

CAVE CREEK DRAINAGE MASTER PLAN

January 2008



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1. INTRODUCTION

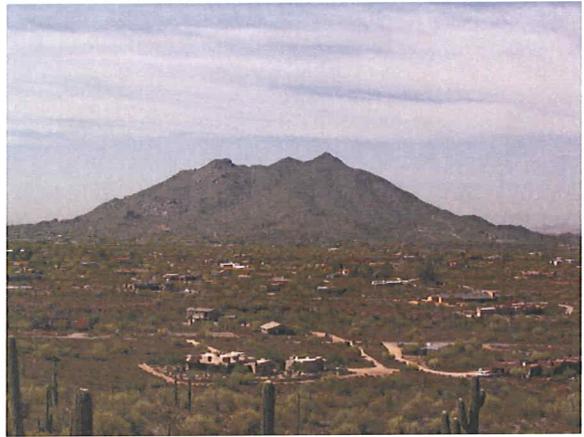
Cave Creek is known for its rustic character, desert setting, and western, independent lifestyle. The landscape setting is predominantly hills and mountains, many with braided or sinuous washes. The scenic desert vegetation is one of many attractions for new and old residents alike.

Development pressures and recent damaging storm events prompted the Town of Cave Creek (Town) to request a *Drainage Master Plan* (DMP) to be initiated by the Flood Control District of Maricopa County (District). The DMP identifies drainage problems and develops solutions to alleviate or manage flooding in the Town area. The DMP is prepared under the authority of Arizona Revised Statutes (ARS) Title 48, Chapter 21. The District contracted with HDR Engineering, Inc. (HDR) to prepare the DMP for the Town. In turn, HDR worked with JE Fuller and LTM Engineering to complete the study as well as with District and Town personnel.

The District plans for regional flood control improvement in advance of development wherever possible. This allows flood control features, if needed, to be built into the context of the natural environment rather than becoming something appearing wedged or forced in. This approach is often more cost effective as well.

The DMP effort included survey and mapping; hydraulics, hydrology, geomorphic and sedimentation evaluation; environmental overview; landscape character resources overview; a series of public meetings and workshops; and the development of elements to minimize the risk of flood related damage. Several technical memoranda, listed below, were prepared over the course of the project; the content of which are summarized in the DMP.

- Survey Report
- Data Collection Report
- Major Wash Identification
- Hydrology Report
- Hydraulics Report
- Geomorphic and Sedimentation Engineering Report
- Ocotillo Wash Floodplain Redelineation and Technical Data Notebook
- Floodplain Delineation of Galloway Wash Tributaries, Willow Springs Wash Tributaries, and Cave Creek Tributaries and Technical Data Notebook
- Flood Response Plan
- Drainage Guidelines
- Scenery Resource Report
- Potential Alternatives Report



A view of the Town of Cave Creek

- Alternatives Formulation Report
- Manning's "n"-value Report
- Two-foot contour mapping

2. PURPOSE AND GOALS

During storms the residents of the Town are frequently stranded at home or prevented from getting home. Residents expect some level of protection from natural hazards, and while they are willing to wait an hour or two for the water to recede before crossing a wash, this delay could be very costly if emergency vehicles are unable to reach their destination. The purpose of the DMP is to identify flooding hazards in the Town and develop strategies to protect the public from these hazards.

The goals of the Cave Creek DMP are:

- Identify flooding issues
- Identify erosion hazard areas and how to protect residents
- Preserve the natural desert and western characteristics of the Town

Specific tasks to achieve these goals include:

- Identify the flooding hazards in the area and prepare the Federal Emergency Management Agency (FEMA) floodplain delineations for selected washes.
- Develop a plan that area floodplain managers, municipalities, and developers will use as a basis for drainage and watershed regulation, improvements, and design.
- Quantify the extent of existing and future potential flooding problems within the Town and develop alternative solutions to reduce flooding and to determine potential emergency access routes to as many residences as it is feasible.
- Conduct a Public Involvement Program to gather and disseminate information regarding flooding, sedimentation, and erosion problems, keeping the citizens of the Town informed on the progress of the study and to obtain acceptance of the study and its findings and recommendations.
- Perform a qualitative evaluation of the erosion and sedimentation patterns and characteristics within the Town and upstream contributing areas. Where appropriate, provide a tool for estimating the long-term benefits of proposed improvements.
- Identify cost-effective, sustainable flood and erosion control alternatives for the project area that may be implemented together or individually, based on scheduling, funding, and cost sharing.

3. DESCRIPTION OF PROJECT AREA

The project boundary encompasses the entire Town plus unincorporated portions of Maricopa County land and portions of land from the Arizona State Land Trust. The Town is located in portions of Township 5 North, Ranges 3 and 4 East and Township 6 North, Ranges 3 and 4 East. The Town is east of the Gila and Salt River Meridian within Maricopa County (*Figure 1* on page 2). The Town is bounded by Maricopa County unincorporated land, Tonto National Forest, Carefree, and the cities of Phoenix and Scottsdale. The study limits are shown in *Figure 2* on page 4.

Much of the study area is hilly terrain. Elevation ranges from approximately 1,750 feet to 3,850 feet, with slopes as steep as 15 percent to as flat as 0.2 percent. Many of the washes are deeply incised with vertical side slopes. Washes are predominantly ephemeral, as they are throughout Maricopa County.

There are several major washes transecting the study area, including Cave Creek, Willow Springs Wash, Ocotillo Wash, Rowe Wash, and Galloway Wash as shown in *Figure 3* on page 5. Approximately 90 linear miles of watercourses were considered for delineation in the preparation of the DMP.

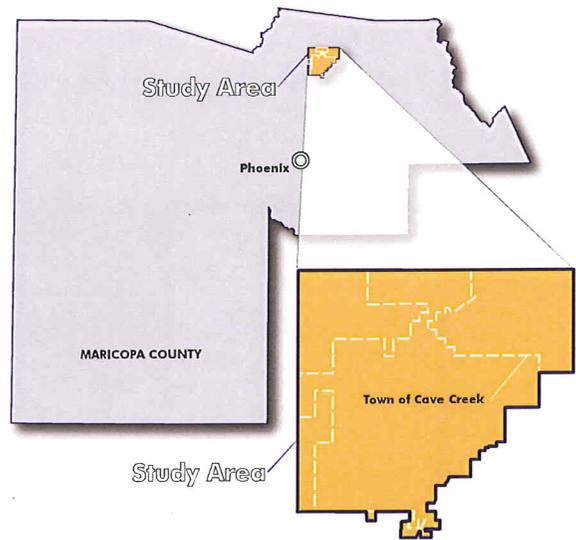


Figure 1. Study area location of the Town of Cave Creek

4. DATA COLLECTION SUMMARY

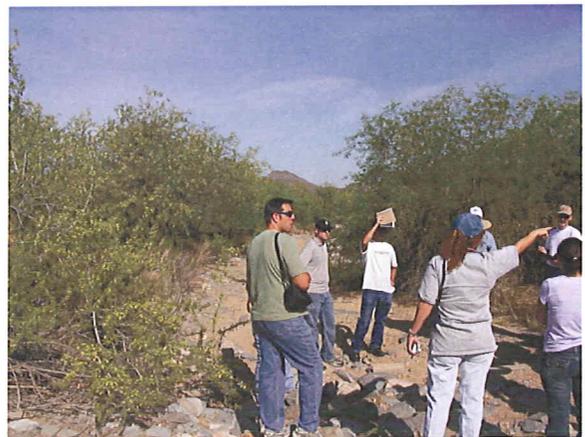
Information was obtained from a variety of sources, including the District, Maricopa County Department of Transportation (MCDOT), the Town, FEMA, the public, and field reconnaissance. Data were obtained from as-built plans, Geographic Information System (GIS), previous studies and reports, photos, and interviews. Research for the project was performed at the local library archives, newspaper databases, District databases, and flood gage records. Additionally, historical aerial photographs were obtained and reviewed.

Current Conditions

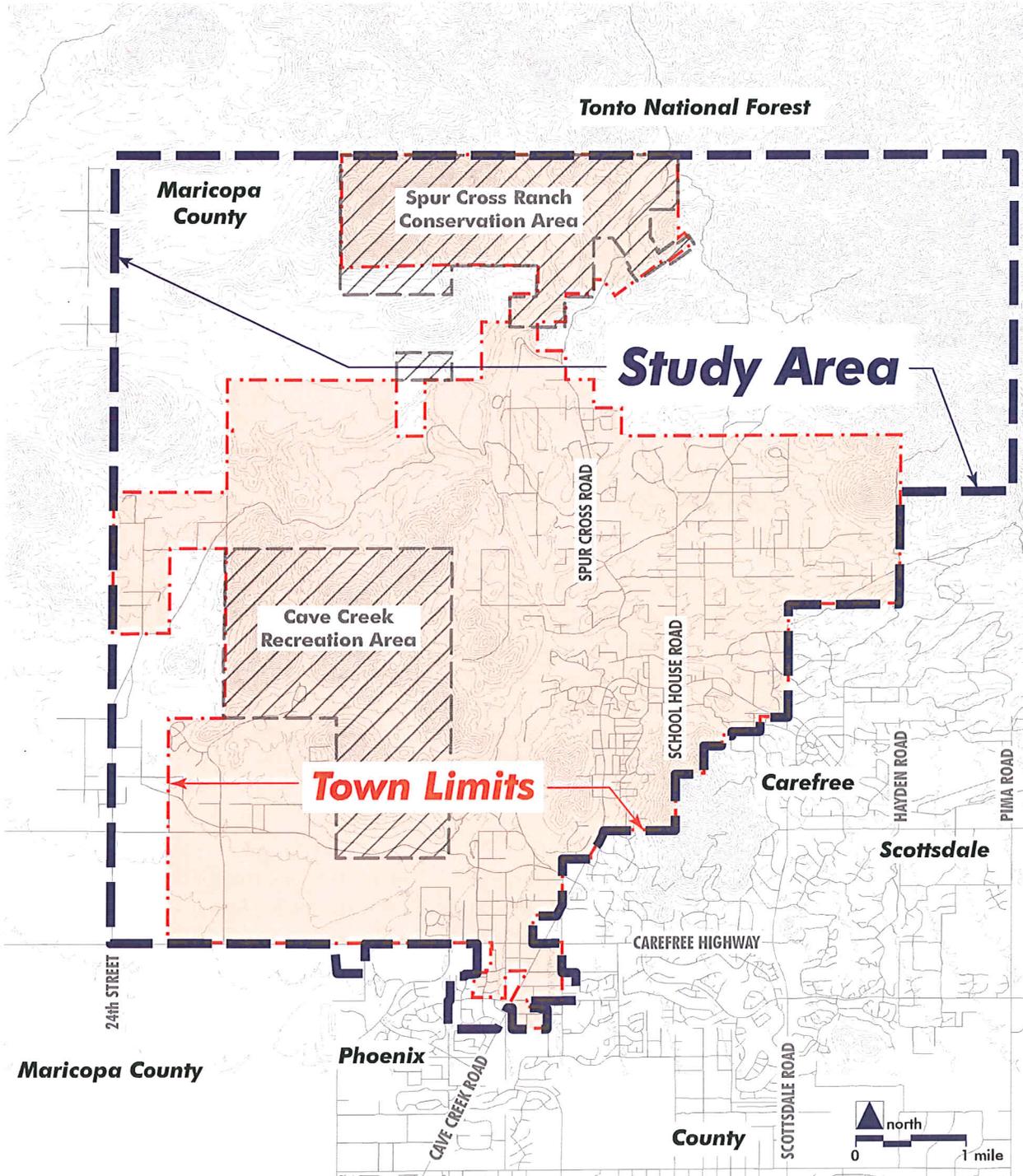
Several major drainage conveyances are located within the Town. Many are mapped as floodplains and/or floodways by FEMA and shown on the Flood Insurance Rate Maps (FIRM) for the study area. The Town's drainage scheme generally consists of culverts or at-grade crossings to cross roadways and washes. A comprehensive inventory of all drainage structures, such as culverts, bridges, bank protection, improved channels, and at-grade roadway crossings was obtained from as-built plans and field reconnaissance. The inventory is available in the Data Collection Report.

Areas of Potential Flooding and Problem Areas

Areas of potential flooding were determined from published maps, studies, field reconnaissance, historic aerial photographs, and interviews with residents. General flooding can be expected in any of the washes throughout the



Field reconnaissance



- Study area
- Town limits

Figure 2. Study area boundary

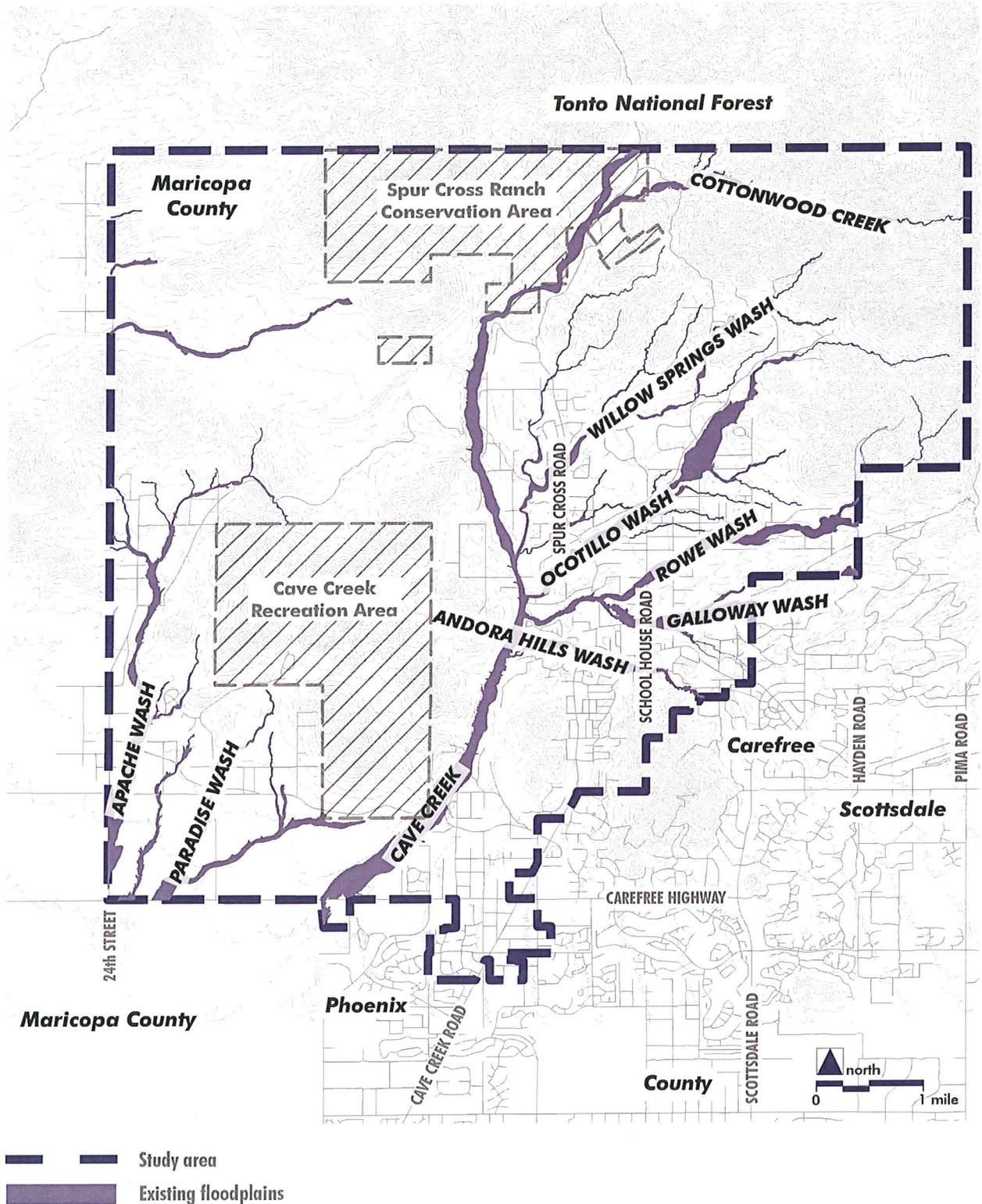
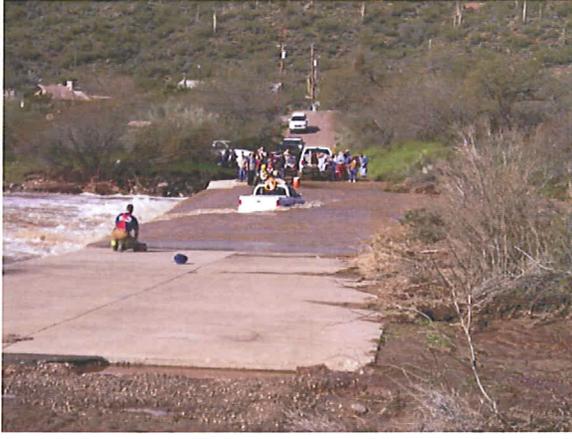
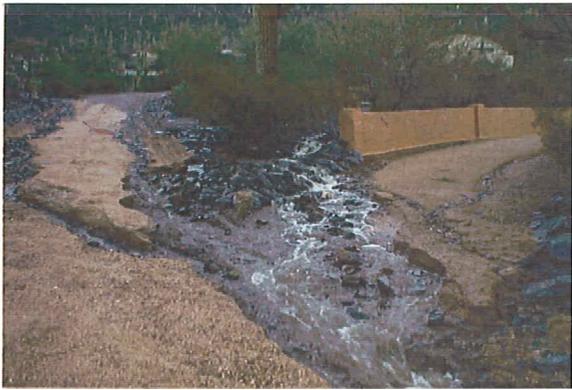


Figure 3. Major washes in the study area



Wash rescue



Washed out road

Town, with additional areas of localized flooding. Potential flooding and problem areas discovered as part of the project are included in Figure 1 of Appendix A.

Additionally, significant washes not currently mapped as floodplains were identified. This information is contained in the August 4, 2006 Technical Memorandum *Cave Creek DMP Major Wash Identification* by JE Fuller/Hydrology and Geomorphology, Inc. and shown later in Section 8 of this report, *Figure 7*. These drainage pathways are expected to convey water during runoff events.

Vehicular and Other Transportation Modes

The Town's road network is a combination of developments using the grid system and others following the topography. Numerous washes in the area result in a grid system whose roads are frequently in conflict with washes.

