Frio River flood in Tilden, July 2002

Chapter 2 – Flood Risk Analysis

31 TAC § 361.33 and 361.34

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2 Flood Risk Analyses

The objective of this chapter is to describe the existing and future condition flood risks. The overall flood risk is determined by defining the flood hazard, exposure, and vulnerability risk as follows and shown in Figure 2-1 below:

- **Hazard** - Determine the location, magnitude, and frequency of flooding;
- **Exposure** - Identify who and what might be harmed within the region; and
- **Vulnerability** - Identify vulnerabilities of communities and critical facilities.

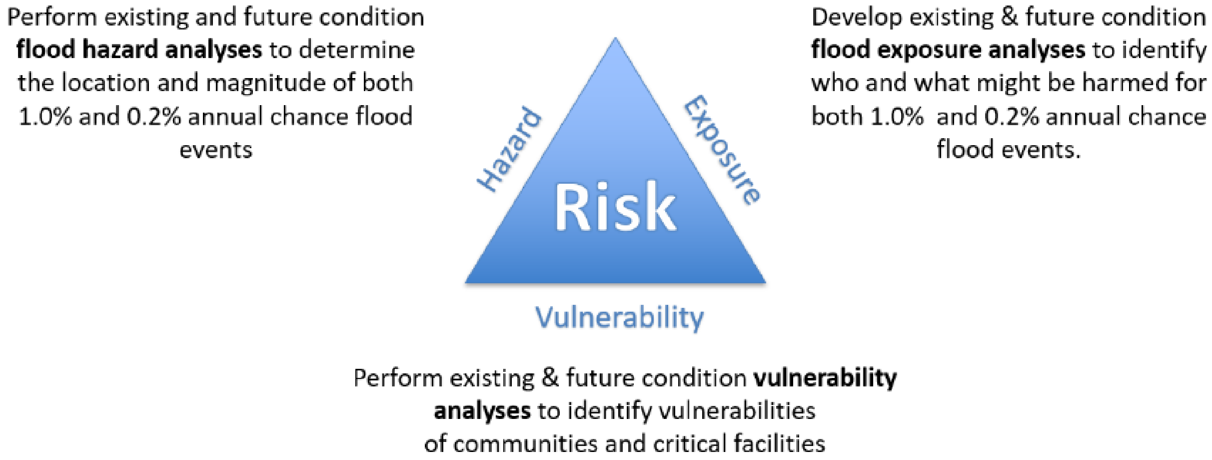


Figure 2-1. Flood Risk Analysis (Source: TWDB Exhibit C Technical Guidelines)

The above information forms the basis for establishing priorities in subsequent planning tasks, to identify areas that need flood management evaluations (FMEs), and to efficiently deploy resources.

2.1 Existing Condition Flood Risk Analyses

2.1.1 Existing Condition Flood Hazard Analysis

The objective of this section is to identify and compile a comprehensive outlook of existing condition flood hazards in the region, including riverine flooding, urban flooding, coastal flooding, and possible flood-prone areas of risks. This effort and the resulting maps are not regulatory in nature but are, instead, intended to gather and present a single, coherent, continuous set of best available information on actual flood risk throughout the region.

To achieve the above objective an existing condition flood hazard analysis was performed to determine the location and magnitude of both 1% annual chance and 0.2% annual chance flood events for the entire region using best available data, including detailed and approximate modeling and mapping data. The process of defining the existing condition flood hazard is as follows:

- **Data Collection** - Collect data and conduct analyses sufficient to characterize the existing conditions for the planning area
- **Availability of Detailed Model Results** - Identify areas where hydrologic and hydraulic model results are already available and summarize the information including the age of the map and modeling information for each area
- **Best Available Data** - Use best available data, hydrologic and hydraulic models for each area
- **Flood Hazard Maps** - Prepare a map showing areas having an annual likelihood of inundation of more than 1% and 0.2%, the areal extent of this information, and sources of flooding for each area
- **Gap Analysis** - Prepare a map showing gaps in inundation boundary mapping and identify known flood-prone areas based on location of hydrologic features, historic flooding and/ or local knowledge

2.1.1.1 Data Collection

Data was collected to obtain best available flood inundation boundaries and to obtain information on additional known flood prone areas. This information is used to determine the existing flood hazard.

Flood Inundation Boundaries

The Texas Water Development Board (TWDB) provided the floodplain quilt, which consists of multiple layers of data from various sources available throughout the state to “quilt” together a single flood hazard dataset. The floodplain quilt does not typically include localized flooding or complex urban flooding problems. Additionally, the Nueces Regional Water Planning Group (NRFPG) obtained inundation boundaries from various entities in the basin and identified known flood-prone areas from stakeholder and public comments.

Additional Known Flood-Prone Areas

Additional known flood-prone areas were determined from historical flood data, local knowledge, and from low water crossing data.

Historical Flood Data

The NRFPG compiled historical flood data from United Stated Geologic Survey (USGS) gage records, National Weather Service (NWS) flood data, publications on historical flood events, and Federal Emergency Management Agency (FEMA) flood damages. This data includes information on past property damage, fatalities, and injuries because of flooding. This information is presented inAppendix C1 – Historic Flood Event Data.

Local Knowledge

Four subregional meetings (one for each subregion) were held May 17 through May 20, 2021, to introduce the regional flood planning process and gather local knowledge of flood-prone areas, flood mitigation projects, and needs. The NRFPG received information on 44 flood-prone areas from these initial meetings. Additionally, an interactive on-line public comment map was posted on the Nueces River Authority's Region 13 website (Home - Nueces Regional Flood Planning Group (Region 13) (https://nueces-rfpg.org)) to allow stakeholders and citizens the opportunity to identify flood-prone areas for consideration in the regional flood plan (RFP).

The NRFPG presented available flood hazard data from the "floodplain quilt", local knowledge, and historical flood data to the public at the June 28, 2021 RFPG meeting. The purpose of this public meeting was to identify additional flood hazards that may have not been identified in the initial maps. Additional flood prone areas were received via the interactive geographic information systems (GIS) map and added to the flood hazard data. The interactive map comment period was open from April through September 2021 and gathered an additional 143 comments on flood-prone areas, which when combined with the initial May 2021 roadshows increased the known flood-prone area total to 187.

Additional outreach was performed in February, March, and April of 2022. Three subregional meetings were held: Mid-basin meeting on March 8 in Cotulla, upper basin on March 21 in Leakey, and Lower basin on March 22 in Sinton. Overall, nine counties, eight cities, one drainage district, the National Weather Service, USGS, and Texas A&M University attended. At the regional meetings, the NRFPG presented the latest updates of the development of the RFP and recorded stakeholders' highest flood-related needs. The NRFPG also sent out an interview request to all entities with flood-related authority in February of 2022 to gain further information on highest flood-related needs, high flood risk areas, and ongoing and potential flood-related projects and studies. Through this effort, 20 interviews with various communities were conducted. Stakeholders' input at the regional meetings and interviews were recorded in detail, discussed afterwards, and incorporated into the RFP. As a result of the additional outreach, the total number of obtained flood-prone points grew by 87 to total 274. The flood-prone points are shown for the entire basin in Figure 2-2 and can be seen in detail on a county level in Appendix B23 – Flood Hazard Risk, Flood Risk Score, and Recommended Flood Mitigation Actions County Maps.

Low water Crossings

Low water crossings (LWCs) are considered potential flood-prone areas due to their inherent life-loss risk during flood conditions. A total of 576 LWCs were identified within the basin (See Section 1.11 for more information on how LWCs were defined and identified). Note this is not an exhaustive list of all known LWCs. For this first planning cycle, the community feedback on flood-prone points is used to identify any additional flood-prone and hazardous LWCs. LWC locations are shown later in the Flood Hazard Map section (Section 2.1.2.4) and associated Figure 2-9 through Figure 2-12. These are also viewable in the county flood hazard maps in Appendix B23 – Flood Hazard Risk, Flood Risk Score, and Recommended Flood Mitigation Actions.

