Introduction

When purchasing a house or property, a largely ignored aspect is the ground that the house sits on and the environment surrounding the property. Before choosing an area in which to buy a home, many people inquire about traffic-noise levels, crime rates, quality of schools, and whether the house is under the flight path of a major airport. It is logically better to obtain this kind of information *before* one buys or builds a home, rather than be surprised the first night by jets taking off from a nearby airport. Similarly, gaining knowledge about geologic conditions in an area will assist prospective homeowners, home builders, developers, and real estate agents to make informed decisions regarding potential problems.

Across Arizona, rocks of all types and ages serve as records of geologic processes that have occurred in the past and are continuing to occur. Some of these processes are merely nuisances to use of the land, whereas others may present serious hazards. We define a *geologic hazard* as any geologic condition or process that poses a risk of injury to humans or damage to structures. Geologic hazards are an unavoidable part of living on planet Earth. From floods to earthquakes to landslides, no place on the Earth is immune from some risk of damage caused by a geologic condition or process. Learning what these conditions are and where they might occur are the first steps toward avoiding them or reducing their effects.

The most widespread and common geologic hazards that should be considered before buying or building in Arizona are

- Floods
- Earthquakes
- Problem soils
- Mass movement
- Subsidence and fissures
- Radon
- Karst
- Abandoned mines
- Volcanic hazards

Virtually every part of Arizona is subject to one or more of these risks, which can be avoided or mitigated, but only with prior knowledge of its existence. Some of these risks, such as radon, are with us every day. Other hazards, such as floods and earthquakes, strike infrequently but with potentially devastating results.

It makes good sense to conduct a thorough inspection of the land before buying a house or property. For home or property buyers, in addition to personal inspection, it might be prudent to find out what information is available regarding geologic hazards in the area. The upfront cost of such inspections is much less than the cost of repairs later. For developers, designing and building with geologic factors in mind may help avoid costly legal battles over damage to structures or loss of property value. For real estate brokers, familiarity with known or potential geologic hazards may help reduce liability if damage occurs on a property.

Our purpose is not to say that any particular parcel of land should not be developed. Rather, in those areas where geologic hazards or limitations are known to be present or where they may potentially exist, knowledge of their existence should help guide planning, design, construction, and maintenance. It remains up to property buyers or owners and local government to determine the level of acceptable risk from geologic hazards. To assist in this evaluation, we have developed this book as a guideline of for home/property buyers. The following pages address the geologic hazards common to Arizona, describe aspects of the geology that should be evaluated before buying or building, present methods to prevent or reduce (mitigate) hazards, and list other appropriate sources of information and assistance.

Floods

(Left) Bank erosion along Rillito Creek in Tucson during the October 1983 flood left the north end of the Dodge Boulevard bridge stranded. *(Photo © by Peter L. Kresan)*

(Above) During the flood of October 1983, the normally dry Santa Cruz River was completely full. This view is from St. Mary's bridge looking south (upsteam) toward downtown Tucson. *(Photo © by Peter L. Kresan)*

Floods In The Desert?

It might seem strange to be concerned about flooding in a dry region like Arizona because deserts, by definition, do not get much precipitation. However, in Arizona a large amount of precipitation can fall in a short period of time. In fact, flooding is probably the most common, widespread, and damaging of all of the geologic hazards discussed in this book. No part of Arizona is immune from hazards associated with flooding. When Arizona was a sparsely populated, predominantly rural state, floods typically were a minor inconvenience. Now that Arizona has large, rapidly expanding metropolitan areas, it is critically important to properly assess and avoid development in flood-prone areas.

Floods cause a tremendous amount of property damage and substantial loss of life in the United States. Even with efforts to improve management of flood-prone areas, damage caused by flooding has continued at a high rate. The Federal Emergency Management Agency (FEMA) estimates that about 4 percent of the total area of the United States is in floodplains. Nine million households and $390 million in property are located in those floodplains.

Although Arizona is dry most of the time, certain weather conditions bring large amounts of moisture into the state. Because of the arid climate, much of the state has sparse vegetation, and hills and mountains are covered with thin and discontinuous soil. With little soil to soak up water and little vegetation to hold water back, much of the precipitation runs off quickly. Flooding can

What are "100-year floods" and floodplains?

The name "100-year flood" implies that over the long term, floods of this size will occur once every 100 years. In this respect, the term is somewhat of a misnomer. In reality, so-called 100-year floods can strike in consecutive years. Actually, the designation of 100-year flood refers to a flood that is believed to have a one percent chance of occurring in any year. Whether or not heavy rain occurs one year does not depend on whether similar rains occurred in previous years (or in previous weeks, for that matter). In more familiar terms, imagine flipping a coin. Although the chance of getting heads is exactly 50-50 for each flip, it is not uncommon to get heads on three or four consecutive flips. The chance of heads or tails on the next flip does not depend on the outcome of the previous flip.

