APPENDIX C

SEDIMENT AND DEBRIS FLOW

Table of Contents

Section **Page**

LIST OF FIGURES

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C.1.0 INTRODUCTION

C.1.1 Purpose and Scope

The purpose of this reconnaissance-level investigation is to identify areas of debris flow occurrence and erosion/sedimentation susceptibility during high intensity precipitation events in the Franklin Mountains area of the City of El Paso, Texas. The scope of the study was limited to the Franklin Mountains and the immediate slope areas where alluvial fan development has occurred in geologic history. The need for this investigation was prompted by the occurrence of a significant stormwater event during Water Year 2006.

During the period of July 27, 2006 to August 6, 2006, a rare meteorological condition formed in western Texas and southern New Mexico that resulted in an intensity that was evaluated as exceeding the 100-year return period on the areas east of the Franklin Mountains and approximately a 250 to 500-year return probability for the areas west of the Franklin Mountains in the City of El Paso, Texas. Flood flows associated with the heavy rainfall contained a higher than typical amount of sediment, including materials that overwhelmed the stormwater management and drainage system in parts of El Paso and resulted in damage that included washed out roads and flooding in urban areas. Flood related damages have been estimated to exceed $200 million. A long period of light precipitation, followed by heavy rain, may have been responsible for debris flow occurrence in the region.

URS Corporation (URS) is currently conducting an investigation with the El Paso Water Utilities (EPWU) Public Service Board (PSB), Stormwater Department, to prepare a Master Drainage Plan. This field mapping effort was conducted as Tasks 3b and 3d under the Scope of Work as part of this plan. The delineation of areas subject to elevated risk of debris flow will be used by EPWU as a basis for defining revised procedures for real estate developers to follow in terms of stormwater hydraulic design and design of stormwater management infrastructure within the City of El Paso and its Extra-Territorial Jurisdiction (ETJ).

C.1.2 Methods of Investigation

A field mapping investigation was conducted to identify and document the location of potential future debris flow deposits within the Franklin Mountains area. Additionally, areas of active erosion and channel instability were mapped in terms of assessing where active streamflow transport processes were occurring. These processes were considered where active erosion of channels was observed in alluvial sediments. The field investigation was conducted from August 4, 2008 to September 3, 2008 using topographic base maps, including United States Geological Survey (USGS) topographic maps, scale 1:24,000, dated 1973, that had a 40-foot contour interval, for the west side of the Franklin Mountains, and topographic maps, scale 1:24,000, dated 2002, that had a 3-foot contour interval, for the east side of the Franklin Mountains. Aerial photographs of the mapped area provided by Texas Natural Resource Information System (TNRIS), dated 2005, also printed with a scale of 1:24,000, were used as a tool to develop the debris-flow hazard/erosion instability maps and delineate the areas of active alluvial fan processes. Use of the aerial photos was important because of difficult access to many areas in the mountains and the limited time available to conduct the mapping. The delineation of mapped areas are shown on Figures C-1 to C-8. Figure C-9 shows a delineation of areas of alluvial fans as characterized by the methods described in “Guidelines for the Geologic Evaluation of Debris-Flow Hazards on Alluvial Fans in Utah“(Giraud, 2005). This methodology identifies proximal, medial, and distal portions of the presumably active alluvial fan processes in the El Paso area. The area mapped for potential future debris flow deposits consisted mostly of bedrock regions within the Franklin Mountains; therefore, the mapping was conducted within the drainage basins upstream of the alluvial fans. It is noted here that the aerial photographs show the topography in a pre-flood condition. Examination of photographic data from other public sources showing post-flood conditions indicates dramatic changes in stream morphology following the July-August 2006 precipitation event.

C.1.3 Description of the Study Area

The Franklin Mountains are a range of peaks approximately 16 miles long and 5 miles wide with a general relief of over 3,000 feet above the surrounding basins. They are comprised of pre-Cambrian to Pleistocene-age rocks and are locally overlain by recent sediment. The rocks consist of granite, rhyolite, marble, quartzite, sandstone, limestone, dolomite, conglomerates, colluvium, and alluvium. The Franklin Mountains are characterized by a single range of knife-edge ridges that are uplifted bedding dipping steeply to the east. The central core of the mountains is comprised of vast exposures of bedrock with little sediment accumulation or soil formation. The slopes of the mountains on both east and west have developed a series of alluvial fans that are both mature to aging/dissecting in the uplands to active/mature in the lowlands. These alluvial fans, because of their relatively moderate slope gradients, have become favorable areas for real estate development. Significant real estate development has occurred on the alluvial fans (particularly on the west slope). This development with its inherent effect of urban hydrology has disrupted the normal life cycle of alluvial fan formation and aging. The developed areas tend to greatly decrease or cease any further deposition/transport of sediments because of the high degree of impervious cover. These developed areas tend to starve the lowlands of sediment with the exception of what is transported directly from the high-gradient mountainous areas through open stormwater channels to the basin below. There are areas of alluvium that were identified in this study that are nevertheless actively eroding because of the nature of their sediments and were thus mapped as part of this investigation. Some areas are particularly susceptible to debris flows because of the nature of their source sediments. In particular, the areas that have a predominant occurrence of granitic rocks contribute significantly to source sediments that develop debris flows. Granitic rocks tend to decompose to a coarse to fine sand that flows readily when saturated with water from precipitation events of sufficient intensity. Areas of a predominant occurrence of granitic rocks also showed numerous accumulations of talus in the higher altitude valleys that are susceptible to potentially catastrophic debris flow. Other areas that are comprised of accumulations of weakly cemented alluvium comprised of limestone/dolostone (and other non-granitic rocks) have been providing source sediments (particularly on the western slope of the Franklin Mountains). These areas have been contributing sediments during storm events that have overwhelmed existing stormwater management systems in the real estate developments down-slope.

C.1.4 Geologic Framework of the Franklin Mountains

The geologic framework of the Franklin Mountains area serves as a significant contributing factor for the conditions that allow debris flows to occur. Among these geologic aspects are source material, topography, geomorphology, and degree of weathering.

The geologic formations that outcrop in the Franklin Mountains area are rocks of Pre-Cambrian to Quaternary age (1.4 billion years old to recent). These geologic formations are comprised of widely varying material that include granite, rhyolite, quartzite, marble, limestone, sandstone, conglomerate, and alluvium. These various materials occur in a wide range of weathering and cementation that directly affects their availability as a source material for debris flow formation or erosion. Harbour (1972) documents the geology of the Franklin Mountains in the northern areas. There are large areas where outcrops of granitic rocks occur. These are generally the areas where the greatest degree of weathering is occurring and generation of materials for debris flows. The second most debris flow prone areas are the portions where older alluvial fan deposits are actively being eroded. Those areas that have already been developed and are well urbanized are generally considered stable and generate little additional materials.

The topography of the Franklin Mountains is a significant factor in the occurrence of debris flows. The Franklin Mountains attain a maximum elevation of 7,192 feet above sea level (at North Franklin Mountain). These peaks form a near continuous ridge line that runs approximately 15 miles from the southern end north to the New Mexico border. The range attains a relief of over 3,200 feet above the surrounding Mesilla and Hueco Valleys. Slopes are generally very steep in the rock outcropping areas of the mountains with lesser grade slopes on the areas of alluvial fan deposition.

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C.2.0 FIELD MAPPING

An approach for mapping potential debris flow deposits was selected to allow mapping to be completed over the entire Franklin Mountain range, an area of approximately 100 square miles, which is nearly surrounded by the El Paso City limits. The fieldwork and mapping was completed in about 10 working days during the period of August 4, 2008 to September 3, 2008. The general approach included the following:

- An initial field reconnaissance was conducted of the entire area via windshield survey of the perimeter of the Franklin Mountains and making observations of alluvial fans that surround the mountains. Potential debris flow deposits could be observed from a distance with the aid of binoculars. A number of debris flow deposits, including one interpreted to have occurred in August 2006, were observed near Fairbanks Drive on the eastern slope of North Franklin Mountain. Although the alluvial fans were located outside the mapped area, they were helpful in observing materials deposited during flood events.
- The debris-flow mapping was conducted by terrain walk in the mountains, often on trails located along and crossing the crest of the Franklin Mountains range, which offered closer views of the potential debris flow deposits. Large areas of the Franklin Mountains were observed from the crest of the range or from valleys below, with the aid of binoculars. In general, the bedrock areas of the Franklin Mountains are relatively rugged, with local relief of 1,000 to 3,000 feet. Many areas were difficult to access because of the steep and rugged terrain. The Castner Range area of Fort Bliss was observable from the perimeter areas only as Fort Bliss-Directorate of Public Works (DPW) denied access to the site.

C.2.1 Field Mapping Results

The occurrence of debris flows in the Franklin Mountains area can be categorized into three specific regimes of flow. These are stream/flood flows (< 20% sediment by volume), hyper-concentrated flow (20-60% sediment by volume), and debris flow (> 60% sediment by volume). These occur in the order of frequency as listed with true debris flow being the least common, although the most potentially destructive.

Results of the field mapping are shown on Figures C-1 to C-8. Potential future debris flow source deposits were mapped as three units, including existing debris flows, talus and colluvial deposits judged to consist of materials that could form debris flows, and alluvial filled channels in the bedrock and alluvium that could contribute materials to debris flows. The existing debris flows included debris flows that probably occurred during the 2006 precipitation event as well as older debris flows that were judged to have potential to contribute materials to debris flows that could form in the future. In these areas, future debris flows would mobilize materials deposited by previous debris flows. Additional deposits were mapped as materials that might form future debris flows, and are often located adjacent to existing debris flows. The materials include portions of talus and colluvial deposits along debris flow channels. Portions of alluvial filled channels were also mapped as potential debris flow deposits because they may contribute materials to the debris flows or bulk up the debris flow. Giraud, 2005, suggests that 80-90% of the volume in the debris flow originates from the channel. In the Franklin Mountains bulking of the debris flows was observed in the narrow, relatively steep ravines in bedrock areas as well as channels on the alluvial filled valleys and fans downstream of the bedrock areas.

Figure C-9 shows areas of delineated alluvial fan processes as related to the proximal, medial, and distal portions of each fan deposit. Under the methods of Giraud, these might be considered as a high, medium, and low risk of debris flow and/or erosion risk. However, it was observed that much of the urbanization and even minor development in the study area (i.e. road, pipeline, and transmission line construction) has largely disrupted the typical processes of alluvial fan process geology. In undeveloped areas, there was observed typical transport of sediments throughout all areas of the fans, indicating that hydraulic analysis of each individual basin and the associated bulking factors for transported sediment should be considered when designing mitigating stormwater infrastructure by real estate developments.