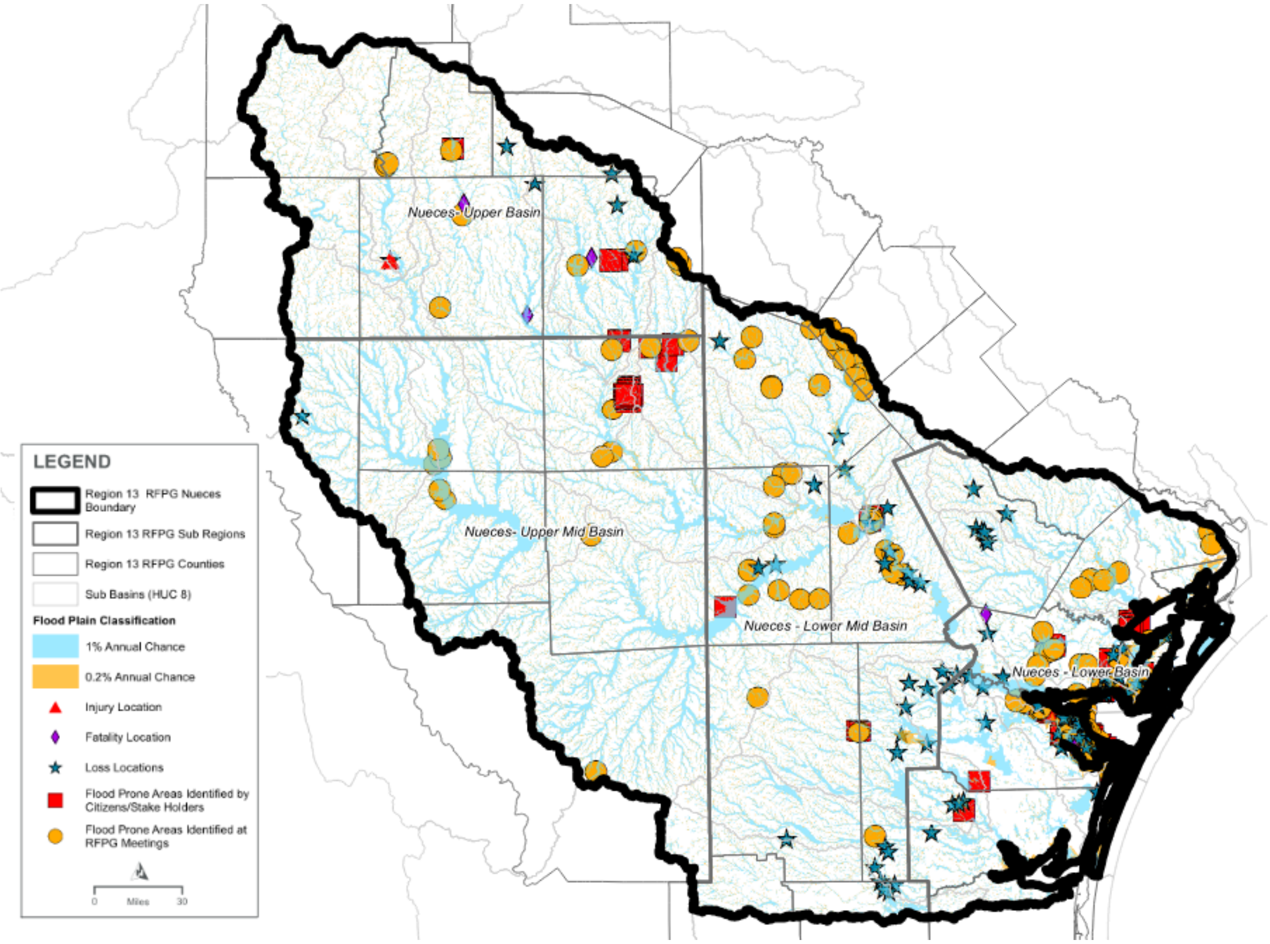


Figure 2-2. Additional Known Flood-Prone Areas

2.1.1.2 Availability of Detailed Model Results

The location of existing available hydrologic and hydraulic model results for mapping are shown for the Nueces Basin in Figure 2-3. Only the National Flood Hazard Layer (NFHL) preliminary and effective data are considered flood mapping data available on a regional scale and based on detailed hydrologic and hydraulic models. The availability of detailed hydrologic and hydraulic models is depicted in Figure 2-4. The remainder of the basin, minus several localized detailed models, are considered approximate model results, which means the models were developed using efficient means for large areas and lack detailed information and development. For example, approximate models may not consider features like roadways that alter flow patterns and may not fully represent natural features like small tributaries and water bodies. Approximate model results include Base Level Engineering (BLE), First American Flood Data Services (FAFDS), Cursory Floodplain Data, and NFHL approximate sources. Most of the basin is based on approximate data. BLE modeling and mapping is projected to be completed for all watersheds in the Nueces basin by the end of Fiscal Year 2023 per TWDB's BLE status viewer.

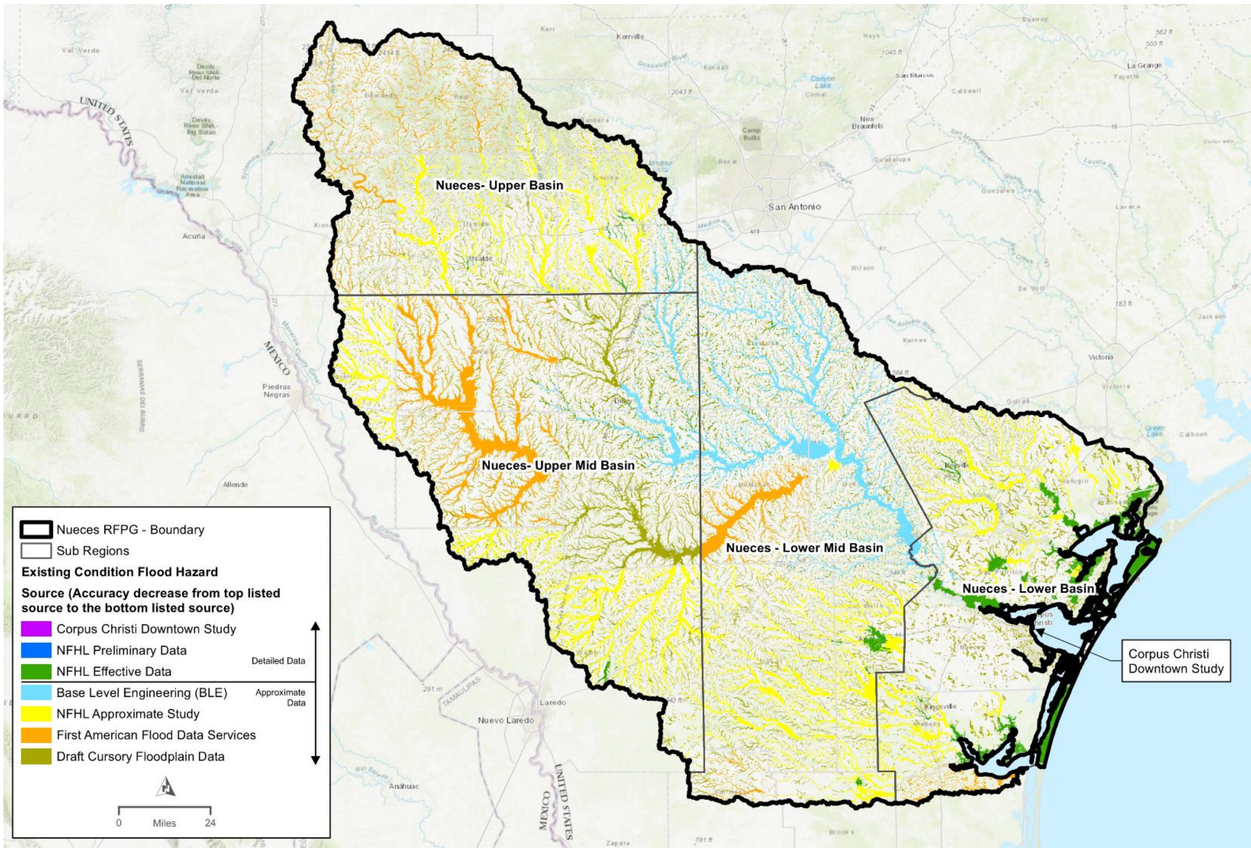


Figure 2-3. Source of Flood Modeling and Mapping Data (Map 5A)

List of Detailed Models

The list of detailed models with brief descriptions are provided below:

NFHL Pending – This data is comprised of the most recent detailed and approximate studies and are pending release as an Effective FIRM.

NFHL Preliminary – This data maps the 1% and 0.2% annual chance storm events and has been issued for public review and awareness of proposed change. Preliminary models available for Nueces County.

NFHL Effective Models (Detailed Study Areas only) – This data has flood hazard information that includes detailed studies (Flood Zones AE, AO, AH, and VE) and is the current effective FIRM. This data includes Letter of Map Revision (LOMR) information that was effective when obtained.

Corpus Christi Downtown Detailed Study Model – Two-dimensional (2D) hydraulic model of the seclusion area performed by HDR in 2016 for the salt flats levee system in downtown Corpus Christi.

Cotulla LOMR Model – Provides a detailed Hydrologic Engineering Center-River Analysis System (HEC-RAS) model used for a 2022 LOMR for the City of Cotulla.

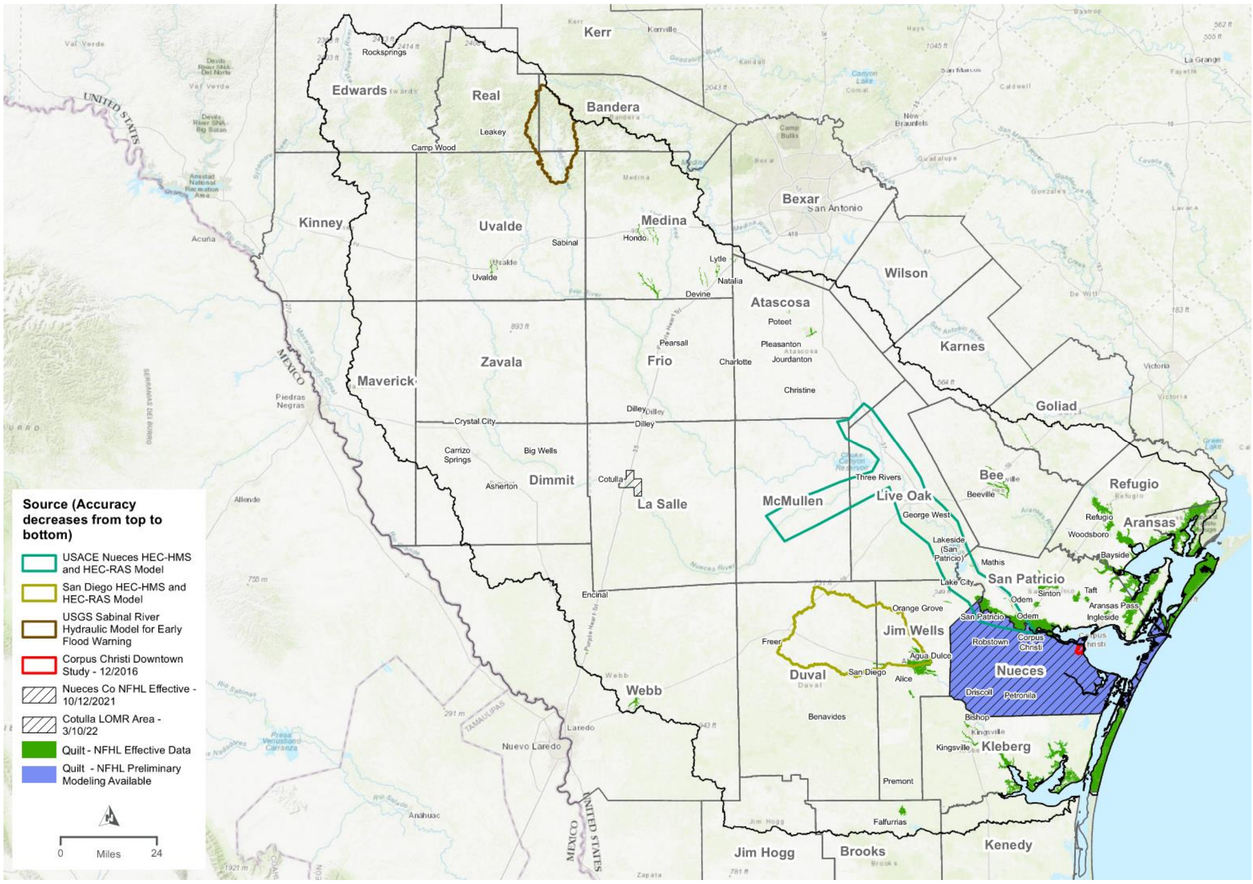


Figure 2-4. Detailed Hydrologic and Hydraulic Model Availability (Map 22)

List of Approximate Models

Base Level Engineering (BLE) – BLE is an efficient modeling and mapping approach that is considered an approximate study and meant to compliment the current effective Flood Insurance Rate Map (FIRM) where applicable. BLE results were provided in the TWDB floodplain quilt as shown in Figure 2-3. Recently, 2021 BLE model results were received for the Laguna Madre area with all watersheds in the Nueces basin scheduled for completion by the end of Fiscal Year 2023 per TWDB's BLE status viewer.

NFHL Effective Data (Approximate Study Areas only) – This data has flood hazard information that includes approximate studies (i.e. Flood Zone A) on the effective FIRM map.

FAFDS – This data contains digitized flood hazard information from previously published FIRMs and FISs and is not available on the NFHL. Available for portions of McMullen, Dimmit, Zavala, and Frio counties.

Draft Cursory Floodplain Data – Draft Cursory Floodplain Data was provided in July of 2021 for the 1% annual chance flood event. The Draft Cursory Floodplain Data was based on a 30-meter digital elevation model (DEM). This data was used for areas with no other floodplain information.

