

Appendix E

Aircraft Accident Data

Location Patterns

For airport land use compatibility planning purposes, the most essential information to have about aircraft accidents is data showing where accidents have historically occurred around airport runways. For general aviation aircraft accidents, the most comprehensive database currently available is the one compiled for the *California Airport Land Use Planning Handbook* published in 2002 by the California Division of Aeronautics. This database contains data on nearly 900 accidents that took place within 5 miles of an airport, but not on the runway itself. The data is from accidents nationwide and covers the 10 years from 1983 to 1992, though not all accidents during this period are included.



Historic accident distribution contours were georeferenced and overlaid on this community airport's runway end using GIS. Data Source California Airport Land Use Planning Handbook, 2002

Figures E-1 and E-2 depict the geographic distribution of arrival and departure accidents relative to the end of the runway that was used or intended to be used. These figures show all the accidents in the database. The California handbook also presents a variety of subset of this data—the distributions for runways of different lengths, for example.

Along with the accident location points, the two figures also show a set of risk contours. The purpose of these contours is to indicate the relative concentration of the accident points. The contours simply divide the data points into five equal groups. The innermost contour indicates the shape that encompasses 20 percent of the points in the least possible area. The remaining contours contain 40, 60, and 80 percent of the points, with the balance of the points lying beyond the 80 percent contour.

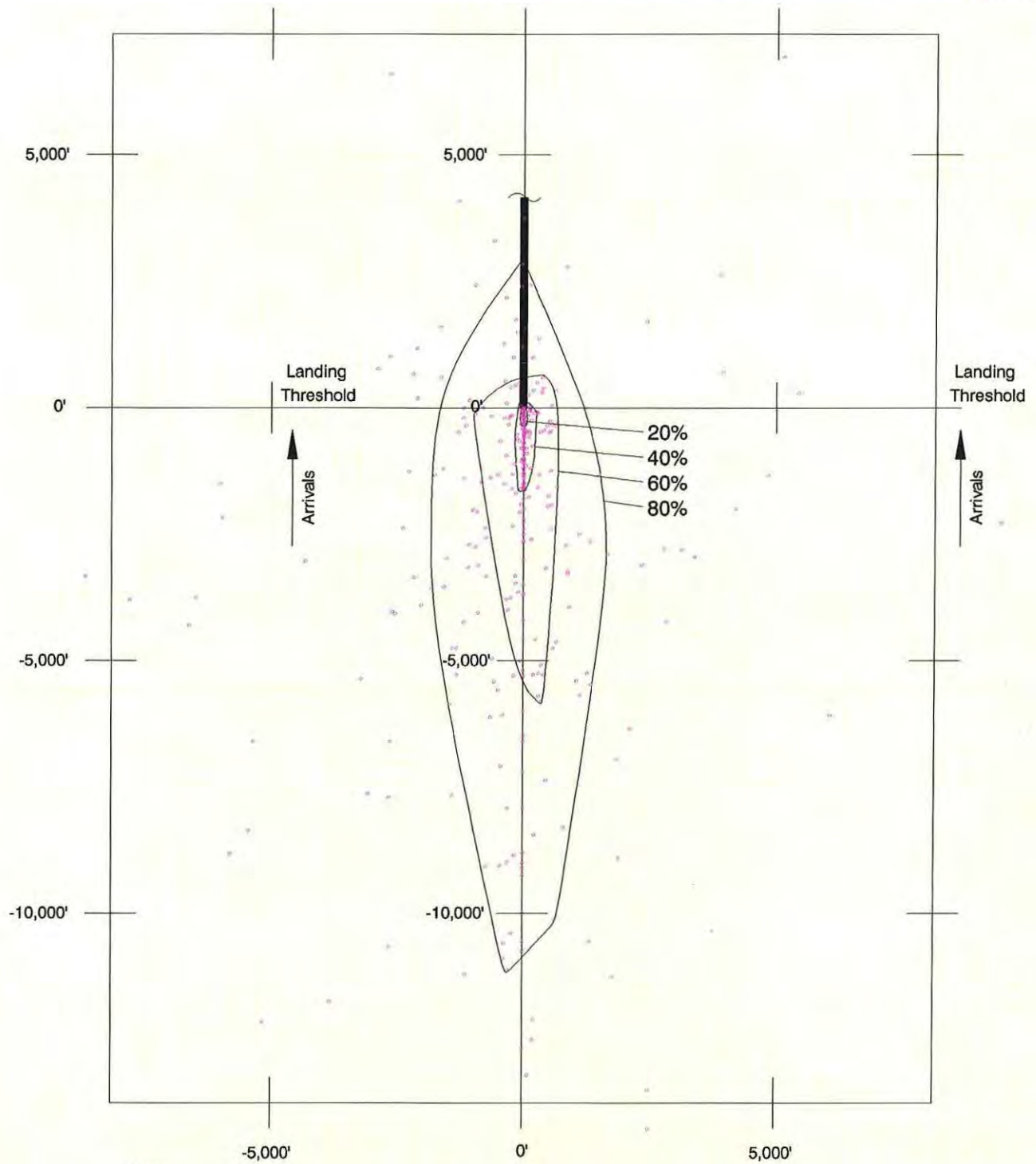
Critical Concept

Historic accident locations apply to both runway ends since accidents can occur at either.

