Geology and Geologic Hazards of the Casa Grande Area, Pinal County, Arizona

by

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Introduction

This report and accompanying maps describe the geology, geomorphology, and geologic hazards of the Casa Grande area in central Arizona. This mapping covers six 7 1/2' quadrangles (*Stanfield, Casa Grande West, Casa Grande East, Coolidge, Double Peak, and Chuichu*), and includes the communities of Casa Grande, Coolidge, and Stanfield. Casa Grande is located approximately 80 km (50 miles) south of Phoenix along Interstate Highway 10 (Figure 1). The map area encompasses basin floors occupied by major stream systems, low mountain ranges, and the gently sloping piedmonts between them. Basin floor areas have been substantially altered for agricultural fields, and the piedmonts and mountain ranges are used for grazing and mining. Casa Grande has developed into a significant population center, however, and rapid development is occurring on the basin floor and the piedmonts around it. The map area includes parts of the Maricopa-Stanfield and Picacho ground-water basins, from which tremendous amounts of water have been extracted primarily for agricultural purposes. This report is intended to enhance our understanding of the physical environment of the Casa Grande area and to aid in planning for wise development in the future.

This mapping effort has focused on the surficial deposits of the Casa Grande area, which had not been mapped in detail before. This surficial geologic mapping complements previous mapping efforts by the AZGS in areas surrounding Casa Grande (Jackson, 1989; Huckleberry, 1992; Pendall, 1994). We have incorporated recent bedrock mapping done in the Sacaton Mountains (Skotnicki and Ferguson, 1996) into these maps. The report is organized into a brief introduction and explanation of mapping methods, unit descriptions, a summary of the geologic and geomorphic framework of the area, and a discussion of geologic hazards.

Climate. The climate of the map area is hot and dry, with extreme seasonal temperature variations and two distinct seasons of rainfall. The average July high temperature at the Casa Grande weather station (elevation 1400 feet above sea level) is 106° F, and the average January low temperature is 35° F. Average annual precipitation at Casa Grande is 8.5 in. Occasional freezing temperatures are recorded at Casa Grande during most winters, but snow is rare and not persistent. Slightly less than one-half of the annual precipitation falls between July and September (Western Regional Climate Center, 1998). Late summer rainfall occurs as heavy thunderstorms when moist air sweeps northwards from the Gulf of California and the Gulf of Mexico. Occasional intense late summer to early fall precipitation may occur in this region as a result of incursions of moist air derived from dissipating tropical storms in the Pacific Ocean. Winter precipitation generally is caused by cyclonic storms originating in the Pacific. It is usually less intense and may be more prolonged, and therefore infiltrates into the soil more deeply than summer rainfall (summarized from Sellers and Hill, 1974).

Methodology

The project area was mapped using several sets of aerial photographs and soil survey maps, with extensive field mapping and observations of soils and stratigraphy. The piedmont areas were mapped primarily using 1:24,000 U.S. Geological Survey aerial photos from 1961 and 1990, augmented by 1936 Soil Conservation Service 1:31,680 photos and soils mapping by Hall and others (1991). Piedmont areas were extensively field checked by the first author, with assistance and suggestions from Phil Pearthree, Steve Skotnicki, and Tom Biggs. Mapping the

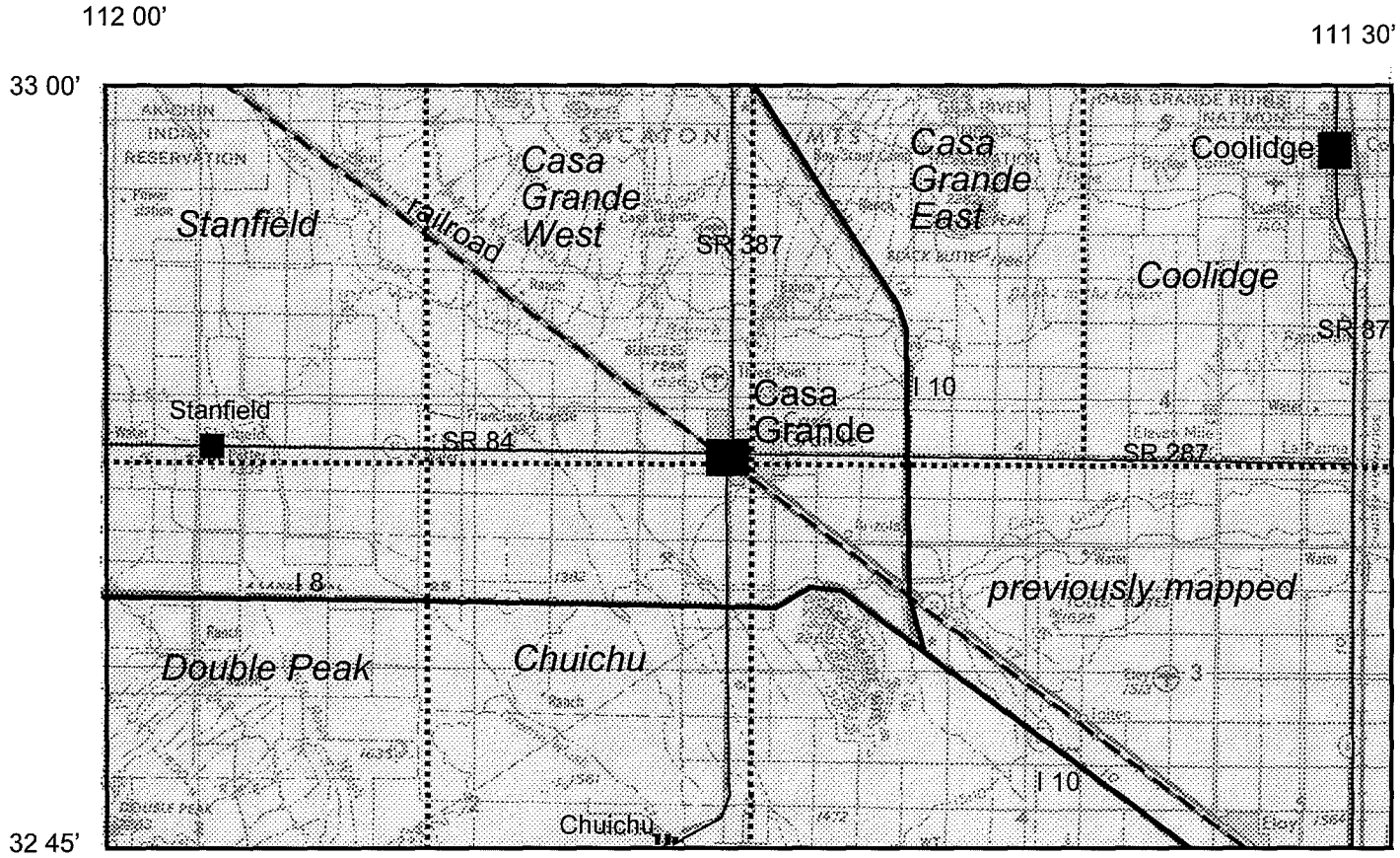

Figure 1. Location map for geologic mapping in the Casa Grande area. The six quadrangles mapped for this project are labeled. The Casa Grande Mountains and Eloy North quadrangles in the southeastern part of the index map were mapped previously by Jackson (1990).

basin-floor areas presented an interesting challenge, because most of these areas have been altered substantially by agricultural activities. Older aerial photos were vital in these areas, because they predate much of the agricultural alteration of the landscape. Basin-floor areas were mapped primarily using the 1936 SCS aerial photos, 1:60,000-scale Army Map Service aerial photos from 1953, and soil survey maps (Hall and others, 1991), with limited field checking. Reservation lands on the northern and southern fringes of the map area were mapped on a reconnaissance basis using aerial photos only; so unit boundaries and labels in these areas should be considered tentative.