Cursory Floodplain Data - The Cursory Floodplain Data was provided in December of 2021 and provides 1% and 0.2% annual chance flood inundation boundaries. This model is based on Atlas 14 rainfall data and available laser altimeter datasets (Lidar) to produce a 3-meter ground surface grid for final mapping. Due to large processing requirements and timing of the draft 2023 RFP schedule, the Cursory Floodplain Data was not incorporated into the 2023 Region 13- Nueces RFP. Cursory Floodplain Data is intended for use for areas with no available flood mapping data until the BLE data becomes available.

Other Available Detailed Hydrologic and Hydraulic Models in the Nueces not used for Mapping

U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) 4.2 model - This hydrologic model encompasses the entire Nueces basin and is part of the Corps Water Management System (CWMS) and is used to develop a real-time simulation (HEC-RTS [Hydrologic Engineering Center-Real Time Simulation]) for watershed stakeholders. The model includes 102 sub-basins, 84 stream routings, 84 junctions, 36 calibration gages and two reservoirs (Choke Canyon and Lake Corpus Christi). Calibration/validation events include July 2002 and June/July 2007 and October 2018. This model, the extent of which is shown in Figure 2-5, is currently under development.

Figure 2-5. USACE HEC-HMS Model Extents (Source: USACE, 2021)

USACE's Nueces River HEC-RAS 5.0.6 Model - This model is also a part of the USACE CWMS for Nueces River and consists of a 1D steady/unsteady model, which includes portions of Atascosa River, Frio River downstream of Choke Canyon, and Nueces River from Tilden down to Odem (between Lake Corpus Christi and Corpus Christi Bay). This model was not used to map the 1% or 0.2% annual chance flood inundation boundaries. This model, the extent of which is shown in Figure 2-4 and Figure 2-6, is currently under development.

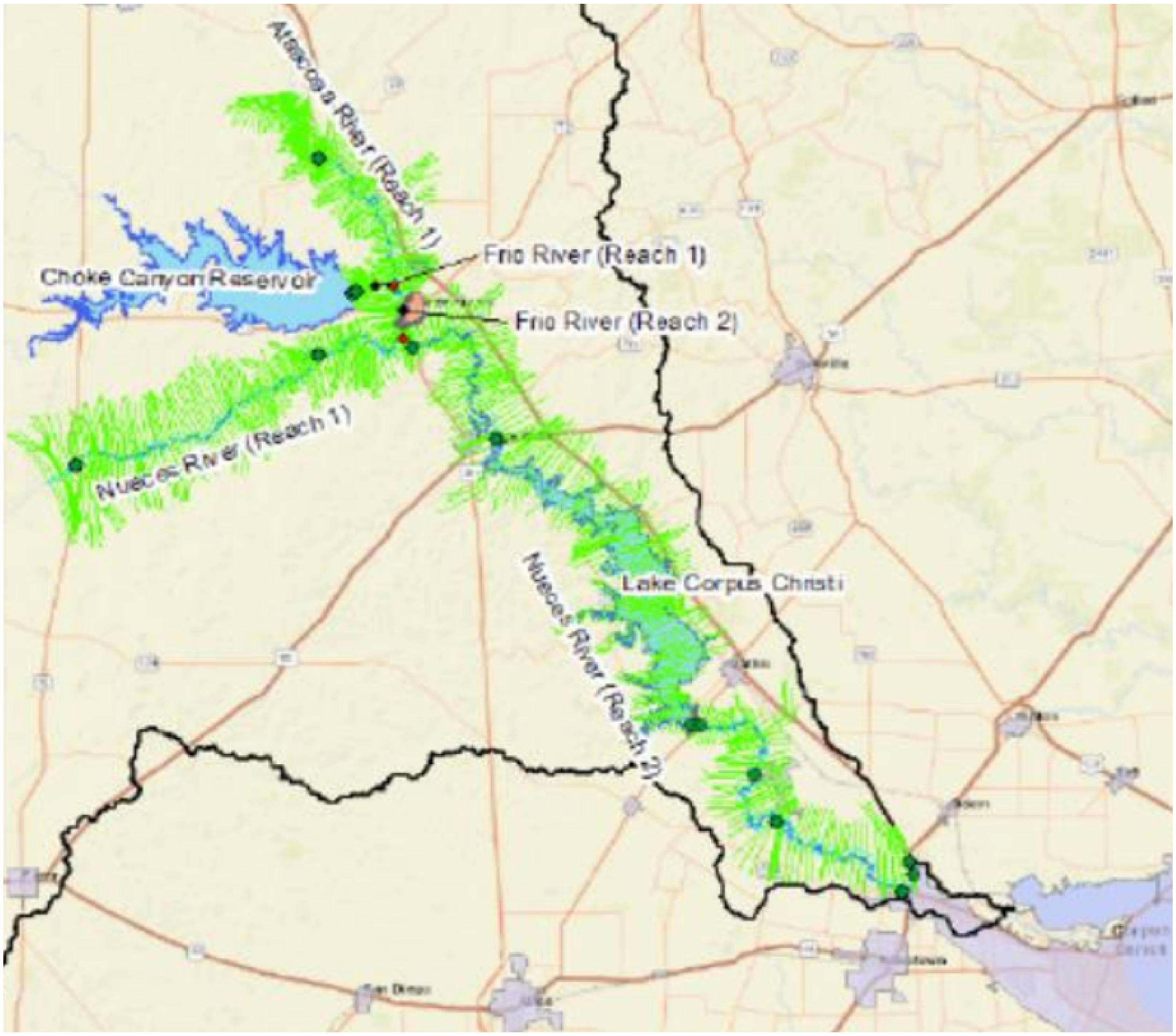


Figure 2-6. USACE Nueces HEC-RAS Model Extents (Source: USACE, 2021)

USACE San Diego HEC-HMS and HEC-RAS models - These models include the main stem of San Diego Creek, in Duval and Jim Wells Counties near Alice, San Diego, and Freer. San Diego Creek, Amargosa Creek, Chiltipin Creek, Muerto Creek, Res de Enmedio, Rosita Creek, San Fernando Creek, Toro Creek, and Lake Alice are modeled. This model was not used to map the 1% or 0.2% annual chance flood inundation boundaries. This model, the extent of which is shown in Figure 2-4 and Figure 2-7, is currently under development.

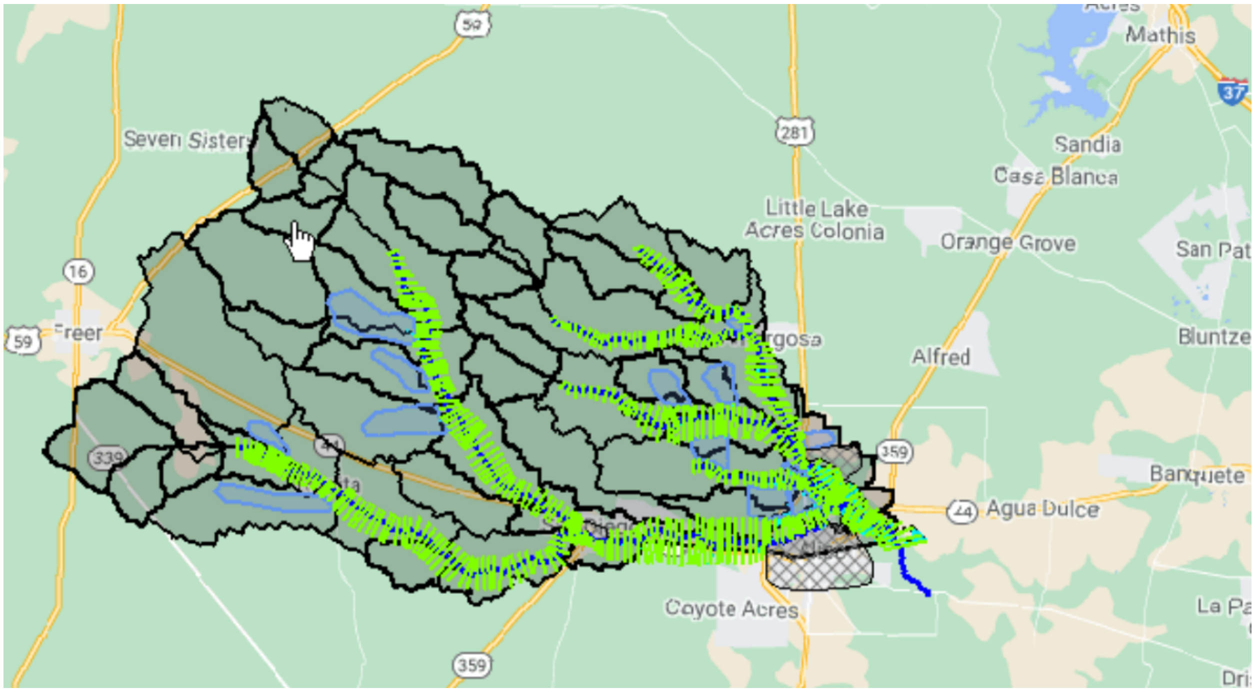


Figure 2-7. USACE San Diego Model Extents (Source USACE, 2021)

USGS Sabinal Flood Warning Model – This model is being developed for the purposes of flood warning and was not used to map the 1% and 0.2% flood inundation boundary. This model, the extent of which is shown in Figure 2-4 and Figure 2-8, is currently under development.