Among the key findings apparent from the data are these:

- About half of arrival accidents and a third of departure accidents take place within the FAA-defined runway protection zone for a runway with a low-visibility instrument approach procedure (a 2,500-foot-long trapezoid, varying from 1,000 feet wide at the inner edge to 1,750 feet in width at the outer end). This fact lends validity to the importance of the runway protection zones as an area within which land use activities should be minimal.
- Although the runway protection zones represent the locations within which risk levels are highest, a significant degree of risk exists well beyond the runway protection zone boundaries. Among all near-airport accidents, over 80 percent are concentrated within 1.5 to 2.0 miles of a runway end.
- Arrival accidents tend to be concentrated relatively close to the extended runway centerline. Some 80 percent occur within a strip extending 10,000 feet from the runway landing threshold and 2,000 feet to each side of the runway centerline.

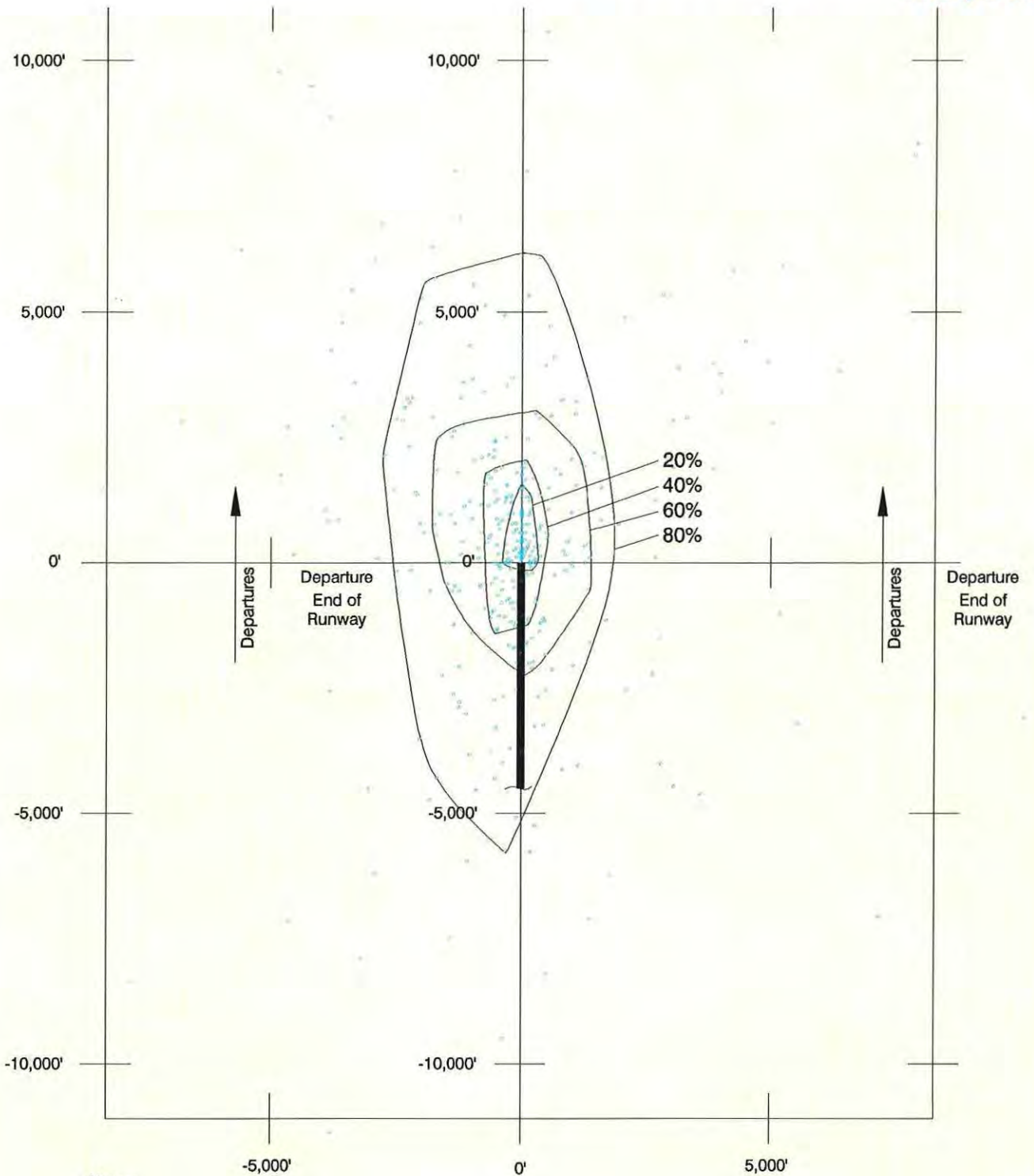
Figure E-1
General Aviation Accident Distribution Contours
All Arrivals