The physical characteristics of alluvial surfaces (channels, alluvial fans, floodplains, stream terraces) were used to differentiate their associated deposits by age. Alluvial surfaces of similar age have a distinctive appearance and soil characteristics because they have undergone similar post-depositional modifications, and they are different from both younger and older surfaces. Young (less than a few thousand years old) alluvial-fan surfaces, for example, still retain clear evidence of the original depositional topography, such as of bars of coarse deposits, swales (troughlike depressions) where low flows passed between bars, and distributary channel networks, which are characteristic of active alluvial fans. Young fan surfaces also show minimal development of soil, desert pavement, and rock varnish and are basically undissected. Very old fan surfaces, in contrast, have been isolated from substantial fluvial deposition or reworking for hundreds of thousands of years. These surfaces are characterized by strongly developed soils with clay- and calcium-carbonate-rich horizons, well-developed tributary stream networks that are entrenched 1 to 10 m below the fan surface, and strongly developed varnish on surface rocks. Old alluvial-fan surfaces may also have smooth, closely packed desert pavements between the entrenched drainages. The ages of alluvial surfaces in the southwestern United States may be roughly estimated based on these surface characteristics, especially soil development (Gile and others, 1981; Bull, 1991).

In this map, surficial deposits are subdivided based on their source (rivers and large washes, smaller tributary washes on piedmonts, wind activity, hillslope processes) and estimated age of deposits. Surface and soil characteristics were used to correlate alluvial deposits and to estimate their ages. Surface pits and exposures along cut banks were used to assess soil characteristics associated with deposits of different ages and from different sources. These descriptions can be found in Appendix A at the end of the report. Soils and surfaces documented in the map area were generally correlated with soils and surfaces described in Quaternary mapping studies of adjacent areas conducted by Jackson (1989), Huckleberry (1992) and Pendall (1994). These correlations were also used to estimate the ages of surficial deposits in the map area.

Following field checking, geologic mapping was compiled on 1:24,000 orthophoto quadrangles. Mapping was subsequently digitized and prepared for final map production by T. Biggs, with assistance from Sean Kneale, Steve Richard, and Pete Carrao. Mapping was conducted as part of the STATEMAP Program of the U.S. Geological Survey, contract #1434-HQ-97-AG-0182.

Map Unit Descriptions

Piedmont Alluvium

These deposits cover most of the gently sloping plains (piedmonts) that surround the mountain ranges of the map area. This sediment was deposited by the smaller drainages of the map area, which head either in the mountains or on the piedmonts themselves. Deposits range in age from modern to early Pleistocene. The lower margins of the piedmonts are defined by their intersection with the planar, very gently north- to northwest-sloping basin-floor deposits associated with the Santa Cruz and Gila rivers and Santa Rosa Wash.

Qy2 - late Holocene alluvium (<4 ka). Unit Qy2 consists of channels, low terraces, and alluvial fans composed of sand, silt and gravel that have been transported in modern drainages. In areas proximal to the mountain front, sediment load is generally sand and cobbles with some boulders; terraces may be mantled with finer sediment. On lower piedmont areas, young deposits consist predominantly of sand, silt, and clay, with local fine gravel. Channels are incised less than 1 m below adjacent terraces and fans. Channels may have single, anastomosing, or distributary patterns. Qy2 surfaces generally appear darker than surrounding areas on aerial photos. Local relief varies from fairly smooth channel bottoms to the undulating bar-and-swale topography that is characteristic of coarser deposits. Vegetation density is moderate. Along the larger washes, vegetation includes palo verde, mesquite, and ironwood trees; smaller washes typically have large creosote and other bushes along them.

Qy1 - Middle to early Holocene alluvium (2 to 10 ka). Qy1 surfaces are broadly rounded and are somewhat isolated from the active flow regime. Surfaces typically are sandy or are covered with fine, unvarnished open gravel lags. Where gravel is present, surfaces appear light colored on aerial photos; where the surfaces are finer grained, they appear dark. Channels are incised <1m below Qy1 surfaces, and may contribute sheetflow to the lowest lying areas of Qy1 during large flow events. Channel patterns typically are distributary. Qy1 surfaces support creosote and other small bushes. They are most extensive on the piedmonts of Casa Grande East and Double Peak quadrangles. Qy1 soils are gravelly loamy sands with little clay or carbonate development (see Appendix A).

Qy - Holocene alluvium, undifferentiated (0 to 10 ka). Mixed channels and alluvial surfaces of Qy1 and Qy2 are composed of sand, silt and gravel, with little varnish or pavement development. Qy surfaces are typically found close to the mountain front where distributary channel networks and associated late Holocene alluvium (Qy2) has dissected and partially covered middle Holocene alluvium (Qy1) to a depth of <1m. Other Qy surfaces are found in lower piedmont areas where Qy1 and Qy2 surfaces complexly interfinger such that they cannot be separated at a 1:24,000 scale.

Qly - Late Pleistocene to Holocene alluvium (0 to 130 ka). Broadly rounded surfaces approximately 1m above active channels composed of mixed alluvium of late Pleistocene and Holocene age. Drainage networks consist of distributary channel networks associated with larger drainages and tributary channels associated with smaller drainages that head on Qly surfaces. Slightly reddened Pleistocene alluvium (unit Ql) is exposed in patches on low ridges and in roads and cut banks of washes, but it is mainly covered by a thin veneer of Holocene fine-grained alluvium (unit Qy). The Holocene surfaces usually are light brown in color and soils have weak subangular blocky structure and minor carbonate accumulation.

Ql - Late Pleistocene alluvium (10 to 130 ka). Ql alluvial surfaces are rounded and moderately dissected relict alluvial fans and terraces, with 1 to 2 m of active channel incision, increasing toward the mountain front. Weakly to moderately incised tributary drainage networks are typical. Ql deposits consist of pebbles, cobbles, and finer-grained sediment. Ql surfaces commonly have loose, open pavements of pebbles and cobbles; surface clasts exhibit weak to moderate rock varnish. Ql soils are gravelly sandy loams with subangular blocky structure, weak clay skins, and Stage II carbonates (Appendix A). The weak to moderate soil development observed beneath Ql surfaces suggests that many of them may be latest Pleistocene in age (~10 to 20 ka). Dominant forms of vegetation include creosote, bursage, and ocotillo.

Qm - Middle Pleistocene alluvium (130 to 750 ka). Qm surfaces are moderately dissected relict alluvial fans, with several meters of active channel incision. Qm surfaces are drained by moderately incised tributary channel networks. Well-preserved Qm surfaces are smooth and have moderately to tightly packed cobble pavements, with moderate to strong rock varnish on surface clasts. Less well preserved surfaces are characterized by loose cobble pavements with moderate to strong varnish, ridge-like topography and carbonate litter on the surface. Soils typically contain reddened, clay loam argillic horizons, with moderate clay skins and subangular blocky structure. Soil carbonate development is typically stage III to IV, but cemented petrocalcic are not common. Qm surfaces generally support bursage, ocotillo, creosote, cholla, and saguaro.

Qo - Early Pleistocene alluvium (750 ka to 2 Ma). Qo surfaces are very old, moderately eroded relict fans with up to 10 m of active channel incision. Tributary drainage networks are strongly developed and entrenched; depth of dissection by channels is similar to Qm surfaces, but areas between channels are more rounded by erosion. Qo surfaces have weak to moderate cobble pavements, and rock varnish varies from very strong to weak. Surface color is lighter than most younger surfaces because the surface soil horizon is carbonate-rich and fragments derived from underlying cemented petrocalcic horizon litter the surface. Qo deposits are only exposed in a few upper piedmont areas at the northwestern margin of the Stanfield quadrangle.

