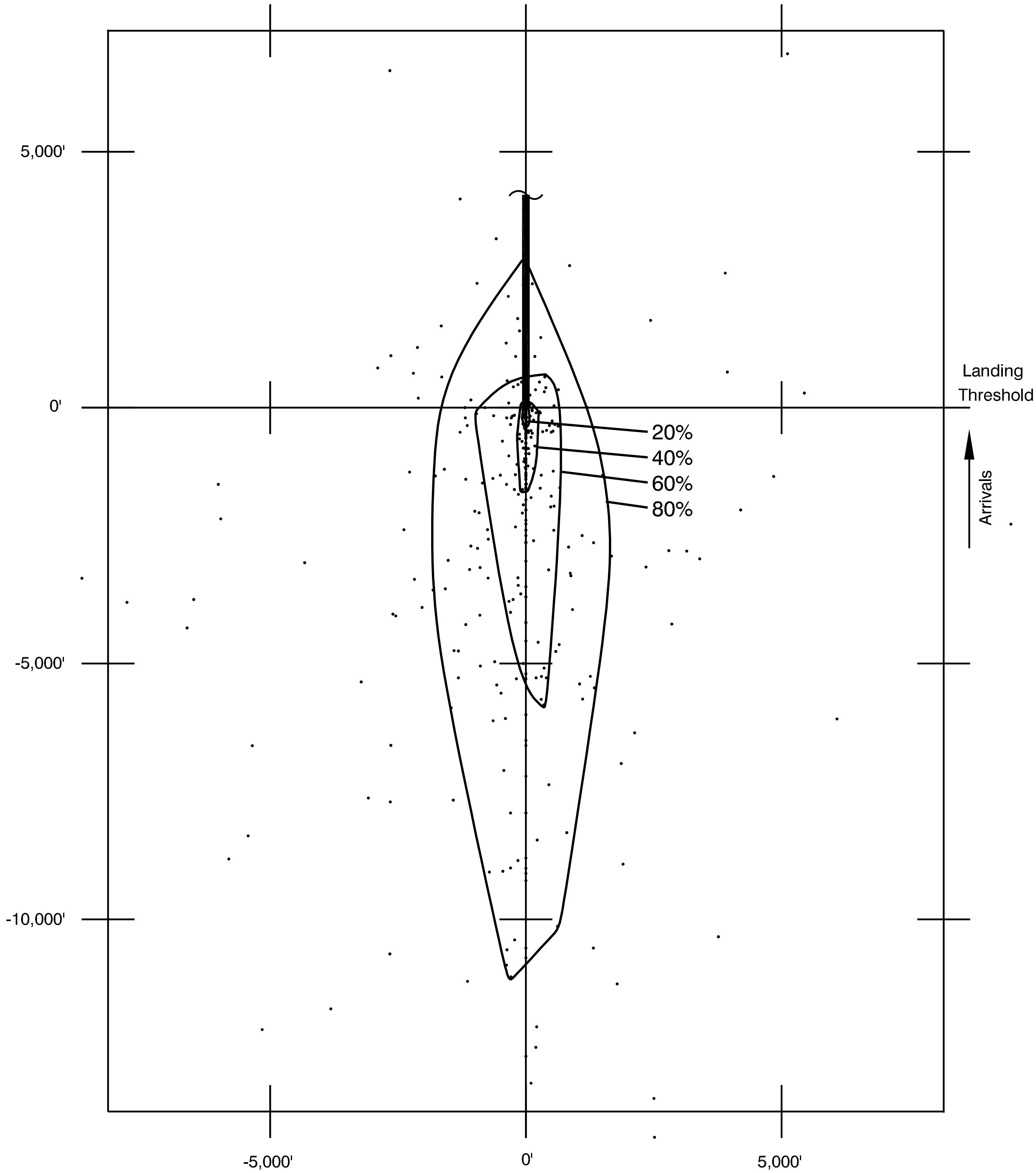


Source: University of California, Berkeley, Institute of Transportation Studies (1993)

FIGURE 9B

Three-Dimensional Plot of Accident Distribution Pattern

General Aviation Aircraft Accident Database

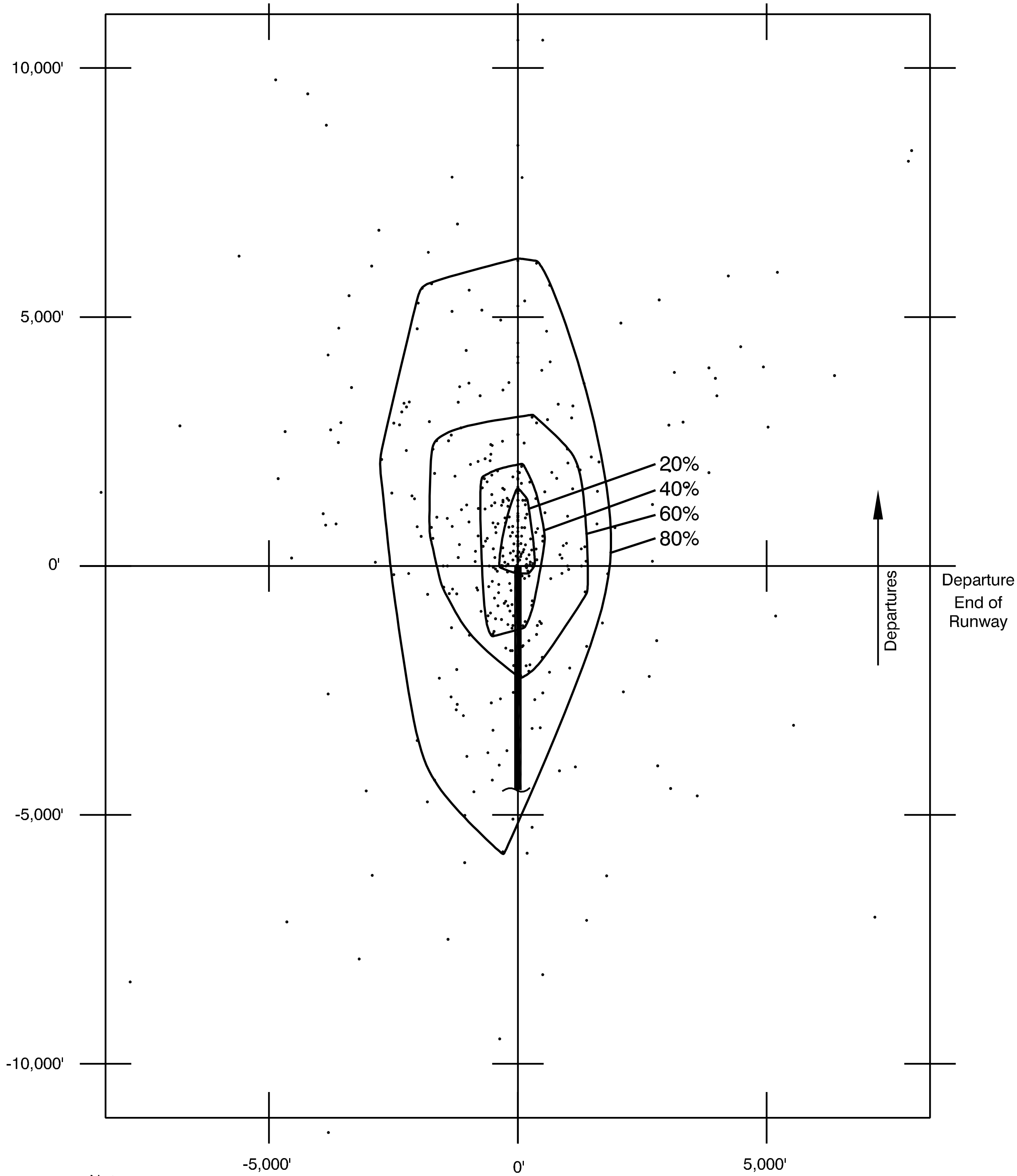


Notes:
445 arrival accidents in database—each dot represents one accident site.
Contours represent relative intensities (highest concentrations) of points in 20% increments.

FIGURE 9C

General Aviation Accident Distribution Contours

All Arrivals

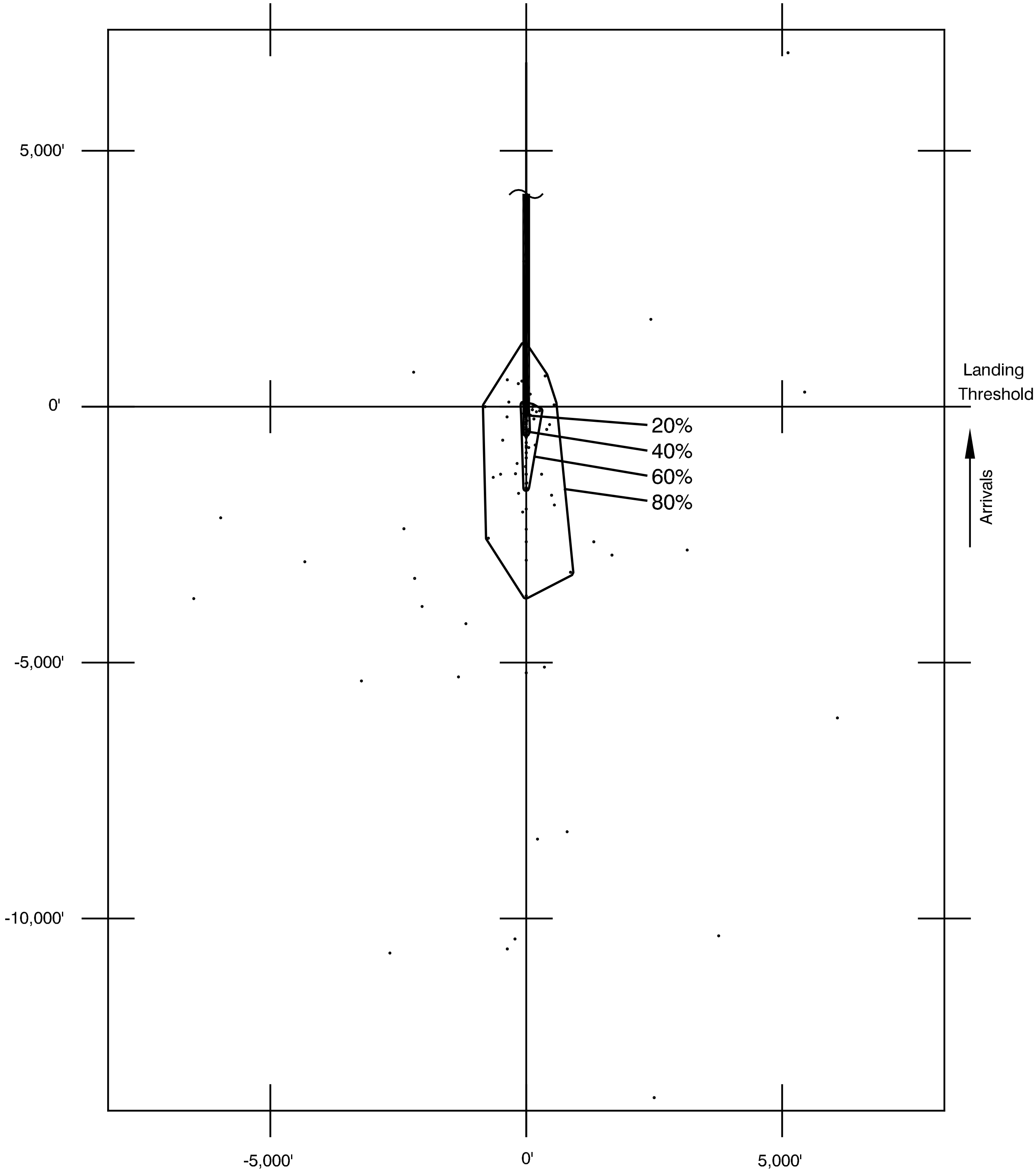


Notes:
428 departure accidents in database—each dot represents one accident site.
Contours represent relative intensities (highest concentrations) of points in 20% increments.

