FINAL ADMS REPORT

SAN TAN WEST

AREA DRAINAGE MASTER STUDY (ADMS)

Contract FCD 2012C011

December 2013

Flood Control District of Maricopa County

Kimley-Horn and Associates, Inc.

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Kimley-Horn and Associates, Inc.

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Executive Summary

This San Tan West Area Drainage Master Study (ADMS) report documents existing and potential flooding hazards for a 35-square mile watershed that is located within a portion of southeast Maricopa County, within the Towns of Queen Creek and Gilbert, Pinal County, and the Gila River Indian Community. The ADMS provides conceptual drainage improvements to mitigate flooding in high hazard flood risk areas that were identified as part of the ADMS study.

The two main goals of the ADMS are:

(1) to identify and quantify flooding and other hazards within the study area, and

(2) to establish guidance for future development that protects public safety and considers the unique natural and physical characteristics of the San Tan West watershed.

The San Tan West ADMS study area is located in southeast Maricopa County from the San Tan Mountains on the south to relatively flat alluvial plains north of Hunt Highway. Sonoqui Wash is the major watercourse in the watershed and forms the northern and eastern boundary of the study area north of Empire Boulevard. The East Maricopa Floodway (EMF) forms the western boundary of the study area north of Empire Boulevard. Flooding in the study area is mainly shallow and distributary in nature with significant potential for flash flooding and high sediment loads.

The San Tan West ADMS report is divided into five main sections which are described below.

Data Collection

Data and information was collected that documents existing flood hazards and drainage issues and problems within the study area. Exhibits were prepared using the collected data to show locations of existing flooding and drainage problems, drainage patterns, locations and types of existing drainage facilities, land ownership, and existing and future land use within the study area. The results of the data collection were used to confirm historic drainage and flooding locations within the study area and used as a basis of evaluation of drainage characteristics in conjunction with the hydrology and hydraulics computer models.

Hydrology and Hydraulics

Hydrology models were prepared for a 2.4-square mile watershed within Pinal County. A model for this small watershed was developed as the runoff contributes to Sonoqui Wash which courses through the eastern and northern boundary of the ADMS study area north of Empire Boulevard. Existing land use conditions models were prepared for the 10-year and 100-year storm events for the 6-hour and 24-hour durations. For the remainder of the ADMS watershed a two-dimensional model (using FLO-2d) was prepared to model the rainfall-runoff characteristics. Two FLO-2d models were developed, the Urban Model for the relatively developed flat area north of Hunt Highway, and the Mountainous Model, to model the area south of Hunt Highway consisting mainly of the San Tan Mountains. The FLO-2d model results provide peak discharges, drainage patterns and flow characteristics for the 100-year 6-hour storm event at key locations within the study area.

Flood Hazard Risk Assessment

The purpose of the flood hazard risk assessment is to 1) inform and educate the public and stakeholders regarding flood hazards and potential flood mitigation measures, 2) prioritize areas for future drainage studies, floodplain delineations or drainage improvement projects, and 3) provide a rational framework for creation of considerations for future development. Flood hazards and problem areas were identified from the study hydrology and hydraulics modeling, sediment technical evaluations, stakeholder input and community outreach through public meetings. The goal of the flood hazard risk assessment is to identify problem areas, and to qualitatively assign a risk to those areas based on flow type (using geomorphic assessment), flow depth and velocity (hydrologic modeling), sediment analysis, and lateral migration risk. Flood hazard maps were prepared that characterized the watershed slopes, future land use, depth of flow, flow velocity, potential erosion and scour, and landform drainage. Flood intensities (combination of maximum velocity and maximum depth of flow) were prepared and categorized as low, medium, or high intensity. Flood hazard risk zones were developed based on the above flood hazard maps and flood intensities. Flood hazard risk zones are defined as high, intermediate, and low. The description of the risk zones is focused on the potential danger or exposure of structures to flooding hazards. Flood hazard strategies were prepared in coordination with the development considerations task (below). The strategies provide a menu of options to mitigate flooding for generalized land uses considering landforms, existing drainage infrastructure, natural drainage, floodplains and development guidelines. These strategies include: property acquisition, non-structural measures, regional and local detention/sediment basins, conveyance facilities, and levees.

Development Considerations

The Development Considerations presents guidelines to protect the public safely from the identified hazards while preserving the natural and beneficial uses of the watershed. The Development Considerations for the San Tan ADMS study area are presented as tools for jurisdictional agencies, developers and engineers to guide future development in way that mitigates risk from existing hazards and reduces the potential for future drainage problems. The Development Considerations were based on existing policies and regulatory guidelines and other considerations such as land use, existing and planned developments, regional drainage systems, and identified flood and erosion hazards. The guiding principle for the Development Considerations of the San Tan ADMS study is No Adverse Impact (NAI). In essence, any future new development or re-development, including improvements on single lots, should not have an adverse drainage impact on adjacent or downstream properties. In order to accomplish NAI, development considerations were developed and recommended. The considerations include recommendations for non-structural measures, low impact development (LID), drainage corridors, erosion hazard setbacks, levees, roadway crossings, walls, fences, and berms, detention/retention, minimum floor elevations, utility crossing, and canals and irrigation structures. An action plan was prepared to identify the steps needed to implement the recommended development considerations

Flood Mitigation Plan

A flood hazard mitigation plan was prepared that identified potential flood mitigation measures to address the high hazard risk zones within the study area. Eight potential mitigation areas were identified and each mitigation area includes a description of the potential mitigation, the flood and erosion hazards that would be

mitigated, an implementation/action plan, and development considerations. In addition, the responsible party, prioritization, and funding mechanisms are discussed for each area.

The San Tan ADMS accomplished the goals of the project to identify drainage issues and problems and to develop potential flood hazard measures to reduce, eliminate, or mitigate those drainage issues. The ADMS provides drainage solutions for eight identified areas within the ADMS as associated with having high flood hazard risk. The flood mitigation plan prioritizes the projects for the eight mitigation areas, and identifies potential funding sources and responsible agencies for implementation of the mitigation plan.

1. GENERAL DESCRIPTION

1.1 GENERAL DESCRIPTION

The San Tan West Area Drainage Master Study (ADMS) was prepared by Kimley-Horn and Associates, Inc. (Kimley-Horn) for the Flood Control District of Maricopa County (District) as part of Contract FCD 2012C011. The study watershed extends from the San Tan Mountains on the south to relatively flat alluvial plains north of Hunt Highway. Sonoqui Wash is the major watercourse in the watershed and forms the northern and eastern boundary of the study area north of Empire Boulevard. The East Maricopa Floodway (EMF) forms the western boundary of the study area north of Empire Boulevard. Flooding in the study area is mainly distributary in nature with significant potential for flash flooding and high sediment loads. See **Figure 1** for an exhibit of the study area.

1.2 PURPOSE AND OVERVIEW

The two main goals of the study are (1) to identify and quantify flooding and other hazards and (2) to establish guidance for future development that protects public safety and considers the unique natural and physical characteristics of the San Tan watershed. As part of the study, hydrologic analyses have been conducted for the watershed, and potential flood and erosion hazards were identified.

1.3 MAJOR STAKEHOLDER INVOLVEMENT

Preparation of the ADMS entailed significant involvement with five key stakeholders in the Study area: the District, the Gila River Indian Community, the Town of Gilbert, Pinal County and the Town of Queen Creek. These stakeholders were involved throughout various phases of the study through workgroup meetings as well as individual meetings. Input from these meetings was used both to identify hazards and develop mitigation strategies. See **Appendix E** for information regarding the stakeholder meetings. The main contacts for the key stakeholders are listed as follows:

Mr. Burke Lokey, P.E., CFM, PMP, Proj. Mgr.
Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009
(602) 506-0867

Mr. Seaver Fields, E.I.T.
Gila River Indian Community
291 West Casa Blanca Road – P.O. Box E
Sacaton, AZ 85147
(520) 562-6003

Mr. Edgar Medina, P.E.
Town of Gilbert
90 E. Civic Center Drive
Gilbert, AZ 85296
(480) 503-6700

Ms. Elise Moore, P.E., CFM
Pinal County Public Works Department
31 N. Pinal Street, Building F
Florence, AZ 85132
(520) 866-6411

Mr. Chris Dovel, P.E., CFM
Town of Queen Creek
22350 S. Ellsworth Road
Queen Creek, AZ 85142
(480) 358-3067

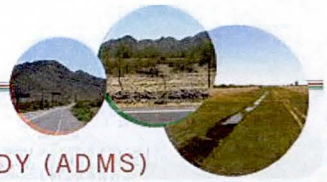
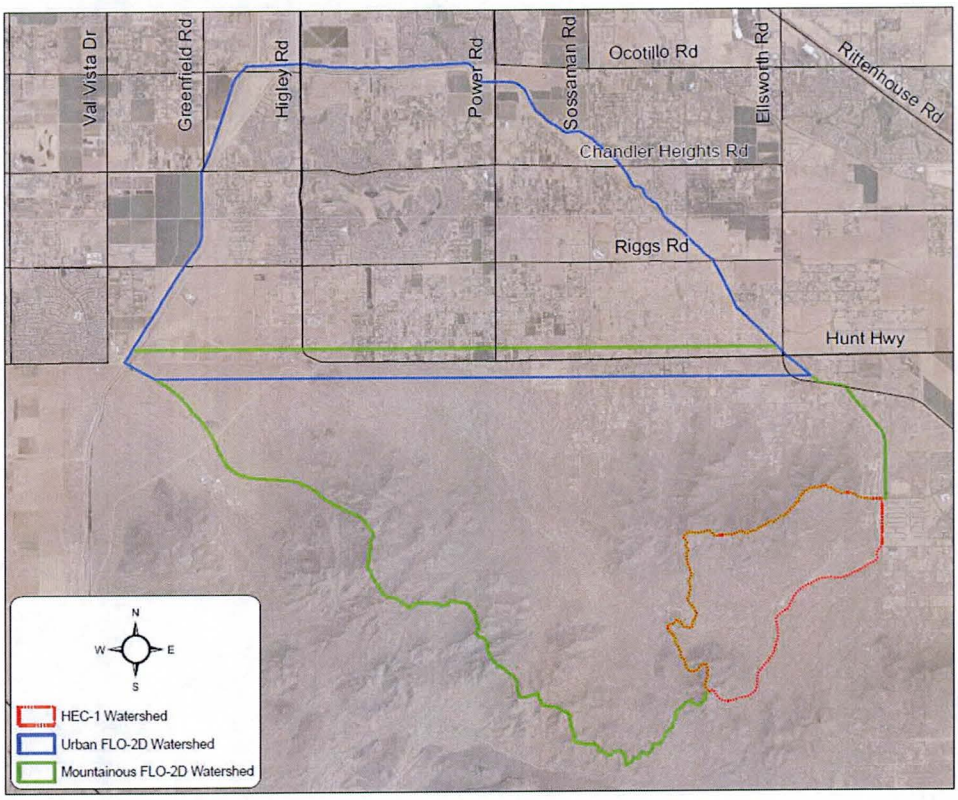


Figure 1. San Tan West Study Area



2. DATA COLLECTION

2.1 INTRODUCTION

The purpose of this data collection section is to summarize the pertinent documentation that was collected as part of the San Tan West ADMS. Over 200 items were collected and reviewed. The Data Collection Inventory is provided digitally in **Appendix F**. Some examples of the data collected as part of this project include:

- Topographic mapping
- Aerial photography with present conditions as well as historical conditions
- Geographic Information Systems (GIS) data layers from the District, Pinal County, Town of Queen Creek, Town of Gilbert, Gila River Indian Community (GRIC), and the Bureau of Land Management (BLM)
- As-built and construction drawings for existing flood control structures, existing roadway projects, culverts, storm drains and irrigation facilities
- Historical flooding data including photos and past newspaper articles from the District and videos from residents
- Drainage Master Studies and Plans
- Site visit photographs and notes
- Current development guidelines

2.2 DATA SOURCING

The data collected as part of the San Tan West ADMS was gathered from various sources. A majority of the data collected for this San Tan West ADMS was collected from the major stakeholders: DISTRICT, Town of Queen Creek, Town of Gilbert, GRIC and Pinal County. Some resident in the watershed also provided videos of flooding in their neighborhoods. Several site visits were conducted as well, by both the Kimley-Horn team and the District.

2.2.1 Methodology

Kimley-Horn developed a list of the type of data requested from each major stakeholder. A written request for the data was prepared and submitted to each. Kimley-Horn's data collection task leader coordinated with each stakeholder to obtain the data. As data was received Kimley-Horn logged all of the information into the Data Collection Inventory. The Inventory contains information including a brief description, author, date received, date of the document, filenames and file folder location. Data collection was an ongoing process throughout the length of the study. A brief description for each of the column headings in the Data Collection Inventory is listed below.

Relevant to Project — A large amount of data was collected, and all of it was logged into the Data Collection Inventory. Data that is relevant to the San Tan ADMS is indicated in this column.

Document — Title of the reference data.

Description	A brief description of the data.
Author	Primary author of the data.
Format	Format that the data was received in (Paper, electronic, etc.)
Type	Type of file for the data that was received (shp, pdf, jpg, hard copy, etc.)
Date Received	Date the data was received from the agency.
Date of Document	The date the data was written or created.
Received From	Agency, firm or website where the data was received from.
Filename	The filename of the data that was received.
Folder	The location of the data within the Kimley-Horn network. Note the folder name is in the format "Date received_Source of data_short description", example (2012-06-11_FCDMC_SanTanWest Hydrology Map)

Hydraulic structures information was collected from as-built drawings, drainage reports for adjacent developments, and field visits. The data was entered into the FLO-2D model to properly depict the existing conditions of each structure.

2.2.2 Flooding Issues

Locations where substantial flooding issues have taken place during storm events were identified. First, Kimley-Horn scanned through the District library for historic documentation of locations where flooding related issues had occurred. Articles and photos included general flooding from large storm events and fissure concerns. The historical data ranged from several storms in the 1960s to the latest record in 2007.

Second, Kimley-Horn regularly visited the site during and after rain events to observe areas where flooding took place during storm events. In particular, during the 2012 summer monsoon season, Kimley-Horn team members visited the site during significant storm events on July 14th and July 29th to document areas of concern.

Finally, meetings were organized with the public works and street maintenance departments of the major stakeholders. Kimley-Horn prepared full-size maps of each jurisdiction and sat down with agency staff and went through each map to identify locations where frequent flooding has been observed. Refer to **Appendix B** for a list of the flooding issues that were documented.

2.3 TYPES OF DATA COLLECTED

The types of data that were requested from the stakeholders included, but were not limited to the following:

1. *FEMA Flood Hazard Boundary Maps*
2. *FEMA Floodplain Delineation Studies*
3. *Letters of Map Amendment and Revisions*

4. *Hydrology/Hydraulic Studies*
5. *Existing Infrastructure/Utilities*
6. *Existing Mapping*
    a. *Topographic Mapping*
    b. *Land Use Data*
    c. *Aerial Photography*
    d. *GIS data*
7. *Drainage Reports*
8. *Planning Documents*
    a. *Master Land Use Plans*
    b. *Development Master Plans*
    c. *General Plans*
9. *Historic Flooding Documents*
    a. *Precipitation Data*
    b. *Flood Photographs*
    c. *Drainage Inquiries*
    d. *Newspaper Articles*
10. *Existing and Proposed Residential Developments*

2.3.1 Geologic Reconnaissance Memorandum

The Geological Reconnaissance Memorandum is currently being prepared and will be included in the final Data Collection Report.

2.3.2 Exhibits

The data collected from the stakeholders and field visits are summarized in the following exhibits. The exhibits were used to help identify flooding hazards. The exhibits can be found in **Appendix F.**

Drainage Issues

This exhibit shows the identified flooding locations or other problem areas within the watershed. The locations were identified from historical articles and photos, Kimley-Horn observed locations and locations identified by the agency public works and street maintenance departments. This exhibit is a supplement to the Flooding Issues list in **Appendix B**.

Existing Facilities

This exhibit contains an inventory of the observed major existing drainage facilities located within the watershed. The existing drainage facilities include culverts, storm drains, and natural and manmade channels. The exhibit also includes extents of existing floodplain delineations.

Land Ownership

This exhibit shows the surface ownership status by entity. The owners shown in the exhibit include the District, Maricopa County, Private, Salt River Project, Irrigation District, State of Arizona, US Bureau of Land Management, Town of Queen Creek, Town of Gilbert, and the Gila River Indian Community.

Existing Developments

This exhibit shows the location and status of the developments within the project watershed. The developments range from developments that are in the conceptual phase to projects that have been completed. The exhibit includes a list of all developments and the acreage of each.

Future Conditions Land Use

This map shows the various land uses within the watershed. The map includes revised land uses that have been identified by General and Comprehensive Plans of each agency. The Land Ownership Map also includes the land use plans for the GRIC and BLM properties located within the project watershed. Data for the Future Conditions Land Use map was prepared by the District.

Landforms

The map shows the geologic and geomorphic map units for the project area. The map units are characterized in terms of their soils and surface characteristics, drainage patterns, vegetation, and topographic relief.

2.4 SUMMARY OF USE OF DATA COLLECTED

The data collected was used in developing a complex two-dimensional model using FLO-2D to show the effects of stormwater in the watershed during various rainfall events. The data shown in the inventory and exhibits was used to develop an accurate model.

Throughout the data collection process, several different sources of drainage issues were identified in the study area. Drainage issues included shallow sheet flow flooding, residential flooding, redirection of runoff from historical paths, sediment buildup in culverts and on public roadways, and earth fissures. The FLO-2D modeling validated the locations where drainage issues were reported by agency and resident input. Issues are generally located in the southern portion of the project area. This area contains less development with lower population density properties.

The major factors for most of the flooding issues are sheet flow conditions and lack of historical regulation of runoff. Historical drainage flow paths have been revised or blocked by property owners. Culverts along Hunt Highway are generally impacted by sediment and do not convey stormwater runoff as originally designed. By identifying the historic drainage issues in the project area, Kimley-Horn was able to validate the two dimensional model by comparing the model results to what is happening in the existing conditions. Having a truthful model, with this data incorporated helped to accurately identify potential mitigation areas.

3. HYDROLOGY AND HYDRAULICS

3.1 PURPOSE

The purpose of hydrologic and hydraulic analysis was to identify and quantify flooding problems and flood hazards in the study area to provide mitigation to increase public safety for residents and property owners. Existing conditions 10- and 100-year HEC-1 and FLO-2D models were developed to achieve these goals. This section documents the analysis, methodology, and results of the model development.

3.2 METHODOLOGY

The hydrologic modeling for approximately 2.4 square miles in the southeast portion of the watershed was prepared using the U.S. Army Corps of Engineers HEC-1 modeling software. The parameters and procedures used to develop the HEC-1 models follow the guidelines established in the 2011 Hydrology Drainage Design Manual for Maricopa County (DDMMC). The HEC-1 model was developed using Drainage Design Management System for Windows (DDMSW), version 4.1.0.1. HEC-1 models were developed for the 10- and 100-year, 6- and 24-hour storm events. The hydrographs from these HEC-1 models were used as inflow to the FLO-2D model developed for the remainder of the project watershed. No hydraulic modeling was completed of any washes in the HEC-1 watershed, as the intent of modeling in this area was only to provide an inflow hydrograph to FLO-2D.

Due to the distributary nature of the remainder of the watershed, the hydrologic and hydraulic modeling was conducted using FLO-2D, District version 2009.06, Build Number D09-13-06-03. The FLO-2D model area was further divided into two models, Urban and Mountainous. The Urban model is bound by Sonoqui Wash to the north and east, the East Maricopa Floodway (EMF) to the west, and Hunt Highway to the south. The Mountainous model is bound by the San Tan Mountains to the south, the EMF to the west, Thompson Road to the east, and Hunt Highway to the north. The two models overlap along Hunt Highway and were linked by writing outflow hydrographs from the Mountainous model and importing them as inflow hydrographs in the Urban model. See **Figure 1** for an exhibit of the different areas.

It should be noted that although Sonoqui Wash and the EMF are included within the FLO-2D model, they are not part of the study. No upstream flow to either channel was included in the model. As such, the discharges, velocities, and water surface elevations calculated in the FLO-2D model for Sonoqui Wash and the EMF are not accurate and will not be reported or documented in this study.

Both the 6- and 24-hour duration storm events were initially included in the FLO-2D model development. The 6-hour storm was recognized as the controlling storm event after the preliminary FLO-2D model submittal to the District. In accordance with direction received from the District, the 24-hour event was no longer run or analyzed. Rainfall files for the 100-year, 24-hour model are provided, but no analysis of this storm event is included.

Detailed information on the development of the HEC-1 and FLO-2D models and parameters is provided digitally in **Appendix F**. A summary of the information is included in the following sections.

3.3 HEC-1 Model Development

3.3.1 HEC-1 Boundary Delineation

The drainage area for the HEC-1 model is approximately 2.4 square miles. This drainage area was based on more than one data source. The western portion of the boundary that is coincident with the FLO-2D area was determined from a TIN created in ArcGIS from break lines and mass point files provided by the District. The remainder of the boundary was delineated using 10-ft county-wide topography dated December 2000, recent aerial photography and several field visits.

3.3.2 HEC-1 Modeling Parameters

National Oceanic and Atmospheric Administration (NOAA) 14 rainfall precipitation values were obtained from the NOAA 14 Index Maps included with the DDMSW. The rainfall depths were reduced using depth-area reduction parameters. The rainfall distribution pattern selected for the NOAA-14 6-hour duration storms was Pattern 1. Typically the selection of the pattern number is based on the size of the drainage area to account for the spatial variability of the storm. Pattern 1 was selected per the project scope to be consistent with the rainfall pattern used in the FLO-2D models developed for the remainder of the ADMS study area.

The Phoenix Mountain S-Graph was used as the unit hydrograph. The K_n value is the estimated mean Manning's n value for all of the channels within an area. The selection of K_n values for this hydrologic analysis varied according to the land use classification. Based on a review of aerial photography, the average Manning's n value in the mountainous areas was estimated to be 0.05 due to rugged terrain and large boulders. The Manning's n was decreased to 0.03 in the hillslope areas, which are characterized by more gentle terrain. The undeveloped desert rangeland and the residential areas have similar land features. Both of these land use categories were estimated to have average Manning's n values of 0.02. These values are reasonable for both the 10- and 100-year storm events.

The Green and Ampt method was used to estimate rainfall losses. The procedures are outlined in the DDMMC. Default values for each of the Green and Ampt parameters are provided in DDMSW for each land use and soil type. The default values were evaluated and revised in accordance with the actual watershed characteristics. The "dry" antecedent soil moisture condition was selected for this model based on guidance provided in the DDMMC. According to the DDMMC, "dry" conditions should be used for soil that is typically in a low moisture state such as desert and rangeland areas similar to those found within the watershed. The residential area within the watershed generally has desert landscaping that would not be regularly irrigated so the residential area was also modeled with a "dry" antecedent moisture condition. Detailed HEC-1 input parameters are provided digitally in **Appendix F**.

3.4 HEC-1 Model Verification

3.4.1 Comparison to Previous Studies

Two models from previous studies were used to verify the results of the HEC-1. The Hunt Highway Widening Empire Boulevard to Thompson Road Drainage Report, RBF, July 20, 2012. The report referenced the 1999 Sonoqui Wash Floodplain Delineation Study, revised March 2004, and the Sonoqui Wash Channelization, Phase

III Riggs Road to Empire Boulevard, FCD 2009C011 Design Data Report, March 21, 2012. These models had comparable results based on differing rainfall, rainfall pattern and unit hydrograph methodologies.

3.4.2 Indirect Methods

The three indirect methods of verification were utilized to further examine the validity of the results. The methods are:

1. Unit Peak Discharge Curves
2. USGS Data for Arizona
3. Regional Regression Equations

All three indirect methods provided a reasonable comparison with the HEC-1 results for the 100-year storm. Indirect Method No. 3 had results outside of the Average Standard Error for the 10-year storm event. Per the project scope, a Pattern No. of 1 was used for the HEC-1 model. This pattern number resulted in more runoff than what would occur if the pattern number was calculated per the DDMMC.

3.5 FLO-2D Model Development

3.5.1 Mapping and Digital Terrain Model

The digital topographic mapping data procured as part of District Contract No. FCD 2009C043, Task order No. 12-San Tan West Mapping was utilized as the basis for the digital terrain model. Mapping was prepared specifically for this project by Pinnacle Mapping Technologies, dated November 17, 2011. The vertical datum is NAVD88, and the horizontal datum is State Plane NAD83, Arizona Central. Contour intervals north of Hunt Highway are 2-ft, and contour intervals south of Hunt Highway are 4-ft.

Grid elevations were assigned to a 20-ft grid mesh using a TIN to Raster approach, where the break line and mass point data (.lf and .pf data files) were used to build a Triangular Irregular Network (TIN) surface in ArcGIS. The TIN was used to build a 4-ft elevation raster, which was then converted to points to use in the FLO-2D Grid Developer System (GDS). The file included more than 38 million points so the multiple file interpolation method in FLO-2D was used to assign elevations. The method does not require points to be imported to the GDS and extends the model interpolation capability.

Based on the elevation comparisons and visual inspections, the TIN to raster approach was used to assign elevations to the FLO-2D grid mesh. Grid elevation assignments were visually examined for discrete "mounds" or "depressions". Grid element elevations representing wash bottoms upstream and downstream of the Hunt Highway structures were smoothed to ensure decreasing elevations in the downstream direction. Conveyance corridors and drainage ditches that are not represented by 1-D channel elements were reviewed for elevation continuity. The review was accomplished by comparing the profiles of the flowpath cut from the TIN with the corresponding grid elements.

3.5.2 Rainfall

Rainfall data files were prepared and provided by the District. Rainfall depths were based on the maximum NOAA 14 rainfall depths for each model. Rainfall reduction factors were then applied to each grid element based on the NOAA 14 rainfall depths.

3.5.3 Base Data Parameters

The District provided two main sources of data for assigning the base parameters. The first was the Surface Feature Characterization shapefile, containing detailed polygons delineating the existing conditions surface characterization based on 2012 aerial photos provided by the District. The second was a shapefile for the *Eastern Maricopa and Northern Pinal Counties Area (Book 655)* soil survey. The southwestern portion of the Urban model and most of the western portion of the Mountainous model were covered by the *Maricopa and Northern Pinal Counties Area and Gila River Indian Reservation (GRIC) (Book 658)* soil survey. Data for the GRIC soil survey area was obtained from the Natural Resources Conservation Service (NRCS) website, and parameters for the study area were developed in coordination with the District as described in **Appendix F**.

3.5.4 Hydraulic Structure Rating Curves

Sixty-two (62) culverts, bridges and weir structures are modeled in the Urban model. A majority of the structures occur along manmade channels and are modeled between channel segments. The remaining structures are smaller in size and modeled between floodplain elements. Thirty (30) culverts, bridges and wall opening structures are modeled in the Mountainous model. The culverts are located along Hunt Highway, the diagonal channel through the Santo Vallarta subdivision and at several driveway locations. See **Figure 2** in **Appendix F**.

The Kimley-Horn team conducted multiple site visits to provide photo documentation of the structures and their maintenance condition. Field checklist sheets and corresponding photos are included digitally in **Appendix F**. Rating tables for the culverts were developed by using culvert nomographs from the Federal Highway Administration (FHWA) Hydraulics Design Series Number 5 (HDS 5) publication dated September 2001. Culverts that were noted to be in poor or moderate maintenance condition were assumed to be 25% to 50% clogged and the capacity in the rating table was reduced accordingly. Rating tables for the culverts at the Cloud Road basin diversion structure (culvert 145), outlet channel splitter structure (culverts 54A and 54B), and overflow weir from Newell Barney Junior High School were obtained from the Sossaman Road Drainage Improvements from Cloud Road to Sonoqui Wash Final Drainage Report prepared by Dibble Engineering. The rating tables for culverts 54A and 54B were adjusted so that the percent of flow distributed to each culvert would match the percent of flow in the design. Culverts less than 24 inches in diameter were not modeled. Culverts were modeled with the amount of sediment observed at the time of the field visits. Rating tables for bridges were developed using HY-8 version 7.2 and the TIN created from topographic mapping for the grid submittal. As FLO-2D runs, the rating tables are adjusted from the original rating tables in order to help with model stability. The adjustments are typically for very small discharge values where a linear interpolation from the table may not be valid. All data for the rating curves is included in **Appendix F**.

3.5.5 Farmer's Dike Embankment

The only embankments modeled as levees are the Farmers' Dike south of Hunt Highway and the small embankment between the eastern end of the Farmers' Dike and the western end of the Santo Vallarta subdivision walls. Two penetrations exist in the mounded embankment that allow flow to pass through the embankment line. One penetration is by Route 131 south of Hunt Highway just east of Higley Road. The second occurs just to the east of the eastern end of the Farmers' Dike. These penetrations easily allow water to flow through the mounded embankment line unimpeded. The two penetrations are reflected in the results of the Mountainous model.

3.5.6 Walls

Walls are modeled by using the levee option within FLO-2D. The top of wall elevation is coded as the top of levee and when the depth of flow against the wall became deep enough, wall failure was modeled. The District provided a guideline on wall failure depths and advised the project team to only fail walls with a "high depth" which was defined as 2.5 ft.

The walls breakline file provided by the District was reviewed to determine locations where walls needed to be included in the FLO-2D model for each watershed. The wall locations were compared to preliminary maps of flow depth and velocity and evaluated for their potential impact on runoff conveyance. The purpose of including the walls in the model is to represent the physical system with improved accuracy. Because of this, the model was run with the walls included as levees and any wall that did not affect the flow patterns was removed. The walls within the Santo Vallarta subdivision formed a boundary along the left bank of the diagonal Box Canyon Wash channel flowing through the subdivision. These walls have five large openings at the base of the walls, which were modeled as hydraulic structures.

The elevations were assigned to the levees from the wall shapefile provided by the District, which included maximum, minimum, and average wall elevations for segments of wall. Elevations assigned to some of the wall segments were much lower than the wall elevations observed in the field and were modified to increase the wall height to five feet above the grid elevation.

Instantaneous levee failure criteria were input for a wall located at the southeast corner of Mews Road and 172nd Street. The wall was set to fail when the flow depth reached three feet against the wall. The rate of failure was set at 1000 ft/hr to represent instantaneous failure. Failure criteria were not included for any other wall because the maximum depths upstream of the remainder of the walls were less than the wall failure depths.

The maximum depth upstream of the walls that did not fail during the 100-year storm event in the Urban Model was 1.01 feet. The maximum depth upstream of the walls during the 100-year storm event in the Mountainous Model was 2.03 feet.

3.5.7 Floodplain Cross Sections

Floodplain cross sections were added to the model to identify hydrographs and peak flows in key areas and known flooding problem locations. In the Urban model, cross sections are located at the major street intersections, along the EMF and north of Hunt Highway where runoff from the Mountainous model is conveyed

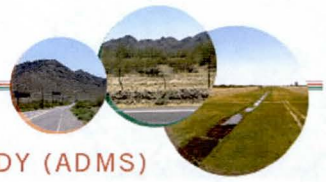
through residential areas and at known flooding locations. In the Mountainous model, cross sections are located along the Farmers' Dike, upstream and downstream of the Box Canyon Wash 1-D channel component, at flow concentrations upstream of roadways and developed areas and near flooding complaint locations. Cross section locations are shown in **Figure 16** in **Appendix A**.

3.6 FLO-2D MODEL VERIFICATION

Storm events occurred on July 14 and 29, 2012 in the San Tan West project area. Following these storm events Kimley-Horn obtained photographic documentation of the results of the storms within the watershed. The photographs were taken the same days as the storm events, but not necessarily during the peak of the storm events. The intent was not to use the storm data to make global adjustments to the models based on these two isolated incidents. Additionally, Kimley-Horn obtained field measurements of high water marks on July 20, 2012 at four locations within the watershed. These documentation efforts were used to assist in verifying the FLO-2D model.

Kimley-Horn obtained the rainfall data used in the FLO-2D models from the District. The District acquired temporal and spatial rainfall data based on precipitation gauge observations, basemaps, and NEXRAD data from MetStat, Inc. for both storm events. The District used this rainfall data to create spatially varied rainfall files (RAINCELL.DAT) for each storm event. The spatially varied rainfall files (RAINCELL.DAT) were used in place of previous rainfall data to model each storm event in FLO-2D.

To verify the FLO-2D model, photographs and measurements taken following the flooding events were compared with the results from the FLO-2D models, see **Appendix F**. These comparisons show that for the most part the models correlate well with the reference storm events. Each photo is presented alongside a screen capture of the FLO-2D results in the area. Those locations that don't match well have notes on what might be need to be adjusted for better correlation in those areas.



4. FLOOD HAZARD RISK ASSESSMENT

The purpose of a flood hazard risk assessment is to a) inform and educate the public and stakeholders regarding flood hazards and possible mitigation measures, b) prioritize areas for future study, floodplain delineations or projects, and c) provide a rational framework for creation of development considerations. Flood hazards and problem areas have been identified from Study hydraulics modeling and sediment technical evaluations, stakeholder input and community outreach through public meetings. The goal of the flood hazard risk assessment is to identify problem areas, and to qualitatively assign a risk to those areas based on flow type (geomorphic assessment), flow depth and velocity (hydrologic modeling), sediment analysis, and lateral migration risk.

4.1 FLOOD HAZARD ASSESSMENT DATA

The first step of this flood hazard assessment was to get an understanding of the watershed. This included review of existing and future land use data and floodplain delineations and preparation of 2-dimensional hydrologic modeling of the watershed. The Geological Memorandum discussed in the data collection section of this ADMS report was used to assist in creation of a Sedimentation Technical Memorandum for the flood hazard assessment. The Geological Memorandum is included as **Appendix C**. The Sedimentation Technical Memorandum is included as **Appendix D**.

In addition to the technical modeling and studies, the major project stakeholders were interviewed to gain an understanding of their goals and objectives for the project. The project team also met with the maintenance staffs from Maricopa County, Pinal County, Gilbert and Queen Creek to determine where they saw the biggest and most frequent drainage issues occurring.

Some of the maps that were created to summarize collected data are described as follows.

4.1.1 Topography Map

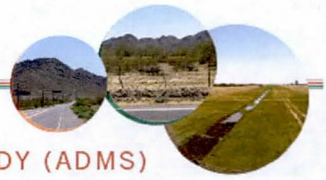
The topographic map, **Figure 6, Appendix F** shows the 10-foot contours for the study area. Evident in the mapping is the piedmont area extending from the San Tan Mountains north toward Sonoqui Wash. Topographic mapping was used to identify areas of steep slopes (darkened areas on the map due to close contour spacing), as well as alluvial fan-like areas (radial contours) and sheet flow areas (low crenulation planar surfaces).

4.1.2 NRCS Soils

Data from the Natural Resources Conservation Service (NRCS) was obtained to prepare the NRCS Soils Map, **Figure 7, Appendix F**. The soils unit map was used to identify broad areas of similar soil types and piedmont landforms. A review of the landforms identified from the NRCS soil descriptions was not sufficiently detailed for this analysis.

4.1.3 Surficial Geology Maps

Please refer to the Geological Memorandum in the Data Collection section of this ADMS for details related to the Geologic mapping. The compiled geology and soils data and the observations made during the geological



field reconnaissance provide the basis for understanding the natural conditions related to stream channel and floodplain development, erosion, scour, sedimentation, and flooding. There are several maps included that are relevant to this Flood Hazard Assessment. **Figure 8, Appendix F**, was compiled from the geological memorandum with drainage issues related to sedimentation indicated.

4.1.4 FEMA Mapped 100-Year Floodplains

There are four mapped 100-year floodplains located within the Study area in Maricopa County. Two Zone A floodplains are mapped, one represents the East Maricopa Floodway (EMF) on the western boundary of the study area, from Ocotillo Road to Hunt Highway. The other Zone A is along Sonoqui Wash from the intersection of Empire Blvd. and S. Ellsworth Road to the intersection of 204th Street and East San Tan Blvd. There is a rather large Zone AO associated with this upstream segment of Sonoqui Wash between the intersection of Empire Blvd. and S. Ellsworth Road to the intersection of East San Tan Blvd. and Hawes Road. Sonoqui Wash is a mapped Zone AE floodplain from this point, north and west to the EMF.

In Pinal County, south of Hunt Highway there are several Zone A floodplains. The floodplains extend from Pinal County unincorporated areas in the San Tan Mountains to Hunt Highway in the Town of Queen Creek. There are two Zone A areas through the Goldmine Mountain subdivision. Some of the lots in the area were removed from the floodplain in a 2008 Letter of Map Amendment (LOMA). The Santo Vallarta subdivision at Grapefruit Street and Hunt Highway was removed from the Zone A floodplain by a Letter of Map Change in 2011. Runoff to the subdivision is conveyed around it in a channel on the south, east and north sides, and through it in a diagonal channel from the southwest to the northeast. See **Figure 9, Appendix F**, for the floodplain map.

Two Letters of Map Revision (LOMRs) are currently underway within the study area. A LOMR was recently completed for the Sonoqui Wash Phase II improvements and is currently being reviewed by FEMA. A LOMR is being prepared for the Sonoqui Wash Phase IIIA improvements and is expected to be submitted to FEMA for review in December 2013. The Phase II and IIIA improvements were not reflected in the existing conditions topography for the study which was flown in November 2011. In addition, the Phase II and IIIA improvements are specific to Sonoqui Wash itself, which is not included in the FLO-2D analysis. Therefore, the floodplain maps do not include the pending changes associated with these improvements.

4.1.5 Drainage Issues Maps

Drainage issues were consolidated and described in the data collection section of this report. Drainage Issues maps are included as **Figure 1, Appendix F**, and the corresponding drainage issues list is included as **Appendix B**. The maps show the locations of all flooding locations or other problem areas within the watershed. The locations were identified from historical articles and photos, Kimley-Horn observed locations and locations identified by the public works and street maintenance departments of each jurisdictional agency.

4.2 Flood Hazard Maps

In addition to the above maps, several flood hazard maps were prepared by Kimley-Horn from the data collected, FLO-2D modeling and interviews with stakeholders and the public. All of these flood hazard maps are based on existing land use conditions at the start of the project. One exception is that a public works project was completed by the Town of Gilbert at the intersection of Riggs and Higley Roads during the development of

the FLO-2D modeling. Some roadside channels and culverts were constructed on the south side of Riggs Road and east side of Higley Road. These project improvements were included in the FLO-2D modeling. Flood Hazard Maps and their use in the flood hazard assessment are discussed in this section. Full-size flood hazard maps are included digitally in pdf format in **Appendix F**. The flood hazard maps do not include the Sonoqui Wash Phase II and IIIA improvements which were not in place at the time of the project aerial survey. In addition these improvements are focused on Sonoqui Wash itself which was not included in the FLO-2D modeling; therefore the flood hazard maps do not reflect these improvements. The future Phase IIIB improvements will consist of a detention basin south of Empire Boulevard and an outlet storm drain and channel system along 202nd street that will discharge into the Phase II channel. The Phase IIIB improvements will affect the study area, and therefore should be included in any FLO-2D analysis of future conditions.

4.2.1 Future Conditions Land Use Map

The Future Conditions Land Use Map was provided to Kimley-Horn by the District. Kimley-Horn reviewed the map and made comments based on field observations. The comments were incorporated by the District. The Future Conditions Land Use Map is provided as **Figure 5, Appendix F**. A comparison of the existing and future land use indicates the areas north of Hunt Highway will continue to become more highly urbanized. Without some form of drainage and flooding mitigation, existing drainage problems will likely get worse over time.