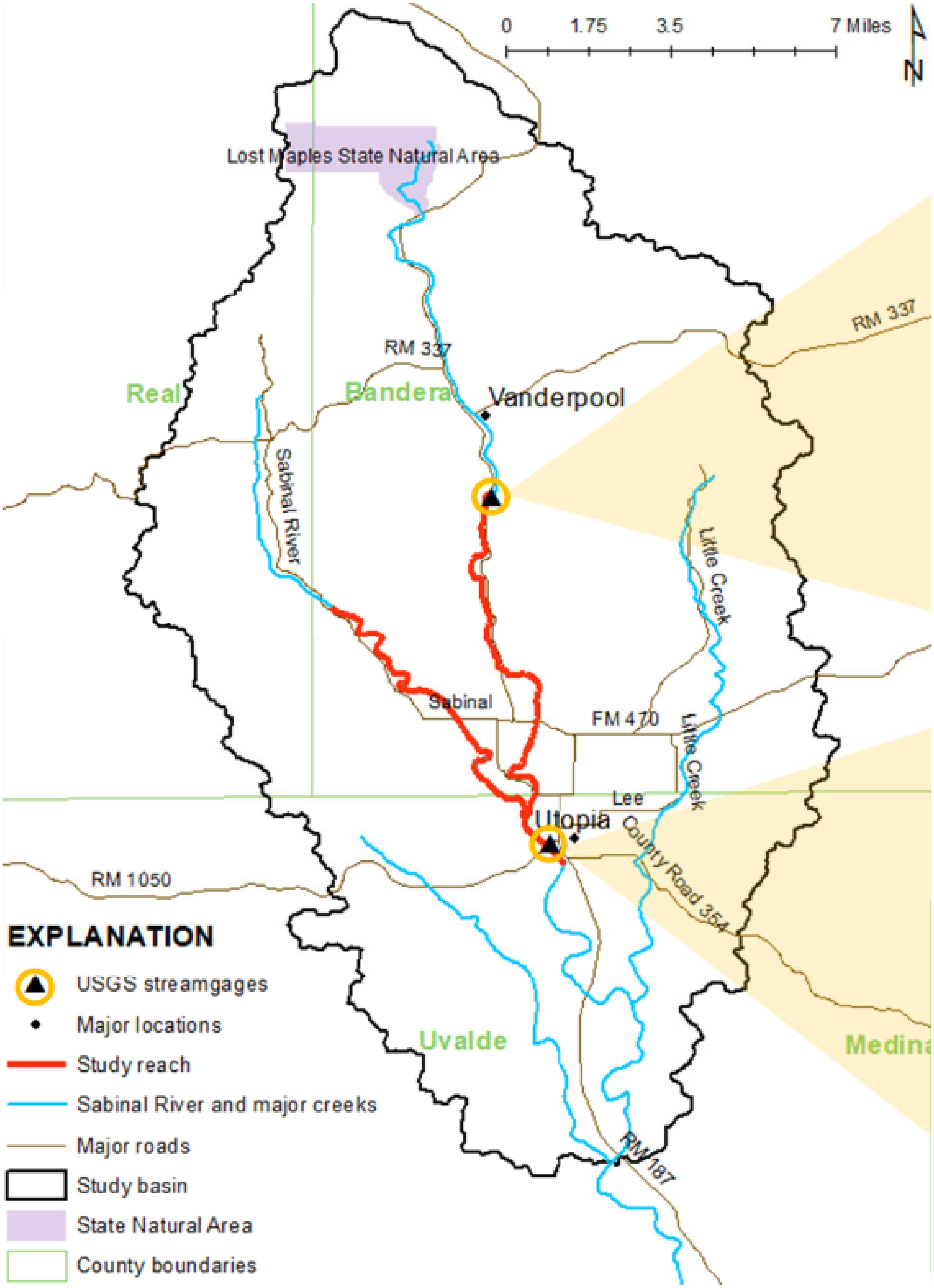


Figure 2-8. Sabinal Model Extents (Source USGS)

2.1.1.3 Best Available Data

The quality of available modeling and mapping data was assessed based on its date and level of detail in development. More detailed floodplain coverages supersede less detailed floodplain coverages for the same location. The best available information was used in the plan to define the extents of the 1% and 0.2% annual chance flood event boundaries. The following list shows the various flood inundation data sets used in order of highest to lowest accuracy.

Detailed Data Sets

1. Inundation boundaries produced by governmental entities through detailed modeling
    a. Corpus Christi Downtown Study
    b. Cotulla LOMR (to be added in the Revised 2023 Region 13- Nueces RFP)
2. NFHL Effective and Preliminary Data

Approximate Data Sets

3. BLE
4. NFHL Approximate Study Areas
5. FAFDS
6. Cursory Floodplain Data
7. Draft Cursory Floodplain Data
8. Additional Known Flood Prone Areas

More recent and accurate Cursory Floodplain Data has been received but not implemented into the inundation boundaries at this time due to their large data processing requirements and the timing of this initial plan. The new Cursory Floodplain Data has 30-meter modeling and 3-meter mapping accuracy and uses Atlas 14 rainfall data. Complete BLE coverage of the basin is anticipated by the end of 2023, which will provide higher accuracy floodplain coverage than other available approximate data sets.

2.1.1.4 Flood Hazard Maps

Areal Extent of 1% and 0.2% Annual Likelihood of Inundation

The 1% and 0.2% annual chance flood inundation boundaries were defined for all waterways with contributing drainage areas larger than 1 square mile for the entire basin. This complete coverage was due in part to the availability of Draft Cursory Floodplain Data flood inundation boundaries for the entire basin. The most accurate inundation boundaries were applied when multiple inundation data sets were available.

A large portion of the regional flood planning area contains approximately 1% annual chance flood inundation boundaries but no 0.2% annual chance flood inundation boundaries (i.e., NFHL approximate study areas or lower accuracy data). Thus, for these areas, the 0.2% annual chance flood inundation boundary had to be estimated for approximate areas by buffering the 1% annual chance inundation boundary by 100 feet to each side. This 100-foot buffer was approximated by evaluating portions of the region that had available detailed studies that defined both the 1% and 0.2% annual chance flood inundation boundary using a similar offset between the 1% and 0.2% annual chance flood inundation boundary.

The existing condition 1% and 0.2% annual chance flood inundation boundaries are provided in the geodatabase (i.e., ExFldHazard) and shown in Figure 2-9 through Figure 2-12 and on a county level basis in Appendix B23 – Flood Hazard Risk, Flood Risk Score, and Recommended Flood Mitigation Actions County Maps.

Source of Flooding

The source or type of flooding can be riverine; pluvial, including urban flooding; or coastal flooding. The various sources of flooding are further defined below. Riverine and pluvial flooding are the primary sources of the 1% and 0.2% inundation boundaries shown in the flood hazard maps, except for flood hazard areas located along the coastline subject to storm surge inundation. Flood hazard areas identified as flood prone were identified from local knowledge of flood prone areas and typically are representative of pluvial or urban flooding. The type of flooding for the 1% annual chance floodplain are shown in xx for the various subregions.

- Riverine Flooding – This type of flooding is caused by bank overtopping when the flow capacity of rivers and streams is exceeded locally. The rising water levels generally originate from high-intensity rainfall creating soil saturation and large volumes of runoff either locally and/or in upstream watershed areas.
- Pluvial Flooding including Urban Flooding – Pluvial flooding occurs when heavy rainfall collects on the landscape. Urban flooding is caused when the inflow of stormwater in urban areas exceeds the capacity of drainage systems to infiltrate stormwater into the soil or to carry it away.
- Coastal Flooding – This type of flooding occurs when normally dry, low-lying land is flooded by seawater.

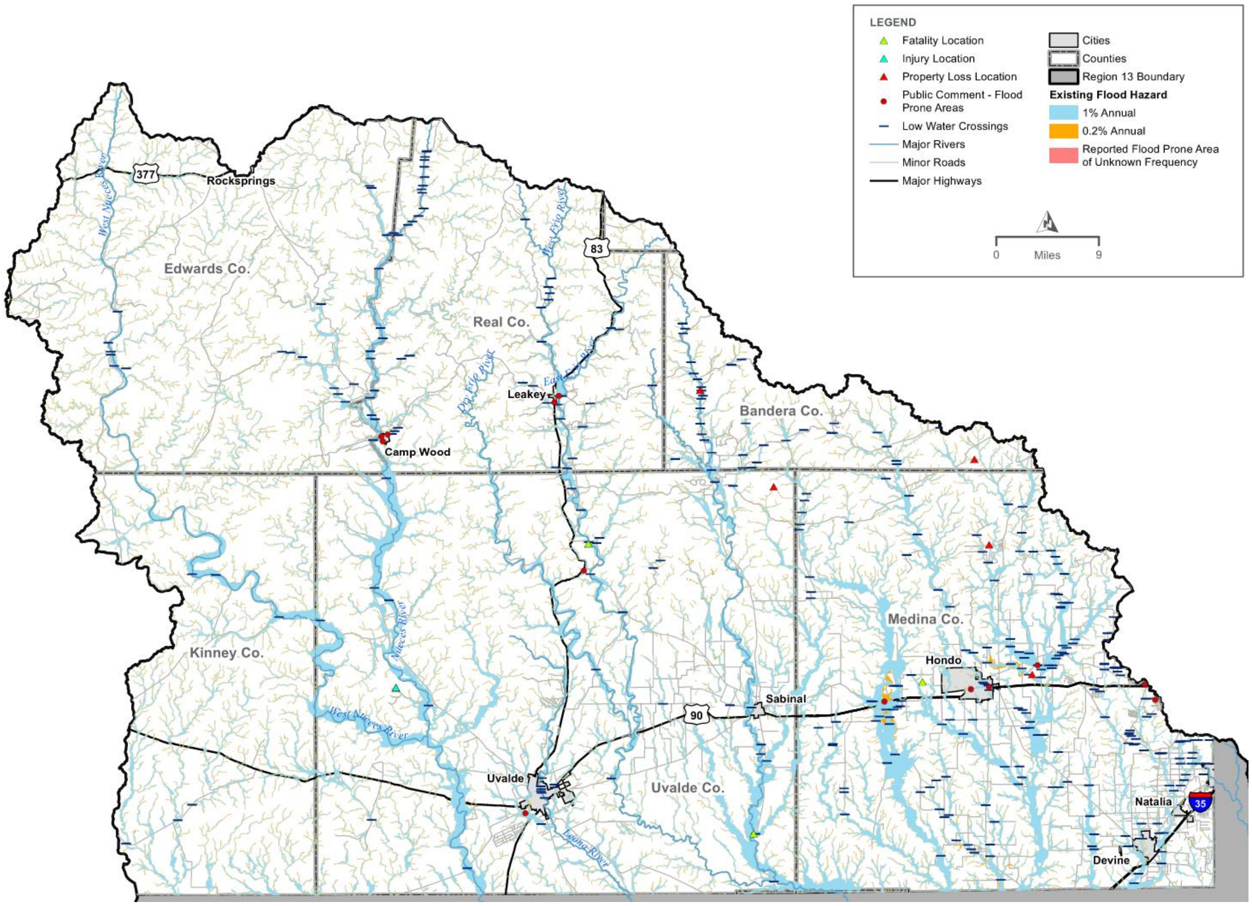


Figure 2-9. Flood Hazard Areas and Source of Flooding in the Upper Nueces Basin (Map 4A)