FIGURE 9D

General Aviation Accident Distribution Contours

All Departures

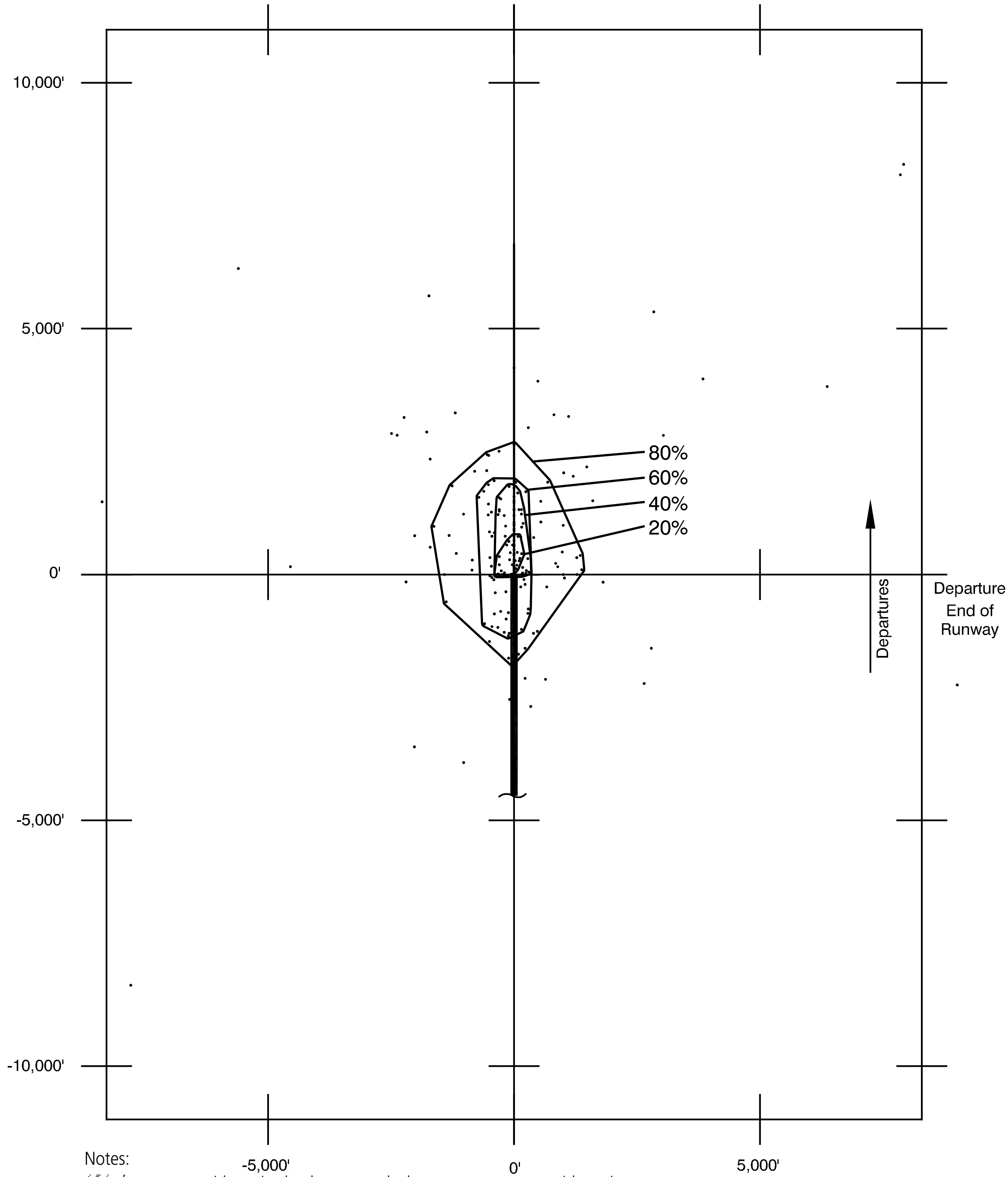


Notes:
153 arrival accidents in database—each dot represents one accident site.
Contours represent relative intensities (highest concentrations) of points in 20% increments.

FIGURE 9E

General Aviation Accident Distribution Contours

Arrival Accidents on Runways of Less than 4,000 Feet

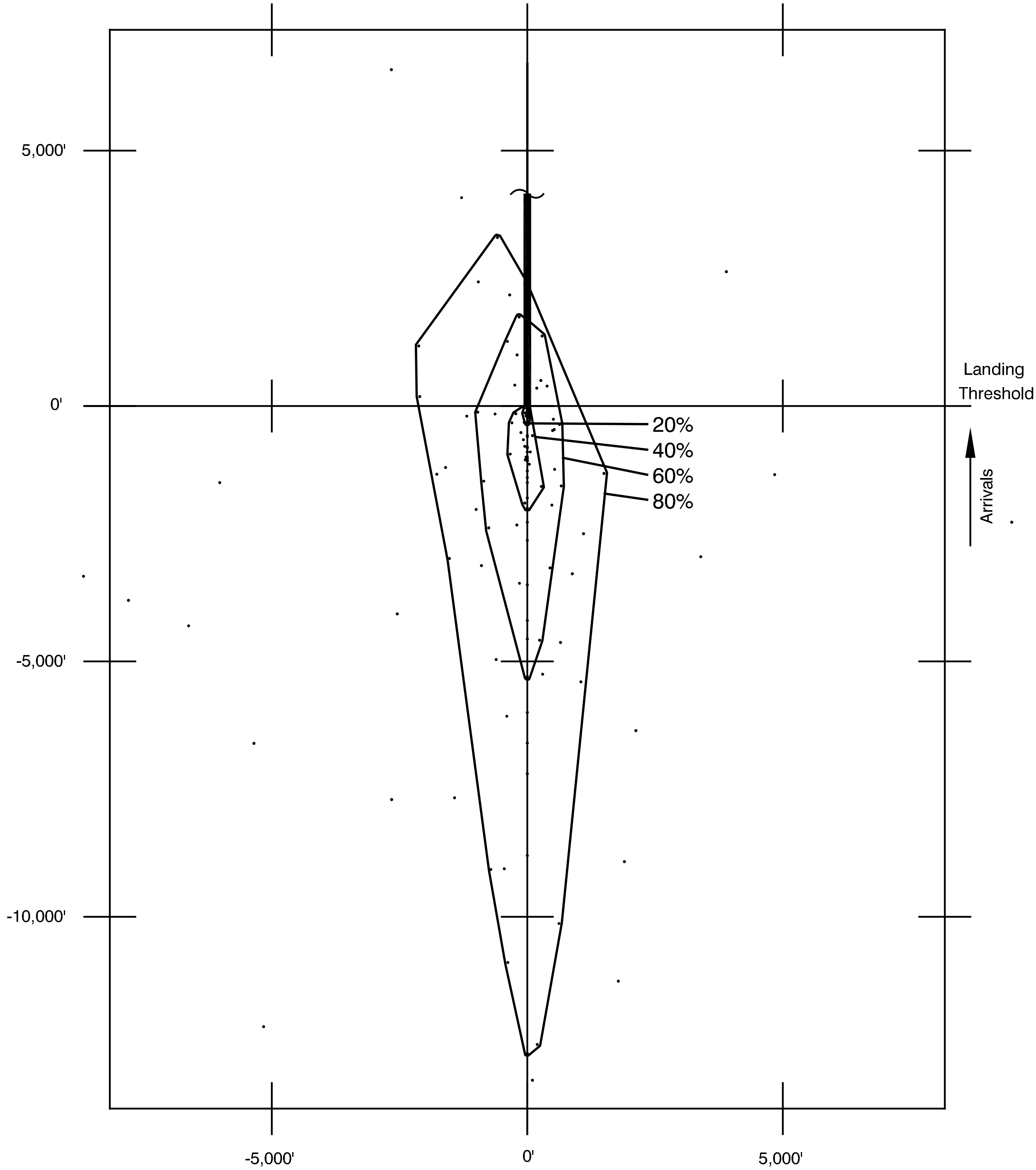


Notes:
191 departure accidents in database—each dot represents one accident site.
Contours represent relative intensities (highest concentrations) of points in 20% increments.

FIGURE 9F

General Aviation Accident Distribution Contours

Departure Accidents on Runways of Less than 4,000 Feet

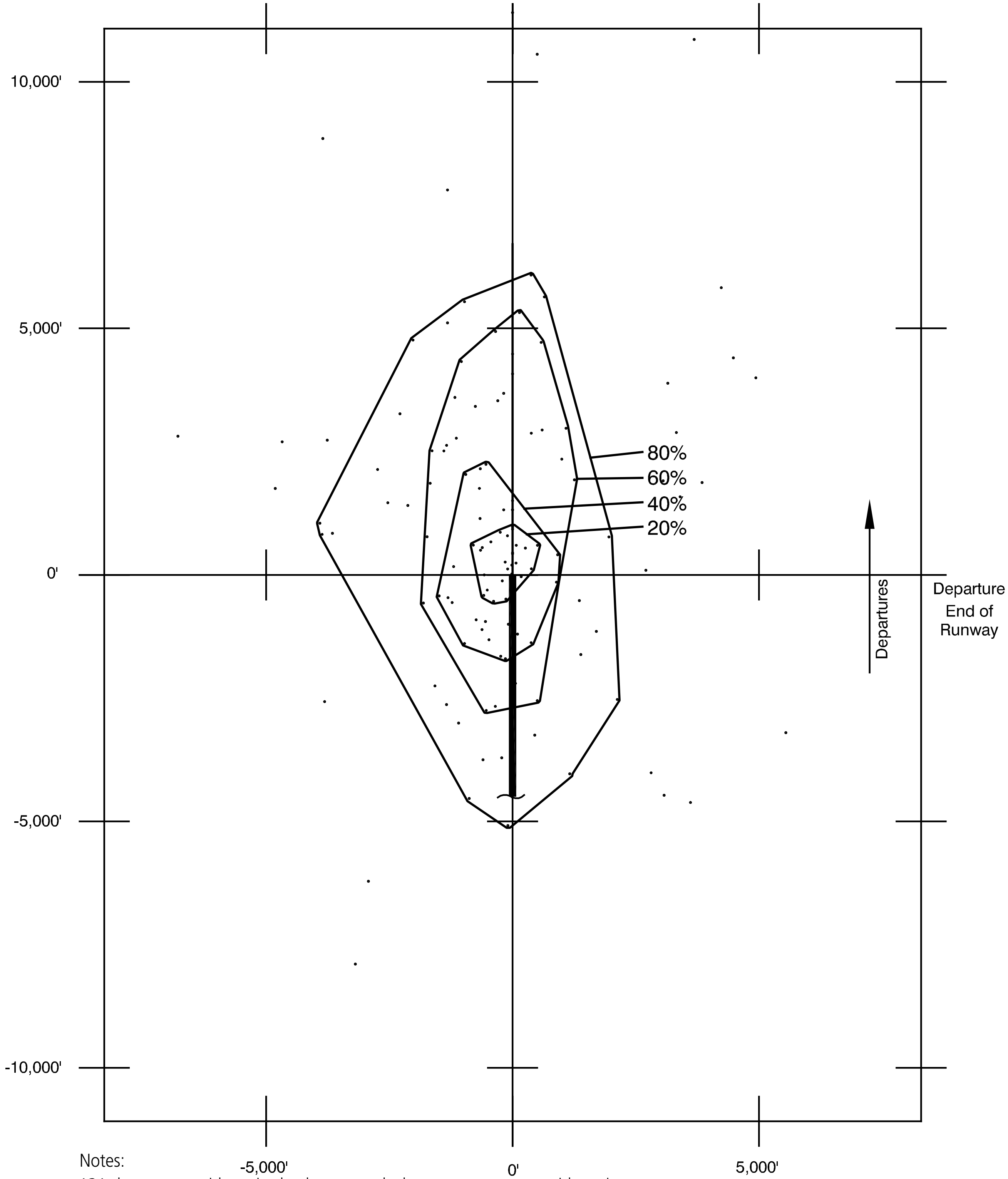


Notes:
150 arrival accidents in database—each dot represents one accident site.
Contours represent relative intensities (highest concentrations) of points in 20% increments.