Records of flood events in Arizona go back 150 years at best, and for most streams the flood record is much shorter or nonexistent. It is impossible to assess the true frequency of heavy rains and major floods with a record this short. In looking at the record of major floods in Arizona, it is clear that what hydrologists think is the 100-year flood may change through time. One Safford farmer has remarked that he must be 445 years old because he has lived through *four* 100-year floods on the Gila River!

Hydrologists use a variety of methods to determine the likelihood of rainfall large enough to produce floods of different sizes. Gages that measure flow in streams provide data that can be used to estimate the size of a 100-year flood. Ideally, the largest flood recorded in 100 years of data collecting would be the 100-year flood. Because no stream or river in Arizona has been monitored for a full 100-year span, the size of the largest flood that could occur in 100 years is calculated using statistical methods. As more data are collected through the years, adjustments are made on estimates of the size and frequency of floods. For example, peak flows of the 100-year flood are adjusted upward if it is apparent that what was originally designated as a 100-year flow repeats about every 20 years. Thus, what was originally called a 100-years flood on a stream may actually be a 20-year flood. Most streams in Arizona do not have flow gages, so there is no long-term record of floods. In these cases, hydrologists typically use the record of floods from streams of similar size to estimate the 100-year flood. After the 100-year flood size is estimated, computer models are then used to delineate the extent of inundation in this flood. This area of inundation is the "100-year", or regulatory, floodplain.

Despite all of its potential shortcomings, the "100-year flood" is the standard flood that is used by federal, state, and most local agencies to delineate and manage floodplains. Development is highly regulated, and generally discouraged, in 100-year floodplain areas. If you purchase a home in a 100-year floodplain through a lending agency, you will likely be required to obtain insurance through the Federal Flood Insurance Program administered by FEMA. If you build a new structure in the 100-year floodplain, regulatory agencies typically require that the floor elevation be one foot above the 100-year water surface and that you do not adversely affect structures downstream.

result if the precipitation is sufficiently intense or prolonged. If your property is located along a large stream or river, then you should be most concerned about fall and winter storms. If the property is near a smaller wash, you should be more concerned with intense, localized summer thunderstorms.

Fall/Winter Storms (Rivers and Larger Streams)

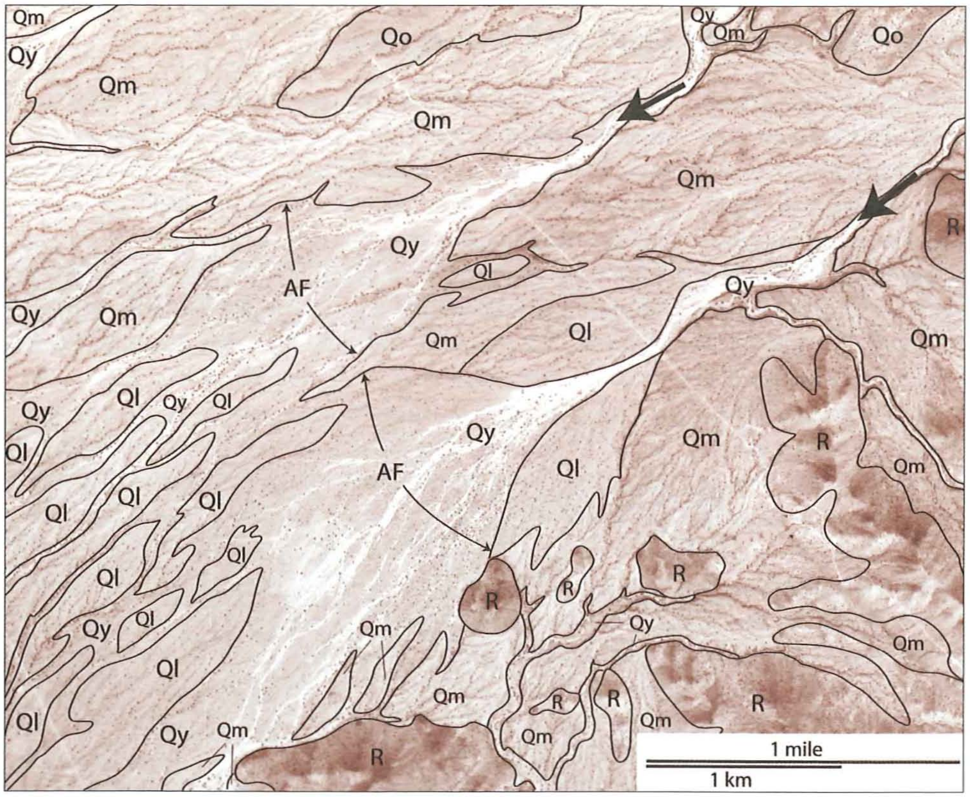
Floods on larger streams and rivers result from regional storms that originate in the Pacific Ocean. In a typical winter, Arizona is affected by numerous storms that do not cause flooding. Occasionally, however, large regional storms lasting for days produce abundant precipitation that can cause flooding. During wet winters, soils become so saturated that runoff increases with each successive storm. Moreover, Arizona is hit periodically by cold storms that produce snow in the high country. If this snow melts too quickly, the runoff can produce floods.