Erosion potential within the Franklin Mountains area was assessed by examining the 2005 TNRIS aerial photo set of the study area and then field checking by terrain walk and vehicle (where possible). Active sediment transport is easily identifiable in aerial photos through the noticeable absence of vegetation in the stream channels. These areas were mapped in pink on Figures C-1 to C-8.

C.3.0 EVALUATION OF SELECTED DEBRIS FLOW SITES

Based on results of mapping potential future debris flow deposits, the Franklin Mountains contain a large number of drainage basins, each with variable size, type of bedrock, amounts and types of surficial deposits, and topography that result in variable potential for future debris flows. Several sites were selected for discussion in this survey as they exhibit stream-flow sediment transport processes that are typical in the study area. These major debris flows and the associated erosion process are discussed in this section.

C.3.1 General Conditions for Debris Flows

The Franklin Mountains consist almost entirely of eroded bedrock terrain typically containing some colluvial-covered slopes, talus slopes, and narrow alluvial-filled valley bottoms. Surficial deposits are therefore relatively small in area and volume. The sparse vegetation, erosion resistant bedrock, and arid climate combine to form conditions favorable for flash flooding; however, debris flows would likely be rare events. Colluvial, talus, and alluvial deposits consist mostly of gravel, cobbles, and boulders with a silty sand matrix that has a relatively high permeability, and would be expected to be free draining. Only during heavy rainfall on relatively steep slopes would the granular materials be mobilized into debris flows. This general observation is discussed further for a number of specific debris flows mapped in drainage basins within the Franklin Mountains.

C.3.2 McKelligon Canyon Debris Flows

In McKelligon Canyon a debris flow was mapped (Figure C-7) that contained gravel to cobble-sized granite clasts deposited in a relatively narrow lobe on top of a small alluvial fan. The lobe also had marginal dikes composed of the granitic debris. The debris flow was deposited on alluvial fan slopes that were flatter than the gradient in the ravine, above the alluvial fan. The coarse, gravel to cobble sized materials may have contained some sand-sized material that was washed away or migrated into relatively coarse underlying material. Some of the debris had apparently entered the intermittent stream channel in the bottom of McKelligon Canyon and was washed away by stream flood flows. The alluvial valley bottom in McKelligon Canyon was eroded by the flood flows, with channels enlarged, vegetation removed, and channel banks eroded to near vertical slopes up to 8 or 10 feet high. Interviews with Texas Parks and Wildlife Department (TPWD) staff at Franklin Mountains State Park (FMSP) revealed that the July/August 2006 precipitation event mobilized significant amounts of stored alluvial materials within McKellgon Canyon that precipitated debris flows throughout lower areas of valley. These debris flows were assessed from an examination of materials observed that indicated the flows were probably in the hyper-concentrated flow regime. The material clasts occurred in the sand to boulder range with the larger clasts comprising the bulk of the material. The large volume of material transported caused significant damage to infrastructure within the McKelligon Canyon Unit of the FMSP that included blocked and damaged roads, damage to building structures (primarily because of re- channelized flood flow); and loss of electrical and plumbing conduits in the Park. This unit of the Park was closed from August 2006 to early 2008 because of the damage. There are still significant post-flood infrastructure repairs ongoing in the Park to mitigate flood flows should they recur. A large earthen retention dam has been constructed at the entrance to McKelligon Canyon to prevent flood and debris flows from reaching the populated and urbanized areas of El Paso on the eastern side of the Franklin Mountains. It is apparent that because of the occurrence of the 2006 precipitation event, a significant volume of alluvial material has been eroded and remobilized within the McKelligon Canyon area. Many of the older alluvial deposits (of early Quaternary age) have been de-stabilized and will serve as significant contributors of new alluvial deposition for decades to come. These materials will eventually be transported into the retention basin at the mouth of McKelligon Canyon. It is likely that maintenance of transportation/stormwater management infrastructure and of the sediment basins may be problematic for the foreseeable future in this area.

C.3.3 Fairbanks Drive Debris Flows

A number of debris flows were observed on the surface of the alluvial fan located west of US 54 (Patriot Freeway) and north of Loop 375 (Trans-Mountain Road) on the east slope of north Franklin Mountain. This area is located on the Castner Range area of Fort Bliss property immediately adjacent to Fairbanks Drive. The debris flows include what was interpreted to be related to the July/August 2006 event and an older, larger debris flow deposit that predated the man-made features at Fort Bliss. This area was documented as one of the most significant of the debris flows that occurred during the August 2006 precipitation event as identified in interviews with EPWU personnel. The debris flow appears to have originated from a drainage basin in the Indian Springs Canyon area on Castner Range. Photo 1 below shows a plan view of the location of Fairbanks Drive. The aerial photo in Photo 2 (looking westward) shows the extent of the debris flow on Fairbanks Drive in its extent from Patriot Freeway to the approximate vicinity of Kellogg Street.

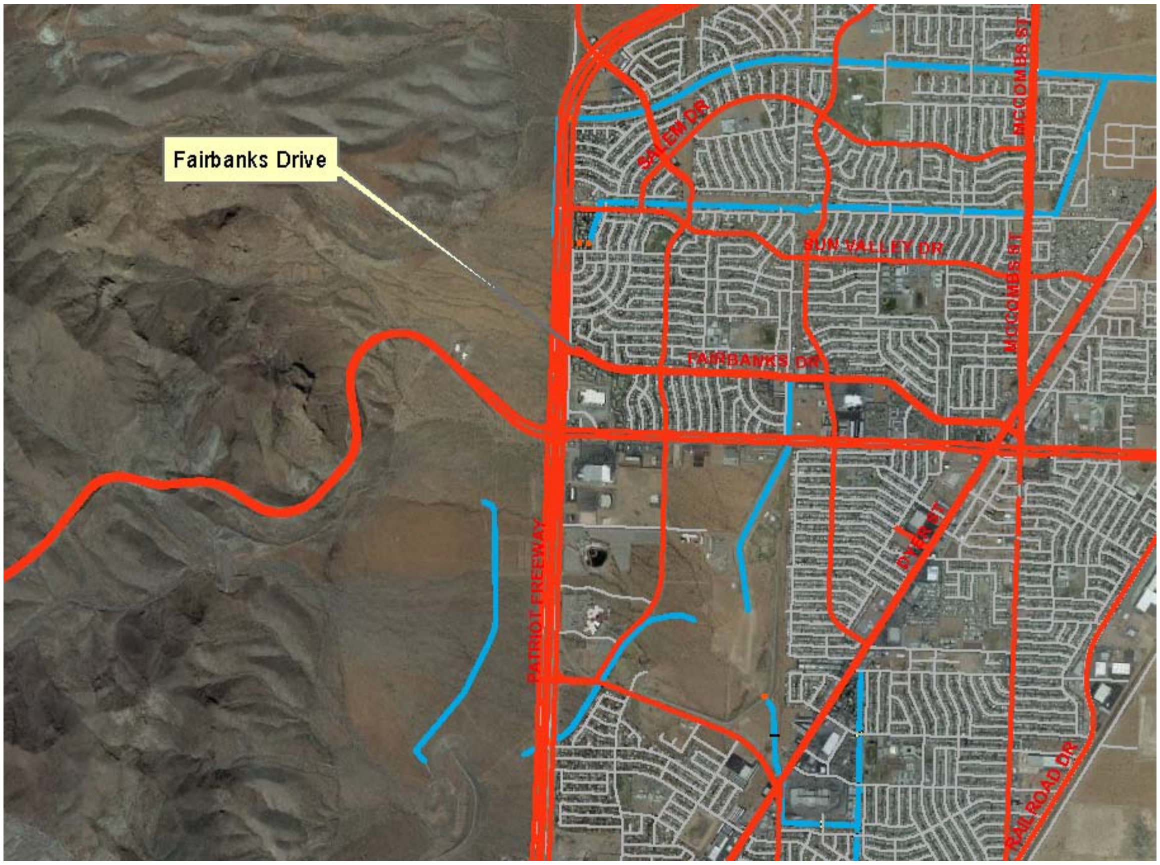

Photo 1. Aerial Photograph showing location of Fairbanks Drive debris flow on east slope of Franklin Mountains (north of Loop 375).

The debris flow that occurred in 2006 was observed to have flowed through three 4-foot by 4-foot concrete box culverts beneath US 54 and into residential streets including Fairbanks Drive and numerous side streets. At the date of the site visit on August 4, 2008, these culverts were approximately 80% blocked with debris-flow sediments. The debris flow was approximately 18 inches thick in exposures immediately west of US 54 and consisted of reddish-brown silty sand with fine gravel. The debris was observed to be composed of mostly clasts having a granitic composition. The sand and fine gravel was also typically weathered to highly weathered, suggesting a decomposed granite source area. Photo 3 shows the debris flow material that was observed at the primary channel where it intersected the TxDOT right-of-way (ROW) and box culvert at Patriot Freeway. The alluvial fan on which the 2006 Fairbanks Drive debris flow was deposited was observed to contain at least one older debris flow that was approximately 4 feet thick and covered almost the entire alluvial fan surface. There were no observed debris/sedimentation basins on the Fort Bliss Castner Range property. It is very likely that a properly sized structure located adjacent and immediately west of the TxDOT ROW of US 54 may have prevented or mitigated the debris flow event of August 2006 on Fairbanks Drive.

Photo 2. Aerial photograph of Fairbanks Drive (looking west with US 54 at top of photo) August 2006 following debris flow originating in Indian Spring Canyon, Fort Bliss, Castner Range.

Photo 3. View of debris flow material in channel at intersection of US 54 and Fairbanks Drive (looking west to North Franklin Mountain). Flow originates in Indian Springs Canyon on Fort Bliss Castner Range.

An example of the decomposed granite areas that are typical of those that probably contributed to sediment in the Fairbanks Drive debris flow is shown in Photo 4 below, although the drainage shown in this photo is in a tributary to Fusselman Canyon on the south slope of North Franklin Mountain. Access to Castner Range was denied by U.S. Army officials at Fort Bliss and therefore there were no direct investigations in this area. Mapping of Castner Range area was from perimeter and aerial photography only.

Photo 4. Accumulation of decomposed granite area with talus and colluvium on the east side of North Franklin Peak with debris flow scars. View from Loop 375 looking north.