FIGURE 9G

General Aviation Accident Distribution Contours

Arrival Accidents on Runways of 4,000 to 5,999 Feet

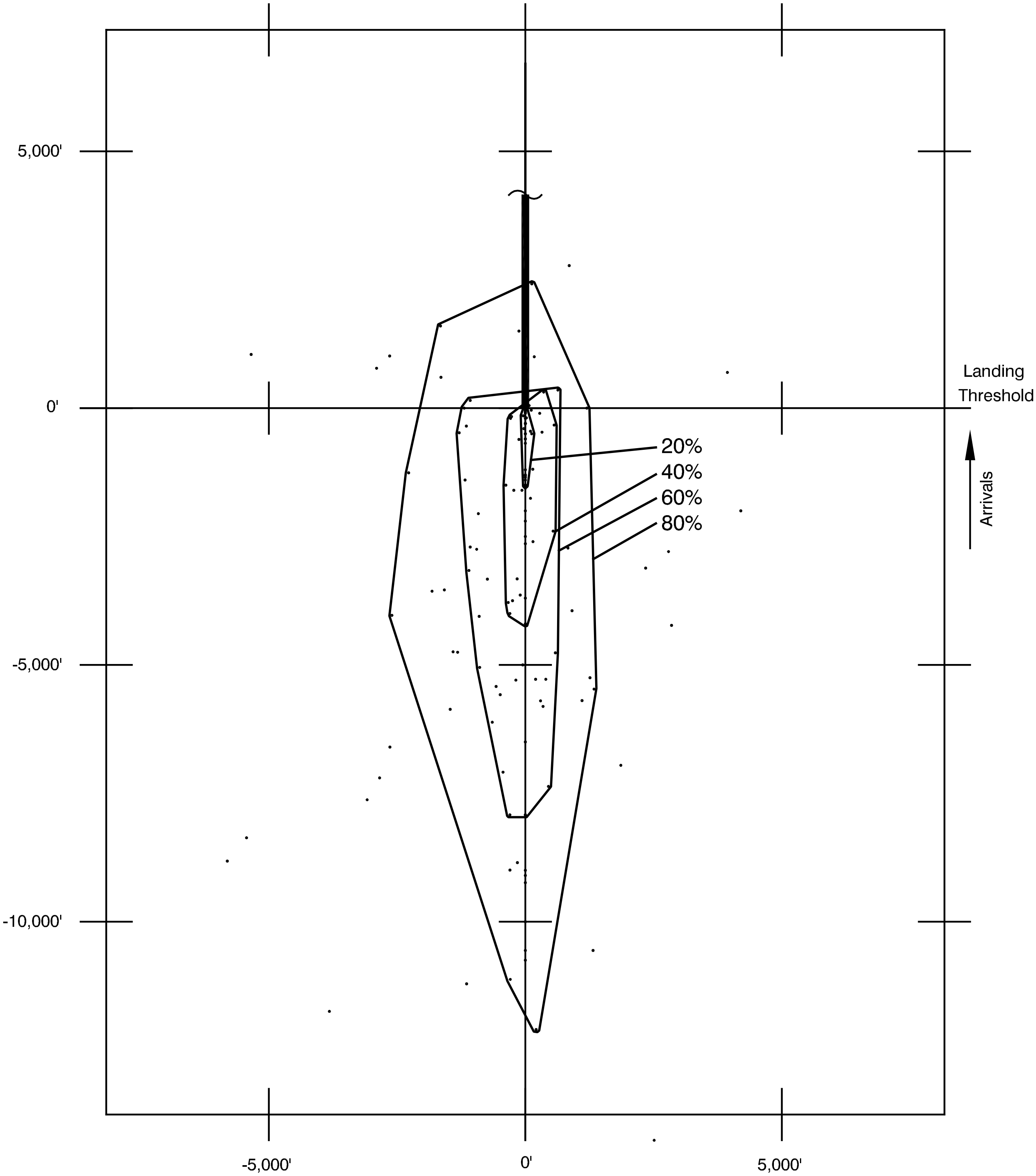


Notes:
131 departure accidents in database—each dot represents one accident site.
Contours represent relative intensities (highest concentrations) of points in 20% increments.

FIGURE 9H

General Aviation Accident Distribution Contours

Departure Accidents on Runways of 4,000 to 5,999 Feet

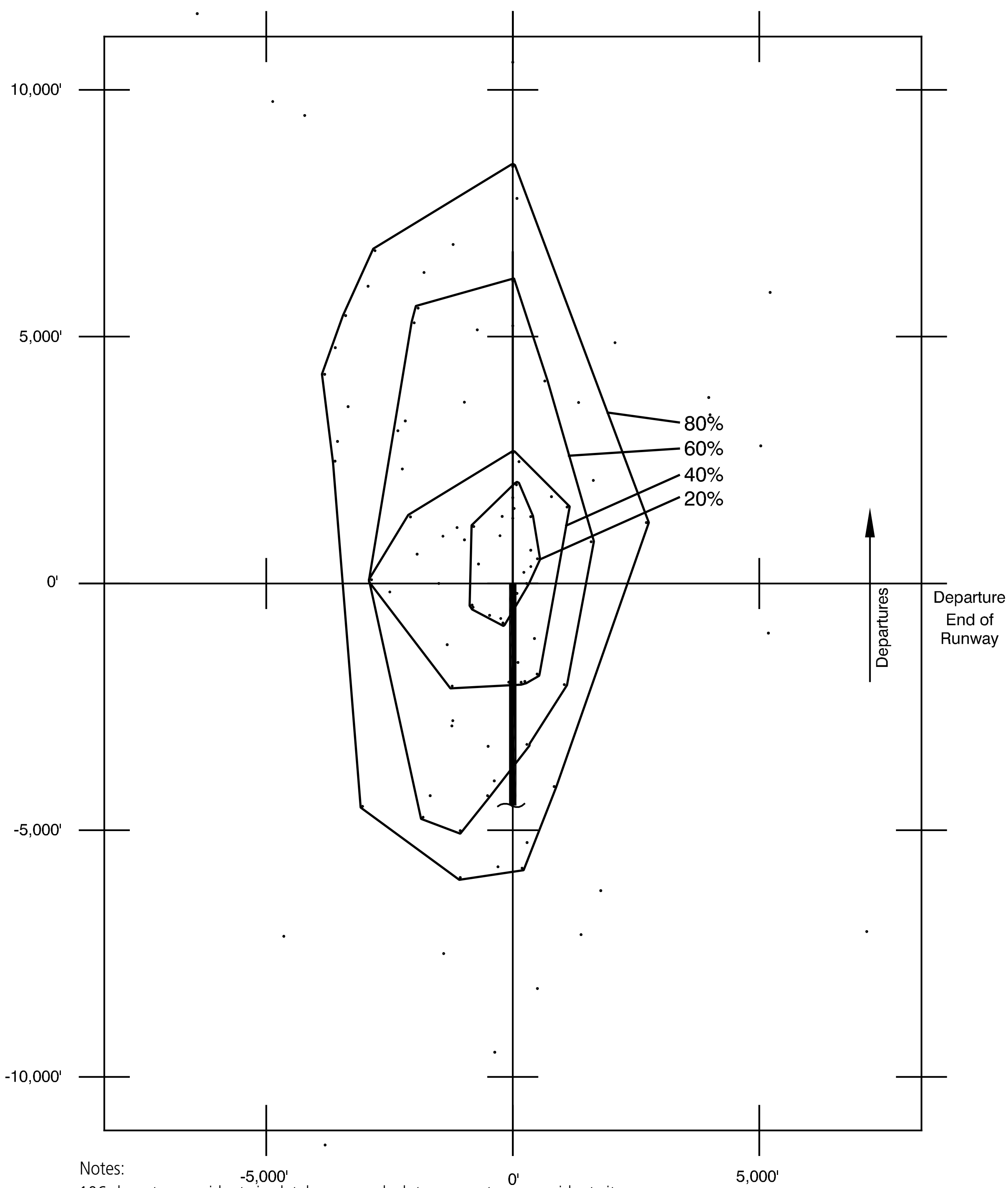


Notes:
142 arrival accidents in database—each dot represents one accident site.
Contours represent relative intensities (highest concentrations) of points in 20% increments.

FIGURE 9I

General Aviation Accident Distribution Contours

Arrival Accidents on Runways of 6,000 Feet or More



Notes:
106 departure accidents in database—each dot represents one accident site.
Contours represent relative intensities (highest concentrations) of points in 20% increments.

FIGURE 9J

General Aviation Accident Distribution Contours

Departure Accidents on Runways of 6,000 Feet or More

each instance. Particularly notable in this regard are the differences based on runway length. To portray these differences, the database was divided into three groups according to the length of the runway associated with the accident and accident distribution contours like those described above were developed.

- Runway lengths of less than 4,000 feet: Figures 9E (arrivals) and 9F departures).
- Runway lengths of 4,000 to 5,999 feet: Figures 9G (arrivals) and 9H (departures).
- Runway lengths of 6,000 feet or more: Figures 9I (arrivals) and 9J (departures).

Note that some of the contours, particularly the outer ones, are quite lopsided in shape. This irregularity can at least partially be attributed to the limited numbers of data points in these subsets (only 100 to 150 in most cases). Remaining unknown is whether an extensive expansion of the database would result in more uniformly shaped contours. It could well be that there is truly a geographic bias in the distribution of accident sites reflecting, for example, the left-hand traffic pattern of most runways. Given this uncertainty, no attempt is made here to produce more refined contours.

Because of the data limitations, the accident distribution contours presented here are considered to be more useful in support of regular, geometrically shaped, safety zones than as safety zones themselves. Also, the contours are purely statistical and do not reflect where aircraft fly at a specific airport.

Regular Geometric Zones

While accident distribution contours as described in the preceding section are helpful as means of portraying the geographic pattern of aircraft accident risks near an airport, they are not very satisfactory as the basis for defining safety compatibility policies. Their irregular shape is one drawback—although, in that respect, they are no different from noise contours. More important is the lack of precision which results from the modest size of the database, especially as associated with the contours for the individual runway-length groups.

Historically, regular geometric shapes have been used to define safety zones around airports. The 1952 *Report of the President's Airport Commission* first used accident location data to define the size and shape of clear zones (now called runway protection zones) intended to be created at the end of each runway. Airport land use commissions also have mostly used regular geometric shapes when adopting airport safety compatibility zones. Many times, the geometric airspace surfaces defined by Federal Aviation Regulations, Part 77, have been used at least as a starting point for establishment of safety zones.

Runway protection zones (RPZs) and FAR Part 77 surfaces, however, both have shortcomings for the purposes of land use safety compatibility objectives. Runway protection zones encompass only the most highly concentrated areas of accident locations near runways. As the data in Chapter 8 clearly indicates, a significant percentage of near-airport aircraft accidents occur in locations beyond the runway protection zones. Part 77 surfaces cover a much greater geographic area, but they were established for the purposes of airspace protection, not safety compatibility. Part 77 surfaces, especially the transitional surfaces, have rather minimal correlation to where aircraft accidents occur around airports.

A detailed analysis of aircraft accident location patterns provides the best basis for determining optimum safety zone shapes and sizes. An ideal set of safety zones should have four characteristics:

- The zones should have easily definable geometric shapes;
- The number of zones should be limited to a realistic number (five or six should be adequate in most cases);
- The set of zones should have a distinct progression in the degree of risk represented (that is, the distribution of accidents within each zone should be relatively uniform, but more or less concentrated than adjacent zones); and
- Each zone should be as compact as possible (the percentage of accident points per acre, its capture rate, should be maximized).

An analysis of this type was conducted for general aviation aircraft accidents as part of the 1993 edition of this *Handbook*. A summary is presented in Appendix G of the present edition. The analysis is supportive of the concept, widely used by airport land use commissions, to establish several safety compatibility zones for areas beyond the runway ends with each increasingly larger zone having fewer land use restrictions. The information presented, though, leaves open the question of how best to apply the accident data to delineation of the safety zones at individual airports. Specifically still missing from this process are two things:

- The need to use the data to develop an overall set of safety zones covering the entire geographic area within which safety is a concern. This process involves deciding the optimum shape and size of the most critical safety zone, then determining the shapes and sizes of successive zones in incremental fashion.
- The need to refine these generic results to fit the conditions present at individual airports.

APPLICATION TO INDIVIDUAL AIRPORTS

Ideally, to minimize the risk which aircraft accidents pose to people and property on the ground near airports, no development would be allowed in the airport vicinity. For most airports, however, this is clearly not a practical approach to land use compatibility planning. The question thus becomes one of deciding which land uses are acceptable and which are unacceptable in various portions of airport environs. The resulting policies are normally portrayed in the form of a set of safety zones and compatibility criteria applicable within each zone.

