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El Paso County
Interior Drainage Study
Methodology and Mapping Results Report

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1 Introduction

The purpose of the El Paso County Interior Drainage Study (Study) is to identify the sources of flooding from the landward sides of the levees along the 65 miles of the Rio Grande within El Paso County, where depths exceed 1 ft based on current conditions. The hydrologic and hydraulic (H&H) modeling, as per FEMA's requirements for the levee certification process, will provide the foundation for the modeling of the proposed levee improvements necessary for accreditation, which is not part of this scope, and may be performed through a separate work authorization.

As part of this Study, AECOM initiated a data collection process and formulated an H&H modeling approach, which were summarized in a draft version of the *El Paso County Interior Drainage Study Data Collection and Modeling Approach Report* (AECOM, 2020). The final version of that report is included in Appendix A and will be referenced as "Appendix A" throughout this Report. Before any modeling took place as part of this Study, a draft version of Appendix A was provided for review and comment to El Paso County (County), El Paso Water (EPWater), and the U.S. Section of the International Boundary and Water Commission (USIBWC) in July 2019. Comments received on the draft have been incorporated in the final version of Appendix A and in the H&H models and mapping that are documented in this *El Paso County Interior Drainage Study Methodology and Mapping Results Report* (Report). The purposes of this Report are 1) to document the resolution of pending items from Appendix A and 2) to document H&H modeling and mapping methodologies and results that were developed in this Study using the approved approach and information presented in Appendix A.

2 Resolution to Pending Data Collection

This section documents the resolution of information and decisions that were pending the feedback of reviewers of the draft version of Appendix A. In Appendix A, there are four numbered sections that were prefaced with the subheading, "Pending Resolution". This section will discuss the resolution of each of those subjects.

2.1 Resolution 1 – American Canal

In Section 2.2 of Appendix A, the "Pending Resolution 1" subsection states the need for understanding what phases of design and construction different sections of American Canal are currently undergoing; so that a decision could be made as to whether the interior drainage associated with the American Canal should be modeled as part of this Study. Following USIBWC's review of Appendix A, Dr. Borah of USIBWC responded with the following status update via email on July 26, 2019:

> *"The upper canal construction work is basically finished. There's some back-filling and other minor punch-list items that are being completed, but the concrete channel is complete. There should not be any change to drainage in this portion of the canal.*
>
> *The middle section will eventually be replaced. However, the design and the construction to follow are on hold due to funding issues. The canal will eventually be enclosed with 2(two) 12 X 13 foot side-by-side box culverts, eliminating the rocks and inflows from the old ASARCO site into the canal.*
>
> *The lower section of the canal is in the design phase. Design expected to be completed this fiscal year. Bid for construction will go out next fiscal year. There are no new outfalls or drains into the*

lower section, but there is a reconfiguration. The canal will also be enclosed from Paisano Drive down the bend by the International Dam or the old La Hacienda. Additional ramps will be placed upstream and downstream of the overchute for excavation purposes. The storm flows coming down the University arroyo remain our primary drainage concern for the USIBWC. "

Due to the different phases of design and construction currently taking place on the upper and lower sections of American Canal, and the uncertainty associated with the design and construction of the middle section, the second bullet of "Modeling Decision 3" (Section 2.3) from Appendix A remains relevant to this Study, and the modeling of American Canal interior drainage was excluded from this Study. This decision was approved by EPWater and the County in a progress conference call/web presentation that took place on January 7, 2020, which supports Modeling Decision 9 (Section 4.2) from Appendix A.

2.2 Resolution 2 - Outfalls

In Section 5.1 of Appendix A, the "Pending Resolution 2" subsection states the need for collecting outstanding data associated with outfall pipes that discharge stormwater into the Rio Grande, particularly in areas where new interior drainage models are being developed as part of this Study. Table 3 from Appendix A lists the outfalls, dimensions, cover/gate status, and data sources associated with information collected at the time Appendix A was drafted (July 2019). Requests for Information (RFIs) were sent to USIBWC and EPWater in July 2019, and an additional RFI was sent to the County in October 2019. In addition, information concerning specific outfalls, such as the Fabens Waste Channel were requested from El Paso County Water Improvement District No. 1 (EPCWID) in November 2019.

Outfall data were received as a result of the RFIs. However, some outfalls located in new interior drainage model areas were still lacking necessary modeling data. Therefore, AECOM performed two field investigations on December 19, 2019 and March 17, 2020 to confirm the existence of outfall locations, dimensions, cover/gate status, and active/inactive status. An updated list of information for outfalls modeled in previous, new, or updated interior drainage model domains is provided in **Table 1** , "Modeled Rio Grande Outfalls". This table identifies which outfalls are modeled in which two-dimensional (2D) domains, and documents if an outfall was field verified by AECOM in the "Outfall Information Source" column. It should be noted that the outfall label numbers in the first column of **Table 1** correspond to figures in this Report, but do not necessarily match outfall labels in figures or tables from Appendix A, which include several more outfalls that were either found to be inactive or insignificant for the purposes of this Study. Outfalls found to be inactive or insignificant were purposely excluded from this Study and previous interior drainage models utilized in this Study.

2.3 Resolution 3 – Pump Stations

In Section 5.1.5 of Appendix A, the "Pending Resolution 3" subsection states the need for collecting outstanding data associated with pump stations discharging directly to the Rio Grande. City of El Paso pump station capacities were provided via email from EPWater in April 2019. Pump station capacities or modeling methods were not modified in previous interior drainage studies utilized as part of this Study. Pump stations are not included in any new interior drainage 2D model domains developed as part of this Study since pump stations do not exist in those areas. **Table 1**, "Modeled Rio Grande Outfalls" specifies the pump station capacities provided by EPWater at outfalls discharging to the Rio Grande.

2.4 Resolution 4 – Recently Completed Projects

In Section 5.2.1 of Appendix A, the "Pending Resolution 4" subsection states the need for collecting as-built information, H&H models, and drainage reports (if available) for recently completed projects contributing to drainage improvements in the International Dam to Riverside Weir Central 2D modeling domain. The list of selected projects (marked with a star* in Table 4 of Appendix A) were either selected by AECOM or were requested by EPWater to be incorporated into this Study.

An RFI for all relevant information related to these eleven projects was submitted to EPWater in July 2019. In October 2019 (and later), EPWater provided as-built plans and drainage design reports, if available, for the selected Projects. Drainage models were not provided. The plans and available reports were reviewed and best available hydrologic models and reports from previous URS studies such as the *El Paso Stormwater Master Plan* (URS, 2009) and the *Interior Drainage Hydrologic and Hydraulic Analysis for El Paso, TX, International Dam to Riverside Weir* (URS, 2016) were obtained.

Based on the information provided and available, the list of projects shown in **Table 2** , “Recently Completed Drainage Improvement Projects Modeled” were selected to be incorporated into this Study. These eight incorporated projects affected HEC-HMS models and/or FLO-2D discharge nodes affecting one percent annual chance (1% AC) flood inundation boundaries in the *International Dam to Riverside Weir* (URS, 2016) 2D modeling domain for the Central El Paso region.

3 Rio Grande Tailwater Assumptions

Section 3 of Appendix A describes the joint probability analysis conducted as part of this Study to analyze coincidental flooding of the Rio Grande with local interior flooding. The analysis showed that it is highly unlikely that a storm in the larger Rio Grande watershed in New Mexico would coincide with a local storm in El Paso. In addition, a case study of the El Paso 2006 flood shows that the rise in the Rio Grande flow observed during that event was likely due to local rainfall. The conclusion of the joint probability analysis, documented as Modeling Decision 5, proposed that the modeling of any new interior drainage areas as part of this Study would apply the base flow in the Rio Grande (approximately 1,000 to 2,350 cfs, depending on river segment in the Study area) rather than the 1% AC Rio Grande flow (roughly 11,000 cfs).

Accordingly, the HEC-RAS 2D models utilized and modified for the purposes of this Study assume base flows in the Rio Grande,but allow for increases in Rio Grande tailwater due to outfalls discharging into the Rio Grande within the same Work Area. Modeling Decision 5, in Section 3.3.3 of Appendix A states this general tailwater assumption that is applied in this Study. It also states that Rio Grade low flow or base flow scenarios would be selected from previously developed interior drainage studies as the models to use for updated modeling and/or mapping purposes in this Study.

Since Appendix A was drafted for review, additional analyses were conducted as part of this Study to investigate the upstream Caballo Dam operations and how it may affect the Rio Grande base flow assumption and the quantity of low flow assumed in the Rio Grande in different parts of the County Study area. These additional analyses and assumptions were used to set modeled Rio Grande base flow values upstream and downstream of American Dam, per the logic presented below.

1. **It is likely that the interior drainage event being studied would occur during the primary irrigation season.**
    a. The primary irrigation season in El Paso occurs during March through October.
    b. From HEC-HMS models associated with previous interior drainage studies, the lag time from the Franklin Mountains to the Rio Grande was estimated to be on the order of 2 hours.

c. The hourly data at the El Paso International Airport gage were sorted to identify the highest 2-hour rainfall depths in the records (see Table 3, below).

Table 3. The Twenty Highest 2-Hour Rainfall Depths at the El Paso International Airport Gage

DATE	El Paso		New Mexico Storm on the Same Day as El Paso		New Mexico Storm One Day before El Paso		New Mexico Storm Two Days before El Paso	
	Max 2-hr Rainfall (inch)	Return period Atlas 14 (yrs)	1-day Rainfall (inch)	Return Period Atlas 14 (yrs)	1-day Rainfall (inch)	Return Period Atlas 14 (yrs)	1-day Rainfall (inch)	Return Period Atlas 14 (yrs)
9/20/1982	2.2	27.1	0.004	<1	0.198	<1	0.066	<1
8/12/2005	1.99	17.8	0.081	<1	0.002	<1	0.071	<1
5/18/1992	1.67	9.3	0.020	<1	0.007	<1	0.000	<1
7/4/1961	1.58	7.7	0.065	<1	0.142	<1	0.121	<1
9/11/1964	1.58	7.7	0.467	<1	0.087	<1	0.016	<1
8/31/1957	1.55	7.2	0.823	<1	0.515	<1	0.358	<1
8/10/1981	1.53	6.9	0.083	<1	0.000	<1	0.013	<1
8/14/2004	1.5	6.4	0.842	<1	0.081	<1	0.009	<1
7/4/1961	1.47	6.0	0.065	<1	0.142	<1	0.121	<1
8/12/1992	1.4	5.1	0.43	<1	0.035	<1	0.009	<1
9/11/1958	1.37	4.8	1.24	1.7	0.181	<1	0.024	<1
8/8/1984	1.36	4.6	0.08	<1	0.421	<1	0.442	<1
7/2/1971	1.34	4.4	0.44	<1	0.000	<1	0.000	<1
9/12/1975	1.33	4.3	1.36	2.4	0.367	<1	0.276	<1
7/15/1976	1.33	4.3	0.08	<1	0.077	<1	0.029	<1
9/2/1962	1.29	3.9	0.09	<1	0.000	<1	0.000	<1
7/5/1968	1.29	3.9	1.21	1.6	0.588	<1	0.132	<1
7/26/1990	1.27	3.7	0.00	<1	0.000	<1	0.000	<1
5/18/1992	1.26	3.6	0.02	<1	0.093	<1	0.000	<1
7/1/2000	1.26	3.6	0.02	<1	0.192	<1	0.514	<1

d. **Table 3**, above, shows that the top twenty 2-hour rainfall events in El Paso all occurred in the months of May through September, and none had significant rainfall events upstream in the Rio Grande one or two days prior.

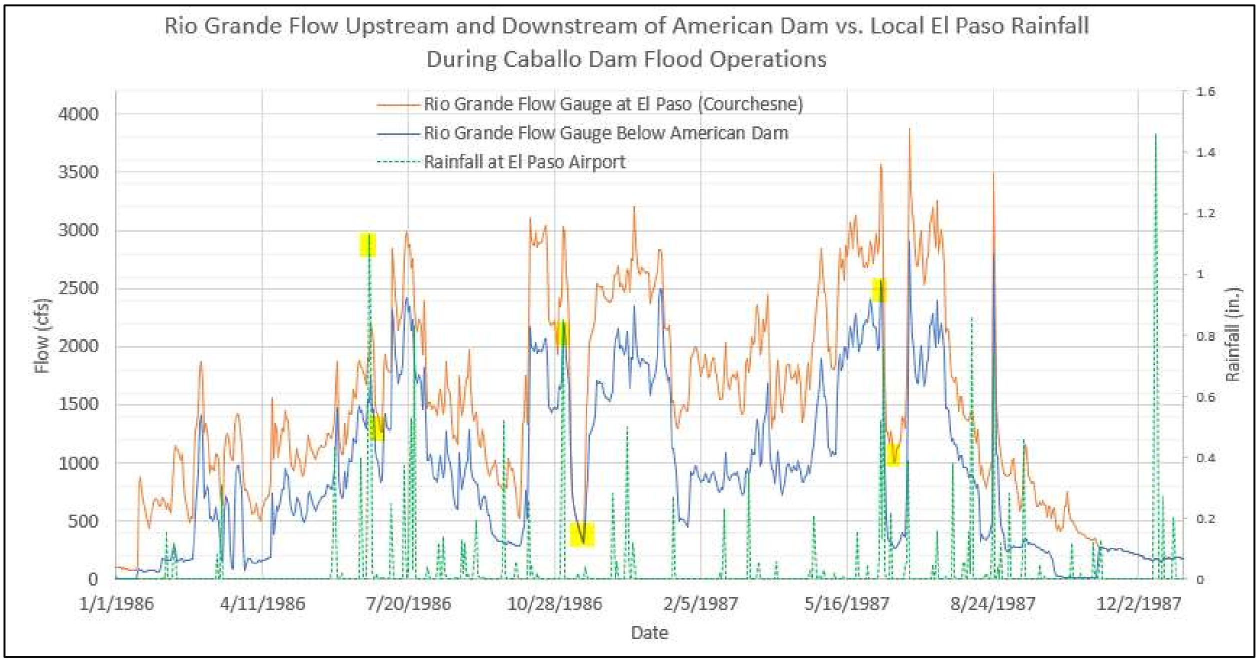
e. It should be noted that there is a series of 5 rain gages in Santa Teresa, NM. The gage with the longest period of record is at the Santa Teresa Airport, with a data record starting in 2002. These gage records are much shorter that of the El Paso Airport hourly rain gage record, which goes back to 1941. Table 3 includes the top 20 2-hour storms measured at the El Paso Airport. Only 2 of the 20 storms in Table 3 occurred during the period of record of the Santa Teresa weather station. The Santa Teresa gage record is too limited for a comparison with the much longer river gage record, which is appropriate for comparison after 1938, the date of completion of Caballo Dam. Also note that rainfall statistics in NOAA Atlas 14 for the area west of the Franklins compared to the area east of the Franklins have a larger variation with elevation than variation spatially at the same elevation. The Santa Teresa gages are all roughly between 3,800 feet elevation and 4,100 feet elevation, and the El Paso Airport rain gage is at about 4,000 feet elevation.

2. **Caballo Dam would be able to reduce releases if an extreme local rainfall event were expected to occur in El Paso as long as the Caballo Dam reservoir was not at or close to the maximum flood capacity of the reservoir. It takes approximately 3 days for any reducing in flow at Caballo Dam to reach the study area.**

a. During flood operations, Caballo Dam releases flows year-round based on the dam's available flood capacity and the capacity of the Rio Grande channel banks downstream of it.

b. Per the May 2012 Revision of the *"Rio Grande Project – Operations Manual":*
   i. Section 4.8 (Emergency Conditions): *"Each Party shall be allowed to make changes to the water order in response to emergencies such as ditch breaks,* ***flood flows****, excessive arroyo inflows, or other accidents to the system. Reclamation shall make the change in the release from Caballo Reservoir as soon as possible*."

c. In the 1986/87, flood operations of Caballo Dam, the Rio Grande gauge flow at El Paso, located upstream of American Dam (plotted in orange below) dropped rapidly in at least 2-3 instances, likely due to emergency curtailing of floodwaters from Caballo Dam because of local El Paso rain events (per rain gauge at El Paso airport, plotted in green below).



Inset Figure 3-1. Rio Grande Flow and El Paso Airport Precipitation Gage Data vs. Time, 1986-1987

d. The volume in Caballo reservoir prior to the three assumed gate-closing events (highlighted in yellow in the plot above) was below the maximum flood storage capacity and above the conservation capacity of the reservoir (see **Table 4**, below).

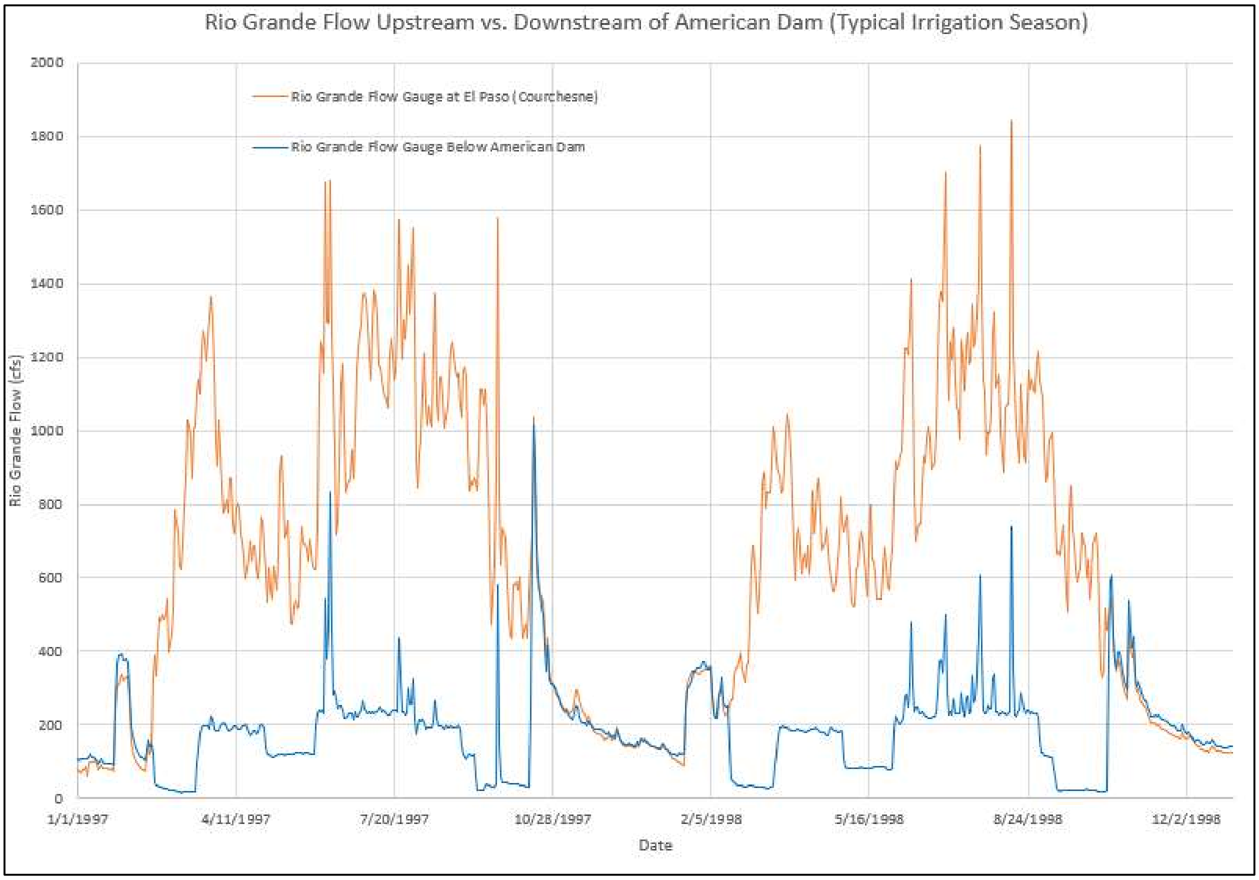
Table 4. Caballo Reservoir Storage, 1986/1987

			(Flood Capacity: 326,624 ac-ft)	(Conservation Capacity: 226,667 ac-ft)
Shutdown No.	Date	Storage (ac-ft)	% of Flood Capacity	% of Conservation Storage
1	6/24/1986	234,000	72%	103%
2	11/3/1986	237,400	73%	105%
3	6/11/1987	244,900	75%	108%

3. Rio Grande flows downstream of American Dam are reduced relative to upstream, even during flood operations at Caballo Dam.

a. Per Rio Grande gauge data below American Dam, sustained flows greater than 800 cfs rarely occurred within the period of record (since 1938).

b. On years when flood operations are not occurring at Caballo Dam, typical Rio Grande flows during irrigation season upstream of American Dam in El Paso are roughly 1,200 cfs on average, and sustained flows below American dam are approximately 200 cfs (Mexico allotment) with short duration increases up to 800 or 1,000 cfs from local events (see plot below).



Inset Figure 3-2. Rio Grande Flow vs. Time, 1997-1998

c. Per the Phase 1 report prepared for Elephant Butte Irrigation District (EBID), EPWater and EPCWID entitled, *Evaluation of Reduced Flow Capacity of the Rio Grande and the Impacts on the Operations of the Rio Grande Project Leasburg Dam to American Dam* (Joint Committee on Rio Grande Project Flood Risk, 2019) and per the *FLO-2D Model Development below Caballo Dam* (Tetra Tech, 2005) report, Rio Grande main conveyance channel capacity is roughly 1,200 cfs in El Paso upstream of American Dam

d. Per the *Operations and Maintenance Manual for Upper Rio Grande Projects* (USIBWC, 2010), the Rio Grande pilot (main conveyance) channel capacity is roughly 1,000 cfs in the Rectification Reach (downstream of American Dam to Ft. Quitman)

4. **Rio Grande Base (Low) Flow Modeling Approach:**

    a. Upstream of American Dam, within County limits, this Study assumes low flows in the Rio Grande of 1,200 cfs in HEC-RAS Preliminary FEMA domain WA1 under the assumption that during flood operations, Caballo Dam operations would limit releases to the current capacity of the Rio Grande main conveyance channel, and could stop flows altogether in case of a local El Paso event or flooding downstream of the dam.

    b. South of El Paso City limits to the County line, the low flow conditions in HEC-RAS Preliminary FEMA domains WA7, WA9, and WA11 will be reduced to 1,000 cfs to match the approximate channel capacity in that reach.

    c. Low flow assumptions applied by others in previous interior drainage studies, documented in Table 1 of Appendix A, will not be modified as part of this Study.

4 Methodology and Results

This section summarizes modeling modifications and mapping methods applied to 2D H&H models that were initially developed in other studies (source models) and presents 1% AC inundation boundaries and depth grids produced from this Study. These model results are displayed in the form of color-classified depth grids in **Figures 1 through 14**. These fourteen figures also include 1% AC Interior Drainage inundation boundaries shown as diagonal black hatching. **Exhibit A** is a Map Index, which shows the data frame locations of **Figures 1 through 14**. Appendix A documents the general assumptions associated with the source models and the background information used to decide which source models to utilize, and which source models to modify. This section is organized according to the models or groups of models associated with each source. The different sources and subsection numbers are listed below:

- 2.1 – Preliminary FEMA Models
- 2.2 – International Dam to Riverside Weir Models
- 2.3 – Doniphan Corridor Models
- 2.4 – Northwest Feasibility Models

The Electronic Files are provided in Appendix C and include the following:

- Documentation for the source studies, which can be referenced for specific methodologies and assumptions related to their corresponding H&H models.
- Original source H&H models obtained.
- Revised versions of source models that were modified as part of this Study.
- Spatial files of 1% AC inundation boundaries, depth grids, and water surface elevation grids that were developed and/or processed as part of this Study, and which are required for levee certification. Spatial files elevations are based on the NAVD88 vertical datum and are in the Texas State Plane Central 4203 Coordinate System.

4.1 Preliminary FEMA Models

The H&H submittal for Phase 2 of the El Paso County Federal Emergency Management Agency (FEMA) mapping project was completed by Compass PTS JV (Compass) for the purposes of investigating the existence and severity of flood hazards and revising the previous Flood Insurance Study (FIS) for El Paso County. Electronic copies of the hydrologic and hydraulic reports associated with the Phase 2 H&H

Submittal, entitled *Final Results of Hydrology Study El Paso County, TX* (Compass 2019) and *Final Results of Hydraulic Study El Paso County, TX* (Compass, 2019), are provided in Appendix C for reference.

The H&H models associated with Phase 2 submittal are the same models that were described as "Draft Preliminary FEMA models" in Appendix A . The most recent versions of these models are referenced as "Preliminary FEMA models" because the H&H models obtained as the source models for this Study are the models associated with the Preliminary mapping data, database, and FIS expected to be released this year in a Preliminary Issuance, which is considered Phase 3 of the FEMA project.

4.1.1 Modeling Software

HEC-RAS, Version 5.0.5 (USACE, 2018) 2D hydraulic models and HEC-HMS, Version 4.2 (USACE, 2016) hydrologic models associated with the Phase 2 H&H submittal were obtained from Compass in July 2019 and September 2019, respectively, to be utilized in this Study. All HEC-HMS and HEC-RAS models developed as part of this Study, which involved modifications to the source models, were developed using the same versions of the software as the original source models except for Work Area 1 (the northernmost 2D domain west of the Rio Grande). HEC-RAS, version 5.0.7 was used in the modified Work Area 1 hydraulic model developed in this Study due to software issues that prevented the modified model from running in the version of HEC-RAS used to develop the source model (HEC-RAS version 5.0.5).

4.1.2 Domain Locations

Four of the eleven Preliminary FEMA 2D hydraulic model domains were utilized and modified for the purpose of this Study. Each HEC-RAS 2D model domain is named according to numbered Work Areas (WA). The full model Work Areas for domains WA11, WA9, WA7, and WA1 are located at the southern and northern portions of the County, along the Rio Grande, and are shown in Exhibits 4, 5, 6, and 7 of Appendix A, respectively.

4.1.3 Modifications to Hydrologic Models

Each Preliminary FEMA hydraulic model domain has an associated hydrologic HEC-HMS model that was developed for the purpose of estimating excess rainfall, which is distributed evenly over the 2D HEC-RAS model domains. General hydrologic assumptions associated with the Preliminary FEMA HEC-HMS models are discussed in Section 4.1 of Appendix A.

Out of the four Preliminary FEMA modeling domains utilized in this Study, only one of the hydrologic models (WA7) was modified for the purpose of this Study. The WA7 hydrologic model was modified because the 2D domain boundary was truncated in order to increase run times and simplify the model. The WA7 domain is relatively large compared to the other domains and also includes several pump stations, basins, and drainage infrastructure assumptions in the East El Paso region. Exhibit 6 in Appendix A shows the Preliminary FEMA HEC-RAS 2D domain and the boundary where it was truncated for this Study. The northwestern boundary of the truncated domain overlaps with the eastern boundary of the *International Dam to Riverside Weir* (URS, 2016) East FLO-2D model domain. In areas that overlap, the *International Dam to Riverside Weir* (URS, 2016) East FLO-2D model domain is recommended to take mapping precedence.

Drainage areas included in the original HEC-HMS models provided correspond to the size of the associated HEC-RAS 2D domains. Flow hydrographs are transferred from upstream to downstream domains in HEC-RAS by extracting flow hydrographs from the upstream domain results and inserting them as input flow hydrographs in the downstream domain at approximately the same locations where flow exited the upstream domain.

Modifications applied to the WA7 hydrologic model are listed below:

- Original Area: 158.7 sq mi
    - New Area: 102.88 sq mi
- Original Curve Number (CN): 73.11
    - New CN: 70.58
- Original Tlag (hr): 47.55
    - New Tlag (hr): 41.64

The above hydrologic parameter modifications were applied using the same source data and calculation methods as the original Preliminary FEMA study. In addition to the hydrologic parameter modifications above, the 1% AC rainfall precipitation values for the truncated WA7 were updated by taking the zonal average of the rainfall raster developed by FEMA for their Phase 2 H&H models. The FEMA rainfall raster utilized leveraged the El Paso Drainage Design Manual (DDM) data within El Paso City Limits, National Oceanic Atmospheric Association (NOAA) Atlas 14 data for Texas and New Mexico outside of El Paso City limits. The rainfall data associated with the original Preliminary FEMA WA7 and the truncated WA7 domain are compared in **Table 5**, below:

Table 5. Modified 1% AC Precipitation Applied to Truncated WA7 Preliminary FEMA Model

Duration	Preliminary FEMA Precipitation in WA7 Domain	Modified Precipitation in Truncated WA7 Domain
	(inches)	(inches)
5-min	0.833	0.825
10-min	1.39	1.38
15-min	1.6	1.58
30-min	1.99	1.97
60-min	2.38	2.36
2-hr	2.71	2.69
3-hr	2.91	2.89
6-hr	3.29	3.27
12-hr	3.8	3.78
24-hr	4.43	4.42

The minimal changes in **Table 5** were applied to the WA7 meteorological model in HEC-HMS, along with the hydrologic parameter changes documented in this section to calculate updated excess rainfall, which is distributed over the modified domain in HEC-RAS using the same methods as the Preliminary FEMA models.
In addition, flow profile lines were cut along the boundary where the WA7 domain was truncated to extract flow hydrographs from the original WA7 domain and insert them as inputs to the truncated WA7 domain along the truncated domain boundary. All other inflow hydrographs from adjacent 2D domains and all normal depth downstream boundary conditions were left unchanged from the source Preliminary FEMA model.

4.1.4 Modifications to Hydraulic Models

The following modifications were made to the specified Preliminary FEMA 2D model domains as part of this Study:

- WA1 Domain Modifications:
  - Five culvert outfalls were added to the model, which discharge into the Rio Grande (see **Table 1** for outfall modeling information).
  - The east 2D domain boundary was expanded to the east to align with the top of the east Rio Grande Levee so that base flows in the Rio Grande could be applied.
  - A constant Rio Grande base flow of 1,200 cfs was added as an inflow hydrograph at the upstream (northwestern) end of the County. The hydrograph was discharged onto the 2D surface within the channel banks of the Rio Grande.
  - The Nemexas Drain Siphon was added to the model downstream of the County limits and southwest of Country Club Road Bridge over the Rio Grande, to allow drainage to flow through the siphon, under the Rio Grande, and continue down the drain.
  - Manning's roughness spatial file included in the original model was reviewed and updated in minor locations as needed, using engineering judgment.
- WA7 Domain Modifications:
  - Two culvert outfalls were added to the model, which discharge into the Rio Grande (see **Table 1** for outfall modeling information).
  - Gaps in LiDAR topography in the Rio Grande were filled in using interpolation of upstream and downstream terrain data included in the original Preliminary FEMA model.
  - The west 2D domain boundary was expanded to the west to align with the top of the west Rio Grande Levee so that base flows in the Rio Grande could be applied.
  - A constant Rio Grande base flow of 1,000 cfs was added as an inflow hydrograph at the upstream (northwestern) end of the domain.
  - A downstream normal depth boundary condition was added for Rio Grande outflow.
  - The 2D domain was truncated to decrease run times, simplify the model, and reduce overlap with International Dam to Riverside Weir (URS, 2016) East FLO-2D domain.
  - Breaklines parallel to the levee were added to the 2D mesh.
  - Manning's roughness spatial file included in the original model was reviewed and updated globally to be consistent with other HEC-RAS 2D modeling assumptions, which were based on 2011 NLCD data.
  - The evenly distributed excess rainfall hydrograph was updated and inflows located along the truncated northwest boundary were applied based on 2D profile line outflow hydrographs extracted from the source WA7 results.
- WA9 Domain Modifications:
  - Breaklines parallel to the levee were added.
  - Manning's roughness spatial file included in the original model was reviewed and updated in minor locations as needed, using engineering judgment.

  - The domain was not expanded to the west levee and Rio Grande base flow was not added to this model because there are no culvert outfalls to the Rio Grande in this domain.

  - Updated inflow hydrographs extracted from the results of outflows at WA7 normal depth boundary conditions were inserted at inflow locations along the boundary between the WA7 and WA9 domains.

- WA11 Domain Modifications:
  - Two culvert outfalls were added to the model, which discharge into the Rio Grande (see **Table 1** for outfall modeling information).

  - Gaps in LiDAR topography in the Rio Grande were filled in using FLO-2D depth and water surface elevation (WSE) spatial files from the *FEMA Natural Valley Analysis* (FEMA, 2016) and using interpolation of upstream and downstream terrain data included in the original Preliminary FEMA model.

  - The west 2D domain boundary was expanded to the west to align with the top of the west Rio Grande Levee so that base flows in the Rio Grande could be applied.

  - A constant Rio Grande base flow of 1,000 cfs was added as an inflow hydrograph at the upstream (northwestern) end of the domain.

  - A downstream normal depth boundary condition was added for Rio Grande outflow.

  - The Manning's roughness spatial file included in the original model was reviewed and updated in minor locations as needed, using engineering judgment.

  - Updated inflow hydrographs extracted from the results of outflows at WA9 normal depth boundary conditions were inserted at inflow locations along the boundary between the WA9 and WA11 domains.

  - Coordination took place via phone calls with EPCWID to attempt to validate preliminary culvert discharge results observed at the Fabens Wasteway and at the Hudspeth Main Canal Culvert (Outfalls 45 and 46, respectively, in **Table 1**).

    - No gages exist on the Rio Grande or at the outfalls discharging to the Rio Grande south of the El Paso City Limits; so data available to validate the HEC-RAS 2D models WA7, WA9, and WA11 are very limited.

    - Experiences observed in the field by EPCWID during the August 2006 flood event were discussed, and hydrologic and hydraulic assumptions included in the 2D model were evaluated.

    - In an attempt to increase flows at the Fabens Waste Channel, which seemed low relative to conditions observed in the field by EPCWID, a sensitivity test was performed, which involved the following variables:

      - Adding breaklines along the Fabens Waste Channel and along the San Felipe watershed divide, located between the two outfalls being investigated.

      - The Island Drain Siphon (which conveys flow from the Border Drain under the Fabens Waste Channel) was removed in some scenarios based on the

EPCWID field observation that it tends to get partially clogged during flood events and capacity becomes limited.

- Multiple walls were added to the model as 2D connections at low points in the Fabens Waste Channel, where flow was escaping to the southeast toward the Hudspeth Main Canal Culvert.

- A range of depths produced from 6 different sensitivity test scenarios were evaluated through coordination with EPCWID. AECOM ultimately selected the sensitivity test scenario with the following modifications for mapping:

    - Additional breaklines were added along the Fabens Waste Channel and San Felipe watershed boundary;

    - The Island Drain Siphon was removed from the model; and

    - Two walls were added along the Fabens Waste Channel.

- Results from the sensitivity test scenarios described above were considered when applying judgment during the floodplain mapping process.

4.1.5 Flood Risk Mapping Methods

Flood depths and water surface elevations were extracted from HEC-RAS 2D model results and a series of post-processing tasks were performed for the development of electronic spatial files for 1% AC inundation boundaries, depth grids, and water surface grids, included in Appendix C. A 2D hydraulic results post-processing and mapping tool named “RAPTOR” was developed by Compass and applied in the FEMA Phase 2 H&H submittal. This same “RAPTOR" tool was obtained and utilized in ESRI’s ArcMap as part of this Study to process results from the HEC-RAS models updated in 2D domains WA1, WA7, WA9, and WA11. When using the “RAPTOR” tool to finalize 1% AC inundation boundaries in this Study, engineering judgment was applied while following similar mapping methods as those performed by Compass during the extracting, smoothing, and finalizing of Zone A inundation boundaries for FEMA’s Phase 2 H&H study.

The purpose of the spatial floodplain file “cleaning” methods applied in FEMA’s Base Level Engineering (BLE) mapping and Zone A mapping processes is to delineate areas of flooding that meet the general criteria of having 1 foot of depth or greater connected to a Coordinated Needs Management Strategy (CNMS) stream or streams having a contributing drainage area of 1 square mile or greater. Preliminary FEMA water lines were used for the mapping process in the extremely flat areas being mapped in this Study instead of the CNMS streams or streams with contributing drainage areas of 1 square mile or greater. The Preliminary FEMA water line spatial file (provided by Compass in April 2020 for use in the mapping process of this Study) include open channels, natural streams, drains, canals, etc., but does not include storm drain conduits. The water line feature is the result of the following sources:

- Effective Flood Insurance Rate Maps (FIRMs);
- Letters of Map Change (LOMCs);
- National Hydrography Dataset (NHD);
- updated water lines from El Paso County;
- City GIS sources and (2009 and 2010) Stormwater Plans; and
- Refinements due to the 2015 LiDAR and 2018 NAIP Imagery as part of the FEMA Phase 2 H&H study.

4.1.6 Results Maps and Study Limits

In general, the figures presented in this section display model results for flood depths greater than 0.5 ft, but the 1% AC inundation boundaries are generally based on areas within the Natural Valley floodplain where flood depths are greater than 1 ft. The inundation boundaries were adjusted based upon the estimated depths, plus other information associated with model topography and the accuracy of the tools used to aggregate areas using engineering judgment.

Figures 1 and 2 display depth and inundation boundaries for the domain, WA1. **Figures 3 and 4** of this report display depth and inundation boundaries for WA7 and WA9, respectively. **Figures 5 and 6** display depth and inundation boundaries for WA11. In **Figures 1 through 6**, flood inundation boundaries are approximately delineated at depths of 1 foot or more connected or adjacent to Preliminary FEMA water lines (shown as “water line”). Considering the very mild slopes and the number of irrigation canals and drains in the Rio Grande Valley, engineering judgment was applied in mapping connected shallow flooding inundation areas, sometimes less than 1 foot, depending on the topography and sources of flooding in the area.

In **Figures 1 through 14**, inundation boundaries are not generally delineated outside of County boundaries, within the river side of Rio Grande levee segments, or outside areas specified as the Natural Valley floodplain (which assumes 1% AC flooding in the Rio Grande with no levee system in place) per FEMA’s Phase 2 H&H submittal. Exceptions to the general rule of only mapping inundation boundaries within the Natural Valley floodplain are applied in areas where connected flooding of 1 foot or more extends upstream or outside of the Natural Valley floodplain.

4.2 International Dam to Riverside Weir Models

As discussed in Section 2.2 of Appendix A, the FLO-2D models developed for the *International Dam to Riverside Weir* (URS, 2016) study are considered the best available interior drainage models for the Central and East regions of El Paso. Out of the eight scenarios modeled in that study (four for the Central domain and four for the East domain), this Study utilized Scenarios 3 (for Central domain) and 7 (for East domain) as source models, which include post-levee improvements, base flows in the Rio Grande of 2,350 cfs, 1% AC local interior flooding, and precipitation data from the City of El Paso Drainage Design Manual. The post-levee scenario was selected because the *International Dam to Riverside Weir* (URS, 2016) report states that the post-levee improvements were implemented prior to the analysis. The selected modeling scenarios assume all Rio Grande outfall gates are open, and consider the flood benefits of storm drain systems by reducing drainage basin runoff hydrographs computed from hydrologic HEC-HMS models before releasing the discharges onto the FLO-2D topographic surface. The drainage area hydrographs are reduced by subtracting the capacities of the storm drain systems (estimated using StormCAD), which consider maximum capacities of pump stations, if applicable. Final documentation of the *International Dam to Riverside Weir* (URS, 2016) study is provided in Appendix C of this Report for reference.