There is one main access road into Town - Cave Creek Road, which loops to the east through Carefree and continues on to Tom Darlington Road. The northern reaches of the

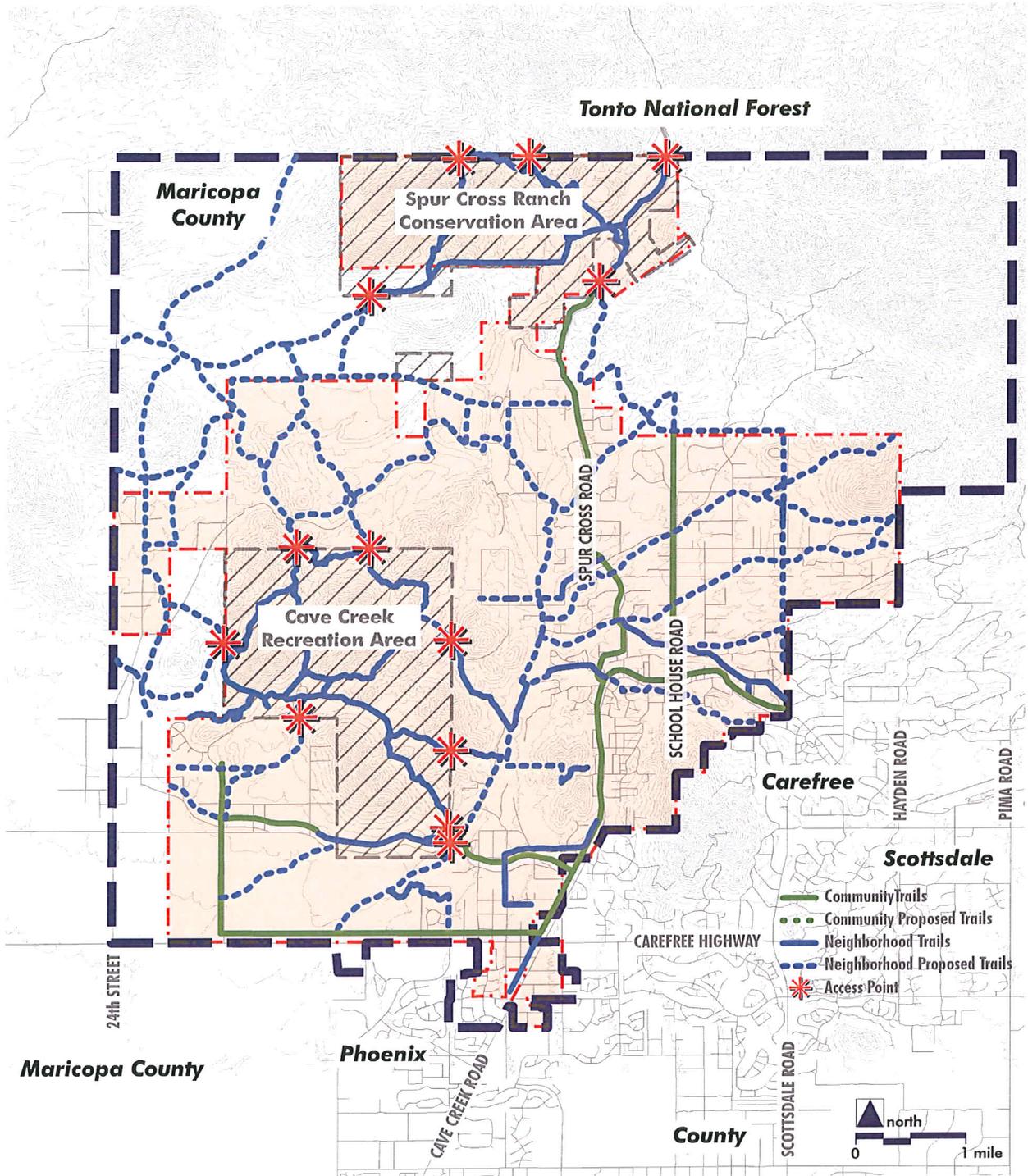
Town are accessed from School House Road and Spur Cross Road, both accessible only from Cave Creek Road. Most of the roads in Town are two-lane asphalt; the rest are unpaved.

The Town has many residents who are equestrians. The Town of Cave Creek trails plan, *Figure 4* on page 7, indicates existing and proposed trail elements in the Town. Many of Town's washes are used as equestrian routes.

Planning Efforts

To provide relevant background information for the DMP, planning documents from the Town of Cave Creek, Town of Carefree, and Maricopa County were reviewed. The purpose was to determine the relevance of these documents to the Cave Creek DMP development process. Specifically, the planning document review examined relevant planning policies, recommendations, standards, and guidelines that potentially could have positive or negative impact on surface water drainage management within the study area. Residential, commercial, and industrial development is a key issue, having significant impact on surface drainage patterns and water quality. Other issues examined include policies effecting native vegetation and the natural topography of the study area.

The study area is generally developed with large-lot, single-family residences, with the exception of downtown which contains commercial and higher-density residential



- Study area
- Town limits
- Floodplains

Figure 4. Town of Cave Creek Trails Plan
 Source: Town of Cave Creek General Plan

development. Additionally, several parks and preserves are located within the study area, these are: Black Mountain Summit Recreation Area, Cave Creek Recreation Area, and Spur Cross Ranch Conservation Area.

Cave Creek General Plan

The *Town of Cave Creek General Plan (2005) (General Plan)* recognizes the importance of the natural features of the community including their importance to the community's high quality of life. The plan offers a vision of the Town that places high value on 'spaciousness', rural character, and associated high quality of life for its citizens. Surface drainage features are protected and enhanced by the *General Plan*, which encourages and proposes low-density development, inclusion of significant amounts of open space within new development, and preservation of existing open space features coupled with minimum disturbance to existing vegetation, wildlife, topography, and natural features of great value. These proposals would positively impact surface water drainage management within the study area.

The *General Plan* additionally addresses trails and their potential impact on river washes. The *General Plan* policy states that trail crossings should be designed to cross the wash perpendicular to the bank, and should be sited so as to minimize negative impacts on river washes and associated vegetation.

The Environmental Planning Element of the *General Plan* specifically addresses surface drainage and recommends policies be implemented to limit disturbance of stream corridors. The plan further recommends wash corridors be delineated with ample open space buffering to protect washes and undesirable development that would impede drainage functions be discouraged. Special attention is given to Cave Creek and other important washes within the municipality. The *General Plan* emphasizes the importance of washes to the character and quality of life found in the Town. In addition to their importance in managing surface drainage, washes define the rural desert character of the community and function as critical wildlife and vegetation corridors. The Open Space Element of the *General Plan* recommends that the Cave Creek floodplain be protected with a 100-foot buffer zone on each side of the wash and its major tributaries, which will be designated as an open space resource in the *General Plan*. The *General Plan* recommends that as the Town grows, more open space be acquired in the amount of 1,300 acres per 1,000 population.

Town of Cave Creek Subdivision Ordinance, Chapters 1 and 5

Ordinance Chapter 1 Principles, Policies and Procedures (2003) Section 1.3 Subdivision Design Principles and Policies responds to the vision of the Town as expressed in the *General Plan*; to support developments that "respect the community's spacious character", in that they result in low-density land uses that are small scale and rural in character. Low-density, small scale development that respects the "spacious" character of the community will contribute positively to existing and future management of surface water drainage in developed areas of the Town. Low-density development which incorporates ample open space will reduce surface drainage volumes and intensity, minimizing negative environmental impacts. *Ordinance Chapter 5 Habitat, Environmentally Sensitive Areas, and Landscape Standards and Procedures (2003)* equally reinforces the vision of the *General Plan* by promoting developments that enhance surface water management practices through preservation and enhancement efforts.

Resolution No. R2005-04 Design Guidelines and Principles

The *Design Guidelines and Principles (2005)* ensures that new construction maintains a traditional scale, appropriate character, and preserves the heritage and environmental qualities of the existing Town core. This document emphasizes special consideration be given to preservation of washes during planning and implementation of new development within the Town core.

Other Town of Cave Creek Documents Reviewed

Town Core Plan and Implementation Program (Neill Vecchia and Associates [1998]), does not address surface drainage as an important element of the Town Core Plan. The *Sanitary Sewer Master Plan* (CH₂MHill, 2006), addresses the need for improvements to the Town's sanitary sewer system to address the increase in population and development in years 2010, 2015, and 2020. This document is related to, but does not directly impact, the DMP process.

Current and Pending Town of Cave Creek Development Plans

Annexation and rezoning of state lands are current issues of importance to the Town. According to the *General Plan Annexation Map* (Town of Cave Creek, March 2006), the Rodger Creek, Willow Springs Wash, and Apache Wash state lands are proposed for annexation by the Town in 2007. These areas include several washes including Rodger Creek and Cave Creek. The proposed annexation areas are planned to be rezoned as Desert Rural and Open Space. Desert Rural is defined by the *General Plan* as maximum one dwelling unit per 190,000 square feet of land.

Town of Carefree General Plan 2020 (June 2002)

The *Town of Carefree General Plan 2020 (Carefree General Plan)* does not directly address surface water management. The *Carefree General Plan* acknowledges that unofficial access to native desert and undeveloped wash areas is readily available to most residents. The plan also notes that drainage flows from the northeast to southwest across Carefree to the portion of Cave Creek that is located in the Town of Cave Creek. Portions of Galloway Wash and Fleming Springs Wash on the west side of Carefree are in the 100-year floodplain. Tributary washes drain the remainder of the Town.

The *Carefree General Plan* places emphasis on the issue of water. Carefree derives most of its drinking water from a local underground aquifer. According to the *Carefree General Plan* “the area aquifer was significantly reduced during the last 15 years and unless conservation measures are taken, will face depletion in 15 to 20 years.” In an effort to address this critical issue, the *Carefree General Plan* recommends policies be put in place to encourage the reuse of retention and wastewater. The *Carefree General Plan* also recommends the Town continue to investigate methods for recharging the aquifer source. Surface water drainage is not addressed in this section of the *Carefree General Plan*.

Town of Carefree Community Standards and Guidelines (2004)

Community Standards and Guidelines addresses design standards and guidelines for major developments within the municipal boundaries of Carefree. Given that Carefree and the Town of Cave Creek have common issues and concerns related to surface water management, the relevance of these standards and guidelines is discussed as follows.

Mountainside (February, 2004)

Residential mountainside development is a reoccurring issue. The *Mountainside Standards and Guidelines* addresses standards and guidelines for on-site drainage, stating that natural drainage patterns should be identified and preserved as part of the desert ecosystems. Native vegetation is also addressed, stating that mature trees, shrubs, and cacti should be preserved “in accordance with the Town of Carefree community vision.” The document also recommends that “in order to preserve natural dips and washes bisecting a site, structures may be suspended over these elements provided they do not impede natural drainage corridors.”

Commercial (February, 2004)

Carefree Commercial Standards and Guidelines document directly addresses treatment of surface drainage features during commercial development, stating “Pursuant to the Zoning Ordinance, Article IX, Section 9.10 (4), washes that have a flow of fifty (50) cubic feet per second during a 100-year storm shall be maintained in their natural location. Additionally, the hydraulic properties of a wash may not be modified at the historical entry and exit point.”

Single Family (February, 2004)

Carefree Single Family Residential Standards and Guidelines goes much further in addressing surface water management, stating “Pursuant to the Zoning Ordinance, Article IX, Section 9.10 (4), washes with a 100-year capacity of fifty (50) cubic feet per second or greater must be maintained in their natural state. Washes below this threshold may be manipulated; however, the hydraulic properties and historic entrance and/or exit points from the property must remain consistent with pre-construction conditions. Such modifications should incorporate larger boulders and plant material to stabilize the banks and convey a natural appearance. Bridging, rather than a wet crossing, for a driveway of a wash with a 100-year capacity of fifty (50) cubic feet per second or greater is encouraged.”

Maricopa County 2020 Eye to the Future Comprehensive Plan (revised 2002)

Maricopa County *2020 Eye to the Future Comprehensive Plan* (revised 2002) directly addresses issues of water management in Maricopa County. The document states, “Since Maricopa County is located in an arid part of the state, water is a precious commodity. Surface water and groundwater are equally important suppliers for the region.” The *Comprehensive Plan* highlights issues and problems related to water pollution in the county, and connects these issue with residential development, and industrial/commercial activities in the county.

The *Comprehensive Plan* makes broad suggestions related to surface drainage management issues. However, the *Comprehensive Plan* does not provide specific recommendations related to surface water drainage that would directly impact the DMP. Related to this, the *Comprehensive Plan* also calls for protection of environmentally sensitive areas, “including mountains and slopes; rivers and significant washes; historic, cultural, and archeological resources; view corridors; Sonoran desert; and wildlife habitat and ecosystems, all of which are interrelated elements.” The County’s Regional Trails Plan indicates a proposed multi-use regional trails connection north to the Town of Cave Creek; it is

unclear exactly where this connection will be located. Therefore, the implications of the development of this regional trails link on the DMP are unknown at this time.

Existing and Future Development Plans for the Town of Cave Creek

Existing developments are shown in the *Data Collection Report* including planned subdivisions and commercial developments. Planned development in the study area at the time of this report consisted of the following:

- Continental Mountain Estates – This residential development is planned east of 72nd Street and north of Continental Mountain Drive, with several potential future roadways and culverts. Final plans have not been submitted to the Town.
- Stagecoach Estates – This residential development is currently under construction. It is located north of Stagecoach Pass and northeast of Cave Creek Road. Field observations indicated that several culverts have been constructed in non-delineated washes.
- Stagecoach Village – This commercial development is planned at the northwest corner of Cave Creek Road and Galloway Drive. Field observations indicated improvements to a non-delineated Galloway Wash Tributary.
- Phoenix Mine Site Redevelopment – This former mine site located adjacent to Spur Cross Ranch Conservation Area was recently purchased by the Town for redevelopment. The planning effort for future development of this site as a public park and museum is currently underway.
- Northwest corner of Cave Creek Road and Carefree Highway (north of the existing CVS Pharmacy) – This property, although located in the Town of Carefree and outside the study area limits, is under construction with a commercial development.
- Cahava Springs – This large-lot residential development is within the Adobe Dam/Desert Hills ADMP area. It is located northeast of the 32nd Street and Rockaway Hills Road intersection. Most off-site improvements have been constructed, but lot build-out has not yet occurred.

5. PUBLIC INVOLVEMENT

Public input was solicited at three public open house meetings or workshops held in the project study area. The first open house was held early in the process, July 26, 2006, to obtain historical information from the public. Information was also gathered from one-on-one conversations and interviews.

Flooding problems and issues discussed centered on what happens when washes that are normally dry flow to capacity. When washes become flooded due to severe runoff, the following situations have been observed to occur:

- When normally dry washes are flooded, vehicles can't get across resulting in one of the following situations;
 - People attempt to cross the flooded wash and get stuck (or worse swept away).
 - People are not able to get home and have to wait for the wash to recede.

- People have to go out of their way and take a different route home.
- People can't get out of their homes and are essentially stranded.
- The flooded washes erode laterally, causing movement and degradation of the wash banks, which endanger structures placed adjacent to the bank.
- Homes or outbuildings built in washes or low-lying areas perceived to be always dry become flooded, generally because the risk of building in or near a dry wash was not recognized by the builder.
- Flood water exceeds the capacity of the wash. Overtopping of the banks occurs and excess floodwaters sheet across the adjacent areas causing potential water damage to homes and personal property.

A complete range of potential solutions to these typical flooding situations was evaluated with the public at the Alternatives Formulation and Preliminary Analysis meeting, on October 12, 2006. This meeting was conducted as a public workshop and resulted in the recommendation of preliminary alternatives or combinations of alternatives to be studied later. At the conclusion of the brainstorming portion of the workshop, five presentations were made representing the efforts of the five community/agency/consultant teams. A number of the same concepts were developed by all the teams, including which techniques were or were not appropriate for the Town. Some teams arrived at unique concepts. Additionally, some of the flood management tools presented by the consultant team were not adopted by any of the community teams.



July 2007 public meeting

On July 10, 2007, a public meeting was held at the Christ Episcopal Church, located at 35500 North Cave Creek Road in the Town. A total of 46 individuals signed in at this meeting. The purpose of the meeting was to inform the public of the project progress, show the area's flooding and erosion problems, present the proposed alternatives to remedy the regional flooding and erosion problems, and request public input regarding the alternatives and any recommendations for other alternatives to be considered. In general, the comments from the public were supportive of the project.

The District used a variety of techniques to publicize the project and the public meetings. Information was announced through direct mailings, press releases, newspaper notices, and through the District's Web site <www.fcd.maricopa.gov>.

The meeting began in an open house format, followed by a PowerPoint presentation by the project team. During the presentation, a project team member gave a brief project update, described the project process, presented the identified drainage issues, detailed the proposed elements of the DMP, and addressed the next steps. Following the presentation, there was a brief question-and-answer session where the audience was able to have their questions answered in an open forum by project team members. After the question-and-answer session, the meeting returned to the open house format. Exhibit boards and handouts were available that illustrated the flooding and erosion problems

and the proposed alternatives. Representatives from the District, Town, and the project team were available to explain the displays and answer questions.

6. ENVIRONMENTAL OVERVIEW

Physical Environment

Topography

The DMP planning area falls within the Basin and Range physiographic province, which is characterized by arid valleys, sloping bajadas, and ephemeral washes. The project area is bordered to the north by the New River Mountains and is situated at an elevation range of approximately 1,750 to 3,850 feet above mean sea level (AMSL).

The project area geology consists of washes of surficial deposits of sand, gravel, and silt. The uplands geology consists of schist and gneiss metamorphosed over time from sedimentary and volcanic rock (Kamilli and Richard, 1998). The United States Department of Agriculture Natural Resources Conservation Service (USDA NCS) Web Soil Survey was used to determine soil characteristics within the project area. Several soil complexes exist. The Pinaleno-Tres Hermanos complex is characterized by a well drained mixed alluvium. The alluvium is classified as a very gravelly clay loam with slopes ranging from 1 to 10 percent. Variations of the Eba complex are present and consist of very gravelly loam soil with varying slopes of 1 to 8 percent and 8 to 20 percent. They are located in both the braided washes and their uplands. The other prominent soil type found primarily in the washes is the Arizo cobbly sandy loam with slopes of 1 to 8 percent.

Cave Creek is an ephemeral wash flowing north to south and is the most prominent drainage in the project area. Small riparian woody plant species such as ironwood and palo verde grow in moderate to dense stands along wash corridor, with one exception - the area north of Cave Creek Road where vegetation is dense for approximately 1,200 feet along the creek corridor. Desertscrub is present outside of the active channel in the terraces. Cave Creek has three major tributaries joining it from the east; Willow Springs Wash, Ocotillo Wash, and Galloway Wash.