River Deposits

Deposits laid down by the Santa Cruz and Santa Rosa Wash cover most of the broad, very low-relief basin-floor areas. The northeasternmost part of the map area probably contains deposits of the Gila River. Surfaces consist of channels, stream terraces and alluvial fans. Most deposits are fine-grained; however, those that are gravelly exhibit mixed lithologies reflecting the large drainage areas of these streams. Most of the area covered by river deposits has been altered by agricultural activities, so there is greater uncertainty regarding the locations of unit contacts than in piedmont areas. Soil descriptions are taken from Hall and others (1991).

Qy2r - Modern channel and terrace deposits (< 100 years). This unit encompasses active channels and low terraces composed of sand, silt, and clay. Natural channel patterns are braided, but modern channels in much of the map area are contained within berms. Soils are classified as Torrifluvents; they are weakly developed and have clay loam or sandy loam textures with little or no evidence of clay movement or carbonate accumulation. These areas are prone to inundation in moderate to large flow events, unless they have been protected by artificial diversion structures.

Qy1r - Holocene floodplain and terrace deposits (<10 ka). The Qy1r units consists of floodplains and terraces that are spatially separated from the main channel system. Qy1r deposits consist of sand, silt, and clay. Soils are classified as Torrifluvents and Camborthids, which are deep, weakly developed soils with some carbonate filaments and fine masses and weak soil structure in near surface horizons. Qy1r surfaces which may experience sheetflooding during large flow events.

Qysr - Holocene striped floodplain deposits (<10 ka). This distinctive unit is characterized by fine-grained surfaces with pronounced dark stripes that trend approximately perpendicular to surface flow directions. The dark stripes consist of alternating vegetation and soil lineations. The stripes have little or no topographic expression, and are not associated with obvious eolian features such as low dunes. Qysr units are generally are adjacent to Qyr2 and Qyr1 and are not much if any higher than these surfaces, which suggests that Qysr areas may have experienced shallow flow during large floods. The areal extent of this unit was inferred primarily from historical aerial photos, because most of the Qysr areas are currently under cultivation. Comparing the distribution of Qysr unit with the soils maps of Hall and others (1991), the distinctive striped pattern that characterizes Qysr overprints several different fine-grained soils of Holocene and Pleistocene age. This suggests that the stripes are a surface phenomenon that has developed during the late Holocene.

Qlrg - Late Pleistocene gravel deposits (10 to 130 ka). Relatively coarse-grained Pleistocene river terraces and alluvial fans that are slightly higher the the surrounding younger surfaces. Qlrg deposits typically consist of pebbles, some cobbles, and sand. Soils associated with the deposits are classified as a Typic Calciorthids, with loam to sandy loam textures, massive to subangular blocky structure, and carbonate coated clasts and nodules wit medium soft carbonate masses at a starting depth of 36-76 cm. Extremely gravelly soils in this unit have silica-lime cemented pan fragments at an average depth of 61 cm.

Qmlr - Middle to late Pleistocene river deposits (~10 to 500 ka). Late or middle Pleistocene river terraces and alluvial fans on the basin floor. In areas that have been cultivated, topographic differences between Pleistocene and Holocene surfaces may be undetectable, but on historical aerial photos Pleistocene surfaces appear to be higher than surrounding younger surfaces. In addition to topographic relief, Qmlr soils are substantially more developed than younger soils. Qmlr soils are classified as Calciorthids, Haplargids and Natrargids; they are fine-grained, and generally have well developed structure and reddened argillic horizons and common soft carbonate nodules at a starting depth of 33 to 66 cm. Soils of the Casa Grande series, included in this unit have natric horizons.

Qor - Middle to early Pleistocene river deposits (~500 ka to 1 Ma). Relict very old river terraces. These surfaces are distinguished by strong carbonate accumulation. Their soils are classified as Petrocalcic Paleargids. Typically, they have saline-sodic fine sandy loam argillic horizons with well developed prismatic to subangular blocky structure, which are underlain by petrocalcic horizons with a thin laminar cap at its top. These surfaces are altered by agricultural activity, and no stratigraphic exposures were observed. It is possible that the petrocalcic horizons are buried by thin packages of much younger surface deposits.

Eolian/Alluvial Deposits

These map units represent areas that are covered by eolian deposits or a mix of alluvium and eolian deposits. They are found on the basin floor and in lower piedmont areas.

Qye - Holocene sand dunes (<10 ka). Unit Qye consists of relatively small eolian dunes found in a number of places on the basin floor. Dunes consist of well-sorted sand. They partly stabilized by creosote, grasses, and bursage vegetation. They appear as irregular topography on topographic maps and may reach a height of 5 m above adjacent surfaces. In some areas mapped as Qye, the topographic expression of dunes has been removed to facilitate agricultural land uses. In these areas, Qye deposits were delineated using soil survey maps (Hall and others, 1991).

Qlye - Late Pleistocene to Holocene alluvium with Holocene eolian deposits (<130 ka). Unit Qlye consists of late Pleistocene alluvium that is typically mantled by 15-25 cm of Holocene alluvium and eolian material. Locally, the late Pleistocene alluvium is exposed at the surface. Qlye surfaces are relatively flat, with <1m of relief between the surface and active drainages. Eolian material is in the form of coppice dunes around individual shrubs and low-relief dunes surrounding clumps of creosote and bursage. Areas that are not covered by eolian material are have open gravel lags with minimal rock varnish.

Qle - Late Pleistocene alluvium with Holocene eolian deposits (<130 ka). Unit Qle consists of late Pleistocene alluvial surfaces that are partially covered by Holocene eolian deposits. Surfaces are planar and quite fine-grained; eolian sands form of coppice dunes around individual shrubs. Qle surfaces appear darker on aerial photos than adjacent Qlye surfaces and they have drainages that are incised ~1m into the surface.

Qlre - Late Pleistocene river gravel deposits and Holocene eolian deposits (<130 ka). Unit Qlre consists of low Holocene sand dunes partially covering Pleistocene river gravels. Gravels are typically pebbles and small cobbles, lithologies are diverse; surface clasts have weak to moderate varnish and pavements range from moderately packed to open, loose frameworks. Qlre gravels are generally best preserved at the highest elevations of the sand dunes and are a minor component of a predominantly eolian surficial unit. Gravel may be more abundant at depth, however.

Qme - Middle Pleistocene alluvium with Holocene eolian deposits (<750 ka). Unit Qme consists of middle Pleistocene piedmont alluvium that is partially covered by Holocene eolian deposits. Surfaces are planar landforms, with vegetated eolian sands alternating with loosely packed, moderately varnished gravel pavements. Primarily because of the location of these surfaces in lower piedmont areas, relief between the Qme surface and active drainages is on the order of <1m. Soils are loamy sands and sandy loams with reddening and clay and carbonate development at a depth of 8 to 30 cm.

Colluvium

Qc - Hillslope colluvial deposits (Holocene and Pleistocene). These are very poorly sorted, angular to subangular deposits that mantle some of the lower slopes of the Sacaton Mountains. Deposits consist of a wide range of particle sizes, from boulders to clay; most are weakly or unconsolidated. Clast lithologies vary with local variations in bedrock lithology. This sediment has been transported and deposited by hillslope processes, such as rockfall, debris flow, sheet wash, and creep.

Bedrock

Bedrock units were mapped and described by Skotnicki and Ferguson (1996) in the Stanfield, Casa Grande West, and Casa Grande East 7 1/2' Quads and by Beikman and others (1995) in the Double Peak and Chuichu 7 1/2' Quads. More detailed descriptions of most of the bedrock units can be found in the former reference. Some bedrock units also occur as pediments in the study area; these bedrock unit labels are followed by a "(p)". Where surficial and bedrock units overlapped in pediment areas, preference was given to surficial units.