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

Source: California Airport Land Use Planning Handbook (2002)

Figure E-2
General Aviation Accident Distribution Contours
All Departures



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

Source: California Airport Land Use Planning Handbook (2002)

- Departure accidents are comparatively more dispersed laterally from the runway centerline, but are concentrated closer to the runway end. Many departure accidents also occur lateral to the runway itself, particularly when the runway is long. Approximately 80 percent of the departure accident sites lie within an area 2,500 from the runway centerline and 6,000 feet beyond the runway end or adjacent to the runway.
- Runway length affects the distribution pattern of accidents. Arrival and departure accident locations tend to be clustered closer to the runway ends of short runways than is the case with longer runways.

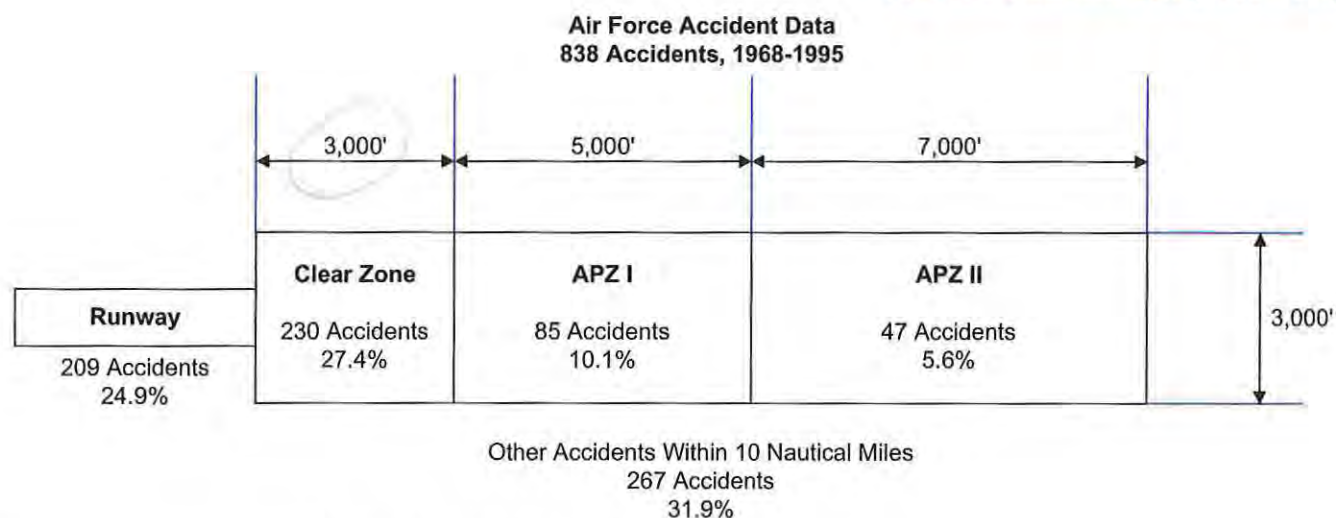
For more detail, see Appendices E and F of the *California Airport Land Use Planning Handbook* (2002) available at: www.dot.ca.gov/hq/planning/aeronaut/documents/alup/ct%20alup%20appendix%20e.pdf and www.dot.ca.gov/hq/planning/aeronaut/documents/alup/ct%20alup%20appendix%20f.pdf

The FAA has summarized similar data for commercial aircraft operations. The database, though, is limited in size and has not been updated to include accidents that have taken place over the last 20 years. As Figure E-3 shows, all of the accidents represented are located within 2 miles of the runway end. The arrival accident sites are heavily concentrated along the extended runway centerline, while the departure accident sites are comparatively more scattered. The pattern is similar to that for general aviation accidents, particularly those associated with long (6,000 feet or more) runways.

The DOD data on military aircraft accident locations is presented in a more summarized format as illustrated in Figure E-3.

The database represents 838 Air Force aircraft accidents over a 28-year period ending in 1995. Equivalent data for Navy and Marine aircraft is not available. The diagram indicates the percentages of accidents on the runway and within distinct zones near the runway ends. As with general aviation and commercial aircraft accidents, the highest concentrations are close to a runway end. Excluding the accidents on the runway itself, a 3,000-foot by 3,000-foot area accounts for 36 percent of the accidents within 10 nautical miles of the runway. Approximately 57 percent of the off-runway accidents have historically occurred within a 3,000-foot-wide strip extending 15,000 feet from a runway. The remainder have taken place farther away including an unknown percentage that can be considered en route accidents beyond the 10-nautical-mile distance from a runway.