It should be noted that Scenarios 4 (for Central) and 8 (for East) were considered by FEMA for the El Paso 2 levee certification, from International Dam to Ysleta-Zaragoza International Bridge, as providing reduced risk on the upcoming Preliminary FIRM issuance. Those Scenarios 4 and 8 assume 1% AC interior rainfall coincident with 1% AC flow in the Rio Grande (all Rio Grande outfall gates are assumed to be closed and storm drains are not considered). Due to the results of the joint probability analysis documented in Section 3 of Appendix A, Scenarios 3 and 7 were chosen for this Study (assuming Rio Grande base flow, all outfall gates open, and storm drains considered) instead of Scenarios 4 and 8. This results in reduced flooding in the Central and East regions relative to the scenarios considered by FEMA in the upcoming Preliminary FIRM issuance.

4.2.1 Modeling Software

FLO-2D, Version 2009.06 (FLO-2D Software, Inc.) hydraulic models associated with the Central and East 2D domains were developed in the *International Dam to Riverside Weir* (URS, 2016) study and were obtained by AECOM to be utilized in this Study. Only one of the two hydraulic domains (the Central domain) was modified as part of this Study. For that Central model, AECOM made updates required to run the model in the latest FLO-2D Pro Version 18.12.20 (FLO-2D Software, Inc., 2018) software, as the older FLO-2D software associated with the original source models is no longer available for purchase.

AECOM also obtained and modified two of the hydrologic models associated with the *International Dam to Riverside Weir* (URS, 2016) study. The Government Hills and Cebada drainage system HEC-HMS, Version 3.5 (USACE, 2010) hydrologic models were obtained and modified in the same version of HEC-HMS as part of this Study.

The original storm drain models used to simulate storm drain and pump system capacities in the *International Dam to Riverside Weir* (URS, 2016) study were developed in StormCAD, Version 8.11.3.77 (Bentley) software. The original StormCAD models were not modified as part of this Study.

4.2.2 Domain Locations

The *International Dam to Riverside Weir* (URS, 2016) FLO-2D model domains are located in the Central and East regions of El Paso, and are shown, along with their contributing drainage systems, in Exhibits 2 and 9 of Appendix A. As part of this Study, recently completed drainage improvement projects contributing to flow hydrographs discharged in the Central and East FLO-2D domains were evaluated and incorporated. Locations of those improvement projects are shown in **Figure 15**.

4.2.3 Modifications to Hydrologic Models

The HEC-HMS models associated with the Cebada and Government Hills drainage systems (two models) were updated as part of this Study to incorporate eight recently completed drainage improvement projects in the City of El Paso. The HEC-HMS drainage systems, primary hydrologic elements, and drainage improvement project locations are shown in **Figure 15**. These projects were selected for incorporation in this Study through coordination with EPWater. **Table 2** documents the modifications made to each of the two HEC-HMS models. Screen captures of the HEC-HMS schematic diagrams of each model before and after modifications are provided in Appendix B.

4.2.4 Modifications to Hydraulic Models

Modifications were made to the Central FLO-2D model from the *International Dam to Riverside Weir* (URS, 2016), which consisted of adjustments required for the model to run on the latest version of FLO-2D software, and the addition of two new discharge nodes in the Cebada drainage system. The adjustments to the Government Hills HEC-HMS model did not results in any modifications to the Central or East FLO-2D domains.

4.2.4.1 Adjustments Due to FLO-2D Software Update

Modifications were required in order to run the Central FLO-2D model on the latest version of the software (FLO-2D Pro Version 18.12.20). The original model was created in an outdated version of FLO-2D software (FLO-2D, Version 2009.0.6) that is no longer available. When running the central model on FLO-2D Pro Version 18.12.20, the model had volume conservation issues and some data conflicts between the levees, grid elevations, and channel banks. The following modifications were made to the Central model in order to run it on the latest FLO-2D software:

- Volume Conservation – Some of the inflow locations in the provided data file were co-located with grids designated as Area Reduction Factors (ARFs). The inflow grids were then relocated to places without ARF designation, and which represented open areas such as streets. Below is a summary of the relocation of inflow grids:
  - 17375 to 17374
  - 23311 to 23662
  - 12658 to 12374
  - 14928 to 14929
  - 3083 to 3205
  - 54651 to 53405
  - 45011 to 45010
  - 40000 to 39999

- Below are modifications made to the Rio Grande 1-D channel components:
  - Some of the channel right banks were added and channel cross-sections were relocated and updated. This was to address the errors resulting from the latest run of the executable.
  - The levee conflicts with the channel geometry were fixed.
  - The hydraulic structures without the reference elevation and another with the reference elevation in the channel cross-sections were left as coded originally.
  - The channel cross-sections top elevations are about 15-ft on average greater than the interpolated grids. Elevation on the grids were updated, but some of those elevations were in conflict with the levee crest elevations. The solution was to modify the elevations on the cross-sections and the grids such that the elevations on the levee crest took precedence.
    - Some modifications were made to the grid elements and the channel cross-sections, but the levee crest was not modified.
    - A script was run to lower the elevations at the banks of the 398 Rio Grande 1D cross-sections.
    - The bank grid elevations were adjusted from the original interpolated elevations to be below the levee crest by at least a half-foot.

- The floodplain cross-section was fixed, as there were some overlapping grids on the cross-section.

- The inflow file was updated with two new inflow points as a result of the hydrologic updates in this Study.

With all of the above changes, the model ran with the newer executable FLO-2D Pro Version 18.12.20.

4.2.4.2 Government Hills Drainage System Analysis

The modifications applied to the Government Hills Drainage System hydrologic HEC-HMS models had flooding benefits north of IH-10, but did not have an effect on the FLO-2D discharge hydrographs released further downstream, in the Central or the East FLO-2D domains. This is because the reduced outflows in Government Hills Channel, which resulted from improvements constructed at Pershing Dam and Van Buren Dam, were ultimately diverted into the Upper and Lower Durazno basins via a diversion at Boone Street Basin (located northeast of the intersection of Yandell Drive and North Boone Street). This diversion ("D_Boone_St_Basin" in the HEC-HMS model) diverts Government Hills Channel inflows in excess of 375 cfs (the assumed downstream storm drain capacity discharging into the Rio Grande) into the Upper and Lower Durazno Basin pond system. This pond system is estimated to have sufficient capacity to store all of the contributing upstream runoff without overflowing into the Central or East 2D domains.

4.2.4.3 Cebada Drainage System Analysis

The modifications to the Cebada drainage system hydrologic model resulted in two new discharge nodes being applied to the Central FLO-2D domain relative to the *International Dam to Riverside Weir* (URS, 2016) study. The two new hydrograph discharge locations are shown in **Figure 15**. One of the discharge locations (related to overflow from the Gateway East Pond) is located south of IH-10 and immediately south of the Gateway East pond, at the intersection of Durazno Avenue and North Cebada Street. The second new discharge location (related to overflow from Magnolia Pond) is located on the westbound main lanes of IH-10, just south of the intersection of East Missouri Avenue and Poplar Street.

The new discharge location south of the Gateway East Pond is where it is estimated that overflow from the pond system consisting of Gateway West Pond, Gateway East Pond, and Cebada Pond (which act as a connected system) would overflow when the pond system and the connected Cebada conduit receive runoff in excess of their combined capacity during the 1% AC flood event. Based on a review of the HEC-HMS and FLO-2D modeling in the *International Dam to Riverside Weir* (URS, 2016) study, it appears the future pond system was previously assumed to have capacity for the 1% AC flood once all phases were constructed.

The second new FLO-2D discharge location in the Central model was inserted where overflows from the Magnolia Pond system are expected to overtop IH-10. This results from the following scenario occurring during the 1% AC HEC-HMS simulation:

- Magnolia Pond outflows exceed the capacity of the new Magnolia Pump Station (assumed to be 175 cfs per coordination with EPWater) and overflow into the Eucalyptus to Cebada storm drain (a 60-inch diameter conduit); and

- Runoff from the drainage area immediately south of Magnolia pond (“A_Eucalyptus_to_Cebada” in HEC-HMS) combine with excess Magnolia Pond outflows and exceed the capacity of the Eucalyptus to Cebada 60-inch diameter conduit (assumed to have a capacity of 100 cfs per the source HEC-HMS model).

Although there was not an IH-10 discharge node associated with the Magnolia Pond overflows in the source FLO-2D model, the original Central FLO-2D model already showed some flooding in this location due to overflows from the Cotton/Dallas pond. Similarly, flooding in the location of the new discharge node for the Gateway East Pond overflow was already present in the original Central FLO-2D modeling due to runoff released from a drainage area to the west of the area. Therefore, the areas inundated by flood depth results of 1 ft or more were only marginally increased in both new discharge locations relative to the original FLO-2D model results for the same scenarios.

4.2.5 Flood Risk Mapping Methods

The Central and East FLO-2D output spatial files were processed using ArcMap, Version 10.6 (ESRI) software to produce 1% AC depth and water surface elevation polygons as well as 1% AC inundation boundaries for depths of 1 foot or greater. These spatial files are provided in Appendix C and are based upon FLO-2D output polygons that have 50 ft x 50 ft grid cell sizes. The following post processing methods were applied in the Central and East FLO-2D domains:

- The maximum 1% AC flow depth GIS shapefiles provided as electronic deliverables for this Study were developed for each domain by combining the FLO-2D outputs “Flow Depth at cell.shp” (depth outside channels) and “DEPCH.OUT” (depth of channel cells) to create a GIS shp file that includes maximum 1% AC depths in both 1D channel areas and 2D overland flow areas. Disconnected flow depths in the Rio Grande, which are isolated from flooding on the landward side of the levees, were deleted from the spatial file outputs.

- The maximum 1% AC Water Surface Elevation (WSE) GIS shapefiles provided as electronic deliverables for this Study were developed for each domain by attributing WSE data to the combined depth shapefile, described in the step above, from the MAXWSELEV.OUT FLO-2D output file by correlating the cell IDs.

- The 1% AC inundation boundary GIS shapefiles provided as electronic deliverables for this Study were developed for each domain by completing the following additional steps:
  - Cells with maximum depths of 1 ft or greater were extracted from the combined depth file described above.
  - All features were merged together and an ArcMap (ESRI) tool called "Multipart to Singlepart" was used to convert the multipart feature into individual features within the same shapefile.
  - Isolated groups of 50 ft x 50 ft grid cells containing only one cell or two adjacent cells, disconnected from other flood depths of 1 ft or greater, were removed by deleting all features with an area less than 5,000 ft^2.
  - Additional inundation boundaries were removed if they did not intersect either the Natural Valley floodplain or the Preliminary FEMA Special Flood Hazard Areas (SFHAs) of "High Risk" that were delineated by FEMA based upon the International Dam to Riverside Weir (URS, 2016) original FLO-2D results from Scenarios 4 and 8.
  - The remaining inundation shp file was then smoothed using the PAEK method in ArcMap (ESRI), with a 200 ft tolerance applied.

4.2.6 Results Maps and Study Limits

Figure 7 displays estimated 1% AC flood depths greater than 0.5 feet and 1% AC interior drainage inundation boundaries for the Central FLO-2D model described in this subsection. Similarly, **Figures 8, 9, and 10** display 1% AC inundation boundaries and depths greater than 0.5 ft for the East FLO-2D domain. Flood inundation boundaries are approximately delineated at depths of 1 foot or more that intersect the Natural Valley floodplain. Inundation boundaries were also mapped in **Figures 7 through 10** at locations which may be outside the Natural Valley floodplain, but which intersect Preliminary FEMA SFHAs of "High Risk" that were delineated by FEMA based upon the *International Dam to Riverside Weir* (URS, 2016) original FLO-2D results from Scenarios 4 and 8. All Rio Grande depth cells or water surface elevations on the river side of the U.S. levees were removed from spatial files shown in **Figures 7 through 10** or submitted as part of this Study.

The East domain FLO-2D model results were not modified relative to the same scenario (Scenario 7 - base flow and 1% AC interior runoff) from the original *International Dam to Riverside Weir* (URS, 2016) study. As discussed in Section 4.2.4.2 of this Report, this is because the flow reductions in Government Hills Channel resulting from improvements applied at Pershing Dam and Van Buren dam were diverted into the Upper and Lower Durazno Basin pond system, which contains the flow and does not discharge into the Central or East domain.

Similar to the East domain, most of the discharge hydrographs released in the Central FLO-2D domain were based on stormwater runoff from each HEC-HMS drainage area, with flow reductions from maximum storm drain system capacities already applied to HEC-HMS outflow hydrographs. However, as discussed in Section 4.2.4.3 of this Report, the updated Central hydrologic analysis resulted in increased estimated discharge from two new discharge hydrographs applied on the IH-10 corridor and just south of the Gateway East Pond. Therefore, flooding in these two areas is marginally increased relative to the FLO-2D results from the same scenario (Scenario 3 - base flow and 1% AC interior runoff) in the *International Dam to Riverside Weir* (URS, 2016) study.

The main reductions of flood inundation areas developed in this Study relative to the FLO-2D inundation boundaries considered by FEMA in the upcoming Preliminary issuance are due to the selection of the Rio

Grande base flow condition (Scenarios 3 and 7 for Central and East, respectively) instead of the coincident 1% AC flooding in the Rio Grande that is assumed in Scenarios 4 (Central) and 8 (East), considered by FEMA.

4.3 Doniphan Corridor Models

As discussed in Section 2.2 of Appendix A, the FLO-2D models developed for the *Interior Drainage Analysis Report for El Paso, Texas, Doniphan Drive to Borderland to American Dam* (USACE, 2018) are considered the best available interior drainage models for the domain coverage area, which can be seen in Exhibit 2 of Appendix A. Out of the four scenarios modeled in that study (base flow vs. 1% AC flow in the Rio Grande for pre-levee improvements and base flow vs. 1% AC flow in the Rio Grande for post-levee improvements), this Study utilized Scenario 1, which includes post-levee improvements, base flows in the Rio Grande of 2,350 cfs, and 1% AC local interior flooding, based on precipitation data from the City of El Paso Drainage Design Manual. The post-levee scenario was chosen because documentation of the Doniphan Corridor (USACE, 2018) states, *"Field investigations confirmed that the CME2/SPE levees were completed between Borderland Road and the El Paso Electric Plant several years prior to this analysis*." The selected post-levee modeling scenario also assumes that all Rio Grande outfall gates are open. Final documentation of the *Doniphan Corridor* (USACE, 2018) study is provided in Appendix C for reference.

4.3.1 Modeling Software

FLO-2D, Pro (FLO-2D Software, Inc.) hydraulic models were developed in the *Doniphan Corridor* (USACE, 2018) study and were obtained by AECOM to be utilized in this Study without modifications. Runoff hydrographs were developed in HEC-HMS, Version 4.1 (USACE) and applied to the FLO-2D model as part of the *Doniphan Corridor* (USACE, 2018) study, and those hydrologic models were not modified as part of this Study.

4.3.2 No Modifications to Hydrologic or Hydraulic Models

As stated above, neither the hydrologic HEC-HMS models nor the hydraulic FLO-2D models from the *Doniphan Corridor* (USACE, 2018) study were modified as part of this Study. This decision was documented in Modeling Decisions 2 and 3 from Sections 2.2 and 2.3 of Appendix A.

4.3.3 Flood Risk Mapping Methods

The Scenario 1 FLO-2D output spatial files were processed using ArcMap, Version 10.6 (ESRI) software to produce 1% AC depth and water surface elevation polygons as well as 1% AC inundation boundaries for depths of 1 foot or greater. These post-processed spatial files are provided in Appendix C and are based upon FLO-2D output polygons that have 50 ft x 50 ft grid cell sizes. The following post processing methods were applied in the Doniphan Corridor FLO-2D domain:

- The maximum 1% AC flow depth GIS shapefile provided as an electronic deliverable for this Study was developed by obtaining the "Max Combined Channel and Floodplain Flow Depth at Cell" FLO-2D output file included in the *Doniphan Corridor* (USACE, 2018) study's final report submittal and deleting all cells with depths of 0 ft.

- The maximum 1% AC Water Surface Elevation (WSE) GIS shapefiles provided as electronic deliverables for this Study were developed for each domain by attributing WSE data to the combined depth shapefile, described in the step above, from the MAXWSELEV.OUT FLO-2D output file by correlating the cell IDs.

- The 1% AC inundation boundary GIS shapefile provided as an electronic deliverable for this Study was developed for the Doniphan Corridor domain by completing the following additional steps:

- Cells with maximum depths of 1 ft or greater were extracted from the combined depth file described above.
- All features were merged together and an ArcMap (ESRI) tool called "Multipart to Singlepart" was used to convert the multipart feature into individual features within the same shapefile.
- Isolated groups of 50 ft x 50 ft grid cells containing only one cell or two adjacent cells, disconnected from other flood depths of 1 ft or greater, were removed by deleting all features with an area less than 5,000 ft^2.
- Additional inundation boundaries were removed if they were located on the river side of the levee segments considered in this domain, if they did not intersect the Natural Valley floodplain, or if they were outside of County limits.
- The remaining inundation shp file was then smoothed using the PAEK method in ArcMap (ESRI), with a 200 ft tolerance applied.

4.3.4 Results Maps and Study Limits

Figures 11 and 12 display estimated 1% AC flood depths greater than 0.5 feet and 1% AC interior drainage inundation boundaries for the *Doniphan Corridor* (USACE, 2018) FLO-2D model described in this subsection. Flood inundation boundaries are approximately delineated at depths of 1 foot or more that intersect the Natural Valley floodplain. All Rio Grande 1% AC flood inundation boundaries outside of El Paso County limits, or those located on the river side of the east Rio Grande levees were removed from the spatial file submitted in Appendix C. However, flood depths are shown outside of the County limits and within the Rio Grande in **Figures 11 and 12** since the flooding is connected to areas inside County limits which are required to be mapped as inundation boundaries for levee certification. Some inundation boundaries extend upstream of the Natural Valley floodplain if there are connected flood depths of one foot or more.

4.4 Northwest Feasibility Models

As discussed in Section 2.2, Appendix A, the FLO-2D models developed for the *Hydrologic, Hydraulic, & Sediment Analysis for Northwest El Paso, TX, Arroyos 38 to 48* (USACE, 2015) are considered the best available interior drainage models for the coverage area, which can be seen in Exhibit 2 of Appendix A. Out of the two scenarios modeled in that study (base flow in the Rio Grande and 1% AC interior flooding with proposed levee gates open vs. 1% AC flooding in the Rio Grande and the interior, with proposed levee gates closed), this Study utilized results from the proposed scenario which includes base flows in the Rio Grande of 1,450 cfs and 1% AC local interior flooding, based on precipitation data from the City of El Paso Drainage Design Manual. The selected modeling scenario also considers a proposed levee/floodwall segment along the east bank of the Rio Grande, between Vinton Bridge and East Borderland Rd with all proposed Rio Grande outfall gates open. Final documentation of the *NW Feasibility* (USACE, 2015) study is provided in Appendix C for reference.

4.4.1 Modeling Software

FLO-2D, Pro (FLO-2D Software, Inc.) hydraulic models were developed in the *NW Feasibility* (USACE, 2015) study and were obtained by AECOM to be utilized in this Study without modifications. Runoff hydrographs were developed in HEC-HMS, Version 3.5 (USACE) and applied to the FLO-2D model as part of the *NW Feasibility* (USACE, 2015) study, and those hydrologic models were not modified as part of this Study.

4.4.2 No Modifications to Hydrologic or Hydraulic Models

As stated above, neither the hydrologic HEC-HMS models nor the hydraulic FLO-2D models from the *NW Feasibility* (USACE, 2015) study were modified as part of this Study. This decision was documented in Modeling Decisions 2 and 3 from Sections 2.2 and 2.3 of Appendix A.

4.4.3 Flood Risk Mapping Methods

The FLO-2D output spatial files were processed using ArcMap, Version 10.6 (ESRI) software to produce 1% AC depth and water surface elevation polygons as well as 1% AC inundation boundaries for depths of 1 foot or greater. These spatial files are provided in Appendix C and are based upon FLO-2D output polygons that have 50 ft x 50 ft grid cell sizes. The following post processing methods were applied to the the *NW Feasibility* (USACE, 2015) FLO-2D domains:

- The maximum 1% AC flow depth GIS shapefile provided as electronic deliverables for this Study was developed by combining the FLO-2D outputs “Flow Depth at cell.shp” (depth outside channels) and “DEPCH.OUT” (depth of channel cells) to create a GIS shp file that includes maximum 1% AC depths in both 1D channel areas and 2D overland flow areas and deleting all cells with depths of 0 ft.

- The maximum 1% AC Water Surface Elevation (WSE) GIS shapefile provided as an electronic deliverable for this Study was developed by attributing WSE data to the combined depth shapefile, described in the step above, from the MAXWSELEV.OUT FLO-2D output file by correlating the cell IDs.

- The 1% AC inundation boundary GIS shapefile provided as an electronic deliverable for this Study was developed by completing the following additional steps:
  - Cells with maximum depths of 1 ft or greater were extracted from the combined depth file described above.
  - All features were merged together and an ArcMap (ESRI) tool called “Multipart to Singlepart” was used to convert the multipart feature into individual features within the same shapefile.
  - Isolated groups of 50 ft x 50 ft grid cells containing only one cell or two adjacent cells, disconnected from other flood depths of 1 ft or greater, were removed by deleting all features with an area less than 5,000 ft^2.
  - Additional inundation boundaries were removed if they were located on the river side of the levee segments considered in this domain, if they did not intersect the Natural Valley floodplain, or if they were outside of County limits.
  - The remaining inundation shp file was then smoothed using the PAEK method in ArcMap (ESRI), with a 200 ft tolerance applied.

4.4.4 Results Maps and Study Limits

Figures 13 and 14 display estimated 1% AC flood depths greater than 0.5 feet and 1% AC interior drainage inundation boundaries for the *NW Feasibility* (USACE, 2015) FLO-2D model described in this subsection. Flood inundation boundaries are approximately delineated at depths of 1 foot or more that intersect the Natural Valley floodplain. All Rio Grande 1% AC flood inundation boundaries, flood depths, and WSE results located outside of El Paso County limits are removed from the spatial files provided in Appendix C. However, flood depths are shown within the Rio Grande in **Figures 13 and 14**, since the flooding is connected to areas on the landward side of the levees. Some inundation boundaries extend upstream of the Natural Valley floodplain if there are connected flood depths of one foot or more.

5 Conclusions

This report provides estimates for extent of flooding interior to the levee system in extreme rainfall events, notably the 1% AC storm. These estimates were based upon current rainfall statistics, recent topographic data, and recent field inventory of major stormwater conveyance systems that strongly affect flood extents. These data sources have been documented in this report and in Appendix A. These predicted extents have also been checked with local stakeholders to identify where flood extents are consistent or inconsistent with local floodplain manager experience in the area. Draft versions of this report, including draft interior drainage mapping results figures were reviewed by the following community stakeholders before finalizing the report:

- El Paso County
- EPWater
- USIBWC
- City of El Paso
- Village of Vinton
- City of San Elizario
- EPCWID No. 1
- Elephant Butte Irrigation District

Isolated flooding areas identified by stakeholders during reviews of preliminary documentation and flood mapping are organized into the following categories:

- Flooding associated with irrigation systems and wasteways in rural areas;
- Localized flooding caused by low-lying depressions in relatively flat drainage areas;
- Local unmodeled storm drain systems in urban areas that do not discharge directly to the Rio Grande or through a pump system; and
- Differences between the recent preliminary FEMA 1% AC Special Flood Hazard Areas (SFHAs) and draft 1% AC interior drainage inundation boundaries developed for this Study.

Importantly, the areas identified by stakeholders for further explanation were primarily small, isolated areas within the full mapped flood extent. This limited feedback was considered confirmation of the general consideration that the full mapped extent was a reasonable portrayal of local flood risk. Detailed comments and comment responses were provided, including explanations of specific areas where inquiries were made about the cause of flooding shown in flood depth figures (**Figures 1 through 14**). The flood locations identified by stakeholders and the flood source explanations are provided in this section.

5.1 Flooding Associated with Irrigation Systems

The following areas were identified for recommended modeling modifications by community stakeholders familiar with flooding adjacent to Rio Grande levees, irrigation systems, and wasteways discharging directly into the Rio Grande:

- Outfall No. 58 (Vinton Cutoff Lateral Wasteway #32B) from **Table 1** (**Figure 1**) was identified to be a different material (RCP) than what was initially modeled (CMP).
    - The 2D HEC-RAS model was adjusted for WA1 so that the Manning's n for Outfall No. 58 is 0.013 instead of 0.019.
- Outfall No. 81 (Shultz Lateral Wasteway #35C) from **Table 1** (**Figure 2**) was initially excluded from the 2D HEC-RAS model for WA1.
    - The outfall was added to the revised 2D HEC-RAS model for WA1, along with relevant upstream culverts to allow flow from Shultz lateral to reach the existing wasteway.

- Flooding associated with Outfall No. 45 (Fabens Wasteway) and Outfall No. 46 (Hudspeth Main Canal Culvert) in the rural areas southeast of San Elizario City Limits to the El Paso/Hudspeth County line (**Figures 3 through 6**).
  - Multiple iterations of model adjustments were applied to HEC-RAS 2D model domain WA11, as described in the final bullets of Section 4.1.4 of this report, as well as to the contributing upstream HEC-RAS 2D domains (WA7 and WA9) in order to simulate prominent ridge lines, siphons, and other drainage features affecting flood extents.

5.2 Localized Flooding in Depressions

Localized flooding areas that were identified by stakeholders in order to inquire about the source of flooding or the model inputs associated with isolated ponding locations are listed below:

- Ponds and ditches in the El Paso Water's Upper Valley Wastewater Treatment Plant at 9070 N Vinton Road (**Figure 1**).
  - Since the topographic LiDAR surface used for the 2D modeling domain includes depressions in this area, the ponds and ditches in the area filled with local drainage and excess precipitation that was distributed evenly over the 2D surface. This area was not mapped as a 1% AC Interior Drainage Inundation Boundary, indicated by the black diagonal hatch lines. Topography shows relatively flat surrounding land with mild slopes from north to south.
- Just south of the Vinton Road Bridge on the west side of the Rio Grande (**Figure 1**) is an undeveloped lot where model depth results show interior floodwater over three feet deep.
  - Although this vacant lot is relatively flat, the ponding locations identified are in a depressed area approximately 3-5 ft deep according to the topographic LiDAR used in the HEC-RAS 2D model for WA1. This localized flooding area was not mapped as a 1% AC Interior Drainage Inundation Boundary, indicated by the black diagonal hatch lines.
- Commercial shopping center northeast of the intersection of Alameda Avenue and Paisano Drive (**Figure 8**).
  - Localized flooding occurs in these large parking lots, which are low-lying areas (roughly 2-3 feet lower than surrounding land) in a relatively flat drainage area primarily comprised of impervious cover.
- Residential neighborhood south of the intersection of Montoya Drive and Elmwood Court (**Figure 11**).
  - Model results show localized flooding occurring in this area, caused by mild, relatively flat drainage areas sloping from north to south. LiDAR shows minor depressions in these locations relative to surrounding land. No storm drains exist in this location.
- Residential neighborhood northeast of the intersection of Montoya Drive and Camino Real Street (**Figure 11**).
  - Model results show localized flooding occurring in this area, caused by mild, relatively flat drainage areas sloping from north to south. LiDAR shows minor depressions in these locations relative to surrounding land. No storm drains exist in this location.

5.3 Unmodeled Storm Drain Systems

Some areas were identified by stakeholders that were questioned because of a lack of full consideration of storm drain capacity. In these locations, existing storm drain systems do not discharge directly to the Rio Grande or to a pump station, so outfall tailwaters may prevent the systems from operating efficiently during the 1% AC event. This study made the basic and reasonable assumption that the storm drain systems identified by stakeholders are not designed for the 1% AC event and will not materially affect floodplains within extremely flat terrain. City of El Paso GIS storm drain data obtained for this Study do not include conduit sizes or pipe inverts in these locations, and no action was taken to survey or model these isolated systems. In these areas, the mapped flood extents may be conservative, but ponding would still be expected to occur during the modeled storm event. Locations identified by stakeholders which do not consider existing storm drains are listed below:

- Residential neighborhood north and west of the intersection of Delta Drive and Fonseca Drive (**Figure 8**).
  - It is assumed that the storm drain systems in these locations do not have capacity for the 100-year event. Therefore, localized flooding is expected to occur on the surface of this depressed areas within a mildly sloped drainage areas generally draining from northwest to southeast.
- Residential and commercial development east of the intersection of North Seville Drive and Alameda Avenue (**Figure 8**).
  - It is assumed that the storm drain systems in these locations do not have capacity for the 100-year event. Therefore, localized flooding is expected to occur on the surface of these depressed areas within mildly sloped drainage areas generally draining from north to south and ponding at low points just north of Playa Drain.

5.4 Comparisons to Preliminary FEMA Special Flood Hazard Areas

Areas affected by channelized and/or out-of-bank flooding within the NW Feasibility Study Area, located on the westside of the county (**Figure 13**), were identified by community stakeholders who compared flood extents from this Study (shown as either depth grids or 1% AC interior drainage inundation boundaries) relative to Preliminary FEMA SFHAs. It is important to note that the differences in inundation footprints are related to differences in mapping methods, modeling methods, topographic data sources, and modeling software when comparing the NW Feasibility Study FLO-2D model results (used in this Study) to the Preliminary FEMA HEC-RAS 2D model results. It is also important to note that the NW Feasibility Study considers a proposed levee/floodwall (the USIBWC Canutillo Phase II Design Project) and proposed outfalls, which the Preliminary FEMA models do not consider. This Study utilized results from a proposed conditions model in this area so that the models and results developed could be used for FEMA levee accreditation once the proposed levee/floodwall is constructed and all other requirements are met. Locations identified by stakeholders with inconsistencies compared to Preliminary FEMA SFHAs are listed below:

- Undeveloped land in Preliminary FEMA Zone AO (shallow flooding) at Flow Path No. 44 and it's divergence just downstream (west) of I-10 (**Figure 13**).
  - Preliminary FEMA FIRMs (July 8, 2020) show a larger floodplain footprint than the flood depths shown in this Study. Shallow flooding inundation areas typically require engineering judgment when mapping. The flood depths shown at this location are based on depth results greater than 0.5 ft from the NW Feasibility FLO-2D models developed for USACE. These differences in model results were considered when refining the 1% AC inundation boundary tie-in locations to the Preliminary FEMA floodplains. The referenced Preliminary FEMA Zone AO risk area is located outside of the1% AC Interior Drainage Inundation Boundary being mapped as part of this Study, indicated by the black diagonal hatch lines. This area is not mapped because it is significantly outside of the Natural Valley floodplain (the approximate mapping limits of this Study).
- Undeveloped land in Preliminary FEMA Zone A for Channel 35 just downstream (west) of I-10 (**Figure 13**).
  - Preliminary FEMA FIRMs (July 8, 2020) show a larger floodplain footprint than the flood depths shown in this Study. These differences in floodplain widths were considered when refining 1% inundation boundary tie-in locations to the Preliminary FEMA floodplains. The referenced Preliminary FEMA Zone A risk area is located outside of the 1% AC Interior Drainage Inundation

Boundary being mapped as part of this Study, indicated by the black diagonal hatch lines. This area is not mapped because it is significantly outside of the Natural Valley floodplain (the approximate mapping limits of this Study).

- Mobile home park southeast of the intersection of Kiely Road and Hemley Road, south of the Preliminary FEMA Zone A for Flow Path No. 45 Split Flow (**Figure 13**).
    - The Preliminary FEMA floodplains show water contained within banks of the Flow Path No. 45 Split Flow channel, while this Study shows out-of-bank flows resulting in overland flooding and adding contributing flow to Channel 35. These differences were considered when refining 1% inundation boundary upstream floodplain tie-in locations to the Preliminary FEMA floodplains. The scope of this Study includes mapping flood depths approximately within the Natural Valley floodplain with connected depths greater than 1 foot. The referenced overbank flow is mostly less than 1 foot and is significantly outside of the Natural Valley floodplain (the approximate mapping limits of our Study). Therefore, it was not mapped as part of this Study.
- Residential neighborhood west of the Preliminary FEMA Zone AE for Flow Path No. 45 crossing at Kiely Road, where the stream makes a 90º turn (**Figure 13**).
    - The Preliminary FEMA SFHAs show the floodplain remaining within the banks of the channel, while this study shows out-of-bank flows at the turn, with flood depths between 0.5 – 2 feet through residential areas downstream of the Flow Path No. 5 turn. These differences were considered when refining 1% inundation boundary upstream floodplain tie-in locations to the Preliminary FEMA floodplains. The referenced overbank flow is mostly less than 1 foot and is significantly outside of the Natural Valley floodplain (the approximate mapping limits of our Study). Therefore, it was not mapped as part of this Study.
- Residential and commercial developments located downstream (west) of Flow Path No. 45A and Flow Path No. 45 Junction (**Figure 13**).
    - Preliminary FEMA FIRMs (July 8, 2020) show a narrower floodplain footprint than the flood depths shown in this Study. These differences were considered when refining 1% inundation boundary upstream floodplain tie-in locations to the Preliminary FEMA floodplains. Since this location of connected flood depths greater than 1 ft is just outside of the Natural Valley floodplain, and because the NW Feasibilty Study considers a proposed levee/floodwall (the USIBWC Canutillo Phase II Design Project), the results from the NW Feasibility Study were mapped from the proposed levee/floodwall to the downstream end of the Vinton Rd crossing, where backwater from the proposed levee/floodwall project are estimated to potentially affect the floodplain. The floodplain upstream of Vinton Rd is not mapped as part of this Study as it is significantly outside the Natural Valley floodplain (the approximate mapping limits of this Study).

6 Limitations

The results and calculations provided in this report were conducted in accordance with reasonable and accepted engineering practices, and the interpretations and conclusions are rendered in a manner consistent with other consultants in the profession. Quantitative evaluations of hydrological and hydraulic studies are approximate and difficult to estimate with complete accuracy. AECOM has endeavored to apply judgement for this evaluation to the degree practical, while utilizing acceptable analysis methods and guidelines for this study.