Tc - Breccia and conglomerate (middle Tertiary). This unit consists of matrix-supported breccias, clast-supported conglomerates, and some red sandstone. Clast sizes range from sand to boulders. It is exposed at Burgess Peak, in the northern part of the City of Casa Grande.

Tb - Basaltic rocks (Tertiary). Fine-grained, mafic volcanic rocks exposed in hills and inselbergs in the southwestern part of the map area.

TKf - Fine-grained, rhyolitic dikes (Cretaceous or Tertiary)

TKp - Granite porphyry dikes (Cretaceous or Tertiary)

TKa - Amphibole-porphyritic dikes (Cretaceous or Tertiary)

TKb - Biotite-porphyritic dikes (Cretaceous or Tertiary)

TKm - Monzonite dikes (Cretaceous or Tertiary)

TKq - Quartz-porphyritic dikes (Cretaceous or Tertiary)

Kgq - Quartz-porphyritic phase of the Sacaton Peak Granite (Cretaceous/Tertiary). Medium-grained equigranular quartz-porphyritic granite to quartz monzonite. It is prominently jointed, and compositional banding of light and dark phases is well developed locally.

Kg - Sacaton Peak Granite (Cretaceous/Tertiary). Medium-grained equigranular quartz monzonite to granite. This unit weathers into steep, rugged buttes covered with medium boulders.

Kgm - Mafic phase of the Sacaton Peak Granite (Cretaceous/Tertiary). Medium-grained, equigranular quartz monzonite to diorite with up to 25% biotite and some hornblende. Locally, it is foliated and lineated, and fresh surfaces are medium to dark gray.

Kgk - K-feldspar porphyritic phase of the Sacaton Peak Granite (Cretaceous/Tertiary)

Kgs - Signal Peak Granite (Cretaceous/Tertiary). Equigranular granite and quartz monzonite. Mineralogically very similar to the Sacaton Peak granite, but it is foliated and locally lineated.

YPzs - Metasedimentary rocks (middle Proterozoic or Paleozoic). Massive, white to light gray, fine-grained metasedimentary rock, probably derived from a lower Paleozoic unit or a middle Proterozoic Apache Group unit.

YCq - Quartzite (middle Proterozoic or Cambrian). Medium-bedded, light gray quartzite, with dark fine laminae; possibly the middle Proterozoic Dripping Springs Quartzite or the Cambrian Bolsa Quartzite.

Yd - Diabase (middle Proterozoic). Dark green, generally fine-grained, but locally medium- to coarse-grained diabase that intrudes Proterozoic rocks.

Ygl - Leucocratic granite (middle Proterozoic). Medium- to coarse-grained equigranular granite. Exposed rock is light gray to light orange. This rock generally forms resistant buttes, and generates angular, cobble-sized detritus.

Yg - Coarse-grained granitoid (middle Proterozoic). Medium- to coarse-grained, K-feldspar porphyritic granite to quartz monzonite. Exposed rock is medium to light gray where fresh; weathered surfaces are rusty tan and locally varnished. This rock forms steep slopes covered with large spheroidal boulders, and fairly broad pediments.

YXg - Foliated coarse-grained granite (early to middle Proterozoic). Medium- to coarse-grained, K-feldspar porphyritic granite or quartz monzonite with abundant biotite. It is foliated and locally lineated. This rock forms dark, resistant hills covered with irregularly shaped boulders.

Xp - Pinal Schist (early Proterozoic). Medium- to coarse-grained quartz-muscovite schist, exposed in small, isolated hills in the western part of the Sacaton Mountains.

Miscellaneous units and symbols

(p) - Pediment

Fairly planar erosional surfaces cut onto bedrock on the upper piedmonts of the Sacaton Mountains. They locally have thin and patchy veneers of middle to late Pleistocene alluvium. Pedimented surfaces are found on bedrock types Kg, Kgq, Kgm, Kgk, Kgs, and Yg. Soils are on pediment surfaces are patchy, but where well-preserved typically have a red-orange color that is diagnostic of middle Pleistocene soils.

d - dump pits

g - sand and gravel pits

m - mines and mine tailings

earth fissures

Geologic/Geomorphic Framework

The Casa Grande area is located in the northeastern part of the Sonoran Desert subprovince of the Basin and Range physiographic province. The physiography of the Basin and Range province in Arizona is characterized by alluvial basins and intervening mountain ranges that formed as a result of normal faulting related to extension of the crust between about 30 and 6 Ma (Shafiqullah and others, 1980; Menges and Pearthree, 1989). The landscape of the Casa Grande area consists of small, low-lying mountain ranges and broad, minimally dissected basins that are typical of the Sonoran Desert subprovince. Bedrock exposures are limited to these mountain ranges and a few outlying knobs (inselbergs) that rise above the basin floors and broad plains surrounding the mountain ranges. Most of the map area is covered by late Quaternary alluvium that was deposited by the Santa Cruz River and the many smaller tributary washes that drain the region. The surficial geology and geomorphology of this area record the gradual transfer of material from the mountains to the surrounding piedmonts and basin floors during the past few million years in the absence of significant tectonic activity.

Pre-Quaternary rocks are extensively exposed in the Sacaton Mountains, along the northern margin of the map area, and in a few hills and isolated inselbergs in the central and southwestern parts of the map area. The Sacaton Mountains are composed almost entirely of plutonic rocks ranging in age from Middle Proterozoic to Early Tertiary. A thin sliver of Paleozoic or Middle Proterozoic quartzite along with some other fine-grained metasedimentary rocks occur along the contact between the area's two most abundant plutonic rock types at the north edge of the map area. The oldest rock, exposed only in the western part of the range, consists of a multiphase, medium- to coarse-grained K-feldspar porphyritic granite that is characterized by magmatic foliations, contacts between phases, and diabase dike swarms that all strike northwesterly (Skotnicki and Ferguson, 1996). Two K-Ar biotite dates from the granite at 870 $\pm$ 18 Ma and 1253 $\pm$ 56 Ma (Balla, 1972) are highly suggestive of a Middle Proterozoic "anorogenic" (approximately 1400 Ma) emplacement age reset by a yonger thermal event, possibly related to intrusion of the diabase dikes, one of which has been dated at 854 $\pm$ 18 Ma (K-Ar biotite, Balla, 1972). Intruding the Proterozoic granite in the west and making up the entire eastern part of the Sacaton Mountains is a suite of Laramide, fine- to medium-grained granitic rocks ranging in composition from granite to quartz monzodiorite. These plutonic rocks, collectively referred to as Sacaton Peak Granite, are typically equigranular, but locally quartz or K-feldspar porphyritic, and characterized by finer-grained, relatively mafic border phases along its contacts (Skotnicki and Ferguson, 1996). Contacts between its internal phases, contacts with older rocks, and swarms of a wide variety of dikes are all northeast-striking, a trend which characterizes the Laramide plutonic rocks throughout southeastern Arizona. Balla (1972) reports three K-Ar biotite ages of 49.8 $\pm$ 0.7 Ma, 62. 9 $\pm$ 1.4 Ma, and 73.4 $\pm$ 1.4 Ma for these rocks, and Pushkar and Damon (1974) report a K-Ar biotite date of 65.5 $\pm$ 1.4 Ma at the Sacaton Porphyry copper deposit. The southeasternmost exposures of the granite (Signal Peak phase of the Sacaton Peak Granite) hosts well-developed, gently south-dipping mylonitic fabrics with down-dip lineations (Skotnicki and Ferguson, 1996). These fabrics are probably related to a major south-dipping detachment fault which is exposed in the Sacaton Porphyry copper deposit (Cummings, 1982). None of the faults at the Sacaton Porphyry copper deposit or elsewhere in the Sacaton Mountains displace surficial deposits, so there is no evidence that they have been active during the Quaternary.