Vegetation

Biotic Community

The project areas fall within the Arizona Upland Subdivision of the Sonoran Desertscrub Biotic Community (Turner and Brown, 1994). Prominent vegetation within this biotic community includes scrub species, low woodland trees, and cacti. Scrub vegetation consisting of creosotebush (*Larrea tridentate*), white bursage (*Ambrosia dumosa*), and brittlebush (*Encelia farinosa*); among others, typically grow along the flats, valley edges, and disturbed areas. The



A typical Town wash

riparian vegetation along drainage ways includes mesquite (*Prosopis spp.*), ironwood (*Olneya tesota*), and palo verde (*Cercidium spp.*); all of which can also be found upland of washes. Cacti are abundant, consisting of columnar cacti such as saguaro (*Carnegiea gigantea*) and fishhook barrel (*Ferocactus spp.*); as well as various species of prickly pear, silver and pencil chollas (*Opuntia spp.*). The project area is intermixed between an urban influence and cultivated environment with the native plant community. The community can be described as palo verde-mixed cacti-mixed scrub. Along drainage ways and atop small islands in active channels, dominant tree species include foothill palo verde (*Cercidium microphyllum*) and ironwood. The palo verde extend to the upland terraces and mix with mesquite. The desertscrub species of creosotebush and brittlebush dominate the ground cover with an understory of Indian ricegrass (*Achnatherum hymenoides*). Intermixed within the scrubland are various cacti species including saguaro, barrel, silver cholla (*Opuntia bigelovii*), and pencil cholla (*Opuntia arbuscula*).

Wildlife

Threatened and Endangered Species

The U.S. Fish and Wildlife Service's (USFWS) list of threatened and endangered (T&E) species for Maricopa County (Query dated August 10, 2007), was reviewed for the possible species presence in the project areas by an HDR biologist. Twelve threatened and endangered species and one candidate species are listed for Maricopa County. Of these species, suitable habitat exists for one of these federally listed species; the federally listed endangered lesser long-nosed bat (*Leptonycteris curasoae yerbabuena*). Although the study area is north of its known historic range and is not known to occur, the nectar-loving lesser long-nosed bat forages on the flowers of saguaro, ocotillo (*Fouquieria splendens*), palo verde, prickly pear, and agave (*Agave spp.*) in desertscrub and grassland habitat. Foraging habitat is present. These bats are a migratory species and are usually not present in Arizona during the winter months (AGFD 2003). There is no listed critical habitat for any federally protected species within the study area.

The Arizona Game and Fish Department (AGFD) Heritage Data Management System was addressed via the on-line Environmental Tool to determine special status species occurrences within three miles of the project areas. The investigation listed the following species: lowland leopard frog (*Rana yavapaiensis*), the Sonoran population of the desert tortoise (*Gopherus agassizii*), and the California leaf-nosed bat (*Mactrotus californicus*). These species are listed both as State of Arizona wildlife species of concern (WSC) and species of concern (SC) under the Endangered Species Act.

Alternatives Analysis - Environmental Considerations

The project alternatives include the establishment of five all-weather access crossings of ephemeral washes and the enhancement of two existing culverts on Cave Creek Road.

Waters of the United States

Waters of the United States (WoUS) which are regulated by the U.S. Army Corps of Engineers (USACE) exist in the study area and consist of Cave Creek, Willow Springs Wash, Ocotillo Wash, Galloway Wash, and their tributaries. Impacts to these washes will require a Clean Water Act Section 404 (CWA 404) permit. The USACE regulates "fill"

at and below the determined presence of the Ordinary High Water Mark (OHWM) in these washes. The amount of impact will determine the type of permit required by the USACE. A Jurisdictional Delineation (JD) will determine the extent of regulatory authority and delineate the total area of impact associated with each bridge and/or culvert alternative. Most likely, the project alternatives fall under the nationwide program and will require a Nationwide Permit 14; for linear transportation crossings. The extent of impact to WoUS will be based on the engineering attributes of the crossings, the width or jurisdictional delineation of the wash, and extent of these impacts upstream/downstream of the project footprint. If this project qualifies under the nationwide program, conditions to meet the State of Arizona water quality certification are included in the authorization.

In compliance with Section 402 of the Clean Water Act, a State of Arizona Pollutant Discharge Elimination System (AZPDES) General Construction Permit (AZG2003-001) and associated Storm Water Pollution Prevention Plan (SWPPP) will be required to construct the alternatives.

There are no wetlands known to occur in the study area, nor are wetlands adjacent to known WoUS present; therefore, no impacts are anticipated.

Threatened and Endangered Species and Special Status Species

Although foraging habitat supporting the lesser long-nosed bat is present in the study area, impacts to the upland cacti and plant species required to sustain and recover the species will not be impacted. Furthermore, the project will not remove potential nesting habitat and no nests are known to occur. For these reason, impacts to the species would not occur.

Impacts are not expected for the lowland leopard frog because it is unlikely to be present in the study areas. The ecology of leopard frogs requires the presence of a permanent water source. While leopard frogs can withstand periods of drought, they are typically found around permanent water sources which do not exist within the study area nor at the proposed crossing areas.

Marginal habitat required for the existence of the California leaf-nosed bat does occur in the uplands around the study area, but impacts to the vitality and sustainability of the species would not occur because the project would not remove suitable foraging and roosting habitat.

Marginal habitat exists for the Sonoran desert tortoise in the study area. Impacts to the vitality and sustainability of the species associated with the alternatives are not likely to occur because suitable habitat for foraging and burrowing exists in the surrounding area but not in the washes, the area of impact within the project footprints. It is recommended that desert tortoise clearance surveys are performed prior to any groundbreaking activities to assure the absence of the species.

Vegetation

Constructing the alternatives could result in impacts to riparian plant species if they were in the projected crossing and or culvert enhancement area. Highly Safeguarded and Salvage Restricted plants would be avoided or salvaged in accordance with Arizona Native Plant Law (ANPL). These plant species would be moved and re-established

within the project limits. Any other native plants would be replaced in-situ and in-kind as required by law. A native plant inventory would be required within the right-of-way for each alternative to identify these protected species.

Landscape Character and Visual Resources

The landscape character of the Town was reviewed to assess the scenic quality and integrity of the existing landscape and to aid in developing aesthetic guidelines to be used for any constructed flood management solutions.

The District prepared a draft *Scenery Resource Report* that included identification of two landscape character types (Tonto and Sonoran Desert), three character subtypes (Sonoran Arizona Uplands, Upper Tonto, and Sonoran Mountain Lands) and four cultural settings (natural, rural, suburban, and industrial). Field visits to the study area revealed that while there are man-made cultural settings, the natural desert still dominates.

The scenic quality and integrity of much of the study area are excellent. There are rock formations, rolling terrain, and patterns of desert vegetation and lush riparian growth. There is high integrity of the vividness, intactness, coherence, harmony, pattern, and balance. For much of the study area, the human caused derivation in form, line, color, and texture has been fairly unobtrusive.

7. HAZARDS IDENTIFICATION SUMMARY

Hydrology

Purpose of Study

The purpose of the hydrology task was to:

- Research existing hydrologic models and studies within the study area;
- Estimate existing and future runoff conditions for a 6- and 24-hour duration for the 100-year, 50-year, 10-year, and 2-year for the areas not covered by existing models or areas needing additional detail.

Hydrologic Study Limits

The hydrologic study limits are shown graphically in *Figure 5* on page 17 and generally consist of the Town of Cave Creek and a small portion the Town of Carefree. However, due to the presence of existing hydrology information, only portions of the study area were subject to new hydrologic modeling. The existing hydrologic models coverage for the remainder of the study area are included as Sheet 2 in Appendix B.

Hydrologic Methodology

The hydrologic methodology for this project was developed in accordance with the *Drainage Design Manual for Maricopa County (DDMMC), Volume I, Hydrology*.

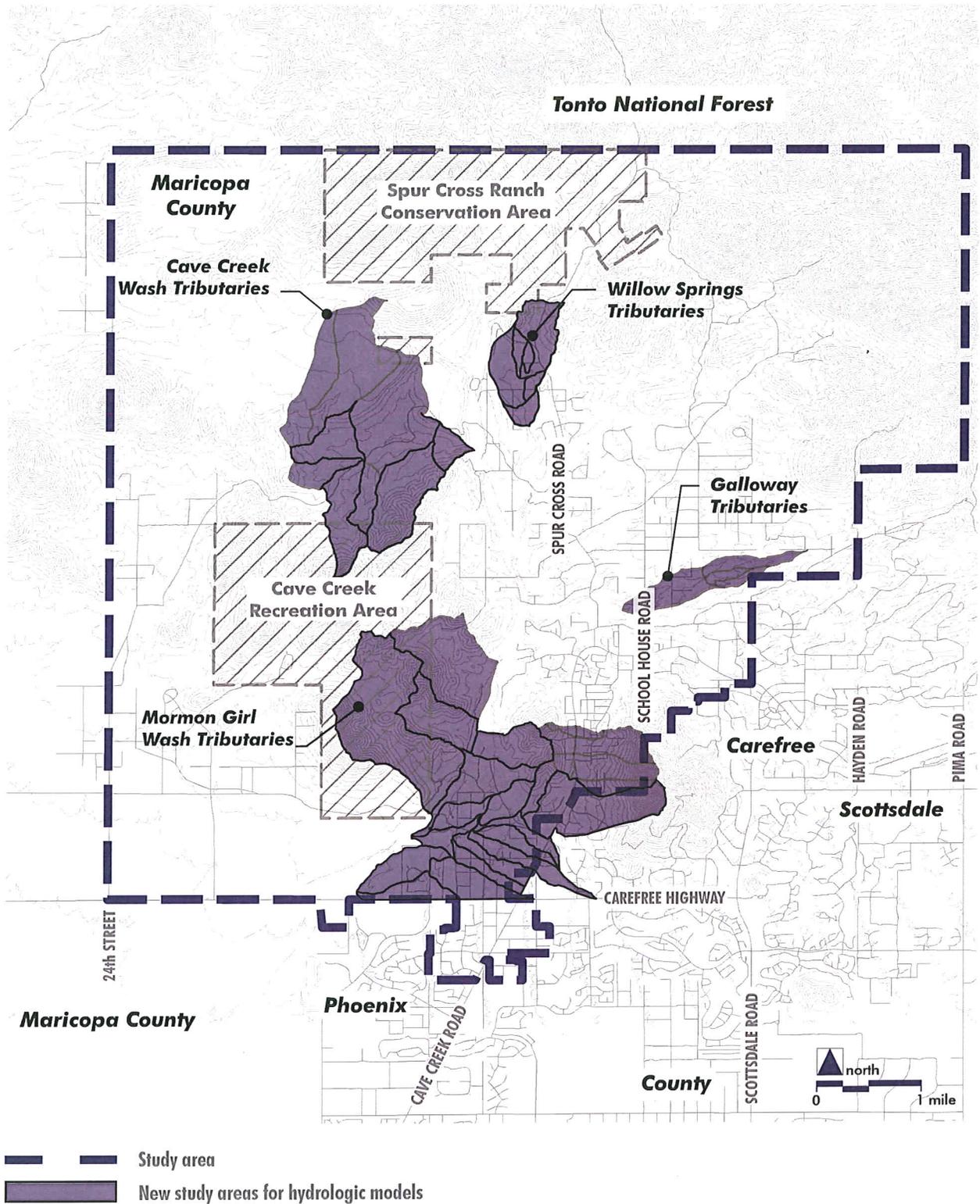


Figure 5. Location of new hydrologic models

Method Description

HEC-1 modeling was developed for existing and future conditions using rainfall depths for a 6- and 24-hour duration for the 100-year, 50-year, 10-year, and 2-year events. The rainfall distribution type is the SCS Type II distribution for the 100-year 24-hour event, and Maricopa County Pattern storms for the 6-hour duration events. HEC-1 rainfall losses were estimated using the Green and Ampt infiltration equation option. The Phoenix Mountain and Desert/Rangeland S-graphs, as defined in the DDMMC were used to generate hydrographs. The normal depth storage routing routine was used for all channel reaches. Representative 8-point cross sections were generated.

Concentration points were included at the limits of the study, at significant tributaries, and at road crossings or culverts. Additional consideration was given to the washes subject to future floodplain mapping under Phase II of this project. Sheet 15 in Appendix F of the study prepared by JE Fuller as part of Phase I analysis has been updated by HDR and depicts the Recommended Phase II Delineations of this report.

The modeling is divided into four groupings based on downstream terminus:

- Willow Springs Wash Tributaries
- Galloway Tributaries
- Mormon Girl Wash Tributaries
- Cave Creek Tributaries

8. RESULTS

A summary of the results are shown in *Table 8.1*

TABLE 8.1: Hydrologic Summary

Storm Event	Concentration Point*	Existing 6-hour Flow (cfs)	Existing 24-hour Flow (cfs)	Future 6-hour Flow (cfs)	Future 24-hour Flow (cfs)
2-year	C-37	560	896	547	878
	C-36	144	230	143	229
	C-47	54	95	54	95
	C-64	303	2106	384	2165
10-year	C-37	1335	1959	1315	1902
	C-36	322	513	321	512
	C-47	161	245	161	245
	C-64	874	2702	959	2751
50-year	C-37	2326	3493	2300	3436
	C-36	506	808	506	806
	C-47	280	411	280	411
	C-64	1496	3534	1566	3596

TABLE 8.1: Hydrologic Summary

Storm Event	Concentration Point*	Existing 6-hour Flow (cfs)	Existing 24-hour Flow (cfs)	Future 6-hour Flow (cfs)	Future 24-hour Flow (cfs)
100-year	C-37	2711	4102	2680	4028
	C-36	585	942	584	940
	C-47	330	491	330	491
	C-64	1765	3852	1830	3898

* Concentration points are discussed and shown in detail in Hydrology Report for the Cave Creek Drainage Master Plan, July 2007. Maps of the watershed concentration points are also included in Appendix B of this report.

C12A is located at confluence of Cave Creek Trib 1 at Cave Creek

C33A is located at confluence of Willow Springs Wash Trib 6 at Willow Springs Wash

C47 is located at confluence of Galloway Wash Trib 2 at Galloway Wash

C64 is located at confluence of Mormon Girl Wash Trib 1 at Cave Creek

Verification

The results of the HEC-1 model were compared to two sources:

- Regression Equations
- Unit discharges (cfs /square mile) comparison with previous studies in the area

Hydraulics

Hydraulic analysis was completed for the project to determine the physical characteristics of the study area watercourses during a rainfall/runoff event. Computer modeling shows the extent of flooding, water surface elevations, depth of flow, and velocity of flow for given events. The hydraulic methodology for this project was in accordance with the DDMMC, Volume II, Hydraulics.

Unnamed Central Tributary to Cave Creek (UCT) and Mormon Girl Wash

A portion of the project area contains a wash which is subject to variable flow conditions resulting from an upstream flow split condition. The wash, designated the Unnamed Central Tributary to Cave Creek (UCT), splits into two tributaries near Carefree Highway and Terravita Way in the Town of Carefree. The northern branch flows through the Town of Carefree and crosses Cave Creek Road between New River Road and Canyon Ridge Drive. Historically, this branch of the wash has been called “Mormon Girl Wash”, and flows through the Town of Cave Creek north of New River Road and eventually discharges into Cave Creek. The southern branch of the UCT crosses Cave Creek Road approximately 1,000 feet north of Carefree Highway and rejoins the north branch near the intersection of 50th Street and New River Road.

The southern branch crossing of Cave Creek Road has been studied as part of two separate studies:

- Carefree Drainage Master Plan Update: 100-year, 24-hour 2-D Floodplain Model (JE Fuller, August 2005) (referred to as “Carefree DMPU”)
- Drainage Report for Lowe’s Home Improvement Warehouse (Shephard Wesnitzer, April 2007) (referred to as “Lowe’s”)

The results of both models are discussed below. It is important to note that the Lowe's study used the results of the Carefree DMPU study upstream of the roadway, where 1,348 cfs arrives from the southern branch of the UCT. However, the results of the detailed study at the roadway between the two studies differ slightly.

Carefree Drainage Master Plan Update 100-year, 24-hour 2-D Floodplain Model

This study was limited to the portions of the wash in the Town of Carefree, up to and including Cave Creek Road. The original study did not provide results at the roadway; therefore, in order to determine the distribution of flow at Cave Creek Road, the electronic model was obtained and new cross sections were cut within the FLO-2D model. No other changes were made to the original model.

The results indicate that flow attenuation (i.e. ponding) occurs upstream of Cave Creek Road, resulting in 847 cfs crossing the road and 127 cfs breaking out to the south. However, this model does not take the conveyance capacity of the culverts into account, so this flow summary does not include flows that may cross the road in the existing culverts. The amount of flow that may be conveyed by the culverts is unknown, due to the large amount of sediment accumulation that has occurred inside and upstream of the structures.

As previously mentioned, a total of 1,348 cfs approaches the road. At the road, according to this model, 847 cfs crosses the road and 127 cfs goes south. The difference between the two totals (1,348 cfs minus 847 cfs minus 127 cfs) is 374 cfs, which is either detained upstream or conveyed across the Cave Creek Road in the existing culverts. Appendix C contains copies of the results of the FLO-2D modeling.

Drainage Report for Lowe's Home Improvement Warehouse

This study used the results of the Carefree Drainage Master Plan Update immediately upstream of Cave Creek Road. However, the study used the more conservative assumption that roadway overtopping instead of attenuation due to ponding would occur. The results indicate that 1,059 cfs crosses the road and 289 cfs breaks out to the south. Additionally, a floodplain was mapped through the Lowe's site using 911 cfs (the difference between the 1,059 cfs and the 911 cfs is retained on-site).

The net difference between the two models at the Cave Creek Road crossing is relatively small, with the Carefree DMPU report at 847cfs (which does not include culvert conveyance, if any) and the Lowe's report at 911 cfs. It is recommended that the flows from the Lowe's report are used when designing improvements to the wash crossing of the south branch of the UCT, which is 911 cfs across Cave Creek Road and 289 cfs to the south.