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Tables 1 and 2

Table 1. Modeled Rio Grande Outfalls

Outfall Label	Description	Texas State Plane Central X Coordinate	Texas State Plane Central Y Coordinate	Size	Levee Segment	Source	Cover	Pump Station	Source Study, 2D Model Domain, and Figure Number
1	RG inflow point 24	352887.1	10705810.4	Modeled as gap in levee with surface area reduction factors	Canutillo Phase II Levee/ Floodwall	NAIP Aerial Imagery (2016)	N/A		NW Feasibility Previous Study (Figure 14)
2	Nemexas Siphon (Not an outfall)	349727.8	10686379.3	72" RCP under the Rio Grande	CME-2	O&M Manual (2010), Dimensions and Profile provided by EPCWID	Metal Grate		Preliminary FEMA WA1 New Interior Drainage Study (East of Figure 2)
3	Montoya Lateral Wasteway #36	351654.4	10681564.6	48" RCP	CME-2	O&M Manual (2010); USIBWC Review Comments	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 11)
4	Montoya Drain Outfall	366880.0	10673122.8	3-5'x5' CBC	CME-2	O&M Manual (2010); USIBWC Review Comments	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
5	Keystone Dam OF (RG Inflow Point 21)	368005.8	10674095.8	96" RCP	CME-2	Doniphan (2018)	Modeled with No Cover	55500 GPM, Phase I (3495 Doniphan)	Doniphan Corridor Previous Study (Figure 12)
7	RG Inflow Point 19	368910.2	10673637.4	2-8x4 CBC, 3-48in RCP	CME-2	Doniphan (2018)	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
8	RG Inflow Point 18	369970.5	10672652.2	2-10x5 CBC	CME-2	Doniphan (2018)	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
9	RG Inflow Point 54	371613.6	10669672.3	10'x4'CBC	CME-2	Doniphan (2018), USIBWC GIS Data	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
10	RG Inflow Point 17	370733.7	10671667.7	2-6X4 CBC	CME-2	Doniphan (2018)	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
11	RG Inflow Point 16	372368.8	10669161.8	2-42" RCP	CME-2	Doniphan (2018)	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
12	RG Inflow Point 15	373083.1	10668562.0	2-42" RCP	CME-2	Doniphan (2018)	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
13	RG Inflow Point 14	373296.7	10667752.9	6-8x6 CBC	CME-2	Doniphan (2018)	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
14	RG Inflow Point 53	373257.5	10667698.4	4-42 in RCP	CME-2	Doniphan (2018)	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)
15	RG Inflow Point 13	373032.0	10666662.5	2-6x5 CBC	CME-2	Doniphan (2018)	Modeled with No Cover		Doniphan Corridor Previous Study (Figure 12)

Outfall Label	Description	Texas State Plane Central X Coordinate	Texas State Plane Central Y Coordinate	Size	Levee Segment	Source	Cover	Pump Station	Source Study, 2D Model Domain, and Figure Number
21	Outfall Surveyed in 2019	383016.1	10653501.3	42" RCP	EP2	FXSA Survey (2019), Conde (2007)	Metal Cover	44500 GPM, Chihuahuita II	Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
22	Survey of downstream road culvert, Sun Metro Outlet	380804.6	10655818.7	2 - 36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Protective Metal Fence		Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
24	Outfall Surveyed in 2019	384192.9	10652508.9	36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Metal grate	Outfall connected to Chihuahuita PS (Total PS capacity 47250 GPM)	Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
25	Outfall Surveyed in 2019	384206.7	10652502.8	36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover	Outfall connected to Chihuahuita PS (Total PS capacity 47250 GPM)	Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
26	Outfall Surveyed in 2019	387348.5	10652742.3	24" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover		Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
27	Outfall Surveyed in 2019	388282.9	10652945.0	54" and 48" RCPs	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover and Metal Grate		Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
28	Outfall Surveyed in 2019	389930.7	10654156.9	3-24" RCPs	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover and Metal Grate		Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
29	Outfall Surveyed in 2019	390920.6	10656166.3	48" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover and Metal Grate		Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
30	Outfall Surveyed in 2019	391058.9	10656278.0	7x5 CBC	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover and Metal Grate		Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
31	Outfall Surveyed in 2019	395887.3	10657866.9	4-5'x5' CBC	EP2	FXSA Survey (2019)	Closed Metal Cover and Metal Grate	64500 GPM, Cebada	Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
33	Outfall Surveyed in 2019	396935.1	10657303.5	2-5.5'x4.5' CBC	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover and Metal Grate		Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
34	Outfall Surveyed in 2019	398163.8	10656292.3	30" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover and Metal Grate		Int'l Dam to Riverside Weir East Previous Study (Figure 8)
35	Outfall Surveyed in 2019	399375.0	10655310.6	30" to 90" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover and Metal Grate		Int'l Dam to Riverside Weir East Previous Study (Figure 8)
38	Outfall Surveyed in 2019	400623.4	10654342.7	30" to 36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover and Metal Grate	Cordova	Int'l Dam to Riverside Weir East Previous Study (Figure 8)

Outfall Label	Description	Texas State Plane Central X Coordinate	Texas State Plane Central Y Coordinate	Size	Levee Segment	Source	Cover	Pump Station	Source Study, 2D Model Domain, and Figure Number
39	Outfall Surveyed in 2019	402742.5	10653567.9	9' RCP	EP2	FXSA Survey (2019), Conde (2007)	No Cover	218500 GPM, Clardy Fox outfall	Int'l Dam to Riverside Weir East Previous Study (Figure 8)
41	Outfall Surveyed in 2019	431442.9	10618031.5	2-36" RCP	EP2	FXSA Survey (2019), Conde (2007)	No cover	56100 GPM, Basin G Pump Station Outfall	Int'l Dam to Riverside Weir East Previous Study (Figure 10)
43	Outfall Surveyed in 2019	438289.4	10606217.0	5-6'x5' CBC	EP3	FXSA Survey (2019), Conde (2007)	Sluice Gates		Preliminary FEMA WA7 New Interior Drainage Study (Figure 3)
44	Outfall Surveyed in 2019	455137.0	10574153.3	3-6'X5' CBC	EP3	FXSA Survey (2019), O&M Manual (2010)	Sluice Gates		Preliminary FEMA WA7 New Interior Drainage Study (Figure 3)
45	Fabens Wasteway	491286.3	10528908.7	4-5'x5' CBC	EP4	FXSA Survey (2019), O&M Manual (2010)	Sluice Gates		Preliminary FEMA WA11 New Interior Drainage Study (Figure 5)
46	Hudspeth Main Canal Culvert	526658.5	10515605.7	5-4'x4' CBC	EP4	FXSA Survey (2019), O&M Manual (2010)	Sluice Gates		Preliminary FEMA WA11 New Interior Drainage Study (Figure 6)
48	East Drain & Texas Lateral	352377.3	10734671.5	2-5'x4' CBC	CME-2	USIBWC Review Comments	Modeled with No Cover		NW Feasibility Previous Study (Figure 13)
49	Aerial Image Outfall	352701.2	10732854.5	Modeled as 17'x4' CBC	Canutillo Phase II Levee/ Floodwall	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		NW Feasibility Previous Study (Figure 13)
50	Aerial Image Outfall	352612.6	10731297.5	Modeled as 8.5'x4' CBC	Canutillo Phase II Levee/ Floodwall	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		NW Feasibility Previous Study (Figure 13)
51	Aerial Image Outfall	352269.4	10726591.6	Modeled as 18'x6' CBC	Canutillo Phase II Levee/ Floodwall	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		NW Feasibility Previous Study (Figure 13)
52	Aerial Image Outfall	352199.2	10724384.9	Modeled as 12'x4' CBC	Canutillo Phase II Levee/ Floodwall	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		NW Feasibility Previous Study (Figure 14)
53	Aerial Image Outfall	352604.4	10717360.9	Modeled as 40'x5' CBC	Canutillo Phase II Levee/ Floodwall	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		NW Feasibility Previous Study (Figure 14)
54	Aerial Image Outfall	352595.9	10715158.9	Modeled as gap in levee with surface area reduction factors	Canutillo Phase II Levee/ Floodwall	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	N/A		NW Feasibility Previous Study (Figure 14)
55	Aerial Image Outfall	352324.7	10728592.0	Modeled as 12'x6' CBC	Canutillo Phase II Levee/ Floodwall	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		NW Feasibility Previous Study (Figure 13)
57	RG Inflow FID 51	412233.6	10648471.4	72" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover	137,250 GPM, Basin A Outfall	Int'l Dam to Riverside Weir Central updated study (Figure 8)

Outfall Label	Description	Texas State Plane Central X Coordinate	Texas State Plane Central Y Coordinate	Size	Levee Segment	Source	Cover	Pump Station	Source Study, 2D Model Domain, and Figure Number
58	Vinton Cutoff Lateral Wasteway #32B	351981.5	10731160.2	36" RCP	CMW	USIBWC GIS Data and Review Comments, AECOM Field Verified	Sluice Gate		Preliminary FEMA WA1 New Interior Drainage Study (Figure 1)
59	Rowley Lateral Outfall	347875.9	10739158.0	36" RCP	CMW	NAIP Aerial Imagery (2016), USIBWC Review Comments, AECOM Field Verified	Flap Gate		Preliminary FEMA WA1 New Interior Drainage Study (Figure 1)
62	Canutillo Lateral Wasteway #34	352182.3	10702794.5	60"x48" CBC	CMW	NAIP Aerial Imagery (2016), USIBWC GIS Data and Review Comments, AECOM Field Verified	Sluice Gate		Preliminary FEMA WA1 New Interior Drainage Study (Figure 2)
63	Pence Lateral Wasteway #34A	350828.3	10700438.7	30" RCP	CMW	NAIP Aerial Imagery (2016), USIBWC GIS Data and Review Comments, AECOM Field Verified	Sluice Gate		Preliminary FEMA WA1 New Interior Drainage Study (Figure 2)
64	Combined La Union Wasteway	350745.6	10697312.8	60"x48" CBC	CMW	NAIP Aerial Imagery (2016), USIBWC GIS Data, AECOM Field Verified	Sluice Gate		Preliminary FEMA WA1 New Interior Drainage Study (Figure 2)
66	Aerial Image Outfall	391267.0	10656406.8	3-24" RCP	EP2	Conde (2007)	Metal Grate		Int'l Dam to Riverside Weir Central Updated Study (Figure 7)
81	Shultz Lateral Wasteway No. 35C	349561.6	10690177.0	30" RCP	CMW	NAIP Aerial Imagery (2016), USIBWC GIS Data, AECOM Field Verified	Sluice Gate		Preliminary FEMA WA1 New Interior Drainage Study (Figure 2)

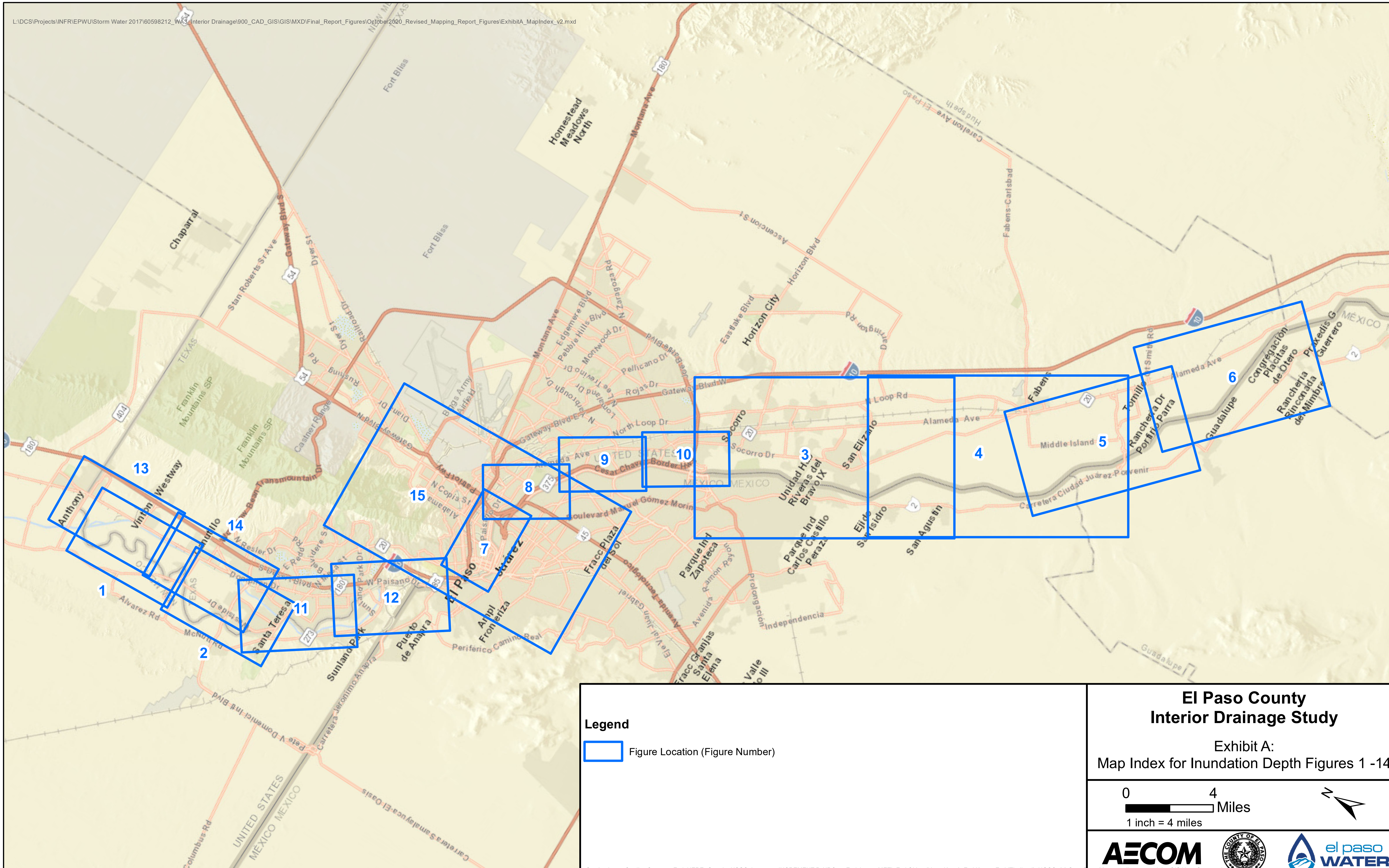
Table 2. Recently Completed Drainage Improvement Projects Modeled

Figure 15 Drainage Project Label	FLO-2D Domain Affected	Drainage System/ HEC-HMS Model	Project Name	Description of Improvements	HEC-HMS Elements Modified	Description of HEC-HMS Modifications	ID of FLO-2D Discharge Cell Affected
4	Central and East	Government Hills	Pershing Dam	Improve Pershing Dam per Work Order 3, Task 4 report by extending and raising aux spillway.	Reservoir element S_Pershing_Dam	The following components of the reservoir element S_Pershing_Dam were updated using as-built data to reflect the raise to the auxiliary spillway: • Elev-Stor Function • Stor-Dis Function	N/A
8	Central	Cebada	CE4 Phase 1c - Copia Pond	Construction of New Copia Pond, north of the RR. Also constructed ditch to route water to pond.	Inserted a new reservoir element (S_Copia_Pond) directly downstream of subbasin A_Russel_Ditch_DS and upstream of J_Cebada_Reservoir_East	Added reservoir element S_Copia_Pond using as-built data to model the Copia Pond via: • Elev-Area Function • Initial Elevation (3775 ft) • Dam Top Outflow Structure (represents overflow out of pond) ○ Elevation – 3799 ft ○ Length – 1640 ft ○ Coefficient – 2.6	47880
9	Central	Cebada	CE4 Phase 2b – Magnolia Pump Station	Construction of Magnolia Pump Station and improvements to existing conduits.	S_Magnolia_Reservoir (new downstream connection), D_New_Magnolia_Reservoir (new diversion), J_Magnolia_Res_Overflow (new junction), J_New_Magnolia_PS (new junction), R_Magnolia_to_Eucalyptus (new upstream connection), J_Eucalyptus_to_Cebada (new Downstream connection)	• The outflow from S_Magnolia_Reservoir was re-routed to a new diversion (D_New_Magnolia_Reservoir) which simulates a maximum pump station capacity of 175 cfs (capacity assumed per coordination with EPWater). • 175 cfs is assumed to be pumped from Magnolia Pump Station to the Rio Grande. • All flow in excess of 175 is diverted to a new Junction J_Magnolia_Res_Overflow, which is routed to J_Eucalyptus_to_Cebada. At this junction, flow from Drainage Area A_Eucalyptus_to_Cabada is added per the original model. • The downstream connection from J_Eucalyptus to Cebada is a diversion that was not modified (D_Capacity_of_60"Counduit) which assumes a maximum capacity of 100 cfs can be discharged to the Cebada/Gateway Pond system via Junction J_Cebada_Inflow. • All flow in excess of the 100 cfs capacity is diverted to a junction, J_I-10 Overtopping, which is the junction from which the outflow hydrograph was extracted that was released at FLO-2D cell 38045 in the updated International Dam to Riverside Weir FLO-2D model.	38045

Figure 15 Drainage Project Label	FLO-2D Domain Affected	Drainage System/ HEC-HMS Model	Project Name	Description of Improvements	HEC-HMS Elements Modified	Description of HEC-HMS Modifications	ID of FLO-2D Discharge Cell Affected
14	Central	Cebada	CE4 Phase 3a - Gateway West Pond (GWW)	Construction of 50-ft deep ponding area to capture runoff North of I-10	• Reservoir element S_Cebada_Reservoir was replaced with new storage element, "S_Gateway_Ponds".	Reservoir element S_Cebada_Reservoir was renamed to S_ Gateway_Ponds. The following components of the reservoir element were updated using as-built data to represent the additional storage, Cebada conduit outflow (capacity of 210 CFS assumed), and overtopping weir discharge outflow created by the combined pond system of Gateway West, Gateway East, and Cebada Ponds: • Elev-Stor Function • Stor-Dis Function Created the following components to model the outflow from both the Cebada conduit and the overtopping of the Gateway East Pond: • Diversion – D_Gateway_Pond_Outflow • Junctions ○ J_Gateway_Conduit ○ J_Gateway_Overtopping_Flow	47880
11	Central	Cebada	CE4 Phase 3c - Morenci Pond	Construction of ponding area to detain peak runoff upstream of watershed. Controls water reaching Gateway ponds.	Reservoir element S_Morenci_Pond	The following components of the reservoir element S_Morenci_Pond were updated using as-built data: • Elev-Stor Function • Stor-Dis Function • Initial Condition (changed from 'Elevation' to 'Inflow=Outflow')	47880
15	Central	Cebada	CE4 Phase 3d - Gateway East Pond (GWE)	Construction of 50-ft deep ponding area to capture runoff North of I-10	Reservoir element S_Cebada_Reservoir was replaced with new storage element, "S_Gateway_Ponds".	Reservoir element S_Cebada_Reservoir was renamed to S_ Gateway_Ponds. The following components of the reservoir element were updated using as-built data to represent the additional storage, Cebada conduit outflow (capacity of 210 CFS assumed), and overtopping weir discharge outflow created by the combined pond system of Gateway West, Gateway East, and Cebada Ponds: • Elev-Stor Function • Stor-Dis Function Created the following components to model the outflow from both the Cebada conduit and the overtopping of the Gateway East Pond: • Diversion – D_Gateway_Pond_Outflow • Junctions ○ J_Gateway_Conduit • J_Gateway_Overtopping_Flow	47880
16	Central	Cebada	CE4 Phase 3h - San Diego Dam	Drains to Dam 6.	Reservoir element S_San_Diego_Dam	The following components of the reservoir element S_San_Diego_Dam were updated using as-built data to reflect the outlet tower updates to the dam: • Method (changed from Outflow Structures to Outflow Curve) • Elev-Stor Function (table renamed, values kept the same) • Stor-Dis Function (added) • Initial Condition (changed from 'Storage' to 'Elevation'= 3973.0 ft)	47880

Figure 15 Drainage Project Label	FLO-2D Domain Affected	Drainage System/ HEC-HMS Model	Project Name	Description of Improvements	HEC-HMS Elements Modified	Description of HEC-HMS Modifications	ID of FLO-2D Discharge Cell Affected
20	Central and East	Government Hills	Van Buren Dam	Improve Van Buren Dam per Work Order 3, Task 4 Report. Drains to Pershing Dam. Is the start of underground conduit that daylights at Pershing Dam	Reservoir element S_Van_Buren_Dam	The following components of the reservoir element S_Van_Buren_Dam were updated using as-built data to reflect the additional storage added to this dam: • Elev-Stor Function • Stor-Dis Function	N/A

Figures and Exhibits



El Paso County
Interior Drainage Study

Exhibit A:
Map Index for Inundation Depth Figures 1 -14

0 4 Miles
1 inch = 4 miles

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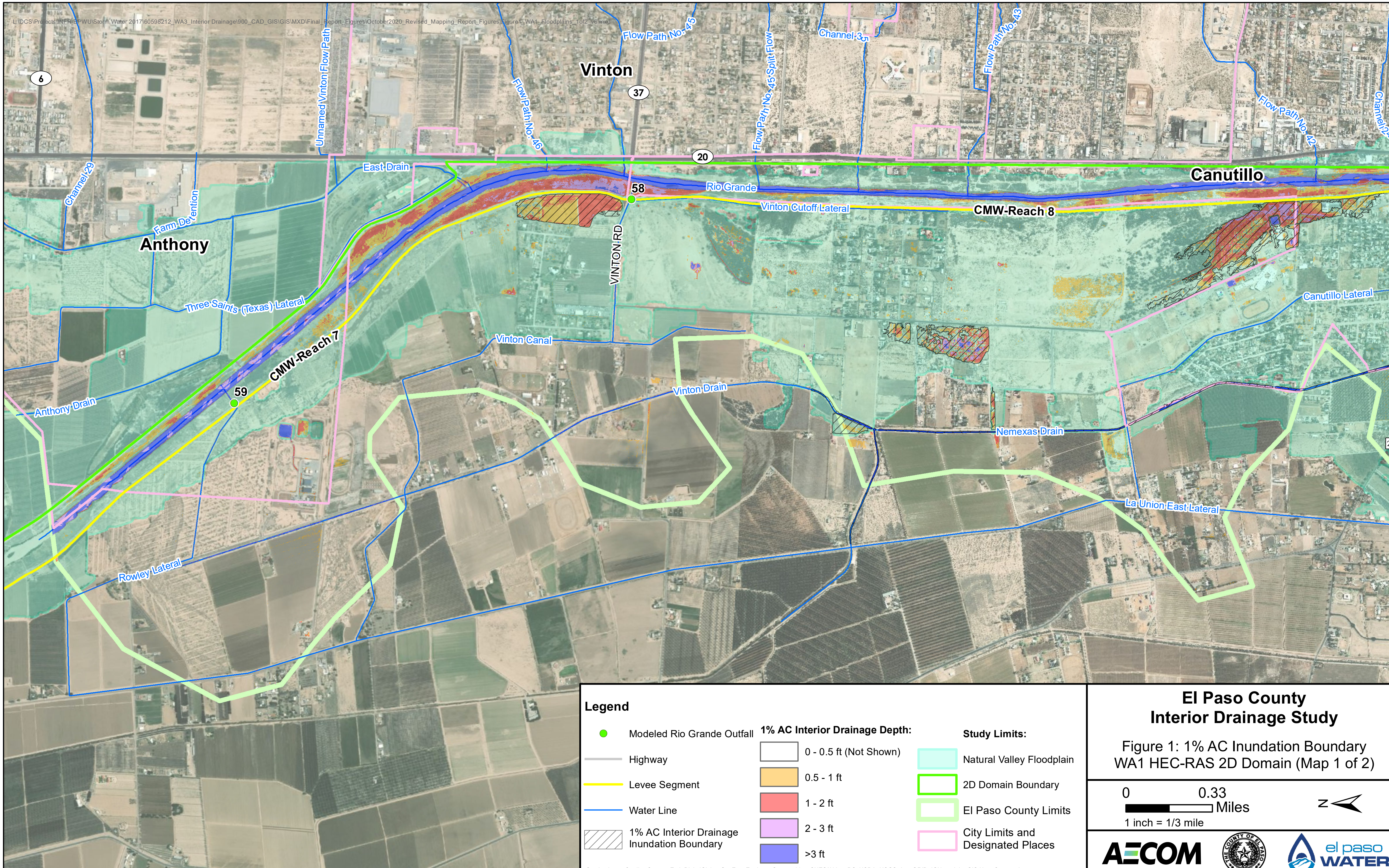
el paso WATER



Legend

- Modeled Rio Grande Outfall
- Highway
- Levee Segment
- Water Line
- 1% AC Interior Drainage Inundation Boundary

1% AC Interior Drainage Depth:

- 0 - 0.5 ft (Not Shown)
- 0.5 - 1 ft
- 1 - 2 ft
- 2 - 3 ft
- >3 ft

Study Limits:

- Natural Valley Floodplain
- 2D Domain Boundary
- El Paso County Limits
- City Limits and Designated Places

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

El Paso County Interior Drainage Study

Figure 1: 1% AC Inundation Boundary WA1 HEC-RAS 2D Domain (Map 1 of 2)

0 0.33 Miles

1 inch = 1/3 mile

N

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THE COUNTY OF EL PASO TEXAS

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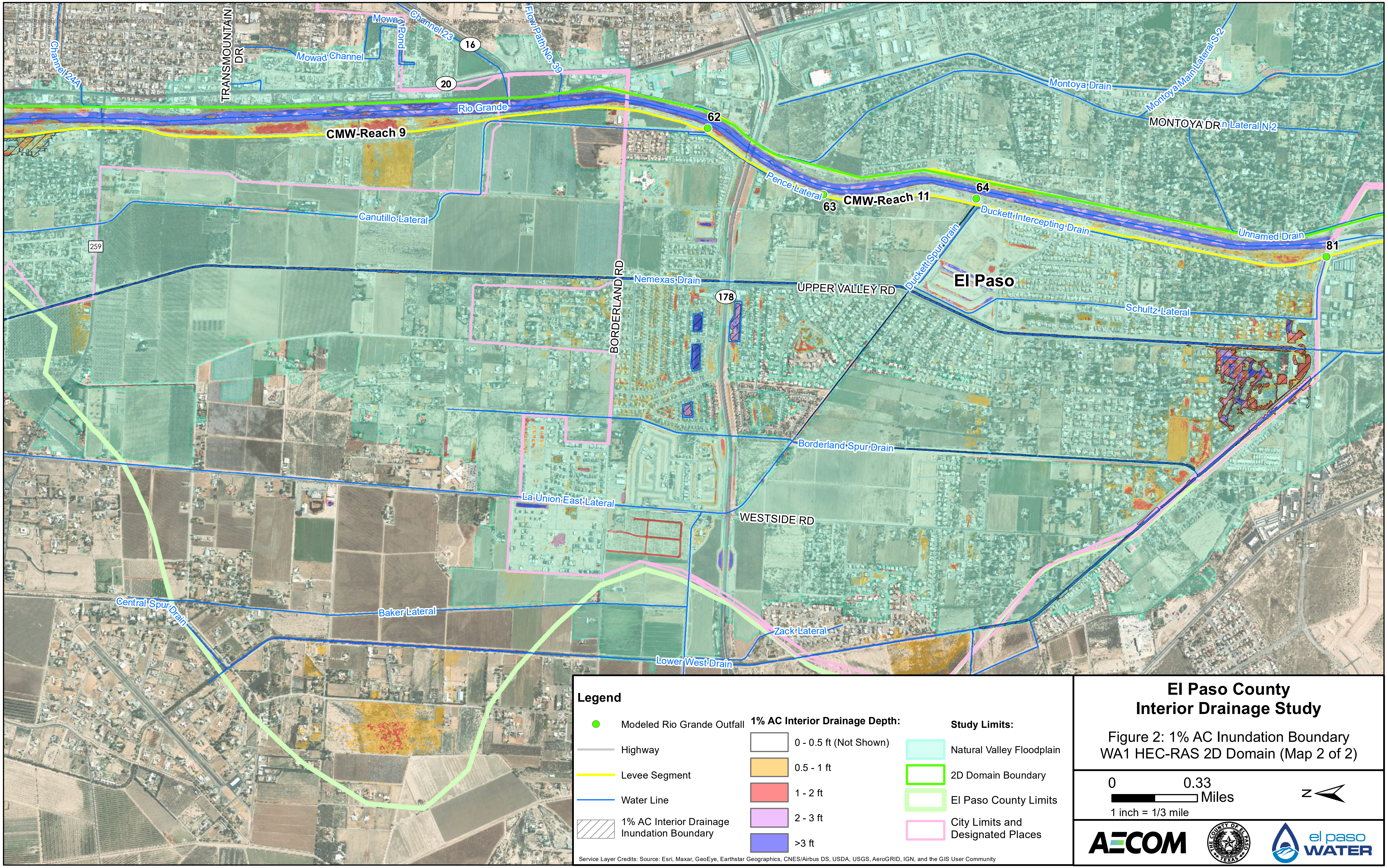

Legend

- Modeled Rio Grande Outfall
- Highway
- Levee Segment
- Water Line
- 1% AC Interior Drainage Inundation Boundary

1% AC Interior Drainage Depth:

- 0 - 0.5 ft (Not Shown)
- 0.5 - 1 ft
- 1 - 2 ft
- 2 - 3 ft
- >3 ft

Study Limits:

- Natural Valley Floodplain
- 2D Domain Boundary
- El Paso County Limits
- City Limits and Designated Places

Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

El Paso County Interior Drainage Study

Figure 2: 1% AC Inundation Boundary
WA1 HEC-RAS 2D Domain (Map 2 of 2)

0 0.33 Miles
1 inch = 1/3 mile

N

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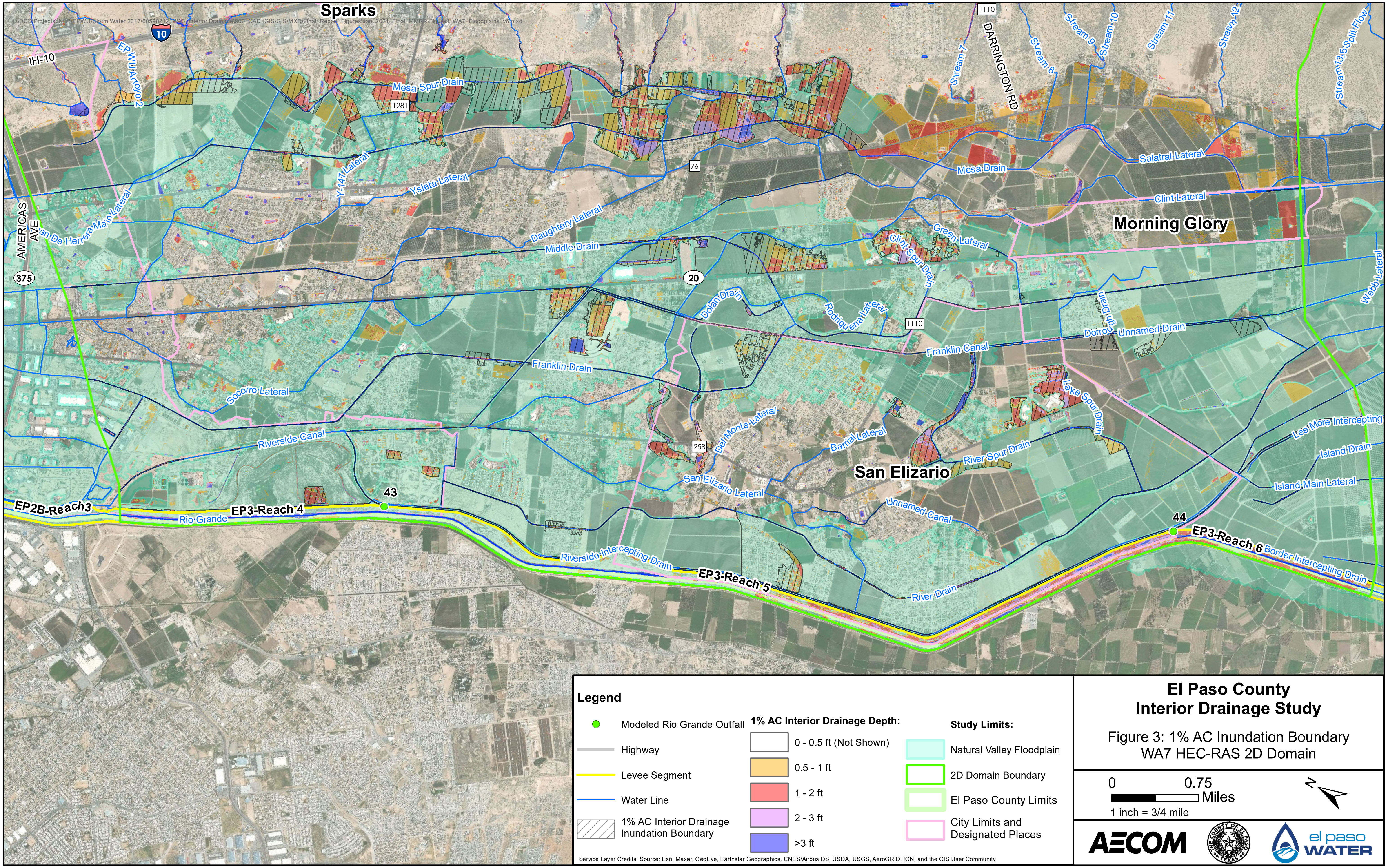
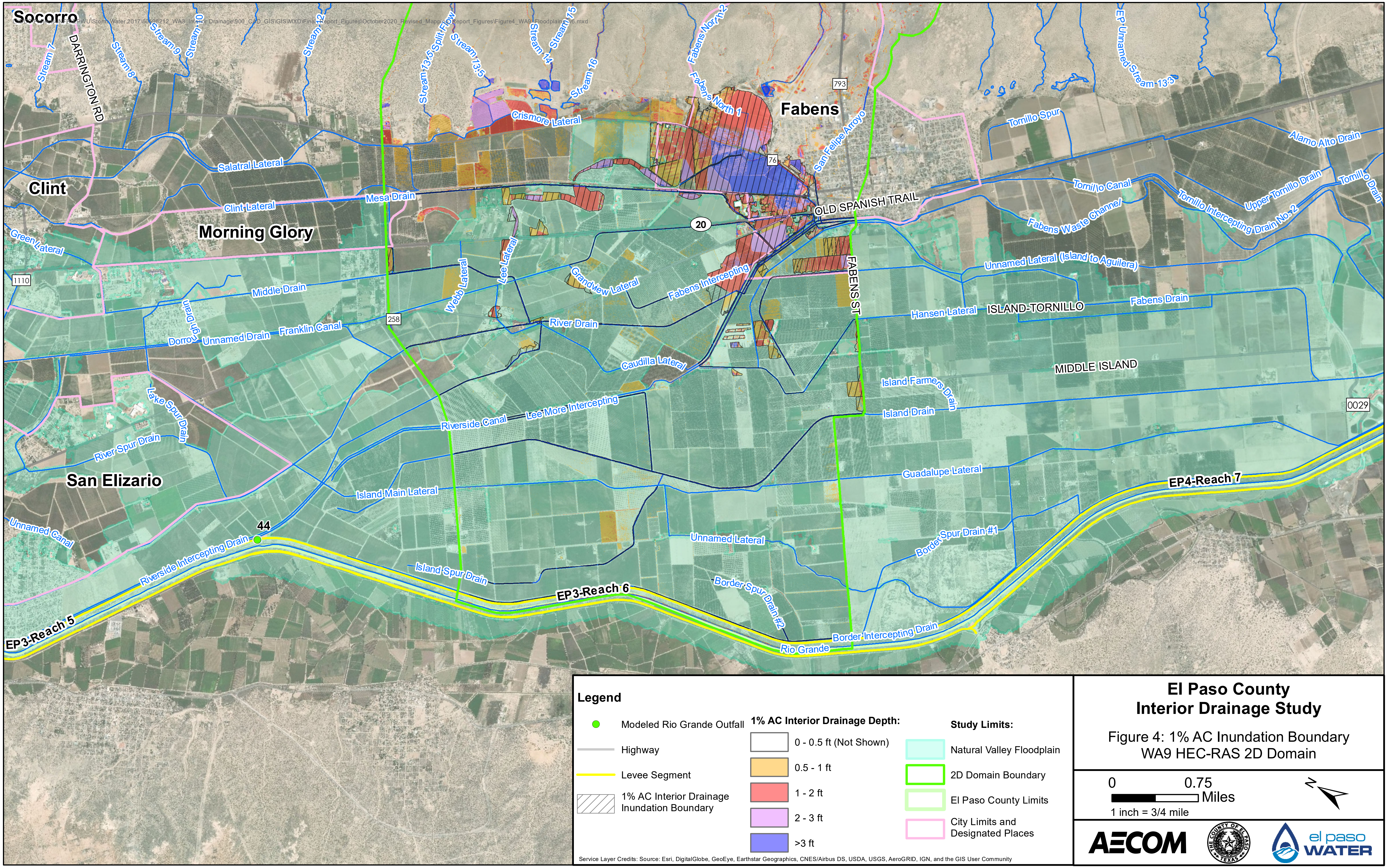
el paso WATER



El Paso County Interior Drainage Study

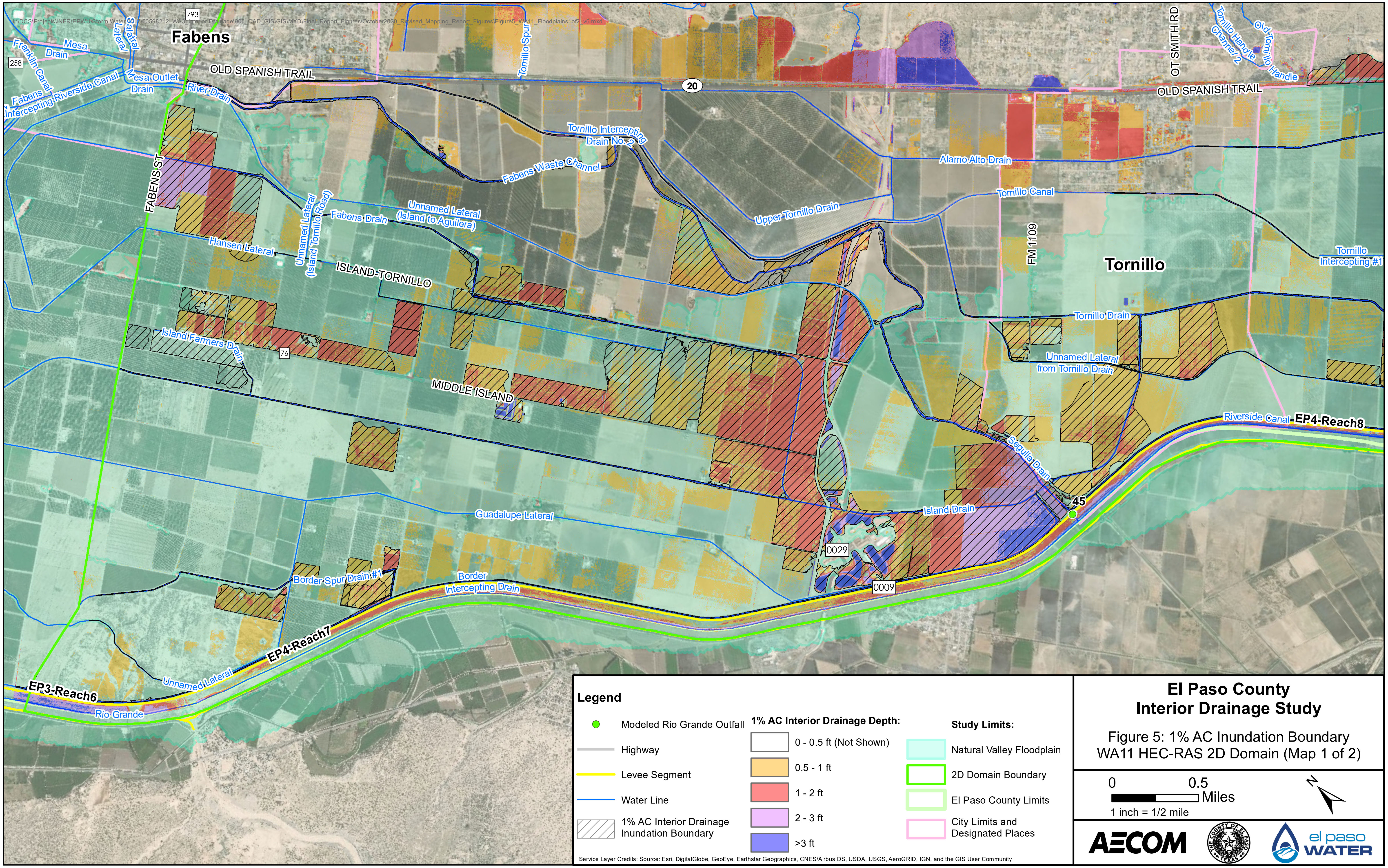
Figure 3: 1% AC Inundation Boundary WA7 HEC-RAS 2D Domain