The geomorphology and surficial geology of the Casa Grande area record its recent geologic evolution. The landscape of southwestern Arizona may be grouped into three main elements: 1) narrow, rugged, but not very lofty mountain ranges; 2) wide, gently sloping piedmonts with minimal topographic relief that fringe the mountains; and 3) broad, flat basin-floor areas occupied by major regional drainage systems. Each of these landscape elements is represented in the Casa Grande area.

The broad, undissected basin-floor areas record the slow, long-term aggradation of the major regional drainage systems that cross the map area. Major flow paths in the map area include the Santa Cruz River, Santa Rosa Wash and North Branch of the Santa Cruz. The North Branch of the Santa Cruz flows south along the east side of the Sacaton Mountains and turns west to flow along the southern piedmont of the Sacatons. Santa Rosa Wash flows from the south and joins flow from the Santa Cruz and the North Branch of the Santa Cruz northwest of Casa Grande. Nearly all of the basin-floor areas are mantled with deposits of these regional drainages. Wide floodplains of these drainages are composed of Holocene deposits of sand, silt and clay, with local gravel. Multiple small, discontinuous channels were typical, and well-defined channels were probably unusual, prior to human alteration of the floodplain for agricultural purposes. Locally, alluvial fans exist along these washes where floodplains are very wide and increase in width substantially downstream (near Chuichu, for example). In the modern environment, however, most channels have been artificially confined between earthen berms to contain low and moderate flows through much of the basin (Rhoades, 1991). During large historical floods of the latter part of this century, however, broad portions of the basin floor were inundated (see Roeske and others, 1989; Wood and others, in review). There is also evidence that flow paths across the map area during large floods have changed significantly since the early 1900's, partly as a result of human alterations of the Santa Cruz channel upstream of the map area (Smith, 1938; Cooke and Reeves, 1976; Wood and others, in review). These changes in channel positions and flow paths were facilitated by the low stream gradients and minimal topographic relief on the basin floors.

Active and recently active channels and floodplain areas are fringed by low Pleistocene terraces and alluvial fans. These deposits, which are prevalent east and south of the City of Casa Grande, record former positions of the Santa Cruz River during the middle to late Pleistocene. Drill-core data from beneath a Pleistocene surface in the central part of the City of Casa Grande reveals an depositional sequence of sand, silt, and clay that includes several well-developed soils (Amoroso, 1997). The cored sequence is about 25 m thick. Based on variations in calcium carbonate content and sediment color, Amoroso argued that there are 5 buried paleosols in the upper 15 m of the sequence. He interpreted the soils as indicating lengthy periods of stability (no deposition) when soil formation occurred, separated by periods of aggradation. He concluded that the entire depositional sequence covers at least 180,000 years. We interpret the surface deposits in this area as being at least 10 ka. Thus, the drill-core data probably record the past several hundred thousand years intermittent aggradation of the Santa Cruz river system in the Casa Grande area.

Piedmonts of the map area are covered by alluvial and eolian deposits, most of which are fairly young. Upper piedmont areas typically have tributary (converging downstream) drainage systems. These areas contain alluvial surfaces that range in age from Holocene to middle, and locally early, Pleistocene. Topographic relief between active channels are adjacent relict alluvial

fan surfaces is generally a few meters or less. There is substantial variation in the extent of young and old alluvial surfaces on upper piedmont areas. This probably depends on the amount and size of sediment supplied from the adjacent mountains along the mountain fronts, and local base-level changes that may cause stream entrenchment. Middle and lower piedmonts have complex distributary (diverging downslope) and tributary drainage networks. Topographic relief is minimal; channels are entrenched less than 2 m below adjacent alluvial surfaces. Broad portions of the middle and lower piedmonts are covered by Holocene deposits. Late to latest Pleistocene deposits are commonly exposed in shallow pits and roadcut exposures throughout these areas, which indicates that the extensive veneer of young deposits is generally quite thin. Middle Pleistocene and older deposits are probably buried beneath a mantle of late Pleistocene and Holocene alluvium on middle and lower piedmonts, because they are rarely exposed in these areas.

The topographic fronts of the mountains are very embayed and sinuous, and outlying inselbergs are common. The steep mountain slopes with limited cover of colluvium attest to the predominance of erosional processes over in situ weathering in the modern environment. Erosion is facilitated by uncommon but intense rainfall and runoff, steep slopes, and sparse vegetative cover. It is likely that significantly more hillslope colluvium covered bedrock slopes in the mountains during glacial pluvial intervals of the Quaternary, especially in ranges such as the Sacaton Mountains that are composed of granitic or metamorphic rocks (Bull, 1991). The dramatic glacial-interglacial cycles of the Pleistocene probably resulted in periods of accumulation of colluvium and erosion of colluvium that are recorded as alluvial fans and fan remnants on the piedmonts. Analysis of packrat middens indicates that the climate similar to today has only existed since about 4 ka (Van Devender, 1990). Late Pleistocene midden samples from the Sonoran Desert contain fragments of juniper, pinyon pine, and Joshua tree, indicating cooler summers and a greater proportion of winter precipitation than today. Precipitation probably reached a maximum during the late Pleistocene (30 to 15 ka), and precipitation falling during winter months would have infiltrated more deeply than summer moisture due to lowered evaporation rates. Due to the increased effectiveness of leaching and equable temperatures, as well as the increased proportion of winter rain, late Pleistocene climate was apparently more conducive to weathering of minerals and accumulation of colluvium on hillslopes than the modern interglacial moisture regime. Much of this Pleistocene colluvium may have been flushed onto the surrounding piedmonts in the past 10,000 to 15,000 years, resulting in the deposition of the broad, thin mantle of Holocene to late Pleistocene alluvium that covers most of the piedmont areas.

Geologic Hazards

This sections summarizes the character and distribution of the principal geologic hazards that exist in the Casa Grande area. This information is fairly general in nature. Detailed site-specific geologic, engineering, hydrologic, or soils investigations may be required to thoroughly assess potential hazards at particular locations. More specific information on soil properties may be obtained from Hall and others (1991), and information on mapped floodplain and flood-prone areas may be obtained from local floodplain management agencies.

Flooding hazards. Flooding hazards in the Casa Grande area may be subdivided into those associated with major regional drainage systems and those associated with smaller tributary drainages. The largest channels in the study area are the Santa Cruz River, Santa Rosa Wash and the North Branch of the Santa Cruz. The North Branch of the Santa Cruz flows southeast along the Sacaton Mountains and turns to the west to flow along the southern piedmont of the Sacatons. Santa Rosa Wash flows from the south and joins the Santa Cruz and the north branch of the Santa Cruz northwest of Casa Grande. Flooding on these large drainages have resulted from regional storms in the winter and late summer - early fall. Their smaller tributaries drain the mountain ranges, the piedmonts, and portions of the basin floors. Floods on these drainages result from intense, localized thunderstorms that occur during the summer or early fall.

The Santa Cruz River, the largest drainage in the map area, flows from southeast to northwest and poses the greatest flood hazard to basin-floor areas. The largest floods in the historical record occurred in 1905, 1914-1915, 1977, 1983, and 1993, with 1983 being the peak of record at gages in the upper Santa Cruz and at the confluence with the Gila River (Laveen gage). The 1983 flood had its source in moisture which persisted from September 27 to October 3, 1983 and was derived from a high-altitude, low-pressure trough combined with additional moisture from Hurricane Octave off the coast of California. Rainfall intensities peaked on October 1st and 2nd as Hurricane Octave combined with the low pressure trough and were greatest in the upper watershed of the Santa Cruz, with 9.90 in. at Mt. Lemmon and 9.72 in. north of Nogales. Peak discharges on the Santa Cruz occurred on October 2nd ; gages in the upper watershed as well as the mouth of the Santa Cruz experienced ~100 year recurrence interval flows. Broad areas of the Maricopa-Stanfield basin were inundated in a northwest-southeast swath across the project area from Chuichu through the majority of the Coolidge 7.5' Quadrangle (Roeske and others, 1989) (see Figure 2).