DEPT. OF TRANSPORTATION GUIDANCE
While the material presented here is intended to represent Department of Transportation guidance, it is not the intent or expectation that the methodologies or examples constitute the only acceptable approaches to the issue of airport land use safety compatibility. In

development of policies for a specific airport, careful attention must be made to the characteristics of that airport's design and use. Characteristics of the airport environs are potentially factors as well. The safety zones and/or compatibility criteria appropriate at one airport may be inappropriate at a different airport. This process is no different from that necessary in calculation of noise contours and establishment of noise compatibility policies.

DEPT. OF TRANSPORTATION GUIDANCE
Development of safety compatibility zones must be done in unison with the definition of criteria applicable within those zones. For both of these components, the particular physical and operational characteristics of the individual airport must be considered. The guidance presented in this chapter serves as a starting point for this process.

Frequency is primarily a factor at airports (or on runways) with very low activity. For most airports, the potential consequences component dominates the overall risk equation.

Unlike the case with noise, there is no uniform, widely accepted methodology for measurement of near-airport aircraft accident risks, let alone a process for creation of safety compatibility policies. There is, however, a substantial amount of data—much of it summarized in Chapter 8—upon which to base the process. The following discussion draws heavily upon analyses done for the 1993 edition of this *Handbook*, additional studies conducted in conjunction with preparation of this update, and the experience gained by airport land use commissions in development of safety compatibility policies over the years.

A point to emphasize is that delineation of safety compatibility zones and definition of criteria applicable within those zones are closely intertwined. The process is usually an iterative one: initial zones and criteria are drafted and then each is fine tuned as necessary in recognition of the peculiarities of the specific airport and its environs. (This process is particularly applicable when compatibility zones and criteria are formulated to take into account a combination of noise and safety compatibility concerns.)

General Approach

The three components of physical risks which were outlined earlier provide the conceptual basis for setting safety compatibility policies. Each of these components needs to be considered either in the delineation of safety compatibility zones or in the definition of the criteria applicable within the zones.

- The spatial distribution component clearly can only be reflected by means of the shape and size of safety compatibility zones.
- Potential consequences are addressed through the compatibility criteria—the limitations on usage intensity and other land use characteristics which affect the potential severity of an accident.
- The frequency component can be accounted for either way—through adjustment of zone sizes or the criteria applicable within each zone.

The choice of safety criteria appropriate for a particular zone is largely a function of risk acceptability. Land uses which, for a given proximity to the airport, are judged to represent intolerable risks usually must be prohibited. Where the risks of a particular land use are considered significant but tolerable, establishment of restrictions may reduce the risk to an acceptable level. Uses which are intrinsically acceptable, generally require no limitations.

Finally, to reiterate the point, it is the potentially severe consequences of aircraft accidents which are the driving concern in setting safety compatibility policies. As reflected in the matrix on page 9-14, only where the likelihood of an accident occurrence is so infrequent as to be considered extraordinary does the acceptability of potentially severe consequences reach a level that usually does not warrant some type of compatibility action.

Basic Safety Compatibility Zones

A total of seven examples of different safety zone configurations are delineated in a series of diagrams shown in the figures on the following pages.

Figure 9K includes safety zone examples for five different types of general aviation runways. Figure 9L presents examples for runways at a large air carrier and military airports. The diagrams divide the airport vicinity into as many as six safety zones in addition to the immediate runway environs (defined by the FAR Part 77 primary surface):

- *Zone 1:* Runway protection zone;
- *Zone 2:* Inner approach/departure zone;
- *Zone 3:* Inner turning zone;
- *Zone 4:* Outer approach/departure zone;
- *Zone 5:* Sideline zone; and
- *Zone 6:* Traffic pattern zone.

DEPT. OF TRANSPORTATION GUIDANCE

When applying these basic safety zones to a particular airport, it is important to recognize that not every runway will fit neatly into one of the categories shown. In many cases, a combination of the shapes and sizes from different diagrams may be appropriate. Also, it may be appropriate to establish different safety zone geometry at opposite ends of a runway. Other factors, such as those listed in the next section, will often need to be taken into account and the safety zone geometry adjusted accordingly. Finally, the criteria applicable within each zone, as discussed later in this chapter, must be considered when setting the boundaries of safety compatibility zones.

Also, note that, when ALUCs use the composite compatibility criteria and map format described in Chapter 3, the addition of noise as a factor is likely to result in compatibility zones which differ from the safety zone examples described here.

The intent of the set of zones depicted for each scenario is that risk levels be relatively uniform across each zone, but distinct from the other zones. The shapes and sizes of the zones are largely based upon the accident data and analyses presented in this and the preceding chapter. The flight paths which aircraft typically follow when approaching and departing a runway—particularly at less than traffic pattern altitude—are also considered, however. Other specific assumptions associated with each diagram are noted.

Even this expanded set of safety zone examples addresses only a few of the many variables which affect accident distribution patterns and attendant risks to land uses near airports. Many variables are too dependent upon the configuration and usage of a particular airport to be broadly generalized. Table 9A lists key airport operational variables which warrant consideration during the development of safety compatibility zones for an individual airport. These factors may necessitate adjustments to the shapes and sizes of the zones.

Several other factors deserve consideration when defining safety zones. These factors involve characteristics of the airport environs.

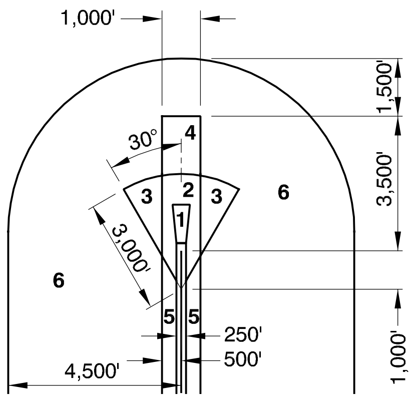
➤ **Airport Area Topography**—Characteristics of the terrain in the vicinity of an airport may sometimes need to be considered when setting safety compatibility zone boundaries. The presence of high terrain, the edge of a precipice, or other such features may influence the location of aircraft traffic patterns. Extension of safety zones may be justified in places where high terrain results in aircraft flying at a relatively low altitude above the ground. Also, some locations might have reduced levels of risk because they are effectively shielded by nearby higher terrain.

DEPT. OF TRANSPORTATION GUIDANCE

The principal reason for adjusting safety compatibility zone geometry in response to existing land uses is to minimize the extent to which development which is only marginally incompatible is classified as nonconforming. (Especially for residential areas, the consequence can be the unnecessary creation of considerable vocal opposition to the compatibility plan.) Such adjustments may be reasonable in locations where safety concerns are moderate to low. However, care must be taken in making adjustments in critical locations close to the runway ends—it is better for existing development to be deemed nonconforming if it is indeed incompatible with airport activity.

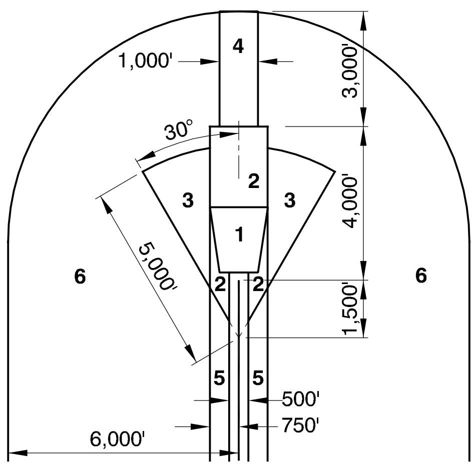
➤ **Existing Urban Developmen**t—In most instances, modification of safety compatibility zone boundaries will be based upon aeronautical factors such as those described Table 9A. At airports in urban settings, adjustments reflecting patterns of existing urban development may also be desirable. Most such adjustments are best made with respect to the compatibility criteria rather than the shapes and sizes of the compatibility zones, but both may be appropriate in some situations.

➤ **Locate Boundaries Based on Geographic Features**—Another manner in which safety zone shapes and sizes might be adjusted in response to



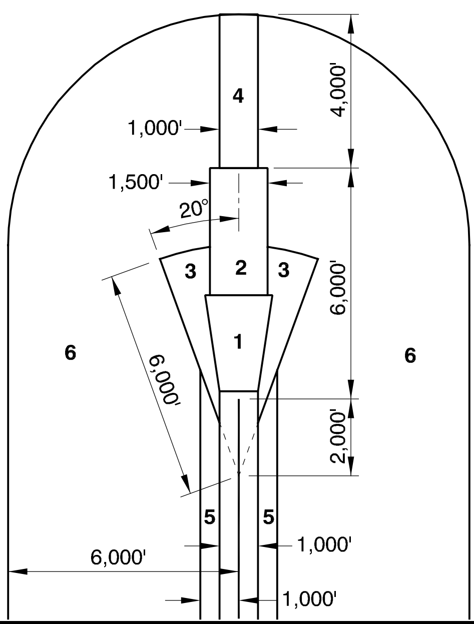
Example 1:
Short General Aviation Runway

Assumptions:
- Length less than 4,000 feet
- Approach visibility minimums ≥ 1 mile or visual approach only
- Zone 1 = 250' x 450' x 1,000'



Example 2:
Medium General Aviation Runway

Assumptions:
- Length 4,000 to 5,999 feet
- Approach visibility minimums ≥ 3/4 mile and < 1 mile
- Zone 1 = 1,000' x 1,510' x 1,700'



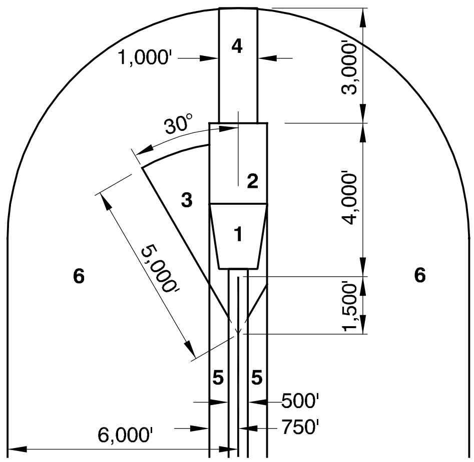
Example 3:
Long General Aviation Runway

Assumptions:
- Length 6,000 feet or more
- Approach visibility minimums < 3/4 mile
- Zone 1 = 1,000' x 1,750' x 2,500'

FIGURE 9K

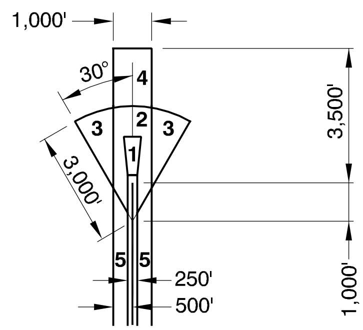
Safety Compatibility Zone Examples

General Aviation Runways



Example 4:
General Aviation Runway with Single-Sided Traffic Pattern

Assumptions:
- No traffic pattern on right
- Length 4,000 to 5,999 feet
- Approach visibility minimums ≥ 3/4 mile and < 1 mile
- Zone 1 = 1,000' x 1,510' x 1,700'



Example 5:
Low-Activity General Aviation Runway

Assumptions:
- Less than 2,000 takeoffs and landings per year at individual runway end.
- Length less than 4,000 feet
- Approach visibility minimums ≥ 1 mile or visual approach only
- Zone 1 = 250' x 450' x 1,000'

Legend

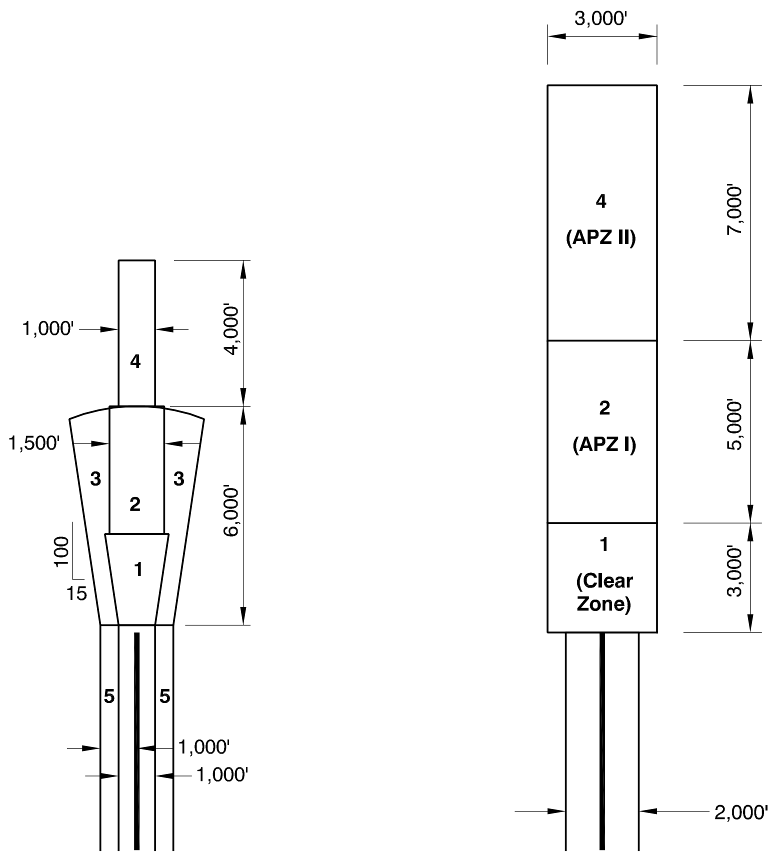
1. Runway Protection Zone
2. Inner Approach/Departure Zone
3. Inner Turning Zone
4. Outer Approach/Departure Zone
5. Sideline Zone
6. Traffic Pattern Zone

Notes:

- RPZ (Zone 1) size in each example is as indicated by FAA criteria for the approach type assumed. Adjustment may be necessary if the approach type differs.
- See Table 9A for factors to consider regarding other possible adjustments to these zones to reflect characteristics of a specific airport runway.
- See Tables 9B and 9C for guidance on compatibility criteria applicable with each zone.