Figure E-3
Air Force Accident Data (1968–1995)



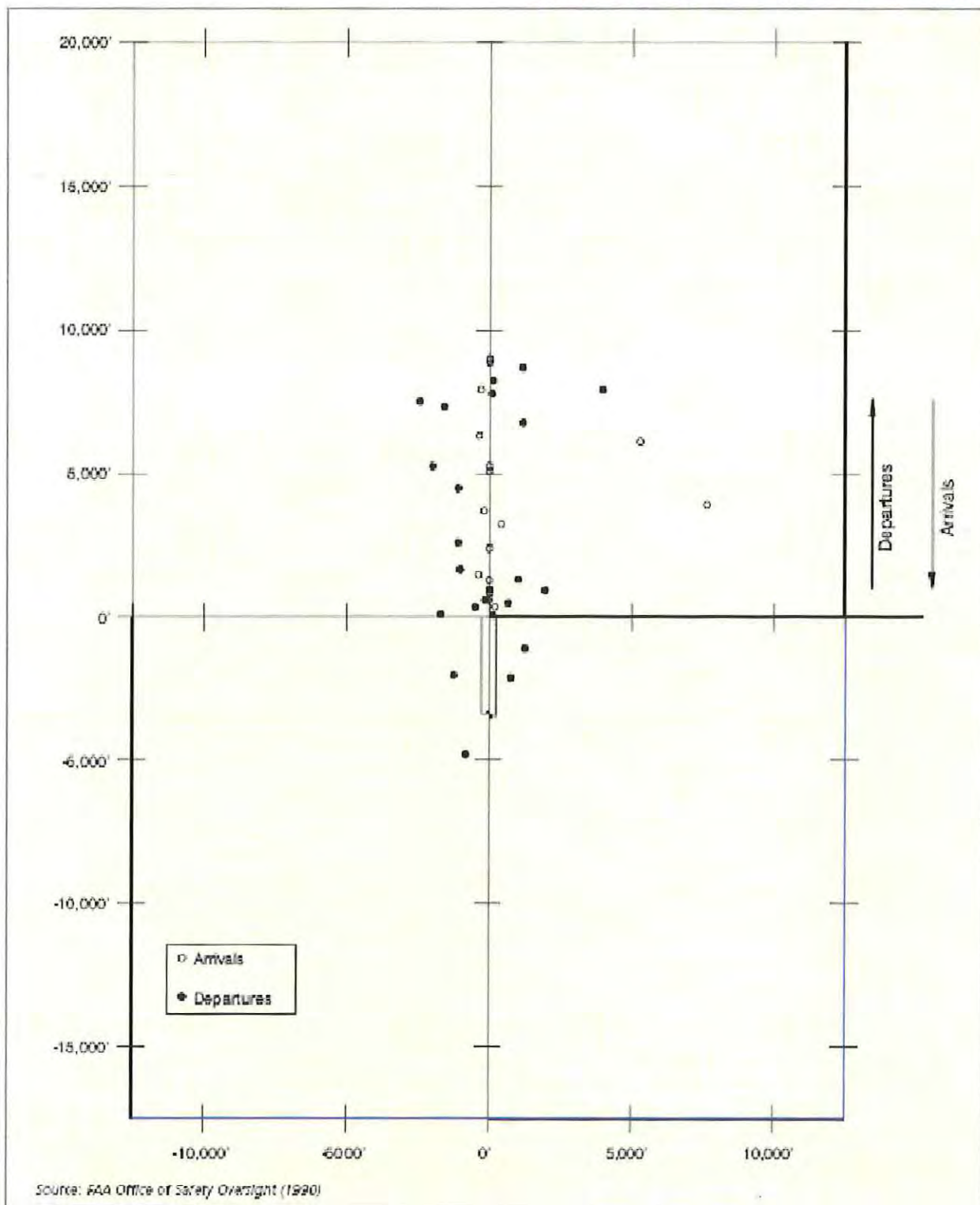
Source: AICUZ Program Manager's Guide. Air Force Handbook 32-7084 (March 1999)

Other Characteristics of Aircraft Accidents

A variety of other data regarding the characteristics of aircraft accidents is available in the California handbook and from Federal Aviation Administration and National Transportation Safety Board (NTSB) websites. A few pieces of information of value to airport land use compatibility planning are summarized below.