4.2.2 Slope Analysis Map

The slope analysis was prepared using the District's 10-foot contour interval digital topography. The primary purpose of this analysis was to identify slopes greater than 15%. The 10-foot topography provided sufficient resolution and was available for the entire study area. See **Figure 10, Appendix F**, for the Slope Analysis Map. The map shows that most of the steep slopes are in the mountainous model area. The steep slopes in the urban model area can be attributed primarily to retention areas and channel slopes. The Seville Community golf course is also a location of steep slopes, but all runoff in that area remains in the golf course.

4.2.3 Depth of Flow Map

The depths of flow were derived from the FLO-2D modeling results. The 100-year, 6-hour storm was the governing storm for this study, based on flow depths. See **Figure 11, Appendix A**, for the resulting depths of flow. The majority of the deepest flows are in the range of 4 to 6 feet. These areas are associated with incised washes south of Hunt Highway on the upper/middle piedmont and areas along or behind the farmer's dike paralleling the south side of Hunt Highway. There are some isolated areas of deeper flow, primarily occurring in the upper watershed.

4.2.4 Flow Velocity Map

The flow velocities were derived from the FLO-2D modeling results, see **Figure 12, Appendix F**. The higher flow velocities (8 to 10 feet per second) are associated with tributary drainage systems emanating from the steeper slopes of the San Tan Mountains and along the farmer's dike and channel paralleling Hunt Highway. Velocities range from 1 to 4 feet per second in the developed areas north of Hunt Highway with velocities between 4 – 8 feet per second in some roadways.

4.2.5 Potential Erosion and Scour Map

This map, **Figure 13, Appendix F**, was derived from the results of the geologic/geomorphic assessment presented in the "Final Geologic Report – San Tan West Area Drainage Master Study" prepared by Geological Consultants (GCI, June 2013), **Appendix C**.

Geomorphology

The geomorphic setting of the San Tan West ADMS is dominated by the San Tan Mountains that defines a portion of the southern boundary of the Chandler-Gilbert basin. A narrow, eroded pediment surface separates the mountain front from the San Tan Mountain piedmont surface that is drained by ephemeral streams that grade toward the north and northwest.

Since the mid-1930s, agricultural development within the basin to the north of the ADMS and within the ADMS study area itself caused the pumping of groundwater from the basin aquifer at rates that greatly exceeded basin recharge. The excess removal of the groundwater has resulted in land subsidence over a very large area of the East Salt River Valley Sub-Basin (ESRV) (Chandler-Gilbert Basin). The stress to the basin sediments induced by the land subsidence has caused earth fissures to form within the piedmont down slope and parallel to a basin bounding fault that is buried by old and young alluvial fan deposits of the piedmont. The orientation of the earth fissure relative to the piedmont slope can, over time, interrupt the natural drainage channels, intercept and redirect runoff to new flow paths.

GCI's stream channel and bank modification assessment focused on the southern portion of the ADMS south of the Hunt Highway corridor where human encroachment into the San Tan Mountains piedmont has caused minimal modification to the surficial geology, to the piedmont slopes, and to the modern stream channels that are incised into older geologic units. For a detailed discussion of the geomorphology of the Study area, see the full report in **Appendix C**.

Erosion and Scour Potential

A general qualitative assessment of potential erosion and scour is provided for the geologic surfaces mapped within the San Tan West ADMS study area. The qualitative assessment considers potential erosion and scour that could result from long duration or high intensity, potentially catastrophic precipitation events. See **Table 1** for a tabular categorization of the erosion and scour potential by geologic unit as presented in the GCI report.

Table 1. Potential Erosion and Scour

Erosion and Scour Potential	Geologic Unit							
	Ya2	Ya2'	Ya	Ya1a	Ya1b	Ma2	Op	B
	Modern Stream Channels	Ephemeral stream channels – obscured (Lower Piedmont)	Disturbed Surfaces (Lower & Middle Piedmont)	Younger Alluvial Surfaces	Older Alluvial Surfaces (Middle Piedmont)	Older Fan Surfaces (Upper Piedmont)	Pediment Surfaces (Upper Piedmont)	Bedrock
High	✓	✓	✓					
Medium				✓	✓			
Low						✓	✓	✓

High erosion scour potential occurs primarily in two areas, stream channels and disturbed areas. The stream channels are mostly south of Hunt Highway in the mountainous areas. The disturbed areas are north of Hunt Highway, in areas that have been developed with both rural and urban developments and agriculture. As a result, the runoff is now concentrated in unlined channels and other conveyances through reworked and disturbed soil. These soils when subjected to high velocity and concentrated runoff are expected to have high erosion and scour potential.

Areas of medium potential erosion and scour are characterized by distributary channels that tend to confine flows. This suggests that they are also subject to scour in response to flood runoff and overbank flooding. Observations of recently deposited soil sediment spread over the gently sloped alluvial surface indicate these alluvial surface soils are subject to periodic sheet flow-induced sedimentation and localized erosion and scour.

Low potential erosion soils occur primarily in the upper watershed. These soils are moderately well cemented and moderately indurated. The soils range from boulder-sized rock fragments near the bedrock pediment and mountain front to coarse sand and gravel further down gradient. Because of the caliche cemented and moderately indurated character of these soils, they are relatively resistant to erosion and scour. Some minor erosion is expected where the residual soils formed in-place on bedrock surfaces are also subjected to shallow sheet flow runoff.

4.2.6 Landform Drainage Characteristics Map

Landforms were delineated on **Figure 14, Appendix F**, based on the interpretation of the various maps presented above. Landforms are closely tied with flow/flooding characteristics found within the Study area. The landforms defined for this study are consistent with another recent study in Maricopa County with similar conditions (Kellogg, 2011). Please see **Appendix C** for detailed descriptions of each landform. The landforms present in the Study area are:

- Mountain Slope Area (> 15% slope)
- Piedmont Area with Tributary Drainage Systems

- Piedmont Area with Distributary Drainage Systems
- Major Riverine and Tributary Flooding
- Shallow Flooding (Developed and Agricultural) Area
- Flood Diversion/Detention Structures

Mountain Slope Area

The Mountain Slope Area landform consists of steep mountainous terrain underlain by shallow or exposed bedrock. Mountain slope areas were identified from the aerial photographs, topographic maps and the Study surficial geology maps. The Mountain Slope Area landform unit was observed primarily within the southern limits of the study area and on the eastern limits south of Hunt Highway in the San Tan Mountain area.

Piedmont Area with Tributary Drainage Systems

This landform unit consists of mildly sloping alluvial surfaces with dendritic tributary drainage networks. Piedmont areas with tributary drainage systems were identified from aerial photographs, topographic maps, NRCS soils maps, and the surficial geology map for the Study. The piedmont areas with tributary drainage system landforms occur as a buffer between the Mountain Slope Landform and the low-sloping piedmont. The watercourses in this landform consist of moderately steep, well-defined incised channels with narrow floodplains.

Piedmont Areas with Distributary Drainage Systems

This landform unit is characterized by mild to low sloping alluvial surfaces with distributary drainage networks. Piedmont areas with distributary systems were identified from aerial photographs, the topographic map, NRCS soils map, and the surficial geology map for the Study. During 'low' flow events, it is expected that the low height and gentle-sloped natural stream banks are relatively stable with very limited down-cutting and lateral erosion.

Major Riverine and Tributary Flooding

A floodplain is defined by FEMA as any land area susceptible to being inundated by floodwaters from any source. Potential floodplains were identified from aerial photographs, topographic mapping, and AZGS mapping. Existing FEMA floodplains were mapped in Maricopa and Pinal Counties, see **Figure 9, Appendix F**. There are no mapped floodplains on the Gila River Indian Community portion of Pinal County.

Shallow Flooding (Developed and Agricultural) Areas

This area has been disturbed by past and on-going major land grading activities for agricultural and development uses. The area is approximately half the land area of the Study area and is primarily located north of Hunt Highway. The area is of low topographic relief and as a result of the major grading the natural drainages have been obscured or obliterated.

Flood Diversion/Detention

A man-made structure acting to divert flow is identified on the south side of Hunt Highway. It is estimated that this "Farmer's Dike was constructed in the 1940s. The dike begins to the south of the Santo Vallarta subdivision

in Pinal County and extends through the Gila River Indian Community west to Route 131 (approximately 168th Street). The dike is parallel to Hunt Highway, approximately 200 feet to the south.

The Cloud Road Basin is one of two major flood control detention basins in the watershed. The basin is located at the southeast corner of Sossaman and Cloud Roads. Another basin has recently been constructed south of Happy Road between Ellsworth Road and 206th Street as part of the Sonoqui Wash Phase IIIA improvements. All newer developments in the Town of Gilbert provide onsite retention per the current development guidelines. These areas are primarily north of Riggs Road and west of Power Road.

The Sonoqui Wash is located on the eastern and northern borders of the San Tan West ADMS watershed north of Empire Boulevard. The wash conveys runoff from the south and east of the intersection of Empire Blvd. and Ellsworth Road north and then west to the EMF. The wash is currently undergoing improvements to create detention areas and channels from the intersection to approximately 204th Street and Riggs Road. Sonoqui Wash was not included in this modeling for this study, but was used as an outfall.

See **Table 2** for a correlation of surficial geologic units from **Figure 8** and landforms on **Figure 14,** both in **Appendix F**. The flood diversion/detention landform is not included in the table as it relates to disturbed area in a non-Ya geologic unit area.

Table 2. Correlation of Surficial Geologic Units and Landforms

	Geologic Unit							
	Ya2	Ya2'	Ya	Ya1a	Ya1b	Ma2	Op	B
Landform	Modern Stream Channels	Ephemeral stream channels – obscured (Lower Piedmont)	Disturbed Surfaces (Lower & Middle Piedmont)	Younger Alluvial Surfaces	Older Alluvial Surfaces (Middle Piedmont)	Older Fan Surfaces (Upper Piedmont)	Pediment Surfaces (Upper Piedmont)	Bedrock
Mountain Slope Area								✓
Piedmont Area w/ Tributary Drainage					✓	✓		
Piedmont Area w/ Distributary Drainage				✓	✓	✓		
Major Riverine and Tributary Flooding	✓							
Shallow Flooding			✓	✓				

4.3 FLOOD HAZARD RISK ASSESSMENT

The Flood Hazard Map was modified to depict the qualitative flood hazard risk based on a combination of the flood hazard and the flood risk assessment.

4.3.1 Flood Hazard Intensity

Flood hazard intensity is based on the methodology presented in the FLO-2D Mapper Manual (Version 2009). The flood intensity is defined by a combination of the maximum flow depth and the product of the maximum flow depth and maximum velocity. The definitions of flood intensities for this project are presented in **Table 3**.

The ranges for maximum depth in **Table 3** were selected after reviewing the depth of flow map and the understanding the location of these flow depths on the study areas. For example, depths of flow greater than 4 feet for the 100-year event occur primarily within the incised channels on the upper to middle piedmont areas south of Hunt Highway and along the Farmer's Dike.

Broad areas that are found within the Low Flood Intensity category include the developed areas north of Hunt Highway. These areas are subject to localized shallow flooding mostly in the streets and constructed channels. Drainage improvements are present in the newer master planned residential subdivisions.

Areas that are within the Medium Flood Intensity category include some of the north/south streets north of Hunt Highway, between Power and Sossaman Roads, and the piedmont areas south of Hunt Highway. There is a significant area of medium flood intensity east of Hawes Road north of Hunt Highway.

Areas included in the High Flood Intensity category include Sonoqui Wash from Hunt Highway to Queen Creek Wash, the area along the Farmer's Dike, and Box Canyon Wash. The other major area of high intensity is located on the far eastern boundary of the Study area west of Thompson Road and south of Skyline Drive. Other significant high intensity areas are located along tributary stream systems coming out of the San Tan and Goldmine Mountains, and in the natural wash on the east side of Sossaman Road between Hunt Highway and Riggs Road.

Table 3. Definitions of Flood Intensities

Flood Intensity	Maximum Depth, h [ft]		Product of maximum velocity, v and maximum depth, h [ft^2/s]
High	$h > 4$	OR	$vh > 4$
Medium	$1.5 < h < 4$	OR	$1.5 < vh < 4$
Low	$0.5 < h < 1.5$	AND	$0.5 < vh < 1.5$

4.3.2 Flood Hazard Risk Zones

The delineation of flood hazard risk zones for existing conditions in the Study area were based on the Depth of Flow and Flow Velocity maps (**Figures 11 and 12**), Future Conditions Land Use map (**Figure 5**), Potential Erosion and Scour map (**Figure 13**), Landforms map (**Figure 14**) and the flood intensities described in **Table 3**. Flood Hazard Risk Zones are defined as High, Intermediate, and Low. The description of the risk zones is focused on the potential danger or exposure of structures to flooding hazards. See **Figure 15** for the Flood Hazard Risk Map. All of the figures mentioned in this section are provided digitally in pdf format in **Appendix F**. Printed Figures 11 and 15 are also included in **Appendix B**.

Table 4. Flood Hazard Risk Zone Definitions

Hazard Risk Zone	Description
High	Buildings and infrastructure are in danger of being severely damaged and/or destroyed. Channel/natural incised wash flooding predominates.
Intermediate	Buildings and infrastructure may suffer damage and possible destruction depending on construction characteristics. Distributary/Tributary flooding predominates.
Low	Buildings and infrastructure may suffer little damage, but flooding or sedimentation may affect structure interiors. Shallow sheet flooding predominates.

4.4 FLOOD HAZARD STRATEGIES

A flood hazard strategies table has prepared in coordination with the development considerations task. The table highlights a menu of options to mitigate flooding for generalized land uses considering landforms, existing drainage infrastructure, natural drainage, floodplains and development guidelines. The generalized land uses are as follows:

- Active Open Space
- Rural Residential
- Small Lot Residential
- Low Density Commercial
- Regional Commercial
- Institutional

4.4.1 Mitigation Measures

There are five mitigation measures defined for this project:

- Property Acquisition
- Non-Structural Measures
- Regional and Local Detention/Sediment Basin
- Conveyance facilities
- Levee

Property acquisition is the purchase of property to remove or reduce the flooding hazard. The property can include land or land with structures. Non-structural measures include development guidelines and policies, including establishment of drainage corridors, erosion hazard setbacks, zoning, floodplains and floodways. There are several areas in the watershed that are affected by sediment erosion and deposition, as well as areas of sheet flow and excessive runoff. In these locations, primarily at the foothills of the mountains on the south side of Hunt Highway, detention and/or sedimentation basins could be a viable mitigation strategy. Conveyance facilities can include roadway culverts, open channels, or closed storm drain systems. Levees can be beneficial to collect large amounts of sheet flow to convey the runoff to a conveyance facility. Levees would need to meet the FEMA levee design criteria in order to be considered for floodplain mapping.

See **Table 5** for a list of mitigation measures. The Flood Hazard Strategies table (**Table 6**) has a menu of options to mitigate flooding and erosion hazards for the generalized land use types.

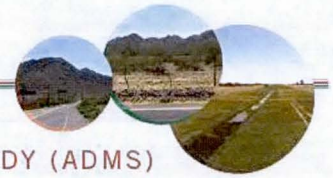


Table 5. Mitigation Measures

Property acquisition	Non-structural measures	Regional and local detention /sediment basin	Conveyance Facilities	Levee structure
1	2	3	4	5

Table 6. Flood Hazard Strategies

Land Use	Flood Hazards										
	Sedimentation / Erosion	Debris Flow	Sheet Flow Flooding	Floodplains	Ponding	Flow Diversions	Distributary / Split Flows	Roads Damaged/ Impassable	Facility Under-performance	Fissures / Land Subsidence	Dike Breach
	Applicable Mitigation Measures from **Table 5**										
Active Open Space	2, 3, 4, 5	3, 4	2, 3, 5	1, 2, 3, 4, 5	1, 2, 3	1, 2, 3, 4	2, 3, 4	3, 4, 5	2, 4, 5	1, 2	4, 5
Rural Residential	2, 3, 4, 5	3, 4	1, 2, 3, 5	1, 2, 3, 4, 5	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	3, 4, 5	2, 4, 5	1, 2	1, 4, 5
Small Lot Residential	2, 3, 4	3, 4	1, 2, 3, 5	1, 2, 3, 4, 5	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	3, 4, 5	2, 4, 5	1, 2	1, 4, 5
Low Density Commercial	2, 3, 4	3, 4	1, 2, 3, 5	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	3, 4, 5	2, 4, 5	2	1, 4, 5
Regional Commercial	2, 3, 4	3, 4	2, 3, 5	2, 3, 4, 5	2, 3, 4	2, 3, 4	2, 3, 4	3, 4, 5	2, 4, 5	2	4, 5
Institutional	2, 3, 4, 5	3, 4	2, 3, 5	2, 3, 4, 5	2, 3, 4	2, 3, 4	2, 3, 4	3, 4, 5	2, 4, 5	2	4, 5

5. DEVELOPMENT CONSIDERATIONS

This Development Considerations chapter presents guidelines to protect the public safely from the identified hazards while preserving the natural and beneficial uses of the watershed. These Development Considerations are presented as tools for agencies, developers and engineers to guide future development in way that mitigates risk from existing hazards and reduces the potential for future drainage problems.

5.1 CURRENT POLICIES AND REGULATORY GUIDELINES

5.1.1 Regulatory Basis

The authority to manage development within flood and erosion hazard zones is regulated through federal, state and local laws. Federal laws, through the National Flood Insurance Program (NFIP), require the State of Arizona to manage development within the regulatory 100-year floodplain. The Arizona Revised Statutes (ARS) differentiate between regulations for development inside and outside the 100-year floodplain.

5.1.2 Arizona Revised Statutes

The ARS describes the powers and responsibilities that the State grants to local government entities.

Zoning Regulations (ARS Title 9)

ARS Title 9, Chapter 4 authorizes cities and towns to prepare a general plan for development. Per ARS 9-461.05(E), the plan consists of community goals and development policies, including the following:

- Reclamation of land
- Flood control
- Pollution prevention of streams and other waters
- Regulation of land use within stream channels and other areas
- Erosion prevention
- Watershed protection

Drainage Regulations (ARS Title 11)

ARS Title 11 allows counties the authority to regulate in areas outside of the regulatory 100-year floodplain, including the following:

- County planning and zoning including subdivision regulation, land divisions and building codes (ARS 11-801 through 866)
- Adoption and enforcement of ordinances (ARS 11-251.05)
- Standards for excavation, landfill and grading to prevent unnecessary loss from erosion, flooding and landslides (ARS 11-251.36)
- Construction of floodwater control works and the use of general funds or levying additional taxes to pay for such projects (ARS 11-257)

- Establish an ordinance to compel owners to remove rubbish, trash, weeds, filth, debris and dilapidated buildings which constitute a hazard to public health and safety (ARS 11-268)

Floodplain Regulations (ARS Title 48)

ARS Title 48 authorizes special districts, such as the District, to regulate within the regulatory 100-year floodplain. These districts have the authority to adopt and enforce regulations, develop guidelines for managing floodplains. Chapter 21 specifically addresses county flood control Districts. Key parts of ARS Title 48 include the following:

- Authorization of board of directors (Board) to adopt by-laws, rules and regulations (ARS 48-2664.(D))
- A requirement that each county organize an FCD (ARS 48-3602)

ARS Title 48 requires that the Board, in conjunction with the FCD, do the following:

- Delineate floodplains in areas where development is ongoing or imminent (ARS 48-3609)
- Adopt and enforce regulations governing floodplains and floodplain management, particularly
    - Regulation of development which may divert, retard or obstruct floodwater and threaten public health, safety or the general welfare (ARS 48-3609)
    - Minimum flood protection elevations and flood damage prevention requirements (ARS 48-3609)
    - Regulation of connections to stormwater drains (ARS 48-3622)

5.1.3 Arizona Department of Water Resources (ADWR) State Standards

ADWR State Standards establish guidelines to be used throughout the state in order to provide a minimum level of flood protection. Relevant State Standards include the following:

- SS4-95 Identification of Development within Sheet Flow Areas (development standards)
- SS5-96 Watercourse System Sediment Balance (lateral migration setback allowance)
- SS6-05 Development of Individual Residential Lots within Flood prone Areas (site plan check list)
- SS7-98 Watercourse Bank Stabilization (design guidelines)
- SS8-99 Stormwater Detention/Retention (design guidelines)

5.1.4 Maricopa County

As directed and authorized by the State, Maricopa County has adopted Floodplain and Drainage Regulations to manage development both within and outside the regulatory 100-year floodplain. Maricopa County has also adopted a Drainage Policies and Standards Manual to provide further guidance on implementing these regulations.

Drainage Regulations

Maricopa County has adopted Drainage Regulations through the Zoning Ordinance (August 2012), specifically Chapter 12 Development Regulations, Section 1205 Drainage Provisions. These regulations focus on areas outside the regulatory 100-year floodplain and include the following:

- The drainage retention and conveyance system must be designed to eliminate/minimize stormwater runoff effects and convey the runoff through the development with minimum detrimental effects (1205.7.6)
- No system shall increase the peak discharge, volume or velocity of runoff or change the point of entry of drainage onto another property (1205.7.6)
- The system must conform to Best Management Practice (BMP) standards for sediment and erosion control (1205.7.6)
- Developments must conform to the Drainage Design Manuals and Drainage Policies Manual (1205.7.6)
- If an Area Drainage Master Study (ADMS) is completed, a plan of uniform rules for development must be prepared and adopted (1205.8.1)

Floodplain Regulations

Maricopa County has also adopted Floodplain Regulations (November, 2011), which the District uses to manage development within the regulatory 100-year floodplain, including the following:

- Defines areas of jurisdiction as Special Flood Hazard Areas (SFHAs) or areas with contributing watersheds with flows greater than 50 cfs in unincorporated areas of the county (Article 3, Section 301)
- Allows Floodplain Administrator to require land developers to delineate floodplains in areas where development is imminent or ongoing (Article 3, Section 302)
- Requires Floodplain Administrator to designate hazard areas on Flood Management Maps. Flood hazards may be identified by high velocity flows, erosion, sediment transport, deposition, unstable soil conditions, unstable flow path, or land subsidence (Article 3, Section 304)
- Allows the District to complete a Watercourse Master Plan (WCMP), including uniform rules for the river or drainage system (Article 3, Section 305)
- Identifies allowable uses and requirements for development within SFHAs (Article 5, Sections 501 through 508)
- Outlines the requirements, process and allowed variances for obtaining a Floodplain Use Permit (Article 4, Sections 401 through 411)
- Summarizes the general development standards required for a Floodplain Use Permit (Article 6, Sections 601 through 615)

Drainage Policies and Standards Manual

The Drainage Policies and Standards Manual (effective 2007, draft 2010) provides guidance and detail on implementation of the Drainage Regulations and Floodplain Regulations. The manual includes the following:

- Drainage planning considerations
- A summary of drainage policies by which the County/District implements regulations and ordinances. These include drainage patterns, hydrology, stormwater quality, floodplain management, erosion hazard management, street drainage, conveyance facilities, stormwater storage facilities, and floodplain use permits for sand and gravel mining
- A summary of federal, state and county regulations
- Comprehensive drainage standards

5.1.5 Town of Queen Creek

The majority of the Town of Queen Creek is located within Maricopa County; however, a portion of the Town is located within Pinal County. For the portions of the Town that are located within Maricopa County, floodplain management is conducted by the District on behalf of the Town. The Pinal County Flood Control District (PCFCD) conducts floodplain management for portions of the Town located within Pinal County. The Town regulates areas outside the regulatory floodplain through the Town's Subdivision Ordinance.

Subdivision Ordinance

Town of Queen Creek Subdivision Ordinance, Subdivision Design Standards and Principles (October 2007) include the following:

- Private properties and public streets must provide for adequate disposal of stormwater
- Drainage systems must follow requirements in the Maricopa County Drainage Design Manuals
- Post-development flows must not exceed pre-development flows in peak runoff, volume or velocity and may not concentrate sheet flows without downstream offsite control
- Dry wells must meet specific design and maintenance plan requirements

Current IGAs with the District

The Town of Queen Creek currently has the following Intergovernmental Agreements (IGAs) with the District

- Queen Creek / Sonoqui Wash Hydraulic Master Plan (IGA FCD 2001R001A)
    - The District is authorized to negotiate and prepare IGAs with the Town of Queen Creek, Town of Gilbert and other parties for the design, construction, operation and maintenance for facilities identified as part of the Queen Creek and Sonoqui Wash Hydraulic Master Plan.
- Sonoqui Wash Channelization – Queen Creek Wash to Chandler Heights Road (IGA FCD 2004A015)
    - The Project Partners (Town of Queen Creek, Town of Gilbert and the District) are responsible for operations and maintenance of that portion of the project within their respective jurisdictions.
    - The Towns of Queen Creek and Gilbert will obtain District review and comments on any future changes or modifications to the project within their respective jurisdictions.
    - The Towns of Queen Creek and Gilbert will conduct annual inspections of the portion of the project with their respective jurisdictions and invite the District to participate.
- Cloud Road and Sossaman Road Basin and Outlet Project (IGA FCD 2010A007)
    - Town is responsible for operations and maintenance of the project.
    - Town will obtain District review and comments on any future changes or modifications to the project.
    - Town will conduct annual inspections of the project and invite the District to participate.
- Sonoqui Wash Channelization Phase II – Chandler Heights Road to Crismon Road (IGA FCD 2009A011, 2009A011A)
    - Town is responsible for operations and maintenance of the project.

- Own is responsible to implement Phase IIB Ellsworth Road to Crismon Road

5.1.6 Town of Gilbert

The Town of Gilbert conducts floodplain management for its jurisdiction through the Town's Code of Ordinances. The Town manages areas outside the regulatory floodplain using the Town's Land Development Code.

Code of Ordinances (Municipal Code)

The Town of Gilbert Code of Ordinances, Floodplain Management, includes the following:

- Restricts/prohibits uses which are dangerous to health, safety and property due to water or erosion hazards, or which result in damaging increases in erosion or flood heights/velocities
- Requires facilities serving at-risk uses to be protected against flood damage
- Controls alteration of natural floodplains, channels and protective barriers which accommodate or channel floodwaters
- Controls filling, grading, dredging and other development which may increase flood damage
- Prevents/regulates obstructions which unnaturally divert or increase flood hazards

Land Development Code

The Town of Gilbert's Land Development Code (July 2012) establishes zoning regulations, design standards and guidelines, and subdivision regulations. It includes requirements for preliminary and final design reviews.

Current IGAs with the District

The Town of Gilbert currently has the following IGAs with the District:

- Queen Creek / Sonoqui Wash Hydraulic Master Plan (IGA FCD 2001RR001A)
    - The District is authorized to negotiate and prepare IGAs with the Town of Queen Creek, Town of Gilbert and other parties for the design, construction, operation and maintenance for facilities identified as part of the Queen Creek and Sonoqui Wash Hydraulic Master Plan.
- Sonoqui Wash Channelization – Queen Creek Wash to Chandler Heights Road (IGA FCD 2004A015)
    - Refer to Section 2.5.2.

5.1.7 Gila River Indian Community

The Gila River Indian Community is currently in the process of developing Drainage and Floodplain Ordinances. The Community's Drainage Design Manual references the District's Drainage Design Manuals.

5.1.8 Pinal County

As directed and authorized by the State, Pinal County has adopted Floodplain and Drainage Regulations to manage development both within and outside the regulatory 100-year floodplain. In addition, the Pinal County Flood Control District (PCFCD) has prepared Rules of Development as part of the Pinal County Area Drainage Master Plan (ADMP)

Drainage Ordinance

The Pinal County Drainage Ordinance (November 1998), regulates drainage of all land within unincorporated areas of the county and is focused on areas outside the regulatory floodplain. The Drainage Ordinance includes the following:

- Requires that a Drainage Clearance be obtained for any development which may adversely affect existing drainage
- Requires a drainage detention and conveyance system to eliminate/minimize stormwater runoff effects and convey the runoff through the development with minimum detrimental effects
- Establishes design parameters for drainage systems, drywells, roads, finished floor elevations, floodplain development, and landscape/grading
- Establishes development drainage requirements and building setbacks

Floodplain Ordinance

Pinal County Floodplain Ordinance (August 2006) regulates development in areas within the regulatory floodplain. The Floodplain Ordinance includes the following:

- Restricts/prohibits uses which are dangerous to health, safety and property due to water or erosion hazards, or which result in damaging increases in erosion or flood heights/velocities
- Requires facilities serving at-risk uses to be protected against flood damage
- Controls alteration of natural floodplains, channels and protective barriers which accommodate or channel floodwaters
- Controls filling, grading, dredging and other development which may increase flood damage
- Prevents/regulates obstructions which unnaturally divert or increase flood hazards
- Requires a Floodplain Use Permit of Clearance for development in unincorporated county land for 100-year flows greater than 200 cfs

Pinal County ADMP Rules of Development

These Rules of Development were prepared as part of the Pinal County ADMP (December 2009) and are intended as guidelines to assist in the identification of flood hazards and implementation of drainage solutions. The Rules of Development includes the following:

- Identifies hazards including: riverine floodplains, erosion, distributary and split flows, alluvial fans, sheet flow, ponding areas, farmlands, hillside areas, subsidence and earth fissures
- Summarizes guidelines for developments such as road and utility crossings, detention/retention basins, levees and embankments, canals and irrigation structures, storm drains and channels, and sand and gravel mining

Current IGAs with the District

Pinal County currently has the following IGA with the District:

- Sonoqui Wash Channelization – Empire Boulevard to Hunt Highway (IGA FCD 2011A007)

- The PCFCD is responsible for operations and maintenance of the project.
- The PCFCD will obtain District review and comments on any future changes or modifications to the project.
- The PCFCD will conduct annual inspections of the project and invite the District to participate.

5.1.9 Other Considerations

Jurisdictional Responsibilities

Below is a summary of floodplain administrator responsibilities for the various jurisdictions in the study area.

Table 7. Floodplain Administrator Responsibilities

Jurisdiction	Floodplain Administrator
Town of Gilbert	Town of Gilbert
Town of Queen Creek, within Maricopa County	District
Town of Queen Creek, within Pinal County	PCFCD
Gila River Indian Community	Gila River Indian Community
Maricopa County, Unincorporated Areas	District
Pinal County, Unincorporated Areas	PCFCD

Land Use, Zoning and Ownership

The land use and zoning within the study area predominantly consist of passive open space, rural residential and medium lot residential. The majority of the area south of Hunt Highway consists of passive open space with some portions zoned for rural residential. The area north of Hunt Highway is significantly more developed, consisting mainly of rural residential, and medium to large lot residential. Small portions of this area consist of golf courses, institutional and both neighborhood and regional commercial. Regional drainage facilities are classified as active open space. The majority of the open space within the study area is either part of the Gila River Indian Community or is part of the San Tan Mountain Regional Park. The remainder of the study area is mainly privately owned. Land ownership and land use maps are provided as **Figures 3 and 5, Appendix F** respectively.

Existing and Planned Developments

As of June 2013, there are 55 existing and planned developments within the study area, shown on **Figure 4, Appendix F**. Of these, 30 developments are greater than 40 acres, and 10 are greater than 160 acres. These larger developments are summarized in **Table 8**.

Table 8. Existing and Planned Developments (Greater than 160 Acres)

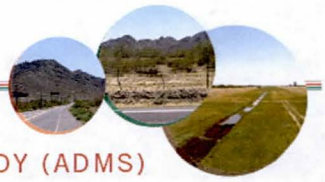
Development	Status [1]	Area [acres]	
			Total
Adora Trails and Mountainwood PADS	Active [2]	64	547
	Complete [3]	10	
	Conceptual [4]	473	
Borgata at San Tan	Active	261	
Freeman Farms	Active	53	242
	Complete	3	
	Conceptual	6	
	Final Plat [5]	180	
Marbella Vineyards	Complete	121	234
	Conceptual	113	
Power Ranch	Complete	269	
San Tan Heights and Cardon Property	Active	1,569	
Seville	Active	379	1,350
	Complete	904	
	Conceptual	7	
	Final Plat	60	
Shamrock Estates	Active	281	414
	Complete	35	
	Conceptual	93	
	Final Plat	5	
Sossaman Estates	Complete	62	348
	Conceptual	286	
The Pecans	Active	154	244
	Complete	5	

Notes

1. *Status as of October 2012.*
2. *Active – under construction.*
3. *Complete – construction completed.*
4. *Conceptual – under conceptual design.*
5. *Final Plat – final plat completed.*

Regional Drainage Facilities

The regional drainage facilities within the study area consist of Sonoqui Wash, the EMF, and the Cloud Road Basin and Channel system.



Transportation Networks

The main transportation network consists of Hunt Highway, which serves a vital connection between Pinal County and southeastern Maricopa County, and the arterial street network. Many of the drainage crossings at the local streets are at-grade crossings subject to flooding during moderate to large storm events.

Utilities

The utilities of primary consideration within the study area are the networks of irrigation canals and pipes associated with the three irrigation districts in the area: Chandler Heights Citrus Irrigation, Queen Creek Irrigation and San Tan Irrigation.

Visual Character

The study area tends to be characterized by a blend of various distinct aesthetic elements: the natural desert of the San Tan Mountains, agricultural fields combined with low density rural development, and master planned developments with medium to large lots.

Multi-use Opportunities

The main multi-use opportunities currently being used in the study area are the use of the Sonoqui Wash channelization improvements for equestrian, bicycle and pedestrian trails. The EMF is also used as part of the bicycle trail system. Potential opportunities include the use of local parks and even the San Tan Regional Park.

5.2 FLOOD AND EROSION HAZARDS

Several flood and erosion hazards have been identified in the study area. This section provides a brief description of these hazards. For more information, refer to the Flood Hazard Assessment and Mitigation Plan.

5.2.1 Floodplains

The Maricopa County portion of the study area contains four 100-year floodplains that have been mapped by the Federal Emergency Management Agency (FEMA). A Zone "A" floodplain is associated with the EMF, located on the western boundary of the study area, from Ocotillo Road to Hunt Highway. The three other mapped floodplains are associated with Sonoqui Wash: a Zone "A" extending from the Empire Boulevard / Ellsworth Road intersection to the 204th Street / San Tan Boulevard intersection; a large Zone "AO" between the Empire Boulevard / Ellsworth Road intersection to the San Tan Boulevard / Hawes Road intersection; and a Zone "AE" floodplain extending along the lower portion of Sonoqui Wash to the EMF.

Several floodplains have been mapped in the Pinal County portion of the study area, extending from the unincorporated areas in the San Tan Mountains to Hunt Highway. Refer to **Figure 9, Appendix F**, for the FEMA Mapped 100-Year Floodplains.

In addition to these mapped floodplains, other inundation areas have been identified through the FLO-2D modeling results as part of this study, with the deepest flows ranging from 4 to 6 feet, typically associated with incised washes south of Hunt Highway or behind the "farmer's dike" paralleling the south side of Hunt Highway.

5.2.2 Shallow Flooding and Ponding

Approximately half of the study area, generally located north of Hunt Highway, is subject to shallow flooding, typically due to disturbance caused by major land grading activities for agricultural and development uses. This area consists of shallow slopes, and natural drainage paths have been significantly impacted or obliterated.

5.2.3 Flood Diversion

A man-made earthen structure, referred to as a "farmer's dike" is located on the south side of Hunt Highway. The dike, which is parallel to Hunt Highway, extends from the Santo Vallarta subdivision through the Gila River Indian Community west to Route 131. Based on a review of historic aerial photographs, it is estimated that the dike was constructed in the 1940s, presumably to protect downstream farm land south of Hunt Highway. The dike appears to provide some level of protection to properties south of Hunt Highway; however, the dike has been breached in the past and therefore also poses a hazard due to the uncertain integrity of the structure.

5.2.4 Distributary and Split Flows

While there are no alluvial fans identified within the study area, the Geologic Assessment prepared for this study identified piedmont areas with distributary drainage systems. Based on the assessment, this landform generally appears to be an older alluvial surface with signs of stability. However, as development occurs in these areas, it becomes increasingly important to preserve these distributary systems in order to avoid significant adverse impacts to downstream properties.

5.2.5 Scour and Sedimentation

As discussed in the Sediment Study Area Memorandum (**Appendix D**) and the Flood Hazard Assessment, a significant amount of sediment is transported through the San Tan watershed, particularly in the piedmont areas with distributary drainage systems. Urbanization of the watershed interrupts the natural supply of sediment to watercourses, resulting in erosion and scour. By interrupting the flow of sediment, development can also cause increased sedimentation and debris, such as through roadway culverts that may not sufficiently pass debris and sediment-laden flows. A significant amount of erosion and sedimentation has occurred during recent flood events along Bell Road south of Hunt Highway.

5.2.6 Lateral Migration

The drainage systems in the study area tend to consist of older, more stable channels. As a result, lateral migration does not appear to be a significant risk.

5.2.7 Land Subsidence and Earth Fissures

Agricultural development within and adjacent to study area over the past 80 years has resulted in groundwater pumping rates that have exceeded the rate of recharge for the basin aquifer. This groundwater removal has caused subsidence over a large area, which in turn has resulted in the formation of earth fissures. As shown on **Figure 8, Appendix E**, the Map of Surficial Geology with Identified Issues, fissures were observed during the geologic field reconnaissance in five areas within the general vicinity of Hunt Highway:

- Area A active earth fissures on the west side of the study area, south of Hunt Highway and west of 164th Street
- Area B earth fissure traces, west of Higley Road and south of San Tan Boulevard
- Area E active earth fissures south of Hunt Highway, east of Sossaman Road
- Area H earth fissures south of Hunt Highway, east of Pioneer Path Road
- Area I active earth fissures on the east side of the study area, south of Hunt Highway

5.3 GAPS, OPPORTUNITIES AND OBSTACLES

5.3.1 Gaps

As previously discussed, the study area is divided by numerous jurisdictions: the Town of Queen Creek, Town of Gilbert, unincorporated Maricopa County, the Gila River Indian Community, and unincorporated Pinal County. While various regulations and ordinances currently provide a framework for managing drainage and floodplain issues within the study area, there are several gaps that could be addressed with consistent development considerations for the area including:

- Guidelines for construction of walls, fences and buildings that could divert or obstruct existing drainage patterns
- Limitations on concentration of existing sheet or distributary flows
- Requirements for erosion protection measures in flood and erosion hazard areas
- Guidance to reduce adverse impacts of urbanization, including low impact development (LID) measures such as reducing imperviousness and preserving existing vegetation
- Delineation of flood hazard limits in areas not currently regulated by FEMA or local jurisdictions
- Stormwater compliance, which will become more challenging as communities grow in population and municipal separate storm sewer systems (MS4) requirements become more stringent

5.3.2 Opportunities

As development continues to occur within the study area, there is a significant opportunity to use some of the identified erosion and flood hazard areas for multiple-use recreational facilities. Possible retention/detention facilities could be used as parks or athletic fields. Preserved wash corridors can serve as open space as well as both pedestrian and equestrian trails, similar to the existing Sonoqui Wash channelization improvements. These corridors would serve to protect public health, safety and property while connecting communities throughout the study area.

The Gila River Indian Community is in the process of developing a Drainage Ordinance and a Floodplain Ordinance for the Community. Since relatively little development currently exists within the Community's portion of the study area, the timely development of those ordinances in conjunction with the Development Considerations of this study presents a unique opportunity to guide future development.

5.3.3 Obstacles

Based on several discussions with the major stakeholders in the study area, it appears the main obstacles appear to be the following:

- **Inadequate identification of flood and erosion hazards prior to development.** Some existing developments appear to not be sufficiently designed to convey offsite runoff impacting the site, particularly those in sheet and distributary flow areas. This places communities at potential risk to various flood and erosion hazards.
- **Late involvement of floodplain administrators in the planning and development review process.** For some developments, especially those without identified floodplains, floodplain administrators have not been involved until relatively late in the development process. This makes it more difficult for floodplain administrators to participate in the identification and effective mitigation of hazards.
- **Lack of public awareness regarding flood and erosion hazards.** It appears public outreach may be needed to raise awareness regarding hazards and to reinforce the role of the public in minimizing risk. This is evident by residents building berms and walls to divert flow and filling or redirecting existing washes and drainage corridors.