This is in contrast to floods that occurred earlier in the century (1914-1915) in which flooding was also prevalent in the northeastern part of the project area along the North Branch of the Santa Cruz (Smith, 1938). The primary cause for this change lies in channel modifications begun around the turn of the century upstream of the map area. In 1910, Colonel William C. Green led the construction of a diversion dam and canal in order to direct flow from the Santa Cruz to a reservoir, and distribute to croplands. These diversion structures were still under construction when the floods of 1914-1915 destroyed the diversion dam and eroded the channel to a depth of 12 feet. During these floods, floodwater was partioned between flow to the northwest across Picacho basin and flow to the west along Greene's Canal. Most of the northwestern branch of flow followed the North Branch of the Santa Cruz through modern Casa Grande, but some followed the course of McClellan Wash northward to join the Gila River (Figure 2). Greene's Canal subsequently became the new main channel for the Santa Cruz. Large floods in 1977, 1983, and 1993 have continued to entrench the canal such that channels in the northeastern part of the study area such as the North Branch of the Santa Cruz and McClellan Wash do not receive significant flow from the upper Santa Cruz River (Wood and others, in review). Both Holocene and Pleistocene surfaces were inundated during 1983 and 1993 along the modern flow path in the Maricopa-Stanfield basin.

In sum, flow paths of the Santa Cruz River have migrated from east to west across the map area during historic times. Areas which are today susceptible to flooding are indicated by the flow paths taken by the 1983 floods (Figure 2). Chuichu, located in the southern portions of the

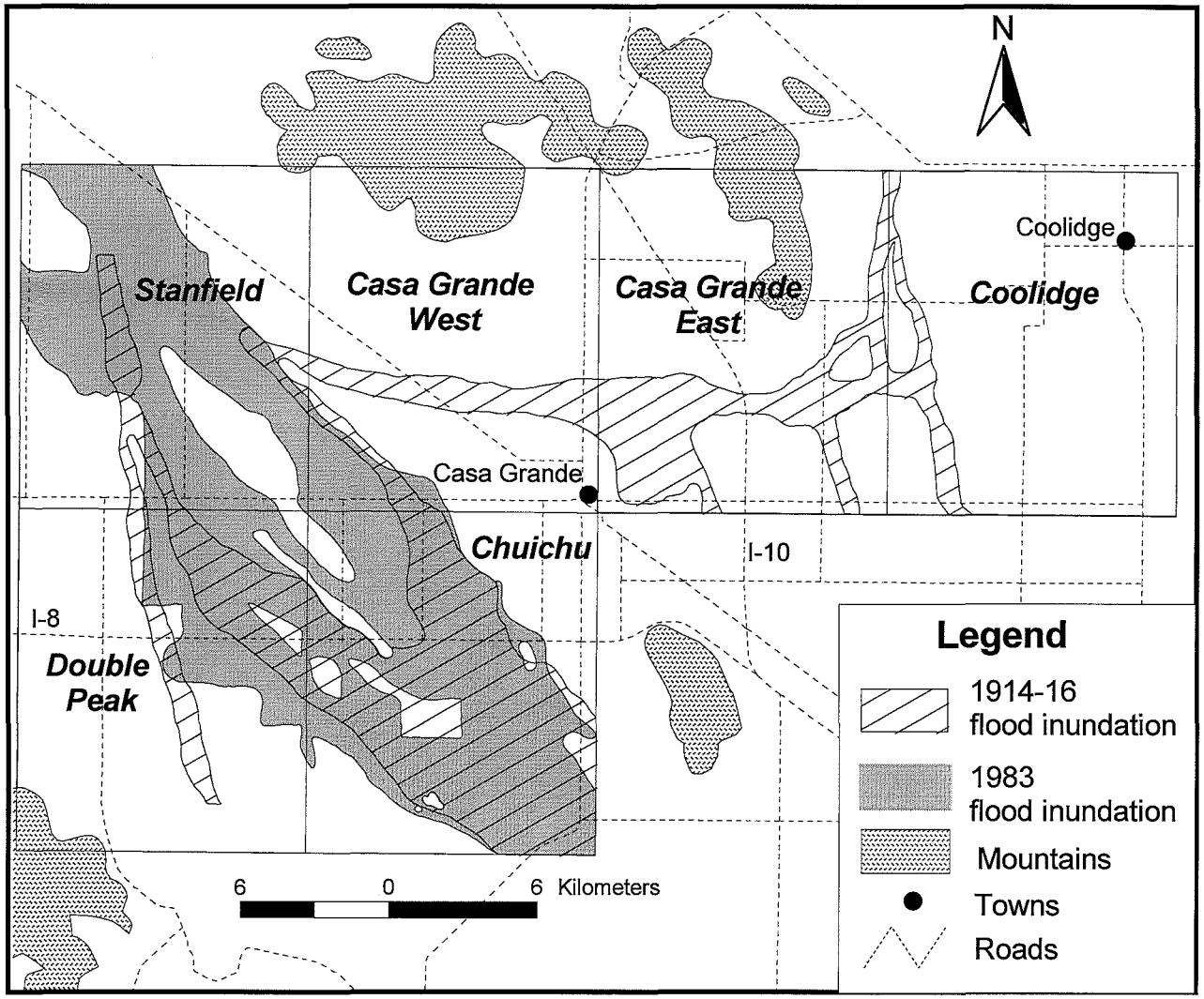

Figure 2. Flood Hazards of the Casa Grande area
The most significant floods which have affected the study area include those of 1914-16, mapped by Smith (1938; 1940) and 1983, mapped by Roeske et al (1989). Present flood hazards are reflected most accurately by the extent of flooding in 1983 due to channel changes in the early 1900's.
(modified from Wood, et al,1996).

project area marks the modern geomorphic transition in the Santa Cruz from a well-defined channel to a broad alluvial plain with intermittent channels (Wood and others, in review). This weakly defined channel pattern along with the low gradient in the area increases the potential for channel changes downstream of this point during large floods. The low relief between young and older surfaces allows for broad inundation in the basin area and current flooding hazard which cannot be confidently predicted by the age of the alluvial surface on the basin floor.

Floods on the relatively small streams that cross piedmont areas are generated by intense, localized thunderstorms that occur in the late summer and early fall. Flood hazards are relatively easy to manage where topographic relief contains floodwater to channels and adjacent low terraces. In these situations, the area that may be impacted by flooding is restricted and should be easy to avoid. It is much more difficult to assess and manage flood hazards associated with alluvial-fan flooding. This type of flooding occurs where topographic relief is minimal and floodwater can spread widely. In these areas, channels may or may not be well defined, and their positions may shift during floods, and inundation is likely to be widespread during floods.

Surficial geologic mapping provides important information about the extent of flood-prone areas on the piedmonts, and it is the best way to delineate areas that may be prone to alluvial-fan flooding. Floods leave behind physical evidence of their occurrence in the form of deposits. Therefore, the extent of young deposits on piedmonts is a good indicator of areas that have been flooded in the past few thousand years. These are the areas that are most likely to experience flooding in the future. Following this logic, the extent of potentially flood-prone areas on the piedmont varies with the extent of young deposits (units Qy2, Qy1, Qy, and Qly). Widespread young deposits (and thus potentially active alluvial fan areas) are found primarily in middle and lower piedmont areas, where topographic relief is minimal. Portions of these areas will be subject to widespread, relatively shallow inundation during large floods, with local deeper, higher-velocity flow in small channels. There are also some active alluvial fans adjacent to the Sacaton Mountains, but generally streams are topographically confined by older deposits near the mountain front. In these areas, flood hazards may be minimized by avoiding development in and immediately adjacent to channels.