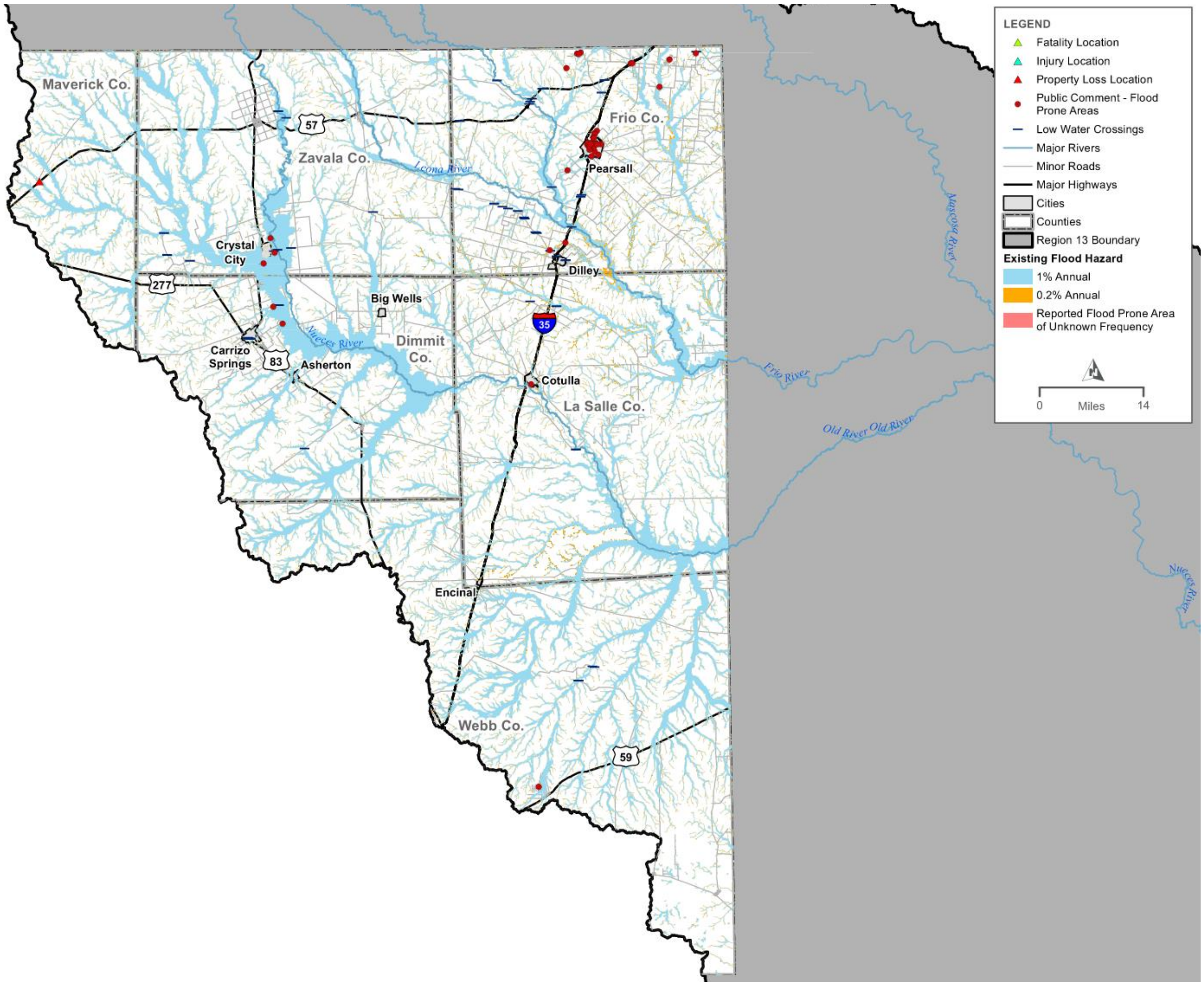


Figure 2-10. Flood-Hazard Areas and Source of Flooding in the Upper Mid-Nueces Basin (Map 4B)

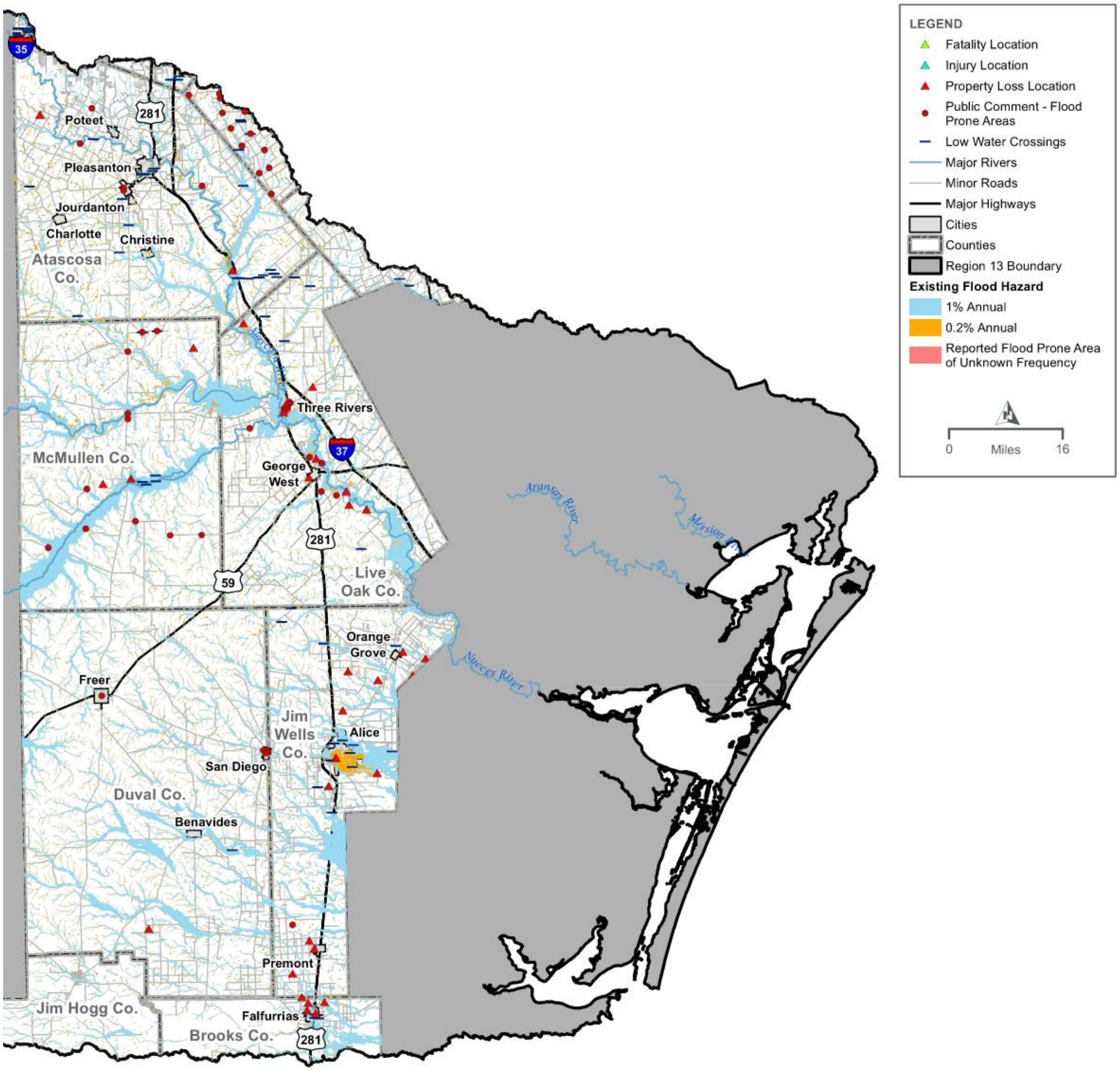


Figure 2-11. Flood Hazard Areas and Source of Flooding in the Lower Mid-Nueces Basin (Map 4C)

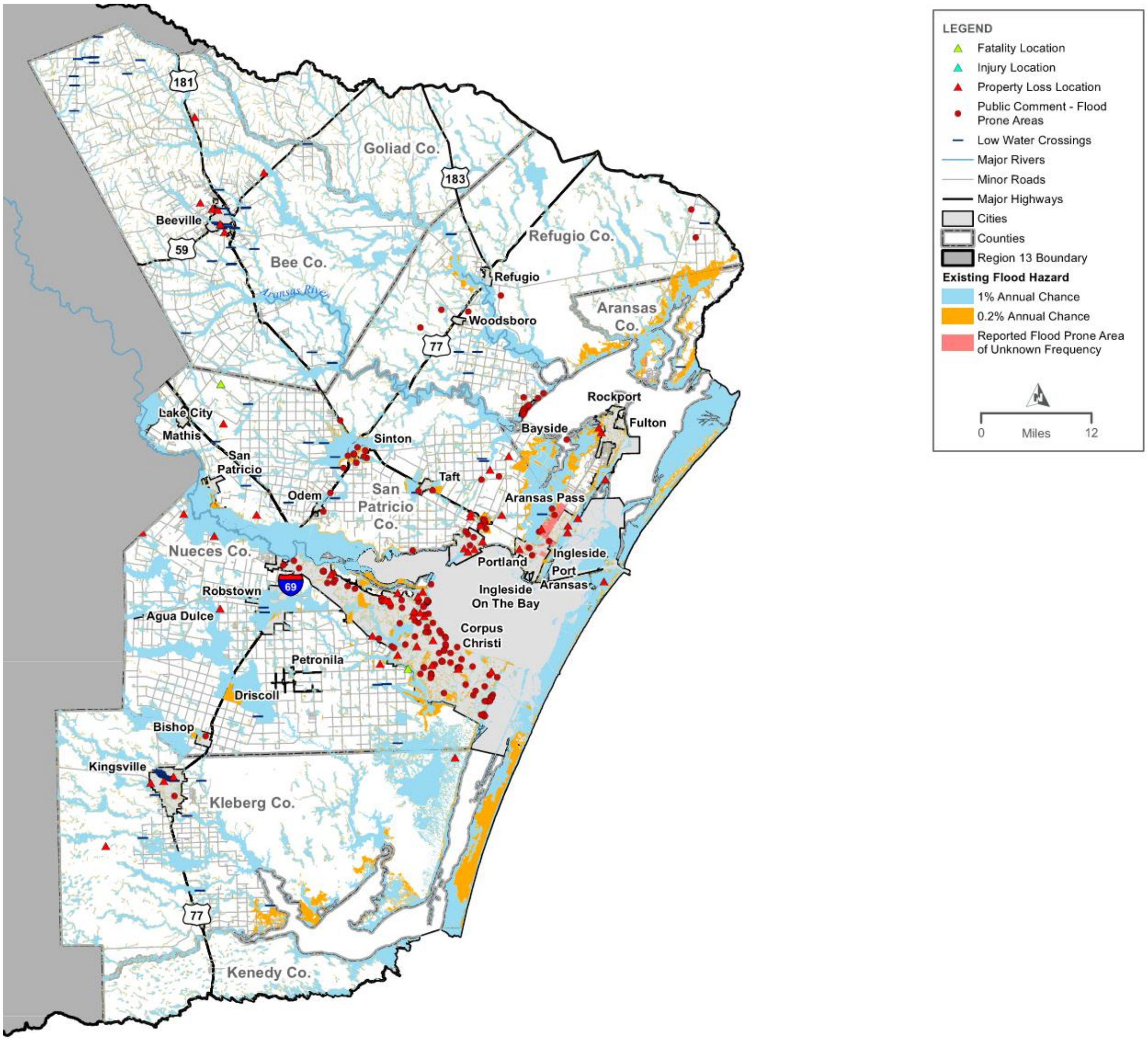


Figure 2-12. Flood Hazard Areas and Source of Flooding in the Lower Nueces Basin (Map 4D)

2.1.1.5 Gap Analysis

The map in Figure 2-13 shows remaining gaps in flood risk inundation boundary mapping relative to identified known flood-prone areas based on the location of hydrologic features, historic flooding, and/or local knowledge for areas that lack modeling and mapping. The map identifies areas with clearly outdated modeling and/or mapping, the absence of modeling and/or mapping, and areas with modeling and/or mapping that require updates. Areas that require updates include areas with significant rainfall frequency data changes. The gap analysis reviews conflicting or overlapping datasets to determine which is considered “best available” for each area within the region. The gaps can be used to recommend potential FMEs.