- **Aircraft Types** – The type of aircraft operated at an airport or on an individual runway at a multi-runway airport is an important compatibility planning consideration. Large, heavy aircraft, especially jets, have the potential to cause major destruction on the ground if an accident occurs. However, all of the aircraft operated by airlines, as well as most business jets operated by corporations, are flown by professional pilots and are maintained at high standards that significantly reduce the frequency of accidents compared to small, private airplanes. On the other hand, these small planes generally produce much less damage on the ground when accidents happen. From a land use compatibility perspective, these differences somewhat balance each other out and other factors—particularly where the accidents occur—become the dominant planning considerations.
- **Relative Frequency of Arrival Versus Departure Accidents** – On the whole, more aircraft accidents occur during the approach/landing phase of operation than during the takeoff/departure phase. However, many landing accidents take place on or immediately adjacent to the runway. Among off-runway, near airport accidents, arrival and departure accidents happen in about equal numbers. This is explicitly true for general aviation, but the more limited data for air carrier accidents suggests it is true for them as well.
- **Controlled versus Uncontrolled Accidents** – In planning for land use compatibility near airports, consideration must be given to the two different forms of aircraft accidents: those in which the aircraft is descending, but is flying and under directional control of the pilot; and those in which the aircraft is out of control as it falls. Available data indicates that a substantial percentage, if not the majority, of general aviation aircraft accidents fall into the former category. Moreover, these data do not include the incidents in which the pilot made a successful emergency landing.
- **Accident Swath** – Swath size is another useful piece of information, especially with respect to planning around general aviation airports. It indicates the area over which accident debris is spread. Swath size in turn depends upon the type of aircraft and the nature of the accident: was the aircraft in controlled flight (an engine failure for example), but then collided with something on the ground or did a catastrophic event (such as a mid-air collision or stall-spin) result in the aircraft making an uncontrolled descent? For small general aviation aircraft, the swath size data suggests that a controlled emergency landing in which the aircraft occupants have a strong chance of surviving is possible in an area about the size of a football field: 75 feet by 300 feet or about 0.5 acre. For larger aircraft, the minimum flight speed is so much higher that the consequences for people on board and anyone in the path on the ground are likely to be severe regardless of the land use or terrain characteristics.

Figure E-4
Commercial Aircraft Accident Location Pattern



Risk Concepts

Central to the task of addressing the safety aspects of airport land use compatibility is the concept of risk. Locations near airport runways are exposed to a greater risk of being involved in an aircraft accident than sites farther away. As development increase the number of structures and people on the ground exposed to risk increases. The question is: how much and what type of development is reasonable? To put it another way: what level of risk is acceptable?

There is no easy answer to these questions; no formula into which all the data can be inserted and a set of safety zones and criteria will result. While the probability of an aircraft accident occurring near an airport can be calculated—see the discussion in the following sections—the real issue is what the response to that risk should be. This aspect of risk is not quantifiable.

It is beyond the scope of this Guidebook to provide a comprehensive discussion of risk concepts. Nevertheless, several points are important to highlight.

 A more in-depth review of can be found in the *California Airport Land Use Planning Handbook* (2002) available at: www.dot.ca.gov/hq/planning/aeronaut/landuse.html

Judging Risk Acceptability

The risk of something negative resulting from an otherwise desirable activity can be measured in terms of two variables:

- The anticipated frequency of the negative event occurring.
- The potential consequences associated with the event's occurrence.

Frequency is calculated in terms of the number of events within a specific time period and location. Consequences can be physical or financial. Physical consequences can be measured in various ways depending on the nature of the event: injuries, fatalities, lost productivity, property damage, etc.

The combination of these two variables can then be used to judge whether the risk is:

- Negligible or acceptable risk (no action is necessary to reduce or protect against the risk).
- Significant, but tolerable risk (the cost of reducing or protecting against the risk must be weighed against the benefits to be gained).
- Intolerable risk (the risk cannot be justified except in extraordinary circumstances).

Intolerable risks are usually associated with events that have both high likelihood of occurrence and high consequences. Significant risks can result from events that have high frequency or high consequences or moderate levels of both, but not high levels of both. The table below illustrates the relationship between the two variables and the overall level of risk.

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

In this chart, aircraft accidents can be considered to fall into the range of rare to extraordinary frequency. To hold the risks to an acceptable level therefore means that actions should be taken to avoid potential consequences that are disastrous or, where accidents are comparatively common, severe. The question to be answered thus becomes: what land use actions are appropriate in response to a significant risk?

Cost of Risk Response

One means of answering this question is to consider not just the risk itself, but the cost of the response. Risks that are deemed intolerable warrant a response almost irrespective of the cost. An acceptable risk on the other hand generally needs no specific action. It is in the middle range of risks—those that are merely tolerable—that costs become important. While avoidance of the risk may be desirable, society has limited resources for addressing risks and priorities often must be set. Risks that fall toward the intolerable end of the spectrum may warrant a response unless the cost is very high; whereas, if the risk is close to being acceptable, action may be appropriate only if the cost is relatively minimal.

When considering this issue in the context of aircraft accidents, two key variables are apparent.