Soil problems. Several types of soil/substrate problems may be encountered in the Casa Grande area (see Hall and others, 1991, for more detailed soils information). Large parts of the basin floors may be susceptible to shrinking and swelling of soils during drying and wetting cycles. Areas with clay-rich Pleistocene soils at the surface (map unit Qmlr) are most likely to be affected, but other areas covered by young deposits have clay-rich Pleistocene soils in the near subsurface (Qysr, for example) and may also be affected by shrink-swell activity. Soil collapse or compaction upon wetting or loading (hydrocompaction) may be an important geologic hazard on the basin floors and lower piedmonts. Hydrocompaction is a reduction in soil volume that occurs when susceptible deposits are wetted for the first time after burial. Deposits that are susceptible to hydrocompaction are typically relatively fine-grained, young sediments that are deposited in a moisture-deficient environment. Deposits in the map area that are the most likely candidates for hydrocompaction are the fine-grained alluvial fans of units Qy1 and Qly on the lower piedmonts, and Qy1r on the basin floor.

Potential soil problems in middle and upper piedmont areas consist of shrink-swell potential, low infiltration rates, and hard substrate. Shrink-swell problems may exist on clay-rich soils of

unit Qm, although the gravel that is common in these deposits may minimize these problems. Excavation may be difficult and near-surface infiltration rates low on the oldest piedmont units (Qm and Qo) due to the existence of carbonate- and silica-cemented hardpans (petrocalcic and duric horizons). Similar problems may be encountered on all surficial units and exposed bedrock pediments in the uppermost piedmont areas because of the existence of bedrock at shallow depths.

Debris flows and rockfalls. Debris flows and rockfalls are potential hazards in and immediately adjacent to the Sacaton Mountains. A few fresh debris-flow scars exist on steep slopes of the Sacaton Mountains. These mass movements most likely occurred during intense precipitation events. They may have been begun as landslides on very steep mountain hillsides that continued downslope as debris flows following stream channels until they encountered the shallower gradient of the larger trunk stream. There is no sedimentologic evidence of debris-flow activity in the young deposits mapped on the piedmont. Rockfalls are a potential hazard below bedrock cliffs and where bedrock outcrops exist at or near the top of steep mountain hillslopes. In these situations, large rocks that are loosened by weathering may cascade violently downhill. The existence of large boulders near the base of a steep slope should be considered evidence of potential rockfall hazard in most cases.

Land subsidence and earth fissures. In the Casa Grande area, agriculture has been a driving force in the local economy and has resulted in the heavy use of ground-water resources. Because ground-water recharge in the area is limited, ground-water withdrawal has resulted in subsidence of the land surface in basin areas and the development of earth fissures near the basin margins.

Earth fissures are surface tension cracks caused by subsidence due to excessive withdrawal of ground water from underlying aquifers. As water is withdrawn from the interstices of aquifer sediment, the material compacts to fill in the empty pore space. If recharge rates are substantially less than withdrawal rates, aquifer compaction may be expressed on the surface as land subsidence and earth fissure development. Land subsidence occurs as a circular depression around areas of greatest ground water pumping (Slaff, 1993) and is usually greatest near the center of this depression. Earth fissures are formed on the edges of the "bowl" by differential compaction as areas of greater subsidence encounter those with less (Schumann and Genualdi, 1986). They begin as tension cracks in the subsurface, and enlarge as they capture surface runoff. As subsurface piping continues, they appear at the surface as small, aligned pits and cracks. When enough of the underlying soil is eroded, the roof over the fissure collapses, and reveals the underlying subsidence crack (Pewe, 1990). On the surface, these features are a preferred flow path for runoff and develop into gullies which may be as deep as 5 m and wider than 15 m (Schumann and Genualdi, 1986). Over time, material from the sides of the fissure and vegetation begin to fill in the fissure such that it becomes a linear depression in the landscape. Fissures may repeat part or all of this sequence if further lateral stresses are induced (Pewe, 1990)

Earth fissures are prevalent in the lower Santa Cruz River valley because of the extensive use of ground water for irrigation agriculture. In the Casa Grande area, ground water pumping began around the turn of the century and intensified in the 1940's (USGS, 1985). The first earth fissures were detected in 1948 near Eloy, Arizona through the releveling of benchmarks (Robinson and Peterson, 1962); by 1977, 425 mi^2 near Stanfield had undergone a subsidence of 11.8 ft (Laney and others, 1978).

Earth fissures in Casa Grande and vicinity have been mapped by Harris (1995) using earth fissure maps of several authors (see Harris, 1995), helicopter surveys, and 1987 aerial photos to identify new fissures and any changes in existing fissures. In the project area, earth fissures are located in Holocene alluvium in the Casa Grande East, Stanfield, and Double Peak 7.5' Quads. They tend to form in groups, parallel to mountain fronts in alluvium of the lower piedmont and may crosscut or follow natural drainage patterns.

Land subsidence and earth fissures pose a hazard to developed areas within the subsidence depression. Canals, highways and irrigation systems are affected more frequently than individual structures such as houses because they crosscut the area of subsidence and are more likely to experience the effects of differential compaction. Changes in the gradient of an agricultural area become problematic for canals and irrigation ditches which function most efficiently at their designed gradient. In addition, entire agricultural fields must be releveled, as was the case in the lower Santa Cruz valley (Schumann and Genualdi, 1986). Water wells become difficult or impossible to operate following subsidence; in many instances, the casing bottom is located below the zone of compaction such that the well itself does not lower with the ground but remains in its original position. This leaves the wellhead elevated above the ground surface and causes well casings which line the well to break or bend, rendering the well useless for the pumping and monitoring of ground water (Slaff, 1993).

Areas of subsidence may also affect the gradient and behavior of stream systems. As a stream enters the subsidence bowl, gradient increases and causes stream incison into previously stable subtrate; as the gradient decreases toward the center of the bowl, the stream loses its capacity to transport sediment and deposits its sediment load on the landscape. Changes in moisture availability, vegetation, and land use may accompany stream adaptations. In some areas the subsidence may be too great to allow streams to exit the depression, thus creating a new flood-prone region.

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Appendix A - Soil Descriptions

Soil No. 1

Alluvial Surface: Ql (Qm buried)

Location: NE1/4, SW1/4, Sec. 18, T5S, R6E ; Casa Grande West 7.5' Quad

Physiographic Position: upper piedmont

Vegetation: Creosote

Sampled by: Jeanne Klawon, May 6, 1998

Remarks: Coppice dune surrounds creosote at top of profile

Av 0-1 cm. 7.5YR 6/4 (dry) sandy loam, 10YR 4/4 (moist), fine platy and vesicular, nonsticky and nonplastic (wet), slightly effervescent, gravel lag on surface.

Bw 1-15 cm. 7.5YR 6/4 (dry) gravelly sandy loam, 10 YR 4/4 (moist), subangular blocky at upper contact grading to massive near base, moderately to strongly effervescent, increase in organic material.

Bk_1 15-27 cm. 7.5 YR 6/4 (dry) extremely gravelly sandy loam with, 7.5 YR 5/4 (moist), subangular blocky, nonsticky and nonplastic, strongly effervescent with intergranualar carbonate and thin discontinuous coatings around gravels.

Bk_2 27-49 cm. 7.5 YR 7/4 (dry) loamy sand, 7.5 YR 4/6 (moist), massive, nonsticky and nonplastic, moderately to strongly effervescent with carbonate filaments and soft nodules.

Bkmb 49-135 cm. 7.5 YR 7/4 (dry) sandy loam, 10 YR 5/4 (moist), vesicular and subangular blocky, slightly sticky and nonplastic, strongly effervescent with intergranular carbonate and carbonate nodules.