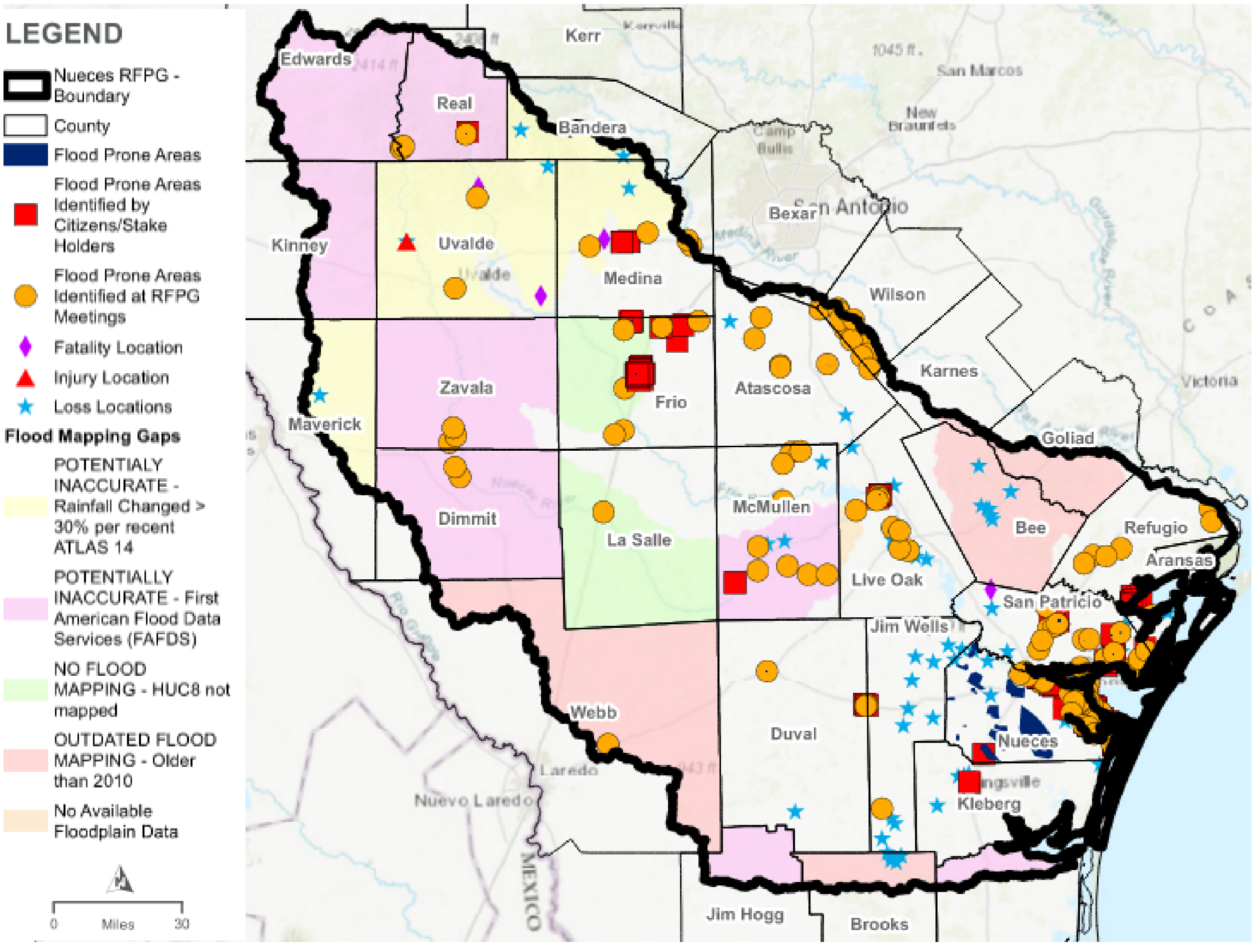


Figure 2-13. Inundation Boundary Gaps and Known Flood Prone Areas (Map 5C)

The following counties, as shown in Figure 2-13, have been identified as having no flood inundation maps available for at least a portion of the counties:

- La Salle
- Frio

The following counties, as shown in Figure 2-13, have been identified as having potentially inaccurate maps due to outdated mapping (includes FAFDS mapping):

- Mapping occurring prior to the year 2000.
  - Edwards
  - Real
  - Kinney
  - Zavala
  - Dimmit
  - McMullen
  - Jim Hogg
  - Kenedy
- Mapping occurring prior to the year 2010.

- Webb
- Brook
- Bee

The following counties, as shown in Figure 2-13 and Figure 2-14, have been identified as having potentially inaccurate maps due to new rainfall data published in 2018, which increased rainfall by more than 30%.

- Maverick
- Kinney
- Edwards
- Real
- Uvalde
- Bandera
- Medina

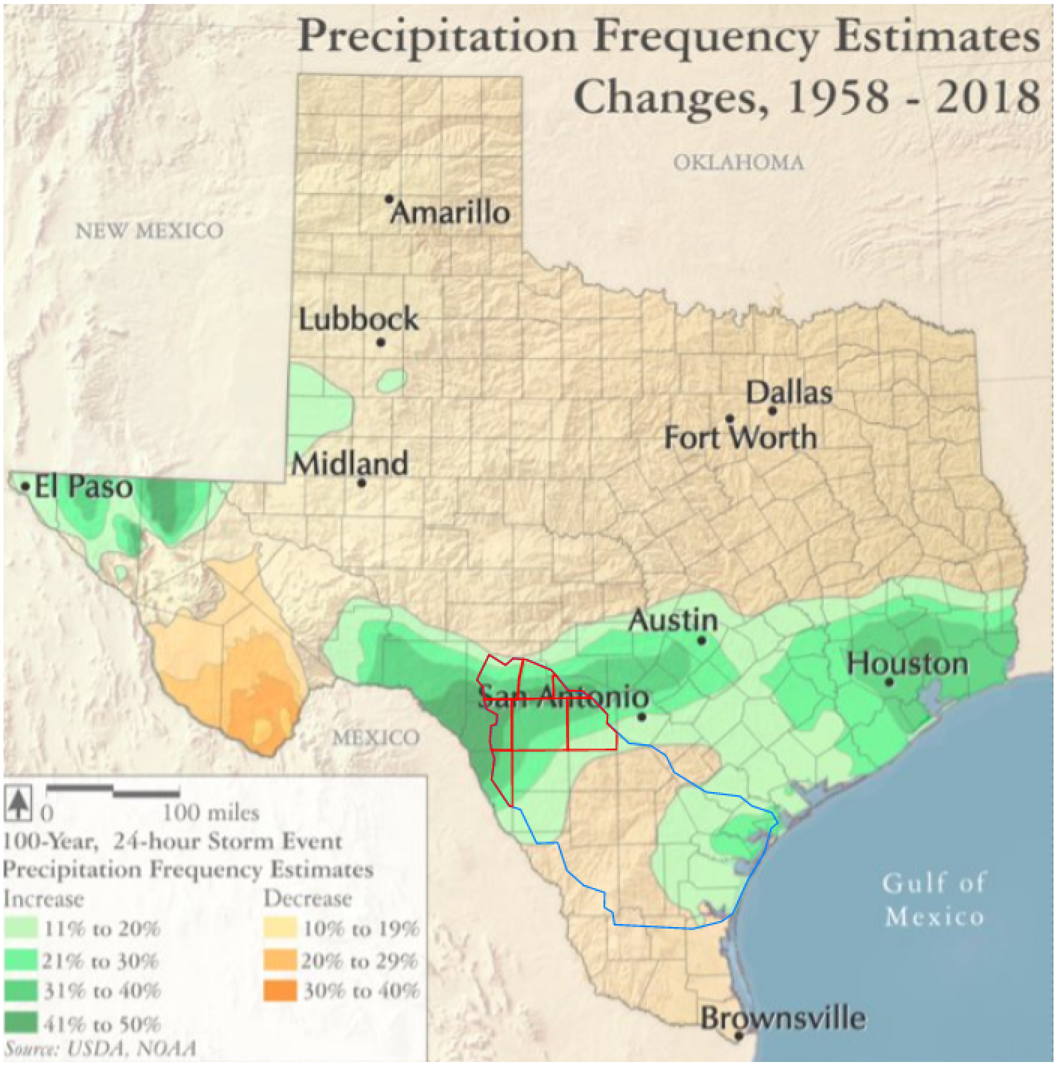


Figure 2-14. Percent Change of Precipitation Frequency Estimates (USDA, NOAA)

2.1.1.6 Existing Condition - Total Land Area at Flood Risk

This flood hazard analysis summarizes total area and agricultural area within the 1% and 0.2% annual chance flood risk, which is summarized by county in Appendix A3 – TWDB Table 3 – Existing Condition Flood Risk Summary Table. Total land area within the Nueces Flood Planning region at risk of 1% annual chance flood inundation is summarized by county and flood risk type (riverine, pluvial, and coastal) in Figure 2-15. In total, 4,578 square miles of land (19.0% of all land in the basin) is at risk of 1% annual chance flood inundation, with 71% of the inundation occurring as the result of riverine flooding. An additional 1,287 square miles or 5,865 square miles of land (24.3% of all land in the basin) is at risk of 0.2% annual chance flood inundation.