These examples are intended to provide general guidance for establishment of airport safety compatibility zones. They do not represent California Department of Transportation standards or policy.

FIGURE 9K *CONTINUED*



Large Air Carrier Runway

Assumptions:
- Minimal light-aircraft general aviation activity
- Predominately straight-in and straight-out flight routes
- Approach visibility minimums < 3/4 mile
- Zone 1 = 1,000' x 1,750' x 2,500'

Military Runway for Large Aircraft

Assumptions:
- Military airport
- Predominately straight-in and straight-out flight routes (must modify for turning routes and traffic pattern activity)

Legend

1. Runway Protection Zone (Clear Zone)
2. Inner Approach/Departure Zone (Accident Potential Zone I)
3. Inner Turning Zone
4. Outer Approach/Departure Zone (Accident Potential Zone II)
5. Sideline Zone

Notes:

- RPZ (Zone 1) size in the large air carrier runway example is as indicated by FAA criteria for the approach type assumed. Adjustment may be necessary if the approach type differs.
- See Table 9A for factors to consider regarding other possible adjustments to these zones to reflect characteristics of a specific airport runway.
- See Tables 9B and 9C for guidance on compatibility criteria applicable with each zone.

These examples are intended to provide general guidance for establishment of airport safety compatibility zones. They do not represent California Department of Transportation standards or policy.

FIGURE 9L

Safety Compatibility Zone Examples

Large Air Carrier and Military Runways

The generic sets of compatibility zones shown in Figures 9K and 9L may need to be adjusted to take into account various operational characteristics of a particular airport runway. Among these characteristics are the following:

- **Instrument Approach Procedures**—At least within the final two to three miles which are of greatest interest to land use compatibility planning, the flight paths associated with precision instrument approach procedures are highly standardized from airport to airport. Other types of instrument approach procedures are less uniform, however. If such procedures are available at an airport, ALUCs should identify the flight paths associated with them and the extent to which they are used. Procedures which are regularly used should be taken into account in the configuration of safety zones (and in setting height limits for airspace protection). Types of procedures which may warrant special consideration include:
  - *Circling Approaches:* Most instrument approach procedures allow aircraft to circle to land at a different runway rather than continue straight-in to a landing on the runway for which the approach is primarily designed. When airports which have straight-in approaches to multiple runway ends, circling approaches are seldom necessary. However, when only one straight-in approach procedure is available and the wind direction precludes landings on that runway, aircraft may be forced to circle to land on at another runway end. Pilots must maintain sight of the runway while circling, thus turns are typically tight. Also, the minimum circling altitude is often less than the traffic pattern altitude. At airports where circling approaches are common, giving consideration to the associated risks when setting safety zone boundaries is appropriate.
  - *Nonprecision Approaches at Low Altitudes:* Nonprecision instrument approach procedures often involve aircraft descending to a lower altitude farther from the runway than occurs on either precision instrument or visual approaches. An altitude of 300 to 400 feet as much as two to three miles from the runway is not unusual. The safety (and noise) implications of such procedures need to be addressed at airports where they are in common use. (A need for corresponding restrictions on the heights of objects also exists along these routes.)
  - *Nonprecision Approaches not Aligned with the Runway:* Some types of nonprecision approaches bring aircraft toward the runway along a path that is not aligned with the runway. In many cases, these procedures merely enable the aircraft to reach the airport vicinity at which point they then proceed to land under visual conditions. In other instances, however, transition to the runway alignment occurs close to the runway and at a low altitude.
- **Other Special Flight Procedures or Limitations**—Single-sided traffic patterns represent only one type of special flight procedures or limitations which may be established at some airports. Factors such as nearby airports, high terrain, or noise-sensitive land uses may affect the size of the airport traffic pattern or otherwise dictate where and at what altitude aircraft fly when using the airport. These procedures may need to be taken into account in the design of safety compatibility zones.
- **Runway Use by Special-Purpose Aircraft**—In addition to special flight procedures which most or all aircraft may use at some airports, certain special-purpose types of aircraft often have their own particular flight procedures. Most common among these aircraft are fire attack, agricultural, and military airplanes. Helicopters also typically have their own special flight routes. The existence of these procedures needs to be investigated and, where warranted by the levels of usage, may need to be considered in the shaping of safety zones.
- **Small Aircraft Using Long Runways**—When small airplanes take off from long runways (especially runways in excess of 8,000 feet length), it is common practice for them to turn toward their intended direction of flight before passing over the far end of the runway. When mishaps occur, the resulting pattern of accident sites will likely be more dispersed around the runway end than is the case with shorter runways. With short runways, accident sites tend to be more tightly clustered around the runway end and along the extended runway centerline because aircraft are still following the runway heading as they begin their climb.
- **Runways Used Predominantly in One Direction**—Most runways are used sometimes in one direction and, at other times, in the opposite direction depending upon the direction of the wind. Even when used predominantly in one direction, a busy runway may experience a significant number of operations in the opposite direction (for example, a runway with 100,000 total annual operations, 90% of which are in one direction, will still have 10,000 annual operations in the opposite direction). Thus, in most situations, the generic safety zones—which take into account both takeoffs and landings at a runway end—are applicable. However, when the number of either takeoffs or landings at a runway end is less than approximately 2,000 per year, then adjustment of the safety compatibility zones to reflect those circumstances may be warranted.
- **Displaced Landing Thresholds**—A displaced threshold moves the landing location of aircraft down the runway from where they would land in the absence of the displacement. The distribution pattern of landing accident sites as shown in Appendix F would thus shift a corresponding amount. The pattern of accident locations for aircraft taking off toward that end of the runway does not necessarily shift, however. Whether the runway length behind the displaced threshold is usable for takeoffs toward that end of the runway is a key factor in this regard. The appropriateness of making adjustments to safety zone locations in response to the existence of a displaced threshold needs to be examined on a case-by-case basis. The numbers of landings at and takeoffs toward the runway end in question should be considered in making this determination.

TABLE 9A

Safety Zone Adjustment Factors

Airport Operational Variables

existing urban development is to have the zone boundaries follow established geographic features. As discussed in Chapter 3, such features might include, roads, water courses, parcel lines, etc. Such adjustments should be made in a manner which provides a level of safety equivalent to that afforded by the applicable generic safety compatibility zones. Adjustments of this type can greatly simplify implementation of a compatibility plan without compromising the rationale used to establish the zone boundaries.

Basic Safety Compatibility Criteria

By emphasizing adjustments to the shape and size of safety zones as necessary to reflect the geographic pattern of aircraft accident risks, the compatibility criteria applicable to each zone can be held relatively constant among most airports. Table 9B provides a qualitative description of the land use characteristics considered acceptable or unacceptable within each of the six basic safety zones. Also indicated are the general risk factors prevalent in each zone.

The types of variables not fully accounted for in the safety zones, though, are ones involving existing land use characteristics of the airport environs. As previously discussed, more intensive development is often considered acceptable within urban areas because the costs of avoiding that development are greater than in rural areas. Table 9C presents a set of specific safety compatibility criteria guidelines formulated with this factor in mind. A distinction is made between current settings which are heavily urbanized versus ones in suburban or rural areas where much of the land remains undeveloped. Note that this urban versus rural distinction is not limited just to differences between one airport and another, it may also be true between various portions of individual airport’s environs. Consequently, it may be reasonable for compatibility criteria to allow comparatively intensive development and/or infill development in one part of an airport vicinity, but not in another.

Guidelines for General Aviation Runways

Figure 9K depicts basic guidelines for general aviation runway safety compatibility zones. Five variations are shown:

- General aviation runway with length of less than 4,000 feet and visibility minimums of 1 mile or visual approaches only;
- General aviation runway with length of 4,000 to 5,999 feet and instrument approach visibility minimums below 1 mile, but not lower than ¾ mile;
- General aviation runway with length of 6,000 feet or more and a instrument approach visibility minimums below ¾ mile;
- General aviation runway with traffic pattern on one side only; and
- General aviation runway with very-low activity levels (less than 2,000 takeoffs and landings projected per year at the runway end under consideration).

Data from the expanded general aviation aircraft accident database has been taken into account in creation of these suggested zones as has the experience of ALUCs in use of the zones shown in the 1993 edition of this *Handbook*.

Runway Length and Approach Visibility Variables

The primary variable among the general aviation runway safety zone examples shown in Figure 9K is the runway length. Additionally, though, different assumptions are made as to the approach visibility minimums for each runway length grouping. For the purposes of illustration, longer runways are assumed to have better instrument approaches. Adjustments to the safety zones may be appropriate for runway ends having approaches which do not match the assumptions noted.

The three examples which focus on runway length as the primary variable are similar, but not identical, to the comparable examples included in the 1993 *Handbook*. A discussion of the differences is included in Appendix G.

Table 9D provides supporting data for three of the general aviation airport safety compatibility zone examples, one in each runway length group. For each of the suggested zones, the table indicates the acreage of the zone and the percentage of arrival, departure, and total accidents which are encompassed within that zone. The capture rates—percentage of accidents divided by acreage—is listed as well.

Single-Sided Traffic Pattern

The single-sided traffic pattern example eliminates the turning zone on the nonpattern side of the runway. This configuration is based upon the assumption that aircraft are less likely to crash in locations over which they normally do not fly. (Insufficient information is available in the general aviation accident database to better assess this operational configuration.) It is recognized, however, that the potential exists for aircraft to deviate to the nonpattern side on either takeoff or landing, especially under emergency conditions. Some amount of buffer is thus important to maintain. Note that the example shown is for a runway in the 4,000-to-5,999-foot length category. Similar safety zone configurations can be devised for other runway lengths.

Low-Activity Runways

The other operational variable which calls for adjustment of the compatibility zones is for runways where activity levels are currently very low and are forecast to remain that way indefinitely. Clearly, the likelihood of an aircraft accident happening is reduced when operational volumes remain low. As suggested previously, this reduced risk could be reflected in compatibility policies either by adjusting the safety zones or by modifying the compatibility criteria. The low-activity runway diagram in Figure 9K works on the basis that adjustment of zone sizes is preferable. Safety compatibility criteria are a reflection of the potential consequences of an accident and that potential does not change even if the activity is low. Furthermore, safety zone shapes and sizes can more readily be adjusted for a single low-activity runway at an otherwise busy airport. Modifying the compatibility criteria would require having different criteria for different runways.