El Paso County
Interior Drainage Study

Figure 4: 1% AC Inundation Boundary
WA9 HEC-RAS 2D Domain

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Fabens
Tornillo
OLD SPANISH TRAIL
20
793
258
76
0029
0009
45
Mesa Drain
Franklin Canal
Salatral Lateral
Fabens Intercepting Riverside Canal
Mesa Outlet Drain
River Drain
Tornillo Spur
OT SMITH RD
Tornillo Handle Channel 2
Old Tornillo Handle
Tornillo Intercepting Drain No. 2
Fabens Waste Channel
Alamo Alto Drain
Tornillo Canal
Upper Tornillo Drain
FABENS ST
Unnamed Lateral (Island Tornillo Road)
Fabens Drain
Unnamed Lateral (Island to Aguilera)
Hansen Lateral
ISLAND-TORNILLO
FM 1109
Tornillo Intercepting #1
Tornillo Drain
Island Farmers Drain
Unnamed Lateral from Tornillo Drain
MIDDLE ISLAND
Riverside Canal
EP4-Reach8
Seguia Drain
Island Drain
Guadalupe Lateral
Border Spur Drain #1
Border Intercepting Drain
EP4-Reach7
Unnamed Lateral
EP3-Reach6
Rio Grande
Legend
Modeled Rio Grande Outfall
Highway
Levee Segment
Water Line
1% AC Interior Drainage Inundation Boundary
1% AC Interior Drainage Depth:
0 - 0.5 ft (Not Shown)
0.5 - 1 ft
1 - 2 ft
2 - 3 ft
>3 ft
Study Limits:
Natural Valley Floodplain
2D Domain Boundary
El Paso County Limits
City Limits and Designated Places
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
El Paso County Interior Drainage Study
Figure 5: 1% AC Inundation Boundary WA11 HEC-RAS 2D Domain (Map 1 of 2)
0
0.5
Miles
1 inch = 1/2 mile
N
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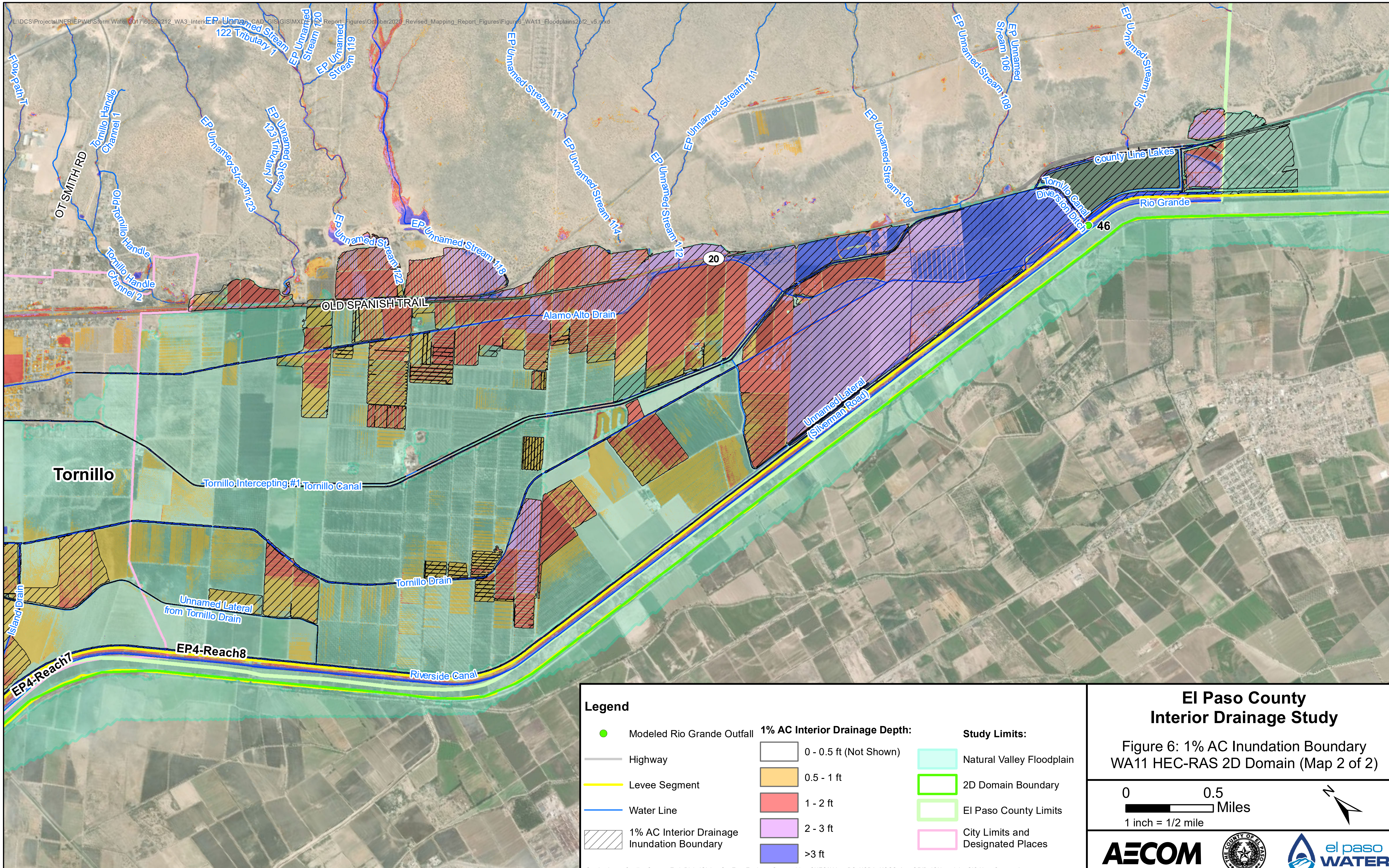
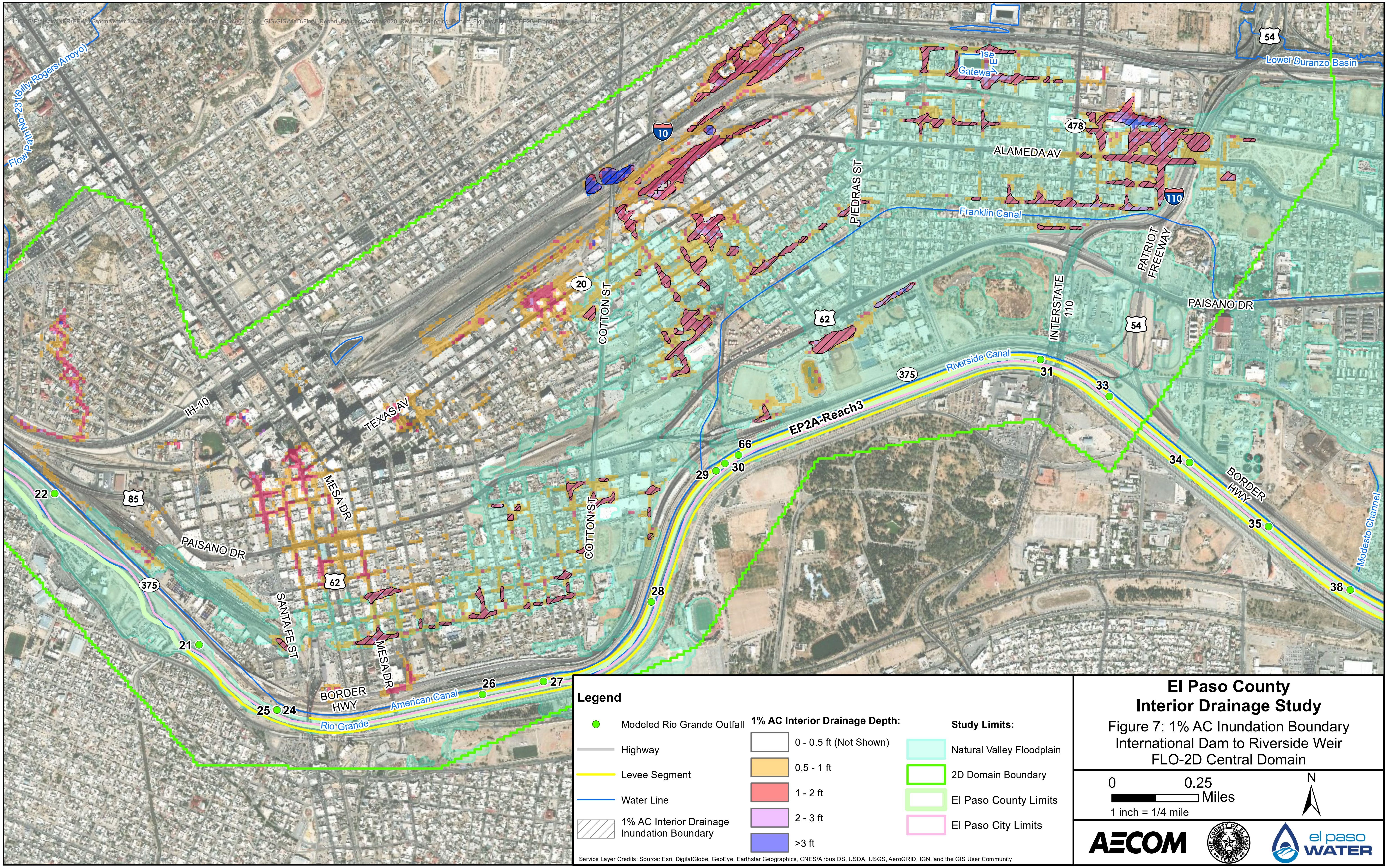


El Paso County Interior Drainage Study

Figure 6: 1% AC Inundation Boundary WA11 HEC-RAS 2D Domain (Map 2 of 2)



Flow Path No. 23 (Billy Rogers Arroyo)
10
54
Lower Duranzo Basin
Gateway
478
ALAMEDA AV
PIEDRAS ST
110
Franklin Canal
PATRIOT FREEWAY
INTERSTATE 110
PAISANO DR
54
20
COTTON ST
62
Riverside Canal
375
31
33
IH-10
TEXAS AV
EP2A-Reach3
66
30
29
34
BORDER HWY
22
85
MESA DR
PAISANO DR
COTTON ST
35
Modesto Channel
38
375
62
28
SANTA FE ST
21
MESA DR
BORDER HWY
26
27
25
24
American Canal
Rio Grande
Legend
Modeled Rio Grande Outfall
Highway
Levee Segment
Water Line
1% AC Interior Drainage Inundation Boundary
1% AC Interior Drainage Depth:
0 - 0.5 ft (Not Shown)
0.5 - 1 ft
1 - 2 ft
2 - 3 ft
>3 ft
Study Limits:
Natural Valley Floodplain
2D Domain Boundary
El Paso County Limits
El Paso City Limits
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
El Paso County
Interior Drainage Study
Figure 7: 1% AC Inundation Boundary
International Dam to Riverside Weir
FLO-2D Central Domain
0
0.25
Miles
1 inch = 1/4 mile
N
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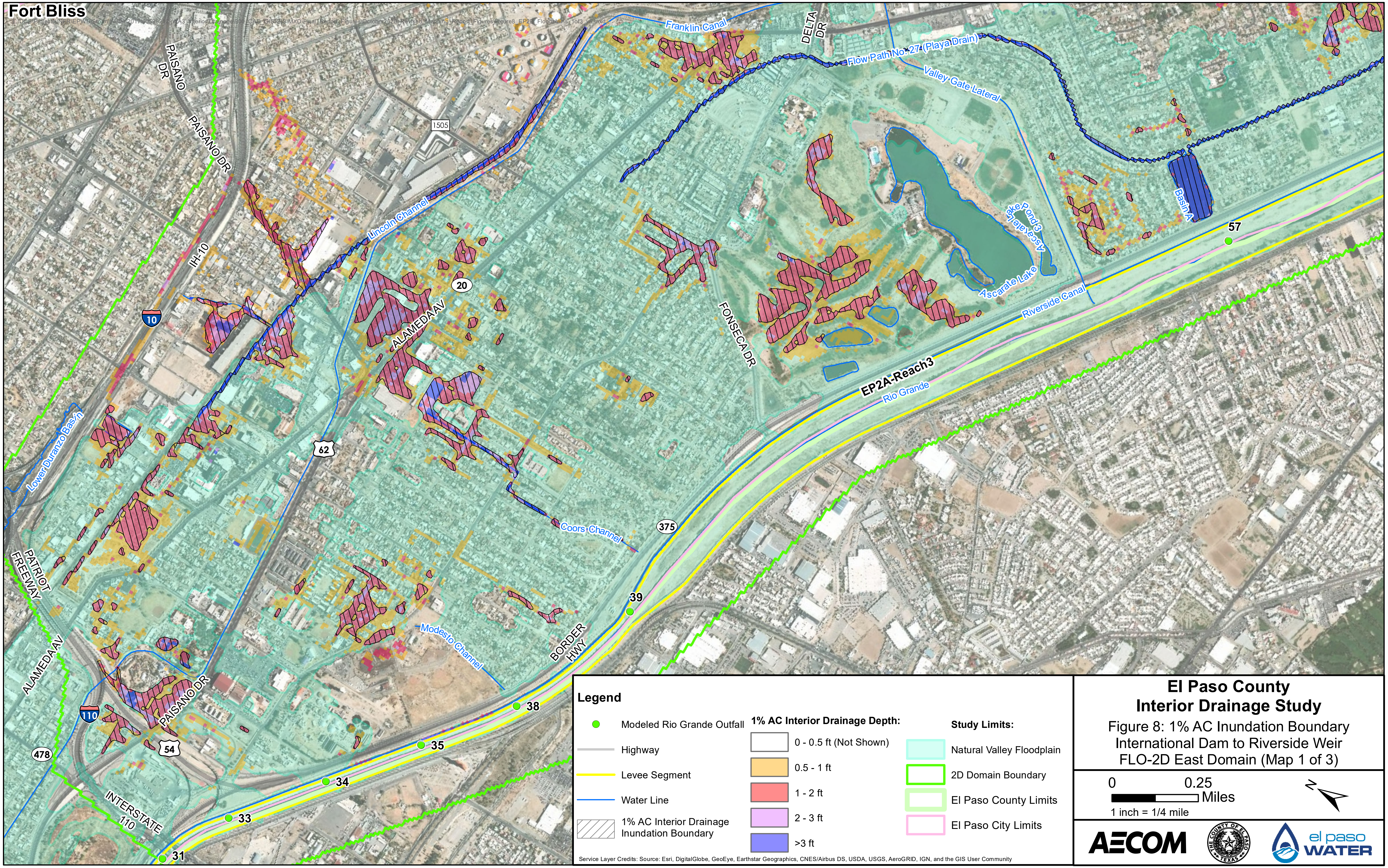
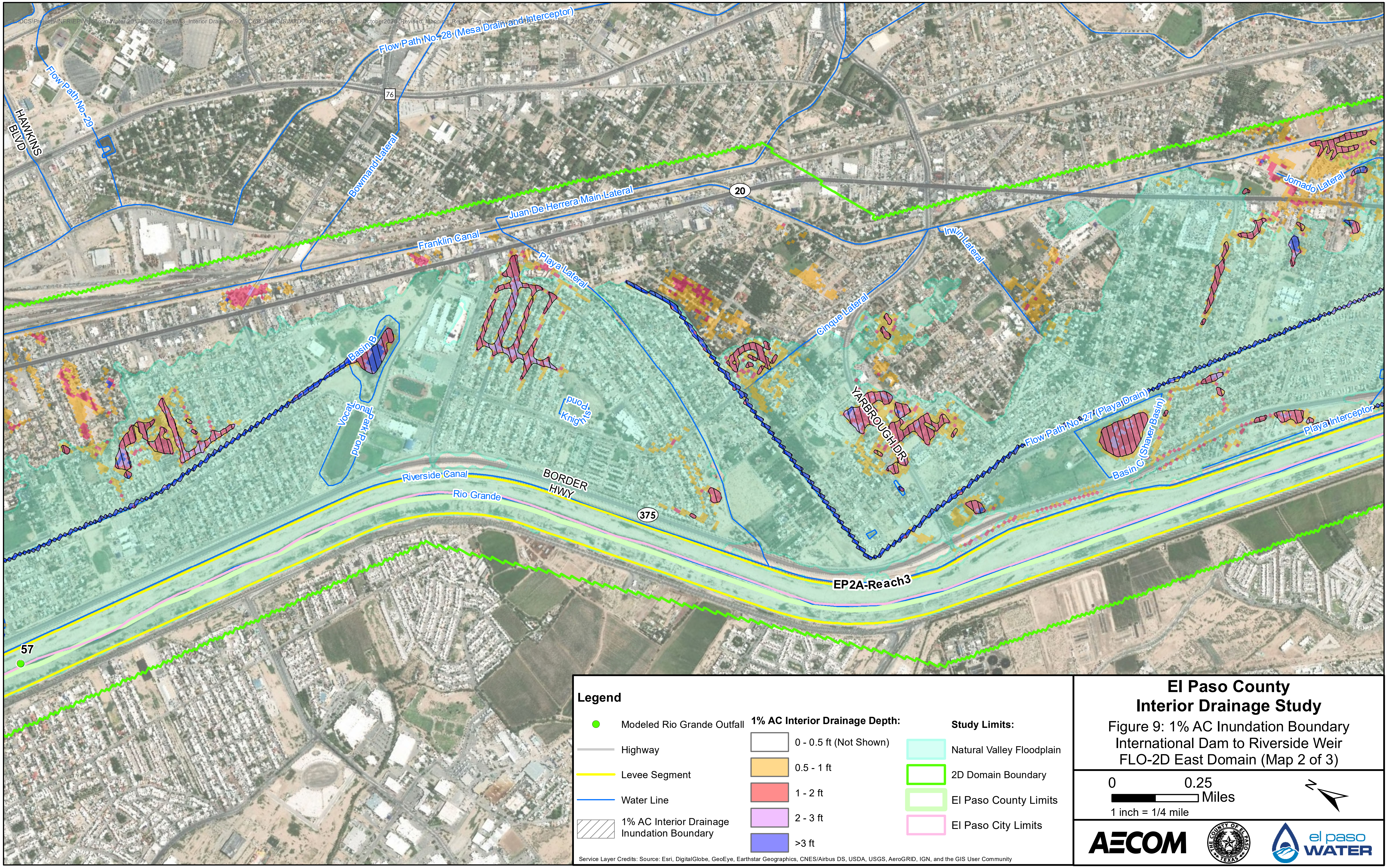
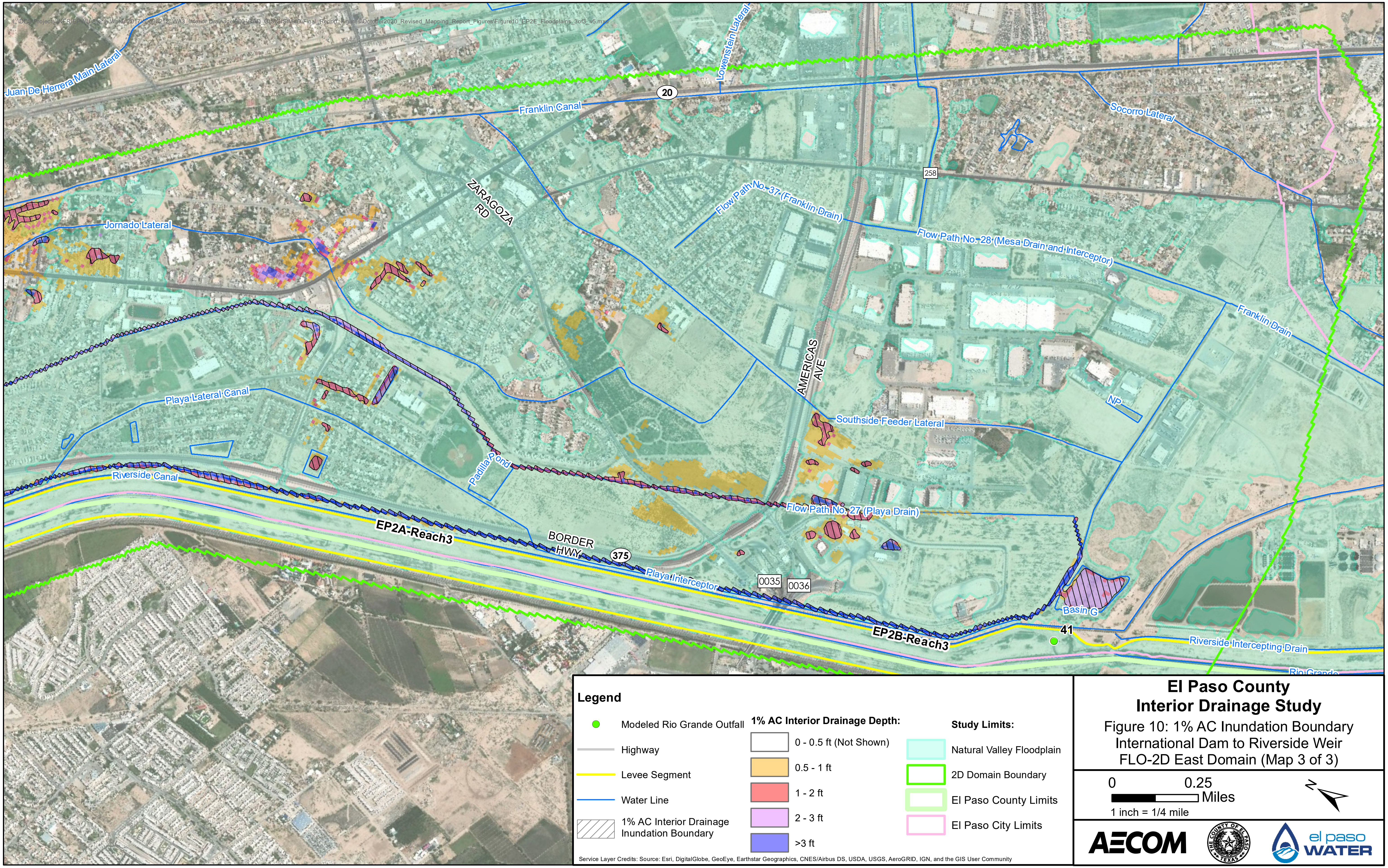


Fort Bliss
PAISANO DR
PAISANO DR
IH-10
10
Franklin Canal
DELTA DR
Flow Path No. 27 (Playa Drain)
Valley Gate Lateral
1505
Lincoln Channel
20
ALAMEDA AV
FONSECA DR
Lake Pond 3
Ascarate Lake
Ascarate Lake
Basin A
57
Riverside Canal
EP2A-Reach3
Rio Grande
62
Lower Duranzo Basin
Coors Channel
375
PATRIOT FREEWAY
39
Modesto Channel
BORDER HWY
ALAMEDA AV
110
PAISANO DR
38
54
35
478
34
INTERSTATE 110
33
31
Legend
Modeled Rio Grande Outfall
Highway
Levee Segment
Water Line
1% AC Interior Drainage Inundation Boundary
1% AC Interior Drainage Depth:
0 - 0.5 ft (Not Shown)
0.5 - 1 ft
1 - 2 ft
2 - 3 ft
>3 ft
Study Limits:
Natural Valley Floodplain
2D Domain Boundary
El Paso County Limits
El Paso City Limits
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
El Paso County
Interior Drainage Study
Figure 8: 1% AC Inundation Boundary
International Dam to Riverside Weir
FLO-2D East Domain (Map 1 of 3)
0
0.25
Miles
1 inch = 1/4 mile
N
AECOM
el paso WATER



El Paso County Interior Drainage Study

Figure 9: 1% AC Inundation Boundary International Dam to Riverside Weir FLO-2D East Domain (Map 2 of 3)



El Paso County
Interior Drainage Study

Figure 10: 1% AC Inundation Boundary
International Dam to Riverside Weir
FLO-2D East Domain (Map 3 of 3)

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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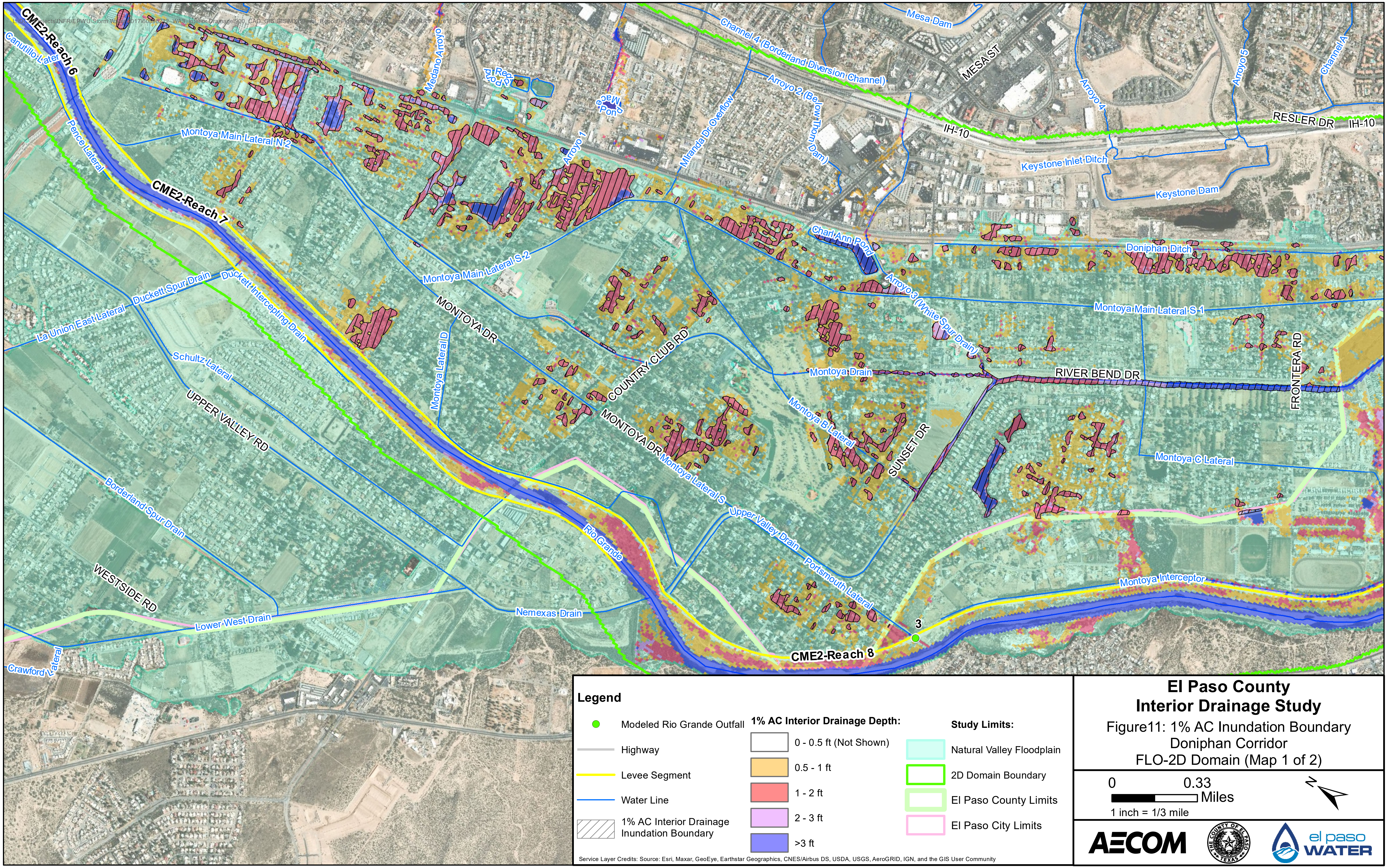

El Paso County
Interior Drainage Study

Figure11: 1% AC Inundation Boundary
Doniphan Corridor
FLO-2D Domain (Map 1 of 2)

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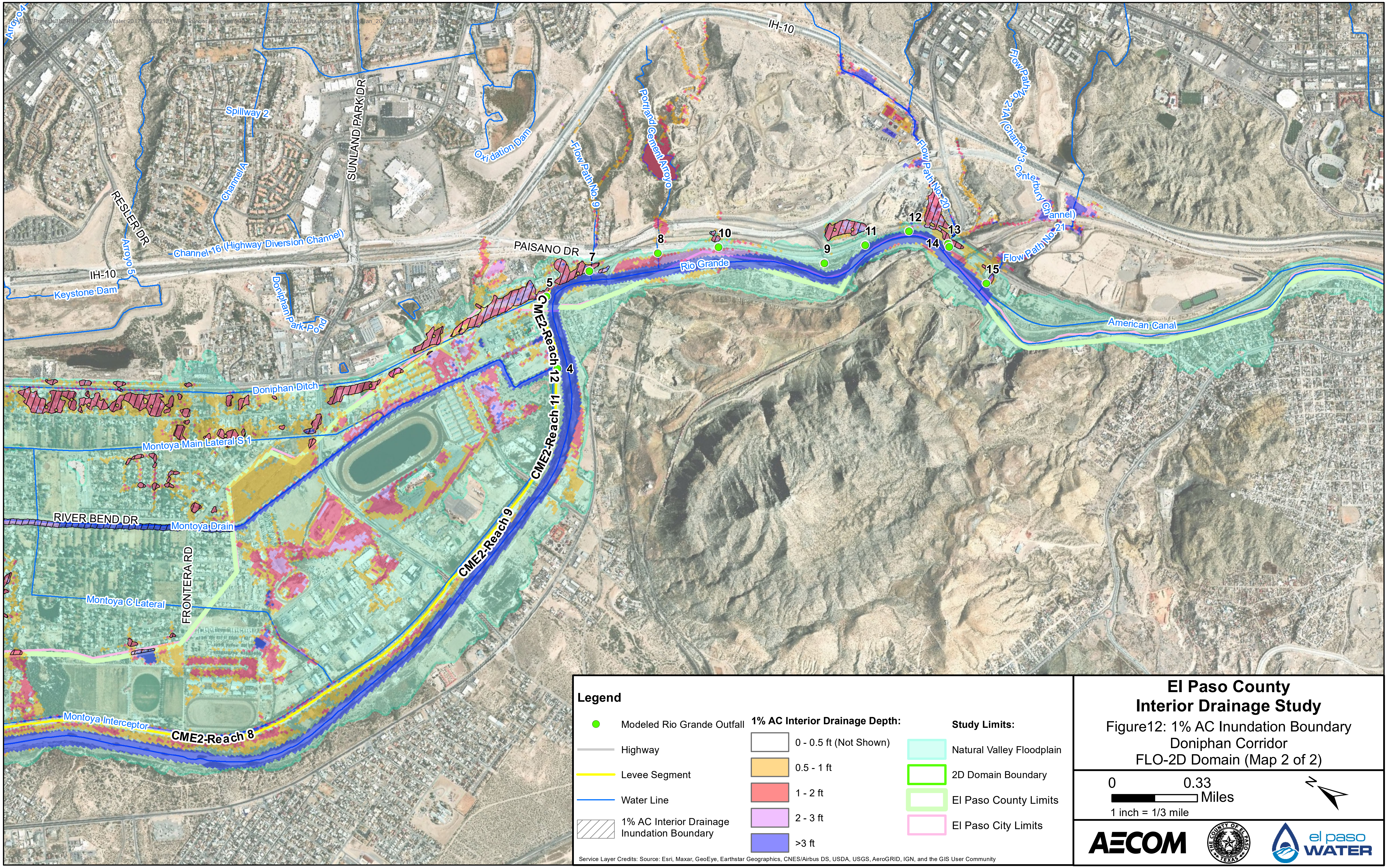
IH-10
PAISANO DR
SUNLAND PARK DR
RESLER DR
Spillway 2
Channel A
Channel 16 (Highway Diversion Channel)
Arroyo 6
Keystone Dam
Doniphan Park Pond
Oxidation Dam
Flow Path No. 9
Portland Cement Arroyo
Flow Path No. 20
Flow Path No. 21A (Channel 3 - Canterbury Channel)
Flow Path No. 21
Rio Grande
American Canal
Doniphan Ditch
Montoya Main Lateral S 1
RIVER BEND DR
Montoya Drain
FRONTERA RD
Montoya C Lateral
Montoya Interceptor
CME2-Reach 8
CME2-Reach 9
CME2-Reach 11
CME2-Reach 12
4
5
7
8
9
10
11
12
13
14
15
Legend
Modeled Rio Grande Outfall
Highway
Levee Segment
Water Line
1% AC Interior Drainage Inundation Boundary
1% AC Interior Drainage Depth:
0 - 0.5 ft (Not Shown)
0.5 - 1 ft
1 - 2 ft
2 - 3 ft
>3 ft
Study Limits:
Natural Valley Floodplain
2D Domain Boundary
El Paso County Limits
El Paso City Limits
Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
El Paso County
Interior Drainage Study
Figure12: 1% AC Inundation Boundary
Doniphan Corridor
FLO-2D Domain (Map 2 of 2)
0
0.33
Miles
1 inch = 1/3 mile
N
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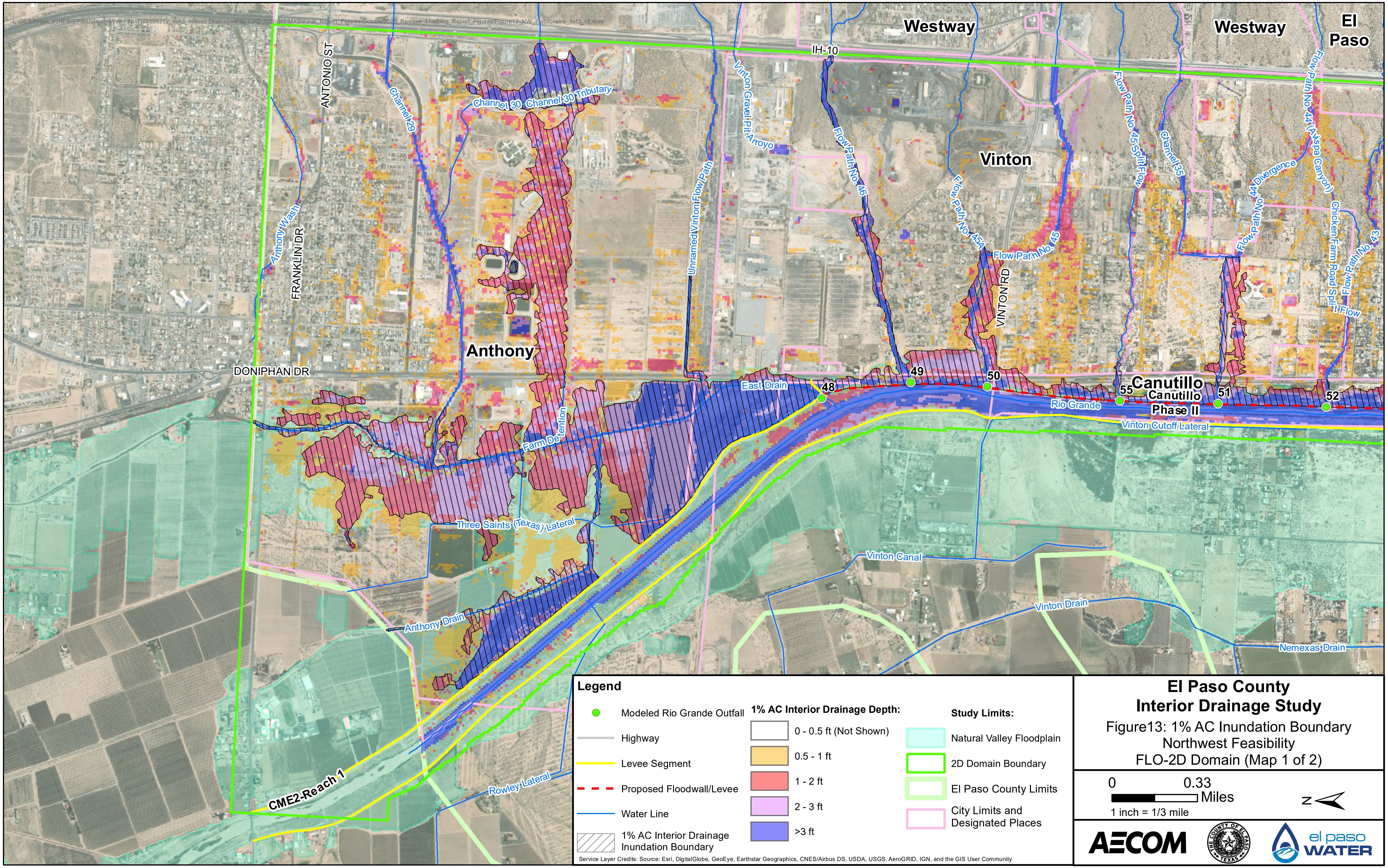

Westway
Westway
El Paso
IH-10
Vinton
Anthony
Canutillo
ANTONIO ST
FRANKLIN DR
DONIPHAN DR
VINTON RD
Channel 29
Channel 30
Channel 30 Tributary
Anthony Wash
Vinton Gravel Pit Arroyo
Unnamed Vinton Flow Path
Flow Path No. 46
Flow Path No. 45A
Flow Path No. 45
Flow Path No. 45 Split Flow
Channel 35
Flow Path No. 44 Divergence
Flow Path No. 44 (Aspa Canyon)
Chicken Farm Road Split Flow
Flow Path No. 43
East Drain
Farm Detention
Three Saints (Texas) Lateral
Anthony Drain
Rio Grande
Canutillo Phase II
Vinton Cutoff Lateral
Vinton Canal
Vinton Drain
Nemexas Drain
Rowley Lateral
CME2-Reach 1
48
49
50
55
51
52
Legend
Modeled Rio Grande Outfall
Highway
Levee Segment
Proposed Floodwall/Levee
Water Line
1% AC Interior Drainage Inundation Boundary
1% AC Interior Drainage Depth:
0 - 0.5 ft (Not Shown)
0.5 - 1 ft
1 - 2 ft
2 - 3 ft
>3 ft
Study Limits:
Natural Valley Floodplain
2D Domain Boundary
El Paso County Limits
City Limits and Designated Places
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
El Paso County
Interior Drainage Study
Figure13: 1% AC Inundation Boundary
Northwest Feasibility
FLO-2D Domain (Map 1 of 2)
0
0.33
Miles
1 inch = 1/3 mile
N
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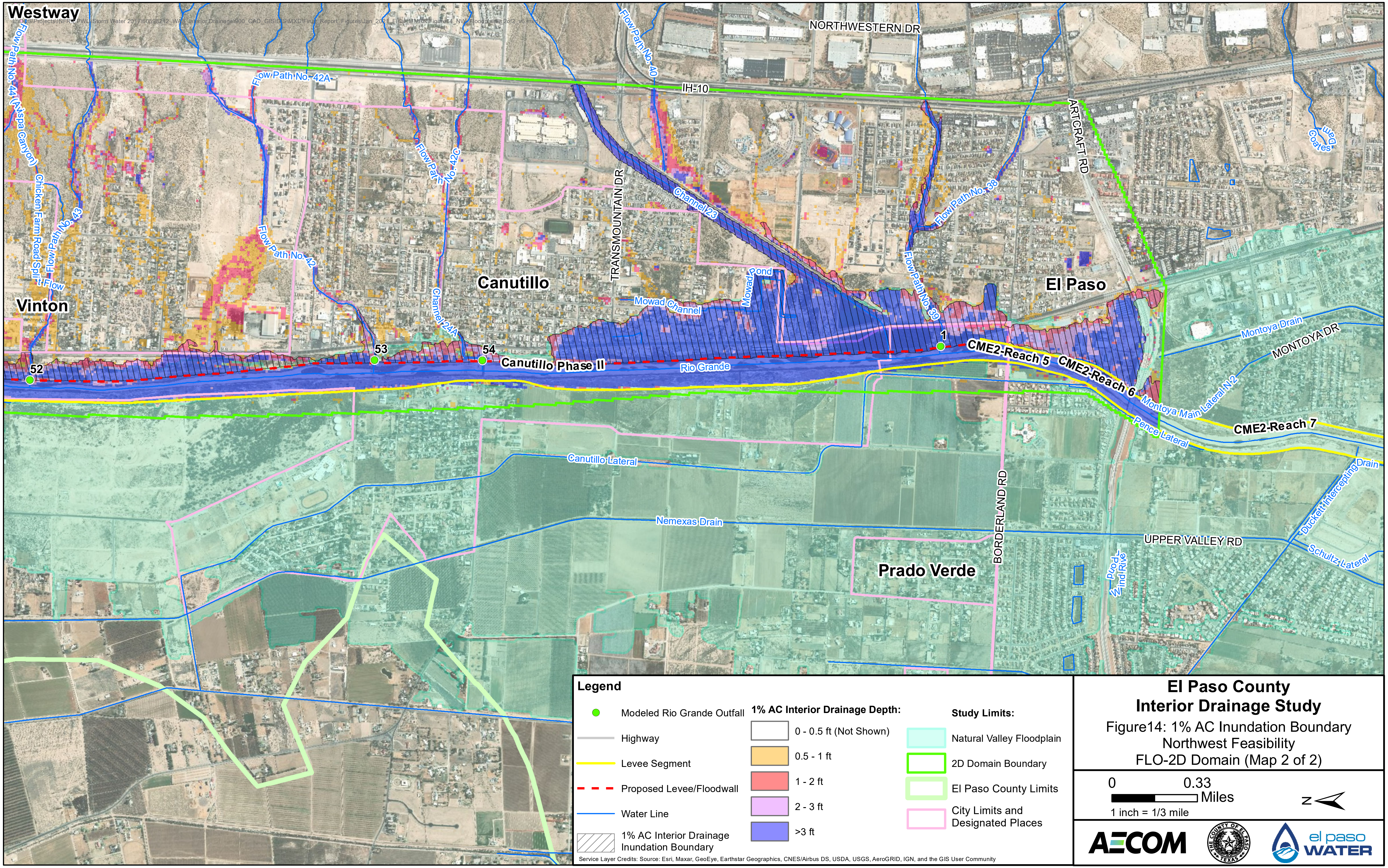
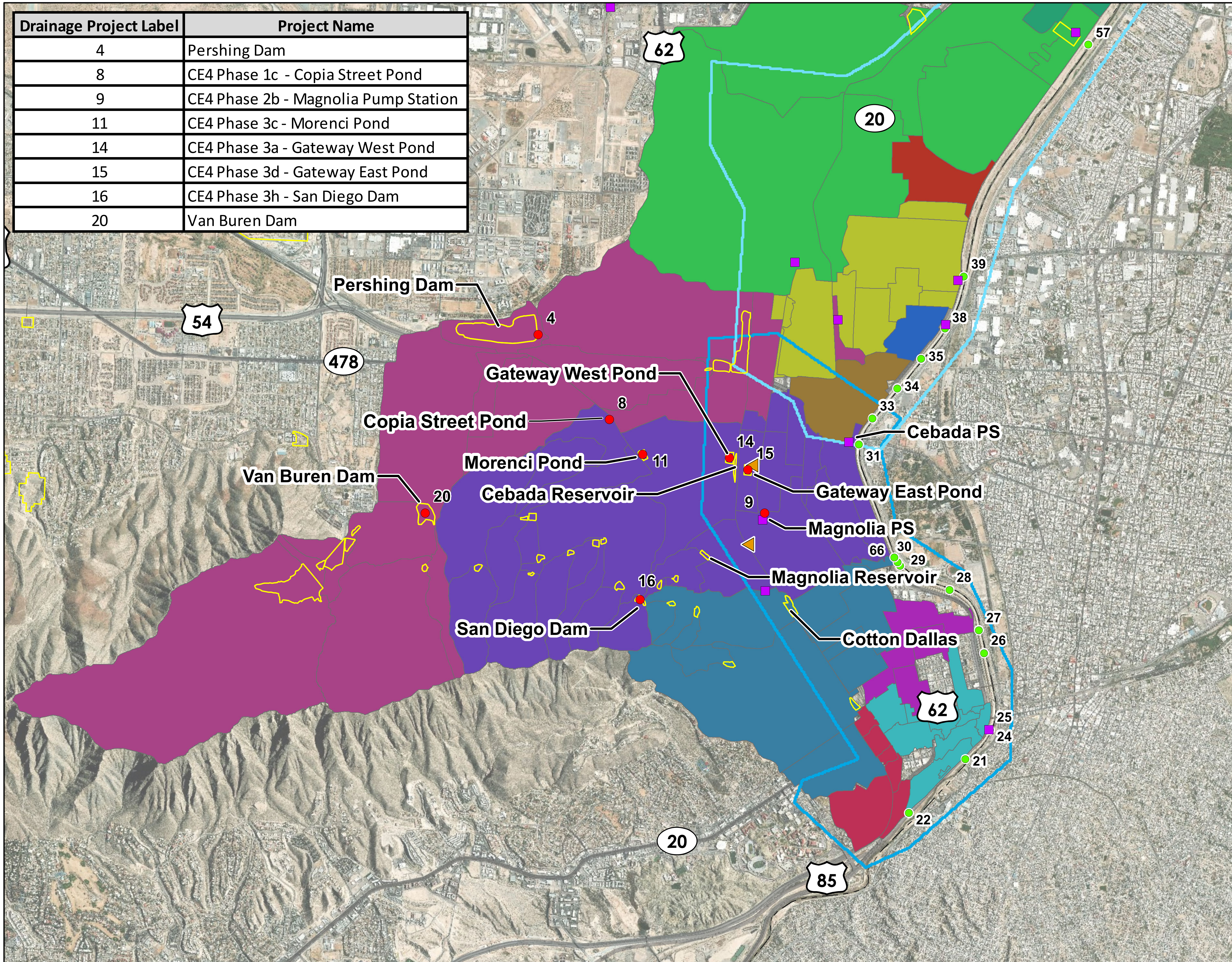