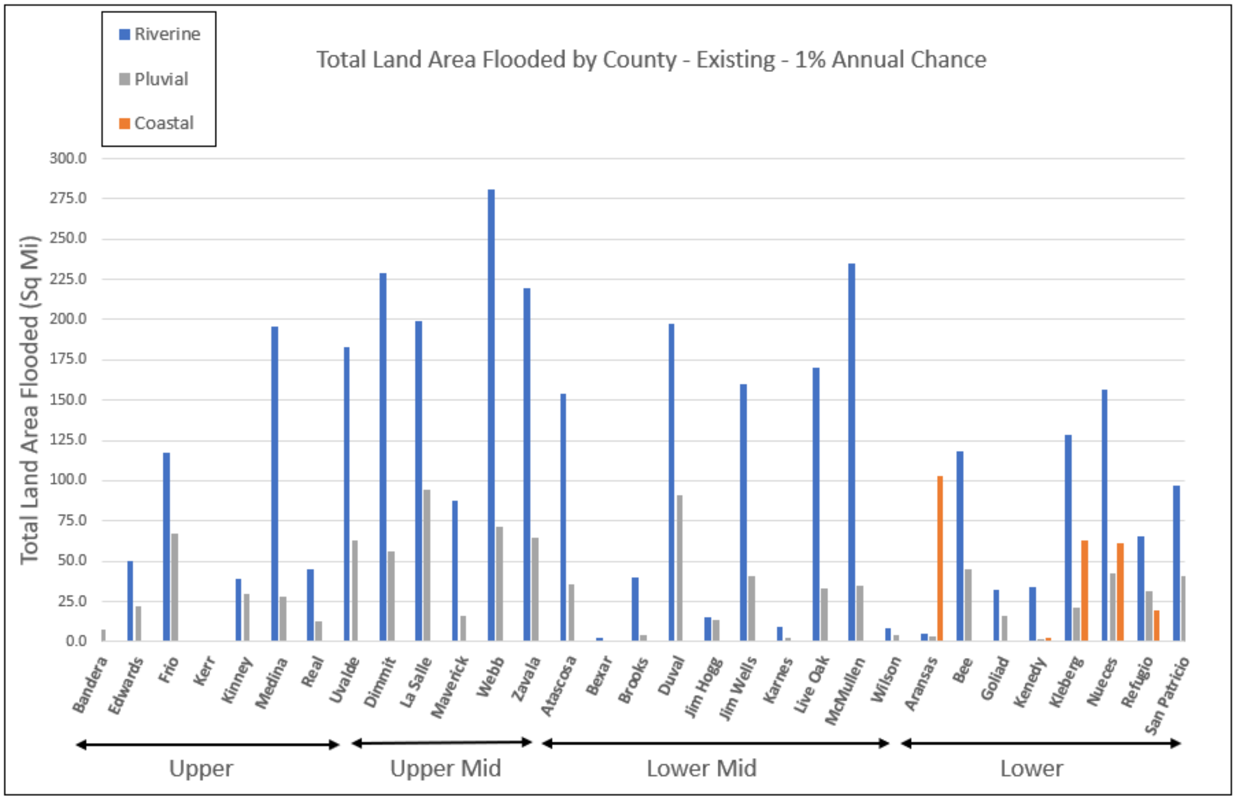


Figure 2-15. Total Land Area at Flood Risk of 1% annual chance storm by Type, County - Existing Condition

2.1.2 Existing Flood Exposure Analyses

2.1.2.1 Analysis of Existing Development within Existing Flood Hazard

The existing flood exposure analyses is a high-level, region-wide, GIS-based analyses to identify who and what might be harmed by flooding. This includes identifying all structures located within both the 1% and 0.2% annual chance flood event and possible flood prone area boundaries, as defined in the existing flood hazard analysis in Section 2.1.1.

The existing condition flood exposure analysis indicated roughly 61,000 structures and a population of 137,000 at potential risk of flooding from the 1% annual chance flood event. This grows to 98,000 structures and a population of 223,000 at potential risk of flooding from the 0.2% annual chance flood event. A heat map was produced to illustrate where these structures are generally clustered in the Nueces Flood Planning Region, as shown in Figure 2-16. From this analysis, several hot spots for flood exposure appear to be:

(1) the City of Corpus Christi area, including Robstown

(2) the Rockport, Ingleside, and Port Aransas areas

(3) cities in the lower basin including Alice, Sinton, Kingsville, Falfurrias, and Beeville

(4) areas along the Nueces River from the City of Three Rivers to Corpus Christi

(5) cities in the upper basin, including Crystal City, Knippa, D'Hanis, Uvalde, Hondo, Pearsall, Devine, Sabinal, and Dilley

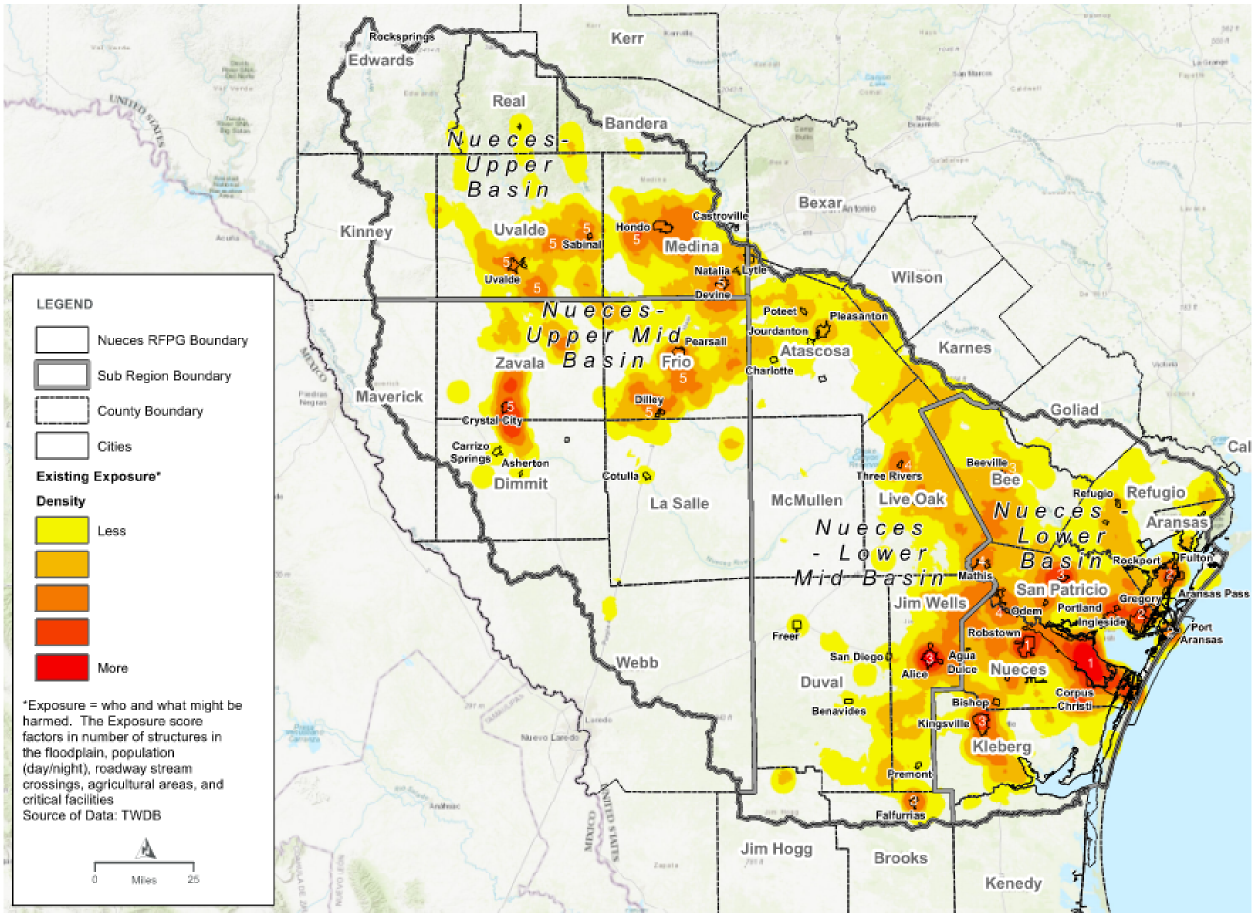


Figure 2-16. Existing Condition Exposure Analysis (Map 6)

2.1.2.2 Proposed Flood Mitigation Projects

This existing flood exposure analysis did not include any flood mitigation projects with dedicated construction funding and scheduled for completion prior to adoption of the next state flood plan.

2.1.2.3 Non-accredited Levees and Dams

This existing flood exposure analysis assumes existing levees or dams are in place and providing flood protection as shown in the best available flood hazard maps. This assumption was made due to data limitations associated with this being the first flood plan. Future flood plan updates should further consider non-accredited levees and dams in the exposure analysis.

2.1.2.4 Flood Exposure to Property, Population, and Infrastructure

See Appendix A3 – TWDB Table 3 – Existing Condition Flood Risk Summary Table, which provides on a county basis the number of structures, population, roadway stream crossings, roadway segments, agricultural areas, and critical facilities located in the 1%and 0.2% annual chance flood risk, and in the possible flood prone areas. The flood exposure analysis includes a determination of day and night population estimates that are located within the flood hazard areas with the higher of the day or night estimate used in estimating the population in the floodplain or flood-prone area.

2.1.2.5 Expected Loss of Function

The exposure analysis indicates that approximately 61,000 structures are at potential risk of flooding from a 1% annual chance storm event. Flooding of structures can cause temporary and/or permanent loss of use and can damage the structural elements through hydrostatic and hydrodynamic loads pushing against the building and its foundation. At a minimum flooded structures incur damage to building materials.

The exposure analysis indicates that approximately 3,200 miles of roadway and 5,400 roadway crossings are at risk of flooding from the 1% annual chance storm event. These roadways have the potential to be impassible for an extended period depending on the depth of flooding. Flooding of roadways can potentially leave populations stranded and inaccessible to emergency services during a time of distress.

2.1.3 Existing Vulnerability Analysis

The objective of this analysis is to identify critical infrastructure amongst the items identified in the existing condition flood exposure analysis and to compute Social Vulnerability Index (SVI) values for each structure identified during the flood exposure analysis. The SVI values were obtained from the U.S. Centers for Disease Control and Prevention (CDC), which calculates SVI using 15 U.S. census variables as shown in

Figure 2-17 to help local officials identify communities that may need support before, during, or after disasters (https://www.atsdr.cdc.gov/placeandhealth/svi/index.html).