C.3.4 North Franklin Mountains Debris Flows

Debris flows were observed in the FMSP (Tom Mays Unit) that consisted of sand, gravel, cobble, and boulder sized granitic clasts. The debris flows appeared to have originated in steeply-sloping ravines surrounded by relatively large talus and colluvial covered mountain slopes. The primary contributing material to these debris flows is the granitic rocks of the Red Bluff Granite Complex. This is primarily Riebeckite Granite that forms cobble-sized granite clasts and decomposes to sand and silt size sediments. The debris flow locations are shown on Figures C-4 and C-6 and adjacent areas mapped as potential future debris flow deposits are located along the base of the talus slopes. The photograph below (Photo 5) shows the narrow U-shaped ravine upstream of the debris flow in the foreground, with talus and colluvial deposits along the margins of the channel.

Photo 5. Photograph of west side of North Franklin Mountain showing talus and colluvial slopes adjacent to "U"-shaped debris flow channel and debris flow deposits in the valley below, northwest side of North Franklin Peak.

The bottom of the ravines where the debris flows originated were "U"-shaped and similar in profile to channels described by Giraud, 2005, and suggested the material in the debris flows had accumulated in the ravines at the base of the talus and colluvial slopes and was mobilized when the material became saturated. The debris flows were observed to have flowed out of the steep ravines and the materials were deposited on less steeply sloping proximal (Giraud, 2005) portions of alluvial fans located in the valley bottom.

The large accumulations of potential debris flow material were characterized by TPWD-supplied literature as "rock glaciers," possibly due to the similarity in appearance of the debris flow materials to rock glaciers present in alpine locations. However, these talus accumulations do not fit the classic definition of a rock glacier, as there are no occurrences of perennial ice within the formations. The surface of the debris flows consists of a relatively poorly graded or well sorted layer of granitic cobbles and small boulders. Sand, silt, and gravel sized materials were observed in the debris flow deposits underlying the upper layer of cobbles and boulders, suggesting the finer materials may have been washed into voids.

C.3.5 Franklin Mountains State Park (Tom Mays Unit) Area Debris Flows

Mapping derived from site visits to the FMSP (Tom Mays Unit) are shown on parts of Figures C-3, C-4 and C-6. These hyper-concentrated flows originate from channels in the Tom Mays Unit of the FMSP north of Loop 375 on the western slope of North Franklin Mountain. Observations show significant development of scarring in several large channels that were not observable in April 2002 photos. Interviews with TPWD personnel indicated that these channels have been enlarged significantly and have mobilized large amounts of sediment. These channels are currently unstable as evidenced by the large amounts of sediment that now accumulate on park roadways following even small to moderate precipitation events. The photo below (Photo 6) shows a view to the southwest from north side of North Franklin Mountain. The drainage channel is well enlarged from the 2006 flooding event and continues to transport large amounts of sediment. Much of the material was reported to eventually reach the Mowad Subdivision and caused extensive flooding in this area.

Photo 6. Photograph of debris flows and eroded channels on FMSP (Tom Mays Unit), looking southwest toward IH-10 and Loop 375 Intersection and the proposed Enchanted Hills Subdivision.

C.3.6 Silver Springs Drive Debris Flow

In the July/August 2006 precipitation event, the Spring Crest Channel that flows from the western slope of the Franklin Mountains (adjacent to McKelligon Canyon Area) received significant amounts of sediment from the upland slopes above the alluvial fans. The primary thoroughfare in the area is Silver Springs Drive that runs in a NE-SW trend along the slope of the alluvial fan in this area. The Spring Crest Channel is currently a trapezoidal, concrete lined channel through this subdivision but receives stormwater flows from the undeveloped areas of the Franklin Mountains up slope. From interviews with EPWU personnel and a site visit by URS personnel in August 2006, it was determined that hyper-concentrated flows entered the Spring Crest Channel and deposited large amounts of cobble-sized and smaller materials. These materials blocked several culverts, most significantly at Silver Springs Drive, and caused an overtopping of the roadway. The culvert and roadway suffered severe damage, closing the roadway. The photo below (Photo 7) was taken following the event.

Photo 7. Photo showing channel, box culvert and damaged roadway at intersection of Silver Springs Drive and Spring Crest Channel following July/August 2006 flood event.

During a site visit by URS personnel in August 2008, significant roadway repairs and channel modifications in progress were observed as part of the Westside Flood Damage Improvements Project. There was also a new sedimentation basin in construction upstream of the intersection of Silver Springs Drive and Castle Rock Drive. This basin was not in place at the time of the July/August 2006 event. An analysis of the geology and drainage basin up slope from this site is that the contributing material is largely limestone clasts and eroded alluvium from early Quaternary alluvial fans. Within this area, as along much of the western frontage of the Franklin Mountains, older alluvial fan deposits have been extensively cemented and “calichefied”. This condition tends to render these older fans relatively stable in current climatic conditions. However, significant hydrologic events such as in August 2006 appear to have eroded deeply incised channels into portions of the older fans and have thus re-mobilized materials. This is a very similar condition to that which was observed in the McKelligon Canyon area. Photo 8 shows significant development of hyper-concentrated flow scarring of the channels above the sediment basin at Thunderbird Drive and Torrey Pines Drive (approximately 1 mile north of Spring Crest Channel). These debris accumulations do not appear in aerial photos dated 2005. It is apparent that the August 2006 event has generated significant amounts of new material that is comprised largely of limestone clasts.

Photo 8. View of hyper-concentrated flow channel (Spring Crest Channel) that contributed to the Silver Springs Drive Debris Flow. View to the southwest from south side of South Franklin Mountain.

C.3.7 Westway/Vinton Canyon Area

The western slope of the Franklin Mountains in the area described as Vinton Canyon and further down-slope is the area described as Westway. There is a series of active alluvial fans in this area that are transporting sediment by stream-flow and hyper-concentrated flow into the Westway subdivision. Field observations showed that even small to moderate precipitation events would mobilize sediment loads sufficient to significantly accumulate in the roadways. Stormwater management in this area is minimal and requires heavy equipment to clear roadways following each significant precipitation event.

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C.4.0 CONCLUSIONS

The Franklin Mountains contain rugged terrain that consists of large exposed bedrock areas and bedrock with a relatively shallow (typically less than 1 foot thick) layer of colluvium. Surficial deposits, including talus, colluvium, and alluvium are relatively small in area and volume. The bedrock and thin colluvial covered slopes probably have a low infiltration capacity during precipitation events and would therefore be prone to flash flooding. Although the talus, colluvium, and alluvium deposits are composed of granular materials, they can be mobilized into debris flows during heavy precipitation events.

During mapping of potential deposits that could form future debris flows a number of existing debris flow deposits were observed. Inspection of the debris flow deposits and their origin, location, and composition was used to identify and map the potential future debris flows. With the exception of the Fairbanks Drive event, the debris flows that occurred during the 2006 precipitation event formed in narrow steep ravines in the mountains and flowed onto the alluvial filled valleys where debris mixed with stream flood flows. Future debris flows might flow greater distances down the alluvial floored valleys and out of the mountains, similar to the Fairbanks Avenue 2006 debris flow, especially if sand and fine gravel sized sediment is available.

The 2006 precipitation event was relatively large in terms of duration and total rainfall. During mapping of potential future debris flow deposits the effects of the 2006 precipitation event were observed and consisted of dramatic amounts of erosion in the alluvial filled valleys within the mountains. The erosion and removal of stabilizing vegetation has resulted in an increase in the amount of sediment available for transport during future flash flood events, as well as debris flows. The increased sediment available for flash flood flow bulking may be present for decades as the finer sediment is washed away, the alluvial channels become armored with gravel, cobbles, and boulders, and the vegetation grows back.

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C.5.0 RECOMMENDATIONS FOR FURTHER INVESTIGATION

In Figures C-1 to C-8, significant areas are mapped as alluvium (pink). These areas were identified as those that were undergoing active sediment transport within their stream courses. That is, they were apparently eroding within the active channels and the mapped areas on either side of the channels were generally unstable and subject to imminent erosion. These mapped areas should be subject to greater scrutiny when considering real estate development upon them. The general level of risk should be considered as moderate and does require hydrologic study prior to designing stormwater infrastructure.

The following general recommendations are made for the design of storm water infrastructure in and around the Franklin Mountains area:

- An examination of the available literature indicates that there is a critical need for updated aerial orthophotography. An existing orthophoto database is available with EPWU that is dated 2006. However, those photos are apparently pre-flood. A contrasting post-flood set of orthophotos is necessary to compare in stereo view to better facilitate analysis of the effects that debris flows have had upon the area landscape.
- Although the debris flows mapped as part of this scope of work were relatively small and did not flow into urbanized areas (except for the Fairbanks Drive debris flow) they do contribute sediment to and bulk up flood flows. We recommend the sediment volume for potential future debris flows used for design be similar to the debris flows that formed during the 2006 event.
- Most of the sediment transported into sediment retention basins during future flash flood events is expected to be eroded from alluvial channels eroded, modified, and formed during the 2006 event. For any given flash flood event, the quantity of sediment associated with future events is expected to be 2 to 3 times the quantity associated with similar sized events that occurred prior to the 2006 event.
- Guidelines for estimating debris flow volumes are based on channel profiles in available sediment (Giraud, 2005). Due to the fact that most future debris flows are expected to occur similar to those during the 2006 event (a 150 to 200-year storm event), and are not expected to travel far enough to reach the sediment basins, we recommend sediment volumes for each event be estimated using a bulking factor applied to the flood flow estimated from the precipitation or storm event. Bulking factors could be estimated from measurements made for past events, with an increased

factor of 2 to 3 to account for the additional sediment present in the alluvial channels.

- A Geographic Information Systems (GIS)-based approach should be applied to analysis of watersheds in the Franklin Mountains area in which runoff from a storm event and estimated sediment bulking factors can be modeled. This approach can best estimate the size of sedimentation basins and appropriate locations for each watershed.

C.5.1 Recommendations for Site-Specific Stormwater Infrastructure

URS has examined the mapped areas of potential sediment and debris flows and made specific recommendations for the approximate locations of sedimentation and debris basins that will serve as mitigating measures to prevent damage to transportation and stormwater infrastructure. A total of 31 sedimentation basin and 23 debris basin sites were identified and are recommended, as shown on Figure C-10. The degree of need for the sedimentation basins was categorized based upon an observation of the type of infrastructure which they may impact (transportation, commercial, or residential). An examination of aerial photographs led to this assessment. All sites shown on Figure C-10 will require additional site specific investigation for actual locations and sizing.