Westway
Vinton
Canutillo
El Paso
Prado Verde
NORTHWESTERN DR
IH-10
ARTCRAFT RD
TRANSMOUNTAIN DR
BORDERLAND RD
MONTOYA DR
UPPER VALLEY RD
Flow Path No. 44 (Aspa Canyon)
Chicken Farm Road Split Flow
Flow Path No. 43
Flow Path No. 42A
Flow Path No. 42
Flow Path No. 42C
Flow Path No. 40
Flow Path No. 39
Flow Path No. 38
Channel 23
Channel 24A
Mowad Pond
Mowad Channel
Coates Dam
Rio Grande
Canutillo Phase II
CME2-Reach 5
CME2-Reach 6
CME2-Reach 7
52
53
54
1
Montoya Drain
Montoya Main Lateral N2
Pence Lateral
Canutillo Lateral
Nemexas Drain
Duckett Intercepting Drain
Schultz Lateral
Wind Rive Pond
Legend
Modeled Rio Grande Outfall
Highway
Levee Segment
Proposed Levee/Floodwall
Water Line
1% AC Interior Drainage Inundation Boundary
1% AC Interior Drainage Depth:
0 - 0.5 ft (Not Shown)
0.5 - 1 ft
1 - 2 ft
2 - 3 ft
>3 ft
Study Limits:
Natural Valley Floodplain
2D Domain Boundary
El Paso County Limits
City Limits and Designated Places
Service Layer Credits: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
El Paso County
Interior Drainage Study
Figure14: 1% AC Inundation Boundary
Northwest Feasibility
FLO-2D Domain (Map 2 of 2)
0
0.33
Miles
1 inch = 1/3 mile
N
AECOM
THE COUNTY OF EL PASO TEXAS
el paso WATER

El Paso County Interior Drainage Study

Figure 15: Recently Completed Projects in International Dam to Riverside Weir Central/East Domains

Drainage Project Label	Project Name
4	Pershing Dam
8	CE4 Phase 1c - Copia Street Pond
9	CE4 Phase 2b - Magnolia Pump Station
11	CE4 Phase 3c - Morenci Pond
14	CE4 Phase 3a - Gateway West Pond
15	CE4 Phase 3d - Gateway East Pond
16	CE4 Phase 3h - San Diego Dam
20	Van Buren Dam



Legend

- Drainage Projects Incorporated
- New FLO-2D Inflow Locations
- Pump Stations
- Modeled Rio Grande Outfall
- Storage Area

Int. Dam To Riverside (2016) Watersheds

Drainage System

- Basin A
- Border Hwy Overpass System
- Cebada Drainage System
- Channel 108 System
- Dallas Drainage System
- El Paso Paisano System
- Fonseca System
- Goverment Hills System
- Hills Park System
- Mission Valley
- Modesto Ditch System
- West Central

Interior Drainage 2D Model Domain

- Int. Dam To Riverside 2016 - East
- Int. Dam To Riverside 2016 - Central

0 0.75 Miles

1 inch = 1.25 miles

N

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Appendices

Appendix A – El Paso County Interior Drainage Study - Data Collection and Modeling Approach Report

Submitted to
EPWater and El Paso County
El Paso, TX

Submitted by
AECOM
9400 Amberglen Blvd
Austin, TX 78729

El Paso County Interior Drainage Study

Data Collection and Modeling Approach Report

January 2021

Table of Contents

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List of Figures and Exhibits

Executive Summary

In February, 2019, El Paso Water authorized AECOM to provide professional engineering services to develop a Rio Grande interior drainage study covering the river reach through the El Paso County. This *Data Collection and Modeling Approach Report* presents a description of the collected data, current data gaps, and proposed hydrologic and hydraulic modeling approach for developing the interior drainage study. The main findings from this report can be grouped into four themes, as discussed below.

1) Previous Interior Drainage Studies in El Paso

Six interior drainage studies were previously conducted along the Rio Grande levee systems in the County, as summarized in Table 1 of this report. The studied areas extend along the levee east of the Rio Grande from the County border in the north to the Riverside weir in the south. The only studied levee system west of the Rio Grande is two isolated levees upstream of the Anapra bridge. Accordingly, there are two unstudied regions in the county: Levee systems west of the Rio Grande (the northwestern region of the county) and the levees to the south of the Riverside weir (east of the Rio Grande).

All of these previous studies meet FEMA's interior drainage certification requirements, except for the requirement to provide water surface elevation (WSEL) maps for flood depths greater than 1 ft. Instead, they provide inundation mapping based upon flood depths, generated via 2D hydraulic modeling. The exception is the American Canal study, which only utilized 1D hydraulic software. The current study will utilize results from best available previous interior drainage studies, where applicable, and will convert depth grids from those previous studies into WSEL maps to meet FEMA levee certification requirements. At locations where two previous studies overlap, the most recent of the studies will be used, as recent studies utilize more recent topographic data and incorporate new drainage structures in the region.

2) Coincident Flooding Analysis

FEMA stipulates that interior drainage studies should include a coincident flooding analysis. Although none of the previous interior drainage studies include a coincident flooding analysis, they all include modeling of the most conservative scenario (1% AC flow in the Rio Grande coincident with 1% AC rainfall on the interior), which is acceptable by FEMA. However, the studies did not explicitly highlight which scenario is more likely to occur. Accordingly, a coincident flooding analysis was carried out by investigating the coincidence of local rainfall (over El Paso) and rainfall over the larger watershed upstream (in New Mexico). This analysis showed that the local rainfall is essentially independent from rainfall upstream of El Paso.

This conclusion was further supported by examining the devastating July 2006 flood: A clear correspondence was observed between the timing of peaks of local rainfall and peaks of flow in the Rio Grande, which suggests that the elevated flow in the Rio Grande was mainly driven by local rainfall. In conclusion, although the new interior drainage hydraulic models developed for this Study will include flow in the Rio Grande modeled as both 1% AC flow and as base flow in separate models, the starting Rio Grande flow conditions of base flow will be recommended for any future floodplain mapping if levees are eventually accredited by FEMA.

3) Proposed Hydrologic and Hydraulic Modeling Approach

H&H models from previous studies will be employed for this Study, and to maintain consistency: Any modifications made to these models will follow the original study in H&H modeling methods and in treatment of specific types of structures. In areas where no previous interior drainage models have been developed, 2D HEC-RAS hydraulic models and 1D HEC-HMS models developed by FEMA for Draft Preliminary floodplain mapping will be utilized as the base models for the purposes of this Study. Moreover, it is proposed to exclude interior drainage area associated with Levee Segment EP1, Reach 1 (American Canal) from this study due to incomplete and ongoing construction and design of the American Canal. It is requested that EPWater and/or the County confirm whether it is acceptable to exclude this area from this Study.

Since the focus of this Study is to model the 1% AC event, and most storm drains within the Study area are not designed to have capacity for the 1% AC event, storm drain networks and associated inlets will not be modeled for new interior drainage analyses associated with this Study. The same applies for culverts. However, in areas without a previous interior drainage study, culverts that are already incorporated in the Draft Preliminary FEMA hydraulic models will be included in this Study. Dams and detention structures included within contributing drainage areas of new interior drainage analyses developed for this Study will also be modeled consistently with FEMA methodology, meaning that best available topography incorporated in 2D model domains will control flow entering the dams, and a 1D discharge culvert will control outflow from the dams in most cases. Finally, the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall will be used in the southern region of the County, which has not had a previous interior drainage study performed.

4) Data Collection and Data Gaps

Previous interior drainage studies, as-builts, satellite imagery, and spatial data were used to identify available data. Terrain data are derived from five sources, the oldest being 2004 TxDOT photogrammetry and the most recent is the 2018 Doña Ana County LiDAR topography along the Rio Grande. Regarding outfalls along the levees, Table 3 in this report presents the collected data in the County for outfalls and their associated pump stations (if applicable). Missing information about these outfalls and pumps are summarized in the "Pending Resolution" column of Table 3, these data are requested to be provided by USIBWC, EPWater, or El Paso County. At this time, AECOM does not propose to incorporate outfall structures associated with the Loop 375 Project into this Study because it is not clear which portions of the Project have been constructed and what the timeline is for completion of the project.

Table 4 summarizes the recently completed drainage infrastructure projects within El Paso City limits and within the contributing drainage area to the EP 2 levee segment. Eleven of the recently completed projects in the Central and East regions (see projects marked with a star [*] in Table 4) are planned to be incorporated into updates of the International Dam to Riverside Weir study, which was the 2D interior drainage study performed for the EP 2 levee segment. This report provides details on the additional information requested by AECOM regarding the projects selected for inclusion, which will also be requested of EPWater in a separate Request for Information (RFI). In addition, AECOM requests more information from IBWC regarding the status of construction of improvements along the American Canal. Similarly, separate RFIs will be sent to IBWC for specific data needs.

1 Introduction

As part of the El Paso County Interior Drainage Study (Study), AECOM initiated a data collection process, which involved coordination with various agencies to acquire data necessary to update existing and proposed hydrologic and hydraulic (H&H) models or to model new areas of El Paso County in order to meet the interior drainage requirement for FEMA levee accreditation along the Rio Grande. Previous interior drainage H&H analyses will be utilized as a starting point for the interior drainage analysis to the extent possible to avoid duplication of previous modeling efforts.

The purpose of this document is to discuss the data collection efforts and findings, to highlight the missing data to be collected in this Study, and to define the H&H modeling approach for locations where new or updated modeling will be performed. Throughout this document, data gaps will be noted at the end of relevant sections, numbered, formatted in *Italics,* and prefaced by the words, "***Pending Resolution.***" In addition, decisions concerning important H&H modeling approaches and methods that will be applied in this Study will be noted at the end of relevant sections, numbered, formatted in *Italics,* and prefaced by the words, "***Modeling Decision.***"

1.1 FEMA Requirements

Per §65.10 in Title 44 of the Code of Federal Regulations (CFR), the Federal Emergency Management Agency (FEMA) stipulates carrying out an interior drainage study as a requirement for a levee to be recognized (accredited) by FEMA. It also states that the following requirements must be met by an interior drainage analysis:

- Identify the source(s) of the flooding.
- Identify the extent of the flooded area.
- Depict the water-surface elevations(s) of the base flood on the landward side if the average depth of flooding exceeds 1 foot.
  - The base flood is the one percent annual chance (1% AC) flood event.
- The analysis must be based on the joint probability of interior and exterior flooding.
  - It is acceptable to select the most conservative approach of assuming 100-year flow in the Rio Grande.
- The analysis must consider the capacity of facilities (such as drainage lines and pumps) for evacuating interior floodwaters.

Furthermore, the interior drainage study should be certified by a Professional Engineer (PE) before it is submitted to FEMA as part of a levee certification package. Certification by a PE is a statement that the analysis has been performed correctly and in accordance with sound engineering practices. This Study will investigate requirements needed for the interior drainage studies to be certified; so that when all other accreditation requirements are met, the interior drainage studies can be submitted to FEMA as part of a levee certification package.

1.2 Interior Drainage Floodplain Mapping

The Natural Valley floodplain is a 1% AC inundation area which FEMA depicts on a Digital Flood Insurance Rate Map (DFIRM) on the landward side of non-accredited levee systems. The Natural Valley flood extents are mapped and modeled under the assumption that a non-accredited levee system is not in place. Once a levee system is accredited by FEMA, the interior drainage base flood inundation boundary (high-risk areas of residual flooding with ponding depths greater than 1 foot) will be shown as Special Flood Hazard Areas (SFHAs) on a DFIRM. These SFHAs can be either Zone A (not a detailed study) or Zone AE (detailed study) floodplains, depending on the level of detail modeled and whether survey data are incorporated in the modeling. The area removed from the Natural Valley floodplain by an accredited levee system will still be shown as a moderate-risk area (labeled Zone X). Flood insurance is not mandatory in Zone X (shaded) areas, but it is mandatory in SFHAs. FEMA strongly encourages flood insurance for all structures in levee-impacted areas.

1.3 Background of Previous and Ongoing Studies

At the time of this report, six interior drainage studies have been conducted along the Rio Grande levee system in El Paso County (County). Each of these studies consider varying scenarios with respect to joint probability of local flooding and riverine flooding. Furthermore, FEMA is currently in the process of developing Draft Preliminary FEMA models for El Paso County.

In areas where a previous interior drainage study has been performed, H&H models from those studies will be assessed for compliance with FEMA certification requirements and other criteria to determine whether updates to the models or results are necessary as part of this Study. In areas without previous interior drainage studies, the draft Preliminary FEMA models will be leveraged as best available models and will be updated as necessary to meet FEMA certification requirements. Note that these Preliminary FEMA models are more detailed as compared to the FEMA Base Level Engineering (BLE) models.

1.3.1 Areas with Interior Drainage Studies

The extents of each previous interior drainage studies along the Rio Grande are illustrated in Exhibit 1. It can be seen that interior drainage studies have been performed for the northern portion of the County, and mostly on the east side of the Rio Grande. Note, there is an area on the west side of the Rio Grande, north of the City of El Paso (City) limits, that is within the County, but was not included in any previous interior drainage studies. Assumptions related to previous interior drainage studies are described in Section 2 of this report. Certification of these interior drainage studies will involve the following:

- Determination of best available study in areas where previous interior drainage studies overlap (see Section 2.2);
- Determination of adherence to FEMA's interior drainage certification requirements (see Section 2.3);
- Determination of modeling assumptions and methods (see Table 1 and Section 2.4)
- A Joint Probability Assessment performed for this Study (see Section 3);
- Assessment of recently completed drainage projects after interior drainage studies were performed (see Section 5.2); and
- Investigation of varying topographic sources utilized in previous studies compared to current best available topography (see Table 1 and Section 5.4).

1.3.2 Areas without Interior Drainage Studies

In July 2019, the Draft Preliminary FEMA hydrologic HEC-HMS models and two-dimensional (2D) HEC-RAS hydraulic models are expected to become available to communities who request them. EPWater has already requested these models from FEMA to be used for the purposes of this Study as best available models in locations where previous interior drainage studies do not exist. Assumptions applied in Draft Preliminary FEMA H&H modeling are described in Section 4 of this report.

The Draft Preliminary FEMA models are conservative in some instances compared to the previously developed interior drainage studies. For example, Draft Preliminary FEMA models include the following assumptions:

- The 1% AC Natural Valley floodplain (which assumes no levee system in place) is mapped in areas where the levee system is not anticipated to be accredited by the time the new FEMA floodplains become effective see Section 4.1.1);
- 1% AC flow in the Rio Grande is coincident with local interior 1% AC flooding, with all gates or covers associated with levee outfall structures closed (see Section 4.1.2); and
- Precipitation outside of El Paso City limits is based upon the National Oceanic and Atmospheric Administration (NOAA) *Atlas 14, Volume 11: Precipitation-Frequency Atlas of the United States* (Atlas 14) (see Section 4.1.3).

Other than mapping the Natural Valley floodplain, FEMA provides several approaches for mapping flood hazard at an individual levee reach that does not meet the criteria for full accreditation. These approaches and their data requirements are provided in Section 4.2 of *Analysis and Mapping Procedures for Non-Accredited Levee Systems* (RiskMAP, 2013). Note that hazard zones behind the levee will vary depending on the followed mapping procedure.

1.4 General Modeling Approach

The following general H&H modeling approach to certifying interior drainage 1% AC flood extents will be applied in this Study for areas with and without previously developed interior drainage studies:

- Areas where previous interior drainage studies have been performed will be reviewed. If necessary, updates will be made to models or model outputs to meet FEMA certification requirements and/or to include recently completed significant drainage projects.
  - Modifications may include converting flood inundation depths to water surface elevations;
  - Recently completed drainage projects will be considered for incorporation into models.
- Areas without previous interior drainage studies will be modeled by modifying the Draft Preliminary FEMA H&H models to meet FEMA interior drainage certification criteria.
  - Modifications may include adding drainage features and/or incorporating survey data associated with Rio Grande outfall structures;
  - Current FEMA H&H modeling methods will be applied.

2 Previous Interior Drainage Studies

This section describes the areas covered by the previous interior drainage studies performed within El Paso County, as well as modeling assumptions and results associated with the studies.

2.1 Two-Dimensional Modeling Software

Almost all of the interior drainage studies shown in Exhibit 1 utilize two-dimensional (2D) hydraulic modeling software to estimate and map interior drainage depths. The only exception is the American Canal study (URS, 2015), which is discussed in Section 2.2.

In 2D modeling, topographic surfaces are developed based on best available data, which is typically Light Detection and Ranging (LiDAR) data and/or survey. The 2D topographic model surface will be referred to as a “2D model domain” throughout this document. Hydraulic roughness parameters in the form of Manning’s n values can be applied to the 2D model domain using spatially distributed polygons, developed in separate software such as ArcGIS, version 10.4.1 (ESRI). Hydrologic modeling can be incorporated within 2D hydraulic modeling software in multiple ways, depending on the software:

- Rain-on-mesh can be applied in conjunction with polygons specifying infiltration parameters, spatially distributed over the 2D model domain. This method is possible with software such as FLO-2D Pro (FLO-2D Software, Inc.), but not with Hydrologic Engineering Center's River Analysis System (HEC-RAS), version 5.0.5 developed by the U.S. Army Corps of Engineers (USACE);
- The hydrology can also be developed using separate one-dimensional (1D) software such as the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), developed by USACE.
  - HEC-HMS results can then be applied to the 2D model domain by either inserting inflow hydrographs or by distributing excess rainfall on mesh. In this approach, soil or infiltration polygons are not needed for hydrologic modeling within the 2D model domain.
  - Both HEC-RAS and FLO-2D software are capable of applying results from HEC-HMS to a 2D model domain with inflow hydrographs and/or excess rain-on-mesh within the same model.

Modeling Decision 1:

- *Based upon software utilized in previous interior drainage studies (FLO-2D) and in the ongoing FEMA floodplain mapping project (HEC-RAS), which are being updated or revised as part of this Study, all 2D hydraulic modeling in this Study will be performed using either FLO-2D (versions 2007.06 or 2009.06) or HEC-RAS 2D (version 5.0.5 or 5.0.7) software, as deemed appropriate. These software are on FEMA's list of approved 2D steady/unsteady flow models.*
- *Hydrology will be applied in one of the methods described above. The method of applying hydrologic modeling results will vary per model, depending upon the methods applied in the best available studies of the specific areas being modeled.*

2.2 Previously Modeled Interior Drainage Areas

The following interior drainage reports were reviewed and summarized in Table 1 as part of this Study:

- *Courchesne* (2013) study - International Boundary and Water Commission (USIBWC) and EPWater Interior Drainage and River Hydraulics Analysis for Courchesne and Nemexas Reach Canalization Project, URS, 2013.
- *International Dam to Riverside Weir* (2016) study - USIBWC Interior Drainage Hydrologic and Hydraulic Analysis for El Paso, TX International Dam to Riverside Weir, URS, 2016.
- *American Canal* (2015) study - USIBWC American Canal Hydrologic and Hydraulic Analysis (Appendix A1), Replacement of American Canal Lining Project, 2015, Draft updates in 2019 under review by USIBWC.
- *NW Feasibility* (2015) study - USACE Albuquerque District and EPWater Hydrologic, Hydraulic, & Sediment Analysis for Northwest El Paso, Tx Arroyos 38 to 48 Southwest Water Design, LLC, 2015.
- *NW Feasibility* (2017) study - USACE Albuquerque District Northwest El Paso General Investigation Study, Appendix D: Hydrology, Hydraulics, and Sediment, 3AE Green, 2017.
- *Doniphan Corridor* (2018) study - USACE Albuquerque District and EPWater Interior Drainage Analysis Report for El Paso, Texas Doniphan Drive, Borderland to American Dam, 3AE Green, 2018.
- *Canutillo Phase II* (2013) study - USIBWC Rehabilitation Improvements for the Rio Grande Canalization Protective Levee System Canutillo Phase II, Hydrologic & Hydraulic Analysis Report, URS, 2013.

The 2D model domains and contributing watersheds associated with previously developed interior drainage studies are illustrated in Exhibit 2. These watersheds generally extend to the northeast, towards the Franklin Mountains. El Paso County and City limits extend to the west side of the Rio Grande along the reach from the northern border of the county to N. Mesa St. This region, west of the Rio Grande, is yet to be studied; as previous interior drainage studies only covered the east side of the Rio Grande from the northern border of the county to River Side Weir (roughly 22 miles south of N. Mesa St), with the exception of the Courchesne study, which includes two isolated levee segments west of the Rio Grande.

As can be seen in Exhibit 2, several studies overlap with one another:

- *Northwest (NW) Feasibility* (2017) study overlaps with the 2D model domain modeled in the 2013 Canutillo Phase II study.
  - The NW Feasibility (2015) study was updated in December, 2017 to include a sensitivity analysis associated with Arroyos 38 and 48, but this did not change the results of the 2015 study. The 2017 study is shown as a separate row in Table 1, but both are considered as one study area in Exhibit 2.
- *Courchesne* (2013) study covers a portion of the larger 2018 Doniphan Corridor study on the east side of the Rio Grande.
- *American Canal* (2015) study is a 1D H&H analysis that overlaps with the 2018 Doniphan Corridor study over a short reach, upstream of the American Dam.
  - The purpose of the American Canal study is to propose improvements to the canal to safely convey the updated design flow per USIBWC criteria, which takes into account 100-yr interior flooding.
  - The scope of the study was later updated to include a sediment analysis in the canal and revisions to the canal design geometry in Section 3 of the report. The revised draft report for the canal design was submitted in 2019 and was still being reviewed by USIBWC as of 4/30/2019.
  - The EP1 levee segment is located between the American Canal on the north and the Rio Grande on the south, along the river reach covered by the American Canal (2015) study.

Pending Resolution 1:
Portions of the American Canal design, which are documented in the American Canal (2015) study report have been constructed or are under construction at this time, but it is not known which portions have been constructed at this time, or what the timeline is for completing the construction. It will be helpful for the purposes of this Study if USIBWC could provide a status update on which portions of the American Canal design have been constructed at this time, and a timeline for completing any ongoing construction. A Request for Information (RFI) will be sent separately from this report to USIBWC to request this information.

Modeling Decision 2:

- *The more recent NW Feasibility Study (USACE, 2015/2017) will be considered the best available interior drainage study for the area that overlaps the Canutillo Phase II 2D model domain because it includes more recent topography, i.e. 2010 LiDAR vs. 2004 Texas Department of Transportation (TXDOT) photogrammetry.*
- *The most recent Doniphan Corridor Study (USACE, 2018) will be considered the best available interior drainage study for the area east of the Rio Grande that overlaps the Courchesne (USIBWC, 2013) 2D Model Domain and the American Canal (USIBWC, 2015) study area as it considers the best available topography (2014 LiDAR) in the area.*
- *The existing conditions 1D HEC-HMS and HEC-RAS models developed for the American Canal Study (URS, 2015) will be considered the best available interior drainage models in the portions that do not overlap with adjacent 2D model domains. These (pre-Project) H&H models were updated as part of the draft design revisions submitted to USIBWC by URS in 2019, but these models are still under review by the USIBWC.*

2.3 Adherence to FEMA Interior Drainage Certification Requirements

As noted in the introduction of this report, per §65.10 in Title 44 of the CFR, FEMA provides the necessary requirements for interior drainage studies to be acceptable by FEMA. These requirements are:

- Identify the source(s) of the flooding.
- Identify the extent of the flooded area.

- Depict the water-surface elevations(s) of the base flood on the landward side if the average depth of flooding exceeds 1 foot.
- The analysis must be based on the joint probability of interior and exterior flooding.
- The analysis must consider the capacity of facilities (such as drainage lines and pumps) for evacuating interior floodwaters.

All of the previous interior drainage studies meet these requirements, except for the requirement to provide water surface elevation (WSEL) maps for flood depths greater than 1 ft. Instead, they provide inundation mapping based upon flood depths, generated with FLO-2D software (a FEMA-approved 2D hydraulic modeling software). The exception is the American Canal study, which only utilized 1D hydrologic (HEC-HMS) and hydraulic (HEC-RAS) software.

Although none of the previous interior drainage studies include a joint probability analysis, they all include modeling of the most conservative scenario (1% AC flow in the Rio Grande coincident with 1% AC rainfall on the interior), which is acceptable by FEMA.

Modeling Decision 3:

- *This Study will utilize results from best available previous interior drainage studies, where applicable, and will convert depth grids from those previous studies into WSEL maps to meet FEMA levee certification requirements for interior drainage studies.*
- *In the case of American Canal, the existing conditions 1D HEC-HMS and 1D HEC-RAS models associated with the 2015 American Canal study, known as "American Canal Hydrologic and Hydraulic Analysis Report (Appendix H), Replacement of American Canal Lining Project" (URS, 2015) will not be used to develop interior drainage WSEL maps because, as noted in Section 2.2, it is not known which portions of the canal have been constructed at this time, or what the timeline is for completing the construction. It is also not clear what design will be selected for the unconstructed portions of the canal. All of these factors affect the interior drainage flood extents.*

2.4 Previous Interior Drainage Model Assumptions

Modeling assumptions and methods applied for H&H analyses and for different types of drainage structures varied for each interior drainage study. This section describes similarities and differences related to modeling assumptions for each of the studies.

2.4.1 Precipitation

All previous interior drainage studies assumed precipitation depths and distributions according to the City of El Paso's 2008 *Drainage Design Manual* (DDM). The DDM divides the City into three drainage regions: Westside, Central, and Eastside, where the precipitation depth is constant in each region for a given storm duration and return period. The DDM precipitation was also used in the region northwest of the City of El Paso (within the County). This Study will use the rainfall from all previous interior drainage studies and will not update it to consider NOAA Atlas 14 rainfall in areas previously studied.

2.4.2 Rio Grande Flow

Modeling assumptions related to flow in the Rio Grande are important for interior drainage studies because the water level in the river affects the ability of the of the outfall structures to drain stormwater runoff from the landward side of the levee system. Four of the previous interior drainage studies from Table 1 modeled both the 100-yr flow (ranging from 8,500 to 13,400 cubic feet per second [cfs]) and the base flow, 2,350 cfs). The exceptions are discussed below:

- The *Hydrologic, Hydraulic, and Sediment Analysis for Northwest El Paso, TX Arroyos 38 to 48* (3AEGreen, 2015) (*NW Feasibility Study*) only modeled base flow in the Rio Grande (1,450 cfs), and the *General Investigation Study* (3AEGreen, 2017), a follow-up sensitivity analysis to the 2015 NW Feasibility study, did not model flow in the Rio Grande as all gates for interior drainage along the Rio Grande were assumed to be closed.
- The 2015 American Canal study assumed that all interior flow (in that reach) is intercepted by the American Canal before it reaches the Rio Grande; consequently, flow in the Rio Grande was not modeled in this study as well.

2.4.3 Gated Outfall Structures

In most of the studies from Table 1, the drainage gates on the Rio Grande were generally assumed to be closed for 100-yr river flow and open for base flow in the river. However, the 2013 Canutillo Phase II study modeled coincident 100-yr riverine and interior flooding with the gates on the Rio Grande open, unless the water level in the Rio Grande is higher than the arroyo at the drainage structure. The coincident flooding analysis from this study showed that the peak flow on the Rio Grande arrives 29.5 hours after the interior drainage peak reaches the arroyo outfalls on the Rio Grande in this study area.

2.4.4 Storm Drains

Storm-sewer systems were not modeled or were assumed ineffective in all of the previous interior drainage studies shown in Table 1, except for the *International Dam to Riverside Weir (URS, 2016) study*. In that study, the capacity of the storm-sewer systems were computed in StormCAD and were used to reduce peak flows from the overall runoff hydrographs that were developed in HEC-HMS. After removing the base of each HEC-HMS hydrograph according to the maximum capacity of each applicable storm sewer system, the resulting runoff hydrographs were inserted onto 2D model domains at discharge point locations using FLO-2D software.

2.4.5 Dams

Methods for simulating the effect of dams or retention basins on hydrology in the previous interior drainage studies varied for each study. The general modeling approach for dams/retention basins in each study that was considered the best available study per region is discussed in this section.

- The *International Dam to Riverside Weir (URS, 2016) study* simulates dams upstream of the 2D model domains using 1D HEC-HMS models based upon models developed in the *El Paso Stormwater Master Plan* (URS, 2009), with detailed elevation-storage-discharge curves incorporated into those models, and resulting outflow hydrographs applied to downstream 2D model domains.
- The *Doniphan Drive Interior Drainage Study* (3AEGreen, 2018) simulated dams by removing the drainage areas contributing to the dams from the hydrologic analysis, under the assumption that the auxiliary spillways would not engage, and the dams would detain all of the 1% AC contributing runoff long enough to make the discharge from the dam insignificant downstream.
- The *NW Feasibility Study* (3AEGreen, 2015) modeled retention basins with either HEC-HMS 1D hydrologic modeling software or in FLO-2D, depending on the structure. Retention basins modeled in 2D were modeled with elevations of the 2D model domain modified as necessary, with other pertinent features such as hydraulic weir structures added to the 2D model domain.

2.4.6 Pump Stations

All previously developed interior drainage studies with the exception of the *International Dam to Riverside Weir* (URS, 2016) study either did not model pump stations or considered them ineffective. The majority of the pump stations in El Paso County are located in the contributing drainage area to the *International Dam to*

Riverside Weir (URS, 2016) study. For that analysis, the maximum capacity of each of these pump stations was applied in StormCAD at the downstream end of each contributing subcatchment system. The pump station capacities applied in the study were provided by EPWater, with the exception of the Chihuahuita II Pump Station, which was not available at the time of the study. It was assumed that the pumps along the Rio Grande only operated during base flow conditions on the Rio Grande, and not during scenarios when the river was assumed to have regional 1% AC flows.

Modeling Decision 4:
Based upon H&H modeling methods applied in previous interior drainage studies (described in this section), any modifications made to models which are updated as part of this Study will incorporate similar modeling methods for H&H and for specific types of structures, to be consistent with the models being modified. However, NOAA Atlas 14 rainfall will be used in the southern region of the county, which has not had a previous interior drainage study performed.

3 Joint Probability Analysis

The USACE manual EM 1110-2-1413 (2018) discusses several approaches for analyzing coincidental flooding which would be acceptable by FEMA as part of the levee accreditation process:

- Perform coincidence assessment to determine the likelihood and the significance of assuming that the riverine and interior flood events are independent;
- Develop the probability distribution for the stage at the location of interest in the interior area; and
- Assume high tailwater in river (gates closed).

The most conservative of these approaches is the assumption of a high tail water level in the river, i.e., all the drainage structures are closed. Most of the previous interior drainage studies modeled scenarios for both 1% AC river levels coincident with 1% AC interior flood events (worst-case scenario, drainage gates closed) and base flow in the river with 1% AC interior flood events (drainage gates open). The studies did not explicitly highlight which scenario is more likely to occur.

3.1 Operation of Interior Closures

The USIBWC *Flood Emergency Operations Manual, Volume III* (Upper Rio Grande Projects, 2013) states that the operation of the gated outfall structures that convey stormwater from the interior side of the Rio Grande levee system into the river is the joint responsibility of the Upper Rio Grande Projects office of the USIBWC and the Federal, State, Counties, Cities, Irrigation Districts and other authorities specified in Memorandums of Understanding (MOUs) between the USIBWC and the appropriate agency. The appropriate agency depends on location and owner/operator of specified outfall structures. The various MOUs included in the *Flood Emergency Operations Manual, Volume III* (Upper Rio Grande Projects, 2013) establish that the USIBWC and the specified agency (including the City of El Paso and El Paso County Water Improvement District No. 1 [EPCWID]) will coordinate on the usage of drainage structures during river flood control operation and localized interior drainage flooding in an effort to attempt to prevent river flood flows from entering the City and County, and to convey drainage flows from the land side of the levee to the main Rio Grande channel.

When the gates are closed, these structures provide a closure system between the Rio Grande River and residential property during river flooding. During “normal” rainfall events, the gates are left open to convey water through those structures into the river. “Normal” storm drainage flows are defined as flows in the Rio Grande River that are less than 60% of the design capacity. The design capacities of the Rio Grande from Percha Diversion Dam to American Canal are specified in the *Joint Powers Agreement Between the*

Elephant Butte Irrigation District (EBID) and the USIBWC (2001), which is included as Exhibit 7 in the *Flood Emergency Operations Manual, Volume III* (Upper Rio Grande Projects, 2013). During river flood control operations, when the flow is at least 60% of the design capacity, the USIBWC will coordinate operation of the gates and drainage structure closures with the appropriate agency.

3.2 Coincidence Assessment

To investigate the coincidence of local interior flooding and flooding in the Rio Grande, rainfall data at the El Paso International Airport were compared to rainfall over the upstream watershed in New Mexico. The analysis was conducted following these steps:

- Hourly rainfall depths were collected from the rain gage at El Paso International Airport with record lengths spanning 1941-2019. The records were obtained from the NOAA National Climatic Data Center website.
- The Watershed in New Mexico contributing to the Rio Grande at the El Paso International Airport was delineated.
- Rain gages with sufficient records in the vicinity of this watershed were identified, and daily rainfall records were obtained from the NOAA National Climatic Data Center website (see Exhibit 3).
- From HEC-HMS models associated with previous interior drainage studies, the lag time from the Franklin Mountains to the Rio Grande was estimated to be on the order of 2 hrs.
- The hourly data at the El Paso International Airport gage were sorted to identify the highest 2-hr depths in the records, based on the 2-hr lag time of the local runoff from the Franklin Mountains to the Rio Grande.
- The lag time from the Caballo dam to El Paso was estimated to be on the order of 1-3 days.
- The 24-hr precipitation records at the upstream watershed gages in New Mexico (with similar periods of record to the El Paso International Airport gage) were collected and converted to daily averages by multiplying each record by 1.15.
- The averages of converted daily records from the upstream watershed gages shown in Exhibit 3 were calculated to represent the rainfall over the upstream watershed for specified days of interest.
- A comparison of regional precipitation over the Rio Grande watershed to local precipitation in El Paso was performed.
  - To account for the lag time in the upstream watershed, the 20 highest 2-hr precipitation events in El Paso were compared to the average of the 24-hr precipitation at the upstream gages for the same day, 1 day before, 2 days before, and 3 days before.
  - The maximum 2-hr depth in El Paso was identified and compared to the average rainfall upstream on multiple preceding days to account for the uncertainty in the lag time of the upstream catchment.
  - The return periods of local El Paso 2-hr duration events and regional 24-hour duration events were estimated based on NOAA Atlas 14 rainfall depths/return periods.
- Results show that the highest 2-hr storms in El Paso had a return period ranging from 27.1 to 3.6 years, while the return period for corresponding 24-hr storms over the large upstream watershed was generally <1 year, with a maximum of 2.4 years, as summarized in Table 2.

This analysis lends to the validity of the assumption that local flooding in El Paso and flooding in the Rio Grande should be treated as independent events.

3.3 Gage Analysis of 2006 Flood

The August 2006 flood, which caused devastation throughout the El Paso area, is an example of the independence of the riverine flood (flood generated by rainfall over the watershed below Caballo Dam) with local floods. This 2006 flood was clearly generated by rainfall on the El Paso area Franklin Mountains. In this section we will discuss these conditions associated with the August 2006 flood:

- Rainfall over the watershed below Caballo Dam versus rainfall over the Franklins; and
- Effect of the local interior flood on flows in the Rio Grande

This section will discuss these implications of the 2006 Flood on the strategy of modeling performed by this study.

3.3.1 Rainfall over the Riverine Basin Versus Local Rainfall

During the period from July 28, 2006 until August 4, 2006 the rainfall at the El Paso International Airport gage was 6.8 inches, while the average rainfall during this period at the upstream Watershed was 1.4 inches (or 2.4 inches if the El Paso, La Tuna gage is included).

3.3.2 Effect of the Local Interior Flood on Flows in the Rio Grande

Hourly flow data in the Rio Grande were obtained from the *Flood Frequency Determination Report* (MAPVI, 2007), which reported the flow records from the USIBWC gauge Rio Grande at El Paso (Site no. 08-3640.00, near NM-273 crossing of the Rio Grande) from July 27 to August 6, 2006. Radar rainfall records over the Franklin Mountains (5 miles northeast of the flow gauge) were obtained from the National Centers for Environmental Prediction/Climate Prediction Center (NCEP/CPC) 4-km global hourly rainfall, and are plotted on the same graph as the flow records. On July 27 (before the region witnessed any rainfall), only base flow was observed in the Rio Grande. However, the spikes in rainfall correspond closely and consistently precede spikes in river flow, e.g., 7/28, 7/31, 8/1, 8/3, and 8/5. This demonstrates the clear generation of riverine flooding by an interior flood generated by rain over the Franklins (see Figure 3-1).