- **Existing Versus Proposed Uses** – One clear distinction is that the cost of reducing or limiting risks is usually greater where development already exists than where land is undeveloped. The cost of removing an incompatible development is greater than the cost of avoiding its construction in the first place. An implication of this point is that allowing an existing incompatible use to remain may be considered tolerable, but permitting a similar new use may be unacceptable.
- **Urban Versus Rural Areas** – A second difference is between urban and rural environments. In urban locations, land values and other development costs typically are higher than in rural areas. The cost—represented by lost opportunity—of limiting development to what might, if not for airport compatibility concerns, otherwise be the land’s highest and best use is thus typically greater in urban areas. Also a factor is that, in urban areas, there are often fewer options as to where land uses that are needed in the community can be placed. Less than ideal location choices consequently may be the best choices. Land uses that may not be entirely compatible with each other may nevertheless be considered as acceptable neighbors. People living in urban areas usually consider these risks as reasonable tradeoffs for the benefits that cities also provide. For these reasons, a particular use may be acceptable near an urban airport, but be inappropriate in an identical location near a rural airport.

Risk Perceptions

Another factor that greatly affects the response to risk is how the risk is perceived. This factor accounts for why two different risks that have very similar likelihood of occurrence and potential consequences may produce very different responses. Public response to a risk is usually driven more by the perception of the risk than by the actual risk based on historical experience or mathematical calculations.

A related factor is perspective—that is, who benefits from the activity and who bears the risk? Risks that may be acceptable to society as a whole, may not be acceptable to an individual or vice versa.

Some of the key variables that affect risk perception are listed in the tabulation below. Also noted is where aircraft accident risks fit with regard to these variables. When looked at in this manner, it is difficult to think of any other types of risks that are highly comparable to those posed to people and property on the ground by the threat of aircraft accidents. To be comparable to aircraft accident risks, not only must the likelihood of occurrence be similarly low, but the character of the risks must be qualitatively similar.

Risk Perceptions	
<i>A risk is perceived to be higher if:</i>	<i>Aircraft accidents are perceived as:</i>
The general public has limited understanding of how the technology or system operates	Involving a form of transportation that is not well understood by most people because they don't fly airplanes
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)	Not well understood—and even if experts may eventually ascertain the cause of an accident, the public may not see or understand the conclusions
The possible consequences of the hazard evoke feelings of dread, especially concerns about death	Giving no advance warning (and people don't tend to look upward for potential danger)
The possible consequences seem unbounded (in magnitude or persistence over time) or are believed to be potentially catastrophic	Including consequences which are unpredictable and potentially catastrophic
The activity is not under one's own control (the risks are not affected by one's own skills)	Not controllable as a function of the individual's skills
The risk exposure is not on a voluntary basis (the exposure cannot readily be reduced by changes in one's lifestyle)	Not voluntary except to the extent that people choose to live near an airport
The hazard is unnatural (not an act of nature)	Not an act of nature
The potential personal or societal benefits to be gained from the activity involved appear to be minimal or nonexistent	Involving an activity (flying) that provides little or no benefit to the people and property owners on the ground who bear the risk
The distribution of risks and benefits among groups or geographically is inequitable	Placing the cost of mitigating the risk on owners of property near the airport
The groups at risk include children, elderly, the infirm, or others regarded as having comparatively little control over their own lives	Placing greater risk on these groups because they would have greater difficulty getting away from the site of an aircraft accident
Highly negative imagery about the technology or system is widespread in the media (especially pictures on television and in newspapers)	Often worthy of nationwide media coverage

Also evident is that for all of the variables listed, aircraft accidents fall at the end of the spectrum that causes the perception of the risk to be greater than the mathematical risk. Even though the frequency of aircraft accidents is low, people focus on the consequences as they have historically occurred and potentially could happen again. For these reasons, a stronger response can be justified for aircraft accident risks than might be warranted for other accident risks.

Establishing Safety Compatibility Policies

Safety Zones

The discussion in this appendix focuses on aircraft accidents and how this data should be used in addressing the safety compatibility of new development around airports. On this basis, we call the zones described here “safety zones.” However, for Washington airports noise, airspace protection, vibration, odors, annoyance, and other impacts of regular aircraft overflights, can be folded into the safety zones to create composite “compatibility zones” and a composite set of compatibility criteria created to match.

Critical Concept

When considering the locations of aircraft accidents relative to the typical traffic patterns at the airport, it is important to recognize that where aircraft normally fly may not be where they fly under emergency conditions. Aircraft accidents often occur in locations that might not be expected merely from examination of flight tracks.

While the risk contours described above are helpful as means of portraying the geographic pattern of aircraft accident risks near an airport, they are difficult to directly use 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 that results from the modest size of the database. Also a consideration is that the irregular shapes do not specifically reflect the different phases of aircraft flight around and airport and the different risk characteristics associated with each phase.

More useful for compatibility planning purposes is to define a set of safety zones based upon the accident location distribution data and risk contours, but having regular geometric shapes. Diagrammed below is a set of six zones originally recommended in the California handbook and utilized in Washington and other states. These zones were defined using the nationwide database of general aviation aircraft accidents described earlier (see Figure E-5).