5.4 DEVELOPMENT CONSIDERATIONS

The guiding principle for the Development Considerations of this study is "No Adverse Impact." In essence, any future new development or re-development, including improvements on single lots, should not have an adverse impact on adjacent or downstream properties. In order to accomplish this, the following development considerations are recommended. It should be noted that the hazards presented in this study are for planning purposes. Future development may require more detailed analyses in order to more fully identify hazards and avoid adverse impacts related to each proposed project.

5.4.1 Non-Structural Measures

Non-structural measures consist of "common sense" best management practices (BMPs) that, if applied to across a watershed, can have a significant impact on reducing risk to flooding and erosion hazards. Many non-structural measures also have an impact on reducing stormwater pollution.

The following non-structural measures should be considered for the study area:

- Permitting measures
  - Identify potential 404 jurisdictional washes during initial stage of development.
  - Involve local floodplain administrator during early stage of development process, especially if development includes flood and erosion hazards shown on **Figure 13, Appendix A**.
  - Require a maintenance plan for all drainage and flood control improvements, whether private or publicly maintained.
- Site design and planning measures
  - Conserve natural spaces and vegetation.
  - Reduce overall impervious area.
  - Reduce directly connected impervious area.
  - Provide wider setbacks between developments and watercourses.
  - Promote use of natural and drought tolerant plants.

- Minimize disturbance envelope, especially in steep or high erosion hazard areas.
- Stabilize disturbed slopes as quickly as possible.
- Stabilize temporary and permanent drainage crossings as quickly as possible.
- Promote efficient irrigation techniques such as water conservation plans and rain-triggered shutoff devices.
- Choose plants that minimize or eliminate the use of fertilizer or pesticides.

- Public outreach and involvement measures
  - Form partnerships with local civic or environmental groups
  - Provide educational materials or workshops
  - Reach out to the diverse audiences in the study area
  - Hold public meetings to allow citizens to provide input
  - Establish community clean-up programs
  - Promote storm drain stenciling
  - Leverage photos and videos taken by residents during storm events

5.4.2 Low Impact Development

Low Impact Development (LID) considerations consist of both planning/design techniques as well as the incorporation of specific structural measures.

Planning new development with LID in mind includes site planning techniques that focus on avoidance and prevention, such as the following:

- Preserving existing vegetation wherever possible
- Reducing overall slopes on the site in order to minimize erosion
- Minimizing the length of steep streets to prevent erosion and flooding
- Reducing overall impervious area through narrower streets, smaller parking areas, and sidewalks only on one side of the street
- Using shared or flared driveways
- Clustering buildings to accommodate either retention or stormwater harvesting areas
- Reducing directly connected impervious areas

Structural LID measures focus on "greener" or more sustainable infrastructure to treat or convey runoff, such as:

- Permeable pavement to promote stormwater infiltration and groundwater recharge for light duty roads, parking lots and driveways
- Swales and infiltration trenches to convey and treat stormwater runoff
- Notched check dams in swales to promote infiltration
- Water harvesting basins adjacent to paved surfaces

5.4.3 Drainage Corridors

Existing washes or major flow paths should be identified on all properties prior to new development or re-development. Developments should delineate and preserve drainage corridors to sufficiently convey runoff through the site in such a manner as to not adversely impact adjacent or downstream properties. Any wash

relocations or concentration of sheet or distributary flows should be done in such a way as to maintain existing condition flow characteristics including, peak flows, water surface elevations, and velocities. Any alteration of downstream flow characteristics should require a technical report substantiating that no adjacent or downstream properties will be adversely affected.

5.4.4 Erosion Hazard Setbacks

Any development adjacent to washes with 100-year peak discharges greater than 50 cfs should have erosion hazard setbacks established per ADWR State Standard SS5-96 Watercourse System Sediment Balance, Guideline 1. Scour protection for the 100-year event should be provided for any habitable building foundation located in a flood or erosion hazard.

5.4.5 Levees

Any levees or levee-like embankments within the study area, particularly the "farmer's dike" south of Hunt Highway, should be evaluated for the following:

- Structural integrity to determine risk of failure and potential failure modes
- Downstream inundation limits to determine risk in the event of failure
- Compatibility with current FEMA policies and criteria regarding levees and levee-like embankments, including design, construction, maintenance, and if applicable, certification
- Upstream impoundment/inundation limits
- Drainage easements required to provide necessary maintenance
- Necessity for preparation of an Emergency Action Plan (EAP) depending on the assessed level of risk

5.4.6 Roadway Crossings

The following should be considered for all roadway crossings within the study area:

- Roadway improvements, including crossings and roadside channels and ditches, should maintain existing flow paths. Any flow diversions, such as with sheet or distributary flows, should be consistent with established drainage corridors. Changes to existing flow characteristics should require a technical report substantiating that the project will not adversely impact adjacent or downstream properties.
- Existing channel thalweg elevations and slopes should be maintained wherever possible. Any significant changes to thalweg elevations, slopes or channel geometry should be evaluated for potential adverse impacts to water surface elevations, velocities, scour and sediment transport patterns.
- Maintenance should be conducted as necessary to allow for conveyance of flows. In particular, crossings should be cleared of sediment and debris after major storm events, and prior to the start of each winter and monsoon season.

Bridges

Bridge improvements should include the following considerations:

- Bridges are preferable to culvert crossings for both major drainage corridors and wide, distributary channels in order to better maintain existing hydraulic and sediment transport conditions.

- Bridges should be designed with the appropriate scour countermeasures in keeping with the jurisdiction and required level of protection for the road.

Culverts

The design of culvert improvements should include the following considerations:

- Culverts should be sized to maintain the existing sediment transport capacity of the wash.
- Culverts should be sized with consideration for potential clogging from sediment and debris, either sized with a clogging factor or constructed with a local sediment/debris basin upstream.
- Culverts should be constructed with adequately sized scour countermeasures upstream and downstream of the culvert as necessary.
- Where an existing culvert is to be replaced or improved, improvements should consider the potential for:
    - Increasing conveyance capacity and potentially adversely impacting downstream properties due to increased flows or velocities; or
    - Decreasing conveyance capacity and potentially adversely impacting upstream properties due to larger inundation limits
    - Ease of maintenance

At-Grade Crossings

The following should be considered for at-grade crossings within the study area:

- At-grade crossings should be limited to only local roads in rural residential areas.
- Scour countermeasures should be implemented as necessary in order to protect the road from long-term degradation.
- The roadway profile should be designed to match the existing channel geometry in such a way as to maintain existing hydraulic and sediment transport conditions.

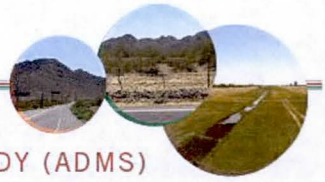
Driveways

Driveway improvements should maintain the designed conveyance capacity of the adjacent roadside drainage ditch or channel, including careful consideration of potential debris and sediment.

5.4.7 Walls, Fences and Berms

Walls and fences should be designed with the following considerations:

- Walls or fences should not be constructed within jurisdictional floodplains unless a technical report can substantiate that the structure does not obstruct the 100-year flood, while accounting for debris, or adversely affect adjacent property owners.
- Walls or fences should have sufficient openings to convey the 100-year flood, while accounting for debris, without adversely affecting adjacent property owners.
- Bottom should have at least six inches of clearance above the natural ground, or if crossing a flow path, at least six inches above the bank of the flow path.



Berms should be designed with the following criteria:

- Maintain existing drainage patterns
- Not adversely affect adjacent or downstream property owners
- Not divert flows, such as with a levee or levee-like structure
- Top elevation should be a minimum of 1 foot below the finished floor elevations of adjacent habitable structures

5.4.8 Detention/Retention

New developments should provide on-site retention with the following considerations:

- The volume associated with the 100-year, 2-hour storm should be retained unless a waiver is granted by the governing jurisdiction.
- The basin should drain within 36 hours through either infiltration or the use of dry wells. The option of draining through a bleed-off pipe into a storm drain system requires jurisdictional approval, and discharge rate must not exceed 1 cfs.
- If the 100-year, 2-hour retention requirement is waived, the development must still meet the following:
    - Post-project peak discharges must not exceed pre-project conditions.
    - Pre- and post-project volumes should be calculated, and it must be demonstrated that any increases do not result in adverse impacts to adjacent or downstream properties.
    - The "first flush" treatment requirement of the governing jurisdiction must still be provided as defined in the corresponding Municipal Separate Storm Sewer System (MS4) permit.

5.4.9 Minimum Finished Floor Elevations

The finished floor elevation for all habitable structures should meet the following criteria:

- Minimum of 1 foot above the regulatory floodplain elevation; and
- Minimum of 1 foot above the natural adjacent grade, including adjacent berms or embankments

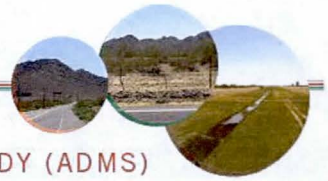
5.4.10 Utility Crossings

The design of utility crossings within the study area should consider the following:

- Underground utilities should be buried below the appropriate design scour depth in the drainage corridor. It is recommended that this depth be based on the 100-year scour event; however, this may be adjusted based on the jurisdiction, type of utility and level of risk.
- The potential for lateral migration should be considered when burying underground utilities. It is recommended that the burial depth be extended laterally based on erosion hazard setbacks.
- Utility poles should be located outside of erosion hazard areas; otherwise, scour protection should be provided.

5.4.11 Canals and Irrigation Structures

The following should be considered both for canals as well as any developments adjacent to a canal:



- Canals should be designed to maintain existing flow patterns not impound or divert upstream flows.
- Cross drainage structures, such as overchutes, should be designed for the 100-year peak discharge. Such structures should be designed with consideration for scour as well as the maintenance of pre-project hydraulic and sediment transport conditions.
- Stormwater runoff should not be conveyed in canals.
- Canals and developments adjacent to canals should be designed considering both fluctuating tailwater conditions and the potential for stormwater impacts.
- If a canal is higher than adjacent grade, development finished floor elevations should be set at least 1 foot higher than the top of the canal embankment.
- Potential canal failure should be considered when designing developments downstream.

6. FLOOD MITIGATION PLAN

The flood hazard mitigation plan identifies potential mitigation areas (PMA) to address the high hazard risk zones within the study area where practical. Each area includes a description of the potential mitigation, the flood and erosion hazards that would be mitigated, an implementation/action plan, and development considerations. In addition, the responsible party, prioritization, and funding mechanisms are discussed for each area. An exhibit of each PMA is included at the end of this report section.

6.1 POTENTIAL MITIGATION AREA #1: FARMER'S DIKE REPLACEMENT

6.1.1 Description

The farmer's dike is a man-made structure that is located approximately 200 feet south of Hunt Highway. It extends from south of the Santo Vallarta subdivision through the Gila River Indian Community to Route 131 (approximately 168th Street). Based on a review of historic aerial photographs, it is estimated that the dike was constructed in the 1940s, presumably to protect downstream farm land.

6.1.2 Hazards

The land downstream of the dike currently consists of rural residential development. While the dike appears to offer some flood protection to Hunt Highway and the rural residential areas, it also poses a significant hazard. The dike has no scour protection measures, it is not regularly maintained, and it is likely that the structure was not constructed with the proper materials and compaction. As a result, the dike has a significant potential for breaching during major storms. Based on field reconnaissance and discussions with stakeholders and local residents, the dike has been breached in the past.

There is a known earth fissure on the western edge of the dike alignment between the western edge of the existing dike and the EMF. Any extension through this area would require fissure mitigation.

6.1.3 Mitigation Implementation/Action plan

Based on the flood hazard assessment, the three main strategies to mitigate the risk of the dike breach are property acquisition, channel improvement, and improvements to bring the dike up to current FEMA levee standards. Due to the large extent of potential flooding downstream of the dike, property acquisition does not appear to be feasible as a stand-alone solution. Construction of a channel could be the most viable alternative. The facility could be constructed parallel to the dike, on the south side, to capture flows upstream of the structure and convey those flows to the west. This option would likely require improvements to the EMF to ensure a controlled outfall. A detention/sedimentation basin could be a component of this option. Flows could be metered out of the basin to reduce channel size. A sedimentation basin would provide a concentrated location for sediment deposition which could reduce maintenance costs for the channel. Another alternative would be either to improve or reconstruct the dike. Because of the uncertain methods used during the original construction, improving the dike is not a recommended option without conducting extensive geotechnical testing. A new levee could be constructed south of the existing structure, and the current dike could either be

left in place or removed. The following table summarizes the advantages and disadvantages of the various mitigation strategies.

Table 9. PMA #1: Farmer's Dike – Mitigation Strategies

Strategy	Advantages	Disadvantages
Property Acquisition	▪ No long-term maintenance	▪ Extremely costly due to size of downstream area
Channels	▪ Protects Hunt Highway and rural residential areas ▪ Allows for more development along Hunt Highway ▪ More compatible with surrounding environment ▪ Potential for future multi-use facilities such as trails or linear parks	▪ Requires outfall structure to EMF ▪ Requires maintenance
Dike Improvement	▪ Protects Hunt Highway and rural residential areas ▪ Allows for more development along Hunt Highway	▪ Unknown integrity of dike ▪ Requires extensive geotechnical investigation ▪ Requires maintenance
Levee Construction	▪ Protects Hunt Highway and rural residential areas ▪ Allows for more development along Hunt Highway	▪ Requires maintenance
Detention/Sedimentation Basin	▪ Reduction in size of channel, dike or levee ▪ Allows for concentration location of sediments, maintenance benefit ▪ Potential for multi-use facilities such as trails or parks	▪ Requires maintenance ▪ Requires outfall

6.1.4 Development Considerations

Development considerations for this potential mitigation area include the following:

- An intergovernmental agreement (IGA) will be required between the District and the Gila River Indian Community (the Community) to design, construct, operate and maintain any structures (channel, dike improvements, levee construction).
- The Community should regulate development upstream of the existing or proposed structures in order to avoid adverse impacts.
- Wash or channel improvements could be compatible with future multi-use opportunities such as pedestrian/equestrian trails or parks.
- If either the existing dike is left in place or a new levee is constructed, an emergency action plan should be prepared in the event that the structure is breached.

- Public outreach is recommended in order to raise awareness of the current hazard caused by the farmer's dike on existing and future development.
- The Community may have future plans to extend the existing subdivision along Hunt Highway. This should be taken into consideration with any potential project alignment.

6.1.5 Responsible Party

While it is uncertain who constructed the farmer's dike, the structure is located on Community land. Any construction related to the farmer's dike will require significant involvement with the Community. An IGA will be required to outline the right-of-way, design, construction, operation and maintenance responsibilities related to a potential project.

6.1.6 Prioritization

Mitigation of the farmer's dike is considered a high level priority due to the significant amount of rural and small lot residential development downstream of the structure; however, due to the extensive coordination required, it is anticipated that the implementation of the solution will be in the medium range of 3 to 5 years. This timeline may need to adjust based on Community's plan to extend the subdivision south of Hunt Highway. It is recommended that agency coordination and public awareness begin as soon as possible.

6.1.7 Funding mechanisms

Due to the extent of the potential mitigation area, it is likely that the area will need to be included as part of the District's Capital Improvement Plan. The areas that benefit from this mitigation concept include Maricopa County, Towns of Gilbert and Queen Creek and the Gila River Indian Community. Funding partnerships should be explored with all.

6.2 Potential Mitigation Area #2: Sheet Flow South of Hunt Highway (Higley Road to Sossaman Road)

6.2.1 Description

The area south of Hunt Highway, between Higley and Sossaman Roads, is impacted by a significant amount of offsite runoff. During small to moderate storm events, runoff from sheet flow and shallow washes collects along the south side of Hunt Highway then continues north across the highway. Runoff subsequently flows through rural residential developments and local roads.

6.2.2 Hazards

During small to moderate storm events, this area is adversely affected by sheet flooding, ponding, sedimentation and erosion, and damaged or impassable roads. In addition, the area is affected by the hazard of the upstream farmer's dike described in the previous section. These hazards also impact Hunt Highway, Higley Road, Power Road and Sossaman Road. In addition, many of the local, unpaved north-south roads act as channels during storm events.

6.2.3 Mitigation Implementation/Action plan

The two main strategies to mitigate the hazards impacting this area are detention/retention and channels. A linear detention/retention basin could be constructed to detain/retain offsite flows. The basin would likely be located on the south side of Hunt Highway. A basin would require an outfall to the Chandler Heights Channel, the Power Road Channel (also see PMA #7) or the EMF. An alternative to a basin is constructing a channel along the south side of Hunt Highway to intercept and convey flows to either the Chandler Heights or Power Road Channels or the EMF. As this area is directly downstream of the farmer's dike (PMA #1), any improvements to the dike should be considered in the implementation/action plan.

Table 10. PMA #2: Sheet Flow South of Hunt Highway (Higley to Sossaman) – Mitigation Strategies

Strategy	Advantages	Disadvantages
Detention/Retention	▪ Reduces peak discharge to downstream areas ▪ Potential for multi-use facilities such as trails or parks	▪ Requires either drywells or outfall to Chandler Heights Channel, Power Road Channel or EMF ▪ Requires maintenance
Channels	▪ May require less right of way than detention/retention ▪ Potential for multi-use facilities such as trails or parks	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ May require slope protection if velocities are erosive

6.2.4 Development Considerations

Development considerations for this mitigation concept include the following:

- An intergovernmental agreement (IGA) will be required between the District and the Gila River Indian Community (the Community) to design, construct, operate and maintain any structures within the Community. Any structures that extend into the Town of Gilbert, Town of Queen Creek or Pinal County will also require that those municipalities be included in the IGA.
- Wash or channel improvements could be compatible with future multi-use opportunities such as pedestrian/equestrian trails or parks.
- Public outreach is recommended in order to raise awareness of the current hazards, particularly the hazard caused by the upstream farmer's dike on existing and future development.
- The Community may have future plans to extend the existing subdivision along Hunt Highway. This should be taken into consideration with any potential project alignment.

6.2.5 Responsible Party

Any construction located on the Gila River Indian Community, the Town of Gilbert, the Town of Queen Creek, and Pinal County will require significant coordination between the affected communities. An IGA will be required to outline the right-of-way, design, construction, operation and maintenance responsibilities related to a potential project.

6.2.6 Prioritization

Similar to the mitigation of the farmer's dike, this area within the Hunt Highway corridor is considered a high level priority due to the significant amount of rural and small lot residential development downstream. Because of the extensive coordination required, it is anticipated that the implementation of the solution will be in the medium range of 3 to 5 years. This timeline may need to adjust based on the Community's plan to extend the existing subdivision to the west. It is recommended that agency coordination and public awareness begin as soon as possible.

6.2.7 Funding mechanisms

Due to the extent of the potential mitigation area, it is likely that this project will need to be included as part of the District's Capital Improvement Plan. The areas that benefit from this mitigation concept include Maricopa County, Towns of Gilbert and Queen Creek and the Gila River Indian Community. Funding partnerships should be explored with all.

6.3 Potential Mitigation Area #3: Sheet Flow South of Goldmine Equestrian Estates Subdivision

6.3.1 Description

The San Tan Mountains discharge a large amount of runoff north towards Hunt Highway. In the area between Hawes Road and Sossaman Road there is an existing subdivision, Goldmine Equestrian Estates. This subdivision realizes significant erosion and sedimentation deposition during most storm events. The runoff crosses Hunt Highway and adversely impacts the local roads and rural residential development to the north.

6.3.2 Hazards

Goldmine Equestrian Estates is adversely affected by several hazards during moderate to major storm events: sheet flooding, sedimentation and erosion, and damaged or impassable roads. These hazards also impact Hunt Highway and the rural residential area to the north.

6.3.3 Mitigation Implementation/Action plan

There are four main strategies to mitigate the risk to the area in the vicinity of Goldmine Equestrian Estates: property acquisition, detention/retention, channels, and storm drains. Due to the large extent of potential flooding at this subdivision and downstream areas, property acquisition does not appear to be feasible as a stand-alone solution. The preferable option appears to be a combination of collector channels and a detention/retention basin located south of Goldmine Equestrian Estates to capture and attenuate flows. Other alternatives include constructing new channels or storm drain systems to capture and convey the flows to Sonoqui Wash, the Cloud Road Basin/Channel or the EMF; however, these appear to be less preferable due to anticipated construction costs.

Table 11. PMA #3: Sheet Flow South of Goldmine Equestrian Estates Subdivision – Mitigation Strategies

Strategy	Advantages	Disadvantages
Property Acquisition	▪ No long term maintenance	▪ Extremely costly due to size of downstream area
Detention/Retention	▪ Protects Hunt Highway and residential areas ▪ Reduces peak discharge to downstream areas ▪ Potential for multi-use facilities such as trails or parks	▪ Requires either drywells or outfall to either Sonoqui Wash, Cloud Road Channel/Basin or EMF ▪ Requires maintenance ▪ Could disrupt sediment continuity to Sonoqui Wash
Channels	▪ May require less right of way than detention/retention ▪ Potential for multi-use facilities such as trails or linear parks	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ May require slope protection if velocities are erosive

Strategy	Advantages	Disadvantages
Storm Drains	▪ May require least amount of right of way ▪ Provides an outfall without additional bridge or culvert crossings	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ Could be costly if designed for large storm event

6.3.4 Development Considerations

Development considerations for this potential mitigation area include the following:

- An intergovernmental agreement (IGA) will be required between the District, Pinal County and the Town of Queen Creek to design, construct, operate and maintain any structures (detention/retention basins, channels, or storm drains).
- Once a design concept has been selected, a preliminary design should be conducted in order to identify/procure right-of-way and preserve the design corridor from further development.
- Detention/retention basins or channel improvements could be compatible with future multi-use opportunities such as pedestrian/equestrian trails or parks.
- Channel improvements may require bridge/culvert improvements as well as delineation of erosion hazard setbacks.
- Public outreach is recommended in order to raise awareness of the current hazards and discourage residents from re-directing offsite flow patterns.

6.3.5 Responsible Party

It is likely that the structures would be located within the jurisdiction of Maricopa County, Pinal County and the Town of Queen Creek. An IGA will be required to outline the right-of-way, design, construction, operation and maintenance responsibilities related to a potential project.

6.3.6 Prioritization

Mitigation of the Goldmine Equestrian Estates area is considered a high level priority due to existing evidence of frequent and repetitive damage caused by storm events. It is recommended that the drainage improvements to this area be implemented within the range of 1 to 3 years. It is recommended that agency coordination, public awareness and conceptual design begin as soon as possible in order to preserve right-of-way as necessary.

6.3.7 Funding mechanisms

Due to the extent of the potential project, it is likely that this project will need to be included as part of the District's Capital Improvement Plan. The areas that benefit from this mitigation concept include Maricopa County, Pinal County and the Town of Queen Creek. Funding partnerships should be explored with all.

6.4 Potential Mitigation Area #4: Sheet Flow South of Riggs Road (Between Grapefruit Drive and Hawes Road)

6.4.1 Description

The area south of Riggs Road between Grapefruit Drive and Hawes Road is impacted by offsite runoff from the south. Runoff from sheet flows and shallow washes collects along the south side of Riggs Road during moderate to major storm events and then overtops the road and continues north.

6.4.2 Hazards

During small to moderate storm events, this area is adversely affected by sheet flooding, ponding, sedimentation and erosion, and damaged or impassable roads. These hazards also impact Riggs Road, Sossaman Road, Hawes Road and the Newell Barney Junior High School.

6.4.3 Mitigation Implementation/Action plan

The three main strategies to mitigate the hazards impacting this area are detention/retention, channels and storm drains. A linear detention/retention basin could be constructed on the south side of Riggs Road to detain/retain offsite flows; however, this basin would require an outfall. Construction of either a channel or storm drain system would allow the collected runoff to outfall to the Cloud Road Basin. The requirements for this project would be affected by the implementation of Potential Mitigation Area #3 (Goldmine Equestrian Estates), which is located upstream. Improvements to resolve flooding at Goldmine Equestrian Estates would reduce the amount of offsite runoff impacting Riggs Road.

Table 12. PMA #4: Sheet Flow South of Riggs Road (Hawes to Grapefruit) – Mitigation Strategies

Strategy	Advantages	Disadvantages
Detention/Retention	▪ Protects Riggs Road, Sossaman Road and school ▪ Reduces peak discharge to downstream areas ▪ Potential for multi-use facilities such as trails or parks	▪ Requires either drywells or outfall to either Sonoqui Wash, Cloud Road Basin or EMF ▪ Requires maintenance ▪ Could disrupt sediment continuity to Sonoqui Wash
Channels	▪ May require less right of way than detention/retention ▪ Potential for multi-use facilities such as trails or linear parks	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ May require slope protection if velocities are erosive
Storm Drains	▪ May require least amount of right of way ▪ Provides an outfall without additional bridge or culvert crossings	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ Could be costly if designed for large storm event

6.4.4 Development Considerations

Development considerations for this mitigation concept include the following:

- An intergovernmental agreement (IGA) will be required between the District and the Town of Queen Creek to design, construct, operate and maintain any structures (detention/retention basins, channels, or storm drains).
- Once a design concept has been selected, a preliminary design should be conducted in order to identify/procure right-of-way and preserve the design corridor from further development.
- Detention/retention basins or channel improvements could be compatible with future multi-use opportunities such as pedestrian/equestrian trails or parks.
- Channel improvements may require bridge/culvert improvements as well as delineation of erosion hazard setbacks.

6.4.5 Responsible Party

It is likely that the structures would be located within the jurisdiction of Maricopa County and the Town of Queen Creek. An IGA will be required to outline the right-of-way, design, construction, operation and maintenance responsibilities related to a potential project. The IGA for this mitigation concept would likely be similar to the IGA for the Cloud Road Basin project.

6.4.6 Prioritization

Mitigation of the hazards within this area is considered a medium level priority due to the medium level of risk determined in the flood hazard assessment. It is anticipated that the implementation of the solution will be in the medium range of 3 to 5 years. It is recommended that agency coordination, public awareness and conceptual design begin as soon as possible in order to preserve right-of-way as necessary.

6.4.7 Funding mechanisms

Due to the extent of the potential project, it is likely that this project will need to be included as part of the District's Capital Improvement Plan. The areas that benefit from this mitigation concept include Maricopa County and the Town of Queen Creek.

6.5 POTENTIAL MITIGATION AREA #5: NEWELL BARNEY JUNIOR HIGH SCHOOL

6.5.1 Description

The area within the vicinity of the Newell Barney Junior High School, located on the northeast corner of Sossaman Road and Riggs Road, is impacted by a significant amount of offsite runoff. During moderate to major storm events, runoff from sheet flows and shallow washes collects along the south side of Riggs Road before spilling north across the road onto the school site. Due to the extent of the offsite tributary area, the school athletic fields are often flooded with water during small storm events.

6.5.2 Hazards

The area in the vicinity of the school is adversely affected by several hazards during moderate and even small storm events: sheet flooding, ponding, sedimentation and erosion, and damaged or impassable roads. These hazards also impact Riggs Road and Sossaman Road.

6.5.3 Mitigation Implementation/Action plan

The three main strategies to mitigate the hazards impacting this area are detention/retention, channels and storm drains. This area is in the vicinity of PMA #4 (Riggs Road from Grapefruit Drive to Hawes Road), so the implementation/action plan for the Newell Barney Junior High School area is very similar. The main difference is that PMA #4 would be focused on specifically mitigating the area around the school. Similar to PMA #3, these strategies consist of detention/retention, channels and storm drains. A proposed linear basin on the south side of Riggs Road would detain/retain offsite flows but would require an outfall. Construction of a channel or storm drain system would both collect runoff and provide an outfall, such as to the Cloud Road Basin. The scope of this project would be affected by the implementation of Potential Mitigation Area #3 (Goldmine Equestrian Estates), which is located upstream. Improvements to resolve flooding at Goldmine Equestrian Estates would reduce the amount of offsite runoff impacting the school area.

Table 13. PMA #5: Newell Barney Junior High School – Mitigation Strategies

Strategy	Advantages	Disadvantages
Detention/Retention	▪ Protects Riggs Road, Sossaman Road and school ▪ Reduces peak discharge to downstream areas ▪ Potential for multi-use facilities such as trails or parks	▪ Requires either drywells or outfall to either Sonoqui Wash, Cloud Road Basin or EMF ▪ Requires maintenance ▪ Could disrupt sediment continuity to Sonoqui Wash
Channels	▪ May require less right of way than detention/retention ▪ Potential for multi-use facilities such as trails or linear parks	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ May require slope protection if velocities are erosive
Storm Drains	▪ May require least amount of right of way ▪ Provides an outfall without additional bridge or culvert crossings	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ Could be costly if designed for large storm event

6.5.4 Development Considerations

Development considerations for this mitigation concept include the following:

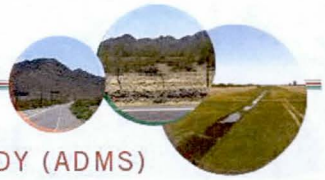
- An intergovernmental agreement (IGA) will be required between the District and the Town of Queen Creek to design, construct, operate and maintain any structures (detention/retention basins, channels, or storm drains).
- Once a design concept has been selected, a preliminary design should be conducted in order to identify/procure right-of-way and preserve the design corridor from further development.
- Detention/retention basins or channel improvements could be compatible with future multi-use opportunities such as pedestrian/equestrian trails or parks.
- Channel improvements may require bridge/culvert improvements as well as delineation of erosion hazard setbacks.

6.5.5 Responsible Party

It is likely that the structures would be located within the jurisdiction of Maricopa County and the Town of Queen Creek. An IGA will be required to outline the right-of-way, design, construction, operation and maintenance responsibilities related to a potential project. The IGA for this mitigation concept would likely be similar to the IGA currently in place for the Cloud Road Basin.

6.5.6 Prioritization

Mitigation of the flooding within the vicinity of the Newell Barney Junior High School is considered a medium level priority due to the medium level of risk determined in the flood hazard assessment. It is anticipated that



the implementation of the solution will be in the medium range of 3 to 5 years. It is recommended that agency coordination, public awareness and conceptual design begin as soon as possible in order to preserve right-of-way as necessary.

6.5.7 Funding mechanisms

Due to the extent of the potential project, it is likely that this project will need to be included as part of the District's Capital Improvement Plan. The areas that benefit from this mitigation concept include Maricopa County and the Town of Queen Creek.

6.6 POTENTIAL MITIGATION AREA #6: SHEET FLOW SOUTH OF CLOUD ROAD CHANNEL

6.6.1 Description

A significant amount of runoff impacts the area south of the Cloud Road Channel from Power Road to 188th Street. Sheet flow from the south accumulates along Cloud Road, and then spills in an uncontrolled manner into the channel.

6.6.2 Hazards

The project area is adversely affected by sheet flooding as well as sedimentation and erosion hazards during small to moderate storm events.

6.6.3 Mitigation Implementation/Action plan

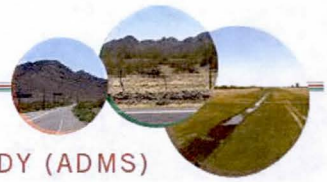
The two main strategies to mitigate the hazards impacting this area are detention/retention and channels. A linear detention/retention basin could be constructed to detain/retain offsite flows. The basin could be located either adjacent to the Cloud Road channel or on the north side of Riggs Road. A basin would require an outfall to the Cloud Road Channel such as through a channel or storm drain system. An alternative to the basin is constructing a channel to intercept flows; such a channel could be constructed in a location similar to the detention/retention basin. A variation of this alternative is to improve Cloud Road Channel to better intercept offsite flows; this would consist of grading on the south side to allow for offsite flows to enter the channel at specific locations and providing erosion protection at these locations.

Table 14. PMA #6: Sheet Flow South of Cloud Road Channel – Mitigation Strategies

Strategy	Advantages	Disadvantages
Detention/Retention	▪ Reduces peak discharge to downstream areas ▪ Potential for multi-use facilities such as trails or parks	▪ Requires either drywells or outfall to Cloud Road Channel ▪ Requires maintenance ▪ Could disrupt sediment continuity to Sonoqui Wash
Channels	▪ May require less right of way than detention/retention ▪ Potential for multi-use facilities such as trails or parks	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ May require slope protection if velocities are erosive
Channel Improvements (inflow points and erosion protection)	▪ Requires least amount of improvements ▪ Requires least amount of additional maintenance	▪ Does not reduce peak discharge ▪ Does not provide protection to property south of Cloud Road Channel

6.6.4 Development Considerations

Development considerations for this mitigation concept include the following:



- An intergovernmental agreement (IGA) will be required between the District and the Town of Queen Creek to design, construct, operate and maintain any structures (detention/retention basins or channels).
- Once a design concept has been selected, a preliminary design should be conducted in order to identify/procure right-of-way and preserve the design corridor from further development.
- Detention/retention basins or channel improvements could be compatible with future multi-use opportunities such as pedestrian/equestrian trails or parks.
- Channel improvements may require bridge/culvert improvements as well as delineation of erosion hazard setbacks.

6.6.5 Responsible Party

It is likely that the structures would be located within the jurisdiction of Maricopa County and the Town of Queen Creek. An IGA will be required to outline the right-of-way, design, construction, operation and maintenance responsibilities related to a potential project. The IGA for this mitigation concept would likely be similar to the IGA for the Cloud Road Basin project.

6.6.6 Prioritization

Mitigation of the hazards within this area is considered a medium level priority due to the medium level of risk determined in the flood hazard assessment. It is anticipated that the implementation of the solution will be in the medium range of 3 to 5 years. It is recommended that agency coordination, public awareness and conceptual design begin as soon as possible in order to preserve right-of-way as necessary.

6.6.7 Funding mechanisms

Depending on the extent of a potential project, the project may need to be included as part of the District's Capital Improvement Plan. If a project is limited only to improvements to the Cloud Road Channel, it could be covered by the District's Small Project Assistance Program. The areas that benefit from this mitigation concept include Maricopa County and the Town of Queen Creek.

6.7 POTENTIAL MITIGATION AREA #7: POWER ROAD CHANNEL

6.7.1 Description

Power Road is impacted by a significant amount of offsite runoff within the study area. A shallow, unimproved channel is adjacent to portions of the road; however, much of the road does not have major drainage conveyances. During small to moderate storm events, runoff from sheet flows and pavement drainage from east-west streets collects along Power Road. This causes moderate flooding along much of the road and the intersection with Riggs Road.

6.7.2 Hazards

During small to moderate storm events, Power Road is adversely affected by sheet flooding, ponding, sedimentation and erosion, and damaged or impassable roads. These hazards also impact the intersection with Riggs Road. It appears that the existing channel may be undersized for the 100-year storm.

6.7.3 Mitigation Implementation/Action plan

The two main strategies to mitigate the hazards impacting this area are detention/retention and channels. A linear detention/retention basin could be constructed along Power Road to detain/retain offsite flows. An alternative to a basin is improving the existing channel along Power Road and extending the improvements as far south as Hunt Highway.

Table 15. PMA #7: Power Road Channel – Mitigation Strategies

Strategy	Advantages	Disadvantages
Detention/Retention	▪ Reduces peak discharge to downstream areas ▪ Potential for multi-use facilities such as trails or parks	▪ May require drywells ▪ Requires maintenance
Channels	▪ May require less right of way than detention/retention ▪ Potential for multi-use facilities such as trails or parks	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ May require slope protection if velocities are erosive

6.7.4 Development Considerations

Development considerations for this mitigation concept include the following:

- An intergovernmental agreement (IGA) will be required between the District and the Town of Queen Creek to design, construct, operate and maintain any structures (detention/retention basins or channels).
- Once a design concept has been selected, a preliminary design should be conducted in order to identify/procure right-of-way and preserve the design corridor from further development.

- Detention/retention basins or channel improvements could be compatible with future multi-use opportunities such as pedestrian/equestrian trails or parks.
- Channel improvements may require bridge/culvert improvements as well as delineation of erosion hazard setbacks.

6.7.5 Responsible Party

It is likely that the structures would be located within the jurisdiction of Maricopa County and the Town of Queen Creek. An IGA will be required to outline the right-of-way, design, construction, operation and maintenance responsibilities related to a potential project. The IGA for this mitigation concept would likely be similar to the current IGA for the Cloud Road Basin.

6.7.6 Prioritization

Mitigation of the hazards within this area is considered a medium level priority due to the medium level of risk determined in the flood hazard assessment. It is anticipated that the implementation of the solution will be in the medium range of 3 to 5 years. It is recommended that agency coordination, public awareness and conceptual design begin as soon as possible in order to preserve right-of-way as necessary.

6.7.7 Funding mechanisms

Depending on the extent of a potential project, the project may need to be included as part of the District's Capital Improvement Plan. If a project is limited only to minor improvements to the Power Road Channel, it could be covered by the District's Small Project Assistance Program. The areas that benefit from this mitigation concept include Maricopa County and the Town of Queen Creek.

6.8 POTENTIAL MITIGATION AREA #8: SAN TAN BOULEVARD WEST OF HIGLEY ROAD

6.8.1 Description

A residential property along San Tan Boulevard west of Higley Road is impacted by channelized offsite flows. Stormwater runoff from Payne Junior High School at the southeast corner of the intersection of Higley Road and San Tan Boulevard is collected and conveyed to the northwest corner of the intersection. The runoff continues west in a channel north of San Tan Boulevard and discharges directly onto the residential property.

6.8.2 Hazards

During small to moderate storm events, the residential property is adversely affected by channelized offsite flows that discharge onto the property. Hazards include localized flooding as well as sedimentation and erosion.

6.8.3 Mitigation Implementation/Action plan

The three main strategies to mitigate the hazards impacting this area are detention/retention, channels and storm drains. The existing basin at the southeast corner of Higley Road and San Tan Boulevard (at the Payne Junior High School site) could be expanded to provide enough volume to mitigate the adverse impacts on the residential property. Construction of either a channel or storm drain system would require an outfall to either the Chandler Heights Road Channel or the EMF.

Table 16. PMA #8: San Tan Boulevard West of Higley Road – Mitigation Strategies

Strategy	Advantages	Disadvantages
Detention/Retention	▪ Could be limited to expansion of basin at Payne Junior High School ▪ Reduces peak discharge to downstream areas ▪ No *signific*ant increase in maintenance at school basin	▪ Requires significant coordination with school ▪ May require drywells ▪ Could have some impact on multi-use facilities at school
Channels	▪ Potential for multi-use facilities such as trails or linear parks	▪ Requires additional right-of-way ▪ Requires additional maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ May require slope protection if velocities are erosive
Storm Drains	▪ May require least amount of right of way ▪ Provides an outfall without additional bridge or culvert crossings	▪ Requires maintenance ▪ Does not reduce peak discharge unless accompanied with detention/retention ▪ Could be costly if designed for large storm event

6.8.4 Development Considerations

Development considerations for this mitigation concept include the following:

- An intergovernmental agreement (IGA) will be required between the District, the Town of Gilbert and the Chandler Unified School District to design, construct, operate and maintain any structures (detention/retention basins, channels or storm drains).
- Once a design concept has been selected, a preliminary design should be conducted in order to identify/procure right-of-way and preserve the design corridor from further development.
- An expansion of the existing basin at the Payne Junior High School may be the least expensive option but would also require significant coordination with the Chandler Unified School District.
- Channel improvements could be compatible with future multi-use opportunities such as pedestrian/equestrian trails or parks.
- Channel improvements may require bridge/culvert improvements as well as delineation of erosion hazard setbacks.
- Storm drains could require the least right-of-way, but could be costly if designed for a large storm event

6.8.5 Responsible Party

It is likely that the structures would be located within the jurisdiction of Maricopa County and the Town of Gilbert. An IGA will be required to outline the right-of-way, design, construction, operation and maintenance responsibilities related to a potential project. The Chandler Unified School District may also be included in the IGA if a proposed solution impacts the existing basin at Payne Junior High School.