Bkb 135+ cm. 7.5 YR 7/2 (dry) gravelly loamy sand, 10 YR 6/3 (moist), massive, nonsticky and nonplastic, strongly to violently effervescent with intergranular carbonate.

Soil No. 2

Alluvial Surface: Qlye

Location: NE1/4, SW1/4, NW1/4, Sec. 2, T6S, R6E; Casa Grande East 7.5' Quad

Physiographic Position: southwest face of active stream channel, lower piedmont

Vegetation: Creosote

Sampled by: Jeanne Klawon, May 6, 1998

Remarks: Thickness of A horizon variable along bankcut

A 0-2 cm. Light yellowish brown (10 YR 6/4) loamy sand, dark yellowish brown (10 YR 4/4) moist, fine platy and vesicular, nonsticky and nonplastic, noneffervescent, sharp wavy contact, gravel lag on surface.

Bw 2-14 cm. 7.5 YR 5/6 sandy loam, dark yellowish brown (10 YR 4/6) moist, weak subangular blocky, slightly plastic and nonsticky, noneffervescent, sharp ? contact.

Bk 14-41 cm. Yellowish brown (10 YR 5/6) loamy sand, dark yellowish brown (10 YR 4/6) moist, massive in upper half to platy in lower half, nonsticky and nonplastic, moderately effervescent with carbonate filaments, irregular nodules and intergranular carbonate, sharp contact.

$Btky_1$ 41-67 cm. 7.5 YR 5/6 (dry) sandy clay loam, dark yellowish brown (10 YR 4/6) moist, subangular blocky, moderate to strongly effervescent with disseminated carbonate, granular gypsum on ped surfaces and minor irregular gypsum nodules, weak clay skins on ped surfaces.

$Btky_2$ 67-109+ cm. 7.5 YR 5/6 (dry) sandy clay loam, dark yellowish brown (10 YR 4/6) moist, subangular blocky, moderately plastic and slightly sticky, moderately effervescent with disseminated carbonate, crystal aggregates of gypsum, clay skins on ped faces.

Soil No. 3

Alluvial Surface: Qlye (Ql? buried)

Location: SE1/4, SW1/4, Sec. 2, T6S, R6E; Casa Grande East 7.5' Quad

Physiographic Position: lower piedmont

Vegetation: Creosote

Sampled by: Jeanne Klawon, May 5, 1998

Remarks: surface lag of quartz and feldspar pebbles

A 0-5 cm. (7.5 YR 6/4) silty clay loam, dark yellowish brown (10 YR 4/4), fine platy and vesicular, very sticky and moderately plastic (wet), noneffervescent, clear wavy contact.

Bw 5-24 cm. (7.5 YR 5/6) loam, (7.5 YR 4/4) moist, massive to weak subangular blocky, slightly sticky and moderately plastic (wet), noneffervescent, minor gypsum crystal aggregates.

Btkb 24-38 cm. (7.5 YR 5/6) gravelly loam, (7.5 YR 4/6) moist, weak vesicular and moderate subangular blocky, slightly sticky and moderately plastic (wet), strongly effervescent with intergranular carbonate, incipient clay skins.

Bkmb 38-48 cm. (7.5 YR 4/6) sandy clay loam, (7.5 YR 4/6) moist, moderate subangular blocky, slightly sticky and moderately plastic (wet), strongly effervescent with discontinuous intergranular and nodular carbonate, gypsum on ped surfaces, incipient clay skins.

Soil No. 4

Alluvial Surface: Qme

Location: NE1/4, NE1/4, Sec. 33, T5S, R5E; Casa Grande West 7.5' Quad

Physiographic Position: middle piedmont

Vegetation: Creosote, bursage

Sampled by: Jeanne Klawon, May 5, 1998

Remarks: surface pit on surface with pebble lag of moderate varnish

Av 0-2 cm. (7.5 YR 6/6) sandy loam, (7.5 YR 4/6) moist, fine vesicular and platy, moderately sticky and moderately plastic (wet), slightly effervescent, clear wavy contact.

Bw 2-8 cm. (7.5 YR 5/6) loamy sand, (5 YR 4/6) moist, massive grading to weak subangular blocky and weak vesicular, nonsticky and nonplastic (wet), slightly effervescent, minor irregular gypsym nodules.

Btk 8-30 cm. (5 YR 5/8) gravelly sandy clay loam, (7.5 YR 5/6) moist, weak subangular blocky, moderately sticky and moderately plastic (wet), strongly effervescent with intergranular carbonate and incipient carbonate nodules, very weak clay skins.

Bt 30-35+ cm. (5 YR 5/6) loamy sand, (5 YR 5/8) moist, weak subangular blocky, nonsticky and nonplastic (wet), slightly effervescent, very weak clay skins.

Soil No. 5

Alluvial Surface: Qy1

Location: SE1/4, SE1/4, Sec. 25, T5S, R6E; Casa Grande East 7.5' Quad

Physiographic Position: upper piedmont

Vegetation: Creosote, grass

Sampled by: Jeanne Klawon, May 13, 1998

Remarks: surface lag

Av 0-1 cm. (7.5 YR 5/4) very gravelly loamy sand, dark yellowish brown (10 YR 4/4) moist, very fine to fine platy and vesicular, loose, noneffervescent, clear smooth contact.

Bw_1 1-16 cm. (7.5 YR 5/6) very gravelly loamy sand, (7.5 YR 4/6) moist, fine platy and subangular blocky, soft, noneffervescent, gradual smooth contact.

Bw_2 16-77+ cm. (7.5 YR 5/6) gravelly loamy sand, (7.5 YR 4/6) moist, medium subangular blocky, soft, noneffervescent.

Soil No. 6

Alluvial Surface: Qlye (Ql, Qm buried)

Location: NW1/4, NW1/4, SW1/4, Sec. 34, T5S, R6E; Casa Grande East 7.5' Quad

Physiographic Position: lower piedmont

Vegetation: Creosote

Sampled by: Jeanne Klawon, May 13, 1998

Remarks: Surface lag of quartz and feldspar pebbles; lowermost two horizons (below the squiggly line) were described at a cut bank approximately 25 m west of the original surface pit. Upper horizons in the cut bank were correlated with those of the surface pit.

A 0-1 cm. (7.5 YR 5/6) gravelly sandy loam, (7.5 YR 4/4) moist, vesicular and medium platyl, slightly hard, slightly sticky to sticky and slightly plastic (wet), noneffervescent, clear wavy contact.

Bw_1 1-6 cm. (7.5 YR 5/6) very gravelly sandy loam, (7.5 YR 4/6) moist, medium subangular blocky, slightly hard, slightly sticky and slightly plastic (wet), noneffervescent, clear smooth contact.

Bw_2 6-34 cm. (7.5 YR 5/6) gravelly sandy loam, (7.5 YR 4/6) moist, medium subangular blocky, hard, nonsticky to slightly sticky and slightly plastic (wet), noneffervescent, clear smooth contact.

$Btkb_1$ 34-41 cm. (7.5 YR 5/6) sandy clay loam, (5-7.5 YR 4/6) moist, vesicular and medium angular blocky, hard to very hard, slightly sticky and slightly plastic to plastic, moderately effervescent with discontinuous carbonate coatings, filaments and partial nodules, weak clay films, abrupt smooth contact.

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$Btkb_2$ 41-57 cm. (5 YR 4/6) gravelly loam, (5YR 4/6) moist, medium subangular blocky, slightly hard, sticky and plastic (wet), strongly effervescent with discontinuous carbonate coatings, moderate clay films, abrupt smooth contact.

Bkmb 57-102+ cm. (7.5 YR 5/6) loam, (7.5 YR 5/6) moist, medium angular blocky, hard to very hard, sticky and plastic (wet), violently effervescent, continuous carbonate coatings and interclast carbonate, weak clay films.
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