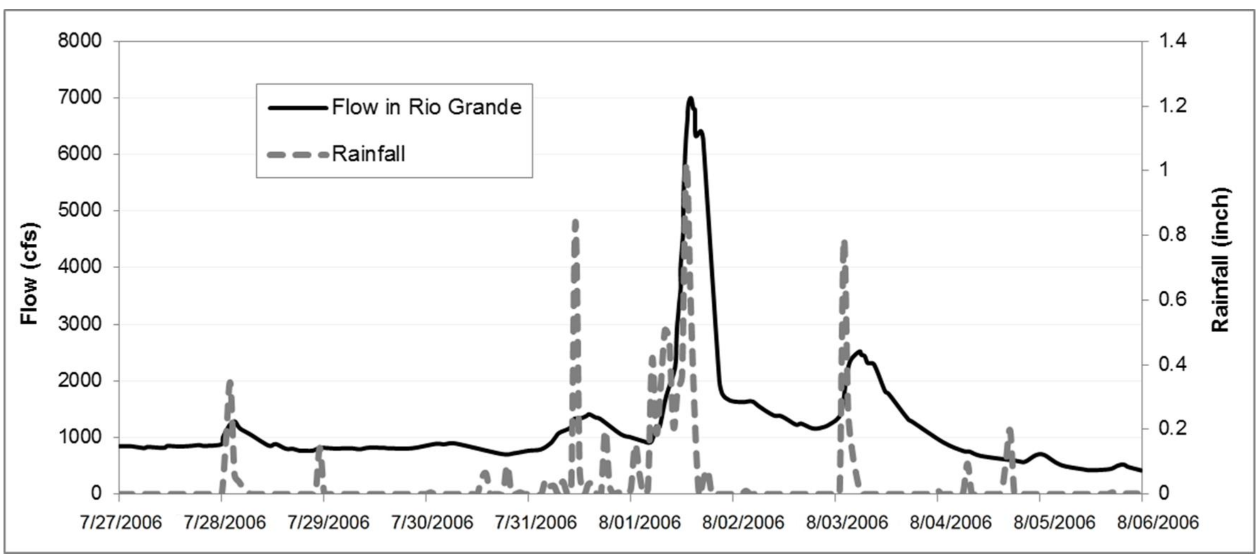

Figure 3-1. Comparison of Local El Paso Rainfall and Flow in the Rio Grande for the July 2006 Flood

3.3.3 Implications of the 2006 Flood on the Modeling Strategy

This example shows that the use of a base flow level in the Rio Grande to estimate tailwater at river outlets from the El Paso area during interior flooding is not accounting for tailwater increases caused by local runoff into the river, as the interior flood alone is large relative to the base flow of the river. Interior modeling needs to include modeling flows into the Rio Grande and accumulation of flood flows in the river.

Modeling Decision 5:
Although the new interior drainage hydraulic models developed for this Study will include flow in the Rio Grande modeled as both 1% AC flow and as base flow in separate models, the starting Rio Grande flow conditions of base flow will be recommended for any future floodplain mapping if levees are eventually accredited by FEMA. Drainage structures discharging into the Rio Grande by gravity which have gates or covers will be modeled as having "no negative flow" flap gates in HEC-RAS to simulate the closure of gates or covers if water levels in the Rio Grande rise due to local runoff (within the 2D model domains being studied) and exceed flood levels on the landward side of levees.

4 Modeling Approach for New Interior Drainage Study Areas

In areas of the County where previous interior drainage studies have not been performed, it is proposed to utilize Draft Preliminary FEMA models (more detailed than BLE models) as the base H&H models for new interior drainage analyses. These models will be updated to meet FEMA interior drainage certification requirements. This section describes the Study team's understanding of the general H&H modeling approach applied by FEMA and explains how the Draft Preliminary FEMA models will be used/modified for the purposes of this Study. It should be noted that any descriptions of FEMA modeling methods and approaches described in this report are not documented or approved by FEMA at this time, and are subject to change as the Preliminary FEMA models are finalized.

4.1 Draft Preliminary FEMA Modeling Assumptions

The FEMA modeling approach involves developing hydrology for large 2D model domains using 1D HEC-HMS software. Excess rainfall results from HEC-HMS are then distributed evenly as excess rain-on-mesh over the HEC-RAS 2D model domains. Hydrologic Unit Code (HUC) watersheds were used as the basis for the boundaries of the FEMA 2D model domains, but the 2D model boundaries vary from HUC watershed boundaries in some locations.

Areas where the Study team proposes to develop new interior drainage analyses based upon the draft Preliminary FEMA models are shown in Exhibits 4, 5, 6, and 7. These exhibits include new 2D model domains compared to original FEMA 2D model domains and adjacent HUC watersheds. The exhibits also include any applicable pump stations, dams, or outfall structures that will be modeled to allow flow into the Rio Grande from the interior, which can affect tailwaters in the Rio Grande.

Modeling Decision 6:

- *2D HEC-RAS hydraulic models and 1D HEC-HMS models developed by FEMA for Draft Preliminary floodplain mapping will be utilized as the base models for the purposes of this Study in areas where no previous interior drainage models have been developed.*
- *To reduce model run-times, FEMA's 2D model domains adjacent to Rio Grande levees will be re-shaped and reduced in size as part of this Study. This will require manipulation of the HEC-HMS basin model areas and loss parameters to develop modified excess rainfall hydrographs for even distribution over truncated 2D model domains.*
- *Outflow hydrographs from upstream portions of 2D model domains that are truncated will be applied as inflow hydrographs downstream, along boundaries where 2D model domains are cut.*
- *Before changing any other aspects of the models, results before and after truncating the 2D domains will be evaluated. If significant changes are observed from the truncation process, or if original model run times are not significantly long, the full 2D model domains from FEMA and the original associated hydrology will be used as a starting point instead.*

- *Once the truncated models are verified to produce consistent results with the original Draft Preliminary FEMA models before truncation, drainage infrastructure will be added/modified in the 2D HEC-RAS model along the Rio Grande levees to evaluate interior flooding related to culverts and drains discharging to the Rio Grande.*

4.1.1 FEMA Mapping Assumptions for Non-Accredited Levees

The Study Team's understanding of FEMA's floodplain mapping assumptions with respect to non-accredited levees include the following:

- All levee systems along the Rio Grande except for EP2 (the levee segment associated with the *International Dam to Riverside Weir* [URS, 2016] interior drainage study) are assumed not to be accredited by FEMA by the time the floodplains become effective. It is uncertain at this time whether all or any portions of the EP2 levee segment will be considered certified at the time the Preliminary FEMA maps become effective.
- 1% AC interior drainage flood depth results from Scenarios 4 and 8 of the *International Dam to Riverside Weir* (URS, 2016) study were converted to water surface elevations by FEMA and incorporated (with exceptions/modifications) as Zone AE SFHAs.
  - Scenarios 4 and 8 assume post levee improvements and 1% AC flow in the Rio Grande (outfall structures closed) for the Central and East models, respectively.
  - FEMA used best available topography (2014) LiDAR to develop base flood elevations from 1% AC flood depths greater than 1 foot.
- The 1% AC Natural Valley floodplain will be mapped as Zone X (moderate risk area) on the landward side of the EP2 levee segment.
- The 1% AC Natural Valley floodplain will be mapped as the SFHA behind all levee systems other than the EP2 levee segment.

4.1.2 FEMA Precipitation

The City of El Paso's DDM divides the city into three drainage regions: Westside, Central, and Eastside, where the precipitation depth is constant in each region for a given storm duration and return period. Outside the city limits, rainfall data for El Paso and New Mexico Counties can be obtained from NOAA Atlas 14, which provides point estimates for depth-frequency-duration. To facilitate precipitation depth computations, FEMA created a raster surface for the 24-hr depth of each storm frequency. In this rainfall raster, the depth in El Paso city limits is constant (based on the depths for each drainage region specified in the DDM), and the precipitation depth outside the city is based on the Atlas 14 point estimates.

Using this raster, the depth over a watershed in two different rainfall zones can be estimated using ArcGIS (ESRI) zonal statistics. This tool calculates a single average rainfall value over the entire watershed based on the proportion of the watershed area in each rainfall zone. This rainfall raster was provided by FEMA on March 12, 2019 per EPWater's request for use in this Study.

Developing rainfall distributions for each 2D model domain requires a series of steps:

- Regardless of whether a modeled area is inside or outside of El Paso city limits, FEMA estimates the rainfall distribution for each 2D model domain using depth-durations ratios applied from Atlas 14 frequency distributions at the centroid of each 2D model domain.
  - The depth associated with each storm duration (15-min, 1-hr, 2-hr, 24-hr, etc.) at the centroid of the 2D model domain can be downloaded from the Atlas 14 website.
- The obtained depths from this procedure are normalized using the 24-hr storm depth, which results in a ratio (< 1) for each storm duration.

- To compute the depths associated with each storm duration which are input by FEMA into the HEC-HMS hydrologic models, these ratios are then multiplied by the 24-hr depth that was determined earlier from the rainfall raster and the zonal statistics tool.
- The storm duration-depth values are input to HEC-HMS as a frequency distribution to compute excess rainfall for each 2D model domain.
- The excess rainfall results from HEC-HMS are then distributed over each 2D model domain in HEC-RAS hydraulic modeling software.

Modeling Decision 7:
The same method as described above will be applied to develop modified rainfall depths and distributions if the original FEMA 2D model domains are modified or truncated.

4.1.3 FEMA Drainage Infrastructure

FEMA modeling assumes the Rio Grande has 1% AC flows coincident with local 1% AC rainfall and assumes that the natural valley floodplain inundates the landward side of non-accredited levees. Under these conditions, most storm drain systems, and outfall structures affecting interior drainage analyses would not be able to drain or are inundated by the natural valley floodplain. Therefore, these structures are either not included or are not modeled in detail as part of the Draft Preliminary FEMA 2D modeling.

Dams, ponds, retention basins, and associated pump stations are included in the FEMA study based on a 2D modeling approach. In this approach, the contributing overland runoff drains into the detention/retention structure and is contained by the dam embankments or depressed storage volume, based on overland flow patterns on the topography of the 2D model domain. If applicable for retention basins or sumps, a pump station is modeled (based on maximum capacity) to the structure into the Rio Grande or other discharge locations. If applicable for detention ponds or dams, an outlet structure such as a principal spillway pipe is inserted at an appropriate elevation to drain the structures.

Modeling Decision 8:
The same method as described above will be applied to any dams that are modeled in 2D domains being modified/updated as part of this Study.

4.2 Area Proposed to Exclude from this Study

There is one location in the County where it is proposed to exclude an interior drainage study. The area proposed to be excluded is shown in Exhibit 8 (EP-1, Reach 1, American Canal). Although a limited interior drainage study was performed as part of the USIBWC American Canal design project in 2015/2019, only flows into American canal were modeled. Flood depths and flood water surface elevations were not mapped as part of this design study. This area is proposed to be excluded from this Study for the following reasons:

- The American Canal design is currently being updated and reviewed by USIBWC;
- The EP-1, Reach 1 levee segment cannot be certified at this time because the reach needs to tie into high ground or demonstrate hydraulic independence.
- As noted in Sections 2.2 and 2.3 of this report, portions of the canal design (which affect interior drainage flood extents) from the 2015 report have been constructed, but the limits of the constructed portions are not known at this time, and a timeline for completing the construction or design are also not clear. USIBWC is currently reviewing recent design changes to the canal.
- The Natural Valley 1% AC floodplain (FEMA, 2016) is very narrow through this reach and inundates relatively few structures compared to other levee segments being considered for certification.

Modeling Decision 9:
It is proposed to exclude the interior drainage area associated with Levee Segment EP1, Reach 1 (American Canal) due to the reasons stated in this section. It is requested that EPWater and/or the County confirm whether it is acceptable to exclude this area from this Study.

5 Data Collection

This section describes data collection efforts as part of this Study for areas that will be modeled as new interior drainage studies and for areas where updates could be made to previously developed interior drainage studies.

5.1 Drainage Infrastructure Data

This section describes data collected and modeling approaches related to drainage infrastructure within El Paso County.

5.1.1 Outfalls

Table 3 shows all Rio Grande outfalls identified as part of this Study. The outfall labels shown in Table 3 correspond to outfall labels in Exhibit 2, which shows outfalls along the Rio Grande relative to previous interior drainage studies performed in El Paso County. This figure excludes outfall labels 44, 45, and 46, which are south of the El Paso City limits, and are shown in Exhibits 4, 5, and 6 of the new 2D model domains to be modeled as part of this Study (discussed Section 4.1). Table 3 includes the source of the outfall information obtained, size of outfall, description of gates or covers, and capacity of pump stations associated with outfalls, if applicable. This table was compiled using data from the following sources:

- Final Survey for the Rio Grande Storm Upstream/Outfall Structures, Frank X. Spencer & Associates, Inc (FXSA), 2019.
- Operations and Maintenance Manual for Rio Grande Projects, Upper Rio Grande Projects American Dam/Carlos Marin Field Office, Appendix I - River and Levee Structures Rio Grande Canalization Project, 2010.
- Preliminary Engineering Analysis Rio Grande Outlet Structures, Conde, Inc., 2007.
- USACE Albuquerque District and EPWater Interior Drainage Analysis Report for El Paso, Texas Doniphan Drive, Borderland to American Dam, 3AE Green, 2018.
- “Nodes” spatial data provided by EPWater, April 2019.
- Unverified spatial data received from the IBWC on May 23, 2019.
- National Agricultural Imagery Program (NAIP) aerial imagery in ESRI ArcMap, 2016.

Pending Resolution 2:
If a column in Table 3 is left blank in this table, the information is unknown at this time. Unknown data for each outfall are summarized in the “Pending Resolution” column of the table. A star (*) next to the outfall label number indicates that additional data are needed to model the outfall in a new interior drainage analysis for this Study. It is requested that USIBWC, EPWater, or El Paso County provide any missing information they may have, with priority given to outfalls marked with stars (*). Any information that cannot be provided and which is necessary for new interior drainage analyses developed for this Study will be measured in a field investigation during the model development phase of this Study.

5.1.2 Storm Drains

Information related to storm drain location, size, shape, and material was collected in the form of as-builts and spatial data as part of this Study. EPWater maintains a Geographic Information Systems (GIS) database of storm drains within City of El Paso limits, and provided these spatial line files (conduits), along with node point files of inlets and pump stations to AECOM on April 18, 2019. In addition, storm drain as-built plans, spatial files, and StormCAD models were obtained from the *International Dam to Riverside Weir (URS, 2016) study*, which was the only previously developed interior drainage study to incorporate storm drains into the analysis. However, the spatial storm drain data obtained for the City do not include elevations and 36% of the conduits do not include pipe sizes. A spatial database of storm drains outside of City limits was not available.

Modeling Decision 10:
Since the focus of this Study is to model the 1% AC event, and most storm drains within the Study area are not designed to have capacity for the 1% AC event, storm drain networks and associated inlets will not be modeled for new interior drainage analyses associated with this Study.

5.1.3 Culvert Crossings

El Paso County maintains a spatial database of culvert crossings and inlets outside of City limits, which were provided to AECOM on March 14, 2019. In addition, the conduit spatial data provided by EPWater on April 18, 2019 included significant culvert crossings within City limits.

Modeling Decision 11:
Since the focus of this Study is to model the 1% AC event, and most culverts within the Study area are not designed to have capacity for the 1% AC event, culvert crossings will not be modeled for new interior drainage analyses associated with this Study unless they are already incorporated in the Draft Preliminary FEMA hydraulic models.

5.1.4 Dams

Information related to flood control dams within City and County limits was obtained from the following sources:

- As-built plans;
- *El Paso Stormwater Master Plan* (URS, 2009);
- *Dam Analysis Report* (URS, 2007); and
- *El Paso County Stormwater Master Plan* (URS, 2010).
- *National Inventory of Dams* (USACE, 2019)

Dams can be modeled with a variety of methods, depending on the software used, storms evaluated, level of detail necessary, and information available for elevation-storage discharge relationships. Since the purpose of this Study is to evaluate the 1% AC event, and since dams are typically designed to detain the 1% AC event, the flood benefits of significant dams will be considered as part of this Study. The location of dams that are within contributing drainage areas of new interior drainage 2D model domains that are to be developed as part of this Study are shown in Exhibit 5, Exhibit 6, and Exhibit 7.

The methods used to consider detention vary between the different interior drainage studies previously developed and the Draft Preliminary FEMA models, which are all being leveraged as part of this Study. For example, in the *International Dam to Riverside Weir (URS, 2016) study*, contributing drainage areas are being modeled in 1D HEC-HMS models based upon models developed in the *El Paso Stormwater Master*

Plan (URS, 2009) with detailed elevation-storage-discharge curves incorporated into those models, and resulting outflow hydrographs applied to downstream 2D model domains.

An alternative simplified 1D modeling approach to simulate dams may include removing the drainage areas contributing to the dam from the hydrologic analysis, under the assumption that the auxiliary spillway will not engage, and the dam will detain all of the 1% AC contributing runoff long enough to make the discharge from the dam insignificant for the purpose of a particular study. This simplified approach was applied in the *Doniphan Drive Interior Drainage Study* (3AEGreen, 2018).

However, if a dam is located within a 2D model domain, it can be modeled by allowing the topographic surface to control how much flow enters the dam through overland runoff, and can allow discharge from the dam by incorporating an outfall conduit, modeled as a 1D culvert in the 2D model domain. This is the modeling approach applied to dams in the Draft Preliminary FEMA models. A simplified approach to modeling dams in 2D would be to just remove the contributing drainage area to the dam from the 2D model domain. Once again, this assumes that the auxiliary spillway of the dam would not engage for the event modeled.

Modeling Decision 12:

- *Dams included within contributing drainage areas of new interior drainage analyses developed for this Study will be modeled consistently with FEMA methodology, meaning that best available topography incorporated in 2D model domains will control flow entering the dams, and a 1D discharge culvert will control outflow from the dams.*
- *Any updates to dams included within the contributing drainage area to the International Dam to Riverside Weir (URS, 2016) study as part of this Study will be modeled consistently with the methods applied in that study, which include incorporation of elevation-storage-discharge curves in a 1D HEC-HMS model. If modifications are made to storage capacity of detention structures to ensure the 100-year runoff is contained, the simplified approach below may be used instead.*
- *Any new detention structures incorporated into the International Dam to Riverside Weir (URS, 2016) study as part of this Study will be modeled with the simplified approach of removing the contributing drainage areas from the 1D HEC-HMS model. Before removing contributing drainage areas from the model, a check will be performed to ensure the new detention structure includes sufficient storage capacity to detain the 1% AC contributing runoff volume.*

5.1.5 Pump Stations

As noted in Table 3, specified outfalls are connected to pump stations that discharge directly into the Rio Grande. EPWater provided spatial point data and capacities of pump stations in the City, but also confirmed that dimensions of wet wells and start/stop elevations for pumps are not available without performing a field visit to each pump station. The only pump station included in the 2D model domain of a new interior drainage analysis developed for this Study is the Basin G Pump Station, which is shown in Exhibit 6.

The *Final Survey for the Rio Grande Storm Upstream/Outfall Structures* (FXSA, 2019) provides confirmation that specified outfalls are connected to nearby pump stations, but it does not always confirm the connected pump station's name or address. If the survey report did not specify a pump station name or address, it was assumed the nearest pump station was connected to that outfall. However, in some cases, it was not clear which pump station may be connected to a surveyed outfall, and an additional reference confirming outfall-survey connections was not found.

Pending Resolution 3:
The "Pending Resolution" column in Table 3 specifies which outfalls have unconfirmed connections to pump stations and which pump stations are missing pump capacity information. It is requested that USIBWC, EPWater, or El Paso County provide any missing pump capacities or connection information they may have, with priority given to outfalls marked with stars (*). Any information that cannot be provided and which is

necessary for new interior drainage analyses developed for this Study will be investigated in a site visit during the model development phase of this Study.

5.2 Recently Completed Drainage Infrastructure Projects

The recently completed and significant drainage infrastructure projects within El Paso City limits were investigated by coordinating with EPWater and TXDOT. This section describes the information requested and obtained at this point in time. Since the EP2 levee reach included in the *International Dam to Riverside Weir (URS, 2016) study* is the only certifiable levee reach in the County, and FEMA is considering the flood depths from the study in their ongoing County floodplain mapping project, priority was given to collecting project information in the Central and East drainage areas associated with the 2016 study.

5.2.1 EPWater Projects

Recently completed projects in the Central and East regions were investigated as part of this Study to be considered as potential updates to the *International Dam to Riverside Weir (URS, 2016) study.* The H&H modeling associated with the 2016 study was mostly completed in 2014, when the draft report was first submitted to USIBWC. Therefore, the drainage projects that occurred since 2014 were researched to consider for incorporation into the previously developed Central and East FLO-2D models as part of this Study.

Coordination took place with EPWater during their process of making internal updates to the *El Paso Stormwater Master Plan* (URS, 2009). Based on as-built plans and unofficial records received from EPWater (used internally by EPWater for CIP tracking purposes), it was found that almost all of the recently completed and significant drainage infrastructure project descriptions obtained, which could influence previously developed interior drainage studies, were located in the Central and East 2D model domains included in the *International Dam to Riverside Weir (URS, 2016) study*.

Exhibit 9 shows the contributing watersheds and 2D model domains of the 2016 study, as well as the locations of the recently completed drainage infrastructure projects in the study area. Table 4, lists out each project for which as-builts were requested, a description of the work completed, and the year that construction was completed (if available).

Pending Resolution 4:
Eleven of the recently completed projects in the Central and East regions (see projects marked with a star [*] in Table 4) are planned to be incorporated into updates of the International Dam to Riverside Weir (URS, 2016) study. It is requested that EPWater and the County provide feedback on whether they agree with these recently completed projects being incorporated into the 2016 FLO-2D model. AECOM has reviewed the available information for these projects and requests the following additional information needed for modeling:

- *Project Label 4: Pershing Dam –Pershing Dam Upgrades to Auxiliary Spillway*
  - *As-built plans and drainage report, if available*
  - *Estimated construction completion date*
- *Project Label 9: CE4 Phase 2b - Magnolia Pump Station*
  - *Contributing drainage area(s) to pump station and force main (map and area)*
- *Project Label 12: CE4 Phase 3e – Kentucky Dam*
  - *Estimated construction completion date*
- *Project Label 14: CE4 Phase 3a – Gateway West Pond*
  - *Contributing drainage area(s) to pond (map and area)*
  - *Estimated construction completion date*
- *Project Label 15: CE4 Phase 3d – Gateway East Pond*
  - *Contributing drainage area(s) to pond (map and area)*

  - *Estimated construction completion date*
- *Project Label 16: CE4 Phase 3h – San Diego Dam Upgrades*
  - *As-built plans and drainage report, if available*
- *Project Label 29: MV5 Phase 1a – Basin G Excavation*
  - *Contributing drainage area(s) to basin (map and area)*
  - *Elevation-Storage Curve/Data (how much volume was added to the pond area)*
  - *Description/documentation of improvements made to Basin G*

Modeling Decision 13:
Eleven of the recently completed projects in the Central and East regions (see projects marked with a star [*] in Table 4) are planned to be incorporated into updates of the International Dam to Riverside Weir (URS, 2016) study. Depending on the timing of updated modeling performed as part of this Study and the FEMA mapping schedule, results from the updated Central and East interior drainage models developed for this Study could potentially be considered as an appeal to the Preliminary FEMA models. Another option for incorporating revisions from this Study into the effective FEMA FIRMs would be to submit the updated model results as a Letter of Map Revision (LOMR) before the new FEMA models become effective. Coordination with FEMA indicates it is likely that changes made during an appeal or LOMR could potentially be incorporated into the DFIRM mapping before it becomes effective.

5.2.2 TXDOT Loop 375 Project

TXDOT is in the process of implementing improvements along Loop 375 for improving regional mobility and safety, as part of a project that started in September 2007. The preliminary drainage report associated with this project was published on TxDOT's website in February 2013, and this report includes various proposed road-side inlets and new outfalls that discharge into the Rio-Grande. Areal images from Google Earth (see Figure 5-1) and pictures from the *Final Survey for the Rio Grande Storm Upstream/Outfall Structures* (FXSA, 2019) show that the project overlaps with previously developed interior drainage study areas and parts of this project have already been constructed.

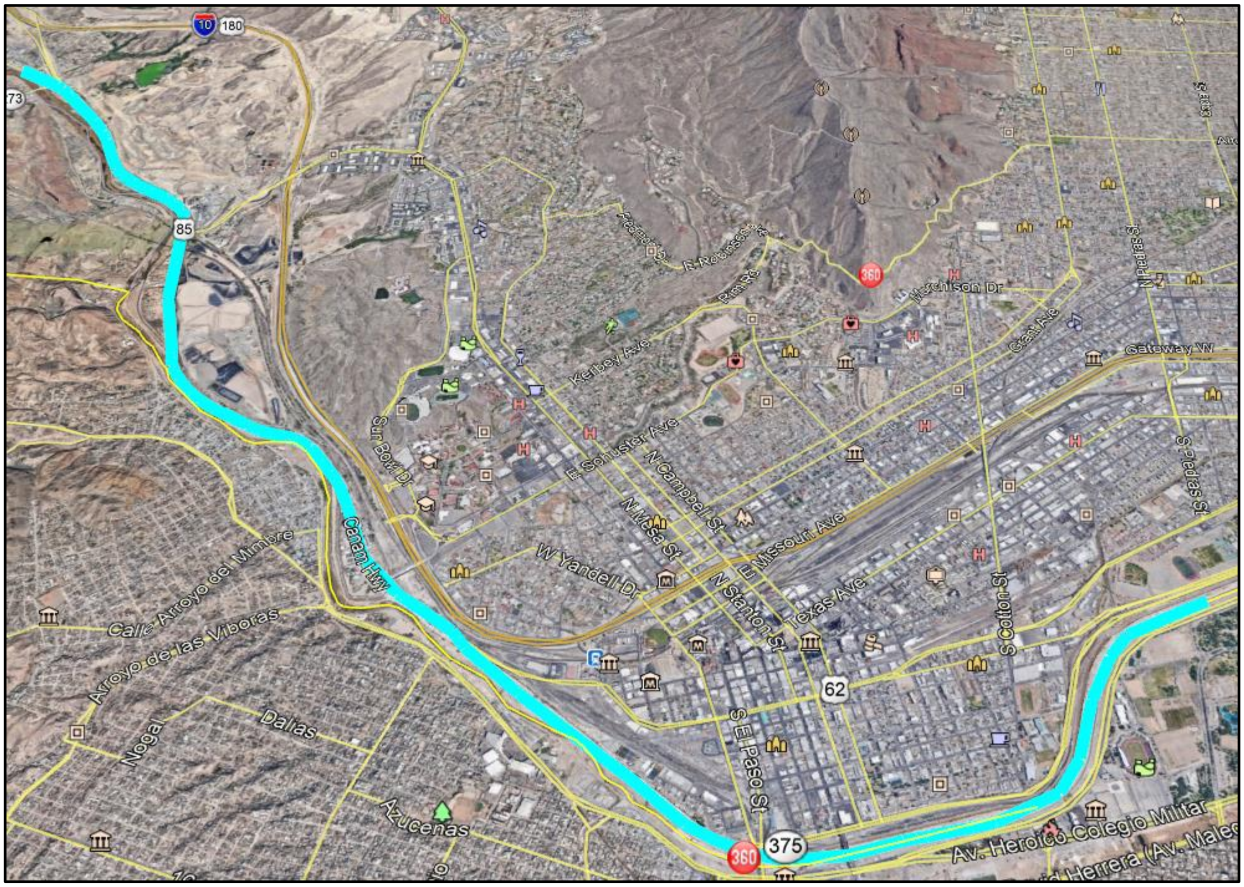

Figure 5-1. Location of Loop 375 Project, shown on Google Earth (Google, 2019).

Modeling Decision 14:
At this time, AECOM does not propose to incorporate outfall structures associated with the Loop 375 Project into this Study because it is not clear which portions of the Project have been constructed and what the timeline is for completion of the project. However, any significant outfalls that have recently been surveyed as part of the Final Survey for the Rio Grande Storm Upstream/Outfall Structures (FXSA, 2019) report will be considered if they significantly effect interior drainage, and are not designed just for roadway drainage purposes.

5.3 Topography

Several topographic sources for digital terrains that can be used in H&H modeling, and specifically as 2D model domains, were researched and obtained for the Study area in El Paso County. These sources include:

- 2004 TxDOT photogrammetry;
- 2010 Doña Ana County LiDAR topography, Geoid 09;
  - The 2010 LiDAR is associated with a projection of NAD83 (2011), New Mexico State Plane, Central Zone, NAVD 88, Geoid 09.
- 2014 LiDAR topography, 2015 TxDOT photogrammetry, Geoid 12A;
  - The 2014 LiDAR is associated with a projection of NAD83 (2011), UTM Zone 13, NAVD88, Geoid 12A.

- 2015 TXDOT Photogrammetry;
- 2018 Doña Ana County LiDAR topography along the Rio Grande;
  - The 2018 LiDAR is associated with a projection of NAD83 (2011), Transverse Mercator, NAVD 88, Geoid 09.

The extents of each of these topographic sources with respect to the new 2D modeling domains proposed to be modeled in this Study are illustrated in Exhibit 10and Exhibit 11.

FEMA acquired and provided the 2004 photogrammetry data, the 2014 LiDAR, and 2010 LiDAR in the form of a combined digital terrain file. However, FEMA is currently processing the 2015 TXDOT photogrammetry data and has agreed to provide the updated combined terrain file to EPWater for use in this Study.

Necessary terrain data for the Northwestern region of El Paso County (west of the Rio Grande and North of N. Mesa St.) was obtained from the 2010 Doña Ana County LiDAR, acquired by FEMA. The extents of this LiDAR and other available topographical data are illustrated in Exhibit 11. According to the Doña Ana County website (https://donaanacounty.org/flood/aerial), LiDAR was initially flown in 2004, and then updated in both 2010 and 2014. However, data for the 2014 update are not currently available for request.

The most recent LiDAR available along the Rio Grande was developed by Doña Ana County Flood Commission and Bohannan-Huston, Inc. and was collected in early 2018. The data were obtained from Al Blair on behalf of EPCWID, who approved use of the data in this Study. FEMA is not currently utilizing this LiDAR in the Draft Preliminary FEMA models. It extends from north of El Paso County to American Dam.

Modeling Decision 15:
In locations where new interior drainage analyses are developed for this Study, the mosaic raster developed by FEMA, which incorporates best available topographic data for each region (excluding the 2018 Rio Grande LiDAR) will be used. LiDAR elevations at surveyed locations of outfall structure inverts will be extracted from the mosaic surface and compared to survey elevations and to 2018 LiDAR elevations, where available. Depending on the comparison results, either 2018 LiDAR or manipulations to FEMA's combined terrain file will be considered to ensure the 2D surface elevation is consistent with any surveyed outfall invert elevations.

6 References

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Tables

Table 1. Acquired Information from Previous Interior Drainage Studies in El Paso County

Study	Study Extents	Flow in the Rio Grande	Levee Gates	Notes	Storm Sewer Systems	2D Modeling software	Rainfall Modeling Approach	Rainfall Data Source	Source of Topographic Data	Reported Ongoing or Complete Construction	Scenario Mapped
Courchesne, USIBWC, Jan 2013	Page 2-1: "The Courchesne Reach is the river segment between the Anapra Bridge on the upstream end and the American Dam on the downstream end."	100-yr flow hydrograph (approx. 8500 cfs) and base flow (2350 cfs)	10 scenarios were carried out as different combinations of river flow, interior storm, gates open/closed, and levee before/after improvements.	Proposed improvements to levee and gates	Not modeled	FLO-2D, 50 x 50 ft grid	None, inflow hydrographs from HEC-HMS	Page 3-2: East side of the Levee from City of El Paso DDM and West of Levee is from NOAA Atlas for New Mexico	• East side of the levee: 2004 contours developed by TxDOT • West side of the levee: 2005 Doña Ana County contours, developed by FEMA	Levee improvements from study have not been constructed at this time.	Depth grid provided for gates open and gates closed scenarios.
International Dam to Riverside, USIBWC and EPWater, June 2016	Page 1: "…study area bounded in the south by the Rio Grande. Interstate Highway 10 (IH-10) and the Franklin Canal represent much of the northern boundary for this study. The upstream boundary was the International Dam, and the downstream boundary was the Riverside Weir."	100-yr flow hydrograph, and base flow (2350 cfs)	Shut: Rio Grande 100-yr Flow (two scenarios) Open: Rio Grande Base Flow (two scenarios)	Pre- and post-levee improvements scenarios were carried out	Modeled using StormCAD with downstream pump station capacities incorporated. Source: EPWU, City of El Paso, U.S. General Services Administration (USGSA), TxDOT, MCi, and USIBWC	FLO-2D, 50 x 50 ft grid	None, inflow hydrographs from HEC-HMS	Page 10: City of El Paso Drainage Design Manual 2008. Records in Table 9 page 39 (pdf count)	2009 City of El Paso LiDAR	Levee improvements from Intl. Dam to riverside weir have been complete. Page 13: "None of the data received for this analysis indicated that any improvements were made to the outfalls along the Rio Grande."	Depth grid was provided for gates open and gates closed scenarios.
NW Feasibility, USACE, May 2015	Page 1: "The study includes the drainages from the northern area of the City of El Paso, TX (Arroyo 38, just north of Mulberry Dam) to the New Mexico-Texas state boundary (Arroyo 48 in Anthony, TX)."	Base flow (1450 cfs)	One gate open and one gate closed scenario	Followed by the 2017 NW Feasibility Study	Not modeled	FLO-2D, updated URS 2013 model 50 x 50 ft grid	Two sections: near mountains using HEC-HMS inflow and Rainfall on grid near the river (west of I-10)	Page 51: City of El Paso Drainage Design Manual 2008 Using West region depth, used 24-hr storm and default HMS rainfall distribution	TxDOT 2004 photogrammetric survey and 2010 LiDAR for the City/County of El Paso	• Stormwater conveyance channel completed in 2014 at Spur 16 highway (TxDOT) • Resler Ponding Areas 1 to 5 • Two new basins near Desert Springs	Depth grid for gates open and gates closed scenarios, gates closed scenario was reported to be more conservative
NW Feasibility General Investigation Study, USACE, Dec. 2017	Page D-15: "...project area is bounded by the New Mexico Stateline on the north, Interstate 10 (I-10) to the east, Artcraft Road to the south and the Rio Grande to the west"	No flow	Shut	This study is a sensitivity analysis as a supplement to the 2015 NW Arroyos 38 to 48 report	Not modeled	FLO-2D, 50 x 50 ft grid	None, inflow hydrographs from HEC-HMS	Used hydrographs from the 2015 NW Feasibility	TxDOT 2004 photogrammetric survey and 2010 LiDAR for the City/County of El Paso	Stormwater conveyance channel completed in 2014 at Spur 16 highway (TxDOT)	No flow in Rio Grande, gates closed (depth grid provided for gates closed scenario)

Study	Study Extents	Flow in the Rio Grande	Levee Gates	Notes	Storm Sewer Systems	2D Modeling software	Rainfall Modeling Approach	Rainfall Data Source	Source of Topographic Data	Reported Ongoing or Complete Construction	Scenario Mapped
Doniphan Corridor, USACE, Mar. 2018	Page 2: " The project area ranges from the Franklin Mountains to the western-most Rio Grande Levee, and from Borderland Road south to the American Dam."	100-yr flow (13,400 cfs), and base flow (2350 cfs)	Shut: Rio Grande 100-yr Flow (two scenarios) Open: Rio Grande Base Flow (two scenarios)	Levee improvements start at Borderland and end at the El Paso Electric Plant to contain 100-yr Rio Grande flow and provide 3 ft freeboard	• Not modeled or taken into account • As-builts from TxDOT and EPWU • Capacity of some systems was estimated	FLO-2D, 50 x 50 ft grid	None, inflow hydrographs from HEC-HMS	City of El Paso Drainage Design Manual 2008 Using West region depth, used 24-hr storm and default HMS rainfall distribution	2014 FEMA acquired LiDAR and 2014 FEMA acquired raw classified Log ASCII Standard (LAS) point files (for Doña Ana County)	• Completed post-2010 levee improvements from Borderland to El Paso Electric Plant. • Newly constructed levee on the east side	Depth grid was provided for all scenarios
American Canal, July 2015	Page 5: "The canal receives water from the Rio Grande via the American Dam and travels along the Rio Grande for 2.1 miles before flowing into the Franklin Canal and the remaining local canal network."	Assumed that excess flow can be diverted to the Rio Grande	Levee not modeled/mentioned	Proposed improvements to the canal to safely convey updated design flow by USIBWC criteria. The report is being updated in 2019 for redesign of the lower reach.	Not modeled (assumed ineffective)	1-D HECRAS (canal only)	HEC-HMS inflow into the canal	Page 6: City of El Paso Drainage Design Manual 2008	El Paso Water Utility (EPWU) 2011 LiDAR data and Bohannan Huston, Inc. (BHI) surveyed data completed in 2011	• New sumps will be used to retain water from the ASARCO drainage sub-basin. • American Canal Upper Reach and Lower Reach Overchute were constructed.	No mapping
Canutillo Phase II, March 2013	Page 1: " project extends along the east bank of the Rio Grande from upstream of the Vinton Bridge to upstream of the Borderland Bridge"	100-yr (10,325 cfs) hydrograph and base flow of 2,350 cfs before and after this hydrograph	• 100-yr in Rio Grande with gates closed and no interior flow • 100-yr riverine and 100-yr interior with gates open unless WSEL in river is higher than the arroyo	• Culverts were designed based on base flow in Rio Grande Scenario • Estimated a delay of 30 hrs between local and Rio Grande peaks	Not modeled	FLO-2D, 50 x 50 ft grid	None, inflow hydrographs from HEC-HMS	Page 8: Westside rainfall from El Paso DDM	TxDOT 2004 Topography and the 2008 El Paso County Orthophotography	Canutillo Phase II levee improvements have not been constructed.	Max WSEL at each location according to the two modeled scenarios

Table 2. Results of Coincident Flooding Analysis

Date	El Paso		Upstream Watershed Gage Data from New Mexico					
			New Mexico Storm on the Same Day as El Paso		New Mexico Storm One Day Before El Paso		New Mexico Storm Two Days Before El Paso	
	Max. 2-Hr Rainfall (inches)	Return Period Atlas 14 (yrs)	1-Day Rainfall (inches)	Return Period Atlas 14 (yrs)	1-Day Rainfall (inches)	Return Period Atlas 14 (yrs)	1-Day Rainfall (inches)	Return Period Atlas 14 (yrs)
9/20/1982	2.2	27.1	0.004	<1	0.198	<1	0.066	<1
8/12/2005	1.99	17.8	0.081	<1	0.002	<1	0.071	<1
5/18/1992	1.67	9.3	0.020	<1	0.007	<1	0.000	<1
7/4/1961	1.58	7.7	0.065	<1	0.142	<1	0.121	<1
9/11/1964	1.58	7.7	0.467	<1	0.087	<1	0.016	<1
8/31/1957	1.55	7.2	0.823	<1	0.515	<1	0.358	<1
8/10/1981	1.53	6.9	0.083	<1	0.000	<1	0.013	<1
8/14/2004	1.5	6.4	0.842	<1	0.081	<1	0.009	<1
7/4/1961	1.47	6.0	0.065	<1	0.142	<1	0.121	<1
8/12/1992	1.4	5.1	0.43	<1	0.035	<1	0.009	<1
9/11/1958	1.37	4.8	1.24	1.7	0.181	<1	0.024	<1
8/8/1984	1.36	4.6	0.08	<1	0.421	<1	0.442	<1
7/2/1971	1.34	4.4	0.44	<1	0.000	<1	0.000	<1
9/12/1975	1.33	4.3	1.36	2.4	0.367	<1	0.276	<1
7/15/1976	1.33	4.3	0.08	<1	0.077	<1	0.029	<1
9/2/1962	1.29	3.9	0.09	<1	0.000	<1	0.000	<1
7/5/1968	1.29	3.9	1.21	1.6	0.588	<1	0.132	<1
7/26/1990	1.27	3.7	0.00	<1	0.000	<1	0.000	<1
5/18/1992	1.26	3.6	0.02	<1	0.093	<1	0.000	<1
7/1/2000	1.26	3.6	0.02	<1	0.192	<1	0.514	<1