Some of the very high priority sites are specifically discussed below.

Fairbanks Drive and Adjacent Fort Bliss - Castner Range - During the July/August 2006 precipitation event, a significant debris flow occurred in this area that originated in Indian Springs Canyon on Fort Bliss Castner Range and flowed downstream through a box culvert under the TxDOT ROW of US 54 into Fairbanks Drive. It seems apparent that the culvert at US 54 may have been of sufficient size to handle the volume of flow during this event. However, the downstream culverts within the residential subdivisions adjacent to Fairbanks Drive were too small and caused an apparent damming effect that “boiled” on the downstream (east) side of the TxDOT ROW. Very large amounts of sand to silt-sized sediment composed of decomposed granite were deposited in the main lanes of Fairbanks Drive as far east as Electric Avenue. This deposition of sediment obstructed the main and interconnecting roadways and caused local street flooding. Observations made in August 2008 at the site indicate that minor hyper-concentrated flow is still occurring in this area even during relatively minor precipitation events. The culverts at US 54 were observed to be 80% obstructed. The most obvious remedy for the control of sediments entering this area would be the construction of a sedimentation basin on the Castner Range property on the immediate upstream side of US 54. The design of this structure would require a site specific investigation. However, a preliminary assessment indicates that the structure may require the length of the dam to extend from the intersection of Loop 375/US 54 north to Sun Valley Drive. Runoff storm water may possibly be shunted to an open channel to be constructed in Fairbanks Drive.

Pre-2006 **Post-2006**

Photo 9. Aerial photographs of Fairbanks Drive/Castner Range Debris Flow showing changes in stream morphology following July/August 2006 flood event.

Photo 10. Recommended locations of potential debris/sedimentation basins to mitigate debris flows on Fort Bliss-Castner Range.

North Franklin Mountains Area - There may be a need in the immediate future for the construction of one or multiple sedimentation basins in the areas on the western slope of the Franklin Mountains north of Loop 375. Of particular concern are the communities of Westway and the Mowad Road subdivisions. In addition, the proposed Enchanted Hills Subdivision is in an "at risk" area because of the extensive hyper-concentrated flow that has moved through this area. These residential subdivisions, while outside of the City of El Paso, are adjacent to an active alluvial fans within City limits. There are large amounts of hyper-concentrated and flood flows that are depositing sediments in this area through the entire range of precipitation events. Also of concern is the area downstream of the FMSP (Tom Mays Unit) (north of Loop 375). There were no observed sedimentation basins in this area. The Mowad Road area was extensively flooded and has been condemned. While development within city limits is still limited in this area, any future commercial or residential development would be at significant risk during future stormwater events. Site specific investigations should be required as indicated in the debris-flow risk map that was developed as part of this investigation.

C.6.0 LIMITATIONS OF STUDY

This study is limited in both scope and geographical extent. The original tasking of the study was to focus on the mountainous and high-gradient slope areas where debris flows and erosion have been historically chronic and problematic. Therefore, the original mapping and supporting aerial photography have been somewhat geographically restricted. It became apparent during the course of this investigation that in order to understand the various hydrological and geohydrological processes occurring in the region the geographic scope of the investigation should be expanded to those areas that were east of IH-10 and west of US 54. In this area were the sites that are either under active depositional/erosion processes or are undergoing active real estate development. There was not generally up-to-date aerial photography available that was post-flood imagery within the areas investigated. TNRIS had only 2005 imagery at the time of the investigation. At the time of writing of this report the 2008 Digital Orthographic Quadrangle set was not yet available but was projected for publication in the future. It is recommended that future investigations collected utilize very recent imagery (less than 24 months old) because of the rapid pace of real estate development in the region. The rapid pace of field investigation (less than 1 month) yields a depth of investigation barely beyond the reconnaissance level. A more comprehensive investigation is recommended utilizing the methods of Giraud (2005). Streams courses should be each individually examined and characterized for level of risk regarding erosion and debris-flow generation. It may be necessary to collect longer-term hydrologic data in the streams during flood events.

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C.7.0 REFERENCES

R.E. Giraud, 2005. Guidelines for the Geologic Evaluation of Debris-Flow Hazards on Alluvial Fans in Utah. Utah Geologic Survey Miscellaneous Publication 05-6.

Harbour, R. L., 1972. Geology of the Northern Franklin Mountains, Texas and New Mexico: U.S. Geological Survey Bulletin 1298, 129 p.

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FIGURES

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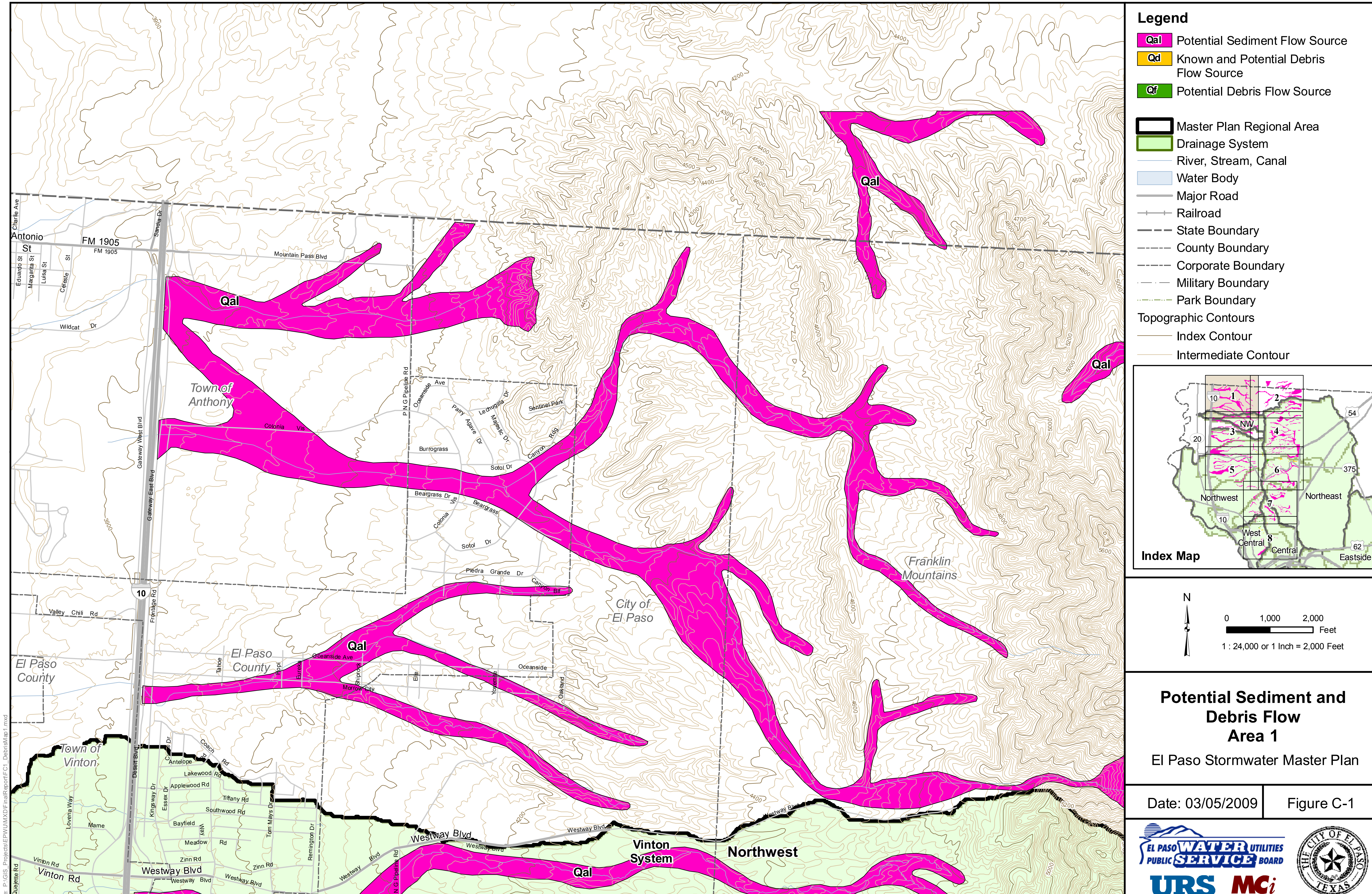