Risk Factors / Runway Proximity	Basic Compatibility Qualities
Zone 1: Runway Protection Zone	
➤ Very high risk ➤ Runway protection zone as defined by FAA criteria ➤ For military airports, clear zones as defined by AICUZ criteria	➤ Airport ownership of property encouraged ➤ Prohibit all new structures ➤ Prohibit residential land uses ➤ Avoid nonresidential uses except if very low intensity in character and confined to the sides and outer end of the area
Zone 2: Inner Approach/Departure Zone	
➤ Substantial risk: RPZs together with inner safety zones encompass 30% to 50% of near-airport aircraft accident sites (air carrier and general aviation) ➤ Zone extends beyond and, if RPZ is narrow, along sides of RPZ ➤ Encompasses areas overflown at low altitudes — typically only 200 to 400 feet above runway elevation	➤ Prohibit residential uses except on large, agricultural parcels ➤ Limit nonresidential uses to activities which attract few people (uses such as shopping centers, most eating establishments, theaters, meeting halls, multi-story office buildings, and labor-intensive manufacturing plants unacceptable) ➤ Prohibit children's schools, day care centers, hospitals, nursing homes ➤ Prohibit hazardous uses (e.g. aboveground bulk fuel storage)
Zone 3: Inner Turning Zone	
➤ Zone primarily applicable to general aviation airports ➤ Encompasses locations where aircraft are typically turning from the base to final approach legs of the standard traffic pattern and are descending from traffic pattern altitude ➤ Zone also includes the area where departing aircraft normally complete the transition from takeoff power and flap settings to a climb mode and have begun to turn to their en route heading	➤ Limit residential uses to very low densities (if not deemed unacceptable because of noise) ➤ Avoid nonresidential uses having moderate or higher usage intensities (e.g., major shopping centers, fast food restaurants, theaters, meeting halls, buildings with more than three aboveground habitable floors are generally unacceptable) ➤ Prohibit children's schools, large day care centers, hospitals, nursing homes ➤ Avoid hazardous uses (e.g. aboveground bulk fuel storage)

TABLE 9B

Basic Safety Compatibility Qualities

Zone 4: Outer Approach/Departure Zone

Risk Factors / Runway Proximity	*Basic Compatibility Qualities*
➤ Situated along extended runway centerline beyond Zone 3 ➤ Approaching aircraft usually at less than traffic pattern altitude ➤ Particularly applicable for busy general aviation runways (because of elongated traffic pattern), runways with straight-in instrument approach procedures, and other runways where straight-in or straight-out flight paths are common ➤ Zone can be reduced in size or eliminated for runways with very-low activity levels	➤ In undeveloped areas, limit residential uses to very low densities (if not deemed unacceptable because of noise); if alternative uses are impractical, allow higher densities as infill in urban areas ➤ Limit nonresidential uses as in Zone 3 ➤ Prohibit children's schools, large day care centers, hospitals, nursing homes

Zone 5: Sideline Zone

Risk Factors / Runway Proximity	*Basic Compatibility Qualities*
➤ Encompasses close-in area lateral to runways ➤ Area not normally overflown; primary risk is with aircraft (especially twins) losing directional control on takeoff ➤ Area is on airport property at most airports	➤ Avoid residential uses unless airport related (noise usually also a factor) ➤ Allow all common aviation-related activities provided that height-limit criteria are met ➤ Limit other nonresidential uses similarly to Zone 3, but with slightly higher usage intensities ➤ Prohibit children's schools, large day care centers, hospitals, nursing homes

Zone 6: Traffic Pattern Zone

Risk Factors / Runway Proximity	*Basic Compatibility Qualities*
➤ Generally low likelihood of accident occurrence at most airports; risk concern primarily is with uses for which potential consequences are severe ➤ Zone includes all other portions of regular traffic patterns and pattern entry routes	➤ Allow residential uses ➤ Allow most nonresidential uses; prohibit outdoor stadiums and similar uses with very high intensities ➤ Avoid children's schools, large day care centers, hospitals, nursing homes

Definitions

As used in this table, the follow meanings are intended:

- *Allow:* Use is acceptable
- *Limit:* Use is acceptable only if density/intensity restrictions are met
- *Avoid:* Use generally should not be permitted unless no feasible alternative is available
- *Prohibit:* Use should not be permitted under any circumstances
- *Children's Schools:* Through grade 12
- *Large Day Care Centers:* Commercial facilities as defined in accordance with state law; for the purposes here, family day care homes and noncommercial facilities ancillary to a place of business are generally allowed.
- *Aboveground Bulk Storage of Fuel:* Tank size greater than 6,000 gallons (this suggested criterion is based on Uniform Fire Code criteria which are more stringent for larger tank sizes)

TABLE 9B *CONTINUED*

Obvious questions posed by the idea of modifying safety zones for low-activity runways are:

- How low must the activity level continue to be for the runway to be considered low activity?
- How much can the safety zones be adjusted in response to the low activity?

In each case, the answer is a relative one. The assumption employed in the example here is that the runway end under consideration has fewer than 2,000 total takeoffs and landings projected annually (roughly 6 operations per day). Less modification is justified when the activity is higher. Beyond about 10,000 annual operations, the basic safety zone configuration should be applied.

The other factor is that locations close to the runway remain critical even when the activity is low. FAA criteria for runway protection zones, for example, do not depend upon aircraft operations volumes, only the types of approach the runway has and the type of aircraft it accommodates. Thus, depending upon where the common flight tracks are located, it is the outer safety zone and/or the turning zone which can most reasonably be modified. In defining safety zones for low-activity runways, special consideration also needs to be given to the mix of aircraft and the existence of any common but unusual flight tracks. Runways used primarily by agricultural aircraft are a prime example of such situations. Safety zones for low-activity runways which are sometimes used by large aircraft also need to be carefully evaluated.

Guidelines for Large Air Carrier Runways

There are numerous factors that distinguish the risks associated with runways predominantly used by air carrier aircraft from those of runways that have a significant number of general aviation operations.

- Nearly all aircraft are flown by professional pilots;
- Nearly all pilots are instrument rated;
- Pilots are more experienced and fly more frequently;
- Typically, there are at least two pilots in the cockpit;
- Many flights are conducted under the more restrictive requirements of FAR Part 121, 135, etc.;
- The majority of flights are conducted under instrument flight plans, even when weather does not require it;
- The vast majority of aircraft have multiple engines and can remain airborne following the loss of one engine;
- Aircraft maintenance programs are monitored by the FAA;
- Aircraft are much newer on average than small aircraft in the general aviation fleet; and
- Essentially all of these airports have electronic landing aids.

All of these factors support the very low frequency of commercial aviation accidents. At air carrier airports, noise tends to be such a dominant consideration that safety is seldom discussed. However, the consequences of an

MAXIMUM RESIDENTIAL DENSITY

Current Setting	Safety Compatibility Zones[a] (1) Runway Protection Zone	(2) Inner Approach/ Departure Zone	(3) Inner Turning Zone	(4) Outer Approach/ Departure Zone	(5) Sideline Zone	(6) Traffic Pattern Zone
Average number of dwelling units per gross acre						
Rural Farmland / Open Space (Minimal Development)	0	Maintain current zoning if less than density criteria for rural / suburban setting				No limit
Rural / Suburban (Mostly to Partially Undeveloped)	0	1 d.u. per 10 – 20 ac.	1 d.u. per 2 – 5 ac.	1 d.u. per 2 – 5 ac.	1 d.u. per 1 – 2 ac.	No limit
Urban (Heavily Developed)	0	0	Allow infill at up to average of surrounding residential area[b]			No limit

[a] Clustering to preserve open land encouraged in all zones.
[b] See Chapter 3 for discussion of infill development criteria; infill is appropriate only if nonresidential uses are not feasible.

MAXIMUM NONRESIDENTIAL INTENSITY

Current Setting	Safety Compatibility Zones (1) Runway Protection Zone	(2) Inner Approach/ Departure Zone	(3) Inner Turning Zone	(4) Outer Approach/ Departure Zone	(5) Sideline Zone	(6) Traffic Pattern Zone
Average number of people per gross acre[a]						
Rural Farmland / Open Space (Minimal Development)	0[b]	10 – 25	60 – 80	60 – 80	80 – 100	150
Rural / Suburban (Mostly to Partially Undeveloped)	0[b]	25 – 40	60 – 80	60 – 80	80 – 100	150
Urban (Heavily Developed)	0[b]	40 – 60	80 – 100	80 – 100	100 – 150	No limit[c]
Multipliers for above numbers[d]						
Maximum Number of People per Single Acre	x 1.0	x 2.0	x 2.0	x 3.0	x 2.0	x 3.0
Bonus for Special Risk-Reduction Bldg. Design	x 1.0	x 1.5	x 2.0	x 2.0	x 2.0	x 2.0

[a] Also see Table 9B for guidelines regarding uses which should be prohibited regardless of usage intensity
[b] Exceptions can be permitted for agricultural activities, roads, and automobile parking provided that FAA criteria are satisfied.
[c] Large stadiums and similar uses should be prohibited.
[d] Multipliers are cumulative (e.g., maximum intensity per single acre in inner safety zone is 2.0 times the average intensity for the site, but with risk-reduction building design is 2.0 x 1.5 = 3.0 times the average intensity).

TABLE 9C

Safety Compatibility Criteria Guidelines

Land Use Densities and Intensities

off-airport air carrier accident are potentially devastating. For land use compatibility planning, defining realistic safety criteria is complicated by the fact that many busy air carrier airports were established decades ago and are now surrounded by urban development.

The accident database relied upon in defining safety zone guidelines for general aviation airports contains data only on general aviation aircraft accidents. Equivalent data for air carrier accidents is comparatively scant. Using data from a 1990 FAA study, Figure 8D in Chapter 8 shows the location pattern for some three dozen near-airport commercial aircraft accidents. A British study also cited in Chapter 8 (Figure 8C) includes additional data, but it is not formatted in a manner showing the overall scatter pattern (data along and lateral to the extended runway centerline are separately summarized).

Both studies portray similar results. The highest concentration of accidents sites are within approximately 1,500 feet of the runway end, but significant numbers occur within an area extending about two miles beyond the runway end. Most of the sites are directly along the runway centerline and the majority of the remainder are within 1,000 feet of the centerline.

This data provides the basis for the safety zones for large air carrier runways depicted in Figure 9L. These zones assume minimal activity by light general aviation aircraft. Also assumed in the example shown is that the runway length is 8,000 feet or more and that essentially all flights are flown straight in and out along the extended runway centerline. To the extent that any of these assumptions do not strictly apply to a specific airport, then modification of the indicated zones should be considered.

As for the criteria applicable within these zones, the presence of large aircraft might argue for greater stringency. That is, the potential consequences of an airline aircraft accident are much greater than they are for small, general aviation aircraft, thus land uses should be more restricted. However, this risk factor is largely offset by the significantly lower frequency of accidents by airline aircraft. Also, the most at-risk locations can be protected by making the most restricted zones relatively large as shown in Figure 9L. Given these factors, the safety compatibility guidelines listed in Tables 9B and 9C can reasonably be applied to large air carrier runways.

Guidelines for Military Runways

Preparation of compatibility plans for military airfields is optional under the State Aeronautics Act (Public Utilities Code, Section 21675(b)).

Guidelines set forth by the U.S. Department of Defense as part of its *Air Installation Compatible Use Zone* (AICUZ) program are the appropriate starting point for ALUC safety compatibility policies for military airport runways. The federal government has prepared individual AICUZ plans for all major military airports.