6.8.6 Prioritization

Mitigation of the hazards within this area is considered a medium level priority due to the medium level of risk determined in the flood hazard assessment. It is anticipated that the implementation of the solution will be in the medium range of 3 to 5 years. It is recommended that agency coordination, public awareness and conceptual design begin as soon as possible in order to preserve right-of-way as necessary.

6.8.7 Funding mechanisms

Depending on the extent of the potential mitigation project, the project may need to be included as part of the District's Capital Improvement Plan. If a project is limited only to minor improvements to Payne Junior High School basin, it could be covered by the District's Small Project Assistance Program. The areas that benefit from this mitigation concept include Maricopa County and the Town of Gilbert.

7. SUMMARY AND RECOMMENDATIONS

7.1 SUMMARY

The goals of the San Tan West ADMS are:

(1) to identify and quantify flooding and other hazards within the study area, and

(2) to establish guidance for future development that protects public safety and considers the unique natural and physical characteristics of the San Tan West watershed.

The identification and quantification of flooding and hazards goal was accomplished cumulatively by several methods. Existing data and information relevant to the drainage problems and issues and physical characteristics within the study watershed and data pertaining to the existing and future planning and land uses was collected from various sources. These sources included the Flood Control District of Maricopa county, project stakeholders (Pinal County, Towns of Queen Creek and Gilbert, Gila River Indian Community and irrigation districts), from public input obtained at a public meeting, and from extensive field reconnaissance by the Kimley-Horn team. Data collected included drainage complaints on file with the noted agencies, existing drainage infrastructure, existing and future land use plans, data required for hydrologic and hydraulic modeling, and geomorphic data used for flood hazard risk assessments.

New hydrology and hydraulic models were prepared for the 10-year and 100-year 6-hour storm events for existing land use conditions. The two–dimensional model, FLO-2D, was used to characterize the rainfall-runoff response of the watershed. Two models were prepared based on a distinct geomorphic land type and characteristic changes. The first model is the Mountainous Model which models the drainage south of Hunt Highway typically associated with the San Tan Mountains. The drainage is typically associated with stream channels originating from the mountains and piedmont surfaces of shallow distributary flow patterns. The hydrology and hydraulic models provided peak discharges, flow drainage patterns, depth of flow and flow velocities for the project study area. The second model is the Urban Model which modeled the drainage patterns and characteristics for the watershed north of Hunt Highway. This urban area consists of developed subdivisions to individual residential lots. The drainage is typically shallow sheet flow with ponded areas.

A geomorphic analysis of the study watershed identified areas that are prone to sediment production, transport, and sediment deposition (erosion hazards). The analysis distinguished land surfaces that are more stable from land surfaces that are less stable from an erosion perspective.

The second goal, providing guidance on future development within the study area, was also accomplished using a cumulative approach. The first step was to prepare the flood hazard risk assessment that identifies areas or zones within the watershed that are more prone to flooding hazards (high hazard flooding and erosion) compared to areas that are less prone (low hazard areas). The high hazard zones and associated flood intensities together resulted in eight areas that were identified for potential drainage improvements to mitigate, reduce or eliminate the flood hazard risks within those areas.

Development consideration guidelines were identified to implement as future development occurs within the watershed. The area of focus for future development for the application of the guidelines is the ADMS area

north of Hunt Highway. The guidelines are based on existing drainage policies and guidelines, ordinances, and drainage standards. Development considerations were based on the approach of No-Adverse Impact (NAI) and recommendations identified for non-structural measures, drainage corridors, erosion hazard setbacks, use of levees, future roadway crossings, impacts of walls, fences and berms, detention/retention, and minimum floor elevations.

Finally, from the results of the ADMS investigations, studies, and analyses, eight high hazard flood risk zones were identified as potential mitigation areas. The ADMS provides potential drainage improvement approaches to each of the zones, describes the flooding hazards within each zone, identifies potential funding partners to implement the drainage improvements, and sets a priority recommendation of which zone(s) should be mitigated first and provides an explanation and reasoning.

7.2 RECOMMENDATIONS

A total of eight Potential Mitigation Areas were presented to the Major Stakeholders and at a Public Meeting in October 2013. PMA #1: Farmers' Dike Replacement determined to have a high beneficial impact and there was a significant level of interest by all the stakeholders. Additional analysis of the concept was undertaken for the District. A potential channel alignment was explored and the District is reaching out to the Major Stakeholders to request support for a project in the area. It is recommended that the District move forward with a Design Concept Report for a channel replacement of the Farmers' Dike, as this project has substantial and far-reaching benefits to the downstream communities.

Mitigation alternatives for the other seven PMAs should be explored further, possibly in an Area Drainage Master Plan. There are benefits associated with each PMA, and the residents of the watershed continue to be impacted by storm runoff.

This ADMS report has several exhibits in **Appendix A** and **Appendix F** that can be quickly referenced by the local jurisdictions. The flow depth, velocity and flood hazard maps are excellent planning tools, but are not intended to be used for detailed design. The Development Considerations outlined in **Section 5** should be considered for adoption into local guidelines for development and stormwater management.

The FLO-2D models prepared for this project have very large files that are very detailed. The major stakeholders have indicated that at this time they do not have capacity to keep the models updated with new development. It is recommended that the District consider development of a program to update the models for the local jurisdictions at regular time intervals (every few years) to extend the useful life of these models and maximize their return on investment.

The present need for flood mitigation projects is evident by the findings in this report. The lack of comprehensive development guidelines, and adherence to existing development guidelines can be related to the existing consequences to public safety, resident well-being, watershed management and sustainability. The San Tan West ADMS can be used by local area jurisdictions, agencies, and land developers to assure implementation of safe development practices considering the flood hazards and characteristics of the study watershed. The San Tan West ADMS will be used long into the future and should be updated as required and necessary as future development occurs and new drainage facilities are constructed within the watershed.

8. REFERENCES

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Appendix A. Figures

Figures 1-10 and 11-14 are provided digitally in Appendix E.

Figure 11. Depth of Flow (100-Year, 6-Hour Storm)

Figure 15. Flood Hazard Risk

Figure 16. Peak Discharge (100-Year, 6-Hour Storm)

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Ocotillo Rd
Lindsay Rd
Val Vista Dr
Greenfield Rd
Higley Rd
Power Rd
Ellsworth Rd
Rittenhouse Rd
Chandler Heights Rd
Riggs Rd
Cloud Rd
Hunt Hwy
Hunt Hwy

Legend

San Tan West ADMS Study Boundary

Maximum Depth

Depth, ft

- 0.04 - 0.1
- 0.11 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 15
- 15 - 24

N
W
E
S

0 5001,000 2,000 3,000 4,000
Feet

Kimley-Horn and Associates, Inc.
2013 KIMLEY-HORN AND ASSOCIATES, INC.
Engineering, Planning and Environmental Consultants
7740 North 16th Street, Suite 300
Phoenix, Arizona 85020 (602) 944-5500

SCALE(H):1"=	2000'
SCALE(V):	N/A
DESIGNED BY:	RAE
DRAWN BY:	JAG
CHECKED BY:	LSM
DATE:	SEPT. 2013

SAN TAN WEST
AREA DRAINAGE MASTER STUDY
FIGURE 11. DEPTH OF FLOW
(100-YEAR, 6-HOUR STORM)

PROJECT NO.
091131022

FCD CONTRACT
2012C011

Ocotillo Rd
Val Vista Dr
Greenfield Rd
Higley Rd
Power Rd
Sossaman Rd
Hawes Rd
Ellsworth Rd
Rittenhouse Rd
Chandler Heights Rd
Cloud Rd
Riggs Rd
Hunt Hwy
Thompson Rd
See Inset A
See Inset B

Inset A
(1" = 600')

Inset B
(1" = 600')

HEC-1 AREA
FLOOD HAZARD
NOT DEFINED

Legend

- Project Boundary
- HEC-1 Watershed
- Fissure

Hazard Zones

Hazard Risk Zone	Description
Low	Buildings and infrastructure may suffer little damage, but flooding or sedimentation may affect structure interiors. Shallow sheet flooding predominates.
Intermediate	Buildings and infrastructure may suffer damage and possible destruction depending on construction characteristics. Distributary/Tributary flooding predominates.
High	Buildings and infrastructure are in danger of being severely damaged and/or destroyed. Channel/natural incised wash flooding predominates.

Future Land Use

- Institutional/Regional Commercial
- Low Density Commercial/Neighborhood Commercial
- Open Space
- Rural Residential
- Small Lot Residential

Flood Intensity

Flood Intensity	Maximum Depth, h [ft]		Product of maximum velocity, v and maximum depth, h [ft²/s]	Description
Low	0.5 < h < 1.5	AND	0.5 < vh < 1.5	Shallow sheet flow; drainage improvements present; localized ponding and flooding; flow depths 1.5 foot or less; disturbed/graded landform; gentle slopes; minor drainage issues.
Medium	1.5 < h < 4	OR	1.5 < vh < 4	Piedmont Areas with Tributary drainage system; minor drainage improvements present; depths of flow range from 1.5 foot to 5 feet; flow velocities range from 2 to 4 feet per second.
High	h > 4	OR	vh > 4	Piedmont Areas with Distributary drainage system; Major rivers/tributaries; no to minor drainage improvements present; flow velocities greater than 4 feet per second; steep slopes; areas along/upstream Farmers' dike.

SAN TAN WEST
AREA DRAINAGE MASTER STUDY

Figure 15. Flood Hazard Risk

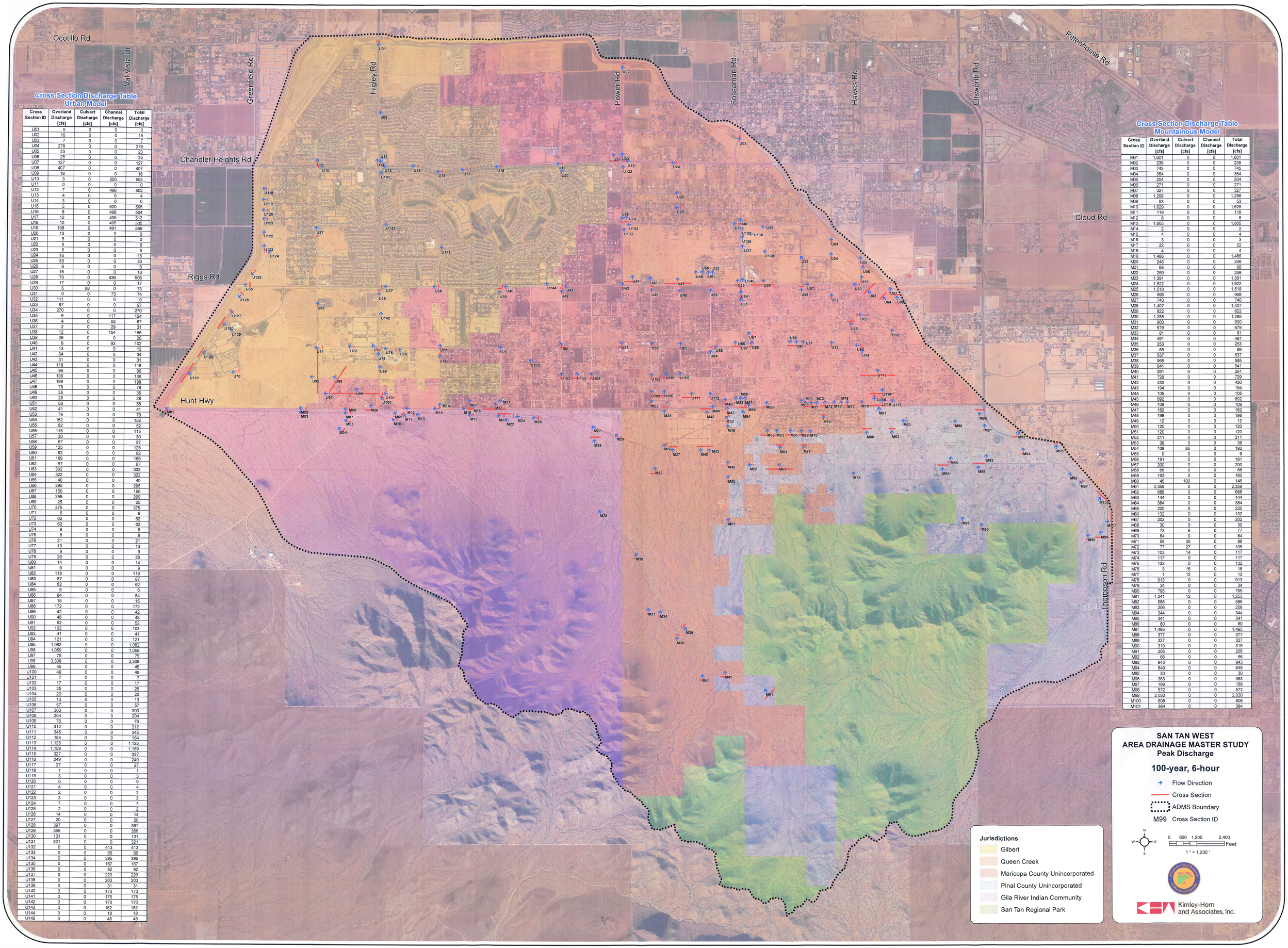
N
W E
S

0 600 1,200 2,400 Feet

1 " = 1,200 '

Flood Control District of Maricopa County

Kimley-Horn and Associates, Inc.



Cross Section Discharge Table Urban Model

Cross Section ID	Overland Discharge [cfs]	Culvert Discharge [cfs]	Channel Discharge [cfs]	Total Discharge [cfs]
U01	0	0	0	0
U02	16	0	0	16
U03	7	0	0	7
U04	278	0	0	278
U05	23	0	0	23
U06	25	0	0	25
U07	127	0	0	127
U08	407	0	0	407
U09	18	0	0	18
U10	3	0	550	553
U11	0	0	0	0
U12	7	0	496	503
U13	4	0	0	4
U14	3	0	0	3
U15	5	0	500	505
U16	8	0	496	504
U17	12	0	499	512
U18	10	0	495	505
U19	108	0	491	599
U20	13	0	0	0
U21	5	0	0	0
U22	6	0	0	6
U23	5	0	0	5
U24	16	0	0	16
U25	33	0	0	33
U26	6	0	0	6
U27	16	0	0	16
U28	70	0	436	506
U29	17	0	0	17
U30	5	68	0	73
U31	0	0	73	74
U32	111	0	0	0
U33	97	0	0	97
U34	270	0	0	270
U35	6	0	117	124
U36	4	0	63	67
U37	2	0	29	31
U38	12	0	154	166
U39	26	0	0	26
U40	9	0	93	102
U41	13	0	0	13
U42	34	0	0	34
U43	31	0	0	31
U44	118	0	0	118
U45	96	0	0	96
U46	136	0	0	136
U47	198	0	0	198
U48	78	0	0	78
U49	35	0	0	35
U50	28	0	0	28
U51	58	0	0	58
U52	41	0	0	41
U53	78	0	0	78
U54	152	0	0	152
U55	52	0	0	52
U56	115	0	0	115
U57	30	0	0	30
U58	57	0	0	57
U59	125	0	0	125
U60	62	0	0	62
U61	169	0	0	169
U62	67	0	0	67
U63	332	0	0	332
U64	322	0	0	322
U65	40	0	0	40
U66	295	0	0	295
U67	150	0	0	150
U68	299	0	0	299
U69	25	0	0	25
U70	375	0	0	375
U71	6	0	0	6
U72	62	0	0	62
U73	62	0	0	62
U74	8	0	0	8
U75	8	0	0	8
U76	21	0	0	21
U77	10	0	0	10
U78	9	0	0	9
U79	26	0	0	26
U80	14	0	0	14
U81	9	0	0	9
U82	119	0	0	119
U83	87	0	0	87
U84	62	0	0	62
U85	6	0	0	6
U86	84	0	0	84
U87	15	0	0	15
U88	172	0	0	172
U89	42	0	0	42
U90	48	0	0	48
U91	52	0	0	52
U92	103	0	0	103
U93	41	0	0	41
U94	121	0	0	121
U95	1,082	0	0	1,082
U96	1,059	0	0	1,059
U97	75	0	0	75
U98	3,308	0	0	3,308
U99	45	0	0	45
U100	49	0	0	49
U101	7	0	0	7
U102	17	0	0	17
U103	25	0	0	25
U104	20	0	0	20
U105	13	0	0	13
U106	57	0	0	57
U107	303	0	0	303
U108	204	0	0	204
U109	76	0	0	76
U110	312	0	0	312
U111	345	0	0	345
U112	154	0	0	154
U113	1,125	0	0	1,125
U114	1,159	0	0	1,159
U115	327	0	0	327
U116	249	0	0	249
U117	27	0	0	27
U118	1	0	0	1
U119	3	0	0	3
U120	0	0	0	0
U121	4	0	0	4
U122	2	0	0	2
U123	3	0	0	3
U124	7	0	0	7
U125	2	0	0	2
U126	14	0	0	14
U127	20	0	0	20
U128	397	0	0	397
U129	356	0	0	356
U130	131	0	0	131
U131	321	0	0	321
U132	0	0	413	413
U133	0	0	66	66
U134	0	0	395	395
U135	0	0	167	167
U136	0	0	92	92
U137	0	0	220	220
U138	0	0	203	203
U139	0	0	31	31
U140	0	0	173	173
U141	0	0	175	175
U142	0	0	170	170
U143	0	0	162	162
U144	0	0	18	18
U145	0	0	45	45

Cross Section Discharge Table Mountainous Model

Cross Section ID	Overland Discharge [cfs]	Culvert Discharge [cfs]	Channel Discharge [cfs]	Total Discharge [cfs]
M01	1,601	0	0	1,601
M02	239	0	0	239
M03	745	0	0	745
M04	354	0	0	354
M05	204	0	0	204
M06	271	0	0	271
M07	327	0	0	327
M08	1,298	0	0	1,298
M09	53	0	0	53
M10	1,629	0	0	1,629
M11	119	0	0	119
M12	8	0	0	8
M13	1,805	0	0	1,805
M14	2	0	0	2
M15	4	0	0	4
M16	3	0	0	3
M17	22	0	0	22
M18	4	0	0	4
M19	1,486	0	0	1,486
M20	246	0	0	246
M21	68	0	0	68
M22	259	0	0	259
M23	1,391	0	0	1,391
M24	1,622	0	0	1,622
M25	1,518	0	0	1,518
M26	998	0	0	998
M27	740	0	0	740
M28	1,407	0	0	1,407
M29	622	0	0	622
M30	1,285	0	0	1,285
M31	900	0	0	900
M32	679	0	0	679
M33	81	0	0	81
M34	491	0	0	491
M35	253	0	0	253
M36	69	0	0	69
M37	537	0	0	537
M38	565	0	0	565
M39	641	0	0	641
M40	261	0	0	261
M41	729	0	0	729
M42	430	0	0	430
M43	194	0	0	194
M44	105	0	0	105
M45	892	0	0	892
M46	109	0	0	109
M47	182	0	0	182
M48	198	0	0	198
M49	12	0	0	12
M50	120	0	0	120
M51	120	0	0	120
M52	211	0	0	211
M53	39	0	0	39
M54	108	85	0	193
M55	9	0	0	9
M56	191	0	0	191
M57	200	0	0	200
M58	66	0	0	66
M59	163	0	0	163
M60	46	100	0	146
M61	2,359	0	0	2,359
M62	688	0	0	688
M63	144	0	0	144
M64	384	0	0	384
M65	220	0	0	220
M66	132	0	0	132
M67	202	0	0	202
M68	30	0	0	30
M69	72	6	0	77
M70	84	0	0	84
M71	58	30	0	88
M72	77	27	0	105
M73	103	14	0	117
M74	117	0	0	117
M75	132	0	0	132
M76	3	16	0	18
M77	1	12	0	13
M78	913	0	0	913
M79	34	0	0	34
M80	795	0	0	795
M81	1,241	12	0	1,253
M82	586	0	0	586
M83	206	0	0	206
M84	344	0	0	344
M85	341	0	0	341
M86	80	0	0	80
M87	1,495	0	0	1,495
M88	377	0	0	377
M89	327	0	0	327
M90	319	0	0	319
M91	205	0	0	205
M92	66	0	0	66
M93	943	0	0	943
M94	849	0	0	849
M95	30	0	0	30
M96	363	0	0	363
M97	169	0	0	169
M98	572	0	0	572
M99	2,030	0	0	2,030
M100	808	0	0	808
M101	384	0	0	384

Appendix B. Drainage Issues

Historical Flooding (HF) Issues

The flooding issues summarized in this document have been identified from historical documents such as newspaper articles and photos that were obtained from the FCDMC library. The flooding issue locations can also be found on the Drainage Issues Map. The "Pages" category refers to the pages of the document where the historical information is located. The "Severity" category is a qualitative scale of the damage as a result of the storm event.

ID	Type (Article, Photos)	Collected From	Article/Photo Description	Location	Date of Document	Pages	Type[1]	Severity[2]	Related Issues[3]
HF-1	Photos	FCDMC, 007.105.1	Flooding Events- Photos #805-811 of earth crack north of Hunt Highway.	North of Hunt Highway, 1/8 Mile east of Sossaman Road	1967-01-26	63, 67, 68	Fissures/Land Subsidence	High	JI-7, JI-8, JI-10, KHA-9
HF-2	Article, Photos	FCDMC, 007.128	Chandler Heights Fissure Widens- Photo.	One mile east of Chandler Heights near Hunt Highway	1964-07-15, 1964-08-12	56	Fissures/Land Subsidence	High	None
HF-3	Photos	FCDMC, 007.132	Related Photos: EMF at Various Stations, Queen Creek Basin- EMF Reach III at Discharge Area from Retention Basin (Close to Last Page).	Queen Creek Basin at EMF	1993-01-20, 1993-01-26	168-174	Sedimentation/Erosion	Medium	None
HF-4	Photos	FCDMC, 007.168	Related Photos: Power Road/ Central AZ Farm towaRoads Chandler Heights Road Flood Damage.	Power Road to Chandler heights Road	1964-08-12, 1971-10-04	9,10	Sedimentation/Erosion	Low	None
HF-5	Article, Photos	FCDMC, 007.196	Related Photos: EMF, EMF east of Higley Road Bridge, EMF at Hunt Highway Field Observation Record.	EMF at Higley Road, EMF at Queen Creek & Hunt Highway and Chandler Heights	1993	10, 11, 60	Sedimentation/Erosion	Low	None
HF-6	Article, Photos	FCDMC, 007.198	Related Stories: Newspaper Photos of Ellsworth and Cloud Road, Flood at Queen Creek Cotton Gin, Queen Creek and Chandler Heights Road photos (#130), History of Phoenix Floods: Queen Creek 1939 (#207).	Ellsworth Road and Cloud Road, Queen Creek Road and Chandler Heights Road	1972-1991		Sheet Flow Flooding		None
HF-7	Article, Photos	Town of Queen Creek, CAP Irrigation leak Riggs w of Hawes.JPG	CAP Irrigation Leak.	Riggs Road, west of Hawes Road	Not Dated	1	Ponding	Low	JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28

1- Types based on various categories defined in the Flood Hazard Risk Assessment of the Area Drainage Master Study (ADMS).

2 - Levels of severity are a qualitative estimation from photos, related documents and discussions with agency employees. **Low** - Small amounts of flooding identified, minor damage to infrastructure. **Medium** - Evidence of moderate flooding, signs of reasonable amount of erosion, evidence of moderate earth fissure . **High** - Significant fissure cracking and widening, major arterial or area affected by issue, substantial amount of flooding, consistent reoccurence of issue during storm events.

3 - Issues that are related to or located near another identified issue.

Historical Flooding (HF) Issues

The flooding issues summarized in this document have been identified from historical documents such as newspaper articles and photos that were obtained from the FCDMC library. The flooding issue locations can also be found on the Drainage Issues Map. The "Pages" category refers to the pages of the document where the historical information is located. The "Severity" category is a qualitative scale of the damage as a result of the storm event.

ID	Type (Article, Photos)	Collected From	Article/Photo Description	Location	Date of Document	Pages	Type[1]	Severity[2]	Related Issues[3]
HF-8	Article, Photos	AZGS	Chandler Heights Fissure Reopened and Swallowed Horse.	Happy Road and 195th Street	2007-07-24	1-3	Fissures/Land Subsidence	High	None
HF-9	Photos	FCDMC, 007.105.2	Flooding Events- Photos #125-135 of Queen Creek Area.	Queen Creek area	1968-07-08	73-83	Sheet Flow Flooding	Medium	None
HF-10	Article	FCDMC, 007.115	Flood Aid and Damages, Related Story: #19 Queen Creek Area, Sossaman Cotton Farm, Chandler Heights Area affected by flooding.	Queen Creek area, Chandler Heights mentioned	1964-10-03	28	Sheet Flow Flooding	High	None
HF-11	Article	FCDMC, 007.118	Related stories: #170 "Rivers Flood Countryside"- 50 San Tan Families Evacuated to Sacaton Due to Flooding.	San Tan	1965-12-24	113	Ponding	High	None
HF-12	Article	FCDMC, 007.170	Related Stories: Gila River Indian Community Mentioned- January Flood Flows Released from Coolidge Dam Flood Reservation Communities Including SanTan (pg. 98).	San Tan	1993-02-07	98	Sheet Flow Flooding	High	None
HF-13	Article	FCDMC, 802.062	Related Flood: Queen Creek and Vicinity- Chandler Heights Irrigation District Mentioned [From AZGS].	Queen Creek vicinity	1954-09-24	7	Sheet Flow Flooding	High	None

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3 - Issues that are related to or located near another identified issue.

Jurisdiction Identified (JI) Issues

The flooding issues summarized in this document have been identified from meetings with the various jurisdictions located within the watershed. The project team met with the respective public works and street maintenance departments. The meetings included discussing areas where flooding occurs frequently and requires maintenance. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Jurisdiction	Description	Location	Type[1]	Severity[2]	Storm Frequency[3]	Related Issues[4]
JI-1	Queen Creek	Bell Road acts as a wash during most storm events.	Bell Road, south of Hunt Highway	Roads Damaged/Impassable	High	High	JI-9, KHA-10, KHA-11, KHA-12
JI-2	Queen Creek	Mandarin Road acts as channel during most storm events.	Mandarin Road, north of Hunt Highway	Roads Damaged/Impassable	High	High	None
JI-3	Queen Creek	Lemon Lane acts as a channel during most storm events.	Lemon Avenue, south of Hunt Highway	Roads Damaged/Impassable	Medium	High	None
JI-4	Queen Creek	196th Street acts as a channel during most storm events.	196th Street, north of Hunt Highway	Roads Damaged/Impassable	Medium	High	None
JI-5	Queen Creek	South of Hunt Highway, a majority of the east and west local roads consistently have issues during storm events.	East/West local roads south of Hunt Highway	Roads Damaged/Impassable	Medium	High	JI-31
JI-6	Queen Creek	Skyline Drive area south of Hunt Highway can contain up to 6"-8" of debris during storm events. Several washes running south to north are passing the debris onto the roads. Some roads have concrete crossings for protection.	Skyline Drive, from Bell Road to Wagon Wheel Road	Debris Flow	High	Low	None
JI-7	Queen Creek	Residential walls built along the north side of Hunt Highway are preventing runoff from being conveyed in the washes. There is a considerable amount of effort given towards removing the debris from the headwalls as a result of the runoff being blocked.	Hunt Highway, from Wild Horse Drive to Sossaman Road	Debris Flow	Medium	Low	HS-1, JI-8, JI-10, KHA-9
JI-8	Queen Creek	Channel located behind development on south side of Hunt Highway between Bell Road and Power Road intercepts offsite flows and conveys around property to Hunt Highway. Residents on north side of Hunt Highway affected by sediment and increased runoff. The residential fences that have been constructed do not hold up during larger storms.	Hunt Highway, Bell Road to Power Road	Sedimentaion/Erosion	Medium	High	HS-1, JI-7, JI-10, KHA-9
JI-9	Queen Creek	Portions of the embankment along Bell Road near Hunt Highway, is eroded away, exposing the existing water lines.	Bell Road from Skyline Drive to Hunt Highway	Sedimentaion/Erosion	High	Low	JI-1, KHA-10, KHA-11, KHA-12
JI-10	Queen Creek	Southern side of Hunt Highway is flooded during normal storms.	Approximately 1,500 feet east of the intersection of Power Road and Hunt Highway	Roads Damaged/Impassable	Medium	High	HS-1, JI-7, JI-8, KHA-9

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3 - Identifies issues that occur during high frequency (small) or low frequency (large) storm events.

4 - Issues that are related to or located near another identified issue.

Jurisdiction Identified (JI) Issues

The flooding issues summarized in this document have been identified from meetings with the various jurisdictions located within the watershed. The project team met with the respective public works and street maintenance departments. The meetings included discussing areas where flooding occurs frequently and requires maintenance. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Jurisdiction	Description	Location	Type[1]	Severity[2]	Storm Frequency[3]	Related Issues[4]
JI-11	Queen Creek	Several scuppers have been damaged from previous storm events. The scupper structure is intact but the soil around the scupper has been completely eroded away.	Riggs Road near the 196th Street intersection	Sedimentaion/Erosion	High	High	HS-7, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
JI-12	Queen Creek	Ponding occurs at the intersection of Hawes Road and Riggs Road.	Hawes Road and Riggs Road	Ponding	Medium	Low	HS-7, JI-11, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
JI-13	Queen Creek	The existing Cloud Road basin outfall splitter structure at the sec of Sossaman Road and Cloud Road is not performing as intended. The trash rack clogs and blocks the Sossaman storm drain outlet to Sonoqui Wash. More runoff than designed for, discharges west to the Cloud Road channel.	Sossaman Road and Cloud Road	Facility Underperformance	High	High	None
JI-14	Queen Creek	Vacant land south of Cloud Road contains a large amount of sheet flow that is impacting the Cloud Road channel.	Cloud Road, from Sossaman Road to 188th Street	Sheet Flow Flooding	Medium	High	None
JI-15	Queen Creek	Intersection ponding.	188th Street and Via De Palmas	Ponding	Medium	High	JI-16
JI-16	Queen Creek	Intersection ponding.	188th Street and Via De Arboles	Ponding	Medium	High	JI-15
JI-17	Queen Creek	Intersection of Sonoqui Wash and Sossaman Road contains culverts that are often clogged, resulting in overtopping and erosion. This location is a consistent problem for the Public Works department.	Sonoqui Wash and Sossaman Road	Sedimentaion/Erosion	High	High	JI-18, JI-19
JI-18	Queen Creek	Sonoqui Wash dip crossing at Via Del Jardin is one of the first areas to close during storm events.	Via Del Jardin and Sonoqui Wash	Roads Damaged/Impassable	High	High	JI-17, JI-19

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4 - Issues that are related to or located near another identified issue.

Jurisdiction Identified (JI) Issues

The flooding issues summarized in this document have been identified from meetings with the various jurisdictions located within the watershed. The project team met with the respective public works and street maintenance departments. The meetings included discussing areas where flooding occurs frequently and requires maintenance. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Jurisdiction	Description	Location	Type[1]	Severity[2]	Storm Frequency[3]	Related Issues[4]
JI-19	Queen Creek	Intersection of Sonoqui Wash and Power Road contains culverts that are often clogged and resulting in overtopping and erosion. This location is a consistent problem for the Public Works department.	Sonoqui Wash and Power Road	Facility Underperformance	High	High	JI-17, JI-18
JI-20	Gilbert	General Flooding area near the intersection of Coldwater Boulevard and Higley Road. Some problems may be mitigated with Monte Verde subdivision and other future improvements being planned at the intersection.	Coldwater Boulevard and Higley Road	Ponding	Low	High	JI-23
JI-21	Gilbert	General flooding area at the Higley Road and Hunt Highway curve. The town has a CIP project planned to help mitigate the issue.	Higley Road and Hunt Highway	Ponding	Medium	High	KHA-6, KHA-7
JI-22	Gilbert	Existing Chandler Heights channel has an adverse slope at the corner of the intersection. This results in standing water in the channel section west of Higley Road.	Higley Road and Chandler Heights Boulevard	Ponding	Low	High	None
JI-23	Gilbert	Residential homes at northeast corner of 165th Place and Coldwater Boulevard consistently flooded from the Higley Road and San Tan Boulevard intersection.	165th Place and Coldwater Boulevard	Flow Diversions	Low	High	JI-20
JI-24	Gilbert	Residential walls have been knocked down during previous storm events.	Indian Wells Drive and 174th Street	Sheet Flow Flooding	High	Low	None
JI-25	Gilbert	General flooding.	164th Street and Cloud Road	Ponding	Medium	High	None
JI-26	Gilbert	Intersection ponding.	Recker Road and Happy Road	Ponding	Medium	High	None
JI-27	FCDMC	Runoff from the San Tan Mountains (GRIC) flooding residential property. Recurring issue that does not affect adjacent properties. Due to breach in "dike" located on south side of Hunt Highway in previous storm events.	Residential property along Stacey Road between Valencia Avenue and Lemon Avenue	Dike Breach	High	Low	None
JI-28	Pinal County	Residents state backyard floods during storm events.	Corner of Creekside Lane along Hunt Highway	Sheet Flow Flooding	Low	High	JI-29

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3 - Identifies issues that occur during high frequency (small) or low frequency (large) storm events.

4 - Issues that are related to or located near another identified issue.

Jurisdiction Identified (JI) Issues

The flooding issues summarized in this document have been identified from meetings with the various jurisdictions located within the watershed. The project team met with the respective public works and street maintenance departments. The meetings included discussing areas where flooding occurs frequently and requires maintenance. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Jurisdiction	Description	Location	Type[1]	Severity[2]	Storm Frequency[3]	Related Issues[4]
JI-29	Pinal County	Significant erosion has caused utilities in area to be installed/designed at deeper locations.	Approximately 2,300 feet southeast of the intersection of Ellsworth Road and Hunt Highway	Sedimentaion/Erosion	High	High	JI-28
JI-30	Pinal County	Significant amount of sediment deposited at intersection. Existing ditch south of intersection filled with sediment and had to be rebuilt.	Empire Boulevard and Wild Horse Drive	Sedimentaion/Erosion	Medium	High	None
JI-31	Pinal County	Large amount of sediment runoff occurs along Wagon Wheel Road during larger storm events. Issue requires maintenance 2-3 times a year.	South of the intersection of Wagon Wheel Road and Sundance Drive	Sedimentaion/Erosion	Medium	High	None
JI-32	Pinal County	Private driveway has washed out in previous storm events.	Sundance Drive and Ellsworth Road	Roads Damaged/Impassable	Medium	High	JI-33
JI-33	Pinal County	Significant amount of sediment deposited at intersection. Existing ditch south of intersection filled with sediment and had to be rebuilt.	Ellsworth Road and Hunt Highway	Sedimentaion/Erosion	Medium	High	JI-32
JI-34	Pinal County	Existing pavement damaged and repair from previous storm events.	Approximately 550 feet west of the intersection of Hunt Highway and Pioneer Path	Roads Damaged/Impassable	Low	High	None
JI-35	Pinal County	Dip crossing east of the residential intersection contains a large amount of runoff during storm events. Noticeable amounts of pavement drainage.	Skyline Drive and Peace Pipe Place	Sheet Flow Flooding	Medium	High	None
JI-36	Pinal County	Several washout areas located along Philips Road.	Phillips Road, west of the intersection with Thompson Road	Sedimentaion/Erosion	Low	High	KHA-29, KHA-31, KHA-32, KHA-33
JI-37	Pinal County	Breakout west of Thompson Road causes significant flooding at nearby homes. County indicated that there have been instances of 2 feet of water passing through the residential parcels.	Residential properties west of the intersection of Thompson Road and Saddle Mountain Trail	Flow Diversions	High	High	None

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Jurisdiction Identified (JI) Issues

The flooding issues summarized in this document have been identified from meetings with the various jurisdictions located within the watershed. The project team met with the respective public works and street maintenance departments. The meetings included discussing areas where flooding occurs frequently and requires maintenance. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Jurisdiction	Description	Location	Type[1]	Severity[2]	Storm Frequency[3]	Related Issues[4]
JI-38	FCDMC	Concern about the proposed roadway elevation impacting runoff to site	NE corner of 164th Street and San Tan (Constellation Way and Coldwater Boulevard)	Flow Diversions	High	High	None
JI-39	FCDMC	Concern about dike being breached and sending additional flow and sediment to household.	18048 E Stacey Road	Dike Breach	High	High	None
JI-40	FCDMC	Runoff flowing through back of property	18809 E Flintlock Dr	Sheet Flow Flooding	High	High	None
JI-41	FCDMC	Heavy flows destroying dirt road	19702 E San Tan Boulevard	Roads Damaged/Impassable	High	High	None
JI-42	FCDMC	Pitting, erosion in road due to flooding	20133 E Happy Road	Sedimentaion/Erosion	High	High	None
JI-43	FCDMC	Dumping is obstructing flow	300 feet south of E Via De Palmas Road and 300 feet east of S 223rd Street	Flow Diversions	High	High	None

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3 - Identifies issues that occur during high frequency (small) or low frequency (large) storm events.

4 - Issues that are related to or located near another identified issue.

2012 Flooding (KHA) Issues

The flooding issues summarized in this document have been identified in site visits by the KHA project team during storm events in the 2012 monsoon season. The project team visited the watershed to observe areas that experienced significant flooding. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Description	Location	Type[1]	Severity	Storm Frequency	Related Issues
			July 14th, 2012			
KHA-1	Ponding along southern edge of Riggs Road.	Riggs Road and Martingale Road	Ponding	Medium	High	None
KHA-2	Ponding along western edge of Higley Road.	Riggs Road and Higley Road	Ponding	Medium	High	None
KHA-3	Ponding along southern edge of Mews Road.	Higley Road and Mews Road	Ponding	Medium	High	None
KHA-4	Ponding along eastern edge of Higley Road.	Higley Road and Happy Road	Sheet Flow Flooding	Medium	High	KHA-5
KHA-5	Ponding along eastern edge of Higley Road.	Higley Road and Happy Road	Sheet Flow Flooding	Medium	High	KHA-4
KHA-6	Ponding at intersection of Hunt Highway with dirt road.	Hunt Highway between Stacey Road and Propulsion Boulevard	Ponding	High	High	KHA-7, JI-21
KHA-7	Ponding along northern edge of Hunt Highway and eastern edge of 172nd Street.	Hunt Highway and 172nd Street	Sheet Flow Flooding	High	High	KHA-6, JI-21
KHA-8	Flooding on eastern edge of 172nd Street with Debris	Hunt Highway and 172nd Street	Debris Flow	Medium	High	None
KHA-9	Flooding of subdivision exit (South Mandarin Drive).	Hunt Highway at Entrance to Santo Vallarta development	Ponding	Medium	High	HS-1, JI-7, JI-8, JI-10
KHA-10	Sedimentation on Bell Road.	Hunt Highway and Bell Road	Sedimentaion/Erosion	Low	High	KHA-11, KHA-12, JI-9, JI-1
KHA-11	Washed out segment of Bell Road.	Bell Road, south of Hunt Highway	Sedimentaion/Erosion	Low	High	KHA-10, KHA-12, JI-9, JI-1
KHA-12	Erosion along western edge of Bell Road.	Bell Road between Hunt Highway and Skyline Drive	Sedimentaion/Erosion	Low	High	KHA-10, KHA-11, JI-9, JI-1
KHA-13	Wash flowing across Hunt Highway with sedimentation.	Hunt Highway between Thompson Road and Empire Boulevard	Sedimentaion/Erosion	Medium	High	None
KHA-14	Sedimentation along Prospector Drive.	Prospector Drive and Mariah Lane	Sedimentaion/Erosion	Low	High	KHA-15
KHA-15	Exposed utilities south of Golddust Drive.	Goldust Drive and Moyes Road	Sedimentaion/Erosion	Medium	High	KHA-14

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3 - Issues that are related to or located near another identified issue.