Considerations must be given to both the upstream and downstream properties when designing improvements. It appears that the flows in the UCT/Mormon Girl Wash system have been poorly understood in the past, before detailed studies were commissioned on the area in the early 2000s. It is unknown what flows were used when designing the residential development along the wash that pre-dates the detailed studies. As part of the Cave Creek Drainage Master Plan report prepared as part of this project, a recommendation exists for mapping the floodplain generated from this wash. The

mapping will be beneficial to surrounding properties to determine the potential flooding risks for both the pre- and post-crossing improvement scenarios using the latest flow information contained in the detailed reports referenced above.

Documentation on the modeling and output is contained with the *Cave Creek Drainage Master Plan Final Hydraulics Report* created as part of this project. Supporting calculations have been provided in Appendix C.

TABLE 8.2: 100-year Flow Amounts at Cave Creek Crossings

Improvement Location	Flow (cfs) 100-year event
Cave Creek Road at UCT, North Branch (Mormon Girl Wash)	1,252
Cave Creek Road at UCT, South Branch	784

Floodprone Properties

The area was examined for residential structures that may be located within floodways. The presence of floodways on properties was determined from existing FEMA mapped floodways, or new floodways identified and mapped as part of this project. Four residences were identified within new or existing floodways in the study limits:

- Ocotillo Wash – 40647 N. Fleming Springs Road
- Ocotillo Wash – 6914 E. Continental Mountain Drive
- Ocotillo Wash – 6447 E. Lone Mountain Road
- Willow Springs Wash, Tributary 6.1 – 5515 E. Honda Bow Road

Two additional structures were previously identified as a result of the Adobe Dam/Desert Hills ADMP study. Both structures are located within the floodway study limits and are located upon a single residence:

- Apache Wash – 39416 N. 28th Street

Table 8.3, below, summarizes the hydraulics characteristics associated with the properties, and Appendix B contains exhibits illustrating the hydraulic characteristics for new residences identified within this study.

TABLE 8.3: Hydraulic Characteristics of Floodprone Properties

Address	Water Surface Elevation (100-year)	Velocity (100-year), fps	Depth (100-year), ft	Critical Travel Time (hours)
40647 N. Fleming Springs Road	2242.93	7.07	4.38	1.5*
6914 E. Continental Mountain Drive	2323.65	4.56	2.32	1.3*

TABLE 8.3: Hydraulic Characteristics of Floodprone Properties

Address	Water Surface Elevation (100-year)	Velocity (100-year), fps	Depth (100-year), ft	Critical Travel Time (hours)
6447 E. Lone Mountain Road	2220.70	8.30	— ⁽²⁾	— ⁽²⁾
5515 E. Honda Bow Road	2200.12	7.66	3.58	4.1
39416 N. 28th Street, Structure 1 ⁽¹⁾	1989.70	3.2	— ⁽²⁾	— ⁽²⁾
39416 N. 28th Street, Structure 2 ⁽¹⁾	1988.00	3.1	— ⁽²⁾	— ⁽²⁾

**Estimated (pro-rated) from original HEC-1 model "CVCRK43R", 1990 Cave Creek/Carefree FDS.*

⁽¹⁾ Property information provided from the Adobe Dam Floodway Structure Risk Assessment from within the Adobe Dam/Desert Hills ADMP.

⁽²⁾ Not available in final report during data collection.

Geomorphic

Geomorphic mapping identifies and classifies differences in the physical characteristics of land surfaces. The physical characteristics of a geomorphic surface provide clues as to its depositional history, stability, and flood potential. In the study of watercourses, geomorphic evaluation reviews the landforms and lateral stability of the watercourses, and documents change over time and into the future.

Sediment Engineering

Sediment can be delivered to the washes in the study area from hillslopes, channel banks, or channel beds. Field observations indicate that many of the smaller drainages in the steeper headwaters of the various washes show large areas of bedrock outcrops. This means that hillslope erosion is not a predominant source of sediment supply in the area. Rather, channel banks and channel beds provide the source of most of the sediment available for transport and deposition.

The sediment evaluation revealed a predominantly degrading fluvial system where the washes are confined between steep bedrock slopes or old alluvial terraces. Flooding and erosion are generally limited to the geologic floodplain between these more resistant surfaces. Long-term effects of urbanization are expected to increase the magnitude and frequency of storm water runoff and decrease sediment delivery to the watercourses. However, current sediment supply is predominantly coming from the channel bed and banks. Therefore, the long-term result is an increased potential for lateral and vertical erosion of channels in the study area and some increase in stream instability. On the other hand, many reaches have channel beds and banks that are composed of relatively resistant bedrock and/or caliche that limit the reach and extent of lateral and vertical erosion in the future.

Flood and Erosion Hazard Zones

The purpose of an erosion hazard zone (EHZ) is to provide the floodplain manager a tool to identify areas that have the potential to be adversely impacted by channel migration and/or changes in channel geometry. The EHZs delineated for the Cave Creek DMP were based on field observations, comparison of historical and recent aerials, the SS 5-96 Level 1 and Level 2, and the equilibrium slope analyses. It is possible that with more detailed, site-specific analysis, the EHZ delineations could be refined in some locations. It should be noted that more detailed, site-specific investigations may still reveal the need for engineered erosion protection measures in order for construction of proposed facilities to be approved by the Town within a delineated EHZ.

The EHZs were established using a combination of data sources and analytic approaches. The methods included field investigation, interpretation of current and historical aerial photographs, topographic map data, Arizona Geological Survey geologic map data, Natural Resources Conservation Service Soil Survey data, data from previous studies in the area, the hydraulic modeling results from the floodplain delineation studies of the study reaches, consideration of the State Standards Level 1 setbacks and Level 2 allowable velocity results, and the equilibrium slope analysis.

The recommended EHZs shown on the next page in *Figure 6* are intended to identify the areas likely impacted by future lateral erosion, or the areas for which more detailed analysis is warranted prior to future development. The EHZs from the Adobe ADMP (JEF, 2004) and Rodger Creek EHZ (JEF, 2001b) studies are also included on the maps. All of the recommended EHZs are based on the engineering judgement and experience of the project engineer/geomorphologist, and therefore cannot be reduced to a single formula or series of equations. In general, the recommended EHZs are conservative. *Figure 6* on page 24 is intended for illustrative purposes only. The EHZ boundaries are also provided in digital format for incorporation into the District's and Town's GIS systems. It is anticipated that the GIS data will be used by Town staff in the evaluation of future building permits.

The recommended best management practice for the EHZs is to prohibit construction of permanent or habitable structures within any delineated EHZ. If development is to occur within established EHZs, a detailed analysis is recommended as part of the design process.

8. POTENTIAL ALTERNATIVES

The following issues summarize the most prevalent flooding concerns noted by residents and the Town. These are fully covered in the *Potential Alternatives Report*:

- Erosion
- Access
- Wash obstructions
- Floodway encroachments
- Sedimentation
- Damaged storm drains

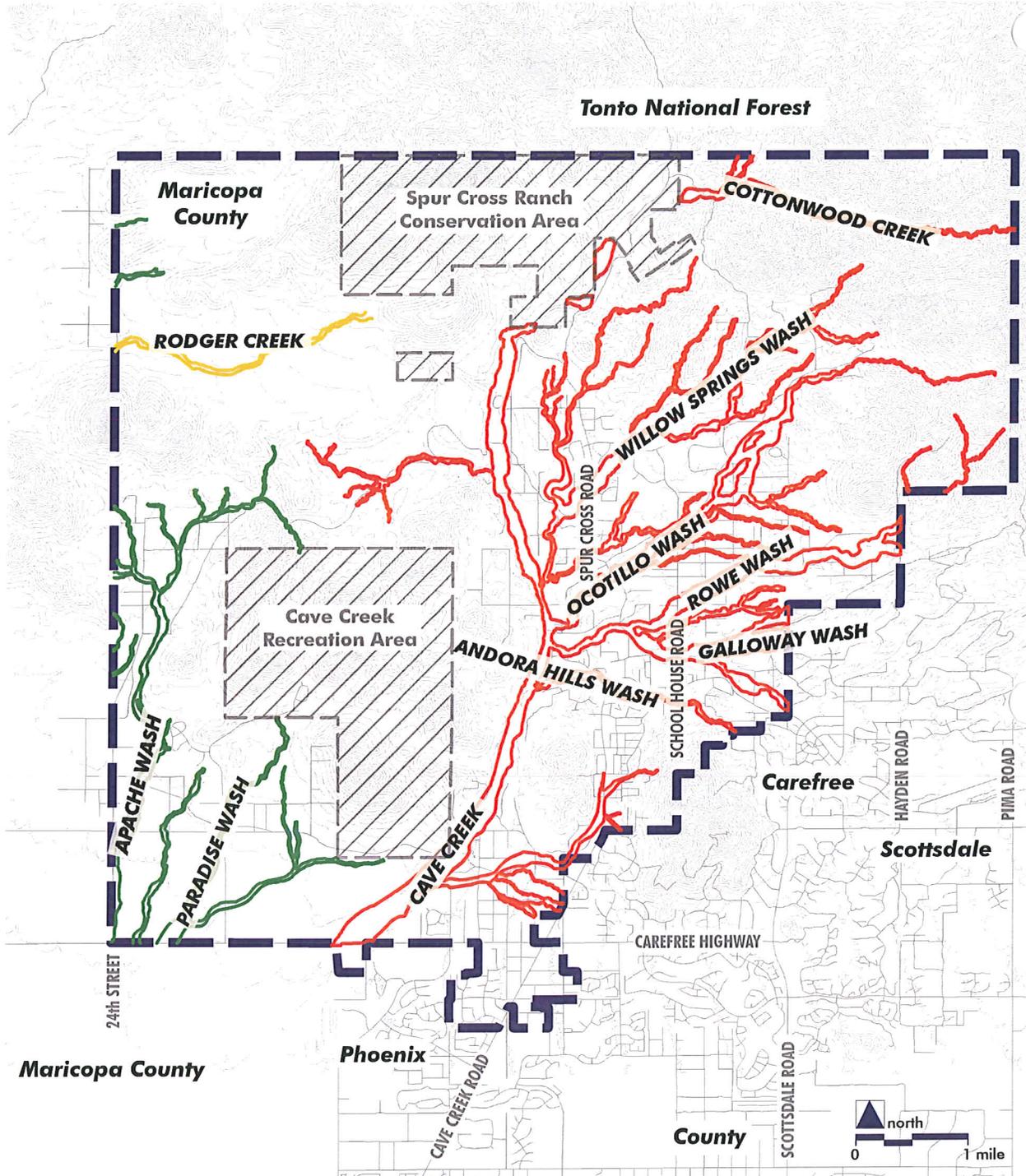


Figure 6. Erosion hazard setbacks

CAVE CREEK DRAINAGE MASTER PLAN

Recommended Alternative Elements

Identify Wash Corridors	<p>Description Although not covered by 100-year floodplain and floodway delineations, washes exist throughout the Town that may pose a flooding hazard and are necessary for local and regional drainage.</p> <p>Product: A wash corridor map was prepared as part of the DMP.</p>
Additional Floodplain and Floodway Mapping	<p>Description Additional 100-year floodplain and floodway maps will help keep people from building in floodplains and floodways, avoid property damage and loss of life, and be usable for updating flood insurance coverage.</p> <p>Product: Floodplain and floodway mapping was prepared as part of the DMP for portions of Ocotillo Wash and for tributaries of Cave Creek, Willow Springs Wash, and Galloway Wash.</p>
Drainage Guidelines	<p>Description A collection of guidelines were developed to assist property owners and developers in making improvements or in new construction. They provide user-friendly guidance for development to ensure safety and preserve the integrity of existing washes.</p> <p>Product: A collection of best management practices was prepared as part of the DMP. Additionally, finalizing and adopting the Draft Grading and Drainage Guidelines for the Town of Cave Creek has been recommended.</p>
Obstruction Removal and Code Enforcement	<p>Description Several locations were identified where obstructions were placed across washes.</p> <p>Product: Locations were identified as part of the DMP. It is recommended that the Town enforce the code and have property owners remove obstructions from washes.</p>
Floodprone Properties Acquisition Program (FPAP)	<p>Description FPAP is an existing District program that provides limited funding for voluntary property acquisition.</p> <p>Product: Properties eligible for the FPAP program were identified within the study area as part of the DMP.</p>
Erosion Hazard Setback Delineations	<p>Description Setback delineations can be used to prevent homes or businesses from being built within an area subject to potential erosion attributable to natural changes in the location of the wash over time.</p> <p>Product: Erosion hazard setbacks were determined for the study area as part of the DMP.</p>
Flood Response Plan	<p>Description A plan was created to document notifications, tasks, and training for responding to flood events.</p> <p>Product: A flood response plan was prepared as part of the DMP—future recommendations for improvements have been made.</p>
All-Weather Access Improvements	<p>Description Improvements that allow access across washes during 100-year flooding were identified.</p> <p>Product: Recommendations for improvements at several locations on Cave Creek, School House, and Spur Cross roads were made as part of the DMP. Conceptual-level design plans and an implementation strategy are included.</p>
Education Program	<p>Description A program was created to provide public education regarding flooding and erosion hazards. Components of the education program include erosion hazards, motorist, and wash continuity education.</p> <p>Product: A suggested program was prepared as part of the DMP for the Town’s implementation.</p>

Potential Solutions

Possible solutions to the identified flooding problems were discussed and evaluated with the team. While certain preferences were held by various individuals as to the appropriateness of the solutions to specific locations, it was agreed that the identified possible solutions can be categorized as follows:

Constructed

- Bridges
- Culverts
- Low water crossings (with grade control)
- Bank protection
- Cut banks
- Channelization
- Basins

Non-structural

- Early flood warning
- Education
- Conservation easements
- Erosion hazard setbacks
- Floodplain delineations

Combinations of these solutions were used to assemble comprehensive alternatives addressing the flooding concerns of the Town. They are acceptable from an aesthetic point of view because they are non-structural, soft, and semi-soft structural options (*Cave Creek Drainage Master Plan Scenery Resource Report*).

Evaluation Criterion

Several criterion were used to evaluate the alternatives. A rating system similar to Consumer Reports' was used to indicate relative differences rather than assigning point values.

- Safety
- Number of people impacted
- Environmental impact
- Relative cost
- Multi-use capabilities
- Degree of improvement
- Context sensitive aesthetics
- Public acceptance
- Agency acceptance

Alternative Descriptions

Rather than one or more distinct alternatives this project focused on possible solutions for specific locations identified as having existing flooding, erosion, or other related problems. These were reviewed by the team at a June 12, 2007 workshop and were reduced to several proposed recommendations. A matrix of the results is attached in Appendix D.

9. MASTER PLAN ELEMENTS

The Alternatives Evaluation Workshop resulted in a combination of recommended structural and non-structural elements, with an emphasis on the latter. Much of the study area is still developing, all be it quickly, and some of the non-structural recommendations can be used to prevent development from occurring in or near the washes, thus allowing continued unobstructed flow.

The following elements (also shown on the following page) were identified as the preferred methods of minimizing losses, hazards, and adversely impacting the public safety and welfare due to flooding.

- Identify wash corridors
- Additional floodplain mapping
- Drainage guidelines
- Wash obstruction removal/code enforcement
- Floodprone Properties Acquisition Program (FPAP)
- Education
- Identify erosion hazard setbacks
- Flood response plan and associated improvement recommendation
- All-weather access
- Adopt and finalize draft grading and drainage guidelines for the Town
- Realign 24th Street

Identify Wash Corridors

The project team identified smaller wash corridors not covered by 100-year delineations (see *Figure 7*, on page 28). These were defined using geomorphic and topographic mapping and field reconnaissance. The Town can use these corridor maps as a tool for enforcing laws related to parcel development and keeping habitable structures out of washes and flooding danger.

Additional Floodplain Mapping

As part of the scope of work for this project, several additional wash floodplains and floodways were delineated for the detailed 100-year floodplain (*Figure 8*, on page 29). They included Ocotillo Wash, Cave Creek tributaries, Galloway Wash tributaries, and Willow Springs Wash tributaries. The previous delineation showed only Zone A or no zone label. The new delineations show zones A, AE, or X.