The AICUZ-recommended accident potential zones (APZs) are illustrated in Figure 9L. The depicted zones assume that flight tracks are straight-in and straight-out. Where different or additional tracks are used on a regular basis, as is often the case, the APZs should be modified or expanded. Considera-

	Safety Zone	Example 1: Runway Length Less than 4,000 Feet			Example 2: Runway Length 4,000 to 5,999 Feet			Example 3: Runway Length 6,000 Feet or More		
		% of Points	Acres	%/Acre	% of Points	Acres	%/Acre	% of Points	Acres	%/Acre
Arrival Accident Sites										
	Primary Surface	29%	–	–	2%	–	–	11%	–	–
Zone 1:	Runway Protection Zone	27%	8	3.35	26%	49	0.53	25%	79	0.32
Zone 2:	Inner Approach/Departure Zone	15%	44	0.34	9%	101	0.09	12%	114	0.11
Zone 3:	Inner Turning Zone	2%	50	0.04	5%	151	0.04	6%	131	0.05
Zone 4:	Outer Approach/Departure Zone	3%	35	0.07	5%	69	0.08	8%	92	0.09
Zone 5:	Sideline Zone	1%	–	–	3%	–	–	1%	–	–
Zone 6:	Traffic Pattern Zone	10%	–	–	11%	–	–	21%	–	–
Total:	*Zones 1-6 + Primary Surface*	*87%*	–	–	*79%*	–	–	*85%*	–	–
Departure Accident Sites										
	Primary Surface	9%	–	–	9%	–	–	16%	–	–
Zone 1:	Runway Protection Zone	17%	8	2.09	14%	49	0.28	13%	79	0.17
Zone 2:	Inner Approach/Departure Zone	28%	44	0.63	11%	101	0.11	3%	114	0.02
Zone 3:	Inner Turning Zone	5%	50	0.10	9%	151	0.06	8%	131	0.06
Zone 4:	Outer Approach/Departure Zone	2%	35	0.06	4%	69	0.06	3%	92	0.03
Zone 5:	Sideline Zone	8%	–	–	8%	–	–	5%	–	–
Zone 6:	Traffic Pattern Zone	24%	–	–	37%	–	–	39%	–	–
Total:	*Zones 1-6 + Primary Surface*	*94%*	–	–	*91%*	–	–	*86%*	–	–
All Accident Sites										
	Primary Surface	18%	–	–	15%	–	–	13%	–	–
Zone 1:	Runway Protection Zone	21%	8	2.65	21%	49	0.40	20%	79	0.26
Zone 2:	Inner Approach/Departure Zone	22%	44	0.50	10%	101	0.10	8%	114	0.07
Zone 3:	Inner Turning Zone	4%	50	0.08	7%	151	0.05	7%	131	0.05
Zone 4:	Outer Approach/Departure Zone	2%	35	0.07	5%	69	0.07	6%	92	0.07
Zone 5:	Sideline Zone	5%	–	–	5%	–	–	3%	–	–
Zone 6:	Traffic Pattern Zone	18%	–	–	23%	–	–	29%	–	–
Total:	*Zones 1-6 + Primary Surface*	*91%*	–	–	*85%*	–	–	*85%*	–	–

Notes:

- Totals may not equal the sum of the numbers above because of mathematical rounding.
- See Figure 9K for the shapes and dimensions of each zone.
- Accident site locations as indicated in expanded general aviation aircraft accident database.

TABLE 9D

Analysis of Safety Zone Examples

General Aviation Runways

tion may also need to be given to providing safety zones lateral to the runway if these areas are not fully contained within the boundaries of the military facility.

The safety compatibility criteria suggested in AICUZ guidelines tend to represent *minimum standards* (more so with respect to noise than safety). Also, the criteria are formatted using a detailed listing of land uses types. ALUCs may choose to use the AICUZ guidelines directly. Alternatively, the safety compatibility guidelines indicated in Tables 9B and 9C may be appropriate, particularly where the ALUC utilizes this format for safety compatibility criteria at other airports within its jurisdiction. In either case, the specific criteria should be reviewed and revised as necessary to fit the operational characteristics of the specific airfield and the land use characteristics of the surrounding area.

Guidelines for Heliports

The guidelines suggested here are applicable to helicopter touchdown and lift-off pads on public-use airports. Additionally, as discussed in Chapter 3, ALUCs have the authority to create compatibility plans for public-use and special-use heliports.

Unlike for airports, very little information is available upon which to base safety compatibility guidelines for heliports. No useful compilation of data on the location of helicopter accidents in the proximity of heliports is known to exist. The only significant policy guidance is contained in the FAA *Heliport Design* Advisory Circular (AC 150/5390-2A), last updated in 1994. The primary concerns of that document are with respect to the design of the touchdown and liftoff pad itself and requirements for obstruction-free approach/departure paths.

As used here, the term *helipad* is considered to relate to *heliport* in the same way that *runway* relates to *airport*. For facilities such as at a hospital, the two terms are basically synonymous.

The one additional FAA safety-related guideline—described as applicable only to public-use facilities—is for creation of helipad protection zones. These zones, equivalent to runway protection zones at airports, extend 280 feet from the edge of the final approach and takeoff area (the latter area, or FATO, is generally larger than the physical pad itself). As with runway protection zones, the helipad protection zone should be clear of incompatible objects and any land uses involving a congregation of people.

Establishment of helipad protection zones is a desirable safety-compatibility objective for all heliports. There are practical limitations to doing so, however. One is that, even when approach/departure routes are formally defined and approved, the highly maneuverable capabilities of helicopters means that their actual routes may differ. The other is that, expect for facilities on an airport, the helipad protection zone is likely to extend onto adjacent property.

Consistent with FAA guidance, the recommendation here is that new heliports be designed so as to place as much of the approach/departure path as possible either on heliport property or along adjacent roads or other publicly controlled lands. As much as practical, buildings (particularly ones higher than the helipad itself) and congregations of people should be avoided within helipad protection zones. Once a heliport is established, the facility owner, local land use jurisdictions, and ALUCs should take whatever actions that are in their respective authorities to preserve compatible uses in the helipad protection zones and, even more critically, to prevent obstructions to the approach/departure surfaces.

Measuring Usage Intensities

The usage intensity or people-per-acre metric used for setting safety compatibility criteria in most compatibility plans (even plans which contain detailed lists of land use types generally have footnotes indicating intensity restrictions for various uses) is not common in other forms of land use planning. The discussion here provides guidance on how usage intensity can be interpreted and measured.

Determining Usage Intensities for Specific Land Uses

The adjacent tabulation lists average usage intensities for several types of nonresidential land uses often found or proposed in the vicinity of airports. Different methods are available by which ALUCs and local land use jurisdictions can estimate the usage intensity of other proposed uses. Each method has its advantages and disadvantages and none is clearly best in all situations. The most common methods are based on:

- Parking requirements as indicated in local parking ordinances;
- Maximum occupancy levels set in accordance with the California Building Code; and
- Surveys of similar uses.

Typical Usage Intensities (People Per Acre)

Light-industrial uses	35–50
Two-story motel	35–50
Shopping center (single story)	75–125
Single-story office structure	50–100
Sit-down restaurant	100
Fast food restaurant	150

Appendix C contains a brief assessment of each of these methods and examples of how usage intensities can be calculated.

Gross versus Net Acreage

Usage intensities can be calculated in terms of the entire site or zone, regardless of streets or parcel lines (its *gross acreage*) or the area of a given parcel (the *net acreage*). Because safety area land use restrictions are applied, at least initially, at a general plan or large development level rather than with respect to small, individual parcels, gross acreage measurements should normally be used for the purposes of safety compatibility criteria. The guidelines indicated in Table 9C are set on the basis of gross acreage averaged over an entire compatibility zone or development site. If net is substituted, the per-acre numeric limitations should be increased (typically 15% to 20%) to account for the acreage devoted streets, etc.

Nonresidential land use intensities (people per acre), as well as residential densities (dwelling units per acre), should both generally be calculated on the basis of gross acreage.

Except in the case of major thoroughfares running through runway protection zones and inner safety zones, the number of people in vehicles can generally be ignored in usage intensity calculations. Roads where traffic is frequently stopped in locations immediately beyond runway ends deserve attention. However, unless the road is newly planned, ALUCs are unlikely to have the opportunity to review these conditions.

Average versus Peak Usage Intensities

Limitations on the numbers of people per acre sometimes are stated as a never-to-exceed maximum and sometimes as an average measured over an

The intensity guidelines indicated in Table 9C are based upon the maximum number of people on the site at any time. If different measures are used, the numbers may need to be adjusted accordingly.

indicated period (typically 2, 8, or even 24 hours). A combination of the two also is possible (e.g., an average of *x* people per acre over an 8-hour period, not to exceed *2x* at any time).

It is recommended that restrictions be stated as a never-to-exceed maximum and the level be set accordingly. This is the same approach as that taken by fire codes for buildings. An averaging approach assumes that an accident will not occur when a higher-than-average number of people is present.

Clustering Versus Spreading of Development

Rarely is the usage intensity of a development spread equally throughout the site. Buildings, for example, normally will have more occupants than the adjacent parking lots. Also, for large developments, most of the buildings and other facilities are sometimes concentrated in one portion of the site, leaving other areas as open space because of terrain, environmental, or other considerations. The latter practice is often referred to as *clustering*. The issues for ALUCs are whether to place limits on clustering or to encourage the practice. Some of the tradeoffs between clustered and spread-out development are as follows.

- **Clustered Development**—The premise behind the concept of clustering is that, in a significant percentage of off-airport mishaps, the aircraft are under some degree of control when forced to land. (The reference here to mishaps is intentional—if a forced landing succeeds with no serious injuries or major damage to the aircraft, it would be categorized as an incident and thus not appear in accident records.) If the area remaining undeveloped is relatively level and free of large obstacles, clustering potentially allows a greater amount of open land toward which a pilot can aim. In addition to reducing the risks for people on the ground, open land provides benefits for aircraft occupants, as addressed later in this chapter. The disadvantage of clustering is that it allows an increased number of people to be in the potential impact area of an uncontrolled crash.
- **Spread-Out Development**—By comparison, a uniform spreading of development may provide fewer emergency landing spots and increase the chance of someone on the ground being injured. On the plus side, a uniform distribution of development limits the maximum number of people who could possibly be in an impact area.

The nonresidential intensity criteria listed in Table 9C indicate maximums both averaged over an entire site and for any single acre.

A compromise between these two strategies represents the optimum approach in most cases. This approach entails limiting the maximum occupancy level of a small area, but otherwise clustering development so as to provide the greatest amount of large open areas. For a small area (one acre is a good guideline), a limitation of two or three times the overall criterion is typical with the lower number applying in safety zones closest to the runway ends.

Uses in Structures versus Ones Not in Structures

Some compatibility plans make a distinction between the acceptable number of people per acre in land uses where people are *outdoors* versus those where the people are *in a building* or other enclosed area.

➤ **Outdoor Uses**—One theory is that people outdoors have more of a chance to see a plane coming as well as more directions in which they can move to vacate the impact area. A greater concentration of people thus is sometimes considered acceptable for such land uses. An important exception, however, is for open stadiums and other similar uses where a large number of people are confined in a small area with limited exits. Such facilities can represent equal or higher risks than similar uses in buildings.

Taking both of these factors into account, the suggested strategy is to set the acceptable number of people in a given area equal for uses either outdoors or in structures. Additionally, restrictions on stadiums and other open facilities occupied by large numbers of people are appropriate.

➤ **Uses in Buildings**—Buildings provide substantial protection from the crash of a small airplane, particularly when the aircraft is still under control as it descends. If a fire subsequently ensues—historically, a relatively infrequent occurrence—it is unlikely to engulf the entire building instantly.

Risk Reduction Though Building Design

Although avoidance of intensive uses is always preferable, a concept which may be acceptable in some situations is risk-reduction special building design. This concept should be limited to airports which are situated in highly urbanized locations and are used predominantly by small aircraft. In these circumstances, consideration might be given to allowing higher numbers of people (no more than 1.5 to 2.0 times the basic intensity) in buildings which incorporate special risk-reduction construction features such as:

- Concrete walls;
- Limited number and size of windows;
- Upgraded roof strength;
- No skylights;
- Enhanced fire sprinkler system;
- Single-story height; and/or
- Increased number of emergency exits.

ADDITIONAL SAFETY COMPATIBILITY CONCERNS

The preceding discussion primarily addresses risks which aircraft accidents pose for people and property on the ground. The responses to these risks are all concerned with limiting the consequences of accidents when they take place near airports. As indicated in the summary at the beginning of this chapter, a separate set of safety compatibility concerns involve land use characteristics which can cause an aircraft accident or contribute to its consequences for people on board the aircraft. The following sections address two such concerns: minimizing injury to aircraft occupants; and hazards to flight.

Minimizing Injury to Aircraft Occupants

As noted at the beginning of this chapter, many aircraft accidents as well as lesser incidents involve aircraft which are under control as they descend and the pilots have some discretion as to where to attempt an emergency landing. Especially for small aircraft, the chances of the aircraft occupants

Although terrain is a critical factor in the survivability of emergency landings, it is not a factor over which ALUCs have any influence. At airports in mountainous or densely forested locations, little open land useful for an emergency landing may exist even if no development is present. For such airports, policies to preserve open land may be pointless. The discussion here is thus directed at airports in flat or moderately hilly terrain.

avoiding serious or fatal injury in such situations is significantly affected by the terrain and land use features at the landing site. Preserving some amount of near-airport open land capable of enabling a survivable emergency landing is therefore a desirable safety compatibility objective.