2012 Flooding (KHA) Issues

The flooding issues summarized in this document have been identified in site visits by the KHA project team during storm events in the 2012 monsoon season. The project team visited the watershed to observe areas that experienced significant flooding. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Description	Location	Type[1]	Severity	Storm Frequency	Related Issues
			July 29th, 2012			
KHA-16	Flooding of Riggs Road due to ponding along southern edge of roadway.	Riggs Road between Lime Drive and 187th Place	Ponding	Medium	Low	HS-7, JI-11, JI-12, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
KHA-17	Flooding of Riggs Road at intersection with 194th Street due to ponding along southern edge of roadway.	Riggs Road and 194th Street	Ponding	Medium	Low	HS-7, JI-11, JI-12, KHA-16, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
KHA-18	Flooded intersection of Riggs Road and 194th Street.	Riggs Road and 194th Street	Ponding	Medium	Low	HS-7, JI-11, JI-12, KHA-16, KHA-17, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
KHA-19	Flooded intersection of Riggs Road and 194th Street.	Riggs Road and 194th Street	Sheet Flow Flooding	Medium	Low	HS-7, JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
KHA-20	Flooding on 194th Street south of Riggs Road.	Riggs Road and 194th Street	Sheet Flow Flooding	High	Low	HS-7, JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
KHA-21	Flooding at intersection of Riggs Road and 194th Street, flooding of residential lots along 194th Street.	194th Street, north of Riggs Road	Sheet Flow Flooding	Medium	Low	HS-7, JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-22, KHA-24, KHA-27, KHA-28
KHA-22	Flooding of Riggs Road due to ponding along southern edge of roadway.	Riggs Road between 195th Place and 196th Street	Roads Damaged/Impassable	High	Low	HS-7, JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-24, KHA-27, KHA-28
KHA-23	Erosion and flooding along eastern edge of 196th Street.	196th Street, north of Riggs Road	Sedimentaion/Erosion	High	Low	None

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3 - Issues that are related to or located near another identified issue.

2012 Flooding (KHA) Issues

The flooding issues summarized in this document have been identified in site visits by the KHA project team during storm events in the 2012 monsoon season. The project team visited the watershed to observe areas that experienced significant flooding. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Description	Location	Type[1]	Severity	Storm Frequency	Related Issues
July 29th, 2012						
KHA-24	Flooded intersection of Riggs Road and 196th Street.	196th Street and Riggs Road	Roads Damaged/Impassable	High	Low	HS-7, JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-27, KHA-28
KHA-25	Sheet flow over Riggs Road to the north causing erosion and scour.	Riggs Road between 196th Street and 196th Way	Sedimentaion/Erosion	High	Low	None
KHA-26	Ponding along southern edge of Riggs Road.	Riggs Road and Hawes Road	Ponding	Medium	Low	KHA-26, KHA-27, HF-7
KHA-27	Flooded plot of available land along southern edge of Riggs Road.	Riggs Road and Hawes Road	Ponding	Medium	Low	HS-7, JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-28
KHA-28	Flooded plot of available land along southern edge of Riggs Road.	Riggs Road and Hawes Road	Ponding	Medium	Low	HS-7, JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27

1- Types based on various categories defined in the Flood Hazard Risk Assessment of the Area Drainage Master Study (ADMS).

2 - Levels of severity are a qualitative estimation from photos, related documents and discussions with agency employees. **Low** - Small amounts of flooding identified, minor damage to infrastructure, small number of issues identified. **Medium** - Evidence of moderate flooding, signs of reasonable amount of erosion, evidence of moderate at earth fissure . **High** - Significant fissure cracking and widening, major arterial or area affected by issue, substantial amount of flooding, consistent reoccurence of issue during storm events.

3 - Issues that are related to or located near another identified issue.

2012 Flooding (KHA) Issues

The flooding issues summarized in this document have been identified in site visits by the KHA project team during storm events in the 2012 monsoon season. The project team visited the watershed to observe areas that experienced significant flooding. The flooding issue locations can also be found on the Drainage Issues Map.

ID	Description	Location	Type[1]	Severity	Storm Frequency	Related Issues
August 3rd, 2012						
KHA-29	Flood damages to utility box and containment structure.	Phillips Road, west of Thompson Road	Sedimentaion/Erosion	Medium	High	JI-36, KHA-31, KHA-32, KHA-33
KHA-30	Debris covering culvert inlets.	Thompson Road and Roberts Road	Debris Flow	Low	High	KHA-35
August 17th, 2012						
KHA-31	Erosion along edge of roadway.	Phillips Road, west of Thompson Road	Sedimentaion/Erosion	Low	High	JI-36, KHA-29, KHA-32, KHA-33
KHA-32	Erosion along roadway endangering utility boxes.	Phillips Road, west of Thompson Road	Sedimentaion/Erosion	Medium	High	JI-36, KHA-29, KHA-31, KHA-33
KHA-33	Flood damage to utility box and containment structure.	Phillips Road, west of Thompson Road	Sedimentaion/Erosion	Medium	High	JI-36, KHA-29, KHA-31, KHA-32
KHA-34	Ponding along west edge of Thompson Road	Thompson Road between Roberts Road and Allen Road	Sedimentaion/Erosion	Low	High	None
KHA-35	Erosion along roadway and sedimentation filling irrigation channel.	Thompson Road between Roberts Road and Saddle Mountain Trail	Sedimentaion/Erosion	High	High	KHA-30

1- Types based on various categories defined in the Flood Hazard Risk Assessment of the Area Drainage Master Study (ADMS).

2 - Levels of severity are a qualitative estimation from photos, related documents and discussions with agency employees. **Low** - Small amounts of flooding identified, minor damage to infrastructure, small number of issues identified. **Medium** - Evidence of moderate flooding, signs of reasonable amount of erosion, evidence of moderate at earth fissure . **High** - Significant fissure cracking and widening, major arterial or area affected by issue, substantial amount of flooding, consistent reoccurence of issue during storm events.

3 - Issues that are related to or located near another identified issue.

Appendix C. Geological Technical Memorandum

SAN TAN WEST ADMS

FINAL GEOLOGY REPORT

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EXP 09-30-2014

GEOLOGICAL CONSULTANTS INC.

Geological Consultants, Inc. Project No. 2012-118
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1.0 INTRODUCTION

This report presents the results of a geologic/geomorphic/soil assessment of the San Tan West ADMS area watershed focusing on the upper, middle, and lower piedmont areas along the north front of the San Tan Mountains. As part of this assessment, attention is also directed to land subsidence affecting portions of the middle and lower piedmont and the known or documented earth fissures (ground cracks) that have formed in response to tensional stress induced by land subsidence. The San Tan West ADMS area is located in the portions of the San Tan and Queen Creek watershed including portions of Maricopa County and Pinal County north and south of Hunt Highway, respectively. The study area is bounded on the north by Queen Creek Road, on the east by Sonoqui Wash and Thompson Road, on the south by the San Tan Mountains drainage basin divide and on the west by the East Maricopa Floodway (Figures 1a and 1b).

1.1 Scope of Work

Information contained herein completes portions of the project scope of work in Task 3.3 Geological Reconnaissance and its related subtask in section 3.3.1 Surficial Mapping. The major work tasks for the geologic/geomorphic assessment include the following:

- Review of available geologic reports and maps for the project area from a variety of sources including, but not limited to, the U.S. Geological Survey (USGS), National Resources Conservation Service (NRCS), Arizona Geological Survey (AzGS), and Arizona Department of Water Resources (ADWR).

- Preparation of preliminary surficial geology and soil maps of the ADMS area using the geology and soil information obtained for the data review subtask.

- Conduct a geological reconnaissance of selected portions of the ADMS area using ground-truth observations to verify and refine the compiled preliminary geologic and soil maps, to determine ground surface, soil, bedrock and earth fissure characteristics and the distribution of the surficial geologic units and features. Geomorphic, flow patterns and drainage characteristics, erosion and sedimentation within selected areas of the San Tan West ADMS area were also examined.

- Provide the geology and soil information gathered for the geological mapping in a manner to assist with the characterization and categorization of drainage patterns, vegetation, topographic relief and documented earth fissures within the ADMS area.

- Geological Reconnaissance deliverables were prepared including surficial geology and soil maps that are included as part of the Geological Reconnaissance Memorandum. The geologic and soil maps include the surficial distribution of the geologic/geomorphic units. The map documentation is developed in a GIS framework and the boundaries between the surficial geologic and soil units are geo-referenced using a high resolution orthophoto and topographic base.

- Scope Item 3.3.1.4

The research, compilation and preparation of the geologic and soil maps and the geological reconnaissance of the ADMS area were conducted under the direct supervisions of Mr. Kenneth M. Euge, R.G., Principal Geologist and Ms. Martina Velasquez, Project Geologist for Geological Consultants Inc. (GCI). GCI is a subconsultant to Kimley-Horn and Associates, Inc. Phoenix, Arizona. Ms. Laurie Marin P.E., CFM is project manager for Kimley-Horn.

1.2 Previous Investigations

Numerous geologic, soils, land subsidence, and earth fissure related investigations have been completed that encompass all or portions of the San Tan West ADMS study area. A summary of the prominent references used to complete the geological assessment for the preparation of the deliverable are summarized in Section 5.0 of this memorandum.

1.3 Purpose of Report

The purpose of the Geologic Report is to:

- document the results of the geological research and the interpretation and observation of the surficial geologic and geomorphic conditions of the San Tan Mountains piedmont within the San Tan West ADMS area and

- provide a qualitative assessment of the distributary and sheet flow areas of the watershed as well as constraints that may impact potential flood mitigation alternatives developed for the ADMS area.

The surficial geological analysis and mapping presented herein includes information regarding the age and type of surficial soil and bedrock units, a qualitative evaluation of potential flood hazards and areas of potential erosion and sedimentation.

1.4 Methodology

The surficial geology within the San Tan West ADMS area includes unconsolidated and consolidated sedimentary soils of the lower piedmont north of Hunt Highway. South of Hunt Highway, the surficial geology includes weakly consolidated and poorly indurated older soils and caliche-cemented, well indurated old sedimentary deposits and well indurated granitic and metamorphic bedrock. The compiled geology and soils data and the observations made during the geological field reconnaissance provide the basis for understanding the natural conditions related to stream channel and floodplain development, erosion, scour, sedimentation, and flooding.

The discussion of "active alluvial fans" in this Geologic Report are used in the context of the geological definition of alluvial fans that have been "geologically active" during the last 10,000 years (i.e. Holocene time). The use of the terms "young", "intermediate", and "old" refer to the relative geologic age of the alluvial fan and fan terrace deposits. The FEMA definition of "active

alluvial fan" in terms of an engineering time scale was not used. However, several factors based on the interpretation of aerial photograph and the limited geological field reconnaissance, such as the presence of desert pavement, caliche cemented soils, and vegetation (saguaros) on the alluvial fan terraces suggest the fan surfaces within the San Tan ADMS project area are relatively stable and that they could be described as and considered to be "inactive alluvial fans" in terms the FEMA Guidelines and an engineering time scale.

Surficial geological mapping was accomplished using relevant geology and soil reports, topographic maps, and aerial photography from various sources and from the subsequent geological reconnaissance of selected portion of the ADMS area. The base geology of the ADMS area was obtained from Arizona Geological Survey open-file geologic maps and geological interpretation of recently flown, high resolution color aerial photography. Additional complementary data were obtained from the U.S. Geological Survey and the National Resources Conservation Service (NRCS). The interpreted geology was plotted on U.S. Geological Survey 7.5-minute topographic quadrangles and aerial photographs that were converted to GIS layers.

All of the surficial geology units contact boundaries compiled on the Geologic Map (Figures 1a and 1b) may vary in accuracy from a few feet to tens of feet. In the areas of gradational soil boundaries, especially in disturbed or developed areas, the boundary accuracies may vary by hundreds of feet. The mapped soil and rock types and their boundaries were verified by the interpretation of aerial photographs and confirmed by observations made during the geological reconnaissance of selected portions of the San Tan West ADMS area.

2.0 GEOLOGIC SETTING

The San Tan West ADMS is located within the Sonoran Desert region in the north-central portion of the Basin and Range Physiographic Province. The Basin and Range Province is characterized by northwest, north, and northeast trending mountains that rise abruptly from broad, elongated, deep sediment-filled valleys produced by block faulting and folding. The mountains and hills south of the ADMS, the San Tan Mountains, are composed predominately of old, Pre-Cambrian age (570 million years ago (mya)) metamorphic schist and igneous granodiorite bedrock, intruded by younger dikes (Ferguson, 1996).

Structurally, the region has been uplifted to its present position by episodes of mountain/basin bounding fault movements (Cooley, 1977). The tectonic episodes and deformation, evident in the orientation of foliation planes and joint dip set discontinuities exposed in the bedrock terrain, have provided the mechanics necessary to form deep intermontane basins that were subsequently filled with sediment.

2.1 Regional Geology

The study area is situated near the south-central border of a broad alluvium-filled valley that is bounded on the south by the San Tan and Sacaton Mountains, on the north and east by the McDowell, Usery, Goldfield, and Superstition Mountains, and on the west by the South Mountains, the Phoenix Mountains, the Union Hills, and the Deem Hills. The alluvial deposits range from a few feet thick near the mountains, due to the presence of a shallow buried bedrock pediment, to more than 10,000 feet southeast of Gilbert. Basin-wide and area-specific

geophysical surveys suggest the presence of this shallow buried bedrock pediment that extends into the Chandler-Gilbert Basin from the mountain ranges that define portions of the basin boundary. The geophysical survey along with well log data indicates that the depths of the buried pediment bedrock surface increases basinward about one to two miles from the mountain and then drops rapidly several hundred to thousands of feet along basin-bounding faults (Jennings, 1977). The buried bedrock high interpreted from gravity data (Jennings, 1977) nearly parallels the mountain front along the north side of the San Tan Mountains, east to west through the San Tan ADMS area. The geometry of the basin boundary provides the focus for and the subsurface structural control for the formation of subsidence-induced earth fissure around San Tan Mountains portions of the basin perimeter (Figure 7).

The geologic units were mapped using the 1994 Arizona Geological Survey Open-File Report 94-7, "Surficial Geology of the Santan Mountains Piedmont Area, Northern Pinal and Eastern Maricopa County Area, Arizona", modified by aerial photograph interpretation and supplemented with a cursory geological field reconnaissance of selected representative geologic deposits within the San Tan ADMS area.

2.2 Geology in the vicinity of the San Tan West ADMS

The San Tan West ADMS extends south into the San Tan Mountains. The mountains are predominately composed of metamorphic schist, and igneous granodiorite bedrock intruded by younger dikes (Ferguson, 1996). Along the margin of the mountains, the alluvium is very shallow. However, the northern limits of the ADMS extend into the alluvial basin where deposits may be as much as 5000 feet thick (Oppenheimer, 1980).

Alluvial basin fill strata within and adjacent to the study area can be grossly subdivided into an upper alluvial unit, a middle fine-grained unit, and a lower conglomerate unit. The upper alluvial unit consists of sand and gravel with some interbedded silt and clay and may range from less than 100 feet near basin margins to more than 350 feet thick in the center portions of the basin. The middle alluvial unit is composed of silt and clay with interbedded sand and gravel. Although the middle unit may range from 100 to 1800 feet thick, near the basin margins it may be absent or indistinguishable from the upper and lower units. The lower conglomerate unit may range from 100 feet near the basin margins to more than 9,000 feet thick (ADWR, 1994). Figure 7 used geophysical interpretations (Jenning, 1977) to provide a graphical depiction of the relative depth to bedrock and the morphology of the sediment/bedrock boundary from the San Tan Mountains piedmont to the basin floor.

2.3 Geologic Units

The geologic units described in this report are based in part on an AzGS report (Huckleberry, 1994 and 1992). Geologic unit code and nomenclature for the map units adopted for this report use the same system used by the AzGS for surficial geologic maps where the primary letters Y, M, and O are used to group young, middle or intermediate, and old, respectively. The lower case "a", "p", and "b" denote alluvial fan surfaces, pediment, and bedrock respectively. In the

undisturbed portion of the study area, the surfaces are further subdivided based on differences in topography and weathering. Tertiary (third level) subdivisions are used for similar surfaces to distinguish relative heights or stream dissection.

Because of the scale of the geologic mapping required to present the surficial distribution of the geologic and geomorphic features such as small geologic or soil unit exposures and small stream channels cannot be resolved or accuractly depicted. Therefore, where these small features and small geologic and soil unit areas are encountered, they are commonly enveloped within adjacent geologic or soil unit areas that are mappable.

2.3.1 Ya2 Modern Stream Channels

Modern ephemeral channels in the upper piedmont mapped as Ya2 have well defined, steep stream banks and in the upper piedmont these streams only convey flows during or following heavy rains. Younger Ya2 channels mapped in the lower piedmont are incised less and will form interconnected distributary drainage patterns. During heavy runoff events, the middle and lower piedmont areas often experience extensive sheet flow flooding. The ephemeral stream channels often interconnect in response to the runoff to form distributary drainage patterns. Channel alluvium generally consists of light colored, loose, unconsolidated gravelly silty sand with angular to subangular gravel to cobbles. Slightly caliche cemented gravelly, silty sand is interlayered with poorly sorted, gravelly silty sands with crude stratification. The alluvium is highly permeable and moderately erosive (Appendix A, Photo G1).

2.3.2 Ya2' Ephemeral stream channels – obscured

Stream channels on the lower piedmont have been obscured by agricultural and urban development. Ya2' surfaces are seldom inundated today due to flood control features but may still be prone to flooding, excessive erosion, and sedimentation under conditions of rare, high intensity or prolonged rainfall due to the redirection and concentration of flow caused by man-made features that act to divert flow, including streets, roads, canals and levees. The largest Ya2' channels are Queen Creek and Sonoqui Wash.

2.3.3 Ya1 Alluvial Fan Surfaces (Subdivided into Ya1a and Ya1b)

Holocene alluvial fan surfaces subdivided into Ya1a and Ya1b based on stream dissection. Ya1 surfaces may be dissected by streams with alluvial grain sizes ranging from cobbles to fine sand. Ya1 surfaces are relatively immature soils slightly enriched with silts and clays near the surface and exhibit a maximum of Stage 1+ carbonate morphology.

2.3.3.1 Ya1a Younger Ya1 surfaces

Younger alluvial surfaces are common on the lower San Tan piedmont and they are located within geologically active alluvial fan areas. Although geologic unit

Ya1a surfaces are common to the lower San Tan Piedmont, remnants of these surfaces are also mapped in the upper piedmont. The surface is relatively flat to gently undulating cut by shallow, distributed drainage channels incised at shallow (<1 foot) depth. The unit is a light to medium tan-brown, angular to subangular gravel in a silty sand matrix with local accumulations of desert pavement. The terrain is flatter and the soil finer grained closer to the basin center with less gravel and more silt and clay. Vegetation is dominated by creosote with acacia and palo verde along washes with isolated saguaros. The unit exhibits evidence of sheet flow and overbank flow (Appendix A, Photo G2).

2.3.3.2 Ya1b Older than Ya1a

Slightly older alluvial surfaces are common to the middle parts of the piedmont. The surface is gently undulating with shallow (1 foot) stream channels excising the surface. Ranging from light to medium tan to gray brown, the unit consists of angular to subangular gravels and cobbles in a sandy matrix. Vegetation is dominated by saguaros, creosote bush, palo verde, and acacia. Evidence of sheet flow is apparent (Appendix A, Photo G3).

2.3.4 Ya Disturbed Surfaces

Ya surfaces occur in agriculturally disturbed areas on the formerly active portions of alluvial fans where agricultural and urban development has obscured boundaries between Ya1 and Ya2 surfaces.

2.3.5 Ma2 Older fan surfaces located on upper piedmont.

Sloping alluvial fan surfaces are mantled with desert pavement consisting of abundant angular to subangular gravel to cobble sized clasts with no patina. The surfaces also exhibit subdued bar and swale topography. The near surface soils are medium to dark orange-brown sandy clay overlying calcic horizons. Near the soil boundary with pediment surface, the caliche cementation is stronger (Stage 4) and shallow (<6 inches) with thick beds. Channels are more deeply incised (3 feet) in this unit. Vegetation is dominated by creosote bushes and prominent saguaros, which suggest surface stability. Acacia and palo verde trees are present along the stream channels. Evidence of sheet flow is apparent with sheet flow concentrated as it intersects the incised stream channels and earth fissure gullies in some of the areas. Where the upper soils are removed to expose the less erosive underlying caliche cemented horizons, the stream channels are subject to minor erosional downcutting and lateral erosion (Appendix A, Photo G4).

2.3.6 Op Pediment Surfaces

Erosional surfaces within the pediment are either mantled with poorly preserved soils or the soils are absent having been removed to expose weathered bedrock. Bedrock outcrops and balds protrude through old cemented fan mixed with colluvium. Reddish

brown oxidation is apparent on exposed bedrock. The surfaces of the divides separating the ephemeral stream channels, where bedrock is not exposed, include young gravelly colluvium and localized areas of old fan terrace remnants. Stream channels are deeply incised in the pediment with almost vertical sides. Bedrock is exposed in channel bottoms and sides with shallow sandy gravel to boulder sediments on the channel bottom. Pediment surfaces are prone to rapid sheet runoff with very little infiltration, feeding stream channels (Appendix A, Photo G5).

2.3.7 B Bedrock

Bedrock in the San Tan West ADMS area includes Pinal Schist, Proterozoic granitoids, Early Proterozoic granodiorite, Middle Proterozoic Granite, Laramaide granitoids, Proterozoic-Cretaceous granitoids, Welded Tuff, Basalt, Sedimentary rocks (Appendix A, Photo G6).

3.0 GEOMORPHIC COMPONENT OF GEOLOGIC MAPPING

Geomorphologic analysis and surficial geological mapping (Figures 1a and 1b) provides information about the age and type of alluvial deposits on piedmonts that is critical in assessing the character of piedmont landforms and can aid to to refine the detailed hydrologic and hydraulic analysis (Pearthree, et al; 2009).

This analysis focused on the identification of recent, modern features that indicate the presence of channel and bank modifications along the channel alignment including apparent channel migration, and evidence of bank cutting and sedimentation. The techniques used to complete the general assessment included cursory comparisons of USGS topographic maps, NRCS soil maps, and recent and older aerial photographs. A preliminary geologic map of the San Tan West ADMS area was compiled using published surficial geologic maps and reports (Ferguson, et al, 1996; Huckleberry, 1992 and 1994). A map of the surficial soil unit distribution was prepared using the NRCS soil reports (Adams, 1974; Johnson, et al, 1998; and NRCS Soil Data Mart, 2011). Subsequent verification and modifications of the geologic unit boundaries were made using high resolution color aerial photography (August 2012) provided by the FCDMC and color digital 1:12,000 scale orthophoto quarter quadrangle aerial photographs (My Topo, 2011). A geological field reconnaissance was conducted to document the exposed geology and the surface and soil characteristics within portions of the upper, middle and lower piedmont areas north of the San Tan Mountains. Stream channel and stream bank segments within the representative piedmont areas were also examined during the field reconnaissance to qualitatively assess channel and bank modifications and their erosion and scour potential.

The geomorphic setting of the San Tan West ADMS is dominated by the San Tan Mountains that defines a portion of the southern boundary of the Chandler-Gilbert basin. The eroded landscape of this bedrock high is typical of the Basin and Range Province. Bedrock exposed within the majority of the San Tan Mountains includes granite and schist. A narrow, eroded pediment surface separates the mountain front from the San Tan Mountain piedmont surface that is drained by ephemeral streams that grade toward the north and northwest (Appendix A, Photo G5).

Since the mid-1930s, agricultural development within the basin to the north of the ADMS and within the ADMS study area itself, caused the pumping of groundwater from the basin aquifer at rates that greatly exceeded basin recharge (see Section 4.0). The excess removal of the groundwater has resulted in land subsidence over a very large area of the the East Salt River Valley Sub-Basin (ESRV) (Chandler-Gilbert Basin). The stress to the basin sediments induced by the land subsidence has caused earth fissures to form within the piedmont down slope and parallel to a basin bounding fault that is buried by old and young alluvial fan deposits of the piedmont (see Section 2.1). The orientation of the earth fissure relative to the piedmont slope can, over time, interrupt the natural drainage channels, intercept and redirect runoff to new flow paths (see Section 4.2.1).

3.1 Stream Channel and Bank Modifications

Stream channel and bank modification assessment focused on the southern portion of the ADMS south of the Hunt Highway corridor where human encroachment into the San Tan Mountains piedmont has caused minimal modification to the surficial geology, to the piedmont slopes, and to the Ya2 drainage channels that are incised into older geologic units. However, north of the Hunt Highway corridor, agricultural activity and, in recent years, residential-commercial development has modified the area encompassing the northern portion of the middle piedmont and the entire gently sloping, lower piedmont area. The grade modifications caused by these developments have resulted in the removal and obscuring of stream channels and banks. As a result, with the exception of larger stream channels near the border of the study area, the stream flow and sheet flow runoff is redirected to paved and unpaved streets and shallow unlined cut channels, many of which are not designed to handle excessive runoff in response to long duration or high intensity precipitation events. With increased residential development in the middle and lower piedmont areas north of Hunt Highway, large-capacity, engineered floodways have been constructed including Queen Creek, Sonoqui Wash, and the East Maricopa Floodway.

3.1.1 Modern Stream Channels (Ya2) and Ephemeral stream channels – obscured (Ya2')

The boundaries (limits) of the mapped modern stream channels deposits (Ya2) do not appear to have been significantly affected by past flood events to cause modifications of the gross channel and bank morphology. However, within the boundaries of the mapped unit, the mapping includes areas of flow splits in the upper piedmont area possibly in response to relatively high velocity, large flow event and overbank flow. The channels within the lower piedmont area are fairly well defined being incised on the order of a few inches to less than three feet (A, Photo GM1). Locally, based on aerial photo and topographic map interpretation, some adjacent stream channels are interconnected forming distributary drainage patterns where excessive flows and sedimentation have induced change in flow patterns that have formed locally braided patterns in response to excessive runoff and localized erosion and sedimentation.

From observations made during the field reconnaissance, some of the lower piedmont streams appear to exhibit evidence of localized headward erosion probably resulting

intercepted sheet flow runoff during or following moderate to heavy rainfall events. The headward erosion increases the length of the stream channels cut into the Ya2 surface. This process extends the channel thalwegs in an upstream direction. The distributary flow patterns may be locally modified by the short-term sheet flow rill erosion and shallow down cutting and headward erosion. During 'low' flow events, it is expected that the low height and gentle-sloped natural stream banks are relatively stable with very limited down-cutting and lateral erosion. Within the upper piedmont mapped as Ya2, these streams have well defined, steep stream banks and only convey flows during or following heavy rains.

The obscured modern stream channels and banks (Ya2') have been graded over by agricultural and development activity. As a result, there is nothing observable that can be used to assess whether or not stream channels and banks have been modified by past flood events. Because of the land surface modifications flow paths are poorly defined. The presence of roads, canals and levees however, can cause floodwater retention as well as the redirection and concentration of runoff that can cause excessive erosion and sedimentation. It is expected that the Ya2' surfaces would be inundated in response to high intensity or prolonged periods of precipitation.

3.1.2 Younger Alluvial Surfaces (Ya1a)

Younger alluvial surfaces (Ya1a) are younger Ya1 (see Section 2.3.4) that are common to the lower San Tan piedmont in active fan areas. These surfaces include shallow, Ya1a distributary channel features formed on the Ya1a surfaces that exhibit characteristics similar to Ya2 surfaces (see Section 3.1.1). The surfaces are prone to periodic sheetflow and overbank flow. Localized stream channel and bank modifications may occur in response to long duration and high intensity storm events that have formed localized distributary patterns on the Ya1a surface that over time could transitions into a modern Ya2 surficial channel network (Appendix A, Photo GM2).

3.1.3 Older Alluvial Surfaces (Ya1b)

Older alluvial surfaces (Ya1b) are older Ya1 surfaces that are common to the middle San Tan piedmont area. The stream channels appear to be more incised and form dendritic drainage patterns in the slightly cemented (Stage I caliche), stratified but poorly sorted cobble to fine sand alluvial soils. Also the presence of Saguaro cacti on the Ya1b surfaces, and the surface of other geologic unit within the study area, suggest the alluvial fan surfaces are relatively stable and inactive over the short term (50 to 100-years). Normal runoff will likely be contained within the channels incised into the Ya1b surfaces. These drainage channels are incised more than three feet below the alluvial surface. The surfaces can be subjected to rare overbank flows as a result of long duration or high intensity flow events. Also during high discharge volume, long duration runoff events, lateral erosion may occur locally and overbank flows could cause localized lateral erosion and shifts over time in the channels (Appendix A, Photo GM3). The extent of the channel modifications will depend on the degree of caliche cementation within the Ya1b geologic unit

3.1.4 Disturbed Surfaces (Ya) (Lower & Middle Piedmont)

The obscured modern stream channels and banks (Ya) have been graded over by agricultural and development activity. As a result, there is nothing observable that can be used to assess whether or not stream channels and banks have been modified by past flood event. Excessive runoff and inundation in response to long duration or high intensity precipitation events could cause adverse effects similar to those experienced in the Ya2' areas (Section 3.1.1).

3.1.5 Older Fan Surfaces (Ma2) (Upper Piedmont)

Older fan surfaces (Ma2) are prominent in the upper piedmont area and well exposed in the Gila River Indian Community (GRIC) portion of the San Tan West ADMS. The well-defined stream channels are incised into the Ma2 surface to depths of about three feet to about 15 feet (Appendix A, Photo GM4). The surfaces of the divides separating adjacent stream channels are mantled with well developed and varnished desert pavement providing qualitative indicators of the antiquity and stability of these older fan surfaces (Appendix A, Photo GM5). Below the silty and clayey sand surficial soil which also support the growth of saguaro cacti, a well-cemented petrocalcic horizon is encountered. As a result, the streams channel banks do not appear to have been significantly affected by past flood events to cause modifications of the gross channel and bank morphology. The stream banks are very steep and may be susceptible to localized, gradual lateral erosional undercutting that over time (probably more than 50 year) will cause stream bank instability and caving.

3.1.6 Pediment Surfaces (Op) (Upper Piedmont)

The pediment surfaces surrounding the perimeter of the San Tan Mountains and its isolated bedrock outliers (inselburgs) are erosional surfaces mantled with very limited or poorly developed granular soils that are commonly caliche cemented at their contact with the underlying bedrock (Appendix A, Photo GM6). During periods of intense or long-term precipitation events, these surfaces are subject to sheet flow runoff. Where stream channels have formed in the pediment surfaces, they are very well defined and the caliche-cemented soils and bedrock is not easily eroded in response to stream flow events. Stream channel and bank modifications are negligible.

3.1.7 Bedrock (B)

The San Tan Mountains and the inselbergs are formed of crystalline bedrock consisting of granite and schist (Appendix A, Photo G6). The bedrock is locally covered by very coarse-grained residual soil, talus, colluvium, and shallow, very strongly cemented (Stage III to IV), and very old alluvial fan remnants. Moderate to deep, stream channels with steep sloped banks are incised into the erosion resistant bedrock and soil. Channels and banks cut into these materials experience negligible modification along their thalwegs or lateral erosion. However, over long periods of time, the channel banks

may be undercut and experience localized bank slumps or rock slides.

3.2 Erosion and Scour Potential

The following general qualitative assessment of potential erosion and scour is provided for the geologic surfaces mapped within the San Tan West ADMS study area. The qualitative assessment considers potential erosion and scour that could result from long duration or high intensity, potentially catastrophic precipitation events. It is acknowledged that some erosion and scour will occur in response to reoccurring, periodic 'normal' flow events.

3.2.1 High Potential Erosion and Scour

3.2.1.1 Modern Stream Channels (Ya2) and Ephemeral stream channels – obscured (Ya2') (Lower Piedmont)

Modern stream channels are flood prone and could be subject to high velocity flood flow. Along the Ya2 channels scour and incision will likely occur along the narrow channel bottom in the upper piedmont. Lateral erosion and scour with limited down-cutting would be expected in the lower piedmont. Where less erosive bedrock or caliche-cemented channel bottom and stream bank soils are encountered, scour would be expected to be significantly less intense. It is expected that the channel will be subject to scour and as flow velocities diminish, bar deposition will occur. Downstream sedimentation could be excessive (Appendix A, Photo ESP1). Unprotected stream banks in unconsolidated sediment will be subject to lateral erosion. The presence of older stratified sediments containing caliche cemented layers underlying the stream channel deposits will limit down-cutting but could aggravate lateral erosion. Concentrated flows in unlined channels and areas of exposed soil through farmland and other developed areas are expected to have high erosion and scour potential and experience lateral erosion where constructed, unlined berms or embankments are encountered.

3.2.1.2 Disturbed Surfaces (Ya) (Lower & Middle Piedmont)

Agricultural and land development on the younger and older alluvial fan surfaces have modified the drainage on these disturbed surfaces. Natural stream channel systems have been obliterated by agricultural and development activity. As a result, the runoff is now concentrated in unlined channels and other conveyances through reworked and disturbed soil. These soils when subjected to high velocity and concentrated runoff are expected to have high erosion and scour potential.

3.2.2 Medium Potential Erosion and Scour

3.2.2.1 Younger Alluvial Surfaces (Ya1a)

Younger alluvial surfaces (Ya1a) soils are younger deposits consisting of poorly sorted gravels and sand (Appendix A, Photo ESP2) that can be susceptible to various types of flow events. These deposits, as well as Ya2 channel deposits of streams cut into the Ya1a surfaces, are moderately erosive when subject to runoff induced by long duration or high intensity precipitation events. The character of distributary channels within this unit that also tend to confine flows suggests that they are also subject to scour in response to flood runoff and overbank flooding. Observations of recently deposited soil sediment spread over the gently sloped alluvial surface indicate these alluvial surface soils are subject to periodic sheetflow-induced sedimentation and localized erosion and scour.

3.2.2.2 Older Alluvial Surfaces (Ya1b) (Middle Piedmont)

Potential erosion and scour affecting the older alluvial surfaces (Ya1b) of the middle piedmont area are (Appendix A, Photo ESP3) similar to their younger counterpart (Ya1a). However, in the upper piedmont stream channels are more deeply incised into the slightly cemented (Stage I caliche) alluvial soils. Although subject to moderate erosion, the relatively high percent of cobble-size rock fragments tends to develop localized armoring of the channel bottom thereby reducing the scour potential. The Ya1b surfaces are also subject to localized erosion and scour due to periodic sheetflow and overbank flow during long duration or high intensity flow events.

3.2.3 Low Potential Erosion and Scour

3.2.3.1 Older Fan Surfaces (Ma2) (Upper Piedmont)

Soils of the older fan surfaces (Ma2) are moderately well cemented (Stage III caliche) and moderately indurated (Appendix A, Photo ESP4). These soils range from boulder-sized rock fragments near the bedrock pediment and mountain front to coarse sand and gravel further down gradient. Well developed hard and relatively impermeable sandy clay layers and calcic layers are present beneath the old fan surface. Because of the caliche cemented and moderately indurated character of these soils, they are relatively resistant to erosion and scour.

3.2.3.2 Pediment Surfaces (Op) (Upper Piedmont)

The pediment surfaces are locally mantled with thin, very hard caliche cemented soils and very gravely sand residual soils in contact with the underlying granitic and metamorphic bedrock (Appendix A, Photo GM6). Erosion and scour is expected to be minimal due to the resistant cemented and gravelly character of the pediment soils where incised by stream channels. Some minor erosion of the uncemented residual soils will occur in response to occasional shallow sheet flow runoff.

3.2.3.3 Bedrock (B)

The crystalline bedrock surface is resistant to erosion and scour except where the bedrock is mantled by thin gravelly residual soil. Some minor erosion is expected where the residual soils formed in-place on the bedrock surface are subjected to shallow sheet flow runoff. Modern Ya2 stream channels cut into the bedrock are commonly armored with coarse gravel to boulder-size rock fragments. (Appendix A, Photo ESP5).

4.0 LAND SUBSIDENCE AND EARTH FISSURES

4.1 Overview

Land subsidence is known to occur in alluvium filled valleys of Arizona where agricultural activities and urban developments have caused substantial over-drafting or removal of groundwater from thick basin aquifers. The magnitude of subsidence is directly related to the subsurface geology, the thickness, and compressibility of the alluvial sediments deposited in the valleys, and the net groundwater decline. According to Bouwer (1977), land subsidence rates range from about one-hundredth to one-half foot per 10-foot drop in groundwater level, depending on the thickness and compressibility of the basin fill sediments.

The major human-induced factor contributing to subsidence is the large scale pumping and removal of groundwater. Nearly all of the populated southern Arizona basins from Phoenix to Tucson have experienced at least a 100-+ foot drop in groundwater level, and an area surrounding the town of Stanfield, Arizona has dropped more than 500 feet. The groundwater level near the study area had dropped from 300 feet to 500 feet by 1986 (Schumann, 1986).

The San Tan West ADMS area is within the East Salt River Valley Sub-Basin (ESRV), one of the seven groundwater sub-basins within the Phoenix Active Management Area (AMA) as defined by the Arizona Department of Water Resources (ADWR). Prior to 1923, the groundwater system in the East Salt River Valley was in equilibrium because the groundwater recharge and outflow were balanced. By 1950, 2.3 million acre-feet per year were needed to meet agricultural demands. As a result, groundwater flow directions were impacted due to the lowering of the water table toward cones of depression around pumping centers that are created by the large scale pumping of groundwater. Cones of water level depression are reported near Scottsdale, Mesa, and Queen Creek (ADWR, VII, 1994).

Groundwater pumping estimates prior to1984 are not readily available for the ESRV, but are available for the entire Salt River Valley (SRV). In 1915, 15,000 acre-feet of groundwater were pumped from wells in the SRV. By 1942, the annual volume of groundwater withdrawn had increased to approximately one million acre-feet. Approximately 2.3 million acre-feet per year were pumped from the aquifer when groundwater withdrawal peaked in the 1950's. By 1992, annual usage in the SRV had decreased to 1.1 million acre-feet. Approximately 304,900 acre-feet of groundwater were pumped from the ESRV in 1990 (ADWR, VII, 1994).

Water levels in the ESRV steadily declined from 1923 to 1976 to more than 400' below original levels near the San Tan Mountain. Water levels rose over most of the ESRV from 1976 to 1983 due to heavy runoff and abundant surface water supply. Changes in water levels during this time ranged from a decline of 175 feet in the cone of depression near Queen Creek to a rise of 93 feet north of Queen Creek (ADWR, VII, 1994). Since the late 1970s to mid-1980s, water level hydrographs for wells in the ADMS area show that water levels in the vicinity have been generally increasing.

4.1.1 Land Subsidence in the Vicinity of the San Tan West ADMS

No published ground subsidence studies have been completed within or adjacent to the San Tan West ADMS. Schumann (1974) estimated that subsidence for the area was between 3 to 5 feet as of that year. As of 1967, 3.9 feet of subsidence had been recorded near the town of Queen Creek (Strange, 1983). Due to the fact that groundwater withdrawal has occurred within the Chandler-Gilbert Basin near the study area and that earth fissures have formed within the study area, it is likely that subsidence has been ongoing near the study area for over 30-years (Strange, 1983). Benchmark elevation data obtained from the National Geodetic Survey (NGS, 2004) for benchmarks approximately four to five miles east and northeast of the central portion of the San Tan West ADMS area, near the south-central portion of the basin, indicated approximately 2.18 to 2.77 feet of subsidence occurred between 1967 and 1992 (Table 1). Additional residual land subsidence has likely occurred since that time. However, as the San Tan West ADMS area lies along the margin of the basin, it is expected that the residual land subsidence would be substantially less. This expectation is confirmed based on the review of InSAR interferograms that indicate little, if any, land subsidence has occurred in the study area from 2004 through 2012 (Figure 4) (Section 4.1.1.1).