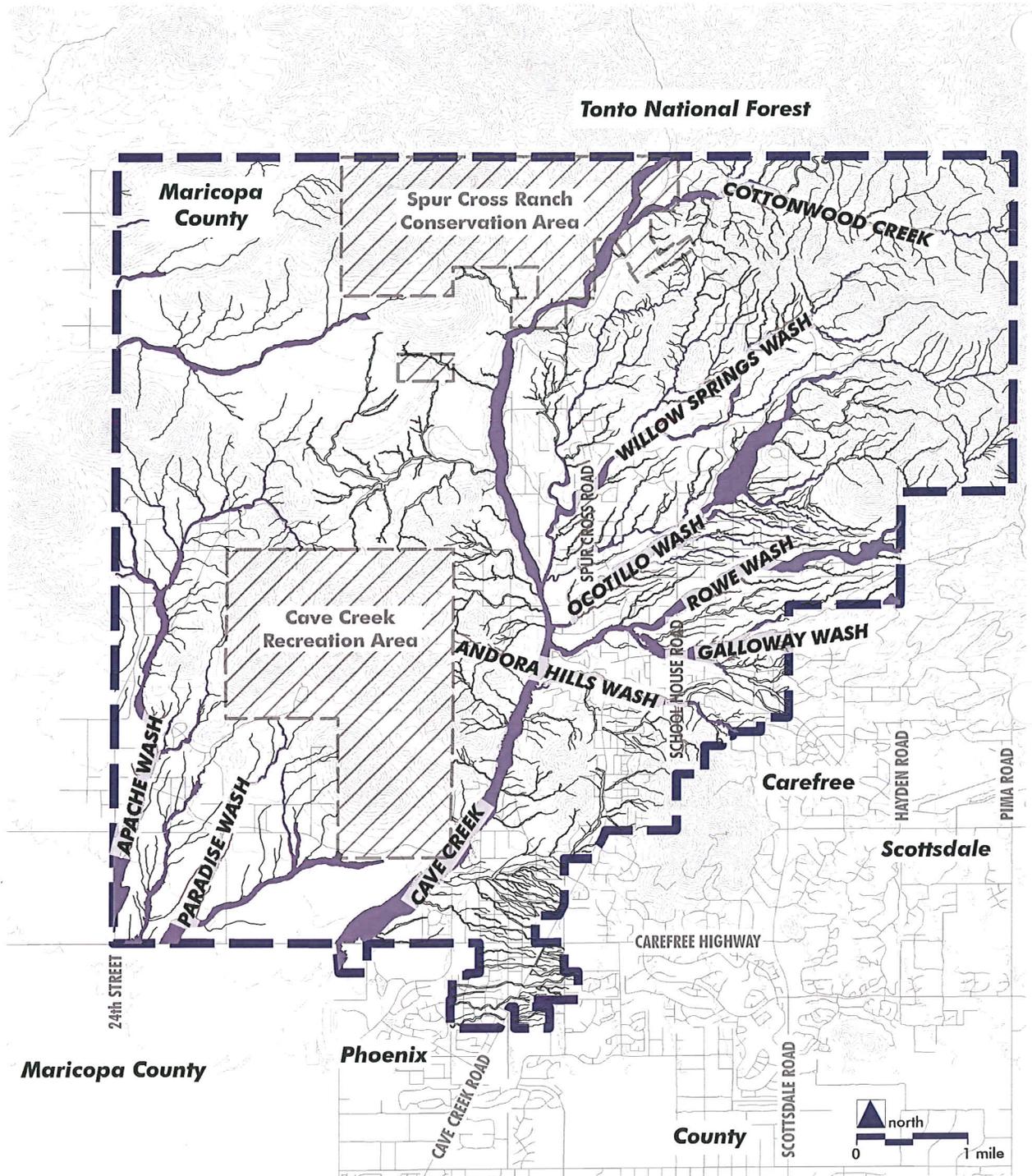


Figure 7. Major wash locations in the Town of Cave Creek

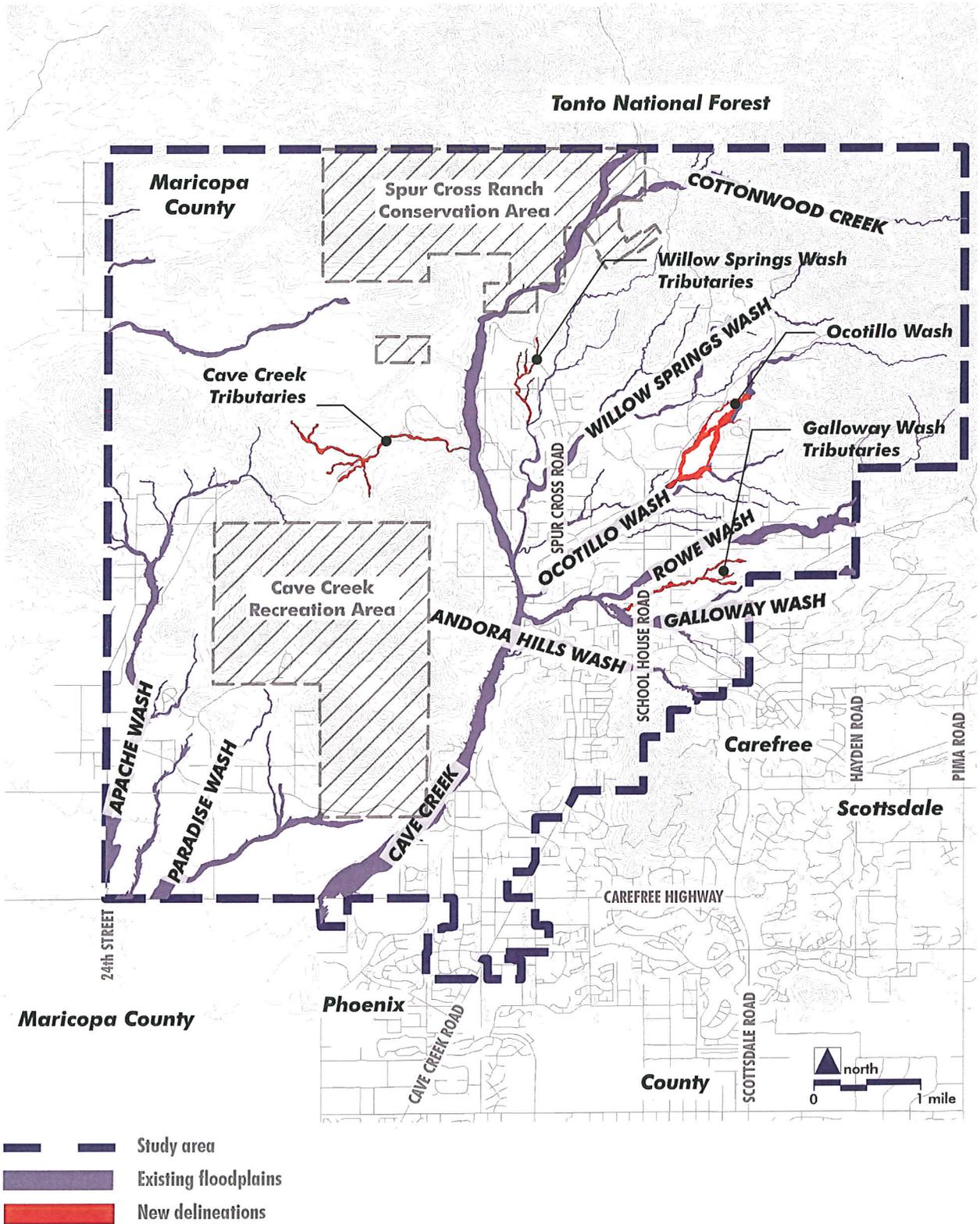


Figure 8. *New delineations*

The specific reaches mapped in this DMP are:

- Ocotillo Wash Zone A Redelineation
- Galloway Wash Tributaries 2, 2A, and 2B
- Willow Springs Wash Tributaries 6, 6A, 6B, and 6C
- Cave Creek Tributaries 1, 1A, 1B, 1C, and 1D

The new delineations were completed at the request of the Town. The new maps will be used by the Town to keep people from building within floodways, helping to avoid loss of life or property from flooding, and can be used by property owners to update their flood insurance. Appendix E of this report contains reduced copies of the work maps and summaries of the hydraulic models.

Additionally, a recommendation for future floodplain delineation is included as part of this DMP. The area known as Unnamed Central Tributary to Cave Creek, or Mormon Girl Wash, does not currently have FEMA-designated floodplains. The area is shown in *Figure 9* on page 31.

As part of the major wash identification and hydrology tasks of this DMP, the area was noted to contain the potential for a significant amount of flow between the two major branches of the wash. Additionally, several minor channels exist that may convey flow.

The area is subdivided with large-lot residential development and associated roadways. This development has, in some instances, impacted the washes with occasional obstructions by fences and structures. Several lots remain undeveloped, and therefore expedient floodplain mapping will help ensure that future development will not adversely impact the floodplain.

The flow amounts in each branch of the wash are subject to upstream conditions. At Terravita Way in the Town of Carefree, a flow split occurs that forms the northern and southern branch as it enters the Town of Cave Creek. This flow split was studied in detail in the Carefree DMP Update (previously discussed). Additionally, upstream improvements are occurring as a result of the recommendations of the Carrefree DMP.

It is recommended that floodplain mapping of the UCT/Mormon Girl Wash branches occur after the following has taken place:

- The completion of construction by the Town of Carefree on an upstream floodwall project
- Enforcement activities to remove existing obstructions within the active conveyance channels (see Wash Obstruction Removal/Code Enforcement” section below)
- Culvert improvements at Cave Creek Road (see All-weather Crossings section below)

Drainage Guidelines

The Town requested the District provide drainage guidelines to assist homeowners and developers in developing their properties. The guidelines are a user friendly document summarizing some of the issues and solutions surrounding flood protection measures. Two major features of the guidelines are that it guides development to ensure safety and it preserves integrity of existing washes. The guidelines address problems associated

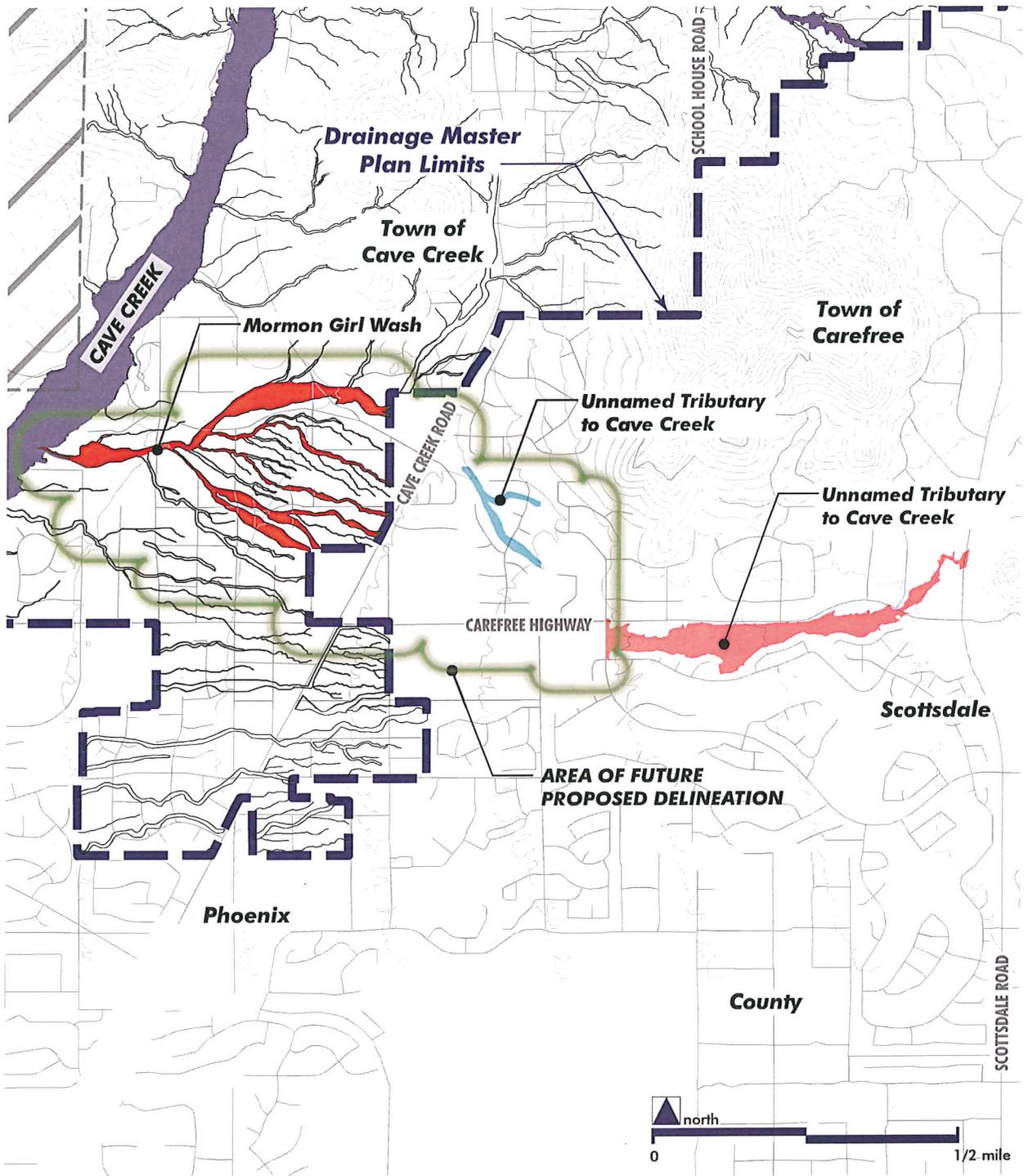
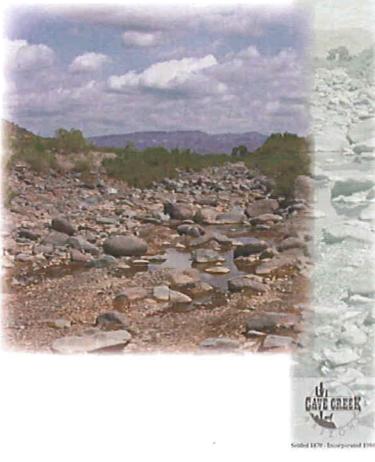


Figure 9. Area of recommended mapping for Unnamed Central Tributary

Drainage Guidelines

BEST MANAGEMENT PRACTICES

A Construction Guide for Development of Subdivisions and Individual Lots in the Town of Cave Creek



Drainage Guidelines

with development impacts and erosion hazards while adhering to the Town's adopted Technical Grading and Drainage Guidelines.

Wash Obstruction Removal/Code Enforcement

There are currently several locations where obstructions have been placed across washes potentially diverting flows onto neighboring properties. It is proposed that these obstructions be removed or modified so that the natural wash flows will not be adversely diverted. The Town has concurred with this recommendation and will be responsible for contacting homeowners and enforcing the changes.

To preserve the function and natural beauty of the drainage system within the Town it is critical that drainage regulations be enforced. There are a number of documented locations within the study area where washes have been partially filled and where obstructions such as concrete masonry walls have been placed. Rapid growth in the area has created significant staffing challenges for the Town to keep abreast of building inspection and code compliance.

Floodprone Properties Acquisition Program (FPAP)

To reduce the occurrence of repetitive property loss, the District works with property owners on projects to remove them from harm's way. Regional structural projects are not always feasible, therefore, the District has developed a proactive Floodprone Properties Acquisition Program (FPAP) to provide limited funding for voluntary, non-structural mitigation measures. The FPAP provides a method for acquiring properties in floodprone areas to protect the public from flooding hazards. The funding comes from the District's Capital Improvement Program on an annual basis.

The program is purely voluntary but the property must meet one or both of the following criteria:

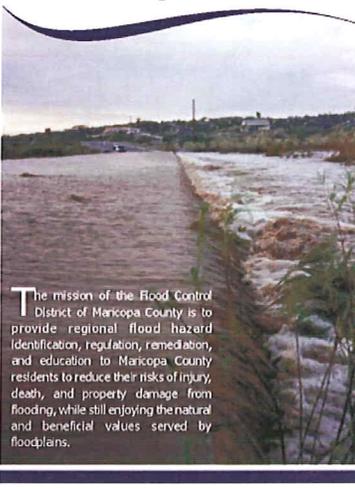
- The property is an inhabited residential structure located in a delineated 100-year floodway, or floodplain if no floodway designation exists, and was built prior to such designation
- The inhabited residential structure located in the delineated 100-year floodplain has experienced documented flood damage.

Commercial properties, vacant parcels, and agricultural and ranching lands do not qualify for the FPAP.

The DMP recommends notifying homeowners within FEMA delineated floodplains that they have the option to be voluntarily relocated under the FPAP, as described in the District's brochure.



Floodprone Properties Acquisition Program



The mission of the Flood Control District of Maricopa County is to provide regional flood hazard identification, regulation, remediation, and education to Maricopa County residents to reduce their risks of injury, death, and property damage from flooding, while still enjoying the natural and beneficial values served by floodplains.

FPAP brochure

Two residences were identified within new or existing floodways:

- Ocotillo Wash - 40647 N. Fleming Springs Road
- Ocotillo Wash - 6914 E. Continental Mountain Drive
- Willow Springs Wash Tributary 6.1 - 5515 E. Honda Bow Road

In addition, two structures located on a single property were identified by others as part of the Adobe Dam/Desert Hills ADMP:

- Apache Wash - 39416 N. 28th Street (Structure 1 and Structure 2)

These five residences are eligible for FPAP.

Erosion Hazard Setbacks

A watercourse may erode laterally over an extended period of time or as a result of a single flood event. To assess the potential and possible magnitude of channel lateral migration, JE Fuller documented hydrologic, hydraulic, and geologic existing and historic conditions for watercourses within the study area that have detailed or approximate floodplain delineations.

The purpose of identifying erosion hazard zones is to provide the floodplain manager a tool to identify areas that have the potential to be adversely impacted by channel migration and/or changes in channel geometry. The erosion hazards zones delineated for the DMP (see previous *Figure 6*) were based on field observations, comparison of historical and recent aerial, the SS 5-96 Level 1 and Level 2, and the equilibrium slope analyses. Cave Creek is exempted from these hazard setbacks due to the volume of the wash. Cave Creek has erosion hazard setbacks and it is recommended by the Town that a Registered Arizona Civil Engineer do a more detailed analysis to determine a site specific hazard level for properties in consideration of development.

The study found a predominantly degrading fluvial system where flooding and erosion are generally limited to the geologic floodplain between higher, more resistant surfaces. Urbanization has had some adverse affects on sediment transport continuity due to channel encroachments and roadway drainage crossings. Additionally, drainage patterns have been locally obscured or redirected. Long-term effects of urbanization are expected to increase the magnitude and frequency of storm water runoff and decrease sediment delivery to the watercourses.

With the hazard setbacks defined, the Town can educate homeowners in monitoring erosion hazards where existing homes are in or near the defined setback lines and can prevent homes or businesses from being built within the setback lines in the future. Persons wishing to build in or near any of these areas should be required to perform some level of engineering analyses in support of their development plan.

Education

Public education is an important on-going effort that will be critical to the success of the DMP. Education of new residents who may be unfamiliar with flood risks and mitigation practices is a particular concern. Information can be disseminated through the Town's Web site, brochures and posters at the Town Complex and other public places, through

schools, and local news media. At a minimum, education campaigns should be launched before the start of each monsoon season.

The three components of the education program are:

- Erosion Hazards Education Program
- Motorist Education Program
- Wash Continuity Education Program

The education program components are described in detail below. The Town will be the primary entity responsible for execution of the education program.

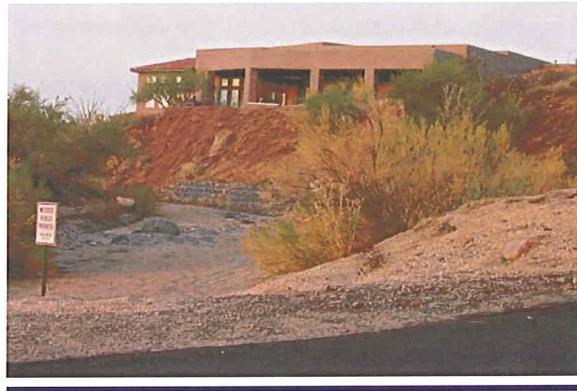
Component #1 - Educate property owners about potential erosion hazards

The Town sits on a landform in the foothills region of the Sonoran high elevation desert characterized by steep slopes, rock outcroppings, and vegetation. The soil and rock stability is not well established and is subject to movement during small to moderate storms.