The California handbook recommends variations on the zones to take into account different runway lengths, types of approach procedures, traffic pattern location, and other factors. As shown in the following diagrams, the suggested zones are larger for longer runways that accommodate larger, faster aircraft than for short runways used only by light aircraft. The same basic shapes and characteristics of the zones apply, however. The six zones can be characterized as follows:

- **Zone 1 – Runway Protection Zone** – This zone encompasses the runway protection zone (RPZ) at each end of the runway and should use the RPZ dimensions established in accordance with FAA standards (RPZ dimensions depend mostly on the visibility minimums for the approach to that runway end). Also included in the zone are the strips of land immediately adjacent to the runway where FAA standards preclude structures. Zone 1 is where the greatest concentration of accidents take place.

- **Zone 2 – Inner Approach/Departure Zone** – This zone wraps around and extends beyond Zone 1 along the runway centerline. Next to the RPZ, it represents the area where the risk of aircraft accidents is the greatest. On departure, aircraft are typically at full power in the initial phase of climb. On approach, they are at low altitude as they prepare for landing.
- **Zone 3 – Inner Turning Zone** – This zone is a wedge-shaped area lying along the sides of Zone 2. It is primarily significant at general aviation airports where most of the flights are visual. At airports where most aircraft approach and depart on instrument flight plans, then the close-in turns which are the concern with Zone 3 can be a narrow wedge. When operating visually, departing aircraft may begin turning over this area to fly toward their destination or to remain in the traffic pattern. Arriving aircraft often overfly this area as well, especially if they are flying a tight pattern. One type of accident known to occur in this area is a low-altitude stall-spin that can happen if a pilot attempts to make too tight of a turn.
- **Zone 4 – Outer Approach/Departure Zone** – This area lies beyond Zone 3 along the extended runway centerline. Aircraft flying straight out or in overfly this area at low-altitude. The zone is particularly significant on runways where much of the operations are on instrument procedures and at busy airports where elongated traffic patterns are common. The risks in this area are moderate, but less than in Zones 1 through 3.
- **Zone 5 – Sideline Zone** – Lying in narrow bands along each side of the runway, aircraft do not normally fly over the sideline zone. The principal risk is from aircraft that lose directional control while landing or just after takeoff. The risks are lower than in Zones 1 through 3 and similar to those of Zone 5.
- **Zone 6 – Traffic Pattern Zone** – The final zone contains the remainder of the airport environment where aircraft fly as they approach and depart the airport or are engaged in flight training. In area, Zone 6 is typically larger than the other zones combined. A substantial percentage of accidents take place here, but they are scattered over the large area.

Each airport is unique. Thus, it is essential to adjust safety zones to fit the airfield configuration, usage characteristics, and other factors associated with a specific airport. Adjusting for runway length is the first step. Additionally, adjustments for approach type, fleet mix, traffic pattern location, etc., may be appropriate for individual runways. For example, adjustments could be considered for runways having displaced landing thresholds, particularly if most landings are made at that end of the runway and few takeoffs come toward that end. Runways having traffic patterns only on one side may dictate some adjustment to Zone 3. Regular use of a runway by special-purpose airplanes such as agricultural, fire attack, and military or by helicopters also may warrant consideration.

Beyond these types of adjustments, reliance on nationwide rather than airport-specific accident data is essential. Because aircraft accidents are infrequent occurrences, the pattern of accidents at anyone airport cannot be used to predict where future accidents are most likely to happen around that particular airport.

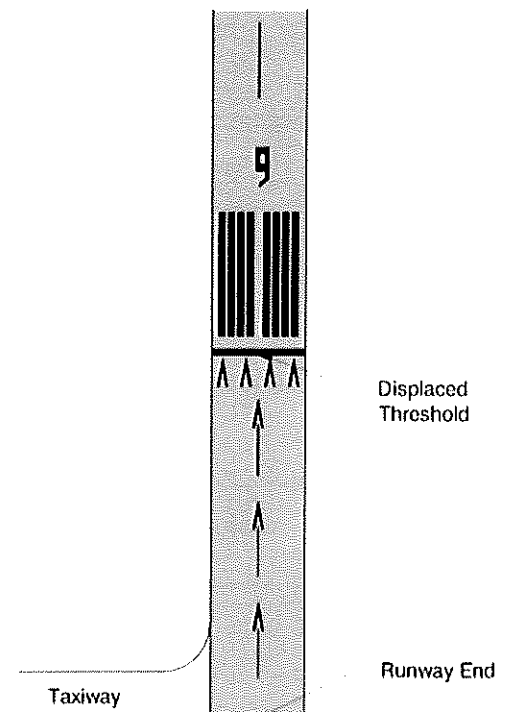
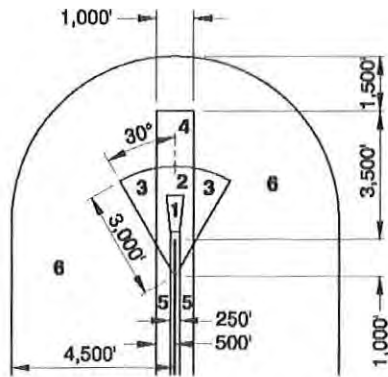
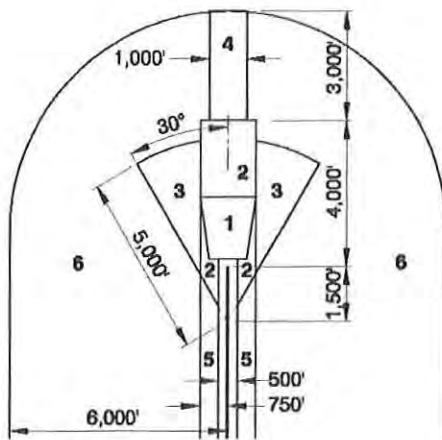