Potential Sediment and Debris Flow
Area 1

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-1

EL PASO WATER UTILITIES PUBLIC SERVICE BOARD

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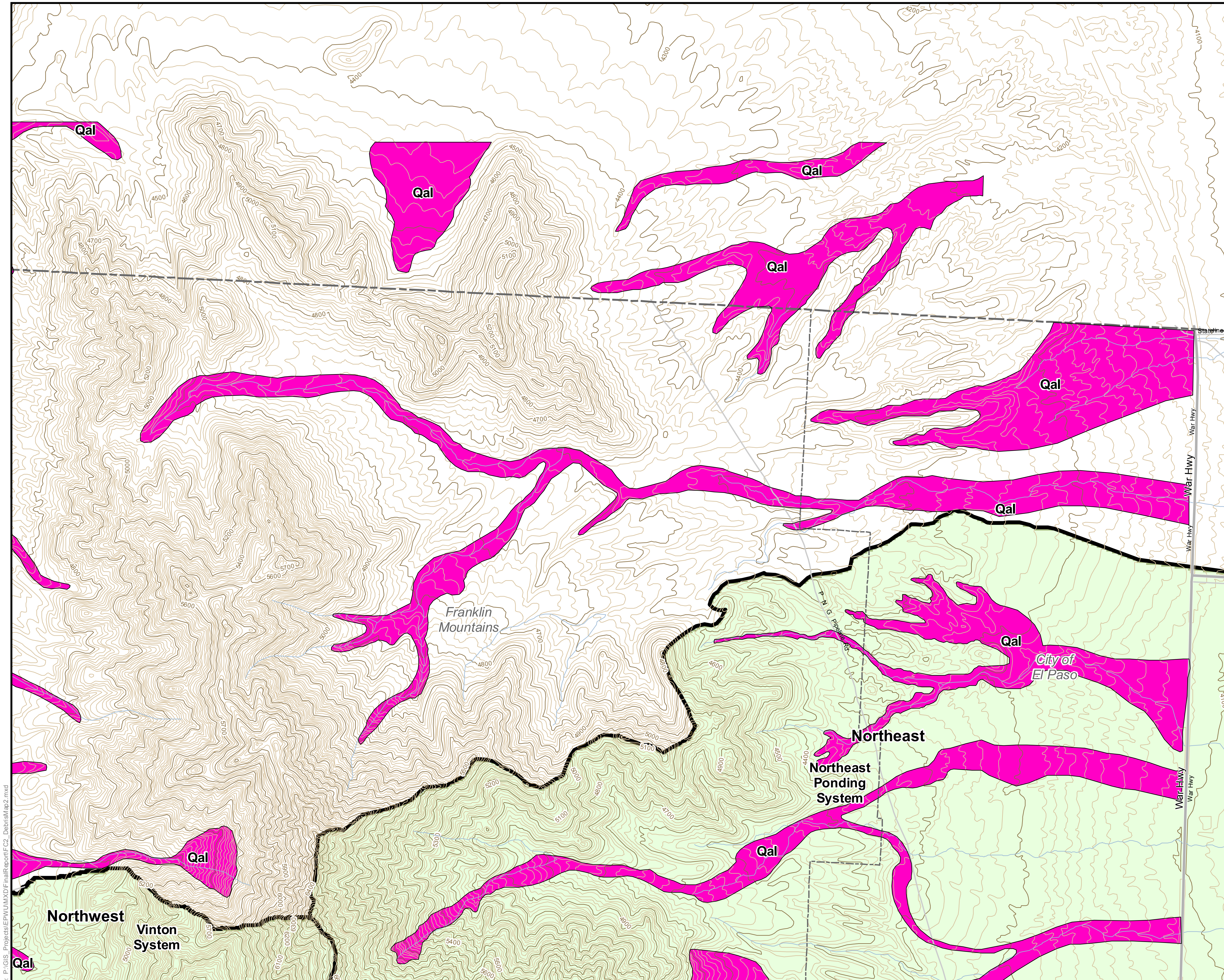
THE CITY OF EL PASO TEXAS

File: P:\GIS_Projects\EPWU\MXD\FinalReport\FC1_DebrisMap1.mxd

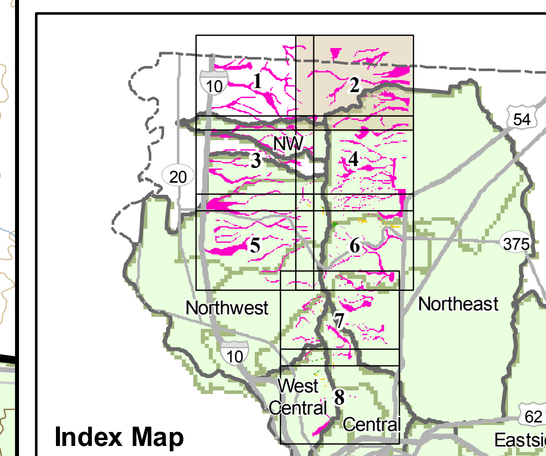


Legend

- Qal — Potential Sediment Flow Source
- Qd — Known and Potential Debris Flow Source
- Qf — Potential Debris Flow Source
- Master Plan Regional Area
- Drainage System
- River, Stream, Canal
- Water Body
- Major Road
- Railroad
- State Boundary
- County Boundary
- Corporate Boundary
- Military Boundary
- Park Boundary

Topographic Contours

- Index Contour
- Intermediate Contour



N

0 1,000 2,000 Feet

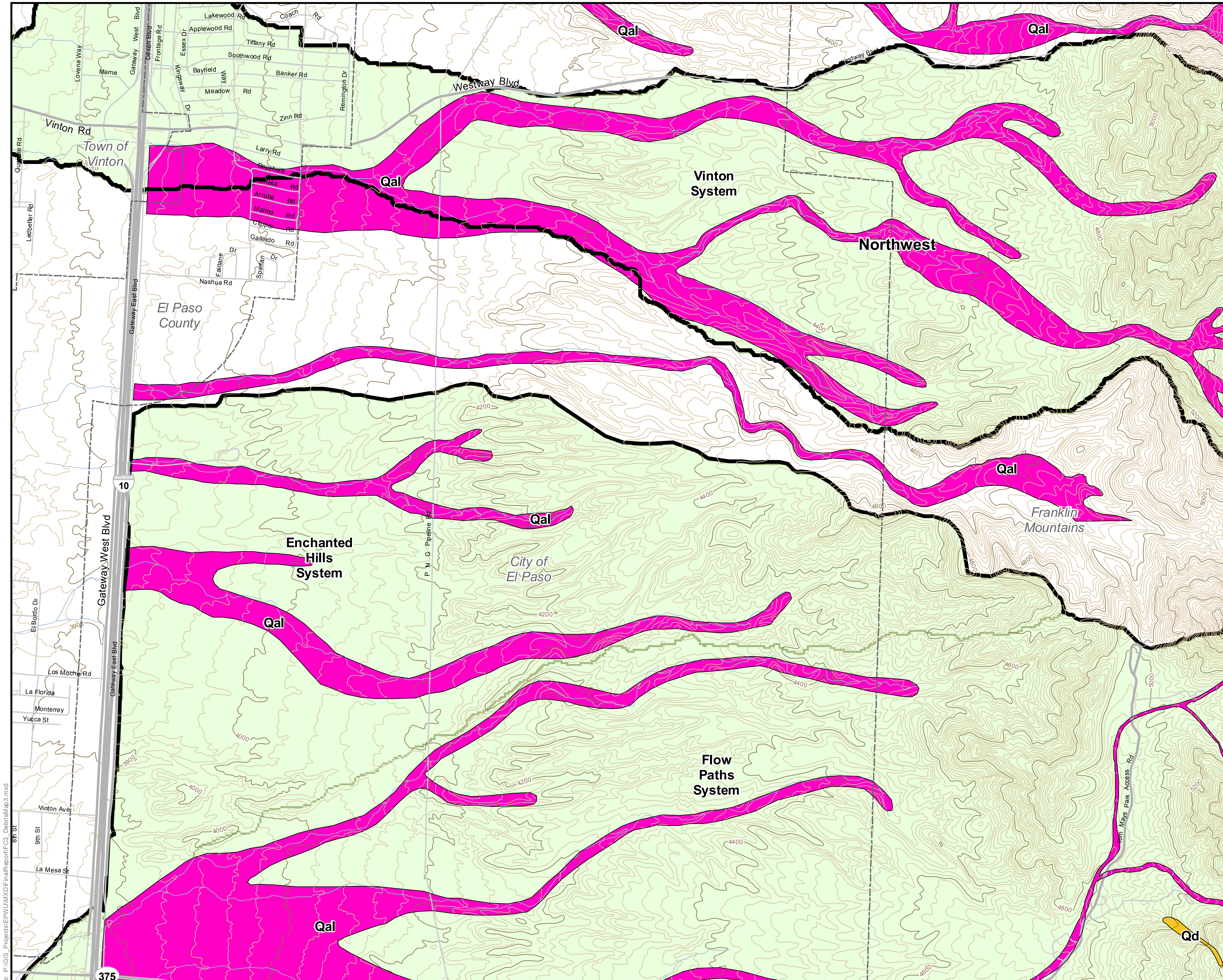
1 : 24,000 or 1 Inch = 2,000 Feet

Potential Sediment and Debris Flow Area 2

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-2

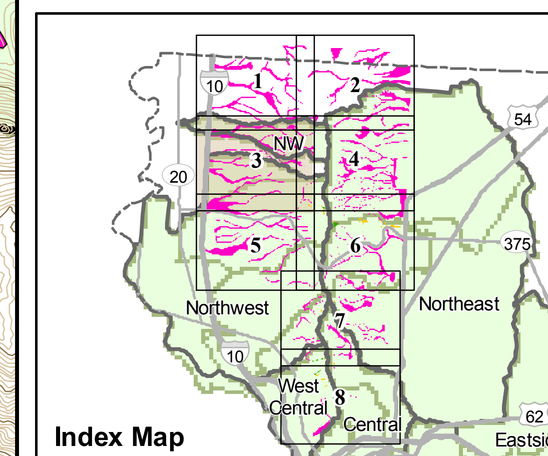


Legend

- Qal — Potential Sediment Flow Source
- Qd — Known and Potential Debris Flow Source
- Qf — Potential Debris Flow Source
- Master Plan Regional Area
- Drainage System
- River, Stream, Canal
- Water Body
- Major Road
- Railroad
- State Boundary
- County Boundary
- Corporate Boundary
- Military Boundary
- Park Boundary