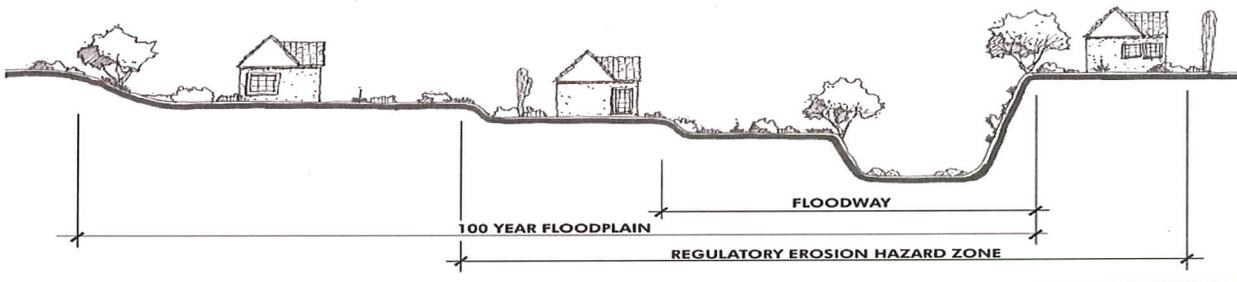
Erosion hazard setback limits (EHSL) are areas adjacent to or within major washes where the placement of structures is prohibited due to the potential for instability. These limits are established to protect structures from erosion-related damages. Existing structures determined to be inside the EHSL should be protected by structural erosion control measures. Examples of structural erosion control measures include loose or grouted riprap, retaining walls, gravity walls, roller compacted concrete, etc. General design guidelines for erosion control structures are found in the *Drainage Design Guidelines* prepared for the Town of Cave Creek.



Sever erosion damage



Erosion encroaching on structure



Erosion hazard setback limits can be beyond what appears to be the edge of the wash

This education program will include a flier for the property owners. Suggested flier language:

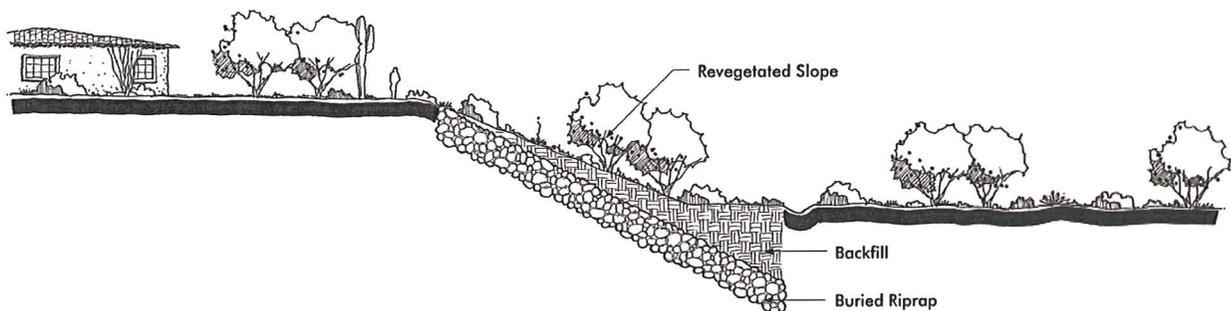
“The Town of Cave Creek sits on a landform in the foothills region of the Sonoran high-elevation desert characterized by steep slopes, rock outcroppings, and vegetation. The soil and rock stability is not well established and is subject to movement during small to moderate storms.

The *Cave Creek Drainage Master Plan* project prepared erosion hazard setback limits (EHSL) for major watercourses within the Town. For the purposes of the EHSLs, a major watercourse is defined as a FEMA designated floodplain. This includes both existing FEMA washes and those prepared for future FEMA submittal.

There are tools you can use to minimize risk to your property. They include monitoring and structural erosion control measures.

- **Monitoring.** Erosion can take place slowly over time, or during a single flow event. Measuring top of bank movement in relation to the at-risk structure can give a general indication of the rate of erosion. However, since a large amount of erosion can occur during a single flow event, this is not a guaranteed indicator of future erosion rates. Additionally, although erosion is monitored, the risk to structures remains.
- **Structural erosion control measures.** Existing structures determined to be inside the EHSL should be protected by some form of structural erosion control measures. Examples of structural erosion control measures include loose or grouted riprap, retaining walls, gravity walls, roller compacted concrete, etc. General design guidelines for erosion control structures are found in the *Design Guidelines* prepared for the Town of Cave Creek.

If you have any questions about protecting your property from erosion hazards, please contact the Town of Cave Creek Engineering Department at:



Buried riprap, a structural erosion control measure, can be concealed with backfill and desert plants

480-488-1400, or in person at 37622 N. Cave Creek Road, Cave Creek, AZ 85331.”

The Program: Send out fliers to identified property owners upon conclusion of the DMP study. Since new development shall be placed outside of the newly-identified EHSL, future notifications are not necessary. However, should existing properties change ownership, the flier should be sent to the new owners.

Who	Property owners with structures inside EHSL area
What	Erosion Hazards Education Program
When	Send out flier to identified property owners upon completion of the DMP. New development shall be placed outside of the EHSL; therefore, no new notifications are necessary
Where	A list of addresses was given to the Town
How	Flier, post flier on Town’s Web site and mail to identified property owners

Component #2 - Educate drivers about not driving in low-water crossings when water is present

Most of the wash crossings in the Town are “at-grade” crossings; meaning they allow water flowing in the wash to pass over the roadway. This is true for wash crossings on both publicly-owned and privately-owned land.

At-grade crossings are effective in the Town due to the low, initial expense and their ability to function during dry periods, which are most days of the year. Those infrequent occasions when washes are flowing, they should not be crossed due to the hazards of becoming stranded or swept downstream.



Newscast regarding ‘stupid motorist law’



Galloway Wash at School House Road, July 23, 2007

Most vehicles attempting to cross the road will lose grip in less than 6 inches of flowing water, and most vehicles can become buoyant in 2 feet of water or less. Nearly half of flash flood fatalities are automobile related. The State of Arizona has instituted the “stupid motorist law” (Arizona Revised Statutes Section 28-910) — individuals who become trapped after driving around barricades or failing to observe posted warnings could be held liable for the cost of their own rescue, as well as the potential additional fines.

Flash floods, producing swift-moving rushes of water several feet high, can occur at any time without warning. Do not cross rain-swollen roads or washes; floodwaters can easily sweep your vehicle away. During flash floods, water in flooded roadways is muddy and often deeper and faster-moving than it appears. Because of this, it is almost impossible for a motorist to see when a flooded roadway has been weakened or destroyed

or if debris is hidden beneath the surface. It does not take much water to undermine and wash away asphalt.

Pay attention to hazard signs and roadblocks; never drive around barricades to cross a flooded roadway or wash. If caught in a flash flood stay with your vehicle, if possible, and do not attempt to make it to shore on your own. Call 911, and, if possible, climb onto the roof and wait to be rescued. Pay attention to, and cooperate with, rescuers when they arrive.

The Program: Fliers should be mailed out to every resident in the Town at the beginning of monsoon season. At this time, also post information/flier at Town Hall and at popular hang-outs that have bulletin boards (coffee houses, feed stores, etc.). The Town should determine locations and execute mailings and postings.

Additionally, the District has commercials which discusses driving during monsoons. The Town's Web site should be updated to contain a link to the District's Web site, ALERT gages, and "driving during storms" videos. People who are already on the Town's e-mail distribution list could have items e-mailed to them as well.

Who	All drivers
What	Motorist Education Program
When	Every year at the start of monsoon season
Where	Town Hall, local bulletin boards, Web site, e-mails
How	Fliers, Web sites (post fliers on Town Web site), in water bills

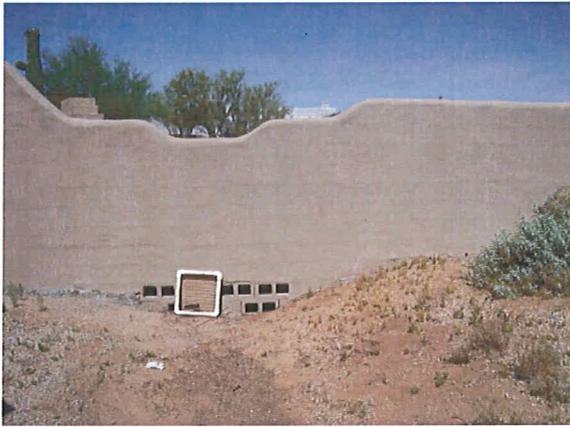
Component #3 - Educate property owners about not diverting water in washes

The manner in which water leaves a property that has been altered by grading can adversely affect downstream properties. Therefore, when grading alters the natural drainage of a property, historical drainage must be maintained at the parcel and or property boundary. This includes drainage location, volume, velocity, sediment yield, and the direction of flow from the parcel or property.

Diverting water or placing fill in a wash is a violation of Arizona Revised Statute (ARS) 48-3615, which states:

“It is unlawful for a person to engage in any development or to divert, retard or obstruct the flow of waters in a water course if it creates a hazard to life or property without securing the written authorization required by Section 48-3613. Where the watercourse is a delineated floodplain it is unlawful to engage in any development affecting the flow of waters without securing written authorization by Section 48-3613.”

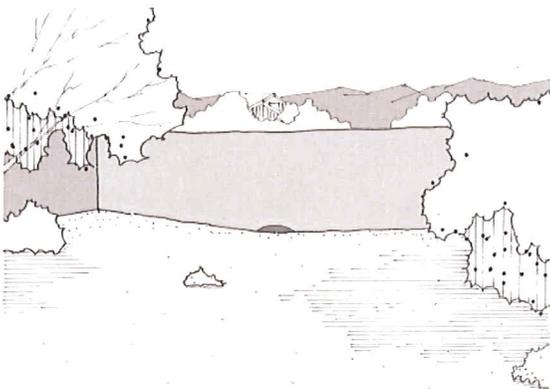
No property wall shall be constructed as to prevent the discharge from the 100-year storm event through any parcel within the Town. Any property walls constructed within or across a wash shall utilize a system to provide adequate conveyance of water. Additionally, all walls are subject to approval by the Town Engineer and should be constructed under permit from the Town of Cave Creek.



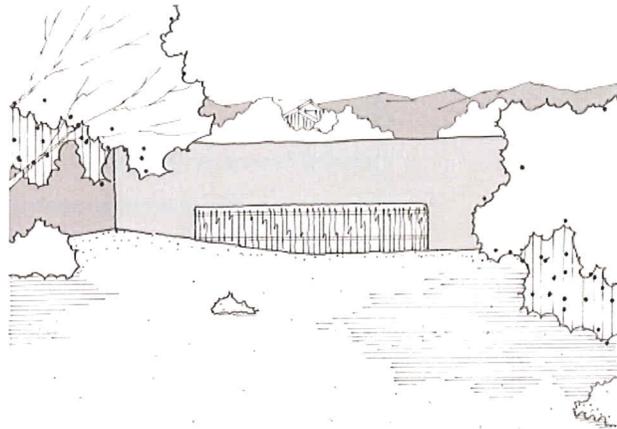
Small drainage openings will restrict natural flows.

If a wall was not constructed under permit and is found to inhibit drainage, the owner may be required to remove or alter the wall. Additionally, sub-standard or blocked openings i.e. openings that may restrict location, volume, velocity, sediment yield, or direction of flow; or that have been blocked, may require reconstruction at the expense of the property owner.

The Program: Send out fliers to all property owners in the Town upon conclusion of the DMP study. Post the *Drainage Guidelines* document on the Town's Web site. The Town



A wall shown with improper openings.



A wall shown with proper openings. Openings shall be sized for proper capacity by an Arizona registered Civil Engineer and approved by the Town Engineer.

is to contact property owners at the recommended addresses for potential enforcement activities (Town to research permit status first).

Who	All property owners
What	Wash Continuity Education Program
When	Immediately for areas determined to be in violation during applications for development (as part of Drainage Guidelines, which should be distributed immediately upon interest to develop)
Where	A list of addresses has been provided to the Town
How	Flier and Drainage Guidelines should be posted on Town's Web site.

Flood Response Plan

A Flood Response Plan (FRP) was completed for the Town and has been implemented by both the District and the Town. Refer to the *Final Technical Memorandum Cave Creek DMP Flood Response Plan*, dated February 15, 2007, prepared by LTM Engineering,

Inc. The plan identifies ALERT gages and recommends additional stage gages, public education tools, and lines of communication during storms.

Cave Creek and its tributaries make up an ephemeral drainage system that collects stormwater, provides habitat for numerous desert and riparian species, and is an important passive recreation resource for residents. However, the system is also subject to flash flooding, causing flooding problems at the numerous at-grade road crossings of the washes. The FRP was developed for the following watercourse delineated segments within the Town boundaries:

- Cave Creek
- Willow Springs Wash and Tributaries 1, 2, 2A, 4, and 5
- Ocotillo Wash
- Rowe Wash
- Galloway Wash and North Tributary
- Andora Hills Wash

Several other washes in the study area were not included in the FRP because they were addressed in the Adobe Dam/Desert Hills FRP. They are Paradise Wash and its tributaries, Apache Wash and Ranieri Tank Wash (west of Cave Creek, east of Apache Wash, and north of Carefree Highway).

Several features of the Town are vulnerable to flooding: major roadway crossings, local and collector street crossings, occupied structures, and recreational activities. The major transportation routes within the Town are Spur Cross, School House, and Cave Creek roads, most of which have at-grade crossings at the washes. Nearly all the wash crossings at the local and collector streets are at-grade. There are a few occupied structures at risk, concentrated in the Ocotillo Wash Zone A portion of the delineated floodplain and along the Willow Springs Wash Tributary 6. Recreational activities within the floodprone areas are predominantly hiking and equestrian trails, both along the roadways and in the washes. The same vulnerabilities on recreational trails coincide with the locations identified for roadways.

The FRP recommends:

- Early notifications so the Town can mobilize if needed prior to the start of significant rainfall
- Specific tasks to be undertaken by the District and the Town for routine operations, flood conditions, and post-flood conditions
- On-going training and exercises in FRP procedures
- Reviewing the FRP annually and updating as needed
- Future improvements such as additional ALERT gages, installing crest gages at selected roadways, increased public education, expanding the notification list, and continued close coordination among participants. These future improvements are important to the success of the FRP.

Active flood warning methods specifically rejected during the October 2006 workshop were:

- Automated telephone notification system. This was viewed as unnecessary and ineffective. If residents are at home and receive the phone call, they will stay at home to avoid flooded areas. If they are not at home, then the call will be unanswered.
- Flashing amber lights with automated crossing arms to warn of flooded low-water crossings. While these would be effective, they would also be visually distracting when not in use and would detrimentally affect the character of the area. They are also undesirable because they would require electrical power, radio or telephone telemetry, calibration, and maintenance. Flashing lights may be acceptable at major crossings such as Spur Cross Road or School House Road. However, automated barriers were rejected by residents and Town staff.
- Manual Gates. Manual closure gates were not supported due to the intrusion on the landscape when not in use. Further, they do not reduce emergency response activities of the Town staff since they must be manually closed and opened.

All-weather Access

All-weather Crossings

Roadway improvements are recommended at several locations as part of the *Drainage Master Plan* to provide all-weather crossings (see *Figures 10a* and *10b* on the next page 40 and 41):

- Culvert improvements on Cave Creek Road (two locations)
- All-weather crossing improvements on School House and Spur Cross roads (five locations)

The improved crossing locations were determined during the alternative analysis phase of the project. Initial locations for improvements were determined through recommendations for access pathways for emergency response from the FRP. The FRP included a determination of the number of residents who were not able to leave or return to their homes during runoff events.

From the list of potential improved crossing locations, an Alternative Development Workshop was held with members of the District, Town, and consultant team. During this workshop, routes of access were compared for different improvement scenarios. The proposed all-weather crossing improvement locations were developed to allow the most access for the least number of improvements. Additionally, traffic patterns and right-of-way ownership were considered.

The access shown by the post-Drainage Master Plan improvements has been prepared under the assumption that traffic will be able to access the Carefree Highway or the Cave Creek Road from south of the DMP study area.

School House Road vs. Spur Cross Road Improvements

During examination of access routes it was determined that approximately the same access to the north could be gained by either improving the major wash crossings on School House Road or Spur Cross Road. A combination of improvements, some on each road, were proposed.

Three improvement locations are necessary for School House Road for the alignment between Cave Creek Road and Ocotillo Wash. School House Road was identified as the

main access road to the northern properties. This is because Spur Cross Road traverses through residential neighborhoods, with a narrower right-of-way and many jogs and curves. Spur Cross Road was additionally selected due to the potential for increased traffic as development continues based on the current open space. Entry to School House Road from Cave Creek Road is from a four-way stop intersection, unlike Spur Cross Road which has an uncontrolled intersection off Cave Creek Road.

North of Ocotillo Wash, School House Road terminates in a residential development. To continue to provide access to the north, the suggested route of travel from School House Road to Spur Cross Road is by Fleming Springs Road. Two crossing improvements on Willow Springs Wash and Willow Springs Wash Tributary 5 are recommended, would provide an enhanced level of public safety by providing routes in and out of the northern portion of the Town.

Table 9.1, indicates the 100-year flow volumes at each proposed improvement location. Although several regulatory agencies allow a lesser design event, the 100-year flow event is recommended for use at these locations. This is because:

- They span existing regulated 100-year floodplains and floodways,
- Constricted openings would cause the floodplain elevations to rise, necessitating re-mapping and potential compensation to affected property owners,
- Constricted openings could cause sediment accumulation and disruption to the natural sediment balance of the wash, and
- The need for all-weather emergency access.

Conceptual design plans for the proposed improvements are included in Appendix F.