Table 1
Summary of Documented Land Subsidence from
NGS Level Survey Data 1967 and 1992

NGS Benchmark	1967 Elevation (ft)	1992 Elevation (ft)	Change 1967 to 1992 (ft)
DU0676	1460.74	1458.25	-2.49
DU0678	1449.14	1446.96	-2.18
DU1573	1430.74	1428.29	-2.45
DU1572	1417.76	1415.27	-2.48
DU0681	1403.96	1401.19	-2.77

(1967 data was adjusted to 1992 base using benchmarks along level line with an A (most stable) classification.)

Assuming the rate of subsidence in the area has continued at a constant rate based on

the 1967-1992 average rate of one-tenth foot per year, the total subsidence in the area through 2012 would be approximately 4.5 feet near the center of the basin. Considering the fact that groundwater levels began to rise in the 1980s, the actual land subsidence in the basin probably occurred at a lower rate which would result in less total subsidence through 2012.

4.1.1.1 Interferometric Synthetic Aperture Radar (InSAR) Analysis

InSAR images (ADWR, 2010 & 2012) for the project area for the period between 2004 and 2010 and between 2010 and 2012, are depicted in Figure 4.

The time period of analysis for the 2004 through 2010 image depicts minimal (less than one-half inch) land subsidence in the project vicinity. However, the latest image for the time period analysis for May 5, 2010 through October 19, 2012 depicts no measurable land subsidence during the 2.7 years interval. Although the 2010-2012 image indicates low rates, residual land subsidence continues within the central portions of the East Salt River Valley several miles north of the San Tan West ADMS area, it appears that residual land subsidence may be abating near the margins of the basin and portions of the sediment-filled basin may be approaching a state of equilibrium.

4.2 Earth Fissures

Fissures occur in unconsolidated sediments, typically near the margins of alluvial valleys or near the bedrock pediment edge where ground water levels have dropped from about 200 feet to 500 feet below ground surface (Schumann, 1986).

Fissures are initiated deep underground when tensile stresses exceed the strength of the soils. Tensile stresses induced by the subsidence continue to increase until the ground breaks to form earth fissures. The fissures then propagate upwards to intersect the ground surface. Early signs of earth fissuring are small en echelon hairline cracks and irregular spaced depressions at the surface. As fissures develop, the cracks grow in length to create fissures one foot to more than ten feet deep when subject to erosion caused by surface runoff. The fissures often have vegetation growing in them because the ground is commonly damper along the earth fissure. Other physical features associated with fissures are slump-related escarpments from one inch to a few inches in height, as well as a drainage pattern associated with the fissures that does not conform to the area's local drainage pattern. Figure 6 includes sketches that depict the sequence of earth fissure development over time, from youth to old age.

Field evidence indicates fissures propagate upward and are exposed after overlying sediments are eroded by surface water runoff from rainfall or irrigation (Pewe, 1982). The surface expressions of the fissures are exaggerated because the initial hairline crack is attacked by water to create wide (10 to 20 feet) and deep (more than 15 feet) erosional gullies that often have vegetation growing in them. The fissures are commonly perpendicular to natural drainage channels. The length of the fissure at the ground surface varies; usually less than one mile but one fissure near Picacho, for example, is more than 9 miles long. These features are easily

recognizable on aerial photographs and in the field except where the land surface is modified by agricultural activities or urban development.

4.2.1 Earth Fissures within the San Tan West ADMS

Numerous earth fissures are located within the San Tan West ADMS boundary (Figure 2). Several of these earth fissures were observed during the field reconnaissance completed by GCI.

Area A, located on the GRIC showed both active and inactive earth fissure gullies. Active earth fissure activity was noticed with both extension of the surface extent of some fissures as well as widening caused by erosion. Evidence of en echelon earth fissure features was also observed. This area appears to have extensive erosion and sheetflow occurring. It should also be noted that piping has occurred on the north side of the levee that is located near the boundary of the GRIC, which could cause the levee to be breached at that location if further erosion around the feature should occur (Appendix A, Photo EF1).

Earth fissure traces located in Area B (Figure 2), west of Higley Road and south of Riggs Road, appeared to be inactive with evidence of filling of the earth fissures. This area appeared to have substantially less erosion than other observed areas. The earth fissure gullies in this area were relatively shallow with incision greater south toward the mountains (Appendix A, Photo EF2).

Area E, located south of Hunt Highway, west of the Goldmine Development (Figure 2). The earth fissures in this area appear to be active with localized stream flow and drainage intercepted by and channeled into the main earth fissure which crosses Hunt Highway. Areas to the northwest of the fissure may experience less drainage due to this channelization. The surface is a typical Ya1b, with less gravel and more sand away from the pediment. Because cementation in the top three feet of soil is slight, this area may produce substantial amounts of sediment during sheet flow if hydraulic conditions produce velocities and shearing stresses large enough to induce erosion and transport (Appendix A, Photo EF3).

Although several earth fissures have been mapped near Area H, located south of Hunt Highway and east of Pigeon Path Road, most of them have been obscured due to residential development (Figure 2). Development grading and selective backfilling has occurred across a large area, covering the earth fissure traces and effectively changing the natural flow toward Hunt Highway (Appendix A, Photo EF4).

Area I is at the eastern boundary of the San Tan West ADMS, south of Hunt Highway. Active earth fissuring was observed in this area which includes extension along fissure traces, widening due to erosion, and newly developed surface expressions of previously unmapped earth fissures. Sheet flow in this area is concentrated as it intersects earth fissures (Appendix A, Photos EF5 and EF6).

5.0 SAN TAN WEST ADMS/ADMP FUTURE PLANNING CONSIDERATIONS

Based on the observed and documented conditions pertaining to the geology and soils and the existing and future potential development within the San Tan West ADMS study area we recommend the FCDMC and Pinal County flood control and flood hazard delineations guidelines be jointly applied to address the following suggested planning considerations as part of future investigations for the San Tan West ADMS/ADMP.

5.1 Interagency Cooperation for Flood Hazard Delineations in the Hunt Highway Corridor

The District and Pinal County Flood Control District, in association with the GRIC, should develop mutually compatible flood hazard delineation guidelines for the hydrologic sub-basins that traverse the jurisdictional boundary defined in part by the Hunt Highway corridor. It is suggested that Maricopa County, Pinal County, and the GRIC establish a joint committee or commission to expand their respective flood hazard delineation regulations to define a zone of mutual responsibility for flood control and to develop definitions and refinements to facilitate flood hazard delineation and "Rules of Development" through the Hunt Highway corridor.

5.2 Partially Developed & Undeveloped Areas in Pinal County

As of the date of this investigation the Pinal County portion of the San Tan West ADMS area south of the Hunt Highway corridor is sparsely developed with relatively large parcels occupied by single-family residential structures and out-buildings. A few "high density" parcels are presently developed and others are in the development planning stage south of Hunt Highway between the GRIC boundary and Thompson Road. These residences and small communities are serviced by secondary paved and graded roads that crisscross the lower, middle and a portion of the upper piedmont of the San Tan Mountains. These roadway alignments are graded through the piedmont terrain and cross ephemeral stream channels that flow down gradient toward the north and northwest. During 2012, substantial precipitation events produced high volume runoff down the natural drainageways until encountering a roadway crossing in the natural channels. Following the path of least resistance, high volume and high velocity sediment-laden runoff was conveyed down the roadway causing extensive scour and lateral erosion and eventually sediment deposition and flooding in low-lying areas near and beyond the Hunt Highway alignment (Laurie Marin, personal communication and photographs, 2013).

Refinements of flood hazard delineation for the piedmont areas of Pinal County where existing and proposed roadway alignments cross natural drainage channels, which could be considered analogous to distributary or split flow channels, should include appropriate hydraulic analyses. The analysis for flood hazard delineations within Pinal County that traverse the Hunt Highway corridor should be integrated with their counterparts in Maricopa County.

5.3 GRIC Flood Control Embankment

Segments of the GRIC flood control embankment and flood channel were examined during the field geology reconnaissance. The embankment/channel alignment is located a few hundred

feet south and parallel to the Hunt Highway alignment from the east boundary of the GRIC to the west boundary of the ADMS area. This 'flood control' system was apparently constructed more than 50-years ago. We understand that a section of the embankment was repaired by the GRIC. However at the time of the geologic reconnaissance, other portions of the embankment and the floodway channel appear to be in a state of disrepair that warrants attention. We are not aware if other repairs or modifications to the structures are in the planning stage.

Observations made during the field geology reconnaissance revealed that several locations along the upstream side of the embankment have been impacted by lateral erosion along the floodway channel. Based on examination of recent District aerial photographs, it appears that channel flows have locally breached the floodway. Based on this information, hydraulic analysis of the flood flow through the GRIC flood way channel and the stability of the embankment should be incorporated into a floodplain and potential inundation analysis surrounding this structure. Design alternatives should be developed to mitigate potential downstream flooding impacts. Likewise the presence of a large earth fissure crack on the downstream side of the embankment section east of Higley Road will need to be addressed to deal with future potential erosional piping beneath the embankment foundation.

5.4 Land Subsidence and Earth Fissure Zones within the Piedmont

Land subsidence within the Chandler-Gilbert Basin has a well documented history of lowering the land surface elevations within the basin (see Section 4.1.1) (Pewe et al, 1982; Strange, 1983; Schumann, et al, 1986; AMEC, 2001; GCI, 2011). The net effect of the subsidence is greatest in the central portions of the basin and less near the margins causing the land surface slope gradient to increase from the basin-bounding mountain fronts to the basin center. The gradient changes over time can result in increases in stream discharge velocities, runoff concentration, erosional down-cutting, and sedimentation.

Several land subsidence-induced earth fissures located within the San Tan Mountains northern piedmont area, including portions of the San Tan West ADMS area, have a history of capturing stream channel and sheet flow runoff. The earth fissures redirect and concentrate the captured runoff. Once earth fissure cracks breach the ground surface, flows can be captured initially by cracks with very small apertures (less than two inches wide). Earth fissures are known to have curvilinear surface ruptures that can extend horizontally several hundreds to several thousands of feet (Figure 2) and to depths believed to be several hundreds of feet. These large open fissures are capable of capturing significant volumes of water and sediment during runoff events. For example, a two-inch wide vertical earth fissure that extends to a depth of 400 feet along a length of 1,000 feet has the capacity to contain approximately 1.5 acre-feet of water without taking into account infiltration seepage losses or increased crack capacity caused by erosion widening. The initial flow velocity is very high entering the crack causing concentrated flow velocities to form vertical erosion pipes that over time will merge and induce lateral erosion, undercutting, and collapse, ultimately forming large fissure gullies several tens of feet wide and deep along the earth fissure trace. Examples of earth fissure captured surface runoff within the San Tan Mountains northern piedmont area includes the following:

- A large curvilinear earth fissure, referred to as the "Y" earth fissure, traverses a portion

of the study area from south to north that crosses Hunt Highway and then Happy Road paralleling the 195th Street alignment northward and then northwest. In August 2005, high volume sheet and channel flow produced by an intense summer monsoon thunderstorm caused flooding through the "Y" earth fissure area. The sheet flow runoff ponded over the earth fissure trace that had been filled-in by a land developer. Rapid Infiltration of the flood water caused erosional piping through the fill and the subsequent capture of the ponded water and stream flow (GCI, 2005, personal observations).

- A series of curvilinear earth fissures and fissure gullies that trend to the northeast and cross Hunt Highway, are located a few hundred feet west of Thompson Road alignment. Stream flow, and sheet flow runoff from high intensity precipitation events in 2012, resulted in discharges along local ephemeral stream channels that drain to the south west of Thompson road and to the northeast where stream channels east of Thomson Road are conveyed by culverts to the west through the Thompson Road alignment. A substantial volume of the flows from these streams was captured by the earth fissures. The captured runoff into the earth fissures resulted in the enlargement of the earth fissure gullies, the extension of the earth fissures along their trace (as much as two hundred feet between 2007 and 2013), and extensive erosional downcutting and stream bank erosion due to the change in base levels upstream from the earth fissures (GCI, 2007 & 2012; GCI, 2013, personal observation).

Because of the potential for land subsidence and earth fissures to modify the hydraulics of both large and small drainage basins, the impact to local floodplain delineations and the design of flood mitigation measures could be significant. Floodplain delineations within the San Tan West ADMS should be refined to include the effect of land subsidence using recent land level surveys and estimates of future potential land subsidence and the effects of earth fissures traversing multiple stream channels and drainage basins. Storm water conveyances constructed thorough or across earth fissures could be impacted by earth fissure- induced issues such as redirection of flows, channel breaches and collapse, soil erosion piping, embankment cracking, and settlement.

The investigations for the site-specific design of earth fissure mitigation measures to deal with potentially damaging effects of earth fissures should incorporate the evaluation of site specific conditions in areas known or suspected to be subsiding, or affected by earth fissures, using a standardized minimum level of investigation (AzGS; 2011). It is expected that future potential land subsidence will be minimal within the San Tan ADMS area because of its proximity to the basin margin. However, on-going or increased pumping of groundwater from the basin aquifer could increase land subsidence rates and tensional stresses within the basin fill. If the Increased tensional stress exceeds the strength of the basin fill soil, new earth fissures could develop around the basin margin and existing earth fissures could be extended along there trace. Therefore, it is suggested that consideration be given to the implementation of a subsidence monitoring program in cooperation with the Arizona Department of Water Resources (ADWR). The ADWR presently monitors and reports land subsidence conditions through their InSAR program. Another approach that could be to consider the establishment of a basin-wide subsidence monitoring "district" similar to ones that have been established in Harris and

Galveston, Texas (Harris-Galveston Subsidence District, 2013), Fort Bend, Texas (State of Texas, 2011) and the Santa Clara Valley, California (Santa Clara Valley Water District, 2013).

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EXPLANATION:

Project Boundary

Ya2	Modern Stream Channels - cobbles, pebbles, gravels, and course sands.
Ya2'	Ephemeral Stream Channels - obscured channels on lower piedmont surfaces.
Ya1	Alluvial Fan Surfaces
Ya1a	Younger Ya1 Surfaces - poorly sorted gravels and sands.
Ya1b	Older Ya1 Surfaces - stratified, poorly sorted cobbles to fine sand.
Ya	Disturbed Surfaces
Ma2	Older fan surfaces located on upper piedmont. Mostly Quartz and Schist clasts ranging from boulders to sands ans gravels.
Op	Pediment Surfaces - erosional surfaces with soils poorly preserved or absent. Tend to form in granite with surface clasts consisting of fine gravel and granule size materials.
B	Bedrock - schist, granitoids, granodiorite, granite, welded tuff, basalt, sedimentary rocks.

Map and Geologic Descriptions modified from:
Huckleberry, Gary, May, 1994.

N

0 1,000 2,000 4,000 6,000 Feet

GEOLOGIC MAP
SAN TAN WEST ADMS
NORTH AREA

Figure 1a

GEOLOGICAL CONSULTANTS INC.
2333 West Northern Ave, Suite 1A
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SAN TAN WEST ADMS

EXPLANATION:

Project Boundary

Ya2 Modern Stream Channels - cobbles, pebbles, gravels, and course sands.

Ya2' Ephemeral Stream Channels - obscured channels on lower piedmont surfaces.

Ya1 Alluvial Fan Surfaces

- **Ya1a** Younger Ya1 Surfaces - poorly sorted gravels and sands.
- **Ya1b** Older Ya1 Surfaces - stratified, poorly sorted cobbles to fine sand.

Ya Disturbed Surfaces

Ma2 Older fan surfaces located on upper piedmont. Mostly Quartz and Schist clasts ranging from boulders to sands ans gravels.

Op Pediment Surfaces - erosional surfaces with soils poorly preserved or absent. Tend to form in granite with surface clasts consisting of fine gravel and granule size materials.

B Bedrock - schist, granitoids, granodiorite, granite, welded tuff, basalt, sedimentary rocks.

Map and Geologic Descriptions modified from:
Huckleberry, Gary, May, 1994.

N

0 1,000 2,000 4,000 6,000 Feet

GEOLOGIC MAP
SAN TAN WEST ADMS
SOUTH AREA

Figure 1b

GEOLOGICAL CONSULTANTS INC.
2333 West Northern Ave, Suite 1A
Phoenix, AZ 85021
phone 602-864-1888
fax 602-864-1899

SAN TAN WEST ADMS

EXPLANATION:

- Earth Fissure Trace
- San Tan ADMS Boundary
- Geologic Reconnaissance Areas

NOTE: Revised from AzGS Earth Fissure Trace Shapefile 4/5/12 and GCI Mapped Earth Fissures 02/17/12.

N

0 1,500 3,000 6,000 9,000 Feet

EARTH FISSURE LOCATION and RECONNAISSANCE AREA MAP

Figure 2

GEOLOGICAL CONSULTANTS INC.
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Phoenix, AZ 85021
phone 602-864-1888
fax 602-864-1899

SAN TAN WEST ADMS

EXPLANATION:

AnA	Antho sandy loam, 0-1% slopes
AnB	Antho sandy loam, 1-3% slopes
AoB	Anto gravelly sandy loam, 1-3% slopes
CeC	Cavelt gravelly loam, 1-5% slopes
Es	Estrella loam
Gf	Gilman fine sandy loam
Gm	Gilman loam
GPl	Gravel pit
Gr	Gravelly alluvial land
Mo	Mohall sandy loam
Mv	Mohall loam
PvC	Pinamt very gravelly loam, 3-5% slopes
Ro	Rock land
Ru	Rough broken land
TrB	Tremant gravelly loam, 1-3% slopes
Vf	Vint loamy fine sand
3	Carrizo-Momoli complex, 1-3% slopes
4	Carrizo-Pinamt complex, 1-5% slopes
5	Casa Grande Carrizo very gravelly coarse sand, 0-1% slopes
11	Cristobal-Gunsight complex, 3-15% slopes
13	Denure-Pahaka complex, 1-3% slopes
25	Pompeii-Lomitas-Rock outcrop complex, 15-65% slopes
26	Quilotosa-Momoli-Vaiva complex, 1-15% slopes
27	Quilotosa-Rock outcrop - Vaiva complex 20-65% slopes
28	Redun-Shontip complex, 1-3% slopes
36	Why-Brios complex, 0-2% slopes

See Appendix A for Soil Descriptions.

N

0 750 1,500 3,000 4,500 6,000 Feet

Modified from: NRCS Soil Survey Eastern Maricopa and Northern Pinal Counties

Gila River Indian Reservation Boundary

Modified from: NRCS Soil Survey AZ658 Gila River Indian Reservation

SOILS MAP
SAN TAN WEST ADMS
NORTH AREA
Figure 3a

GEOLOGICAL CONSULTANTS INC.
2333 West Northern Ave, Suite 1A
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phone 602-864-1888
fax 602-864-1899

SAN TAN WEST ADMS

EXPLANATION:

AnA	Antho sandy loam, 0-1% slopes
AnB	Antho sandy loam, 1-3% slopes
AoB	Anto gravelly sandy loam, 1-3% slopes
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25	Pompeii-Lomitas-Rock outcrop complex, 15-65% slopes
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27	Quilotosa-Rock outcrop - Vaiva complex 20-65% slopes
28	Redun-Shontip complex, 1-3% slopes
36	Why-Brios complex, 0-2% slopes

See Appendix A for Soil Descriptions.

N

0 750 1,500 3,000 4,500 6,000 Feet

Modified from: NRCS Soil Survey AZ655
Eastern Maricopa and Northern Pinal Counties

Gila River Indian Reservation Boundary

Modified from: NRCS Soil Survey AZ658 Gila River Indian Reservation

SOILS MAP
SAN TAN WEST ADMS
SOUTH AREA
Figure 3b

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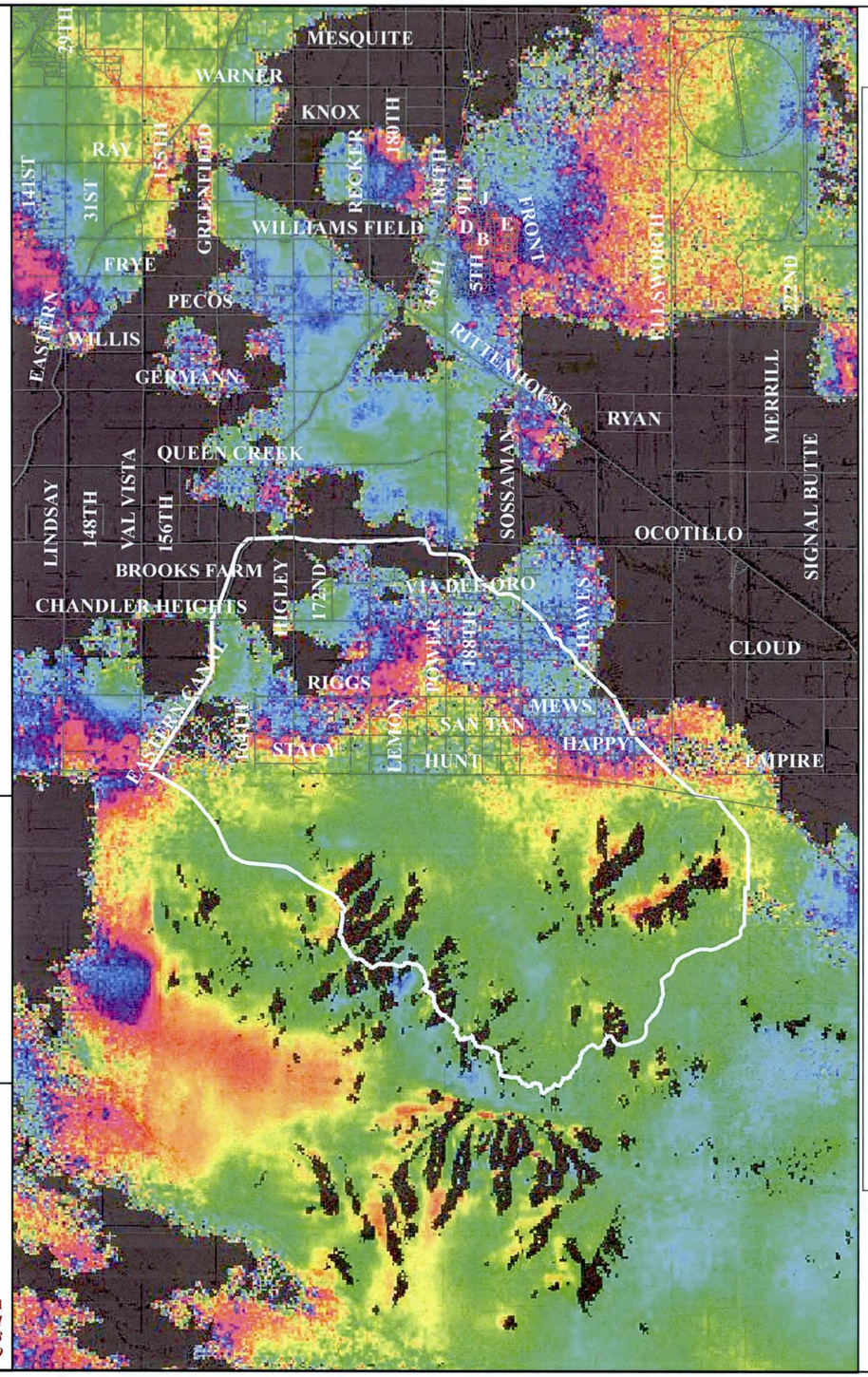
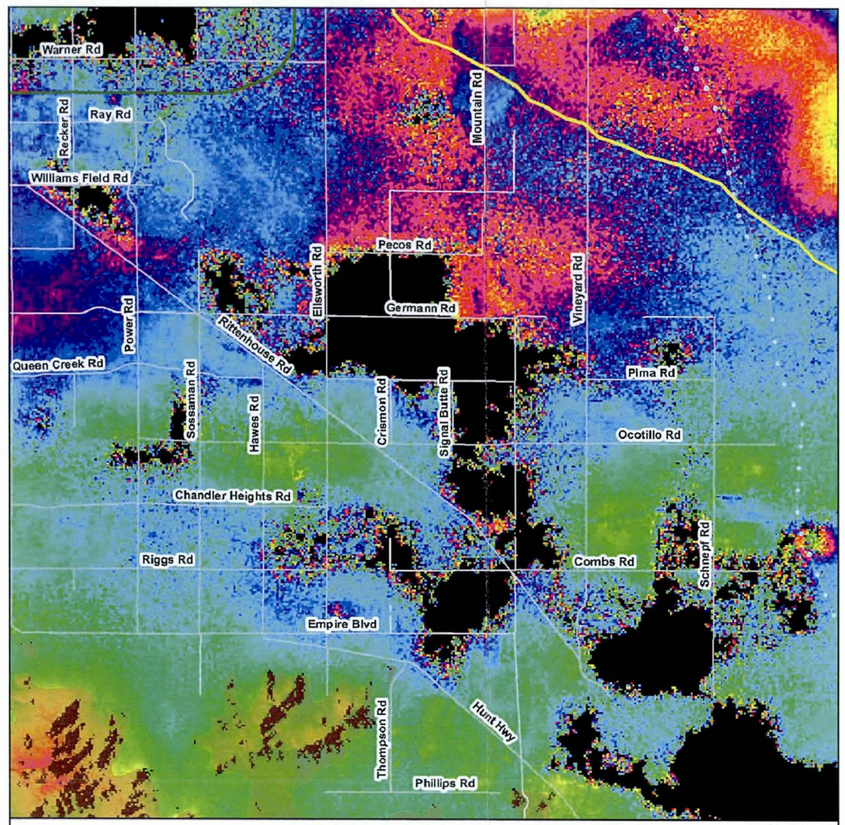
SAN TAN WEST ADMS

EXPLANATION:

Image on the left was created using data processed and produced by the Arizona Department of Water Resources (ADWR). ©ESA 2004-2012

Image on the right was provided by the Arizona Department of Water Resources (ADWR). ©ESA 2004-2012





Radarsat-2 Interferogram for the Queen Creek Area
Maricopa and Pinal Counties
Time Period of Analysis: 2.7 Years 05/15/2010 To 10/19/2012

© MDA 2010 - 2012

-2.8 cm ← 0 → +2.8 cm
Subsidence — Uplift

Subsidence Feature
Hardrock
CAP Canal

Highways and Interstates
Interstate
US
State
Roads

Decorrelation (black areas) are areas where the phase of the received satellite signal changed between satellite passes, causing the data to be unusable. This occurs in areas where the land surface has been disturbed (i.e. bodies of water, snow, agriculture areas, areas of development, etc).

1:105,428
0 0.5 1 2 3 4 Miles

ARIZONA DEPARTMENT OF WATER RESOURCES

N

0 0.5 1 2 3 Miles

InSAR INTERFEROGRAM IMAGES

Figure 4

GEOLOGICAL CONSULTANTS INC.
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fax 602-864-1899

SAN TAN WEST ADMS

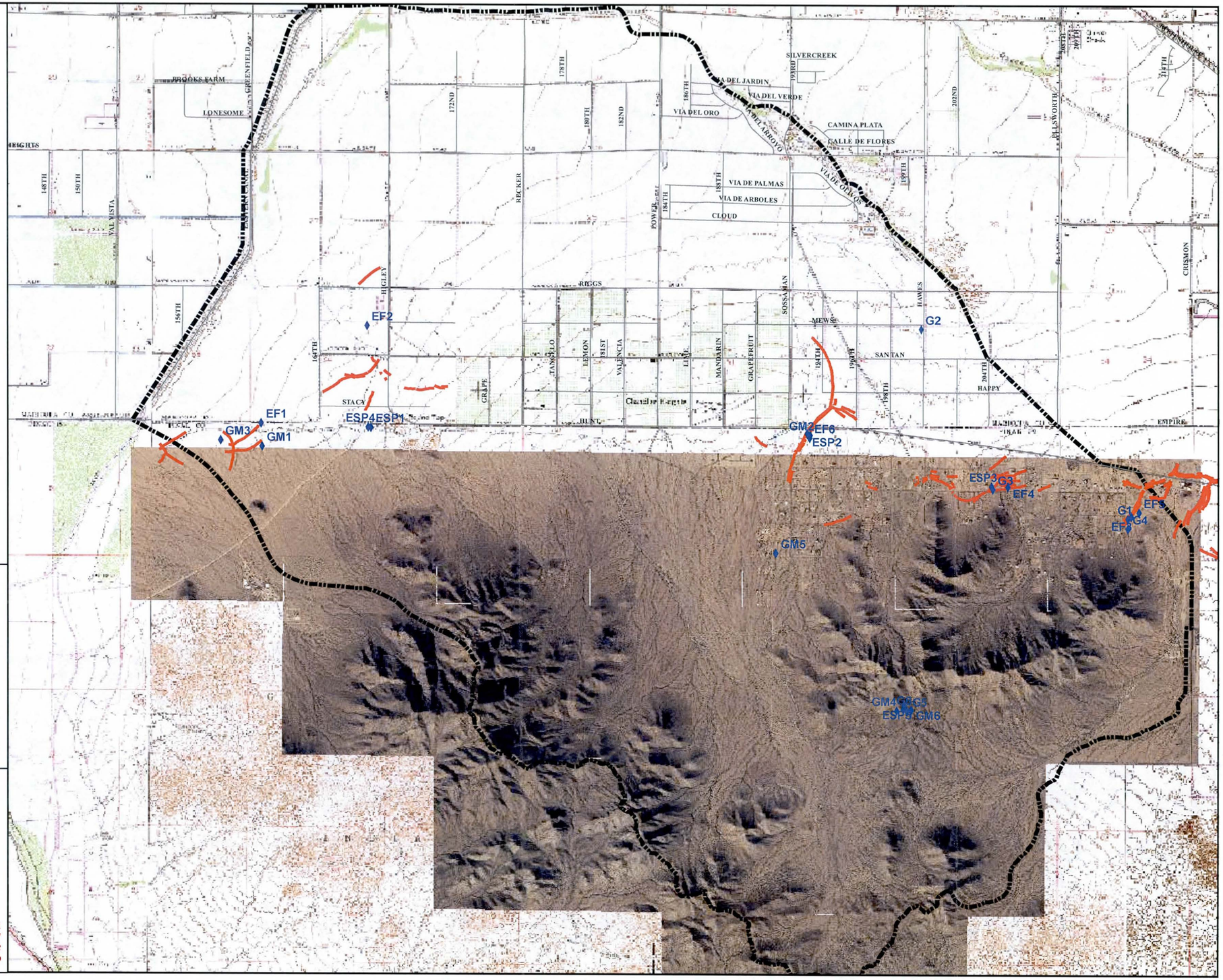
EXPLANATION:

- Earth Fissure Trace
- San Tan ADMS Boundary
- Photo Location

NOTE: Revised from AzGS Earth Fissure Trace Shapefile 4/5/12 and GCI Mapped Earth Fissures 02/17/12.

N

0 1,500 3,000 6,000 9,000 Feet



GEOLOGIC REPORT
PHOTOGRAPH LOCATIONS

Figure 5

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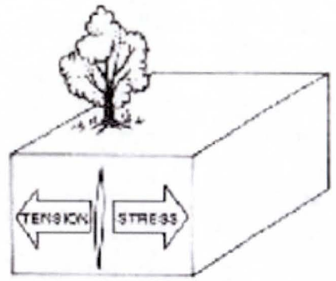
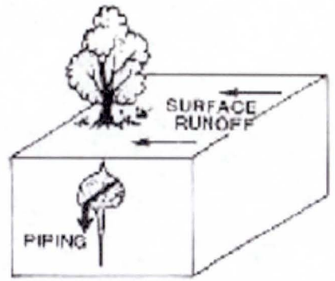
fax 602-864-1899

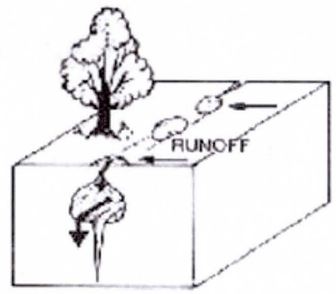
SAN TAN WEST ADMS



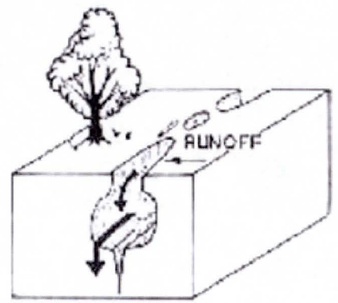
1. Lateral stresses induce tension cracking



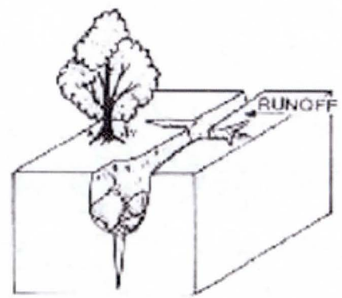
2. Surface runoff and infiltration enlarge crack through subsurface piping



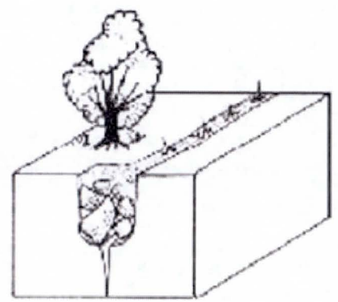
3. As piping continues, fissure begins to appear at surface as series of potholes and small cracks



4. As infiltration and erosion continue, fissure enlarges and completely opens to surface as tunnel roof collapses



5. The entire fissure is opened to the surface and enlargement continues as fissure walls are widened, excessive slumping and side-stream gullying occur



6. Fissure becomes filled with slump and runoff debris and is marked by vegetation lineament and slight surface depression, it may become reactivated upon renewal of tensile stress

STAGES OF EARTH FISSURE DEVELOPMENT

Figure 6

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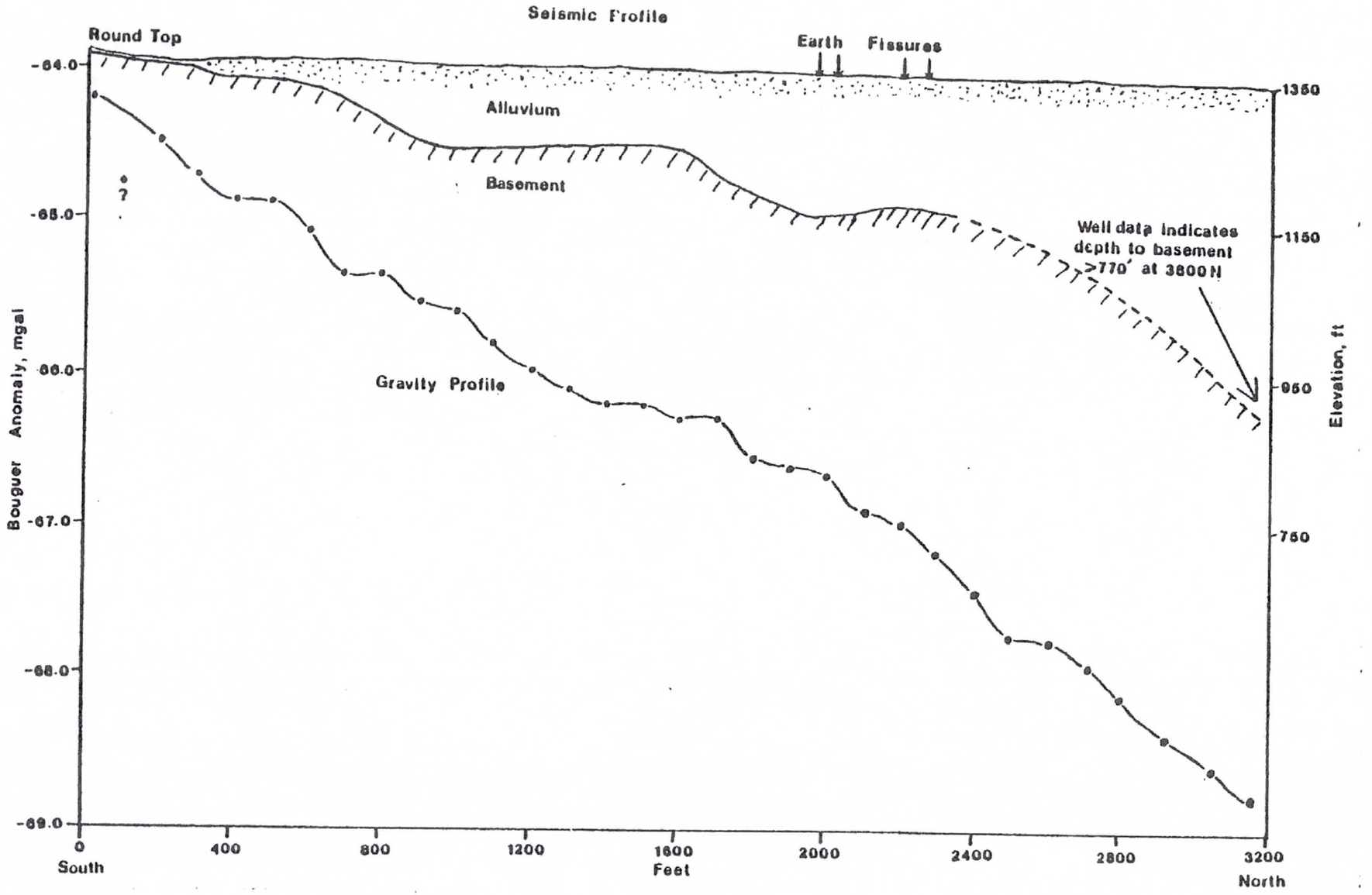
SAN TAN WEST ADMS



Gravity and seismic refraction profile - Higley Road north of Round Top.

Profile modified from:

Jennings, Douglas; 1977; Geophysical Investigations Near Subsidence Fissures in Northern Pinal and Southern Maricopa Counties, Arizona.

Subsurface Profile
Higley Road North of Round Top

Figure 7

GEOLOGICAL CONSULTANTS INC.
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SAN TAN WEST ADMS

Appendix D. Sediment Study Area Memorandum

San Tan West Area Drainage Master Study

Contract FCD 2012C011 (PCN 481.01.20)

Task 3.6 River Mechanics: Final Report

Prepared for the Flood Control District of Maricopa County

on behalf of Kimley-Horn and Associates, Inc.

December 2013

Expires 12/31/2014

WEST CONSULTANTS, INC.

Expires 12/31/2014

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Table 2. Correlation between KHA's "Drainage Issues" figure and the drainage issues identified from historical documents obtained during data collection related to sedimentation issues shown in Figure 1. The *Severity* category is a qualitative scale of the damage as a result of the storm event. Issues that are related near each of the flooding issue locations are listed in the *Related Issues* column. 6

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San Tan West Area Drainage Master Study (ADMS) Task 3.6 River Mechanics Identification of Sediment Study Areas

1 Introduction

The purpose of this report is to fulfill the River Mechanics portion of the Scope of Work (SOW) for the San Tan West Area Drainage Master Study (ADMS) project (Contract Number FCD 2012C011, PCN 481.01.20). The primary assignment as outlined in the SOW in Task 3.6 is to "recommend areas to study for sediment transport, scour, deposition, lateral migration, and other river mechanics issues as appropriate to achieve the goals and objectives of the ADMS." The SOW goes on to specify the following data to be used to identify Sediment Study Areas: (1) stakeholders input, (2) geologic reconnaissance, and (3) field reconnaissance. The final step of Task 3.6.1 is as follows:

> *Prepare a watershed map and memorandum that identifies active and incipient sedimentation problem areas, documents the current sedimentation conditions at each, and tabulates critical sedimentation locations. The memorandum shall provide detailed recommendations for sediment analyses proposed for the San Tan West ADMS. The SUBCONSULTANT shall provide an outline of the report/memo to the CONSULTANT and DISTRICT for review and approval.*

WEST Consultants, Inc., (WEST)—acting in the capacity of a subconsultant to Kimley-Horn and Associates, Inc. (KHA)—was retained to complete the required tasks as outlined in the SOW Task 3.6. This report can be considered the final "Sediment Study Area Memorandum" provided to KHA and the Flood Control District of Maricopa County (District) fulfilling this scoped item (see Task 3.6.2). The remainder of this report describes the data used in the analysis herein, the methods used to identify sedimentation problem areas, proposed methods for future sedimentation analyses that could be incorporated into a more detailed sedimentation study of the project area, and the final results and conclusions fulfilling the SOW Task 3.6.