Characteristics of Open Land

Ideal emergency landing sites are ones which are long, level, and free of obstacles, much like a runway. Certainly, the closer that open land areas around airports can fit these criteria the better. For small aircraft, however, successful (meaning survivable irrespective of the damage to the aircraft) emergency landings can be accomplished in much less space. Data from the general aviation aircraft accident database indicates that the median swath length for accidents in which the aircraft was under at least some control is less than 150 feet (see Table 8D).

As a general guideline, open land sites should be at least 300 feet long by 75 feet wide (about 0.5 acre or the size of a football field) to be considered useful. Such sites should be relatively level and free of objects such as structures, overhead lines, and large trees and poles that can send the plane out of control at the last moment. Parking lots, while not ideal, also can be considered as acceptable open lands in urbanized settings.

Guidelines for Extent of Open Land Near Airports

Determining the desirable number of open land sites or the percentage of open land in an airport vicinity is a complex proposition. To assist in this decision, the following three observations are offered:

- The accident location patterns illustrated in Chapter 8 and the data presented in Table 8C reveal that accidents in which aircraft are under control are bunched relatively close to the runway ends—mostly within about 3,000 feet—both for arrivals and departures.
- The number of takeoff accident sites located a short distance laterally from the departure (climb-out) end of the runway may indicate that pilots have either headed for an open spot in that location or have attempted to turn around and land on the runway from the opposite direction, but not quite succeeded.
- A pilot's discretion in selecting an emergency landing site is reduced when the aircraft is at low altitude. Particularly at low altitude, the chance of a pilot seeing and successfully landing in a small open area is increased if there are more such spots from which to choose. At traffic pattern altitude (800 to 1,000 feet above the runway), a small airplane should, in the event of engine failure, normally be able to reach the runway from anywhere within the pattern. On takeoff, a small plane generally must have reached an altitude of at least 400 to 500 feet above the runway for a return to the runway to be possible following engine failure.

Each of these observations speaks to the need for preserving more and preferably larger open areas in locations near runways than in other portions of airport environs. On this basis, the following guidelines are suggested.

➤ **Runway Protection Zones**—Maintain all undeveloped land clear of objects in accordance with FAA standards.

➤ **Inner Approach/Departure Zones**—Seek to preserve 25% to 30% of the overall zone as usable open land. Particular emphasis should be given to preserving as much open land as possible in locations close to the extended runway centerline.

➤ **Inner Turning Zone**—At least 15% to 20% of the zone should remain as open land.

➤ **Outer Approach/Departure Zones**—Maintain approximately 15% to 20% open land within the overall zone, again with emphasis on areas along the extended runway centerline.

➤ **Sideline Zone**—Adjacent to the runway ends and runway protection zones, 25% to 30% usable open land is a desirable objective.

➤ **Traffic Pattern Zone**—Elsewhere within the airport environment, approximately 10% usable open land or an open area approximately every ¼ to ½ mile should be provided.

Open land areas need to meet minimum size criteria to be of value. Therefore, the above guidelines are only practical when applied with respect to land use patterns proposed in general plans, specific plans, or large developments (generally 20 acres or more), not to individual smaller parcels. Both public and private lands should be counted. If the indicated amount of open land can be provided totally on public property, individual private parcels may not need to have any.

One final factor to consider is the pattern of the existing land uses in the airport vicinity. In rural, agricultural areas, requirements for preserving open land can usually be met with little restriction on the prevailing land use form. However, in urban locations, if open land is defined to mean *no development* of private property, the potential for inverse condemnation must be recognized. To avoid this prospect, the property must be allowed to have an economically viable use. In urban areas, open land is generally only a viable land use designation if the property is in public ownership or its natural environmental constraints make development infeasible or inappropriate. If no development is the desired end, the airport proprietor may need to acquire the property or at least the development rights.

See the discussion of inverse condemnation in Chapter 3.

Hazards to Flight

Unlike the preceding land use characteristics which can only affect the *severity* of an aircraft accident (for better or worse), hazards to flight can be the *cause* of an accident. Hazards to flight fall into three basic categories:

- Obstructions to the airspace required for flight to, from, and around an airport;
- Wildlife hazards, particularly bird strikes; and

See the Safety Policy Foundations section earlier in this chapter for a summary of established federal regulations regarding these types of hazards.

- Other forms of interference with safe flight, navigation, or communication.

Airspace Obstructions

Figure 9M depicts an example of Part 77 surfaces for an airport with a precision instrument approach runway.

Limiting the heights of structures to the heights indicated by the Part 77 surfaces provides an ample margin of safety for normal aircraft operations. The guidance provided by Part 77 is not absolute, however. Deviation from the Part 77 standards does not necessarily mean that a safety hazard exists, only that offending objects must be evaluated by the Federal Aviation Administration and that mitigative actions such as marking or lighting be taken if appropriate.

The airspace surfaces defined by TERPS are typically complex and not easily mapped. Nevertheless, compatibility plans would benefit by including this information if possible. At a minimum, the plans should note the general locations where TERPS surfaces may be critical. ALUCs should request FAA analysis of tall objects proposed for construction in these areas.

In some locations, such as adjacent to a runway, objects exceeding the Part 77 height limits may not be regarded as a hazard. On the other hand, tall objects in the approach corridors—especially along instrument approach routes—may pose risks even though they do not penetrate the defined Part 77 surfaces. Such objects also can adversely affect the minimum instrument approach altitudes allowed in accordance with the U.S. Standard for Terminal Instrument Procedures (TERPS). TERPS is particularly likely to be more restrictive than Part 77 when:

- The approach is not aligned with a runway;
- The procedure includes a circle-to-land option with low minimums;
- The missed approach segment has a low minimum altitude and requires a turning movement; and/or
- High terrain is present beneath portions of the approach procedure which lie beyond the limits of the Part 77 surfaces.

Wildlife Hazards

Both the Federal Aviation Administration (contact the Airport Safety & Certification Branch, AAS-317, at the FAA's Washington Headquarters) and the U.S. Department of Agriculture's Wildlife Service (an office is located in Sacramento) have staff who specialize in managing wildlife hazards at airports. State and local resource agencies may also be able to contribute expertise in managing specific species. The principal concern of ALUCs, though, is with regard to proposed land uses which can increase attraction of birds and other wildlife hazardous to aircraft operations.

Birds are the most common wildlife hazard near airports. Both migratory and nonmigratory species may be of concern. Although the risk of bird strikes is most serious along the corridors required for takeoffs and landings, the concern extends to elsewhere in the airport vicinity. Any land uses which can attract birds should be avoided, but those which are artificial attractors are particularly inappropriate because they generally need not be located near airports. Sanitary landfills are a primary example of the latter type of activity. The FAA recommends that such uses be kept at least 10,000 feet from any runway used by turbine-powered aircraft.

Other land uses that may become artificial attractors include:

- Golf courses with water hazards;
- Drainage detention and retention basins;
- Wetlands created as mitigation measures;
- Landscaping, particularly water features;
- Wildlife refuges; and
- Agriculture, especially cereal grains.

Wildlife other than birds can be also be a concern, depending upon an airport's geographic setting and surrounding land uses. Deer are the most

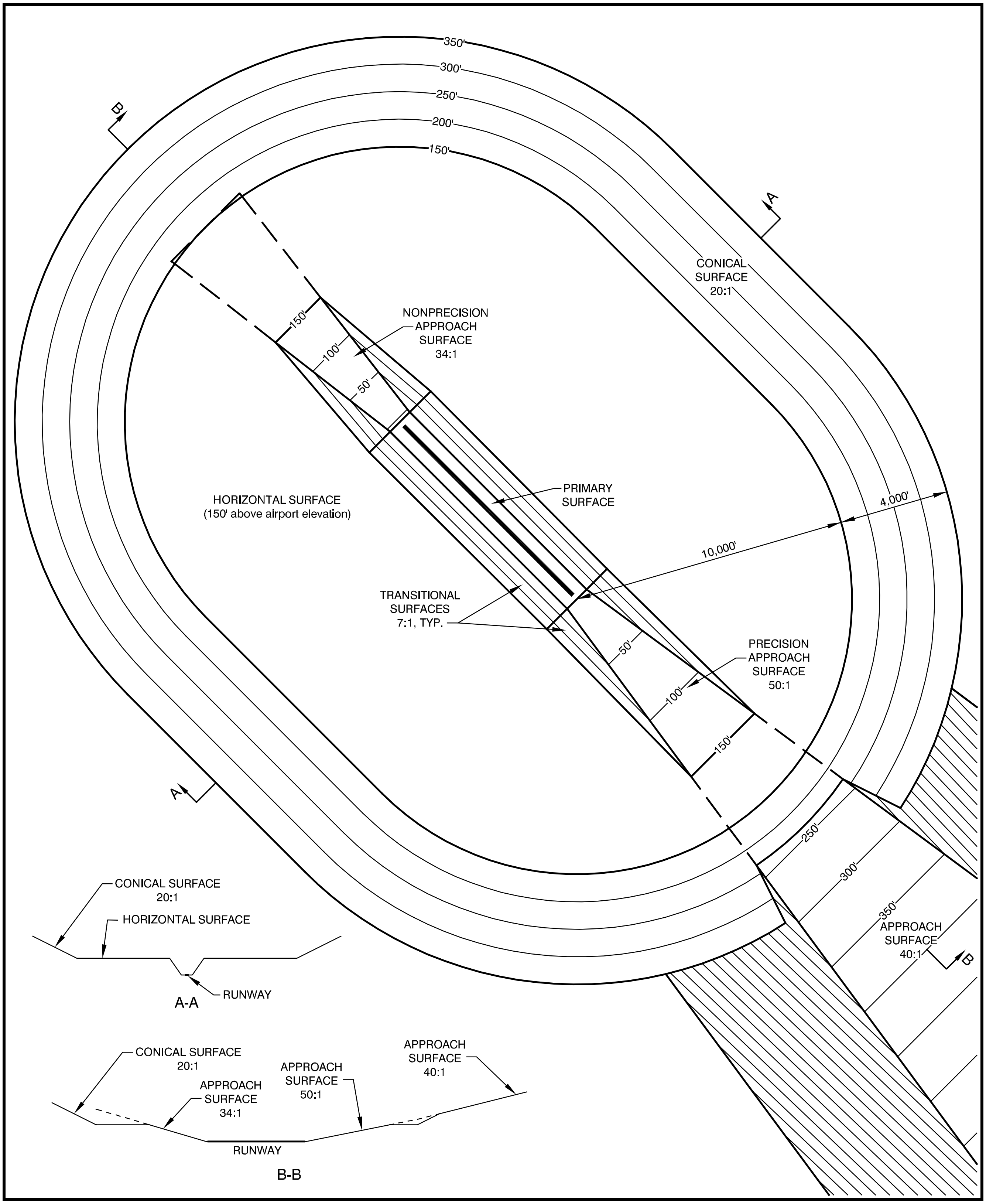


FIGURE 9M

Example of Airspace Protection Surfaces

FAR Part 77

common problem. However, coyotes and other species may also become hazards.

Other Flight Hazards

In addition to the physical hazards to flight posed by tall objects and wildlife, other land use characteristics can present visual or electronic hazards.

- **Visual Hazards**—Visual hazards include distracting lights (particularly lights which can be confused with airfield lights), glare, and sources of smoke.
- **Electronic Hazards**—Electronic hazards include any uses which interfere with aircraft instruments or radio communication.

Questions have arisen from some airports and ALUCs as to whether temporary searchlights such as those used for advertising constitute a hazard to flight. The FAA does not regulate the siting or operation of searchlights and is aware of no significant problems associated with them.

There are no specific FAA standards for visual and electronic hazards. Potential hazards are evaluated on a case-by-case basis. This often occurs only after a problem has arisen. However, ALUCs can request an FAA evaluation of proposed development when certain features appear to be potentially hazardous. Also, ALUC policies should require that outdoor lights are shielded so that they do not aim above the horizon. Additionally, for projects near the airport, outdoor lighting should be flight checked at night to ensure that they do not blind pilots during landings and takeoffs.