TABLE 9.1: 100-year Flow Amounts

Improvement Location	Source	Event	Flow (cfs) 100-year event
Cave Creek Road at UCT, North Branch (Mormon Girl Wash)	JEF, 2005	100-yr	1,252
Cave Creek Road at UCT, South Branch	Shephard Wesnitzer, 2007	100-yr	911
Cave Creek Road immediately north of Carefree Highway	Shephard Wesnitzer, 2007	100-yr	289
School House Road at Galloway Wash	JEF, 2000	100-yr, 24-hr 100-yr, 6-hr	10,908 9,070
School House Road at Rowe Wash	JEF, 2000	100-yr, 24-hr 100-yr, 6-hr	5,094 4,898
School House Road at Ocotillo Wash	FIS, 2005	100-yr	4,630
Spur Cross Road at Willow Springs Wash	FIS, 2005	100-yr	4,800
Spur Cross Road at Willow Springs Wash Tributary 5	CH2M Hill, 1990	100-yr	631

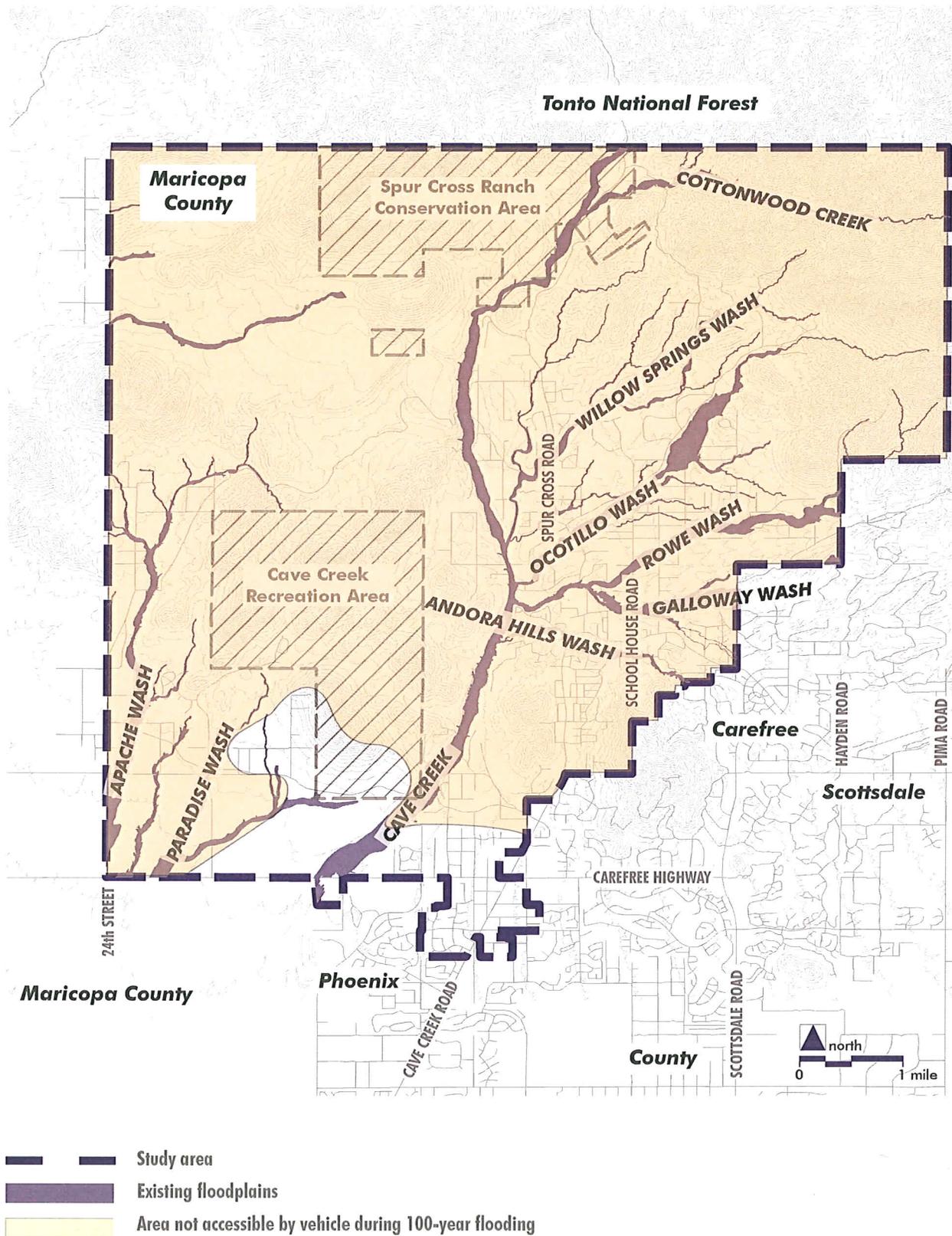


Figure 10a. All-weather access locations — pre-Drainage Master Plan improvements

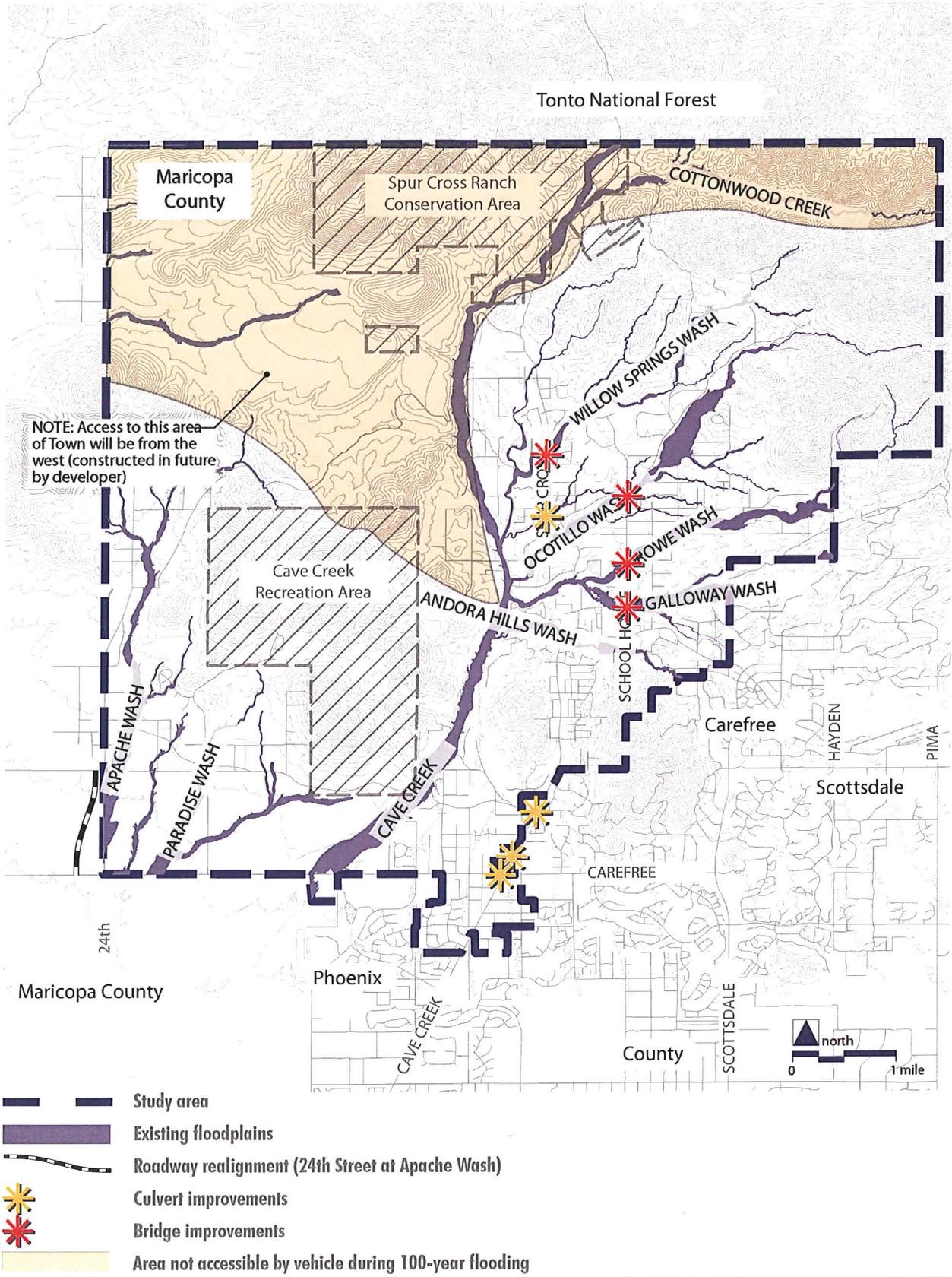


Figure 10b. All-weather access locations — post-Drainage Master Plan improvements

Culvert Improvements

Improvements to the culverts crossing Cave Creek Road at the UCT to Cave Creek, North and South Branches, are part of the recommended plan. The northern branch of the wash has been historically referred to as the Mormon Girl Wash. Currently, the culverts at both crossing locations are undersized and filled with sediment. Roadway flooding is expected during larger runoff events.



Sediment filled culvert.

These wash crossing locations are within the Town of Carefree. However, the Town of Cave Creek is responsible for maintenance of the roadway. Crossing improvements will benefit the residents of the Town by providing access to the north.

The *Carefree Drainage Master Plan* previously recommended improvements at this location. Conceptual design was completed as part of that DMP; however, the flows used to size the proposed improvements were updated as part of the *Carefree Drainage Master Plan Update*. The Update developed a 2-dimensional model to better characterize the effects of an upstream flow split. The crossings were redesigned in this DMP to reflect the updated flow information.

Additionally, an improvement of the existing 18-inch culvert across Cave Creek Road immediately north of Carefree Highway is recommended to accommodate the break out flow from the UCT southern branch. Based on the break out flow amounts, it is recommended that this culvert is upsized to handle 289 cfs.

A detailed design of this crossing was not completed as the ultimate configuration of the intersection and Carefree Highway is not known. Improvements are planned as part of a Maricopa County Department of Transportation project to widen Carefree Highway, and the design of the crossing should be coordinated with that project. Additionally, improvements along the north side of Carefree Highway between Cave Creek Road and Cave Creek should be developed in order to convey the 289 cfs along the north side of the roadway to Cave Creek.

An additional culvert improvement is located at Spur Cross Road and Willow Springs Wash, Tributary 5. The existing triple 42-inch-diameter corrugated metal pipes are proposed to be replaced with triple 8-foot by 3-foot reinforced concrete box culverts. This improvement would eliminate the impassible roadway flow overtopping which currently occurs during 100-year runoff events.

Aesthetic treatments, discussed in subsequent sections of this report, should be applied to all culverts. Additionally, several commercial manufacturers of pipe arch products are available that may be substituted for standard box culverts and are generally aesthetically pleasing. Current cost estimates indicate that these products are more expensive for the relatively small sizes proposed in this plan; however, during final design, these products may still be considered.

All-weather Crossing Improvements

All-weather access crossings are proposed at three locations on School House Road (at Galloway, Rowe, and Ocotillo wash crossings). One all-weather crossing is proposed on Spur Cross Road at Willow Springs Wash (see *Table 9.2*).

TABLE 9.2: All-weather Crossing Improvements

Location	Crossing Length (ft)
School House Road at Galloway Wash	400
School House Road at Rowe Wash	650
School House Road at Ocotillo Wash	400
Spur Cross Road at Willow Springs Wash	450
Spur Cross Road at Willow Springs Wash Tributary 5	N/A*

*Due to the small size needed at this location, this crossing is proposed as a culvert; see discussion.

The lengths listed in the table include sufficient length to span the existing regulatory floodways. During final design, these lengths may be refined based on type of structure and abutment design. Aesthetic treatments and multi-use considerations are discussed in the subsequent sections of this report, and should be applied to all crossings.

Adopt “Grading and Drainage Guidelines for Town of Cave Creek

JE Fuller has prepared the “Town of Cave Creek Technical Design Guidelines, Grading and Drainage.” These guidelines contain important recommendations for drainage design within the Town. These guidelines were submitted to the Town Council on October 15, 2007 and are pending approval.

Realignment of 24th Street

The Adobe Dam/Desert Hills ADMP recommended the realignment of 24th Street to remove it from the active floodplain/floodway of Apache Wash. This has not been implemented to date, and is an important component to allow access to the residents in the western portion of the study area. Refer to Figure 10b for a graphic illustration of the Proposed 24th Street roadway realignment. Implementation is recommended.

10. LANDSCAPE, AESTHETIC TREATMENT, AND MULTI-USE OPPORTUNITIES

One objective of the DMP is to incorporate aesthetics and multi-use opportunities into flood control solutions for the study area. Flood control solutions can greatly benefit the

community when they successfully blend engineering, aesthetics, and multiple uses. This section describes existing landscape conditions and the proposed landscape, aesthetics, and multi-use opportunities which are recommended for the study area

Landscape

The landform in the Town is rugged with canyons and steep slopes. Washes in the higher elevations are v-shaped and narrow becoming wider and u-shaped in the lower reaches of the watersheds (*Figure 11*). The rugged nature of the landscape provides visual interest in the variety of rock types and colors (*Figure 12*).

Overlaid on the natural landscape are the cultural or man-made impacts. Much of the Town is rural, large-lot development (*Figure 13*) maintaining some of the natural desert vegetation and providing wide open vistas. The Town core is a small urban component with a western character (*Figure 14*), mainly adjacent to Cave Creek Road between Spur Cross Road and School House Road. There are a few suburban subdivisions with grid street systems laid over the braided wash system.

Vegetation

Revegetation shall blend with the native surrounding, native vegetation in species and density (*Figure 15*). Existing vegetation, especially specimen trees and large shrubs should be preserved in place.

The natural vegetation is typical Sonoran Desert, specifically Arizona Upland Sonoran. The Sonoran Desert is distinguished by its diversity in plant species, particularly cactus. The Town's slightly higher elevation and precipitation rate make it more lush than the lower metropolitan valley and tends to remain greener throughout the summer months. The dominant plants are palo verde, ironwood, saguaro, and bursage (*Figure 16*). At the highest elevations of the Town of Cave Creek, the palo verde-bursage vegetation begins to give way to piñon-juniper. Washes in the Town can also have lush riparian vegetation characterized by the abundance of cottonwoods (*Figure 17*).

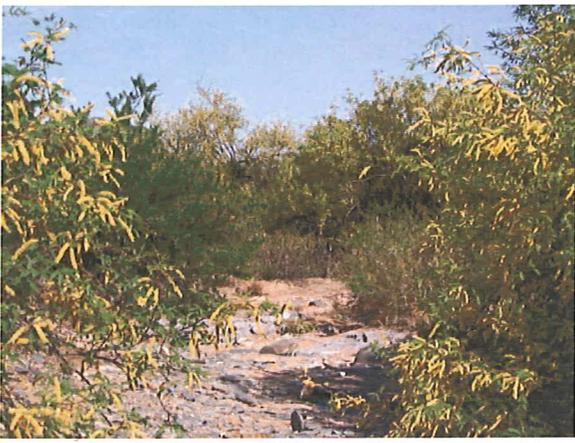


Figure 11: Wash with dense vegetation and rocky bottom



Figure 12: Rock outcrop

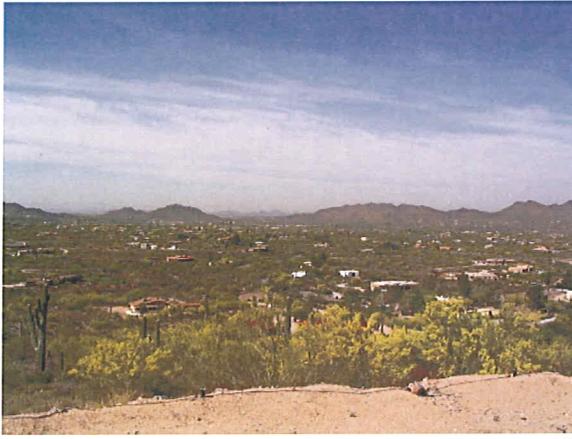


Figure 13: Large-lot development dominates the Town of Cave Creek

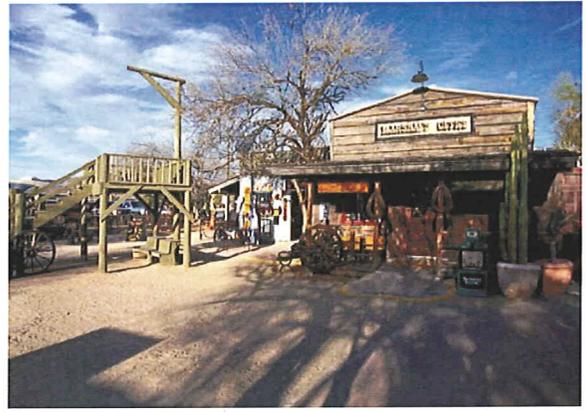


Figure 14: Western Character in downtown

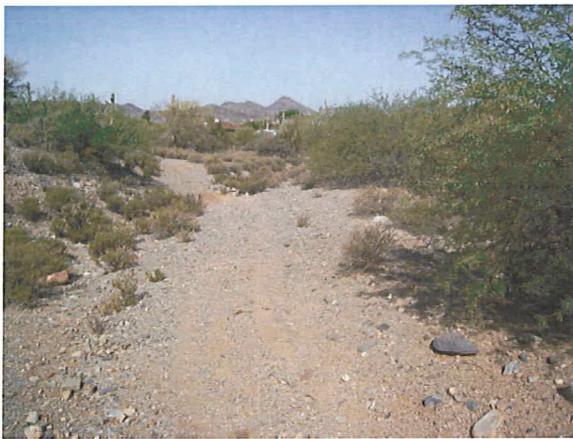


Figure 15 A natural vegetated wash



Figure 16: Saguaro and palo verdes

Desired Landscape Character

Since the study area is dominated by natural desert, the recommended landscape theme is maintaining the natural Sonoran Desert. The preferred elements are recommended to have vegetation and colors that blend with the natural surroundings.

Aesthetic Treatment

The two constructed elements proposed for the Town are all-weather crossings and improved culverts. The other Master Plan elements are non-physical such as mapping of floodplains/floodways and erosion hazard setback, FRP, wash obstruction removal plan, and education. Aesthetic guidelines for the constructed elements are outlined below.

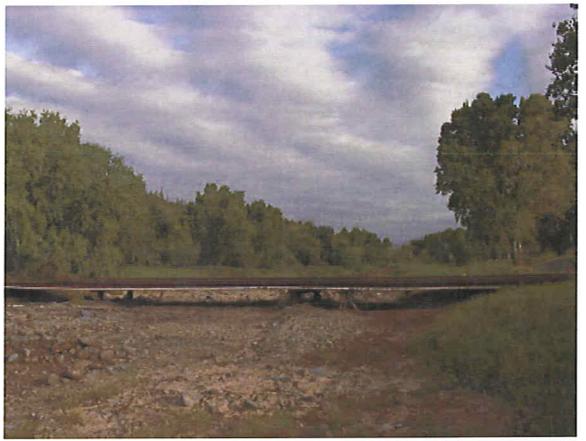


Figure 17: Cave Creek with cottonwoods

All-weather Crossings

All-weather crossings can be an aesthetic addition to the landscape — consider the appeal of the covered bridges in the east and mid-west. Crossings in the Town, however, should have a western desert character. The aesthetics should be three-dimensional in that the detailing is pleasing to those traveling over the crossing as well as those under or near the sides.

The overall form of the crossing is most important and should be simple and uncomplicated. Second, and as important, it should fit visually into the context of the site. Elements to consider are proportion, rhythm, balance, and unity. Timeless design and quality materials and construction will maintain the attractiveness of the bridge for its anticipated life.