The remainder of this report is broken into four sections. Section 2 will present the identification of sedimentation problem areas based on stakeholder input. Section 3 will present the identification of sedimentation problem areas based on geologic reconnaissance of the study area. Section 4 will present the identification of sedimentation problem areas based on field reconnaissance of the study area. Finally, Section 5 will provide a summary and conclusion to the repot as well as present recommended sedimentation analyses that could be incorporated into a more detailed sedimentation study of the project area in the future.

It should also be noted that all references to alluvial fans in this report are referring to alluvial fan landforms identified in the geology report completed for this ADMS (Geological Consultants, Inc., 2013). The report herein does not attempt to evaluate if there are any active alluvial fans on the site as per the definitions provided in the Federal Emergency Management Agency (FEMA) alluvial fan flooding documentation (FEMA, 2002). Additionally, the geology report used herein as a basis for sediment analysis (Geological Consultants, Inc., 2013) also did not use the FEMA alluvial fan methodologies to define alluvial fan landforms from a geologic perspective.

2 Identification of Sedimentation Problem Areas from Stakeholder Input

KHA met with various stakeholders at meetings during which KHA staff met with personnel from various municipalities and agencies to determine areas of concern for flooding/drainage issues (including those areas of concern associated with sedimentation problems). WEST utilized the results of these interviews along with the shapefiles developed by KHA identifying the areas of concern from the various stakeholders to isolate the areas of concern for sedimentation problems in the San Tan West ADMS watershed. The jurisdictional drainage issues related to sedimentation can be seen in Figure 1 (pink stars). Also shown in Figure 1are areas of concern related to sedimentation issues in the study watershed identified by KHA in their historical document review during the data collection phase of this study. These locations are shown with green stars in Figure 1. Finally, land fissures as mapped by the Arizona Geologic Survey have been included in Figure 1 as well.

The "Drainage Issues" figure developed by KHA for their data collection report for the San Tan West ADMS (KHA, 2013) describes in greater detail the problems identified at the locations shown in Figure 1. To correlate these locations to the "Drainage Issues" figure developed by KHA, Table 1 and Table 2 have been included in this report to summarize the problems reported at the corresponding locations in KHA's "Drainage Issues" figure and to provide the common identifier for sedimentation drainage issues identified by stakeholders (unique ID's begin with "JI" for "jurisdictional issues" in Table 1) and the sedimentation issues identified from document review during data collection (unique ID's begin with "HF" for "historical flooding" in Table 2). For the exact locations of these points based on their unique identifier, please refer to the large-scale plots in KHA's "Drainage Issues" figure (KHA, 2013).

It should also be noted that there might be slight jurisdictional bias in regards to stakeholder input regarding sedimentation issues in the watershed. As can be seen in Figure 2, Queen Creek, Pinal County, and Maricopa County reported issues related to sedimentation in the study watershed, while the Town of Gilbert and the Gila River Indian Community did not report any sedimentation issues. This could be indicative of fewer sediment issues in these two jurisdictions, or it could be indicative of the relative priority of sedimentation issues in relation to general flooding problems for these two jurisdictional staff.

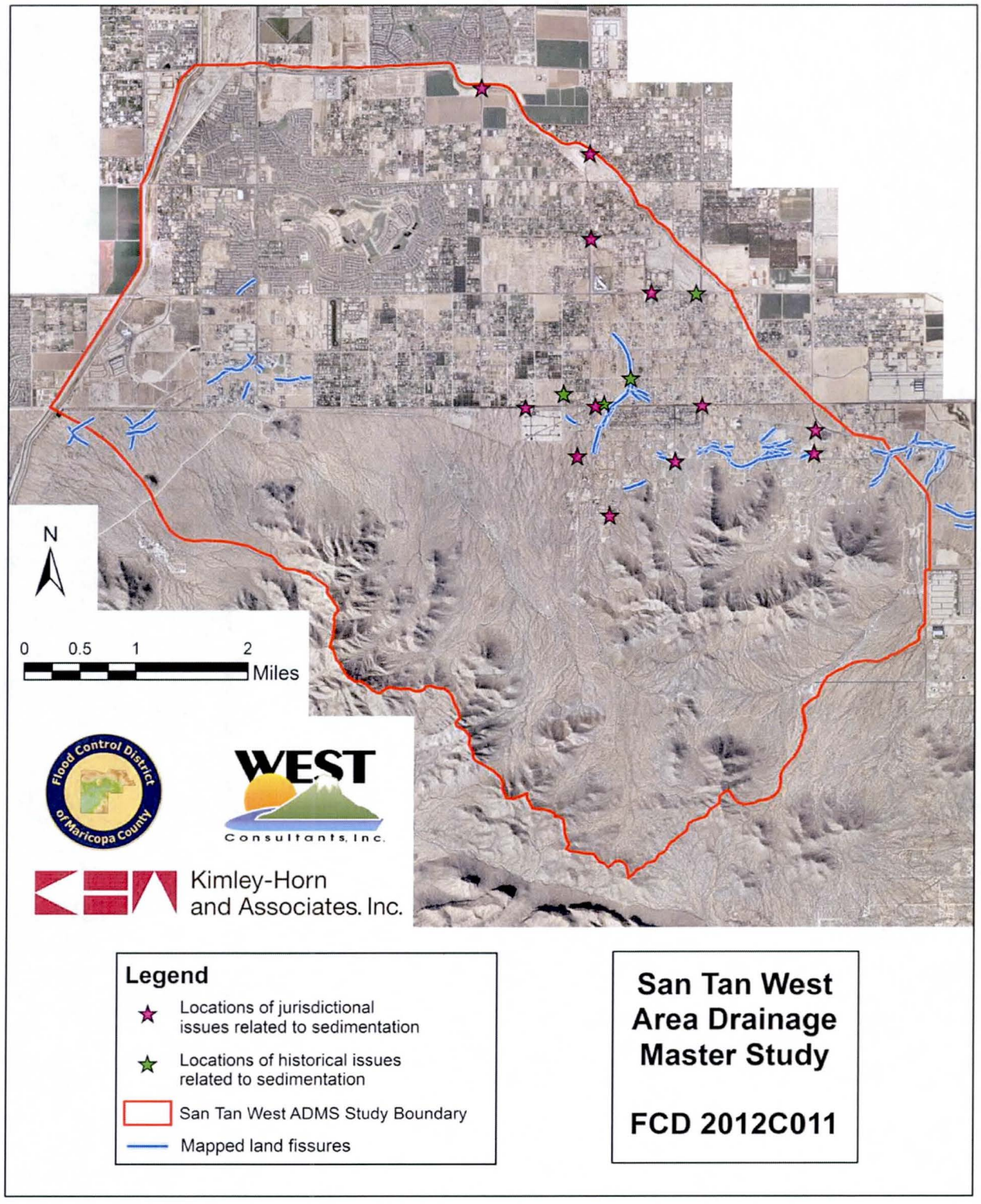

Figure 1. Drainage issues identified by local stakeholders and from historical documents obtained during data collection related to sedimentation issues.

Table 1. Correlation between KHA's "Drainage Issues" figure and the drainage issues identified by local stakeholders related to sedimentation issues shown in Figure 1. The *Severity* category is a qualitative scale of the damage as a result of the storm event. The *Storm Frequency* category is used to identify issues that occur during high frequency (small) or low frequency (large) storm events. Issues that are related near each of the flooding issue locations are listed in the *Related Issues* column.

ID	Jurisdiction	Description	Location	Type	Severity	Storm Frequency	Related Issues[1]
JI-6	Queen Creek	Skyline Drive area south of Hunt Highway can contain up to 6"-8" of debris during storm events. Several washes running south to north are passing the debris into the roads. Some roads do have concrete crossings for protection.	Skyline Drive, From Bell Road to Wagon Wheel Road	Debris/Sediment	High	Low	
JI-7	Queen Creek	Residential walls built along the north side of Hunt Highway are preventing debris to pass through the washes. There is a considerable amount of effort given towards removing the debris from the headwalls.	Hunt Highway, from Wild Horse Drive to Sossaman Road	Debris/Sediment	Medium	Low	HS-1, JI-8, JI-10, KHA-9
JI-8	Queen Creek	Channel located behind development on south side of Hunt Highway between Bell Road and Power Road intercepts offsite flows and conveys around property to Hunt Highway. Residents on north side of Hunt Highway affected by sediment and increased runoff. The residential fences that have been constructed do no hold up during larger storms.	Hunt Highway, Bell Road to Power Road	Debris/Sediment	Medium	High	HS-1, JI-7, JI-10, KHA-9
JI-9	Queen Creek	Portions of the embankment along Bell Road near Hunt Highway are exposing the existing water lines.	Bell Road from Skyline Drive to Hunt Highway	Scour	High	Low	JI-1, KHA-10, KHA-11, KHA-12
JI-11	Queen Creek	Several scuppers have been damaged from previous storm events. The scupper structure is intact but the soil around the scupper has been completely eroded away.	Riggs Road near the 196th Street intersection	Scour	High	High	HS-7, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
JI-13	Queen Creek	The existing splitter structure at the intersection of Sossaman Road and Cloud Road is not doing its intended job and is collecting a large amount of debris. The blocked runoff then ponds into Cloud Road and causes flooding issues along Cloud Road.	Sossaman Road and Cloud Road intersection	Debris/Sediment	High	High	

[1] *Refer to KHA's "Drainage Issues" figure for more specific details on complaints listed in this column (KHA, 2013)*

Table 1 (cont'd). Correlation between KHA's "Drainage Issues" figure and the drainage issues identified by local stakeholders related to sedimentation issues shown in Figure 1. The *Severity* category is a qualitative scale of the damage as a result of the storm event. The Storm Frequency category is used to identify issues that occur during high frequency (small) or low frequency (large) storm events. Issues that are related near each of the flooding issue locations are listed in the *Related Issues* column.

ID	Jurisdiction	Description	Location	Type	Severity	Storm Frequency	Related Issues[1]
JI-17	Queen Creek	Intersection of Sonoqui Wash and Sossaman Road contains culverts that are often clogged and resulting in overtopping and erosion. This location is a consistent problem for the Public Works department.	Sonoqui Wash and Sossaman Road	Debris/Sediment	High	High	JI-18, JI-19
JI-19	Queen Creek	Intersection of Sonoqui Wash and Power Road contains culverts that are often clogged and resulting in overtopping and erosion. This location is a consistent problem for the Public Works department.	Sonoqui Wash and Power Road	Debris/Sediment	High	High	JI-17, JI-18
JI-30	Pinal County	Significant amount of sediment deposited at intersection	Empire Boulevard and Wild Horse Drive	Debris/Sediment	Medium	High	
JI-31	Pinal County	Sandy runoff occurs along Wagon Wheel Road during larger storm events. Issue requires maintenance 2-3 times a year	South of the intersection of Wagon Wheel Road and Sun Dance Drive	Debris/Sediment	Medium	High	
JI-32	Pinal County	Private driveway has washed out in previous storm events	Near intersection of Sun Dance Drive and Ellsworth Road	Debris/Sediment	Medium	High	JI-33
JI-33	Pinal County	Significant amount of sediment deposited at intersection. Existing ditch south of intersection filled with sediment and had to be rebuilt.	Intersection of Ellsworth Road and Hunt Highway	Debris/Sediment	Medium	High	JI-32

[1]*Refer to KHA's "Drainage Issues" figure for more specific details on complaints listed in this column (KHA, 2013)*

Table 2. Correlation between KHA's "Drainage Issues" figure and the drainage issues identified from historical documents obtained during data collection related to sedimentation issues shown in Figure 1. The *Severity* category is a qualitative scale of the damage as a result of the storm event. Issues that are related near each of the flooding issue locations are listed in the *Related Issues* column.

ID*	Type (Article, Photos)	Collected From	Description	Location	Date of Document	Pages	Type	Severity	Related Issues[1]
HF-1	Photos	District (FCDMC call number 007.105.1)	Flooding Events-Photos #805-811 of Earth Crack North of Hunt Highway	North of Hunt Highway, 1/8 Mile East of Sossaman Road	1967-01-26	63, 67, 68	Fissures	High	JI-7, JI-8, JI-10, KHA-9
HF-2	Both	District (FCDMC call number 007.128)	Related Stories: "More Rainfall Possible Tonight In Phoenix"-Chandler Heights Storm, Chandler Heights Fissure Widens- Photo	Chandler Heights, Crack is 1 mile east of Chandler Heights near Hunt Highway	1964-07-15, 1964-08-12	8-10, 56	General Flooding, Fissures	High	
HF-7	Photos	Town of Queen Creek, Central Arizona Project Irrigation leak Riggs w of Hawes.JPG	Central Arizona Project (CAP) Irrigation Leak	Riggs Road West of Hawes Road	Not Dated	1	General Flooding	Low	JI-11, JI-12, KHA-16, KHA-17, KHA-18, KHA-19, KHA-20, KHA-21, KHA-22, KHA-24, KHA-27, KHA-28
HF-8	Both	Arizona Geological Survey (AZGS)	Chandler Heights Fissure Reopened and Swallowed Horse	Happy Road and 195th Street	2007-07-24	40911	Fissures	High	

[1]*Refer to KHA's "Drainage Issues" figure for more specific details on complaints listed in this column (KHA, 2013)*

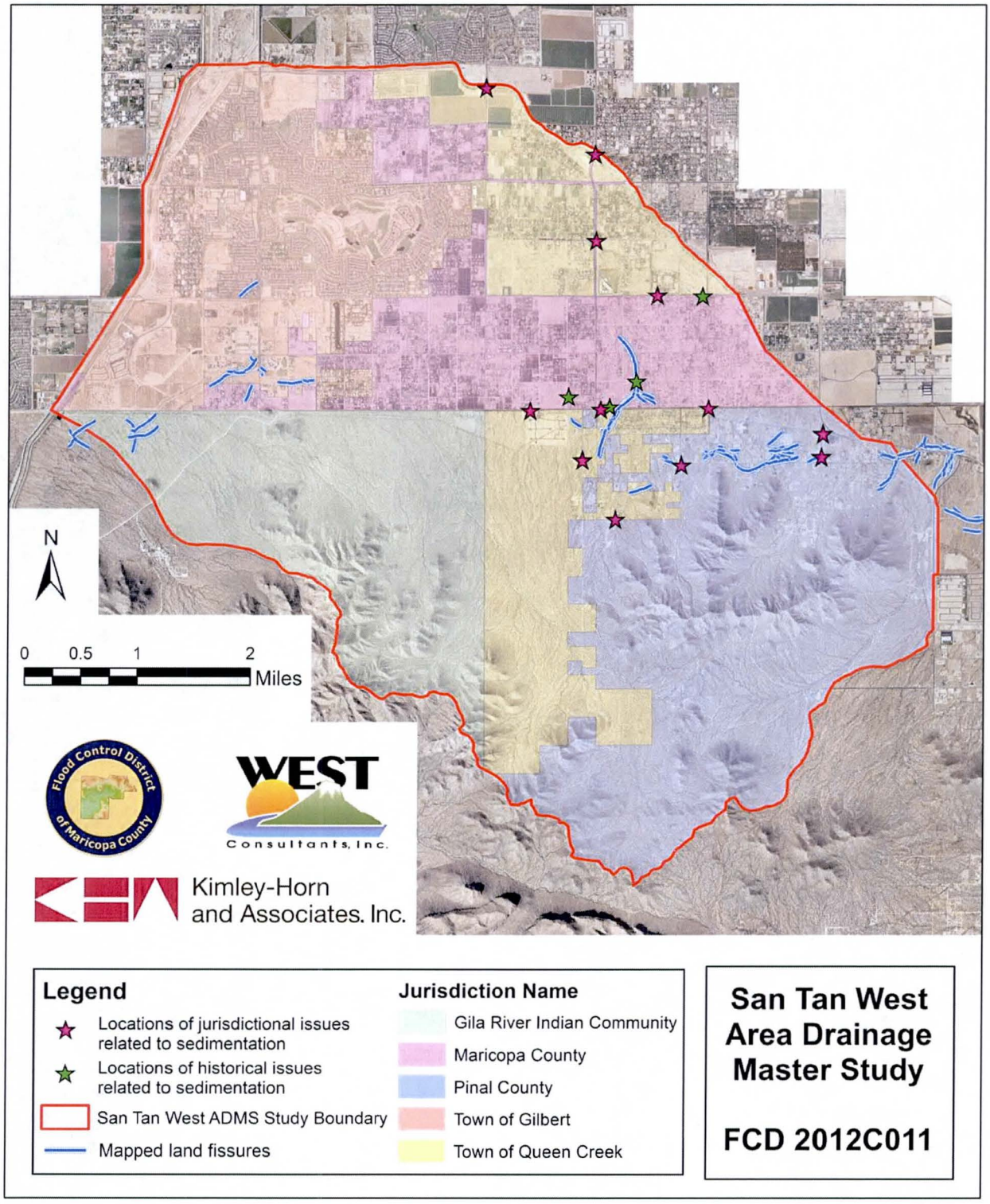

Figure 2. Drainage issues identified by local stakeholders and from historical documents obtained during data collection related to sedimentation issues shown in relation to jurisdictional boundaries.

3 Identification of Sedimentation Problem Areas from Geologic Reconnaissance

KHA subcontracted with Geological Consultants, Inc., to perform a surficial geology assessment of the study watershed. The result of this investigation was a surficial geology map (Geological Consultants, Inc., 2013). WEST utilized the results of this mapping effort to address areas of possible concern for sedimentation in the future. Figure 3 shows the final results of the surficial geology mapping with symbology that represents geologic units more susceptible to erosion (red end of the color scale being the most susceptible to erosion and sediment production from a geologic perspective) and geologic units less susceptible to erosion (green end of the color scale being the least susceptible to erosion and sediment production from a geologic perspective). Additionally, non-erodible bedrock is represented as black in Figure 3. While these bedrock areas weather and are a source of sediment transported via fluvial processes further into the watershed over geologic time scales, these areas were not considered in this analysis for two reasons. First, the time scales generally considered for engineering studies are much shorter than geologic time scales, from a 20- or possibly even 50-year planning study to a single hydrologic event occurring over the course of hours. These time scales are not such that bedrock weathering would produce a significant amount of sediment transported via fluvial processes in the watershed compared to sediment eroded and transported from soils. Second, the more imminent concern for extremely high-slope areas (defined herein as slopes greater than 15 degrees or 27 percent slope) which correspond for this study watershed closely with the geologic units defined as bedrock and associated bedrock weathering would be gravity-driven landslides and rock fall processes as opposed to fluvial transport of sediments (although fluvial processes could impact landslides and rock falls as well). As these gravity-driven processes fall outside of the scope of this study, the extremely high-slope areas defined as bedrock geologic units were not considered further in this analysis. The information provided visually in Figure 3 is repeated in Table 3 providing the same information for geologic units as defined by Geological Consultants, Inc. (2013), and associated erosion susceptibility as defined by WEST.

The remaining geologic units in the study area were ranked in their relative order of importance in regards to fluvial sediment transport, erosion, and deposition processes. WEST ranked the geologic unit classification of "modern stream channels (Ya2)" as the most susceptible to erosion and sediment transport via fluvial sediment processes. While these geologic units may not be the primary sediment producers when considering the volume of sediment introduced to the system, these corridors would likely comprise the majority of sedimentation processes in stream channels (i.e., aggradation/degradation, lateral migration, etc.), and would therefore correspond to the majority of the noticeable sedimentation issues from a perspective of subsequent analysis in this study for use in management and operations.

Two other geologic units defined for the study watershed are closely related to the "modern stream channels (Ya2)" from a sedimentation perspective: "ephemeral stream channels – obscured (Ya2')" and "Ma2 over Ya." As can be seen from Figure 3, these areas are shown with a red hatch as opposed to a solid red background. This is done to indicate that these areas in the study watershed are composed of

primarily engineered drainage channels that have been carefully designed and documented in regards to hydraulic design functions including sedimentation issues. The area labeled as "ephemeral stream channels – obscured (Ya2')" in the geologic delineation is made up of primarily the lower Sonoqui Wash alignment. The area labeled "Ma2 over Ya" in the geologic delineation is made up of primarily the East Maricopa Floodway alignment. Both of these areas are susceptible to erosion and sediment transport processes as they would receive sediment delivered from the upper portions of the study watershed. However, these areas would likely not be the source of significant volumes of sediment in the system as the land within these delineations outside of the Sonoqui Wash and East Maricopa Floodway alignments is developed, has low-slope areas not conducive to sediment transport processes, and has channels that have been designed as stable systems with erosion control measures in place. These transport zones may be considered areas of possible sedimentation issues in the future primarily because the loss of conveyance capacity (e.g., due to significant aggradation) could pose the risk for loss of flood-protection function of these structures. At the same time, these areas are not being recommended for further study herein due to the significant amount of study/documentation for sediment issues related to the design of these channels. WEST would recommend referring to these documents for additional resources regarding sedimentation issues in these engineered drainage channels (e.g., WEST Consultants, Inc., 2000; Kirkham Michael and Associates, Inc., 2002; JE Fuller Hydrology & Geomorphology, Inc., 2012).

Following the classification of "modern stream channels (Ya2)," "ephemeral stream channels – obscured (Ya2')," and "Ma2 over Ya" as the principal areas of the realization of sedimentation issues in the watershed, the geologic units associated with the production of sediment transported via fluvial processes in the modern stream corridors follow as the most susceptible to erosion in specific order. The first geologic unit assigned to this group was "pediment surfaces (Op)" which makes up a small percentage of the total watershed area in a minimally-developed portion of the study area near the southernmost point of the watershed. This was defined as the most susceptible to erosion behind "modern stream channels (Ya2)" due to its correlation with steep slopes near the uppermost portions of the watershed. However, this is furthest from development and areas of concern based on jurisdictional input and data collection; therefore, it was recognized this area would be a likely source of fluvial sediment production, but this area would not be a specific area of focus for future sedimentation analysis in the watershed due to its remote location.

The next three geologic units associated with the production of sediment transported via fluvial processes in the modern stream corridors following "pediment surfaces (Op)" as the most susceptible to erosion are all defined geologically as alluvial fan surfaces in the geology report (Geological Consultants, Inc., 2013). It should be noted that a geologic classification as an alluvial fan surface is not to the same as the general definition of an active alluvial fan surface from a fluvial sediment transport context or from FEMA's alluvial fan analysis methodologies (FEMA, 2002). For the study area herein, the "younger Ya1 surfaces (Ya1a)," which is a subdivision of the "alluvial fan surfaces (Ya1)" as defined in the geology report (Geological Consultants, Inc., 2013), displayed flow split locations based on review of aerial photographs in the areas defined within this geologic unit. Additionally, another recent Pinal County study identified the easternmost geologic unit with the Ya1a classification (near the intersection of

Ellsworth Road and Hunt Highway) as a "hydrologic alluvial fan" (Entellus, 2006); it should be noted that this report did not utilize FEMA's methodology (FEMA, 2002) to identify active or inactive alluvial fans. The study area for the Entellus (2006) study included the portion of the San Tan West ADMS watershed south of Hunt Highway and east of the Power Road alignment. Based on the observation of flow splits and the correlated study in Pinal County (Entellus, 2006), the Ya1a geologic landform was estimated to be the most susceptible to erosion and sedimentation issues of the three geologic classifications of alluvial fans. The other two alluvial fan surface classifications—including "older than Ya1a (Ya1b)," also a subdivision of the "alluvial fan surfaces (Ya1)," and "older fan surfaces located on upper piedmont (Ma2)"—are also likely significant sediment producers in this watershed due to their correlation with significant slopes and the fact that these areas are generally less-developed than areas identified as less susceptible to erosion. It should be noted that these areas are primarily identified in the southern, mountainous, upstream portion of the watershed—primarily south of Hunt Highway. Most of the northern, lower-slope portion of the watershed does not include these same geologic unit classifications of geologic alluvial fans (i.e., Ya1a, Ya1b, and Ma2).

It should be noted that the Santo Vallarta property (located immediately south of Hunt Highway between the 187th Street and 190th Street alignments) was analyzed by Dr. Richard French for a determination of hydraulic processes occurring on the site and the ability with which the storm water drainage system design concept would be competent to adequately mitigate off-site flood hazards (French, 2009). In the conclusions of that report, Dr. French stated the following (French, 2009):

> "The Santo Vallarta property is located on either a distributary flow area or an inactive alluvial fan. On an engineering time scale, the landform is stable and channel avulsions are not expected. Localized erosion and/or deposition will be no more than would occur in similar stable landform areas."

The property in question is entirely within an area defined in the geologic unit characterization as "older than Ya1a (Ya1b)" and "older fan surfaces located on upper piedmont (Ma2)" with intersecting areas of "modern stream channels (Ya2)." While this report does not classify any geologic alluvial fan surface identified in the geology report (Geological Consultants, Inc., 2013) as either an "active" or "inactive" alluvial fan, this statement from the Santo Vallarta report (French, 2009) would indicate that the "older than Ya1a (Ya1b)" and "older fan surfaces located on upper piedmont (Ma2)" may be considered as inactive fan surfaces from a fluvial sediment transport context.

Finally, the geologic units defined as least susceptible to erosion for this analysis include "gravel pit (inactive)" and "disturbed surfaces (Ya)." The "gravel pit (inactive)" definitions accounted for a small portion of the total watershed area, and inspection of aerial photographs showed that these areas had few indications of active erosion or deposition; the inspection of aerial photographs also showed that these areas had been developed since the gravel mining had occurred. As such, these were classified as less susceptible to sedimentation processes and issues. Finally, the area defined as "disturbed surfaces (Ya)" made up the majority of the developed, suburban areas of the study watershed in the northern portion of the watershed (north of the Maricopa County/Pinal County border). This area made up the majority of the southern watershed as well. This area was considered the least susceptible to sediment

processes due to (1) the generally low slopes in the area, (2) the significant urban and commercial development with increased impervious areas no longer susceptible to sedimentation, and (3) the decreased connectivity of natural sediment transport pathways allowing sediment to be transported through the system. While this area could have local issues associated with sediment buildup due to the lack of connectivity of natural sediment transport pathways allowing sediment to be transported through the system, it is not expected that sedimentation issues will be prominent in this area in the future (as reflected by the lack of sedimentation issues brought to light by the Town of Gilbert). Finally, the large berm and drainage channel feature constructed just south of Hunt Highway is another reason this area will likely not face significant sedimentation issues in the future; this local drainage feature will be discussed in greater detail in the field reconnaissance section of this report, Section 0.

The above conversation can be explained with the classic delineation of a watershed into three "zones" including (1) a production zone where sediment is eroded and supplied to the system, (2) a transport zone where sediment in general is transported from the production zone (although sediment can be deposited and then later eroded in watercourses of the transport zone during short-term hydrologic events), and finally, (3) the deposition zone where sediment eroded and transported from higher portions of the watershed is finally deposited. This delineation can be considered on many scales, such as the largest scale of an entire watershed down to much smaller scales such as a single hillslope where sediment is eroded near the top of the slope, transported along the slope, and deposited at the bottom of the slope. For the San Tan West ADMS watershed, the watershed-scale delineation of these zones would place the production zone in the steeper, mountainous portion of the southern watershed, the transport zone along the stream channels and shown in the regions denoted as point '1' and point '2' (see the conversation in the following paragraphs and Figure 4) of the central portion of the watershed as well as the engineered channels of Sonoqui Wash and the East Maricopa Floodway, and the deposition zone in the northern, suburban portion of the watershed with lesser slopes. Table 3 includes a classification of sediment process zones for each of the geologic units as defined by Geological Consultants, Inc. (2013). The classification of zones per geologic unit in Table 3 along with the visualization of the geologic units in Figure 3 can be used to visualize the approximate conceptual areas of these zones at the watershed scale for the San Tan West ADMS. Again, it should be noted that these "zone" definitions are considered at the watershed scale, and these definitions do not ensure that all three processes will not occur at local scales within any of the general zone definitions from a broader scale. For example, the definition of the suburban portion of the watershed as a "deposition" zone from the perspective of the watershed scale does not indicate that the authors are excluding the possibility of local areas of erosion and therefore sediment production in this portion of the watershed.

Based on the analysis herein of the geologic reconnaissance completed for this project, any future analysis of sedimentation issues in the study watershed should address first and foremost the stream channel corridors to determine local aggradation/degradation issues or lateral migration issues affecting specific features of concern. This becomes especially evident when the jurisdictional issues identified by stakeholders and historical locations of sedimentation concerns identified during data collection shown in Figure 1 are overlain on the geologic map shown in Figure 3. This figure is shown in Figure 4 along with photographs taken by KHA during preliminary site visits that highlight sedimentation issues noted

during two low-return interval flooding events that occurred in the watershed in July 2012 (discussed in greater detail in Section 0of this report).

In Figure 4, it is evident that most of the sediment issues are generated in the middle area of the southern half of the watershed (denoted '1'), where Ya2 and Op soils degrade and are transported overland through the Ya1a region. Hence, this area should be the initial focus of future sedimentation analyses. Similarly, the combination of the production zone soil (Op) and the transport zone soils (Ya2, Ya1a, and Ya1b) within the eastern area and specifically upstream of the Cloud Road Basin (near point '2' in the figure and the remainder of the eastern study watershed draining into the Cloud Road Basin) combine to create sediment transport conditions that may adversely affect downstream infrastructure as well. As such, the area should be the second-most critical focus of future sedimentation analyses. The numbers will be utilized throughout the remainder of the report to discuss areas of concern for future sedimentation issues.

Table 3. Relative ranking of susceptibility to sediment transport processes and approximate zone classifications for the geologic classification mapping performed by Geological Consultants, Inc. (2013).

Geologic classification from Geological Consultants, Inc. (2013).	*Relative ranking of susceptibility to sediment transport processes classification (8 being the most susceptible, 1 being the least; colors in the table below correspond to the color scale in Figure 3)*	*Approximate definition of sediment "zone" for the various geological classifications*
Bedrock	N/A	Production Zone
Disturbed surfaces (Ya)	1	Deposition Zone
Gravel Pit (Inactive)	2	Transport Zone
Older fan surfaces located on upper piedmont (Ma2)	3	Production Zone
Older than Ya1a (Ya1b)	4	Transport Zone
Younger Ya1 surfaces (Ya1a)	5	Transport Zone
Pediment surfaces (Op)	6	Production Zone
Ephemeral stream channels – obscured (Ya2') and Ma2 over Ya	7	Transport Zone
Modern stream channels (Ya2)	8	Transport Zone

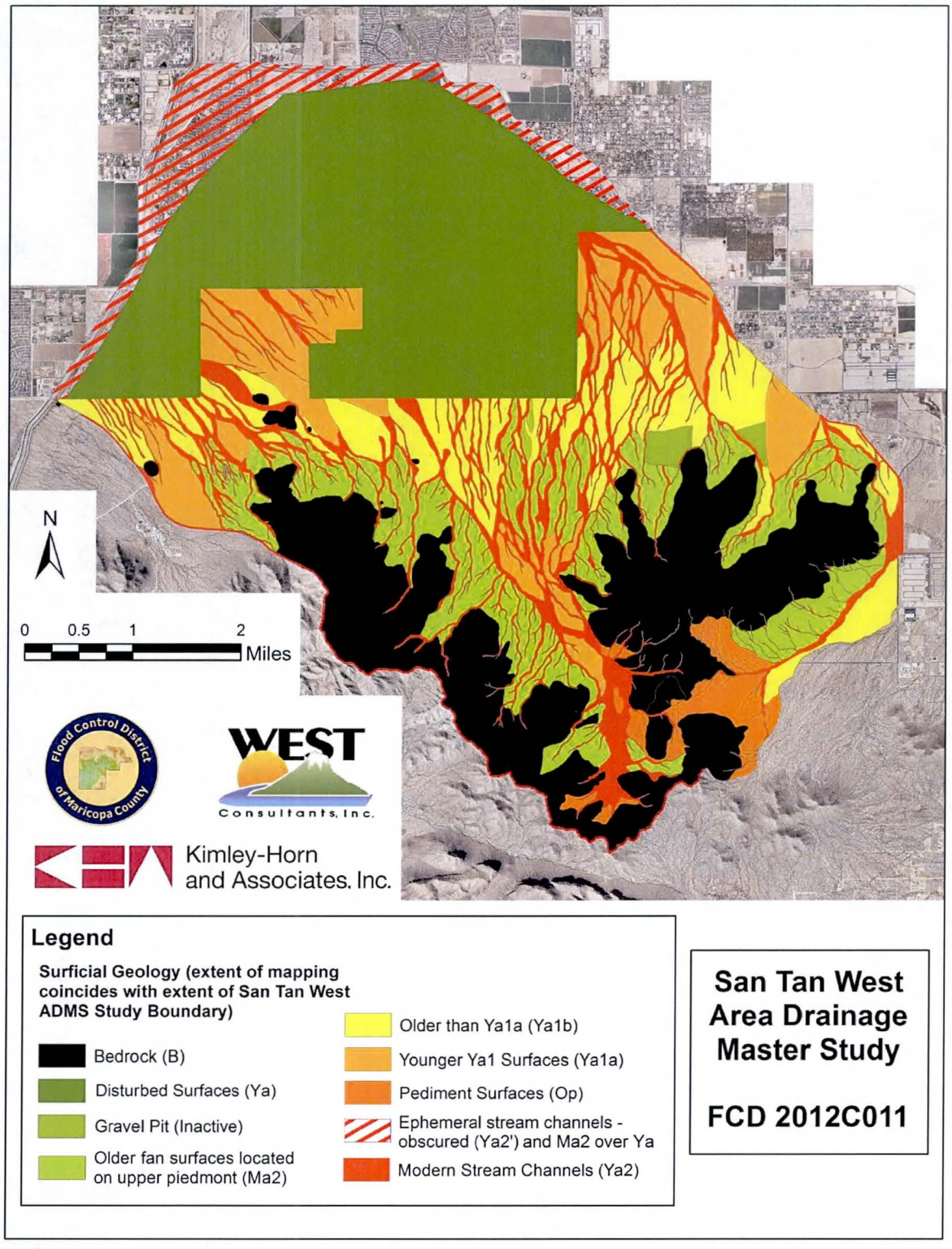

Figure 3. Surficial geology in the San Tan West ADMS Watershed with the color scheme indicating geologic units more susceptible to erosion (red end of scale) to less susceptible to erosion (green end of scale) with black representing non-erodible bedrock. See geology maps (Geological Consultants, Inc., 2013) for additional detail in delineations of the geologic areas.

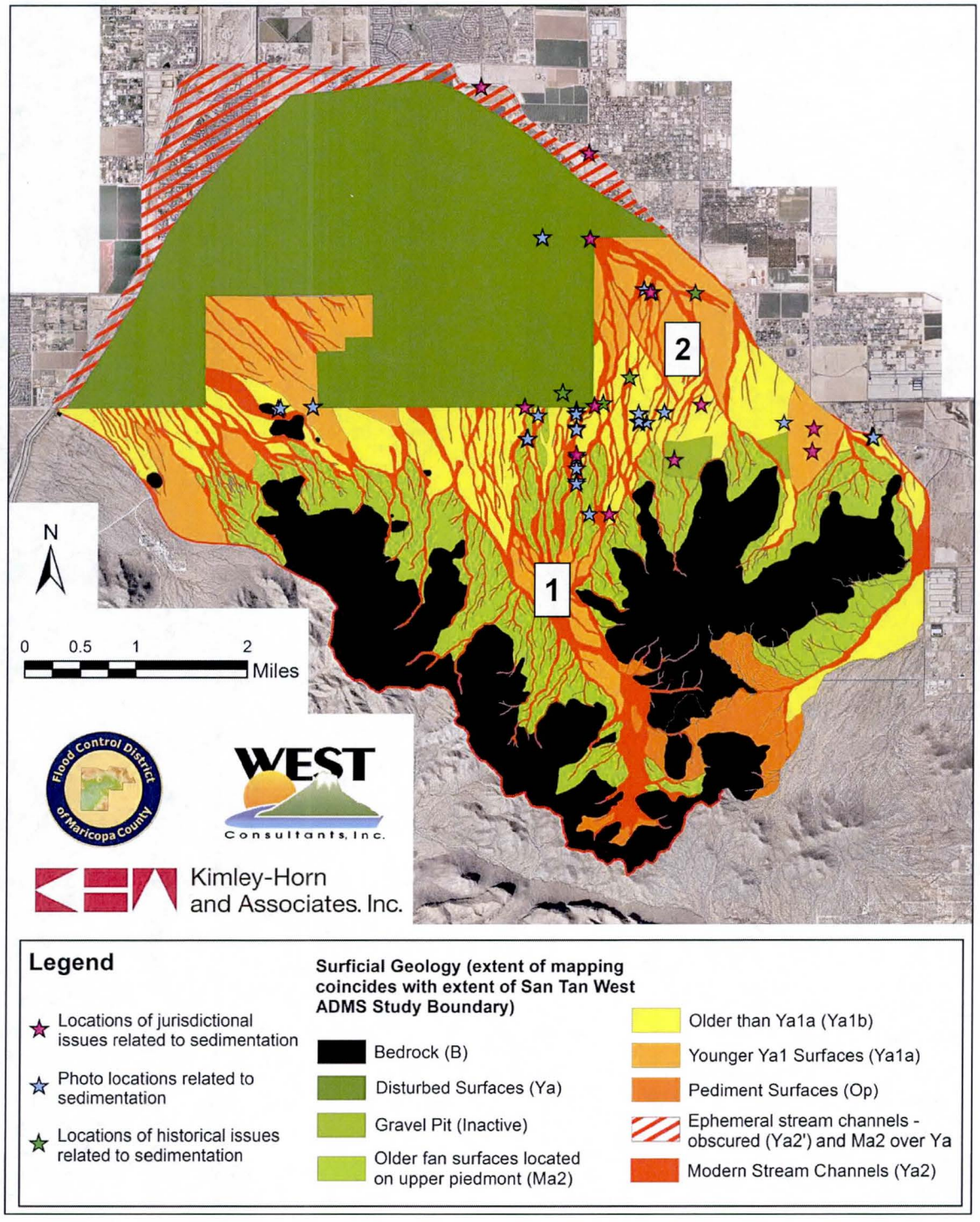

Figure 4. Surficial geology in the San Tan West ADMS Watershed (identical color scheme to Figure 3) shown with sediment issues identified by local stakeholders, identified from historical documents obtained during data collection, and identified during preliminary site visits. Sites 1 and 2 labeled in the figure above are areas of specific sedimentation concern (see text for further explanation). See geology maps (Geological Consultants, Inc., 2013) for additional detail in delineations of geologic areas.