Topographic Contours

- Index Contour
- Intermediate Contour



N

0 1,000 2,000 Feet

1 : 24,000 or 1 Inch = 2,000 Feet

Potential Sediment and Debris Flow Area 3

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-3

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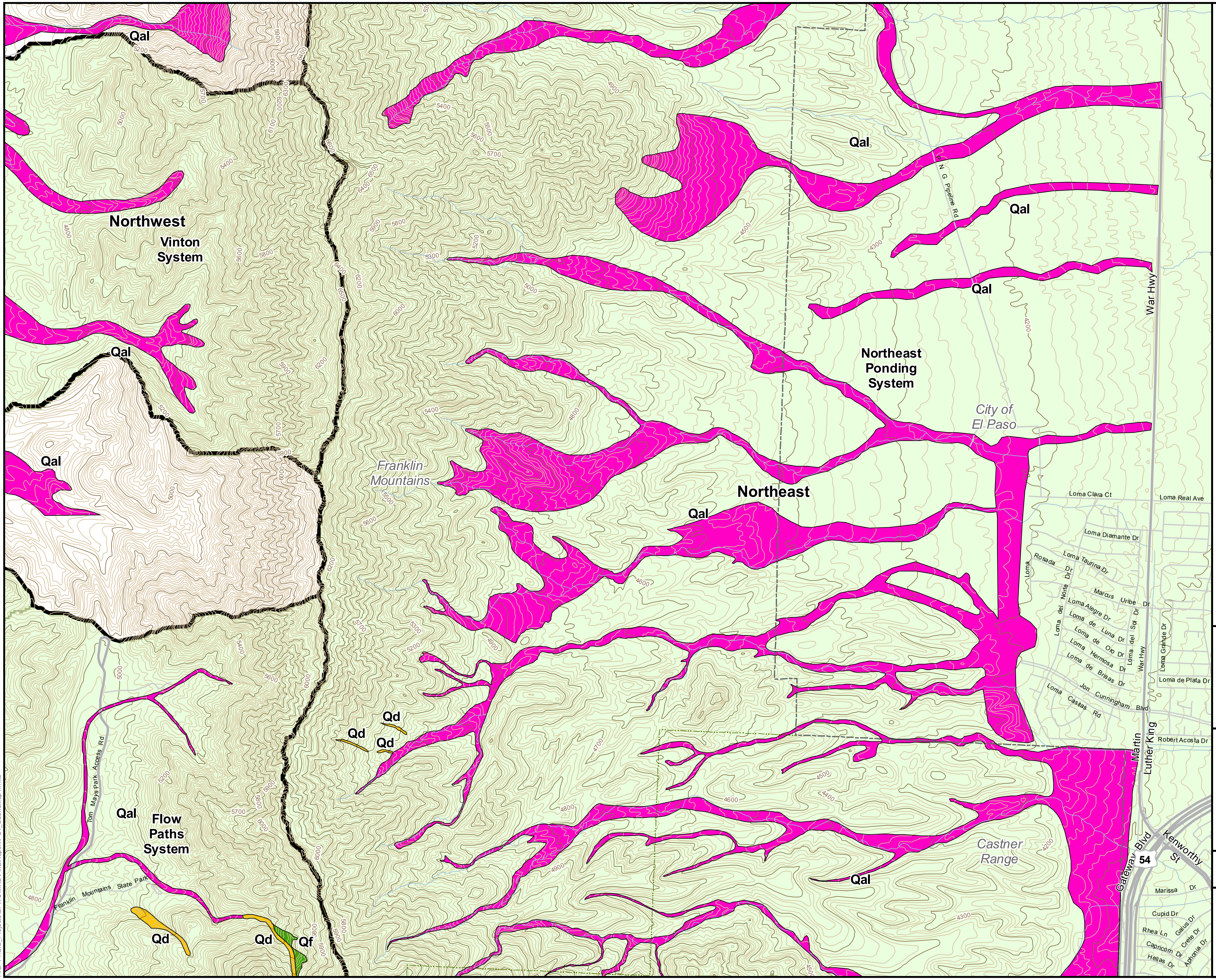

Legend

- Qal — Potential Sediment Flow Source
- Qd — Known and Potential Debris Flow Source
- Qf — Potential Debris Flow Source
- Master Plan Regional Area
- Drainage System
- River, Stream, Canal
- Water Body
- Major Road
- Railroad
- State Boundary
- County Boundary
- Corporate Boundary
- Military Boundary
- Park Boundary

Topographic Contours

- Index Contour
- Intermediate Contour

Index Map

N

0 1,000 2,000 Feet

1 : 24,000 or 1 Inch = 2,000 Feet

Potential Sediment and Debris Flow Area 4

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-4

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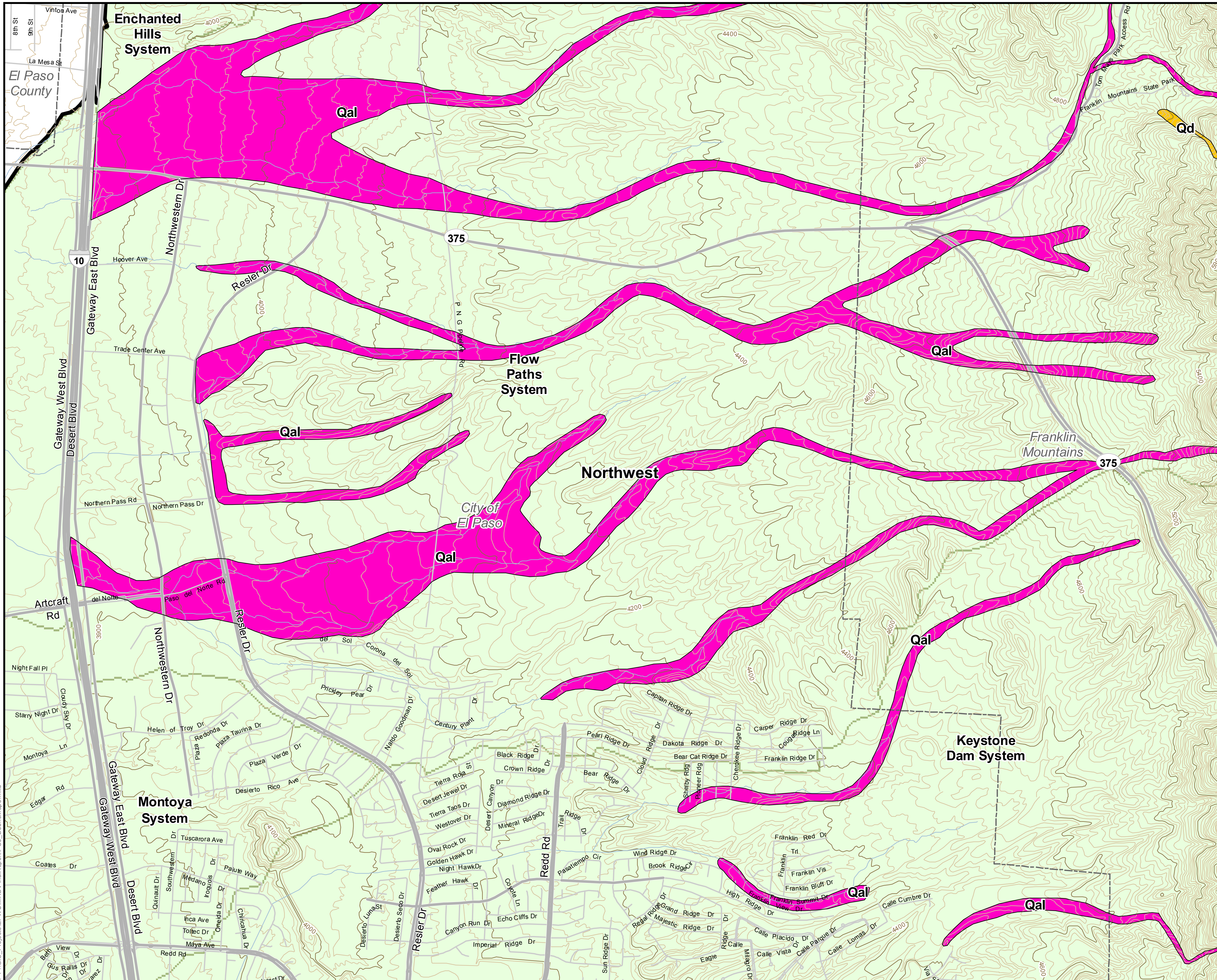
File: P:\GIS_Projects\EPWU\MXD\FinalReport\FC4_DebrisMap4.mxd

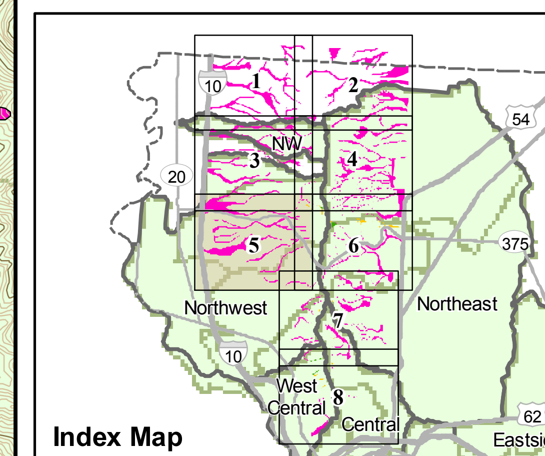


Legend

- Qal — Potential Sediment Flow Source
- Qd — Known and Potential Debris Flow Source
- Qf — Potential Debris Flow Source
- Master Plan Regional Area
- Drainage System
- River, Stream, Canal
- Water Body
- Major Road
- Railroad
- State Boundary
- County Boundary
- Corporate Boundary
- Military Boundary
- Park Boundary

Topographic Contours

- Index Contour
- Intermediate Contour



N

0 1,000 2,000 Feet

1 : 24,000 or 1 Inch = 2,000 Feet

Potential Sediment and Debris Flow Area 5

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-5

El Paso Water Utilities Public Service Board

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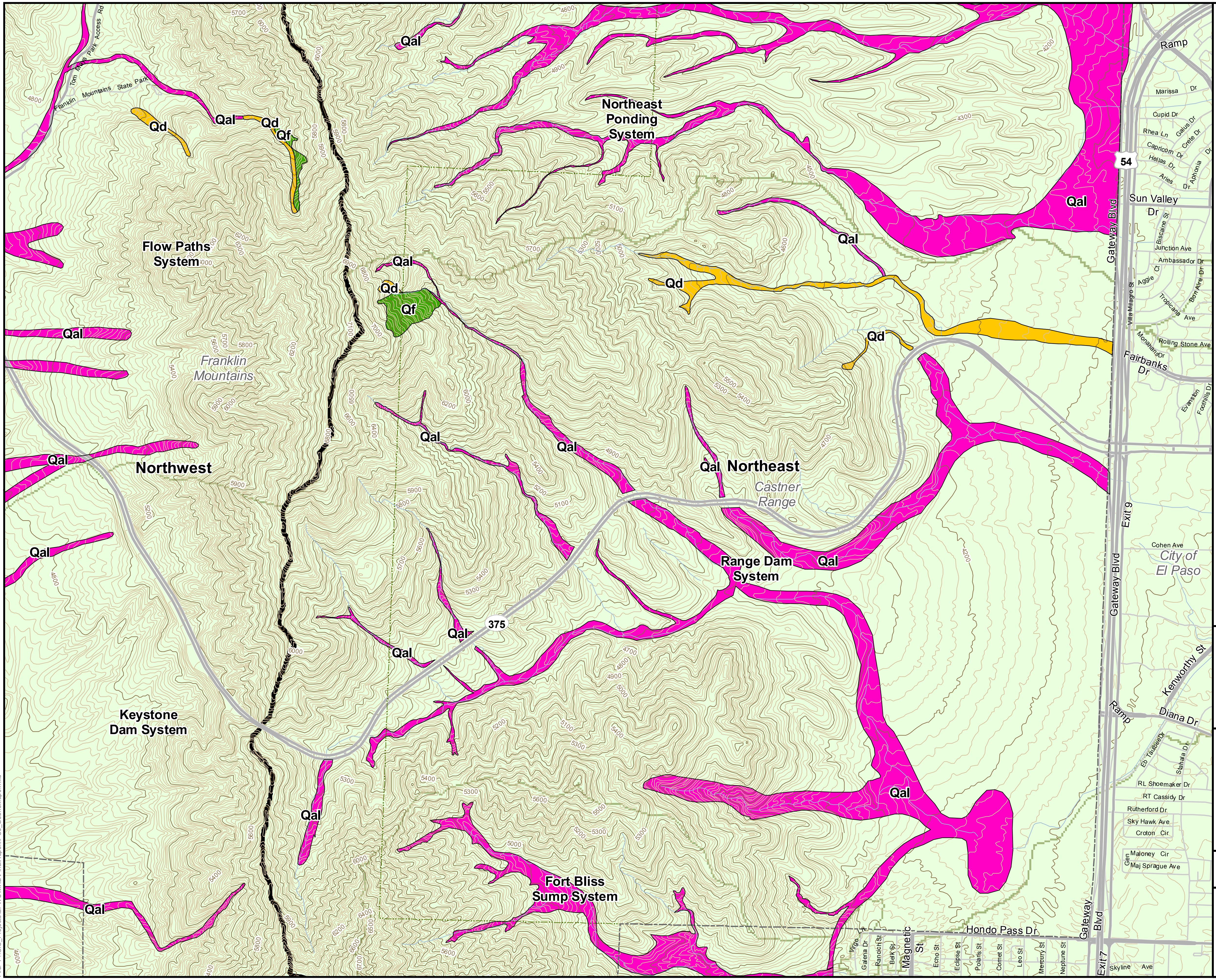
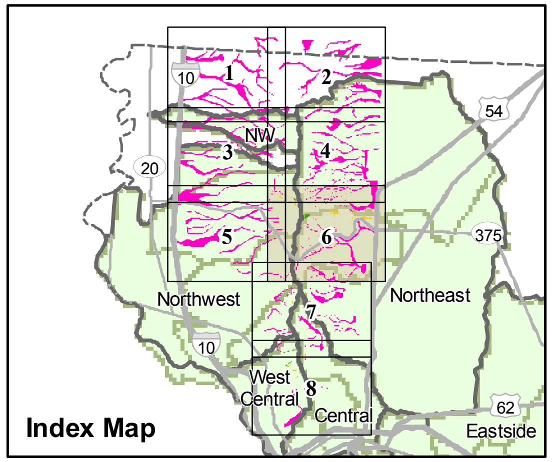