Figure E-5
Safety Compatibility Zone Examples
General Aviation Runway



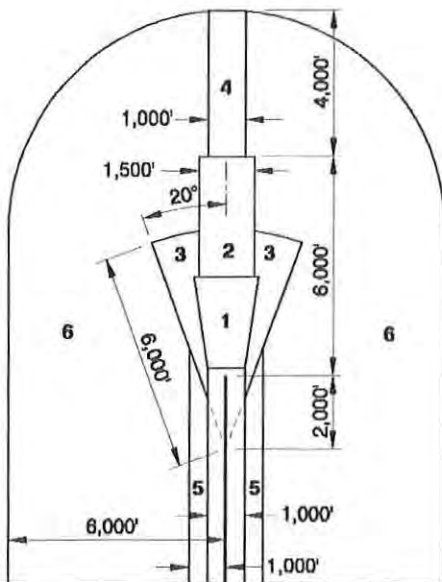
**Example 1:
Short General Aviation Runway**

- Assumptions:
- Length less than 4,000 feet
 - Approach visibility minimums \geq 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 \geq 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'

Source: California Airport Land Use Planning Handbook (2002)

Safety Criteria

The second half of the process of establishing safety policies is to decide upon the criteria that should apply within each of the zones you have delineated. Even more than for the mapping of the zones, there are no absolute rules here, only general guidance. Ultimately, the decision comes back to the issue of acceptable risk.

Several types of land use characteristics are particular concerns with regard to safety compatibility. Criteria should be written to address each of these.

- **High-Intensity Uses** – Given that the potential for injury or death to people on the ground is usually considered the greatest potential land-use-related consequence that could result from aircraft accidents, then limiting the number of people in harm’s way is the foremost safety compatibility objective. Typically, the limit is defined in terms of a maximum acceptable number of people per acre of a project site and referred to as a “usage intensity” limit. Deciding upon a specific limit for each safety zone can be challenging, so you may want to instead emphasize land use types. See Chapter 3 for guidance on what land use types are compatible or incompatible with the airport.
- While the criteria outlined here are all safety related, creation of a combined set of criteria that also considers noise, airspace protection, vibration, odors, and other impacts of regular aircraft overflights is highly encouraged.
- **Residential Uses** – Residential development is usually described in terms of density—the number of dwelling units per acre—rather than intensity or people per acre. Mathematically, a relationship can be drawn between the two by knowing the average number of persons per household. For safety compatibility purposes, however, residential density limitations should not be equated to the usage intensity limitations for nonresidential uses. Society tends to seek a higher degree of protection for people’s homes than for most other types of land uses. On this basis, restricting residential development to a density lower than the equivalent nonresidential intensity limit is desirable. Better yet, because of noise and overflight impacts, the best choice is to not introduce new residential development in the approach safety zones (Zones 1 through 5) except perhaps if the densities are very low (less than 1 unit per 5 acres).
 - **Uses Having Vulnerable Occupants** – These uses are those in which the majority of occupants are children, elderly, and/or disabled—people who have reduced effective mobility or may be unable to respond to emergency situations and get out of harm’s way. Primary uses in this category include: children’s schools (grades K–12); day care centers; hospitals and other health care facilities, especially where anesthesia is used during operations or patients remain overnight; and nursing homes.
 - **Hazardous Materials Storage** – Aboveground storage of large quantities of hazardous materials (flammable, explosive, corrosive, or toxic) poses special concerns to the extent that an aircraft accident could cause release of the materials and thereby pose dangers to people and property in the vicinity. Avoidance of such uses or ensuring that the facilities are adequately protected against the consequences of an aircraft accident are recommended.
 - **Critical Community Infrastructure** – This category pertains to facilities the damage or destruction of which would cause significant adverse effects to public health and welfare well beyond the immediate vicinity of the facility. Particular examples include: emergency services facilities such as police and fire stations, emergency communications facilities, and power plants and other utilities.