All-weather crossings would be low profile, with rustic detailing and stone or dark colored concrete supports as suggested in *Figure 18*.

An open rail design can create a more refined crossing with a lighter appearing span as suggested in *Figure 19*. Avoid large, flat concrete surfaces by adding shadow lines and patterns to break up the blankness. Crossing support column shape must account for scour.

Balance aesthetics with function, constructability, and future maintenance. Aesthetic design does not have to increase the cost of long-term maintenance.

Provide bike lanes and sidewalks across bridges to provide all-weather crossing ability for several modes of travel.

Crossings should provide for trail and equestrian access over or around the feature rather than through.

Culverts

Culverts should not incorporate plain, gray concrete or concrete masonry unit headwalls, wingwalls, or aprons, but should instead have stained concrete (*Figure 20*), native rock veneer (*Figure 21* and *Figures 22* and *23* on next page) gabion mattresses, or other types of treatments. Culverts should allow for continuity of trails by realigning the trails around and over culverts, not through them.



Figure 18: A simulated crossing in Cave Creek

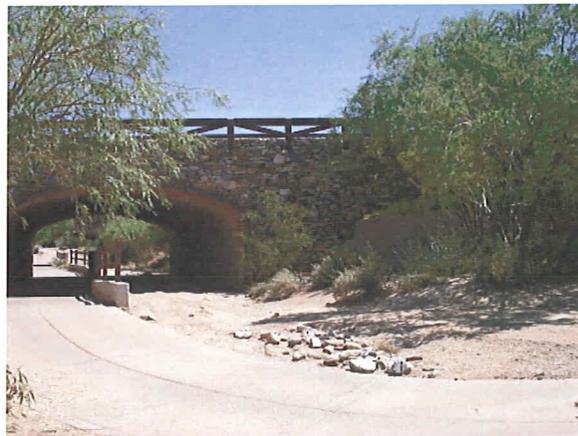


Figure 19: An all-weather crossing with rustic detailing



Figure 20: Stained concrete headwall

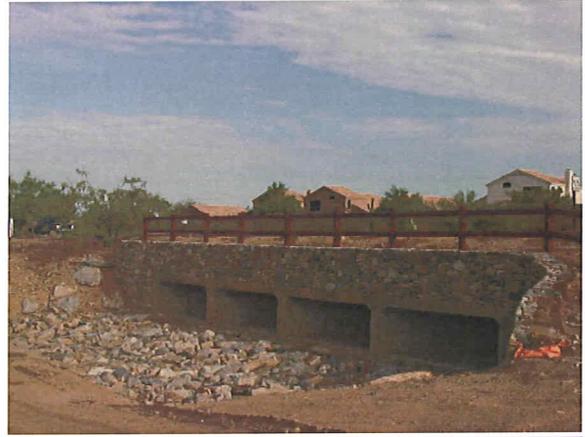


Figure 21: Stone headwall

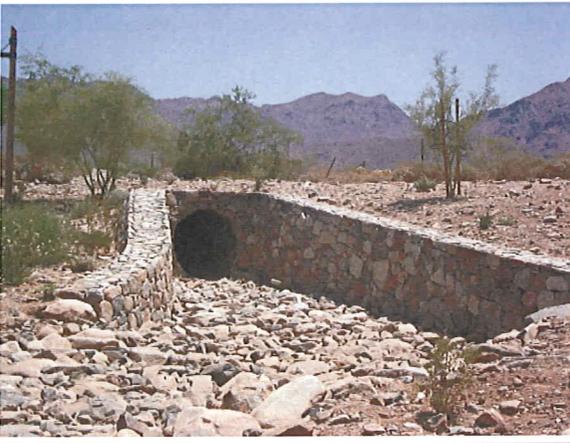


Figure 22: Stone culvert



Figure 23 Culvert with rustic detailing

Culverts should be designed so that they cause the least visual intrusion or physical obstruction while providing adequate conveyance capacity. Keeping vertical extensions to no more than 6 inches above the proposed grade helps limit visual interruptions. However, this guideline does not apply to barriers needed for pedestrians and bicycles. Appropriate vegetation screening can minimize any visual intrusion. Using rocks and boulders can also help especially where there are natural rocks and boulders occurring.

Like the all-weather crossings, the culverts will be designed with stone and/or dark colored or stained concrete and rustic detailing.

Construction materials should complement the surrounding scenic resources in color, form, and texture.

Low-Water Crossings

Low water crossings generally do not visually impact the landscape setting. Sometimes the paving over the culverts differs from the roadway paving, but they are generally flush with the existing roadway pavement. The paving color can be matched to the surrounding landscape. The structural component on the downstream side can be constructed of colored concrete or stone.



Figure 24: Buried bank protection after construction.

Bank Protection

The least intrusive bank protection is buried bank. Once installed and the landscape revegetated, it is no longer visible (see Figure 24). The revegetation should be designed to match the surrounding natural landscape in species and density.

Cut Banks

Bank protection for natural cut banks can be buried between the bank edge and the buildings (see Figure 25). When backfilled and revegetated, they are not visible. Revegetation should be designed to match the surrounding natural

landscape in species and density.

Grade Control Structures

Grade control structures can blend with the landscape setting if they are built of materials native to the site (Figure 26) rather than engineered out of grey concrete.

Colors

Colors for all constructed features should blend into the background. The use of medium to dark earth tones (browns and greens) will help (Figure 27). Staining is preferable to painting.

Grading

Grading should restore the topography to as close to natural contours as possible. Embankments, basins, and channels should meander so they feather into the landscape. Avoid paved embankments by providing 4:1 slopes that can be revegetated. Rock mulches or stone riprap also help to stabilize slopes and should have a random “desert paving” appearance (Figure 28), not the uniform, 2 inches of decomposed granite often used in commercial development.

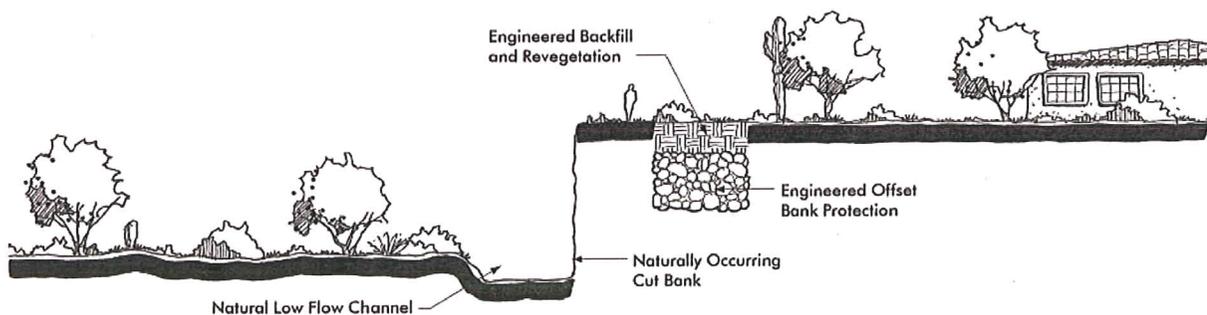


Figure 25: Cut bank

Minimize alterations to natural land forms. Basins and channels should appear as naturally formed elements of the environment rather than as engineered structures.

Refer to the draft *Scenery Resource Report* for specific grading guidelines for basins and channels.

Multi-use Opportunities

Flood control alternatives can often offer multiple-use opportunities complementing the recreation and open space needs of the local community. At minimum, they should not hinder or detract from the recreation desires of the residents. The Town is predominantly an outdoor, passive recreation community. The Town's vision for trails is "to create accessible, non-motorized trail connections to recreational open spaces throughout the Town that do not affect the overall quality or integrity of the natural environment for the enjoyment of our citizens and future generations." Equestrian facilities, in particular, are important to Town residents. There is less emphasis on open, turf active play areas and ball fields.

There are two large passive recreation areas within the study area - Cave Creek Recreation Area (2,922 acres) and Spur Cross Ranch Conservation Area (2,235 acres). Both areas are predominantly used for trail related activities such as hiking, mountain biking, and equestrian. The Cave Creek Recreation Area additionally offers camping facilities. Spur Cross Ranch is new to the Maricopa County Parks system and is under development. There are also several other small open spaces: Black Mountain Preserve, Gateway Desert Awareness Park, Go John Mountain, Saguaro Hill, and Brenner's Hill. The Town's trail system (refer back to *Figure 4*) was designed to tie into many of these recreation areas and is heavily focused around the abundant washes. Maintaining access along the washes and across the various roadways will be key in the DMP.

Proposed constructed options for the DMP are all-weather crossings and culverts. In both cases, if the location of these features intersects one of the identified trails,

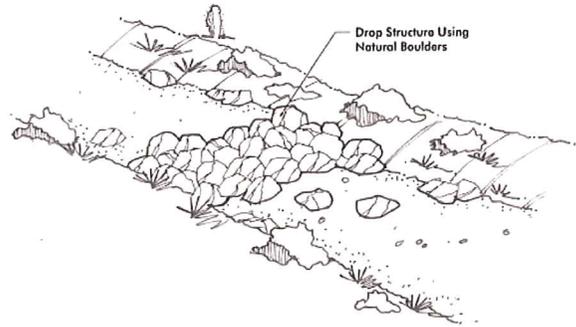


Figure 26. Grade control structure using on-site materials.

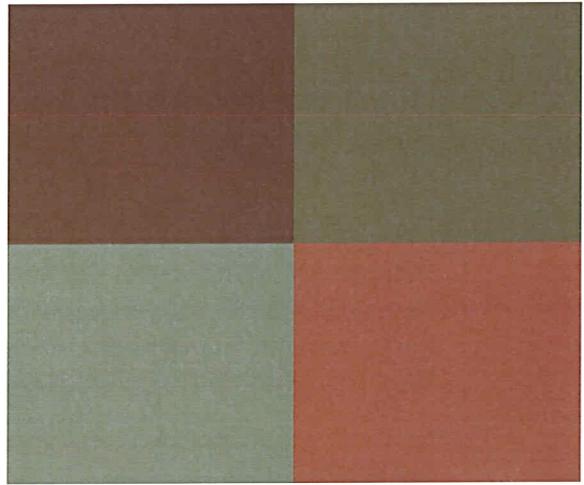


Figure 27: Desert colors



Figure 28: Natural desert paving

accommodations should be made in the design to route trail traffic around the crossing and over the road. The trail route should be clearly visible and signs added as needed.

Land

Parcel Ownership

Parcel ownership within the study area is generally held either privately, as part of a park or conservation area, or as State of Arizona Trust Lands. For detailed maps on land ownership for the project area refer to Appendix B of this report.

Rights-of-Way and Easement Requirements

Obtaining rights-of-way and temporary construction easements will be necessary to construct the proposed all-weather access crossings and culvert improvements. Proposed conceptual rights-of-way are shown on the improvement plans contained in Appendix A of this report.

Major Utilities and Utilities Conflicts

In general, utilities present within the right-of-way may include water, sewer, gas, fiber optic, storm drain, telephone, and cable. Water service in the Town is provided by Global Water Company with occasional well sites and storage tanks within the Town.

Research was performed through the Town and Blue Stake to determine specific utilities present at each site. The results of the research are shown on the conceptual improvement plans contained in Appendix A of this report.

Notable utilities include the presence of a relatively deep-gravity PVC sewer line in Cave Creek Road, a sewage lift station adjacent to the proposed northern culvert crossing improvement on Cave Creek Road, and buried or overhead fiber optic lines at most crossings.

Conceptual Design Cost Estimates

Cost estimates were prepared for the recommended all-weather access crossings and culvert crossing improvements. A conceptual estimate is shown in *Table 9.3*; detailed information on each estimate is included in Appendix E of this report. Estimates are prepared in 2008 dollar projections and include design and construction estimates and contingencies.

TABLE 9.3: Conceptual Cost Estimate

Improvement Location	Cost* (2008 dollars)
Cave Creek Road at UCT, North Branch (Mormon Girl Wash)	\$965,000
Cave Creek Road at UCT, South Branch	\$616,000
School House Road at Galloway Wash	\$4,196,000

TABLE 9.3: Conceptual Cost Estimate

Improvement Location	Cost* (2008 dollars)
School House Road at Rowe Wash	\$7,005,000
School House Road at Ocotillo Wash	\$4,436,000
Spur Cross Road at Willow Springs Wash	\$4,420,000
Spur Cross Road at Willow Springs Wash Tributary 5	\$458,000

*includes design and construction costs

11. IMPLEMENTATION PLAN

Implementation Recommendations

Successful implementation of the *Drainage Master Plan* will result after completion of several important elements:

- Adopt the Recommended Plan. The plan must be adopted by both the Cave Creek Town Council and the Maricopa County Board of Directors.
- Solicit Public and Stakeholder Support. An understanding of the plan elements and agreement by the stakeholders (Maricopa County, State Land Trust, Town of Cave Creek) to support the plan is key to successful implementation.
- Secure Funding. Funding sources should be pursued as soon as possible, especially construction elements such as all-weather and culvert improvements.
- Acquire Land. Easements and rights-of-way would need to be acquired for elements requiring construction. Because of the area's rapid growth, opportunities for managing and mitigating flooding are rapidly diminishing and land cost are rising.
- Proceed with Design Phase. Several elements of the recommended plan will require preparation of design plans and specifications. These projects should proceed as soon as possible to reduce current flood and erosion risks to property and lives.

Opportunities and Constraints

Opportunities to implement the *Drainage Master Plan* include:

- Partner with the development community to preserve and protect the Town's natural drainage system and provide all-weather access.
- Adopt the *Cave Creek Drainage Master Plan* and the Town's *Drainage Guidelines* and enforce existing drainage regulations.
- Take advantage of the District's expertise in installing flood detection equipment. The District currently operates a very sophisticated flood detection system throughout Maricopa County, including the Town of Cave Creek, and is an excellent resource. Additionally, the District has been willing to operate and maintain equipment purchased by a local community.

- Enhance the Town's Web site to include education on flood and erosion risks and mitigation strategies.

Potential constraints to implementing the *Drainage Master Plan* include:

- Lack of funding
- Insufficient staff resources to inspect new development and remediate code violations.
- The District's FPAP is strictly voluntary. If eligible residents decline to pursue a buy-out, they remain at high risk for flooding.

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GLOSSARY

100-year (or base) Flood	A flood event that statistically has a 1 out of 100 (or one percent) chance of being equaled or exceeded on a specific watercourse in any given year. A flood event of this magnitude is often used to determine if flood insurance is either advisable or required on a property.
ADMP	A plan which identifies the preferred alternatives of those identified in an ADMS. An ADMP provides minimum criteria and standards for flood control and drainage relating to land use and development.
Braided	A braided watercourse is one flowing in several dividing and reuniting channels resembling the strands of a braid.
CFS	The measuring unit of cubic feet per second (cfs), which is used to quantify the amount of flow in a wash. A cubic foot is equivalent to 7.5 gallons of water. Thus, 1 cfs is 7.5 gallons of water passing by you every second..
Channel	An open conveyance of surface stormwater having a bottom and sides in a linear configuration. Channels can be natural or man-made. Channels may have levees or dikes along their sides to build up their depth. Constructed channels can be plain earth, landscaped, or lined with concrete, stone, or any other hard surface to resist erosion and scour.
Culvert	A hydraulically short conduit which conveys surface water runoff through a roadway embankment or through some other type of flow obstruction.
Degradation	A deepening of a channel over time or in a single storm event due to erosion processes.
Delineation	Defining the physical boundaries of a stream, floodplain, jurisdictional wash, etc.
Development	A man-made change to property, such as buildings or other structures, mining, dredging, filling, grading, paving, excavation, or drilling operations..
Discharge	The amount of water that passes a specific point on a watercourse over a given period of time. Rates of discharge are usually measured in cubic feet per second (cfs).
Ephemeral	A watercourse or portion of a watercourse that flows only in direct response to rainfall.
Erosion	The wearing away of land by the flow of water.
FCDMC	Acronym for Flood Control District of Maricopa County.

FEMA	An independent federal agency established to respond to major emergencies that state and local agencies don't have the resources to handle. FEMA seeks to reduce the loss of life and protect property against all types of hazards through a comprehensive, risk-based emergency management program. Visit the FEMA web site at www.fema.gov .
FIRM	Acronym for Flood Insurance Rate Map
Flood Insurance Rate Map (FIRM).	Issued by FEMA, these maps show special hazard areas, including the 100-year floodplain. They also show flood insurance risk zones and other flood-related information applicable to a community.
Flood Response Plan	A plan developed for a particular waterway, watershed or jurisdiction that identifies flood hazards and defines methods for avoiding them and for minimizing losses to property.
Floodplain (100-year)	The area adjoining a watercourse that may be covered by floodwater during a flood. Storm runoff and flood events may cause alterations in the floodplain in certain areas. .
Floodway	The floodway is that portion of the floodplain reserved by FEMA for the conveyance of floodwaters during a 100-year flood. Buildings and/or structures that would obstruct flow are not allowed within the floodway boundaries.
Gabion	Gabions are rock-filled wire baskets or mattresses that can be a structural form of erosion protection.
Hydraulics	A field of study dealing with the flow pattern and rate of water movement based on the principles of fluid mechanics.
Hydrology	A field of study concerned with the distribution and circulation of surface water, as well as water dynamics below the ground and in the atmosphere.
Inhabited Residential Structure	A house, townhouse, condominium, apartment complex of four units or less, manufactured home, or mobile home designed to be used as a permanent structure, used principally for residence, and that is actually occupied by the owner or a tenant as a residence. The associated lot, up to 10 acres, is also included.
Scour	Erosion due to the mechanical process of water removing earthen material from a channel bottom or banks.
Sediment	Soil particles, sand, and minerals washed from the land into aquatic systems as a result of natural and human activities.
Sedimentation	A large-scale process where sediment is transported by water and deposited downstream.
Setback	The minimum distance required between a man-made structure and a watercourse. This distance is measured from the top edge of the highest channel bank or the edge of the 100-year flood water surface elevation.

Storage

The volume of water stored in a basin or behind a dam – usually expressed in acre-feet. It differs from capacity, which is the volume of water stored at the emergency spillway elevation.

Watercourse

Any minor or major lake, river, creek, stream, wash, arroyo, channel or other topographic feature on or over which waters flow at least periodically. Watercourse includes specifically designated areas in which substantial flood damage may occur.

Watershed

An area from which water drains into a lake, stream or other body of water. A watershed is also often referred to as a basin, with the basin boundary defined by a high ridge or divide, and with a wash, river or lake located at a lower point.