Table 3. Outfalls

Exhibit 2 Outfall Label	Description	Size	Levee Segment	Source	Cover	Pump Station	Pending Resolution
0*	Montoya Siphon Station (O&M)	Modeled as 2-50'x6' CBC and 1-40'x6' CBC	CME-2	O&M Manual (2010)	Modeled with No Cover		Size, Cover
1	RG inflow point 24	Modeled as gap in levee with surface area reduction factors	CME-2	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	N/A		
2*	Nemexas Siphon (O&M)	72” Concrete Pipe under the Rio Grande	CME-2	O&M Manual (2010)			Confirm Size, Cover
3	Montoya Lateral Wasteway #36	48" RCP	CME-2	O&M Manual (2010); IBWC Review Comments			Cover
4	Montoya Drain Outfall	3-5'x5' Conc Box	CME-2	O&M Manual (2010); IBWC Review Comments			Cover
5	Keystone Dam OF (RG Inflow Point 21)	96" Pipe	CME-2	Doniphan Interior Drainage (2018)		15000 GPM, Phase I (3495 Doniphan)	Size, Connection to Pump Station, Cover
7	(RG Inflow Point 19)	2-8x4 CBC 3-48in RCP	CME-2	Doniphan Interior Drainage (2018)			Cover
8	(RG Inflow Point 18)	2-10x5 CBC	CME-2	Doniphan Interior Drainage (2018)			Cover
9	(RG Inflow Point 54)	10’x4’ CBC	CME-2	Doniphan Interior Drainage (2018)			Cover
10	(RG Inflow Point 17)	2-6X4 CBC	CME-2	Doniphan Interior Drainage (2018)			Cover
11	(RG Inflow Point 16)	2-42" RCP	CME-2	Doniphan Interior Drainage (2018)			Cover
12	(RG Inflow Point 15)	2-42” RCP	CME-2	Doniphan Interior Drainage (2018)			Confirm Size, Cover
13	(RG Inflow Point 14)	6-8x6 MC-8-1-MBC	CME-2	Doniphan Interior Drainage (2018)			Cover
14	(RG Inflow Point 53)	4-42 in RCP	CME-2	Doniphan Interior Drainage (2018)			Cover
15	(RG Inflow Point 13)	2-6x5 CBC	CME-2	Doniphan Interior Drainage (2018)			Cover
16	3-5'x5'x34' Conc Box (O&M)	3-5'x5'x34' Conc Box	CME-2	O&M Manual (2010)			Cover
17	3-5'x5'x50' Conc Box (O&M)	3-5'x5'x50' Conc Box	CME-2	O&M Manual (2010)			Cover
18	3-36" RCP (2019 Outfall Surv)	3-36" RCP	EP1	FXSA Survey (2019)	Closed Metal Sluice Gates		
19	4-8'x5' (2019 Outfall Surv)	4-8'x5'	EP2	FXSA Survey (2019)	Sluice Gates		
20	2-12'x12' Conc Box Culv (2019 Outfall Surv)	2-12'x12' Conc Box Culv	EP2	FXSA Survey (2019)	Metal Gates upstream and downstream		
21	42" RCP (2019 Outfall Surv) (O&M)	42" RCP	EP2	FXSA Survey (2019), Conde (2007)	Metal Cover	47250 GPM, Chihuahuita	Confirm Connection to Chihuahuita PS
22	Survey of DS road culvert, Sun Metro Outlet	2 - 36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Protective Metal Fence		Size and Function
23	DS side of culvert; Overflow from American Canal	US 2-10'x5'; DS 2-8'x7' conc box culv	EP2	FXSA Survey (2019), Conde (2007)	Metal Cover Upstream, Metal Gate Downstream		
24	36" RCP (2019 Outfall Surv) (O&M)	36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Metal grate	47250 GPM, Chihuahuita	
25	36" RCP (2019 Outfall surv) (O&M)	36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover	47250 GPM, Chihuahuita	
26	24" Concrete Pipe (2019 Outfall Surv) (O&M)	24" Concrete Pipe	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover		
27	54" and 48" RCP (2019 Outfall Surv) (O&M)	54" and 48" RCP	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		

Exhibit 2 Outfall Label	Description	Size	Levee Segment	Source	Cover	Pump Station	Pending Resolution
28	3-24" RCP (2019 Outfall Surv) (O&M)	US 1- 36L, DS 3-24" RCP	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		
29	48" RCP (2019 Outfall surv) (O&M)	48" RCP	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		FXSA supersedes Conde size
30	7x5 Conc Box Culv (2019 Outfall surv)	7x5 Conc Box Culv	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		FXSA supersedes Conde size
31	4-5'x5' Box Culverts (2019 Outfall Surv)	4-5'x5' Box Culverts	EP2	FXSA Survey (2019)	Close Metal Cover and Metal Grate	64500 GPM, Cebada	
32	6'x5' Box culv (2019 Outfall surv) (O&M)	6'x5' Box culv	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		FXSA supersedes Conde size
33	2-5.5'x4.5' Conc box (2019 Outfall Surv) (O&M 5x5)	2-5.5'x4.5' Conc box	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		FXSA supersedes Conde size
34	30" RCP (2019 Outfall Surv) (O&M)	30" RCP	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		
35	90" RCP (2019 Outfallsurv) (O&M)	30" to 90" RCP, Conde	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		FXSA supersedes Conde size
36	36" RCP (2019 Outfall Surv)	36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate		FXSA supersedes Conde size
37	30" RCP (2019 Outfall Surv) (O&M)	30" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal cover		
38	36" RCP (2019 Outfall Surv) (O&M)	30 to 36" RCP	EP2	FXSA Survey (2019), Conde (2007)	Close Metal Cover and Metal Grate	Cordova	FXSA supersedes Conde size; Confirm Connection to Pump Station and Unknown Pump Station Capacity
39	9' RCP (2019 Outfall Surv)	9' RCP	EP2	FXSA Survey (2019), Conde (2007)	No Cover	113000 GPM, Clardy Fox	
40	Discharge from Franklin Canal	US 4-5'x4x; DS 2-4'x4' Conc Box culv	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Sluice Gates		
41	2-36" RCP (2019 Outfall Surv)	2-36" RCP	EP2	FXSA Survey (2019), Conde (2007)	No cover	18700 GPM, Basin G	Size
42*	Overflow from American Canal	4-6'x6' Box Culv	EP2	FXSA Survey (2019)	No cover at outlet, metal sluice gates at inlet	18700 GPM, Basin G	Size, Connection to Pump Station
43*	5-6'x5' box culv (2019 Outfall Surv) (O&M)	5-6'x5' box culv	EP3	FXSA Survey (2019), Conde (2007)	No Cover		
44*	3-6'X5' Box Culv (2019 Outfall Surv) (O&M)	3-6'X5' Box Culv	EP3	FXSA Survey (2019), O&M Manual (2010)	No Cover		
45*	Fabens Wasteway	4-5'x5' Box culvert	EP4	FXSA Survey (2019), O&M Manual (2010)	No Cover		
46	Managed by Hudspeth's Irrigation District	5-4'x4' Box Culv	EP4	FXSA Survey (2019), O&M Manual (2010)	Sluice Gates		
47	Aerial Image Outfall from Anthony Drain	30"x48" Concrete Pipe	CME-2	NAIP Aerial Imagery (2016), IBWC GIS Data	Metal Gates		Confirm Size, Cover
48	East Drain & Texas Lateral	2 – 5'x4' CBC	CME-2	USIBWC Review Comments	Modeled with No Cover		Size, Cover
49	Aerial Image Outfall	Modeled as 17'x4' CBC	CME-2	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		Size, Cover
50	Aerial Image Outfall	Modeled as 5'x4' CBC	CME-2	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		Size, Cover
51	Aerial Image Outfall	Modeled as 18'x6' CBC	CME-2	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		Size, Cover

Exhibit 2 Outfall Label	Description	Size	Levee Segment	Source	Cover	Pump Station	Pending Resolution
52	Aerial Image Outfall	Modeled as 12'x4' CBC	CME-2	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		Size, Cover
53	Aerial Image Outfall	Modeled as 24'x2' CBC	CME-2	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		Size, Cover
54	Aerial Image Outfall	Modeled as gap in levee with surface area reduction factors	CME-2	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	N/A		
55	Aerial Image Outfall	Modeled as 28'x6' CBC	CME-2	NAIP Aerial Imagery (2016), NW Feasibility FLO-2D Model	Modeled with No Cover		Size, Cover
56	Out of service/blocked	60" RCP	EP2	FXSA Survey (2019), Conde (2007)	Bolted Metal Plate		Conde supersedes, no size from FXSA
57	Outfall Survey; RG Inflow FID 51	72" RCP	EP2	FXSA Survey (2019), Conde (2007)	Closed Metal Cover	47250 GPM, Basin A	
58*	Vinton Cutoff Lateral Wasteway #32B	36" RCP	CMW	IBWC GIS Data and Review Comments, AECOM Field Verified	Sluice Gate		Confirm Size, Cover
59*	Rowley Lateral Outfall	36" RCP	CMW	NAIP Aerial Imagery (2016), AECOM Field Verified, IBWC Review Comments		Flap Gate	Size, Cover
60*	Aerial Image Outfall		CME-2	NAIP Aerial Imagery (2016)			Size, Cover
61*	Aerial Image Outfall	30"x36"Concrete Culvert	CMW	NAIP Aerial Imagery (2016), IBWC GIS Data			Confirm Size, Cover
62*	Canutillo Lateral Wasteway #34	60"x48" Box Culvert	CMW	NAIP Aerial Imagery (2016), IBWC GIS Data and Review Comments, AECOM Field Verified	Sluice Gate		Size, Cover
63*	Pence Lateral Wasteway #34A	30" RCP	CMW	NAIP Aerial Imagery (2016), IBWC GIS Data			Confirm Size, Cover
64*	Aerial Image Outfall - Combined La Union Wasteway	60"x48" Box Culvert	CMW	NAIP Aerial Imagery (2016), IBWC GIS Data	Sluice Gate		Confirm Size and Cover
65	Behind Water Treatment Plant	36" RCP	EP2	Conde (2007)			Size, Function, Cover
66	Aerial Image Outfall	3-24" RCP	EP2	Conde (2007)			Cover
69*	IBWC GIS Data Outfall	16" Cast Iron Pipe	CMW	IBWC GIS Data			Confirm Size, Cover
70*	IBWC GIS Data Outfall	20" Cast Iron Pipe	CMW	IBWC GIS Data			Confirm Size, Cover
71*	IBWC GIS Data Outfall	16" Cast Iron Pipe	CMW	IBWC GIS Data			Confirm Size, Cover
72	IBWC GIS Data Outfall	12"x36" Pipe	CW	IBWC GIS Data			Not included, outside County
73	IBWC GIS Data Outfall	36"x42" Culvert	CW	IBWC GIS Data			Not included, outside County
74	IBWC GIS Data Outfall	30"x40" Culvert	CW	IBWC GIS Data			Not included, outside County
75	IBWC GIS Data Outfall	36"x42" Culvert	CW	IBWC GIS Data			Not included, outside County
76	IBWC GIS Data Outfall	30"x40" Culvert	CW	IBWC GIS Data			Not included, outside County
77	IBWC GIS Data Outfall	18"x39" Culvert	CW	IBWC GIS Data			Not included, outside County
78	IBWC GIS Data Outfall	30"x36" Culvert	CW	IBWC GIS Data			Not included, outside County
79	IBWC GIS Data Outfall	36"x40" CMP Culvert	CW	IBWC GIS Data			Not included, outside County
80	IBWC GIS Data Outfall	24" Cast Iron Pipe	EP1	IBWC GIS Data			Confirm Size, Cover
81	Shultz Lateral Wasteway No. 35C	30" RCP	CMW	NAIP Aerial Imagery (2016), IBWC GIS Data and Review Comments, AECOM Field Verified	Sluice Gate		

* Indicates an outfall is in an area to be modeled as a new interior drainage study and either dimensions, cover, or pump station capacity/connection are unknown at this time.

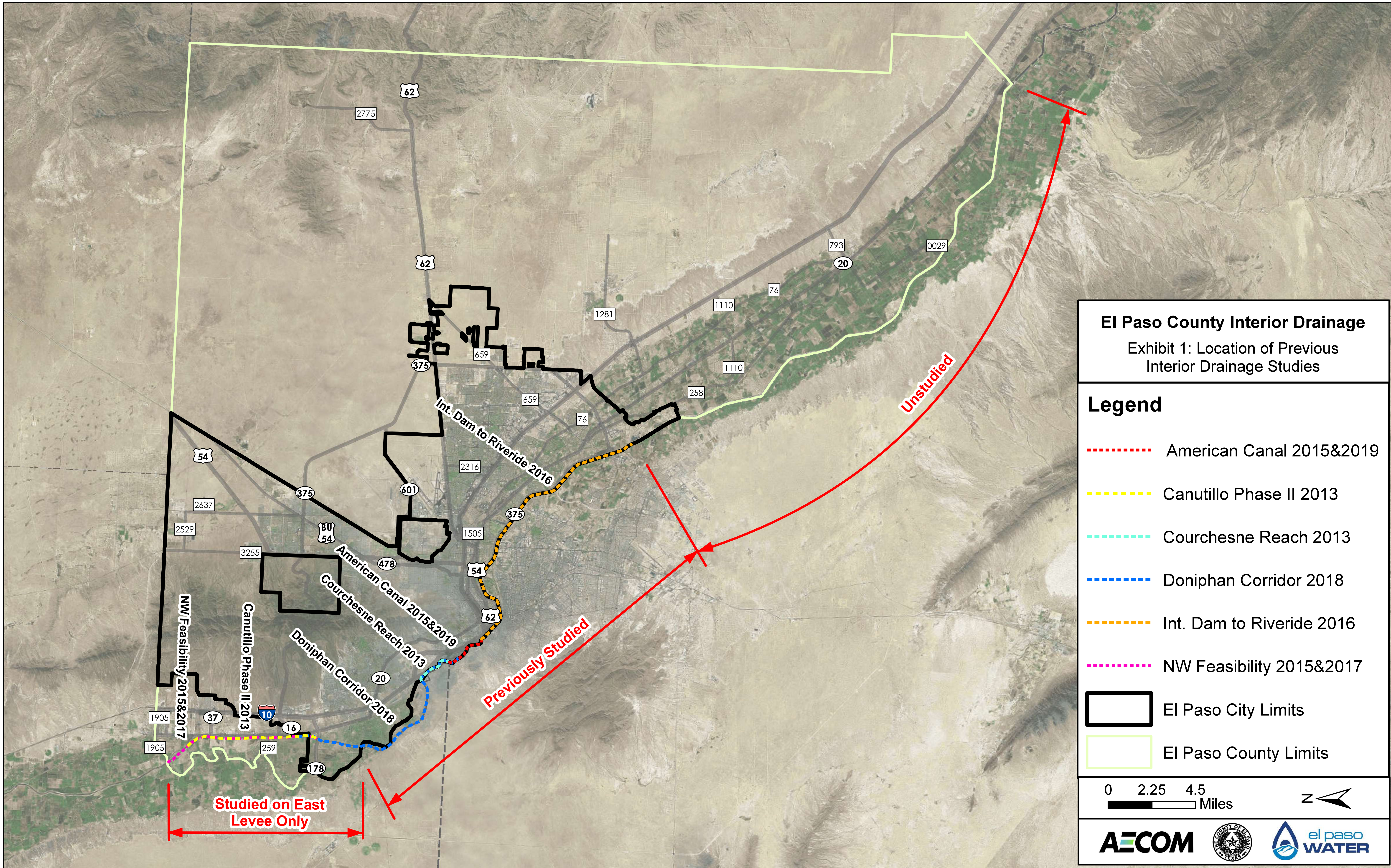
Table 4. Completed Projects

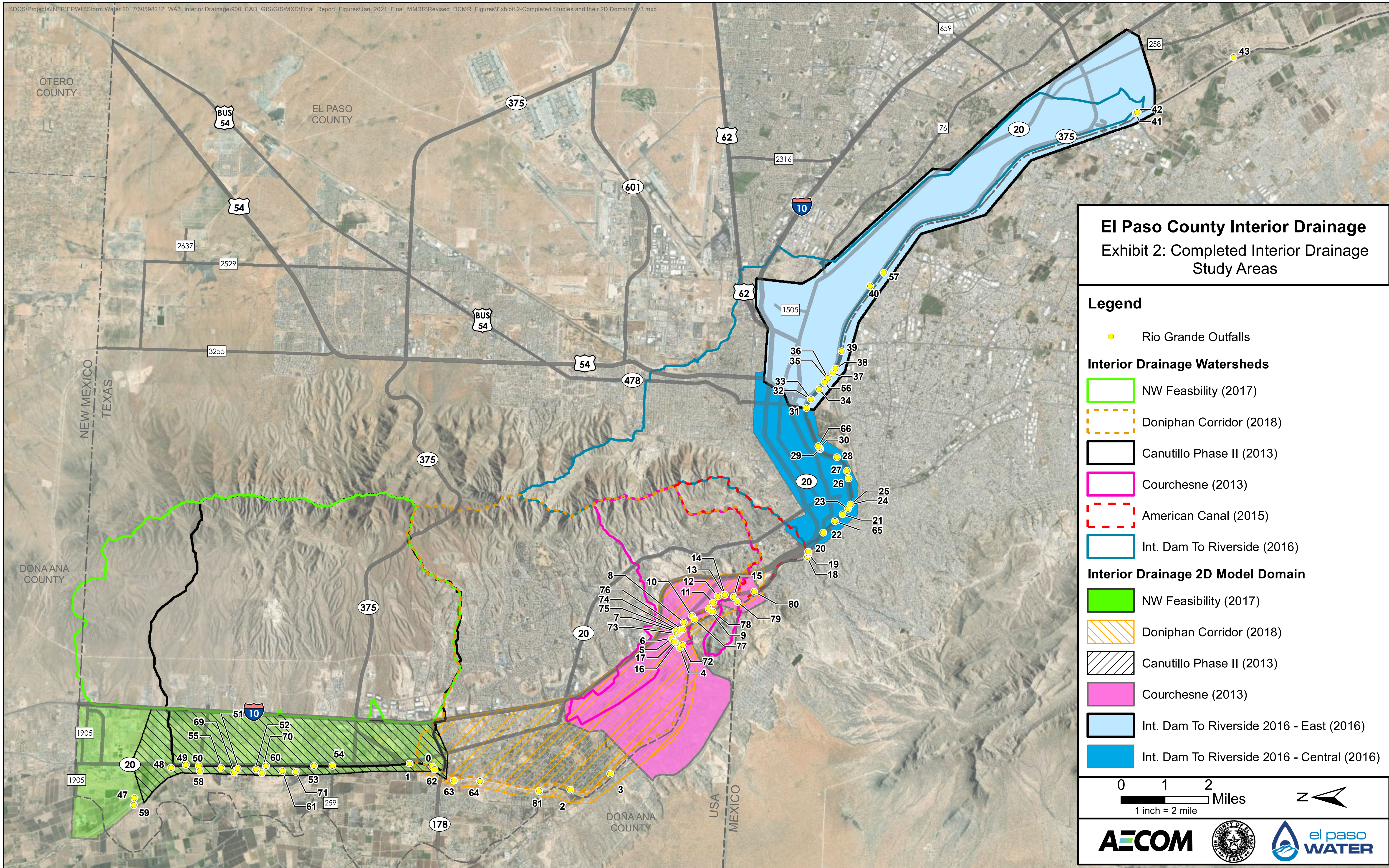
Exhibit 4 Drainage Project Label	Drainage Region	Drainage System	Master Plan Project Identifier	Project Name	Issue to be Addressed	Description of Improvements	Status	Est. Completion date if applicable
2	Central	Government Hills	CE2	CE 2 - Pollard Park-Pond	Multiple culverts along Government Hills Channel are undersized and contribute to channel flooding in localized areas.	Construction of Park and Pond to detain peak flows to allow street runoff to enter the Government Hills Channel, currently undersized at various crossings	Complete	2016
0	Central	Government Hills	CE2	CE 2 - Austin Pond	Multiple culverts along Government Hills Channel are undersized and contribute to channel flooding in localized areas.	Construction of Pond to detain peak flows allowing runoff to enter the Government Hills Channel, which is undersized at various crossings	Complete	2017
3*	Central	Government Hills	CE3	CE3 - Saipan Pump Station and Park-Pond Improvements	Flooding in the Government Hills System	Pond and pump station south of I-10, east of Lincoln Park.	Complete	2012
4*	Central	Government Hills	Pershing Dam	Pershing Dam	Pershing Dam - upgrade to reduce frequency of flooding through aux spillway	Improve Pershing Dam per Work Order 3, Task 4 report by extending and raising aux spillway.	Complete	Unknown
6, 7	Central	Cebada	CE4	CE4 Phase 1a - Cebada Conduit Clearing of Utilities and Desilting of Magnolia Pond	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Clearing and relocating of existing utilities in Cebada Outfall Conduit. Desilting of Magnolia Pond	Complete	2017
8*	Central	Cebada	CE4	CE4 Phase 1c - Copia Pond	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on I-10 and on Cebada Road.	Construction of New Copia Pond, north of the RR. Also constructed ditch to route water to pond.	Assumed to be Complete	2018
39	Central	Magnolia	CE4	CE4 Phase 2a - Magnolia Gravity Main	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Storm drains from Magnolia, Pump Station and Force Main to Rio Grande and pond. Overflows go to Cebada.	Complete	2017
9*	Central	Magnolia	CE4	CE4 Phase 2b - Magnolia Pump Station	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Storm drains from Magnolia, Pump Station and Force Main to Rio Grande and pond. Overflows go to Cebada.	Complete	2017
37	Central	Magnolia	CE4	CE4 Phase 2c - Magnolia Force Main and Outfall to Rio Grande	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Storm drains from Magnolia, Pump Station and Force Main to Rio Grande and pond. Overflows go to Cebada.	Complete	2017
36	Central	Magnolia	CE4	CE4 Phase 2d - Pond	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Storm drains from Magnolia, Pump Station and Force Main to Rio Grande and pond. Overflows go to Cebada.	Assumed to be Complete	2019
14*	Central	Cebada	CE4	CE4 Phase 3a - Gateway West Pond (GWW)	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Construction of 50-ft deep ponding area to capture runoff North of I-10	Complete	2017
10	Central	Cebada	CE4	CE4 Phase 3b - Gateway Tunnel	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Construction of tunnel for installation of 60-in pipe to equalize volume within GWW and GWE ponding areas	Complete	2017?
11*	Central	Cebada	CE4	CE4 Phase 3c - Morenci Pond	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Construction of ponding area to detain peak runoff upstream of watershed. Controls water reaching Gateway ponds.	Complete	2014/2015
15*	Central	Cebada	CE4	CE4 Phase 3d - Gateway East Pond (GWE)	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Construction of 50-ft deep ponding area to capture runoff North of I-10	Assumed to be Under Construction	Unknown, Previously expected to be completed 2017

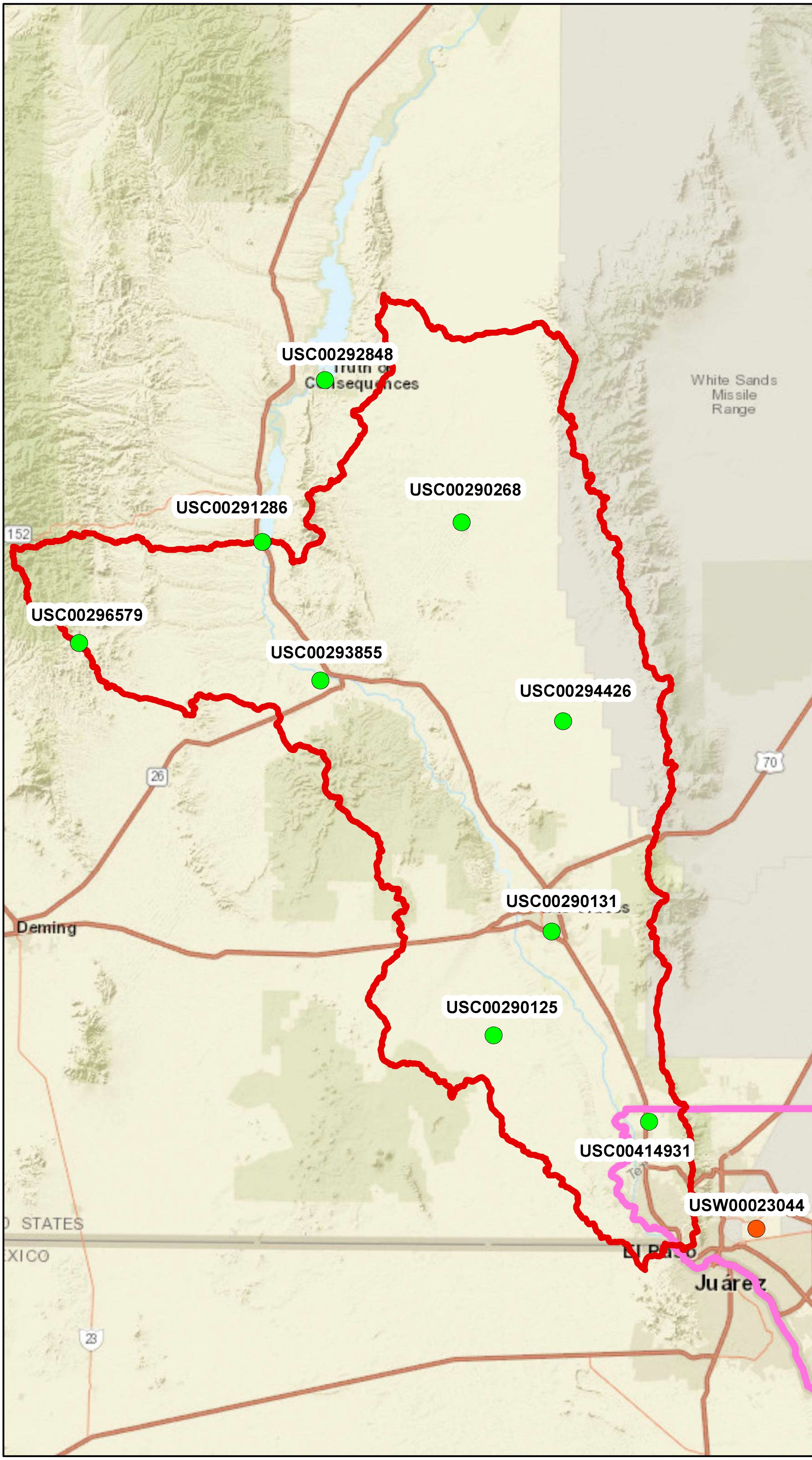
Exhibit 4 Drainage Project Label	Drainage Region	Drainage System	Master Plan Project Identifier	Project Name	Issue to be Addressed	Description of Improvements	Status	Est. Completion date if applicable
12*	Central	Cebada and Magnolia	CE4	CE4 Phase 3e - Kentucky Dam	Conveyance problems through Cebada Reservoir and Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Excavation of existing Dam to add capacity and installation of underground drainage system to capture bypass runoff. In Magnolia watershed. Discharges to new Piedras/Magnolia Pump Station, 175cfs to River.	Assumed to be Under Construction	Unknown, Previously expected to be completed 2017/2018
13	Central	Cebada and Magnolia	CE4	CE4 Ph 3f -Louisiana Dam Improvements	Conveyance problems through Magnolia systems cause major flooding on IH-10 and on Cebada Road.	Expansion and inlets to existing Dam. In Magnolia watershed. Was under construction May 2018.	Assumed to be Complete	2018
16*	Central	Cebada and Magnolia	CE4	CE4 Phase 3h - San Diego Dam	Upgraded to meet TCEQ dam safety criteria	Drains to Dam 6.	Assumed to be Complete	2018
17, 40	Central	Dallas	CE5	CE5 Phase 1a - Dallas Conduit Clearing of Utilities	Protection of area from 1% AC storm	Clearing and relocating of existing utilities in Dallas Outfall Conduit. Phase 1 recommends the construction of a 115 cfs pump station on the east side of Dallas Reservoir.	Complete	2013
18	Central	Dallas	Dam 9	Dam 9 Upgrade - Denver Ave.	Dam No. 9 has CMP pipe outlet.	Replace CMP principal spillway on Dam No. 9. Drains to Dallas Pond. Project is to increase detention capacity of existing facility.	Assumed to be Complete	2018
19	Central	Cebada and Magnolia	Dam 7	Upgrade Dam 7 - Tremont Ave. (aka Tremont Reservoir)	Dam crest is estimated to overtop at slightly greater that 1% AC flood	Increase dam crest or improve spillway (TBD). Drains to Magnolia. Desilting project as well?	Assumed to be Complete	2018
20*	Central	Government Hills	Van Buren Dam	Van Buren Dam	Van Buren Dam - Upgrade	Improve Van Buren Dam per Work Order 3, Task 4 Report. Drains to Pershing Dam. Is the start of underground conduit that daylights at Pershing Dam	Complete	2012
29*	Mission Valley	Basin G	MV5	MV5 Phase 1a - Basin G Excavation	The current configuration and capacity of Basin G is causing tailwater to significantly restrict the capacity of the major drains and Interceptor System in Mission Valley. There is a need for additional storage in Basin G.	Excavate existing Basin G area to a depth of 20 feet.	Complete	2009
34, 35, 38	Mission Valley	Basin G	MV5	MV5 Phase 1a - Replacement of undersized crossings	The current configuration and capacity of Basin G is causing tailwater to significantly restrict the capacity of the major drains and Interceptor System in Mission Valley. There is a need for additional storage in Basin G.	Replace the undersized crossings at Carl Longuemare and Southside, and re-grade the Franklin Drain Interceptor so that water will flow to the basin from both the Playa Drain and the Interceptor System.	Complete	2010/2012 (printed date/seal date - drain & culvert improvements)
33	Mission Valley	Basin G	MV8	MV8: Basin C / Shaver Park	Basin C is currently serving as a detention area for water from surroungding neighborhoods. After leavinhg the basin, water enters the Playa Drain where it constributes to the capacity problems of the drain	Excavation of Basin and Park-Pond Improvements are Complete	Park Pond Complete. Does not include PS or culverts from SWMP project.	Unknown
30	Northeast	Fort Bliss Sump	NE6	NE6 - Johnson Pond	Erosion along Lincoln Ave. due to the flows in the downstream portion of the Johnson Channel.	Construct New Retention Basin	Complete	2016

* Indicates that as part of this Study, a recently completed project is planned to be incorporated into an updated version of the International Dam to Riverside Weir (URS, 2016) study.

Exhibits


El Paso County Interior Drainage
Exhibit 1: Location of Previous Interior Drainage Studies
Legend
American Canal 2015&2019
Canutillo Phase II 2013
Courchesne Reach 2013
Doniphan Corridor 2018
Int. Dam to Riveride 2016
NW Feasibility 2015&2017
El Paso City Limits
El Paso County Limits
0 2.25 4.5
Miles
N
AECOM
el paso WATER
Unstudied
Previously Studied
Studied on East Levee Only
Int. Dam to Riveride 2016
American Canal 2015&2019
Courchesne Reach 2013
Doniphan Corridor 2018
Canutillo Phase II 2013
NW Feasibility 2015&2017


El Paso County Interior Drainage
Exhibit 2: Completed Interior Drainage Study Areas
Legend
Rio Grande Outfalls
Interior Drainage Watersheds
NW Feasbility (2017)
Doniphan Corridor (2018)
Canutillo Phase II (2013)
Courchesne (2013)
American Canal (2015)
Int. Dam To Riverside (2016)
Interior Drainage 2D Model Domain
NW Feasbility (2017)
Doniphan Corridor (2018)
Canutillo Phase II (2013)
Courchesne (2013)
Int. Dam To Riverside 2016 - East (2016)
Int. Dam To Riverside 2016 - Central (2016)
0 1 2
Miles
1 inch = 2 mile
AECOM
el paso WATER
OTERO COUNTY
EL PASO COUNTY
DOÑA ANA COUNTY
NEW MEXICO
TEXAS
USA
MEXICO



0 7.5 15 Miles

N

AECOM

Legend

- El Paso Intl Airport
- Upstream Gages
- Contributing Watershed
- El Paso County Limits

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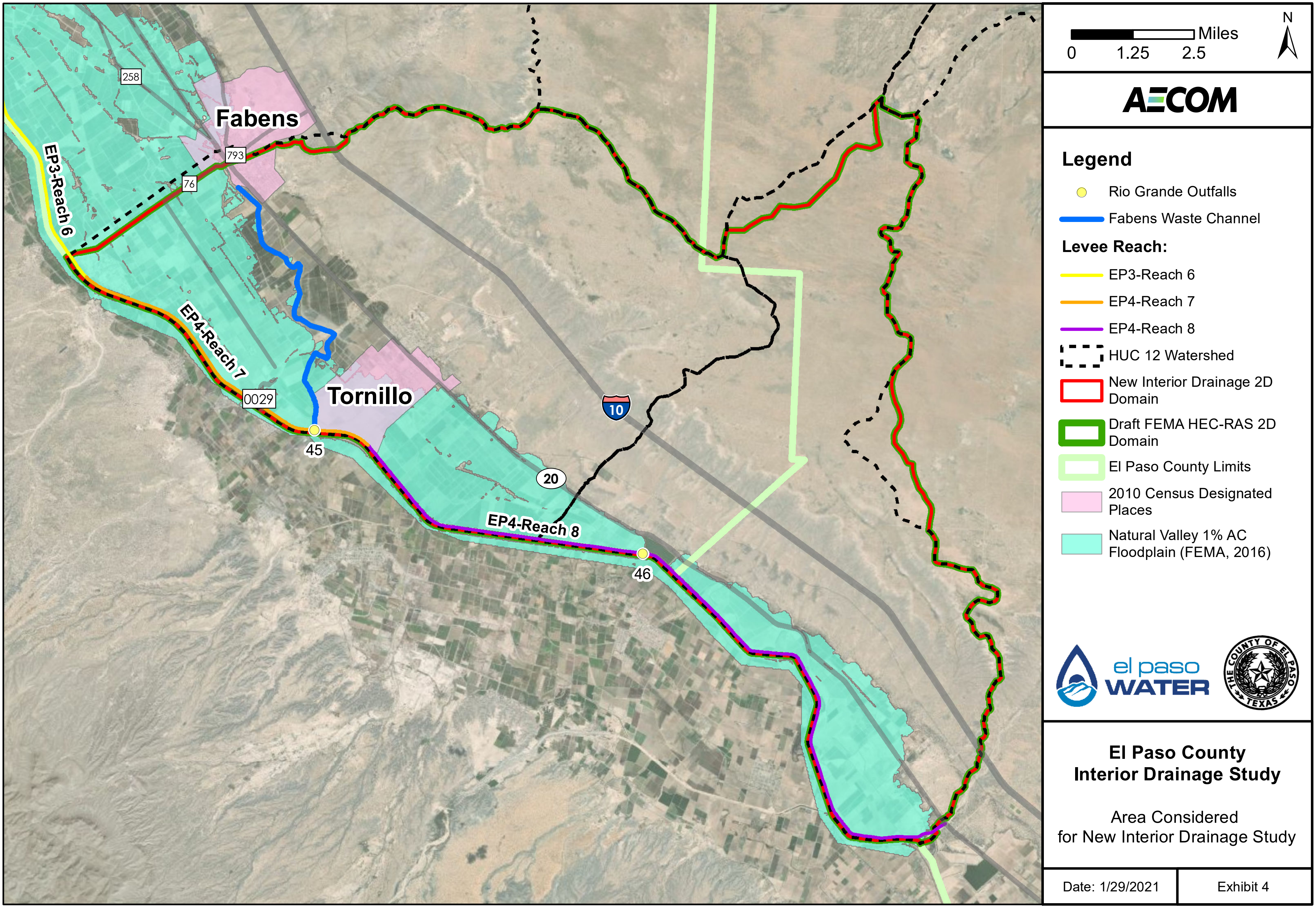
El Paso County Interior Drainage Study