Weather patterns in the late summer or early fall can direct dissipating hurricanes and tropical storms into Arizona. Copious rainfall from these regional-scale systems can generate floods on both small and larger streams.

Summer Storms (Smaller Washes)

Most floods on smaller washes in Arizona occur during the "monsoon" season of the middle and late summer. Intense surface heating results in moisture being drawn into Arizona from the Pacific Ocean and the Gulf of Mexico. Thunderstorms are generated when this relatively moist air is heated and rises, or when it is forced to rise over mountains. Much of Arizona's yearly rainfall comes during this summer rainy season in the form of isolated, occasionally severe afternoon thunderstorms. These storms commonly develop quickly, generate intense wind and lightning, dump their rain, and then dissipate as quickly as they formed.

Floods from monsoon storms typically are highly localized. Unusually intense storms can result in 3 inches or more of rainfall in an hour over small areas. Rainfall of that intensity will generate flash floods on small washes. During these flash floods, normally dry



Aerial photograph of the western piedmont of the White Tank Mountains, which shows alluvial surfaces of different ages. The approximate ages of the deposits in thousands of years (ka) are as follows: Qy, younger than 10 ka; Ql, 10 to 150 ka; Qm, 150 to 800 ka; Qo, older than 800 ka. Areas labeled R are bedrock. The arrows point to relatively large drainages that begin in the mountains and flow from right to left across the piedmont. The areas of recent alluvial-fan flooding (labeled AF) along these drainages are identified by extensive young deposits (Qy). The older fans (units Ql, Qm, and Qo) compose much of the piedmont and have been isolated from floods associated with the larger drainages for more than 10,000 years.

streambeds can fill to their banks and overflow in a few minutes. Flash flooding is particularly dangerous because rain may be falling in only a very small area, with blue sky elsewhere. Because flash floods can travel many miles, people downstream may not be aware that rain is falling upstream. Highly localized, intense flooding may occur on short stretches of a few small washes but nowhere else.

Flood-Prone Areas In Arizona

The most important step that can be taken to minimize property damage by flooding is to avoid building in areas that are prone to flooding. Because of the potential risk to life and property from floods, government agencies restrict development in floodplains. Most floodplains have been delineated solely based on engineering or hydrologic methods. In addition to traditional engineering studies, detailed geologic maps that depict the extent of young deposits along washes and rivers are an extremely useful source of readily available information that can be used to help define the extent of flood-prone land along streams.

Rivers and Streams

Flood-prone areas along rivers and streams include channels and adjacent floodplains. Flood flows in channels are deep, rapid, and obviously hazardous. Floodplains are relatively flat areas adjacent to channels that get flooded occasionally. Flood flows on floodplains are much shallower and less rapid than in channels, and flooding history on floodplains is reflected by the presence of fine-grained, geologically very young material.

In the desert southwest, river and stream floods cause damage in two ways. First, water may overflow the natural confines of a stream channel and inundate low-lying surrounding areas. The second is by widening of the stream channel itself through bank erosion, thereby taking out roads, bridges, and houses on the adjacent floodplain. During the major 1983 flood in Tucson, for example, the banks of the Rillito River migrated laterally as much as 2,700 feet.

Development on floodplains has been an important issue in urban areas in Arizona. Floodplains offer wide expanses of flat land, a seemingly ideal location for development. Before the enactment of floodplain regulations, many developers took advantage of such flat land, and homes and buildings have been constructed within floodplains or near stream banks that were subject to erosion.