Legend

- Qal — Potential Sediment Flow Source
- Qd — Known and Potential Debris Flow Source
- Qf — Potential Debris Flow Source
- Master Plan Regional Area
- Drainage System
- River, Stream, Canal
- Water Body
- Major Road
- Railroad
- State Boundary
- County Boundary
- Corporate Boundary
- Military Boundary
- Park Boundary

Topographic Contours

- Index Contour
- Intermediate Contour



Index Map

N

0 1,000 2,000 Feet

1 : 24,000 or 1 Inch = 2,000 Feet

Potential Sediment and Debris Flow Area 6

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-6

El Paso Water Utilities Public Service Board

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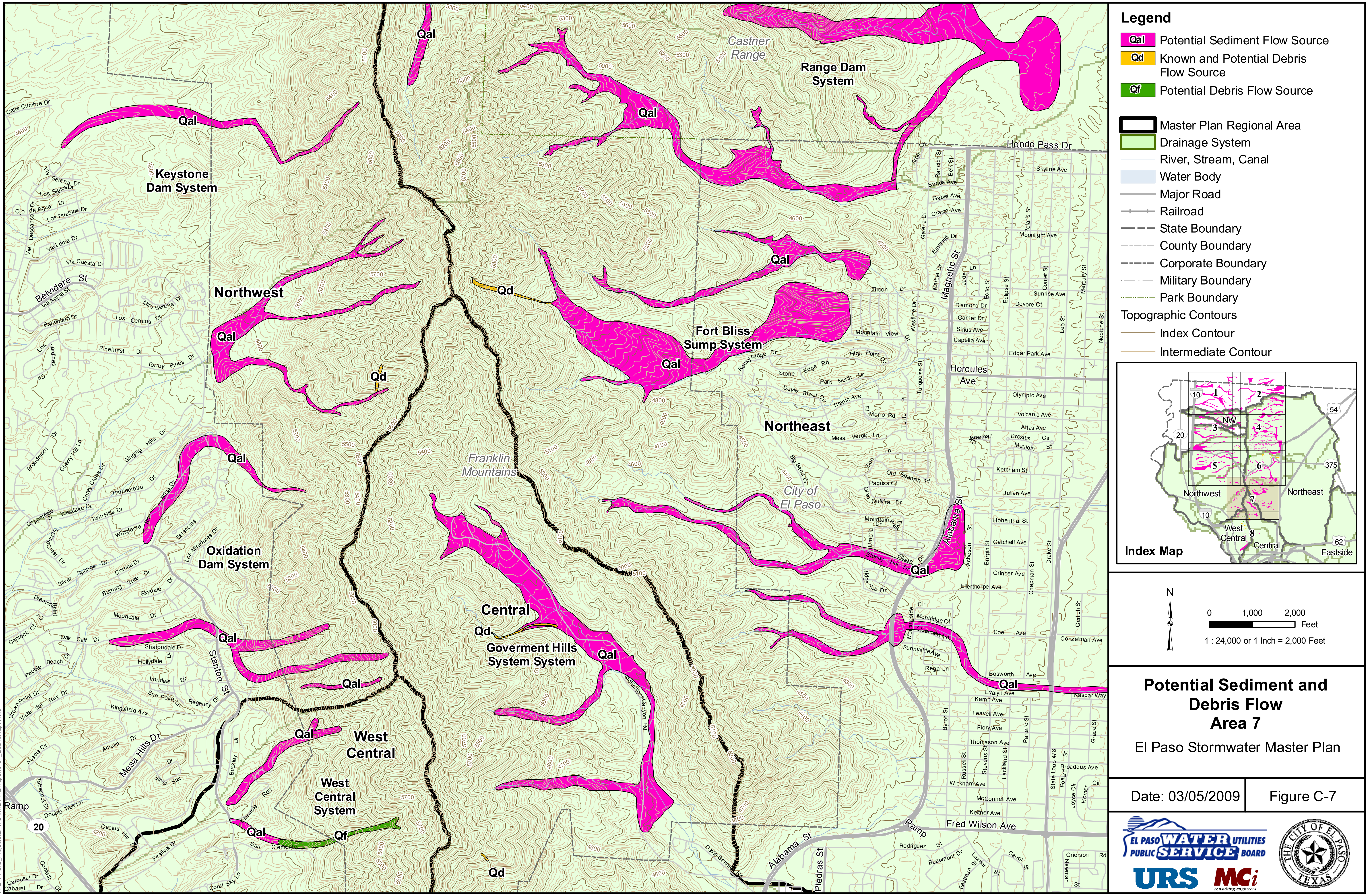

Potential Sediment and Debris Flow Area 7

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-7

EL PASO WATER UTILITIES PUBLIC SERVICE BOARD

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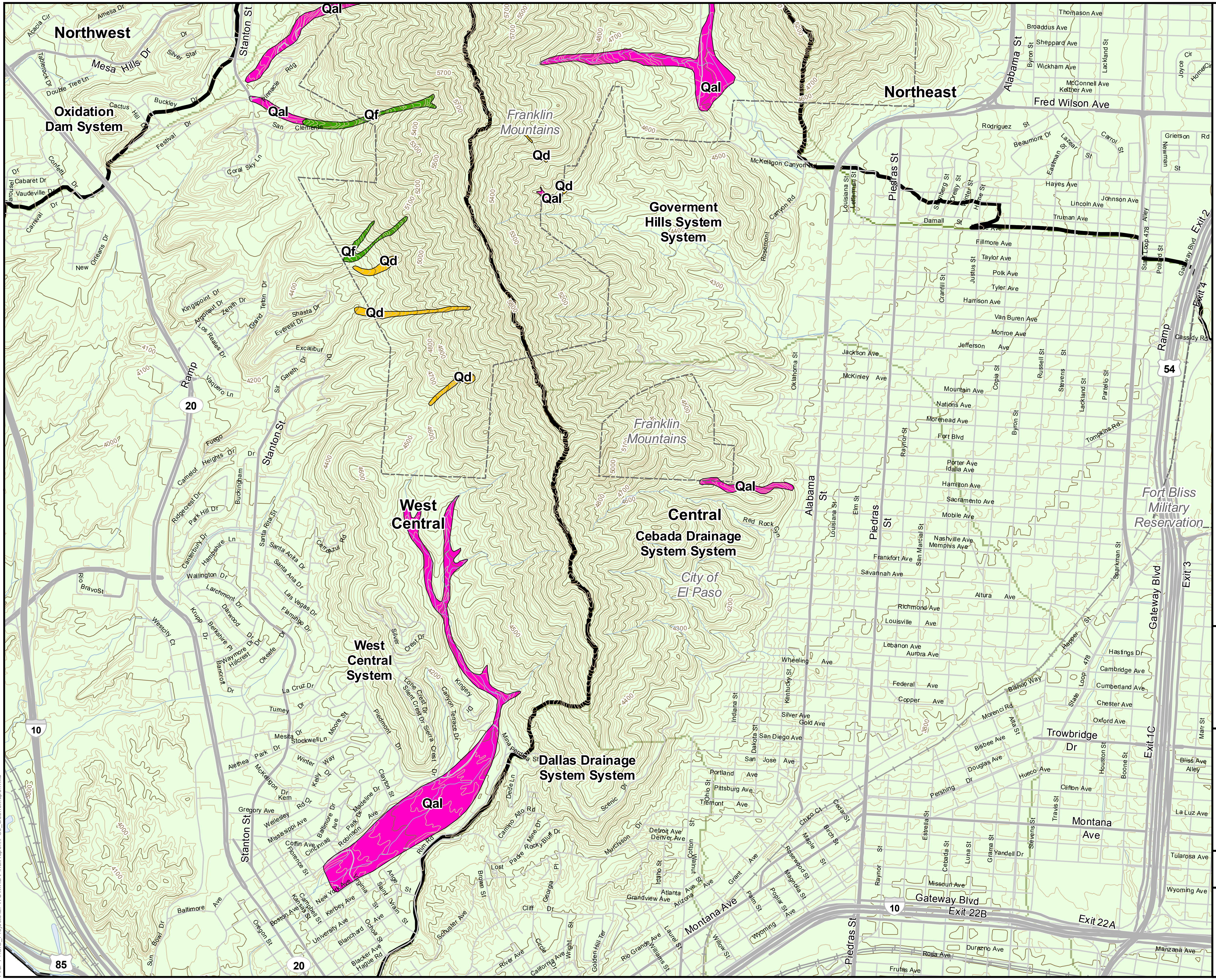
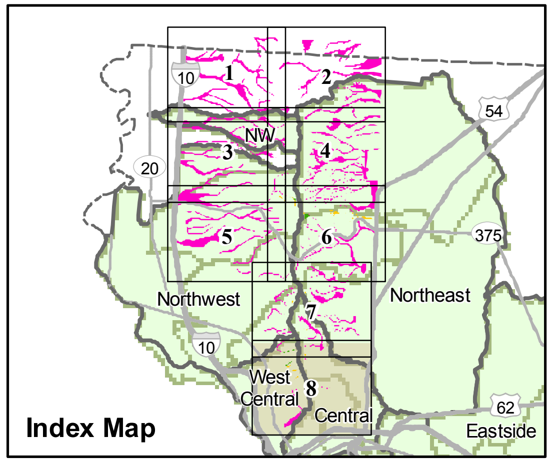