Rainfall Gages in El Paso and New Mexico Used for Coincident Flooding Analysis

Date: 4/26/2019	Exhibit 3



Fabens
Tornillo
EP3-Reach 6
EP4-Reach 7
EP4-Reach 8
258
793
76
0029
10
20
45
46
Miles
0
1.25
2.5
N
AECOM
Legend
Rio Grande Outfalls
Fabens Waste Channel
Levee Reach:
EP3-Reach 6
EP4-Reach 7
EP4-Reach 8
HUC 12 Watershed
New Interior Drainage 2D Domain
Draft FEMA HEC-RAS 2D Domain
El Paso County Limits
2010 Census Designated Places
Natural Valley 1% AC Floodplain (FEMA, 2016)
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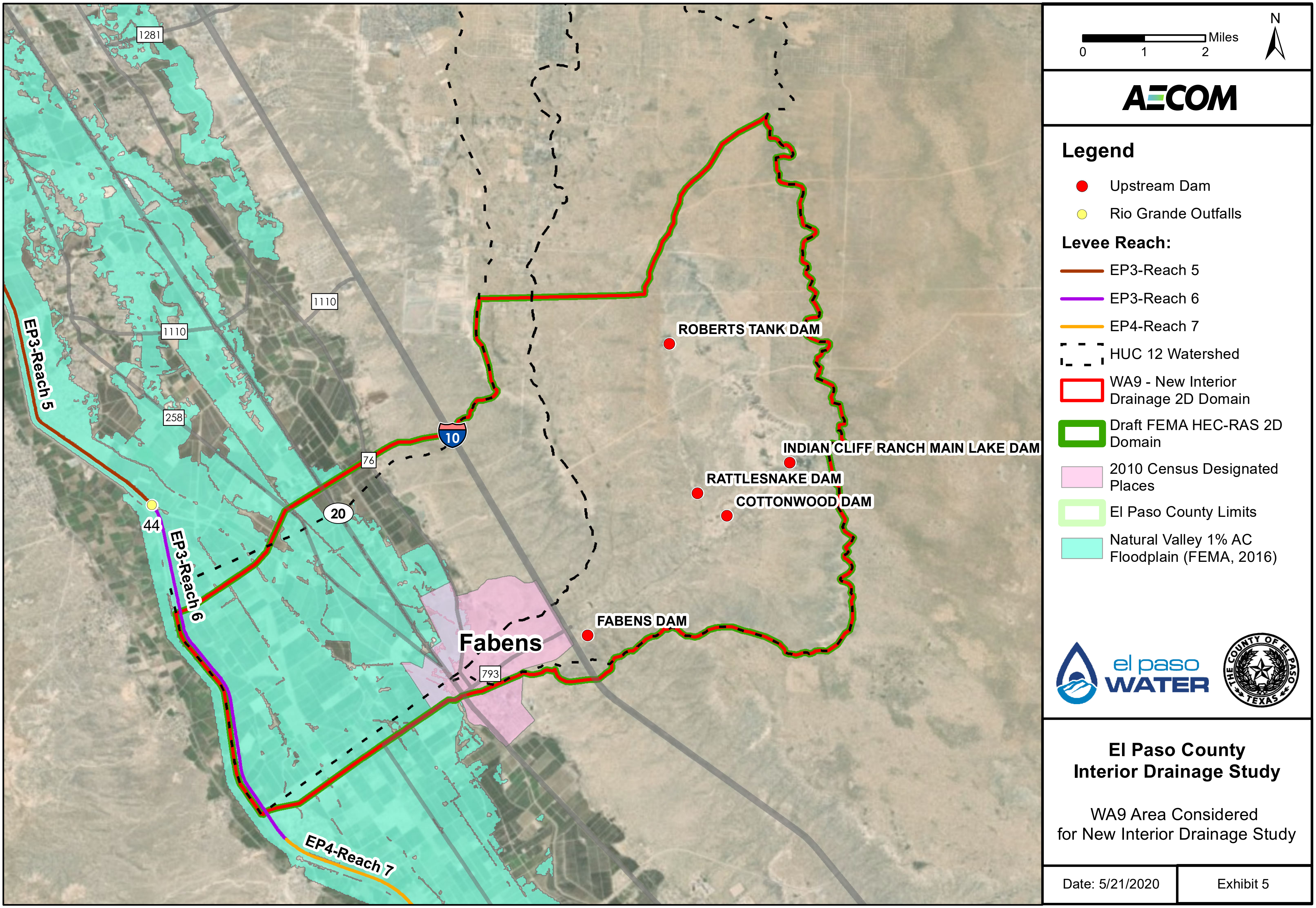
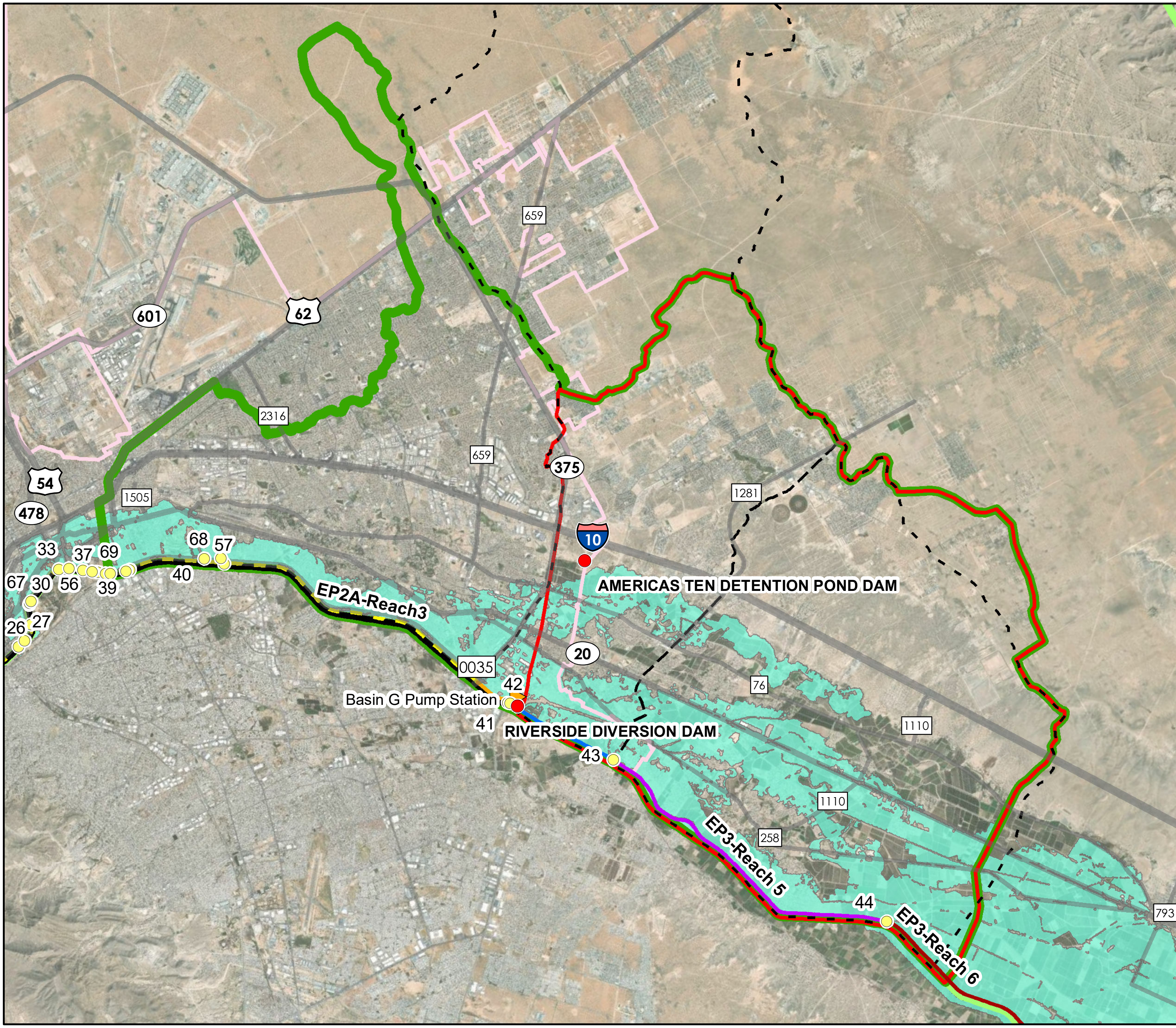
THE COUNTY OF EL PASO TEXAS
El Paso County Interior Drainage Study
Area Considered for New Interior Drainage Study
Date: 1/29/2021
Exhibit 4



El Paso County Interior Drainage Study

WA9 Area Considered for New Interior Drainage Study

Date: 5/21/2020	Exhibit 5



Miles
0 1.25 2.5

N

AECOM

Legend

- Upstream Dam
- Rio Grande Outfalls
- Pump Station in 2D Domain

Levee Reach:

- EP2A-Reach3
- EP2B-Reach3
- EP3-Reach 4
- EP3-Reach 5
- EP3-Reach 6
- Int. Dam to Riveride 2016 (Interior Drainage Study)
- HUC 12 Watershed
- WA7 - New Interior Drainge 2D Domain
- Draft FEMA HEC-RAS 2D Domain
- El Paso County Limits
- City of El Paso Limits
- Natural Valley 1% AC Floodplain (FEMA, 2016)

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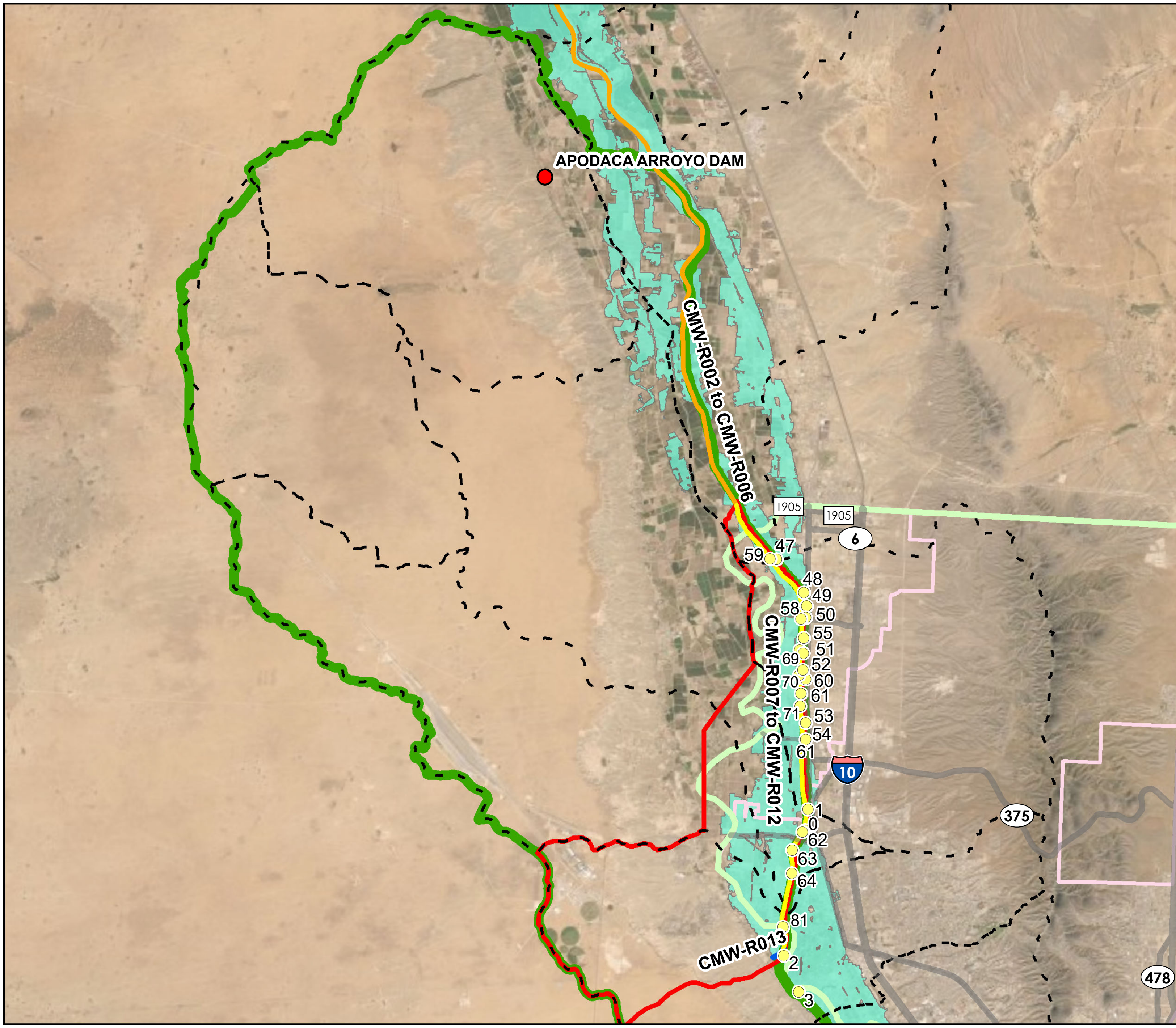
El Paso County Interior Drainage Study

WA7 Area Considered for New Interior Drainage Study

Date: 1/29/2021	Exhibit 6



Miles
0 1.75 3.5
N

AECOM

Legend

- Upstream Dam
- Rio Grande Outfalls

Levee Reach:

- CMW-R002 to CMW-R006
- CMW-R007 to CMW-R012
- CMW-R013
- HUC 12 Watershed
- New Interior Drainage 2D Domain
- Draft FEMA HEC-RAS 2D Domain
- El Paso County Limits
- City of El Paso Limits
- Natural Valley 1% AC Floodplain (FEMA, 2016)

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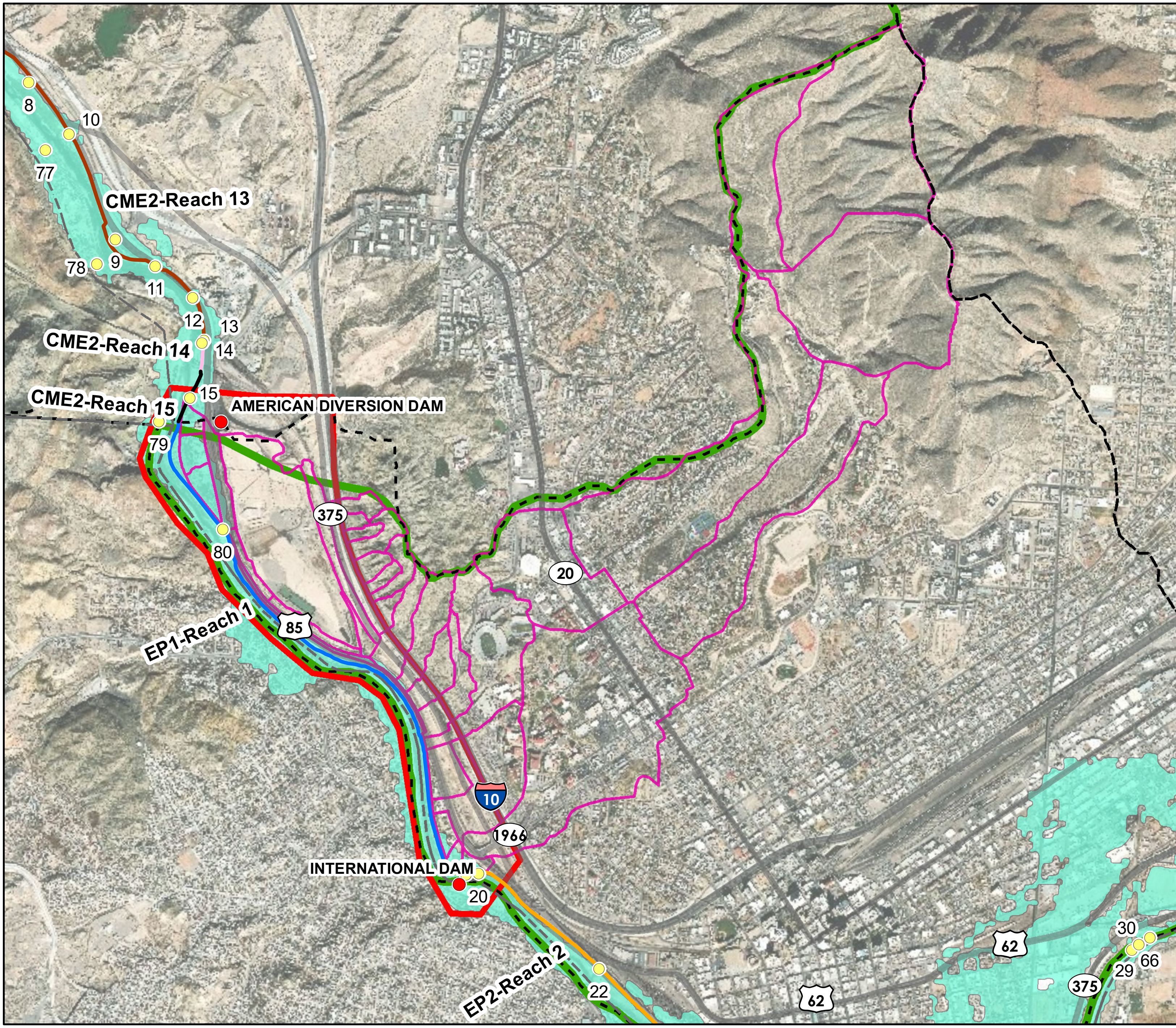
El Paso County Interior Drainage Study

Area Considered for New Interior Drainage Study

Date: 1/30/2021	Exhibit 7



Miles
0 0.25 0.5
N

AECOM

Legend

- Upstream Dam
- Rio Grande Outfalls

Levee Reach:

- CME2-Reach 13
- CME2-Reach 14
- CME2-Reach 15
- EP1-Reach 1
- EP2-Reach 2
- HUC 12 Watershed
- Drainage Areas Contributing to American Canal (IBWC 2015)
- New Interior Drainage 2D Domain
- Draft FEMA HEC-RAS 2D Domain
- El Paso County Limits
- Natural Valley 1% AC Floodplain (FEMA, 2016)

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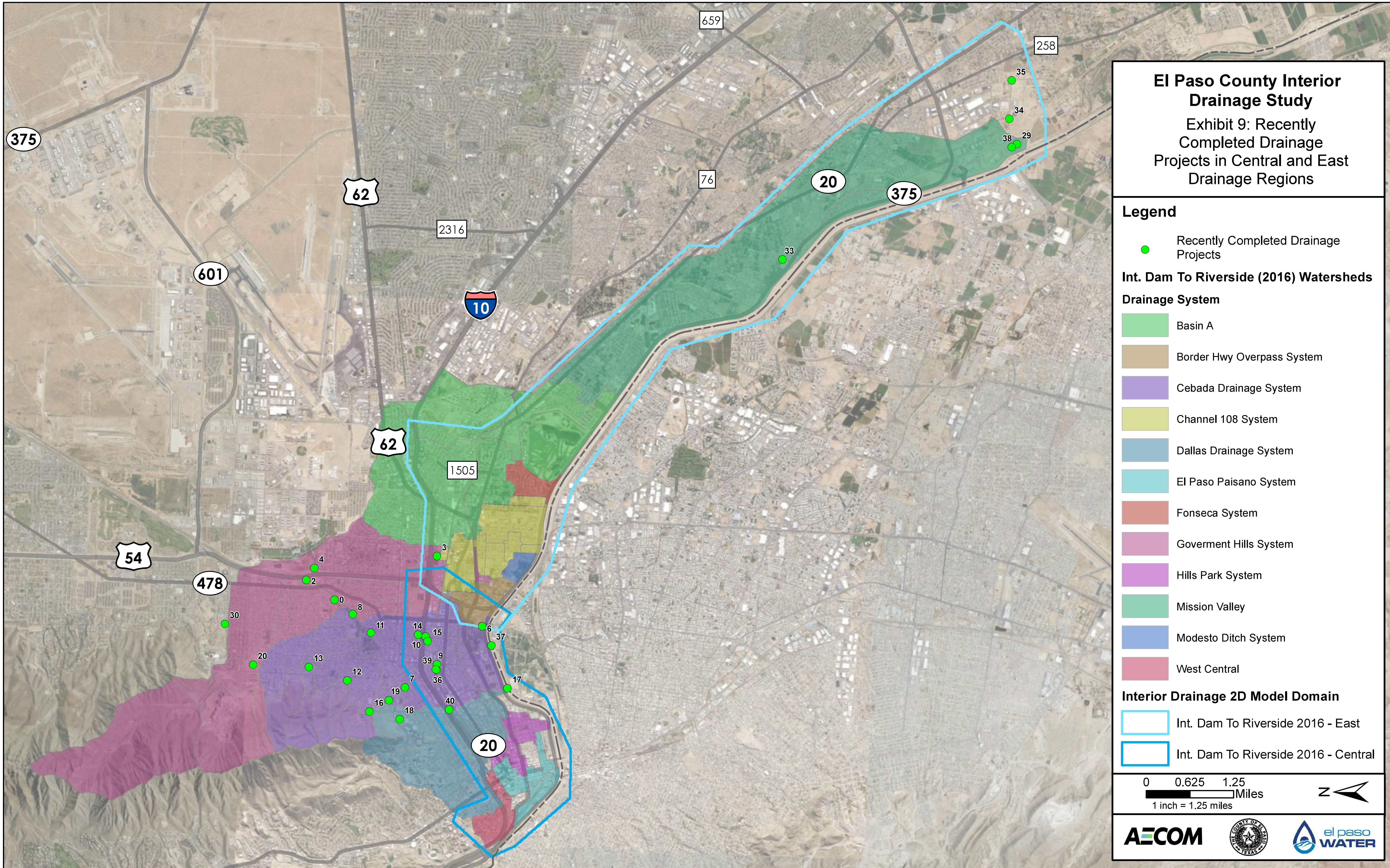
El Paso County Interior Drainage Study

Area Considered for New Interior Drainage Study

Date: 12/4/2020	Exhibit 8



El Paso County Interior Drainage Study
Exhibit 9: Recently Completed Drainage Projects in Central and East Drainage Regions
Legend
Recently Completed Drainage Projects
Int. Dam To Riverside (2016) Watersheds
Drainage System
Basin A
Border Hwy Overpass System
Cebada Drainage System
Channel 108 System
Dallas Drainage System
El Paso Paisano System
Fonseca System
Goverment Hills System
Hills Park System
Mission Valley
Modesto Ditch System
West Central
Interior Drainage 2D Model Domain
Int. Dam To Riverside 2016 - East
Int. Dam To Riverside 2016 - Central
0 0.625 1.25 Miles
1 inch = 1.25 miles
N
AECOM
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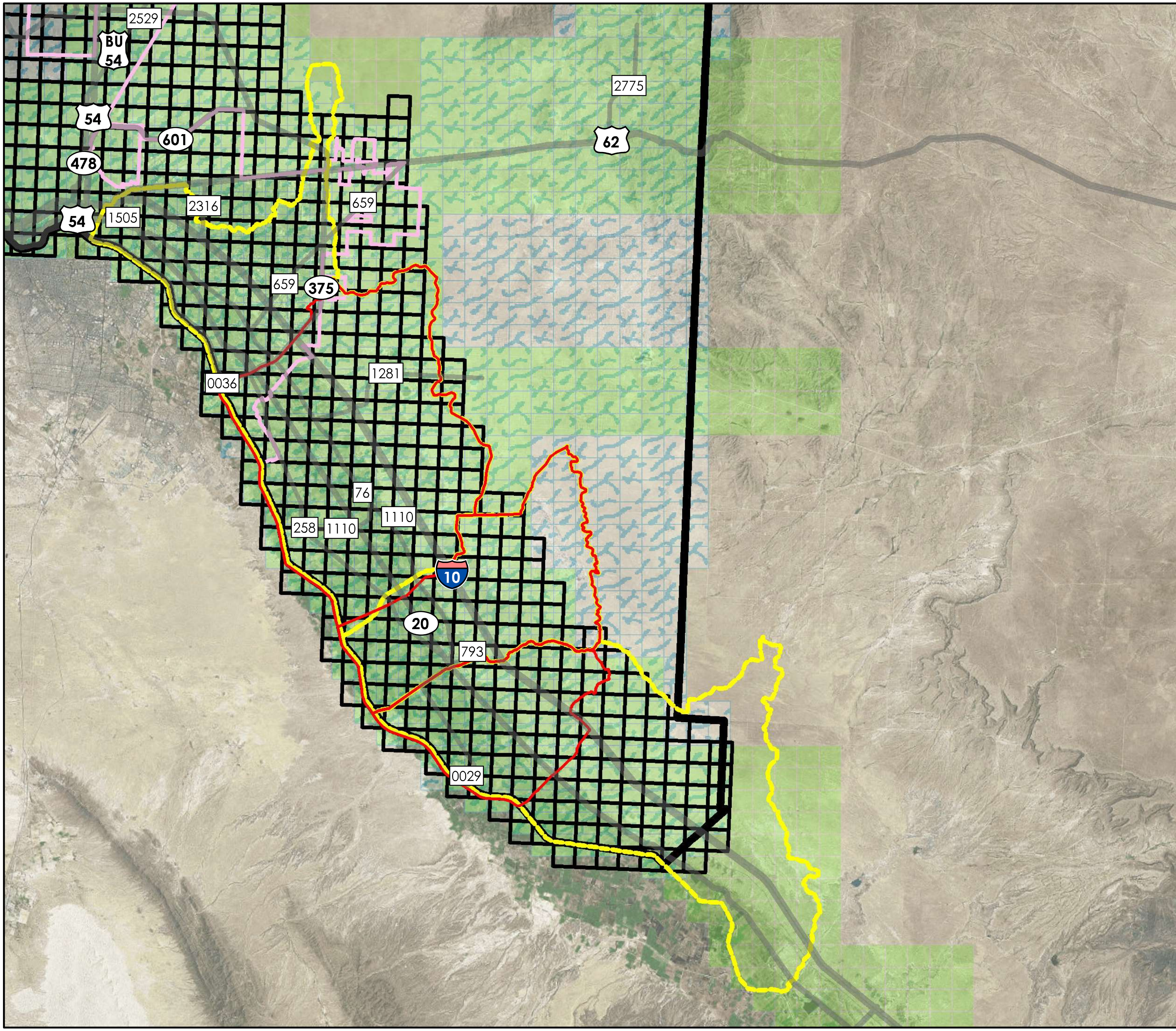
375
62
601
10
54
478
659
258
76
2316
20
1505



Miles
0 3 6
N

AECOM

Legend

New Interior Drainage 2D Domain
Draft FEMA HEC-RAS 2D Domain
El Paso County Limits
City of El Paso Limits
2014 El Paso LiDAR
2015 TXDOT Photogrammetry
2005 TXDOT Photogrammetry

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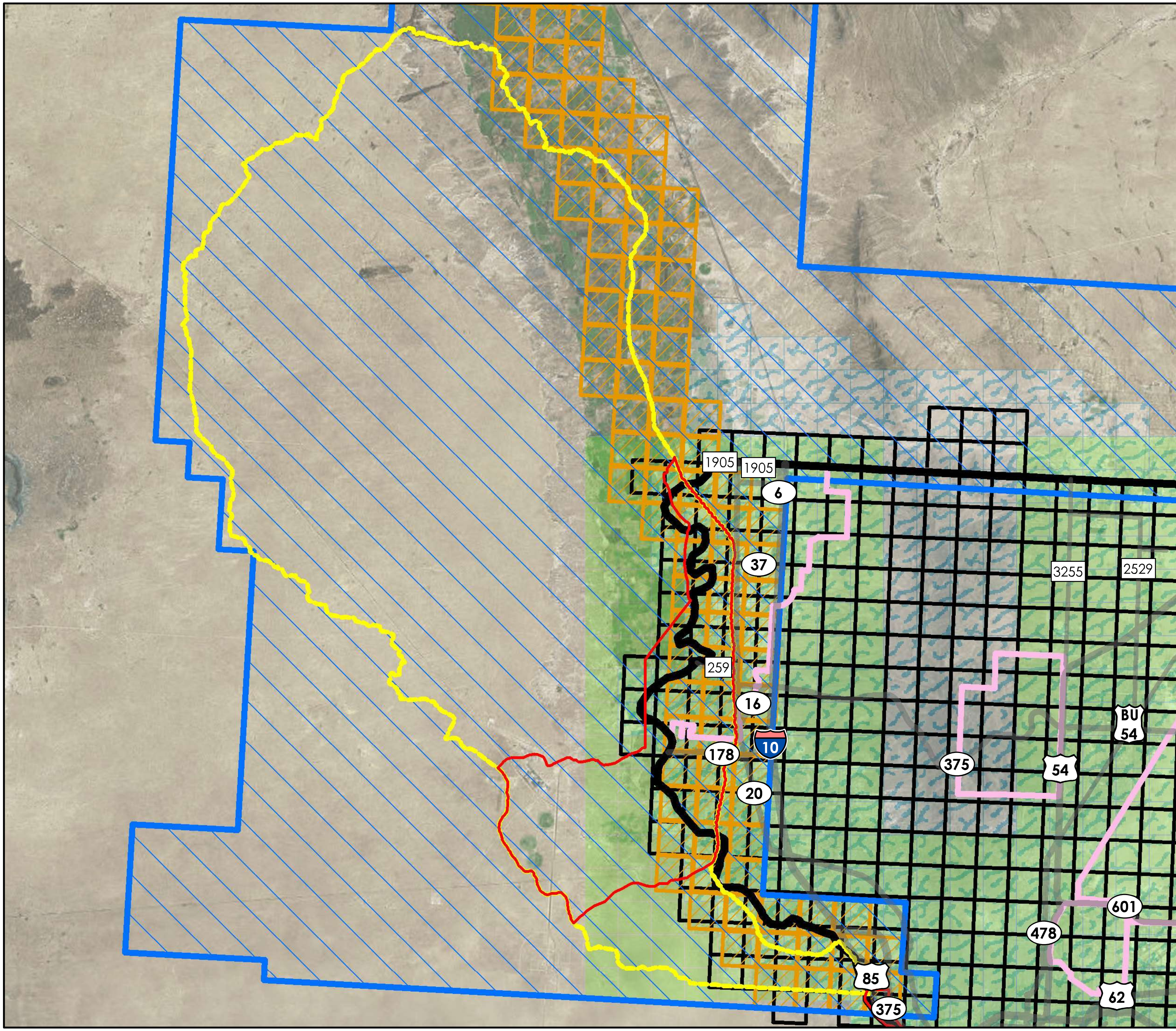
El Paso County Interior Drainage Study

Topographic Sources for New Interior Drainage 2D Domains

Date: 4/30/2019 | Exhibit 10



Miles
0 2 4
N

AECOM

Legend

- New Interior Drainage 2D Domain
- Draft FEMA HEC-RAS 2D Domain
- El Paso County Limits
- City of El Paso Limits
- 2010 Doña Ana LiDAR
- 2018 Rio Grande LiDAR
- 2014 El Paso LiDAR
- 2015 TXDOT Photogrammetry
- 2005 TXDOT Photogrammetry

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El Paso County
Interior Drainage Study

Topographic Sources for New Interior Drainage 2D Domains

Date: 4/30/2019

Exhibit 11

Appendix B – International Dam to Riverside Weir Modified HEC-HMS Schematics

Figure B2: Cebada HEC-HMS Schematic Before Modifications.

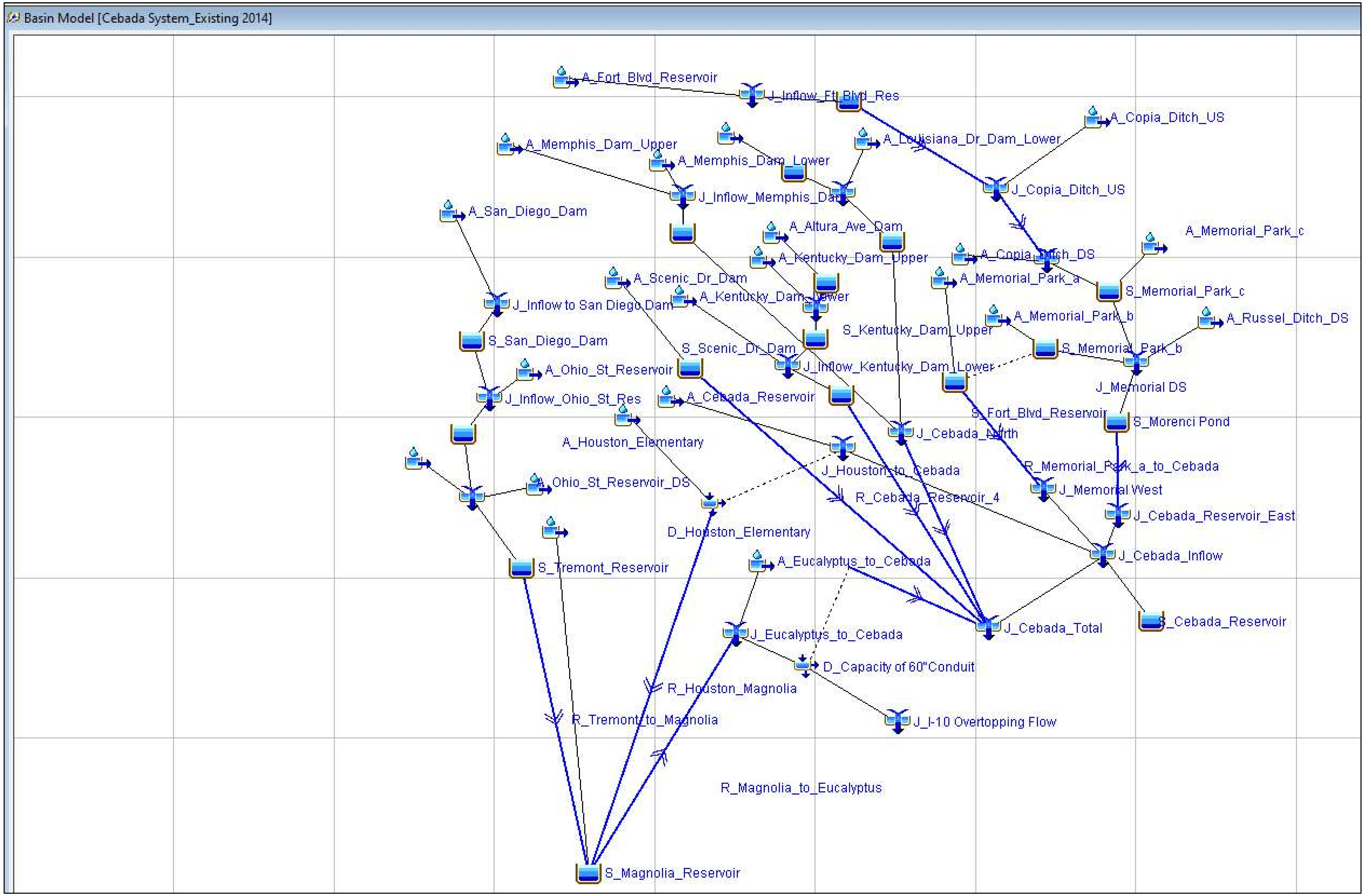
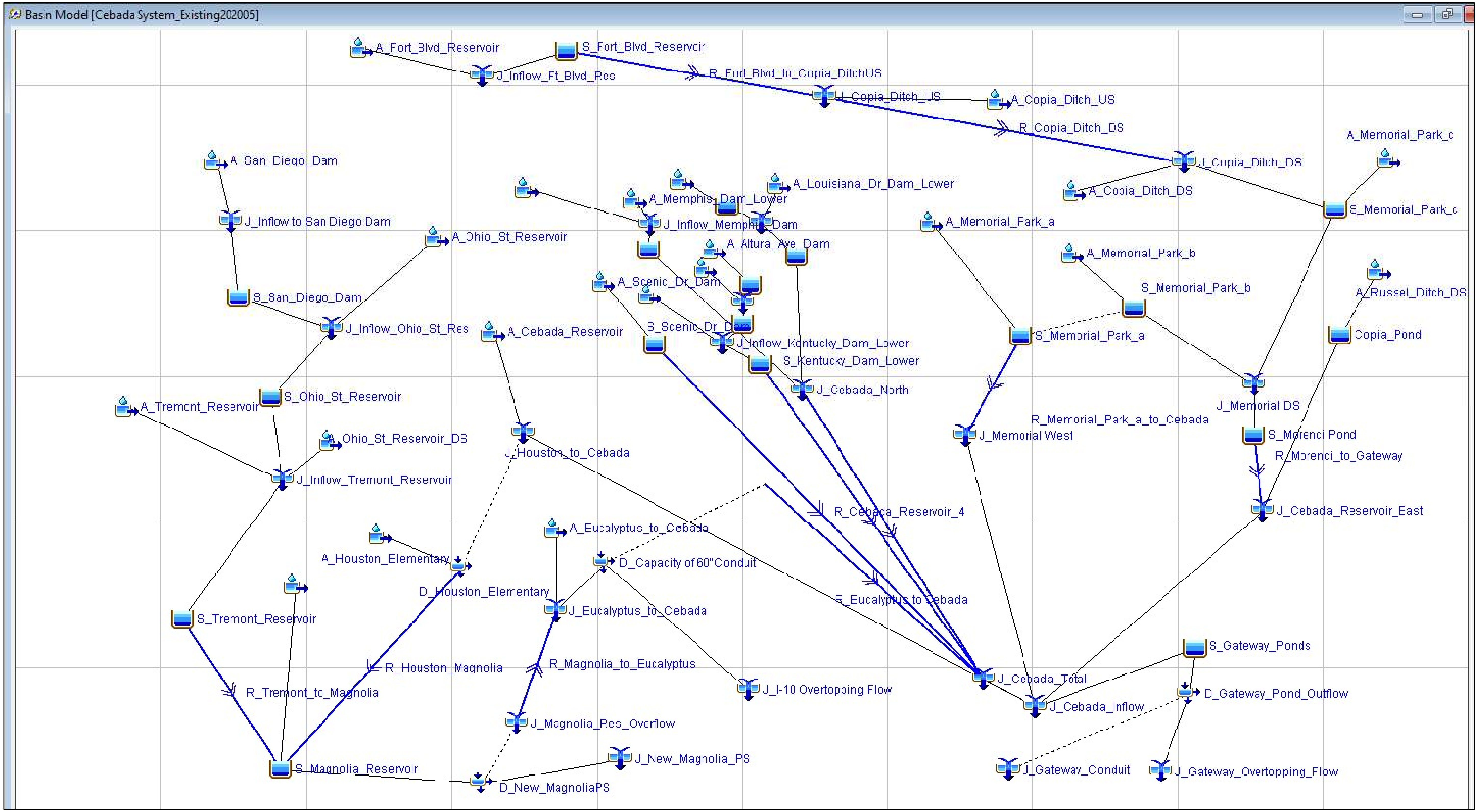


Figure B3: Cebada HEC-HMS Schematic After Modifications.



Appendix C – Electronic Files

Appendix C - Electronic Files

File Structure Guidance

Overall File Structure:

- AppendixC_Electronic_Files
  - Data_Collection
  - Hydraulic_Models
  - Hydrologic_Models
  - Spatial_Files

Data Collection File Structure:

- AppendixC_Electronic_Files
  - Data_Collection
    - Previous_Studies
      - Doniphan Drive IDA 03222018
      - EPWU 2016 El Paso Interior Drainage
      - Preliminary_FEMA_Phase2_HandH_Submittal
      - USACE NW Feasibility

Hydraulic Models File Structure:

- AppendixC_Electronic_Files
  - Data_Collection
  - Hydraulic_Models
    - Doniphan_Corridor_FLO-2D
    - International_Dam_to_Riverside_Weir
      - Original_FLO-2D
        - Central_Post_Levee_River Base
        - East_Post Levee_River Base
      - Updated_FLO-2D
        - Central_FLO-2D_vPro_Model
    - NW_Feasibility_FLO-2D
    - Preliminary_FEMA
      - Original_Preliminary_FEMA_RASv5_0_5
        - WA1
        - WA11
        - WA7
        - WA9
      - Updated_Interior_Drainage_Models
        - Updated_RASv5_0_5
          - WA11_20200527
          - WA7_20200414
          - WA9_20200410
        - Updated_RASv5_0_7
          - WA1_20201128

Hydrologic Models File Structure:

- AppendixC_Electronic_Files
  - Data_Collection
  - Hydraulic_Models
  - Hydrologic_Models
    - International_Dam_to_Riverside_Weir
      - HEC-HMS_v3.5
        - Original_Cebada_HMS
        - Original_Government_Hills_HMS
        - Updated_Cebada_HMS
        - Updated_Government_Hills_HMS
    - Preliminary_FEMA
      - HEC-HMS_v4.2
        - Original_Preliminary_FEMA_HMS
          - WA1
          - WA11
          - WA7
          - WA9
        - Updated_WA7_HMS_Model
          - WA7

Spatial Files Structure:

- AppendixC_Electronic_Files
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  - Hydraulic_Models
  - Hydrologic_Models
  - Spatial_Files
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        - Doniphan_Corridor.shp
        - East_El_Paso.shp
        - NW_Feasibility.shp
        - WA1.shp
        - WA11_prj.shp
        - WA7_Prj.shp
        - WA9_prj.shp
    - Depth_Data
      - Grid_Raster
        - wa1_1pctdpth
        - wa11_1pctdpth
        - wa7_1pctdpth
        - wa9_1pctdpth
      - SHP
        - Central_EP_1pctDpth.shp
        - Doniphan_1pctDpth.shp
        - East_EP_1pctDpth.shp
        - NW_Feasibility_1pctDpth.shp
    - Inundation_Boundaries
      - SHP
        - Central_EP_1pct_Inundation_Boundary.shp
        - Doniphan_1pct_AC_Inundation_Boundary.shp
        - East_EP_1pct_Inundation_Boundary.shp
        - NW_Feasibility_1pct_AC_Inundation_Boundary.shp
        - WA1_1pct_AC_Inundation_Boundary.shp
        - WA11_1pct_AC_Inundation_Boundary.shp
        - WA7_1pct_AC_Inundation_Boundary.shp
        - WA9_1pct_AC_Inundation_Boundary.shp
    - Levee_Segments
      - Modeled_Levee_Segments.shp
    - Outfall_Locations
      - Modeled_Rio_Grande_Outfalls.shp
    - WSE_Data
      - Grid_Raster
        - wa1_1pct_wse
        - wa11_1pct_wse
        - wa7_1pct_wse
        - wa9_1pct_wse
      - SHP
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        - Doniphan_1pct_WSE.shp
        - East_EP_1pct_WSE.shp
        - NW_Feasibility_1pct_WSE.shp