Smaller Washes

Flood hazards associated with the thousands of smaller washes in Arizona are as important as the more obvious hazards associated with the larger rivers. As urban areas spread out into the adjacent desert, development increasingly encroaches onto piedmonts (literally, "the foot of the mountains"), which are gently sloping plains between the mountain fronts and the lower, almost flat valley floor. Much of southern, central, and western Arizona consists of piedmonts, which represent

Much of the Floodplain Management in Arizona is done by County Flood Control Districts

- Cochise County Floodplain Division (Highway and Floodplain Department, Bisbee)
- Coconino County Flood Control District (Department of Community Development, Flagstaff)
- Flood Control District of Maricopa County (Public Works Department, Phoenix)
- Pima County Flood Control District (Transportation and Flood Control Department, Tucson)
- Yavapai County Flood Control District (Flood Control Department, Prescott)
- Yuma County Flood Control District (Department of Community Development, Yuma)

Other Sources of Information On Flood Hazards

Arizona Division of Emergency Management
Arizona Floodplain Management Association
Arizona Department of Water Resources (Flood Warning and Dam Safety Division)
Most larger cities in Arizona manage their own floodplains
Federal Emergency Management Agency

Examples of floodplain restrictions (summarized) in various counties around the state include:

- ✓ Buildings must be set back from designated streams or washes because of bank erosion hazard. Setback varies from 30 to 500 feet, depending on size of expected peak flood.
- ✓ Lots must have safe access by standard vehicles.
- ✓ Mobile homes near floodplains must be anchored to the ground so they don't float away.
- ✓ The lowest floor of a built house or the lowest frame of a mobile home must be at least one foot above the expected base flood height (usually the 100-year flood).
- ✓ The natural flow of washes may not be diverted or obstructed without a special permit.
- ✓ Fences may not be placed across washes at wash level because they may trap floating debris, which could form a temporary dam and worsen flooding.
- ✓ Development in a floodplain shall not increase the height of the base flood by more than one foot.
- ✓ Flood insurance may be mandatory in certain areas to obtain federal financing.

most of the land potentially open for development near rapidly growing population centers of the state.

Parts of some piedmonts are subject to alluvial fan flooding, where floodwaters spread out across broad areas and channels may shift during large floods. Piedmonts are typically drained both by a few relatively large streams that begin in adjacent mountains and by many smaller washes that begin on the piedmont. On active alluvial fans, washes commonly fan out into increasingly smaller washes that spread out downstream, in contrast to the normal situation where many small streams come together downstream to form a single, large stream. During alluvial fan flooding, floodwaters spread out and inundate wide areas. New channels can grow quickly if the water takes a new path during flooding. Detailed geologic maps that depict the distribution of young deposits on piedmonts generally are reliable indicators of the extent of flood-prone land along washes and on alluvial fans.

In urban areas, potential for flooding is increased by the amount of land that is covered with buildings and pavement. When the ground is covered, rain has no chance to infiltrate and so must run off. In urban areas, even light rains can fill streets curb-high with runoff. Flooding in cities happens more quickly and with less rainfall than in undeveloped areas.

Preventing Or Reducing Flood Damage

Before purchasing or building a home, it is wise to find out whether the site is in a known floodplain and, if it is, whether it is necessary to purchase flood insurance. This information should be available from county flood-control districts or city floodplain-management agencies. If you are considering building a home in a rural area, avoid areas adjacent to washes, even if the washes seem small and harmless.

Solutions to flooding problems in areas that are already developed are usually difficult and expensive. It is possible to protect property and lives by increasing channel capacity or solidifying channel banks. Such measures have been enacted along the larger streams and rivers in urban areas. If homes are in areas that have experienced repeated or serious flooding, it may be more cost-effective for government agencies to purchase the property than to protect the homes against future flooding.

Because bank erosion is common during floods in Arizona, it is prudent not to build structures immediately adjacent to stream banks. The outside banks of bends in stream channels are particularly vulnerable to erosion. For that reason, floodplain regulations in some counties stipulate that development is not allowed within a certain distance from stream banks. Some houses and developments are exempt ("grandfathered") from parts of floodplain regulations because they were built before the laws were enacted. Older houses may have been built in floodplains and wash bottoms where, today, building would not be allowed.

Where To Go For Information

Most counties, cities, and towns have regulations that govern land use and construction in or adjacent to floodplains. Before building or buying, check with the city or county planning and zoning, community development, or engineering departments to learn of land-use restrictions and building codes. To find out if a property is in a designated floodplain, check with the city or county planning and zoning or community development department, your realtor, your insurance agent, or the Federal Emergency Management Agency (FEMA). Several counties in Arizona have Flood Control Districts, which are special agencies responsible for floodplain management outside incorporated cities. Contact information for federal, state, county, and local agencies is provided on the Arizona Geological Survey (AZGS) website. Finally, geologic maps (available at the AZGS) can provide a useful perspective on flood-prone areas associated with piedmonts and along streams and rivers.

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