Legend

- Qal — Potential Sediment Flow Source
- Qd — Known and Potential Debris Flow Source
- Qf — Potential Debris Flow Source
- Master Plan Regional Area
- Drainage System
- River, Stream, Canal
- Water Body
- Major Road
- Railroad
- State Boundary
- County Boundary
- Corporate Boundary
- Military Boundary
- Park Boundary

Topographic Contours

- Index Contour
- Intermediate Contour



Index Map

N

0 1,000 2,000 Feet

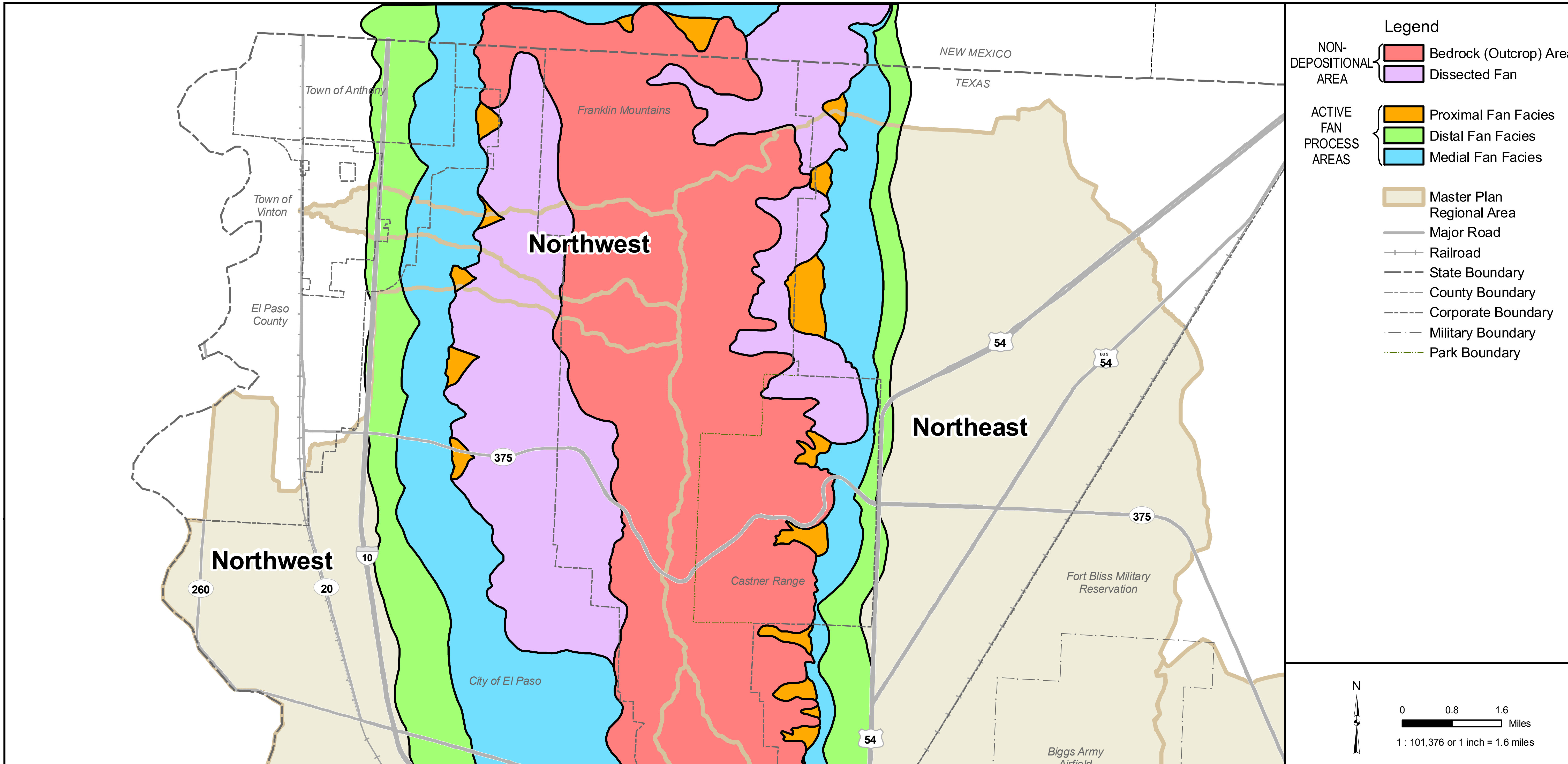
1 : 24,000 or 1 Inch = 2,000 Feet

Potential Sediment and Debris Flow Area 8

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-8



Alluvial Fan Development

El Paso Stormwater Master Plan

Date: 03/05/2009 | Figure C-9

EL PASO WATER UTILITIES PUBLIC SERVICE BOARD

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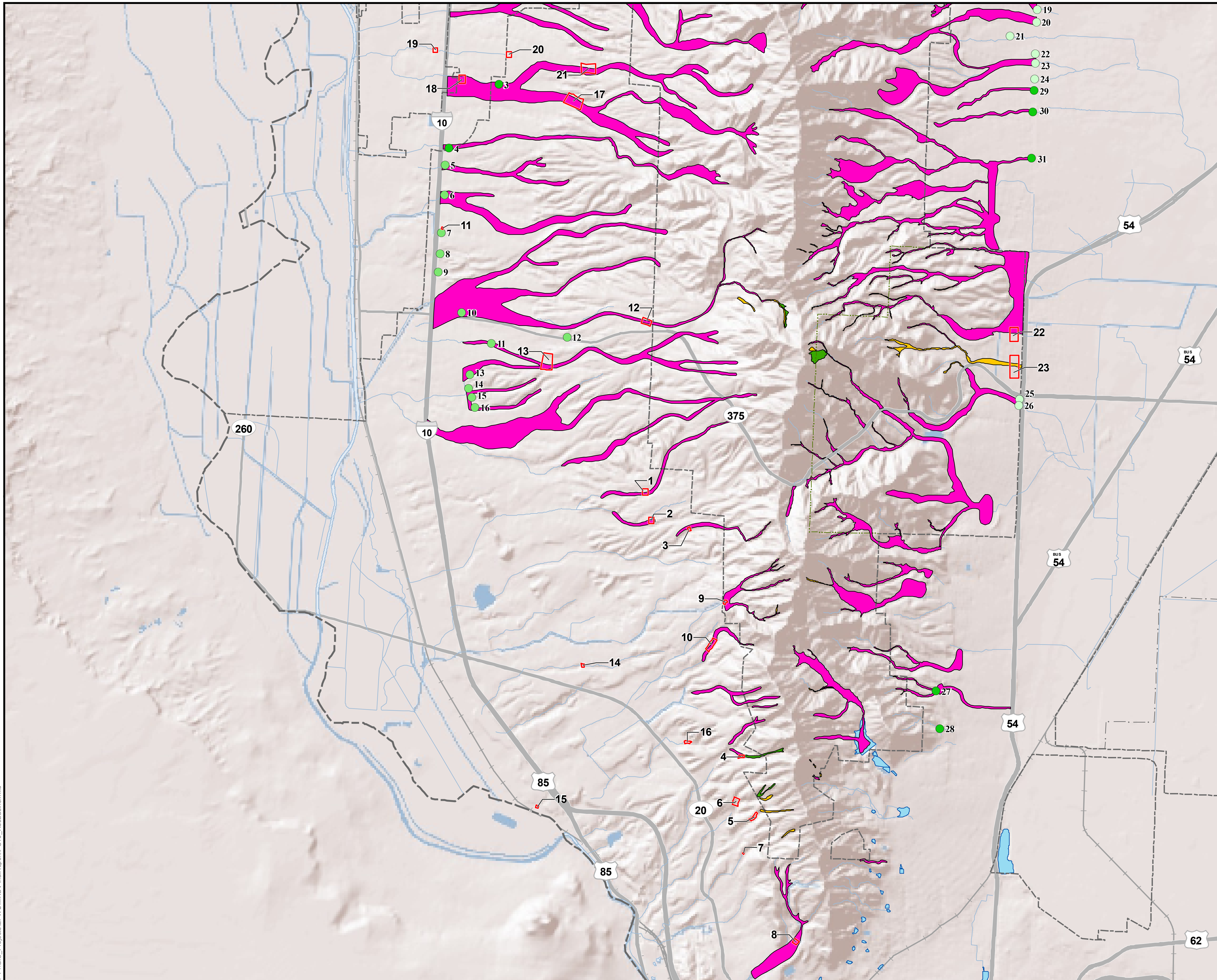

Legend

- Recommended Debris Flow Basin
- Recommended Sedimentation Basins

Priority

- 1
- 2
- 3

- Potential Sediment Flow Source
- Known and Potential Debris Flow Source
- Potential Debris Flow Source
- Dam/Reservoir
- Major Road
- Railroad
- Streamline
- Water Body
- State Boundary
- Corporate Boundary
- Military Boundary
- Park Boundary

N

0 3,500 7,000 Feet

1 : 84,000 or 1 Inch = 7,000 Feet

Recommended Locations for Debris Flow and Sedimentation Basins - Franklin Mountains Area

El Paso Stormwater Master Plan

Date: 03/05/2009

Figure C-10

El Paso Water Utilities Public Service Board

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File: P:\GIS_Projects\EPWU\MXD\FinalReport\FC10_RecBasins.mxd