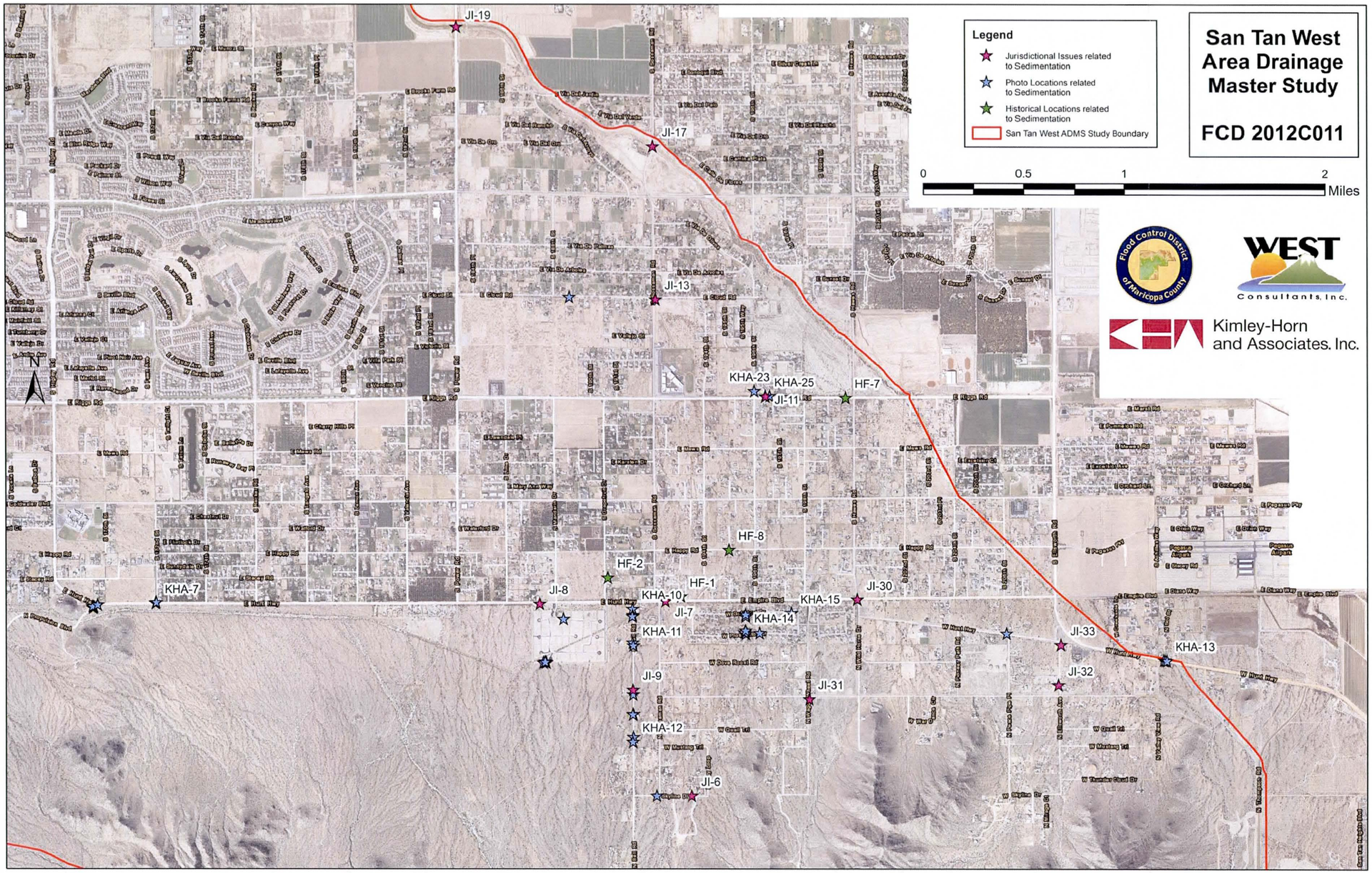

Figure 5. Zoomed-in view of Figure 4 showing labels for locations of sediment issues identified by local stakeholders (JI-##), identified from historical documents (HF-##), and identified during preliminary site visits (KHA-##). The labeling of the specific locations matches the "Drainage Issues" figure developed by KHA in the data collection report (KHA, 2013). It should be noted that the locations of sedimentation issues identified during preliminary site visits (i.e., blue stars) are not all labeled in this figure as the "Drainage Issues" figure did not explicitly discuss every picture obtained in the field. More information on every location can be found with the electronic data delivered with this report.

4 Identification of Sedimentation Problem Areas from Field Reconnaissance

The SOW for the field reconnaissance task of the River Mechanics portion of the project states the following:

Conduct field reconnaissance to identify active or incipient sedimentation problem areas;

- *Areas of abnormal sediment production such as disturbed land or denuded land surfaces.*
- *Flow concentration points experiencing local erosion.*
- *Zones of sediment deposition.*
- *Watercourses exhibiting streambed aggradation or degradation.*
- *Watercourses with banks that are susceptible to lateral migration.*
- *Collect sediment samples.*

During preliminary site visits during low-return-interval hydrologic events occurring on July 14 and July 29, 2012, KHA personnel obtained photos of active sedimentation problem areas. This section will report on those identified locations and propose a final site visit to address the other sedimentation issues addressed in the list above from the SOW.

The sites identified on the "Drainage Issues" figure developed by KHA and corresponding to some of the photo locations shown in Figure 4 above are described in greater detail in Table 4 below. The site photos corresponding to the KHA unique identifier for each photo have been included in Appendix A of this report as well.

From these site visits, the areas of primary concern for watercourses exhibiting streambed aggradation/degradation or lateral widening are the photos near Bell Road (significant sediment deposition on roadways can be seen in these photos). The photo taken at site KHA-10 corresponds to the eastern drainage pathway of the two drainage pathways stemming from point 1 (Figure 4) as the primary area of interest for sediment analyses moving forward. Both of these pathways (one flows to the west and the one identified in photo KHA-10 flows to the east) are shown in an aerial photograph in Figure 6. The berms on the downstream (i.e., northern) side of each of these drainage channels direct flows to the east and west along the drainage channels. The typical dissipation of flow and sediment near the downstream end does not occur; instead, flow and sediment are concentrated in one of these two drainage pathways. As can be seen from Photo A-3 of Appendix A (corresponding to site KHA-10), significant sediment loading in the eastern drainage pathway caused a large sediment deposit on Bell Road once the flow exited the confines of the drainage channel. These drainage features and associated sediment would be the highest priority for future sediment analyses in the watershed area. Issues persisted further north along Bell Road as well (see Photos A-4 and A-5 corresponding to sites KHA-11

and KHA-12, respectively). This is the result of sedimentation processes impacting the roadway (primarily roadside scour and sediment deposition on the roadway). While the drainage pathways shown in Figure 6 should be the primary focus of future sediment analyses, sedimentation issues across the remainder of the area denoted as point 1 (Figure 4) upstream of these channels would be the next highest priority for sediment analyses.

The remainder of sedimentation issues identified during the preliminary site visits were associated with the sites in the eastern portion of the watershed (KHA-13, KHA-14, KHA-15, KHA-23, KHA-25, and KHA-30) and to a much lesser degree the sites in the western portion of the watershed (KHA-6 and KHA-7). Based on these findings, additional sediment analyses should focus primarily on the drainage features entering the Cloud Road Basin from the eastern portions of the watershed. The drainages in the western portion of the watershed would be less important for sedimentation analyses, as the observed issues were less severe in this area.

While local sedimentation problems likely could exist in the developed, suburban portion of the northwestern watershed, the relative importance of these areas did not seem significant during the site visits in comparison to the sedimentation in the southern (i.e., south of Hunt Highway) and northeastern portions of the study watershed.

Table 4. Correlation between KHA's "Drainage Issues" figure and the drainage issues identified with field photographs taken during two low-return-interval flooding events in July 2012 shown in Figure 4. The *Severity* category is a qualitative scale of the damage as a result of the storm event. Issues that are related near each of the flooding issue locations are listed in the *Related Issues* column.

ID	Description	Location	Date of Photo	Severity	Related Issues[1]
KHA-6	Ponding at intersection of Hunt Highway with dirt road	Hunt Highway between Stacey Road and Propulsion Boulevard	2012-07-14	High	KHA-7, JI-21
KHA-7	Ponding along northern edge of Hunt Highway and eastern edge of 172nd Street	Hunt Highway and 172nd Street	2012-07-14	High	KHA-6, JI-21
KHA-10	Sedimentation on Bell Road	Hunt Highway and Bell Road	2012-07-14	Low	KHA-11, KHA-12, JI-9, JI-1
KHA-11	Washed out segment of Bell Road	Bell Road south of Hunt Highway	2012-07-14	Low	KHA-10, KHA-12, JI-9, JI-1
KHA-12	Erosion along western edge of Bell Road	Bell Road between Hunt Highway and Skyline Drive	2012-07-14	Low	KHA-10, KHA-11, JI-9, JI-1
KHA-13	Wash flowing across Hunt Highway	Hunt Highway between Thompson Road and Empire Boulevard	2012-07-14	Medium	
KHA-14	Sedimentation along Prospector Drive	Prospector Drive and Mariah Ln	2012-07-14	Low	KHA-15
KHA-15	Exposed Utilities south of Gold Dust Drive	Gold Dust Drive and Moyes Road	2012-07-14	Medium	KHA-14
KHA-23	Erosion and flooding along eastern edge of 196th Street	196th Street north of Riggs Road	2012-07-29	High	
KHA-25	Northerly sheet flow over Riggs Road	Riggs Road Between 196th Street and 196th Way	2012-07-29	High	
KHA-30	Debris covering culvert inlets	Thompson Road and Roberts Road	2012-08-03	Low	KHA-35

[1]*Refer to KHA's "Drainage Issues" figure for more specific details on complaints listed in this column (KHA, 2013)*

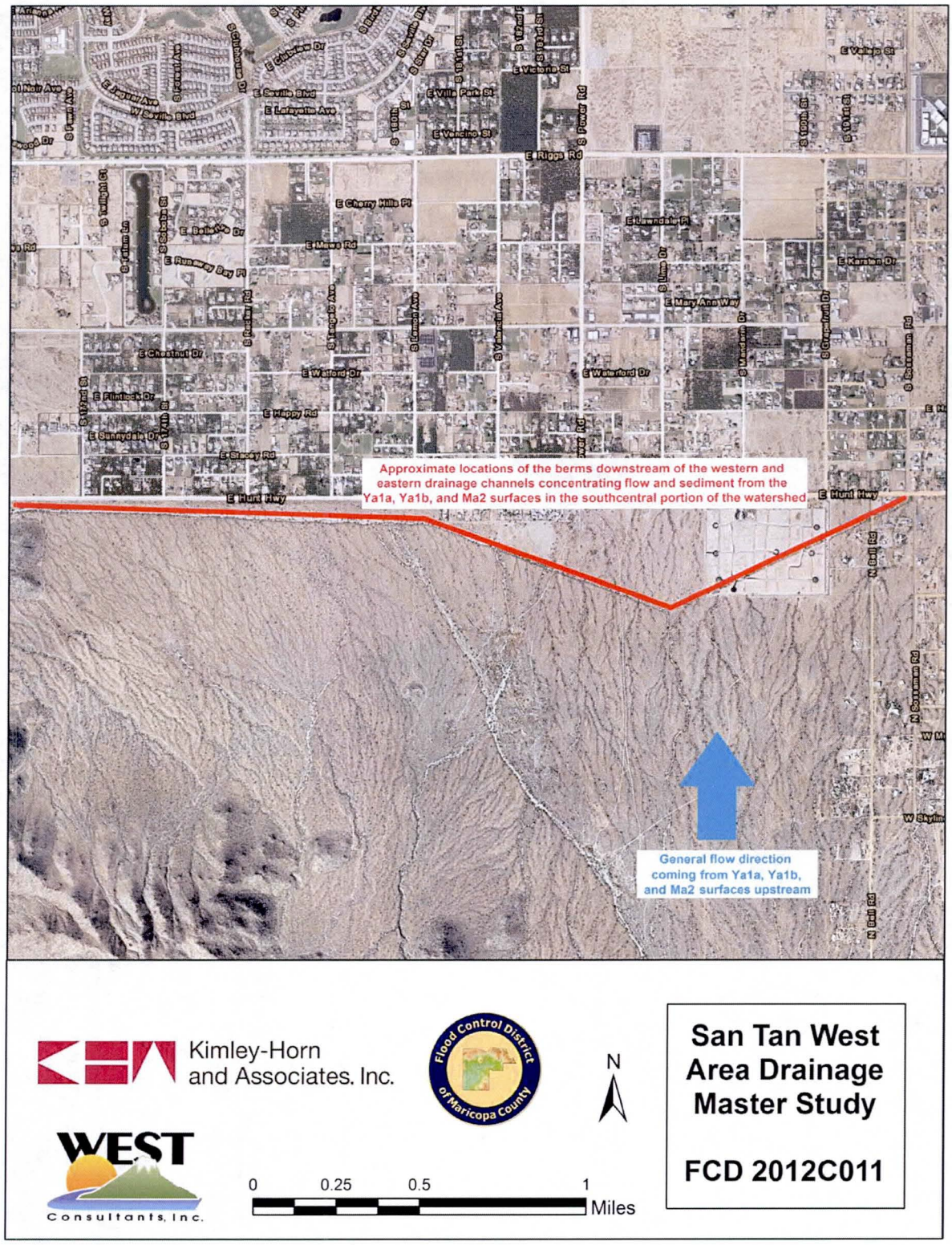

Figure 6. Location of berms that direct runoff of overland flow and sediment away from Hunt Highway.

5 Summary and Recommended Future Sediment Analyses

5.1 Summary

The preceding discussion provided the results of this reconnaissance-level sedimentation analysis of the San Tan West ADMS. The analysis herein included the following items as per the SOW: (1) stakeholders input, (2) geologic reconnaissance, and (3) field reconnaissance. Also as mentioned in the SOW, the preceding report provides watershed maps identifying active and incipient sedimentation problem areas while documenting the current sedimentation conditions at each location. Each of these areas could be considered critical sedimentation locations, and the relative importance of each of these areas to overall sedimentation processes can be found in Table 3.

To summarize the findings from this analysis, the drainage features and the sediment produced from point 1 (Figure 4) would be the highest priority for future sediment analyses in the watershed area. This is made exceedingly evident when reviewing the specific locations of sedimentation problems based on stakeholder input, historical document review, and photographic documentation of sedimentation problems as shown in Figure 4. The sedimentation problems identified along Bell Road are directly resulting from the sediment production and processes in this area. The next general area of greatest concern would be areas delineated as "modern stream channels (Ya2)" in the geologic definition as these were identified as being the general areas most susceptible to erosion and sediment transport via fluvial processes in the study watershed. Following these two areas, the identified order of relative importance for sedimentation problems related to the geologic units discussed in Section 3 above will define the remaining order of importance for sedimentation issues and focus areas for future sedimentation analyses. The entire list is summarized briefly below. It should be noted that the Areas of Concern A through D are considered herein to be of relatively high importance in overall sediment transport processes. Areas of Concern E through J, while still susceptible to sedimentation issues, are considered general areas of concern (as they correspond to wide-ranging geologic delineations and not specific areas in the study watershed) and their relative risk compared to Areas A through D are likely less. This is also denoted by a red line in the list below differentiating these two sections.

- Areas of concern for future sedimentation problems (see Figure 4 for relative locations):
    - ***Area of Concern A – highest concern)*** Drainage channels and berms upstream of the Santo Vallarta property south of Hunt Highway shown in Figure 6 and more generally the sediment produced from point 1 area (Figure 4). These areas are likely the most susceptible to significant future problems related to sedimentation.

    - ***Area of Concern B)*** Natural drainage pathways labeled as "modern stream channels (Ya2)" that empty into the Cloud Road Basin in the eastern part of the study watershed (i.e., those channels near point 2 in Figure 4contributing flow and sediment to the Cloud Road Basin).

    - ***Area of Concern C)*** Remaining natural drainage pathways labeled as "modern stream channels (Ya2)" in the delineation of geologic units not included in 'Area of concern B' above.

    - ***Area of Concern D)*** Engineered and constructed drainage pathways for flood control purposes (i.e., Sonoqui Wash and the East Maricopa Floodway) labeled as "Ephemeral stream channels – obscured (Ya2')" and "Ma2 over Ya" in the delineation of geologic units.

Authors ascribe relatively high risk to these specific locations

Authors ascribe relatively lower risk to these more generalized locations of lesser concern

    - ***Area of Concern E)*** Areas labeled as "pediment surfaces (Op)" in the delineation of geologic units.

    - ***Area of Concern F)*** Areas labeled as "younger Ya1 surfaces (Ya1a)" in the delineation of geologic units.

    - ***Area of Concern G)*** Areas labeled as "older than Ya1a (Ya1b)" in the delineation of geologic units.

    - ***Area of Concern H)*** Areas labeled as "older fan surfaces located on upper piedmont (Ma2)" in the delineation of geologic units.

    - ***Area of Concern I)*** Areas labeled as "gravel pit (inactive)" in the delineation of geologic units.

    - ***Area of Concern J – lowest concern)*** Areas labeled as "disturbed surfaces (Ya)" in the delineation of geologic units.

Review of the final FLO-2D model results for the San Tan West ADMS confirms the relative order of areas listed above for future sedimentation research. The flooding depths and velocities in the drainage channels upstream of the Santo Vallarta property south of Hunt Highway are much deeper with greater velocities than flows from other parts of the watershed due to the concentration of flows in these channels caused by the berms. Therefore, erosive force and the possibility of sediment transport processes occurring in these channels would be most pronounced in these drainage channels. Similarly, the next area of primary concern from a sedimentation perspective based on review of the FLO-2D model results would be the natural drainage pathways in the area (i.e., areas labeled as "modern stream channels (Ya2)" in the delineation of geologic units) as flooding depths and velocities are greater in these small channels than other areas on the grid.

5.2 Recommended Future Sediment Analyses for the Study Watershed

Future detailed sediment analyses could be employed to better quantify possible sedimentation issues in the study watershed. Specific recommended tasks that could be initiated to complete this objective include field sampling, computation of upland sediment loading using methodologies outlined in the District hydraulics manual (District, 2013), a temporal analysis of aerial photographs to identify areas with lateral bank migration, quantitative assessment of bedload and sediment transport capacity in channels throughout the watershed through additional results extraction from the FLO-2D models developed for the San Tan West ADMS, and numerical sediment transport modeling. Each of these tasks is discussed in greater detail individually below.

Considering the various areas identified as areas of future concern for sedimentation issues above and the recommended future sedimentation analyses proposed herein, a list of areas to include in future sedimentation analyses (ranked in relative order of importance) is provided below. It should be noticed that this list varies only slightly from the ranked list of areas of sedimentation concerns in the watershed; the only difference is that the engineered channels and areas contributing to the Cloud Road Basin—both very high priorities on the list of future concern for sedimentation issues—are near the bottom of the list for recommended areas of focus for future sedimentation analyses. This is due to the significant studies completed for both of these areas previously and the lack of sufficient hydrologic and hydraulic analysis within the San Tan West ADMS to conduct a complete sedimentation analysis of these areas solely from the results of this ADMS. Additional hydrologic and hydraulic information would be needed to supplement the results of the San Tan West ADMS before a full sedimentation analysis of these areas could be conducted. See the list below for additional discussion of these two areas. Similarly to the areas of concern for sedimentation listed above, it should be noted that the Areas of Future Study 1 and 2 are considered herein to be of relatively high importance in overall sediment transport processes. Areas of Concern 3 through 10, while still susceptible to sedimentation issues, are considered less critical for future sedimentation analysis due in part to the fact that some of these areas correspond to wide-ranging geologic delineations and not specific areas in the study watershed and due in part to the previous study that has been done for certain specific areas. This demarcation is also denoted by a red line in the list below differentiating these two sections.

- Recommended areas of focus for future sedimentation analyses (see Figure 4 for relative locations):
    - ***Area of Future Study 1 – highest recommendation)*** Drainage channels and berms upstream of the Santo Vallarta property south of Hunt Highway shown in Figure 6 and more generally the sediment produced from point **1** area (Figure 4). This area is likely the most susceptible to significant future problems related to sedimentation.
    - ***Area of Future Study 2)*** Remaining natural drainage pathways labeled as "modern stream channels (Ya2)" in the delineation of geologic units not included in 'Area of Future Study 9' below.

Authors ascribe relatively high interest to these specific locations

Authors ascribe relatively lower interest to these more generalized locations of lesser concern

- ***Area of Future Study 3)*** Areas labeled as "pediment surfaces (Op)" in the delineation of geologic units.

- ***Area of Future Study 4)*** Areas labeled as "younger Ya1 surfaces (Ya1a)" in the delineation of geologic units.

- ***Area of Future Study 5)*** Areas labeled as "older than Ya1a (Ya1b)" in the delineation of geologic units.

- ***Area of Future Study 6)*** Areas labeled as "older fan surfaces located on upper piedmont (Ma2)" in the delineation of geologic units.

- ***Area of Future Study 7)*** Areas labeled as "gravel pit (inactive)" in the delineation of geologic units.

- ***Area of Future Study 8)*** Areas labeled as "disturbed surfaces (Ya)" in the delineation of geologic units.

- ***Area of Future Study 9)*** Natural drainage pathways labeled as "modern stream channels (Ya2)" that empty into the Cloud Road Basin in the eastern part of the study watershed (i.e., those channels near point 2 draining flow and sediment to the Cloud Road Basin). This area is the near the bottom of the list of recommended focus areas for future sedimentation analyses due to prior studies related to sedimentation and sediment transport processes that has been conducted for these drainage areas in the final design of the Sonoqui Wash Phase III engineered channel (JE Fuller Hydrology & Geomorphology, Inc., 2012). This area is also low on the list of recommended future sediment transport analyses because the San Tan West ADMS study area does not include the entirety of the drainage area upstream of the Cloud Road Basin. Therefore, additional hydrologic/hydraulic analyses would be necessary to supplement the hydrologic/hydraulic analyses conducted for this ADMS before an adequate sedimentation analyses could be completed for this area.

- ***Area of Future Study 10 – lowest recommendation)*** Engineered and constructed drainage pathways for flood control purposes (i.e., Sonoqui Wash and the East Maricopa Floodway) labeled as "Ephemeral stream channels – obscured (Ya2')" and "Ma2 over Ya" in the delineation of geologic units. This area is the last on the list of recommended focus areas for future sedimentation analyses due to significant prior study related to sedimentation and sediment transport processes that has been conducted for these engineered channels (e.g., WEST Consultants, Inc., 2000; Kirkham Michael and Associates, Inc., 2002; JE Fuller Hydrology & Geomorphology, Inc., 2012). This area is also last on the list of recommended future sediment transport analyses because the San Tan West ADMS study area does not include the entirety of the drainage area

upstream of the Sonoqui Wash or the East Maricopa Floodway. Therefore, additional hydrologic/hydraulic analyses would be necessary to supplement the hydrologic/hydraulic analyses conducted for this ADMS before an adequate sedimentation analyses could be completed for these channels.

The following sections outline the recommended future sediment analyses listed above in greater detail.

5.2.1 Additional Site Visit

WEST recommends one additional site visit to collect sediment samples to arrive at typical sediment gradations for sediment transported in the areas of concern outlined above, including primarily point 1 (both near the apex and within the eastern and western drainage channels at the downstream end) and the drainage features emptying into the Cloud Road Basin. Additionally, further reconnaissance could be done to identify areas of local erosion and sedimentation problems in the northwestern portion of the watershed that have not been identified to this point.

5.2.2 Sediment Yield Computations

WEST recommends computing the inputs for the District's recommended method for estimating sediment yield using the Modified Universal Soil Loss Equation (MUSLE) methodology (District, 2013). The LS factor based on the slope grid from the topography (which has already been developed for this study as shown in Figure 7 below) could be computed very quickly at this point, and much of the soils and land use information necessary to fully calculate the MUSLE computation of overland sediment production and runoff distributed spatially throughout the watershed using GIS methodologies have already been developed for the San Tan West ADMS. With very little additional GIS processing, the spatial distribution of sediment production in the watershed could be completed to aid in future quantitative sediment analyses of erosion, transport, and deposition throughout the study watershed. These sediment yield computations could be informed directly by hydraulic calculations of the FLO-2D results in this study (refer to Section 0 below for further explanation).

5.2.3 Lateral Bank Migration Risk Assessment

WEST recommends assessing lateral bank migration risk for the primary watercourses in the areas of concern identified in this report using two methodologies: the District's lateral migration estimation methodology and the utilization of historical and current aerial photographs collected for this ADMS to perform geomorphic planform assessment of lateral bank migration. The District's lateral migration estimation methodology can be found directly in the District hydraulics manual (District, 2013). The geomorphic planform analysis from aerial photographs could be divided into the following two steps. First, WEST proposes to review the aerial photographs from a zoomed-out map scale to identify qualitatively the areas with the most distinct planform changes to determine if the general categorization of the areas of concern outlined in this memo (point '1' and point '2' from Figure 4)

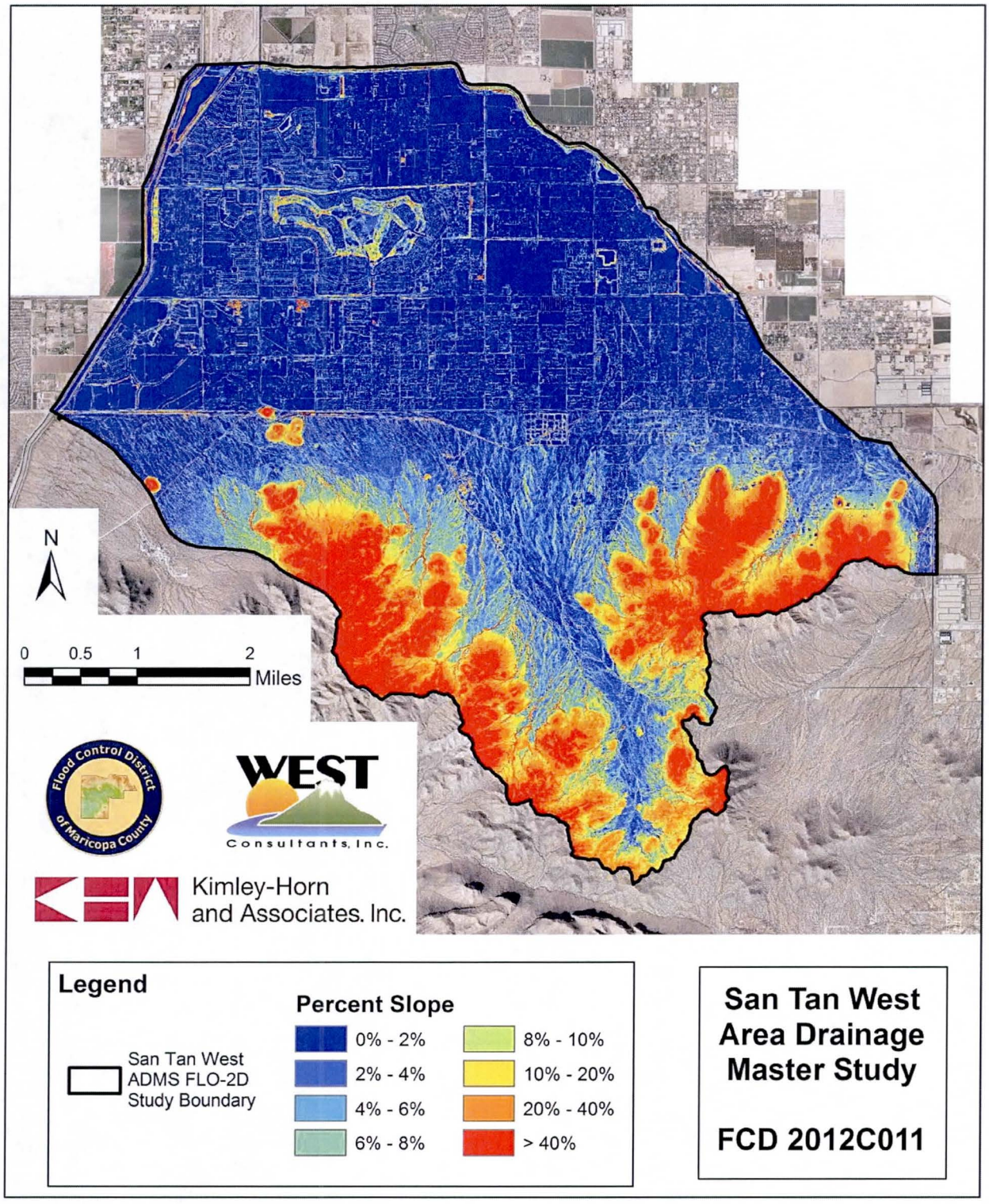

Figure 7.Slope grid of the FLO-2D study watershed based on the final topography developed by KHA that could be used to developed the LS grid for input to the MUSLE computation of overland sediment production.

corresponds to the most active lateral migration processes. Second, WEST proposes to quantitatively assess lateral bank migration rates at areas of principal concern by tracing bank lines in GIS and utilizing the changes in bank line geometry to calculate historic lateral bank migration rates.

5.2.4 Bedload and Sediment Transport Capacity Computations from FLO-2D Results

WEST recommends conducting a quantitative assessment of bedload and sediment transport capacity in channels throughout the watershed through additional results extraction from the existing FLO-2D models. By adding additional floodplain cross sections to the model domain in FLO-2D at specific areas of interest for sedimentation in the study watershed and rerunning the models, additional hydraulic information can be extracted at these locations to compute sediment transport characteristics of channels or washes needed to complete bedload and sediment transport capacity computations. These types of computations are useful in the design or modification of channel stabilizing structures or watershed-scale solutions to sedimentation problems (e.g., required reduction in upstream loading to reduce the risk of significant continued aggradation).

5.2.5 Application of FEMA's Stage 2 Analysis to Define Active and Inactive Alluvial Fans

WEST and the River Mechanics Branch of the Engineering Division of the District recommend possibly conducting FEMA's Stage 2 Analysis as per their alluvial fan flooding methodology with enhancements proposed by the District to define active and inactive alluvial fans in the study area. This will help corroborate the previous Pinal County study (Entellus, 2006) which identified a "hydrologic alluvial fan" landform in the study area (without specifying the status of the identified fan as "active" or "inactive") and the Santo Vallarta report (French, 2009) which stated that fan surfaces were "inactive" for engineering time scales. Additionally, this task would help better define future sedimentation studies and floodplain mapping methodologies acceptable to FEMA for the study area, depending on the results of the Stage 2 Analysis.

5.2.6 Numerical Sediment Transport Modeling

Finally, WEST recommends possibly conducting numerical sediment transport modeling in the future for use in the study area. The sediment transport computation module of FLO-2D could be used directly with the base conditions hydrology/hydraulics FLO-2D models developed for this ADMS, or another numerical sediment transport model could be used for this task. This would be the most detailed future sedimentation analysis proposed herein for the study area.

6 References

Entellus, Inc. 2006. Pinal County Area Drainage Master Plan: Phase A, Goldmine Mountain. Prepared for the Pinal County Department of Public Works.

Federal Emergency Management Agency (FEMA). 2002. Guidelines and Specifications for Flood Hazard Mapping Partners – Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping.

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French, Richard H, PhD, P.E. 2009. "Letter to Mr. Scot Schlund, Managing Sr. Principal, in regards to the Santo Vallarta Property."Dated October 7, 2009.

Geological Consultants, Inc. 2013. Geologic Assessment of the San Tan West ADMS.Prepared for the Flood Control District of Maricopa County on behalf of Kimley-Horn and Associates, Inc.

JE Fuller Hydrology & Geomorphology, Inc. 2012. Sonoqui Wash Channelization, Phase III: Riggs Road to Empire Boulevard. Prepared for the Flood Control District of Maricopa County.

Kimley-Horn and Associates, Inc. 2013. San Tan West Area Drainage Master Study Data Collection Report. Prepared for the Flood Control District of Maricopa County.

Kirkham Michael and Associates, Inc. 2002. East Maricopa Floodway Chandler Height Basin Design: Predesign Study. Prepared for the Flood Control District of Maricopa County.

WEST Consultants, Inc. 2000. Sediment Transport Analysis - Queen Creek and Sanokai Wash Hydraulic Master Plan, East Maricopa Floodway Capacity Mitigation Study, Final Report. Prepared for the Flood Control District of Maricopa County on behalf of Huitt-Zollars, Inc.

Appendix A: Pictures of Sedimentation Issues from the Preliminary Field Reconnaissance

Photo A-1 – Local erosion feature at KHA-6

Photo A-2 –Local sediment and debris buildup feature at KHA-7

Photo A-3 – Sedimentation on Bell Road from the eastern branch of the split flow path along the berm at KHA-10

Photo A-4 – Washed out portion of Bell Road at KHA-11

Photo A-5 – Erosion along western edge of Bell Road at KHA-12

Photo A-6 –Wash and sediment flowing across Hunt Highway at KHA-13

Photo A-7 –Sedimentation along Prospector Drive at KHA-14

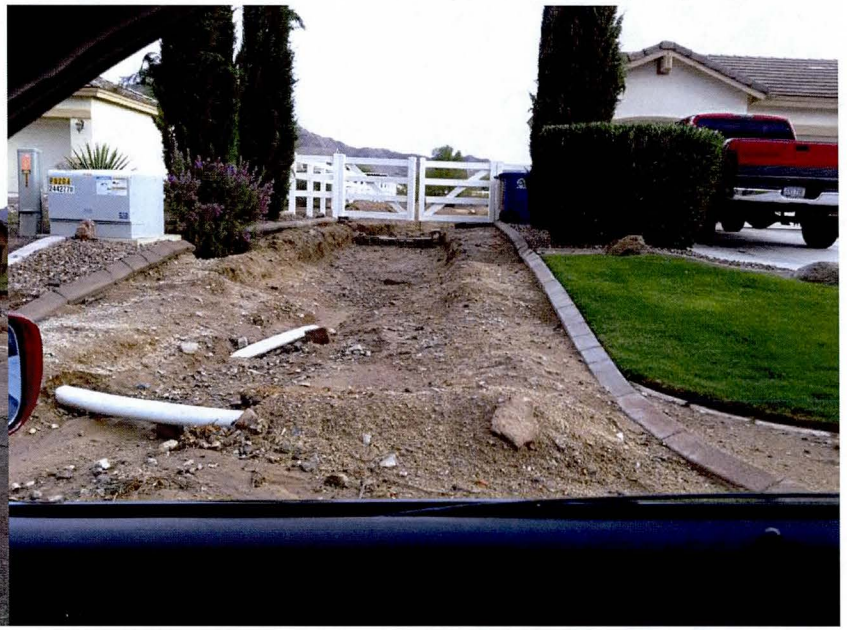


Photo A-8 – Exposed Utilities south of Golddust Drive at KHA-15

Photo A-9 – Erosion and flooding along eastern edge of 196th Street at KHA-23

Photo A-10 –Northerly sheet flow over Riggs Road and local erosion at KHA-25

Appendix E. Stakeholder and Public Involvement

Stakeholder Strategy

For this study, the primary stakeholders were the Towns of Gilbert and Queen Creek, Pinal County, and the Gila River Indian Community (GRIC). Although Arizona State Land Department (ASLD) has some holdings in the vicinity, these were not considered substantial enough to involve ASLD especially considering that the primary focus of the study is to identify existing problems. A list of stakeholder contacts is provided.

The goals of the study include compiling available information about existing problems, developing a comprehensive and detailed (fine resolution) FLO-2D model of the study watershed, using the model to corroborate and quantify the identified problems, and working with the stakeholders to develop a consensus concerning which of those problems should be recommended for additional work. The core of the stakeholder coordination strategy included a series of formal group meetings as well as numerous informal one-on-one meetings to identify those issues and concerns specific to individual stakeholders.

Three formal meetings were held. The first, held July 17, 2012 was an initial orientation to familiarize the stakeholder representatives with the project team, the scope of work and proposed work plan, and the anticipated timetable. This meeting was also used to help identify appropriate contacts within each organization for the purpose of acquiring historical and anecdotal flooding data. The second, April 29, 2013, was a workshop focusing on stakeholder needs and expectations. This meeting was also used to report project status and provide the stakeholders with a better understanding of the capabilities and constraints of the FLO-2D model. The third and final meeting, October 10, 2013 was also a workshop at which the (near final) results of the data collection and modeling efforts were presented to the group, along with the problem areas identified by the team. An additional objective was to provide a preview of the information to be presented at the final public meeting.

The group was provided with a draft copy of the ADMS Report prior to the meeting and encouraged to critically review the draft with respect to possible improvements and clarifications. The workshop was also used to determine the amount of interest each stakeholder might have with regard to participation in future mitigation projects for the identified problems. Several good ideas were developed including extension of the Farmer Dike channel to solve some of the persistent drainage problems impacting residents of Maricopa County, Queen Creek, and Pinal County. These ideas were captured and documented in the Recommendations section of the ADMS Report.

All of the study materials including the model files will be provided to each of the stakeholders for their use and to enhance and facilitate future project coordination.

STAKEHOLDER CONTACTS

Mr. Burke Lokey, P.E., CFM, PMP, Proj. Mgr.
Flood Control District of Maricopa County
2801 W. Durango Street
Phoenix, AZ 85009
(602) 506-0867

Mr. Seaver Fields, E.I.T.
Gila River Indian Community
291 West Casa Blanca Road – P.O. Box E
Sacaton, AZ 85147
(520) 562-6003

Mr. Edgar Medina, P.E.
Town of Gilbert
90 E. Civic Center Drive
Gilbert, AZ 85296
(480) 503-6700

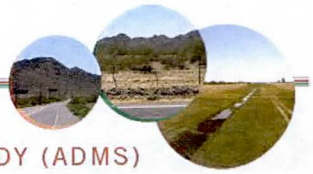
Ms. Elise Moore, P.E., CFM
Pinal County Public Works Department
31 N. Pinal Street, Building F
Florence, AZ 85132
(520) 866-6411

Mr. Chris Dovel, P.E., CFM
Town of Queen Creek
22350 S. Ellsworth Road
Queen Creek, AZ 85142
(480) 358-3067

All meeting notes and copies of handouts for each stakeholder meeting are included in the digital data in **Appendix F**.

Public Involvement

Two public meetings were held throughout the project. Both took place at the Newell Barney Jr. High School at the northeast corner of Sossaman and Riggs Roads. The first meeting was May 7, 2013 and was attended by District and Kimley-Horn staff and approximately 20 residents. The objective of the meeting was to inform the public about the goals of the study, and to gather local input on the drainage issues in the area. The project team displayed preliminary model results in the form of animation of the FLO-2D model runoff depths. The second meeting was held October 10, 2013 and was attended by District and Kimley-Horn staff, representatives from the GRIC, the Towns of Gilbert and Queen Creek, and 50 residents. The goal of this meeting was to communicate the near final results of the model, gain input, and discuss the Potential Mitigation Areas as defined in Section 6 of this report. Full size maps were prepared for both meetings, and residents' comments were recorded on the maps. All meeting notes and copies of the maps are included in the digital data in **Appendix F**.



Appendix F. Digital Files

- Data Collection
- Figures
- Geologic Report Support Data
- Hydrology and Hydraulics Support Data
- Sediment Study Area Memo Support Data
- Stakeholder and Public Involvement Support Data
- ADMS Report (PDF Format)

Kimley-Horn and Associates, Inc.

APPENDIX F – DIGITAL DATA

This jump drive contains Appendix F of the San Tan West Area Drainage Master Plan final report.

Items included on the disk are:

Data Collection

- Data Collection Log
- Flooding Issues List

Figures

- All report figures listed in Table of Contents, List of Figures

Geologic Report Support Data

- Information in support of the Geological Technical Memorandum in Appendix C of the report:
  - Geology shapefiles
  - Geology photo shapefiles

Hydrology and Hydraulics Support Data

- Information in support of Section 3, Hydrology and Hydraulics in the report:
  - FLO-2D Model Development Memorandums and Responses to Comments
  - FLO-2D Models and Supplemental Data

Sediment Study Area Memo Support Data

- Information in support of the Sediment Study Area Technical Memorandum in Appendix D of the report:
  - See Readme.txt file for contents

Stakeholder and Public Involvement

- Meeting notes, handouts, exhibits and sign-in sheets

ADMS Report-Final

- Final complete sealed report