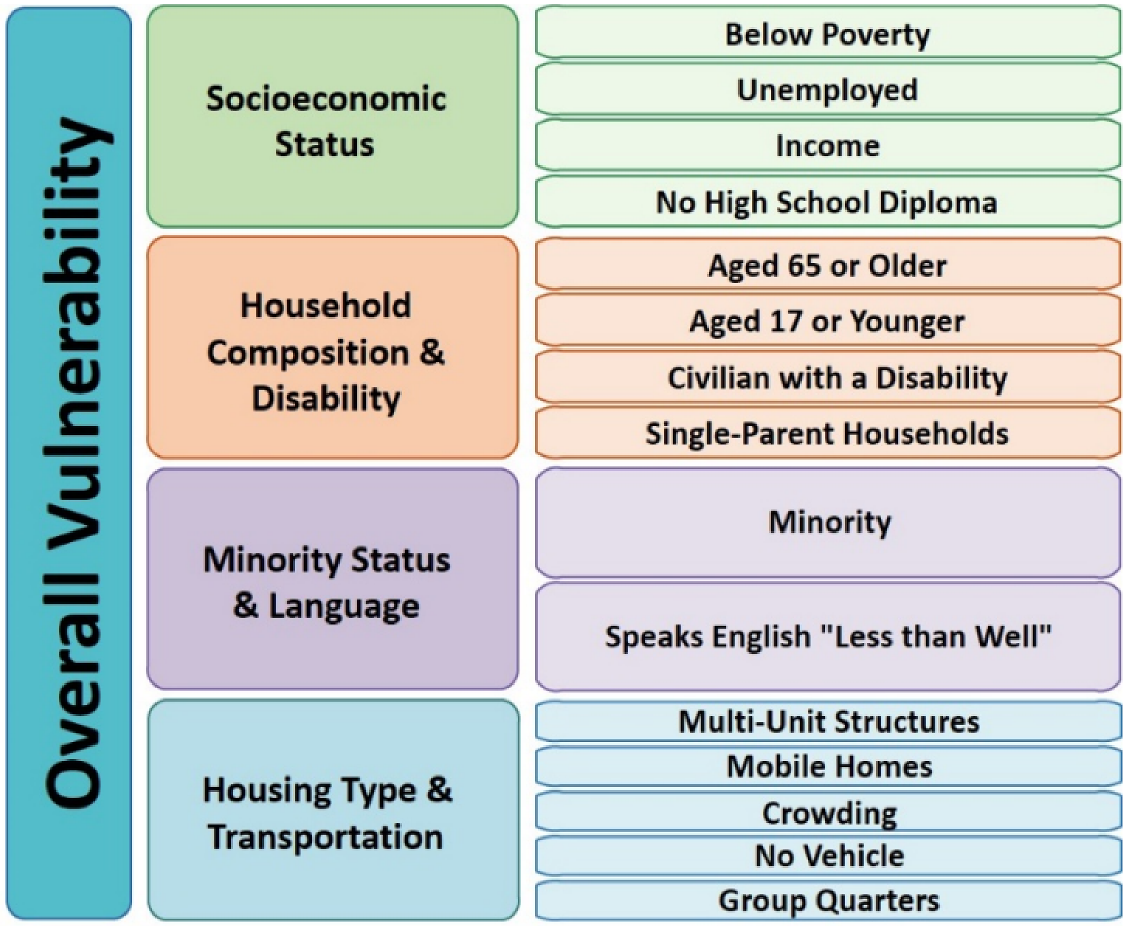


Figure 2-17. SVI Variables (CDC SVI 2018)

SVI is intended as the proxy for resilience for this planning cycle. The higher the SVI, the higher the vulnerability. The TWDB provided building data with SVI values for use in this analysis. An assigned SVI value over 0.75 for any given structure is consider vulnerable in this analysis.

2.1.3.1 Vulnerability of Critical Facilities

Critical infrastructure includes any schools (K-12), hospitals, police stations, and fire stations in the region. The flood vulnerability analysis identified approximately 445 critical facilities in the 1% annual chance flood inundation. Figure 2-18 shows the location of critical infrastructure in the region most vulnerable to flooding. Appendix A3 – TWDB Table 3 – Existing Condition Flood Risk Summary Table provides the number of critical facilities identified on a per county basis.

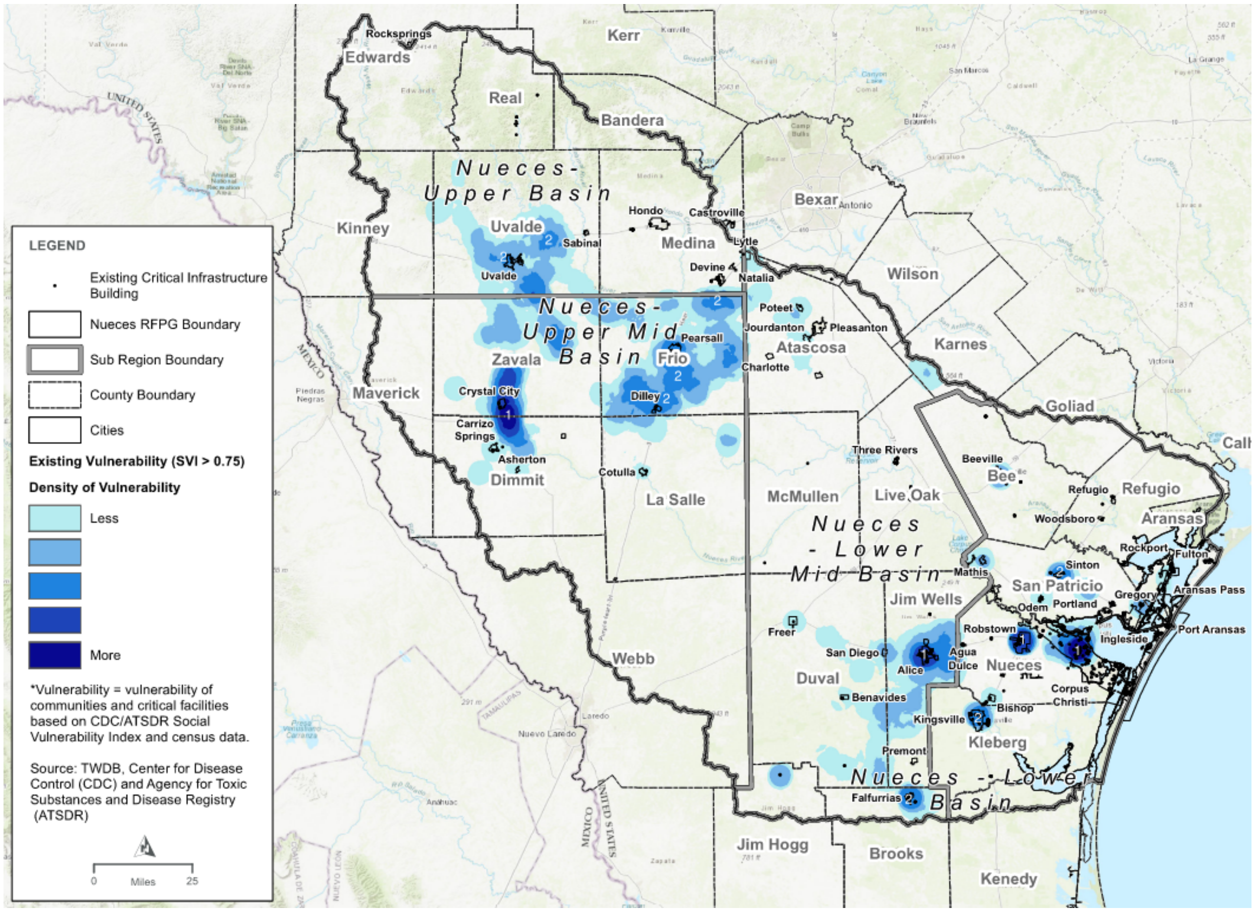


Figure 2-18. Existing Condition Vulnerability Heat Map and Location of Critical Infrastructure

2.1.3.2 Resilience of Communities Located in Flood-prone Areas

The average SVI of features in floodplain or flood-prone areas per county is provided in Appendix A3 – TWDB Table 3 – Existing Condition Flood Risk Summary Table**.** Locations of high SVI areas located in floodplains or flood-prone areas are shown in Figure 2-18.

(1) Most vulnerable areas - Corpus Christi and Robstown area, City Alice, and Crystal City

(2) Other vulnerable areas - Kingsville, Sinton, Falfurrias, Dilley, Pearsall, Devine, Uvalde, and Knippa.

2.2 Future Conditions Flood Risk Analysis

A future condition flood risk analysis was performed to approximate the flood hazard extents projected in 30 years' time or the year 2050. The future condition analysis also defines the additional flood exposure and vulnerability risk.

2.2.1 Future Condition Flood Hazard Analysis

2.2.1.1 Projected Population and Development Trends and Practices

Chapter 1 discusses projected population and development trends and practices. The population of the Nueces basin is expected to grow from 1.14 million in 2020 to 1.52 million in 2050. New land development and population increases are projected to be the largest near the major population centers of the Cities of Corpus Christi, San Antonio, and Laredo. Other high growth areas by percent growth include the cities of Jourdanton, Lytle, Poteet, Pleasanton, and Crystal City, and the counties of Webb, Wilson, and Atascosa.

Population growth generally correlates to an increase in urbanization. This, in turn, leads to an increase in impervious ground cover as land use changes. Unmitigated, urbanized areas will increase watershed rainfall runoff leading to higher water surface elevations in the region's rivers, creeks, and channels during extreme rainfall events. New land development could potentially place new structures in the floodplain or flood-prone areas, especially in areas with limited flood plain regulations and enforcement.

Population growth over the next 30 years is considered a significant factor in the future conditions flood risk for the Nueces Region's riverine systems. However, for the coastal regions, population growth and the associated additional impervious cover is not considered to influence the future inundation conditions. The relative sea level rise (RSLR), which considers multiple factors such as climate change, land subsidence, and glacial melting, was the primary factor in the coastal areas.

2.2.1.2 Identification of Future Condition Flood Risk

When developing a predicative assessment for future conditions flood risk, the TWDB contract scope requires that each region consider two major factors: unmitigated population increase and climate change. The following is a list of potential factors that can influence future flood conditions:

- Precipitation increases due to climate change
- Rising sea levels
- Land subsidence
- Population growth and associated development increases (impervious cover)
- Natural stream migration changes to existing waterways
- Implementation of constructed drainage infrastructure

The Nueces Region includes a significant coastal area, that has different flood patterns and drainage challenges as compared to inland, riverine areas. Thus, the future condition flood risk is determined using separate approaches for inland riverine areas and for coastal areas. The following sections describe the approaches used for each.

2.2.1.3 Inland Riverine Future Conditions

For the 2020 to 2023 planning cycle, the development of the future flood hazard for riverine systems (inland areas) is dependent on population growth and a corresponding horizontal floodplain buffer applied. This inland approach was established due to the lack of available detailed floodplain data and hydrologic/hydraulic models.

The horizontal floodplain buffers, summarized in Table 2-1, were developed to approximate the increase in the 1% and 0.2% annual chance flood inundation boundaries, based on population increases projected from 2020 to 2050 from TWDB 2021 Regional Water Plan data. Population increases are applied, as appropriate, to the existing 1% and 0.2% annual chance boundaries to obtain the future condition boundaries surrounding cities and concentrated populated areas.

Table 2-1. Future Condition Buffers based on Estimated Population Increase

Estimated Population Increase	Estimated, corresponding buffer in floodplain width (ft)	
	1% Annual Chance Event	0.2% Annual Chance Event
0%	0	0
1%	5	5
5%	20	15
10%	40	30
15%	60	45
25%	100	75
50%	200	150

Horizontal buffers were established by estimating the anticipated water surface increase due to increased development and determining the corresponding horizonal floodplain increase based on available LiDAR terrain for several areas throughout the watershed, including the upper hill county, minor/major tributaries and rivers through the watershed, and conveyance systems near cities.

Population growth projections outside of concentrated areas within the remaining county regions were determined using the same 2021 Regional Water Plan population information. These populations are the remaining counts beyond the cities and districts within each respective county. Based on projected population density increases within the county regions, it was determined that maximum increases were less than 20 people per square mile. Based on these assessments, it is estimated that no floodplain increases attributed to population growth will occur outside the city areas; therefore, they show no change. Future 1% and 0.2% annual chance floodplain areas within the county regions, outside of cities or populated areas, are assumed to match the existing floodplain limits.

2.2.1.4 Coastal Future Conditions

Relative sea level change is estimated on best available existing data. The following data sources are currently available and reviewed for this task.

- *National Research Council (NRC) (1987) Responding to Changes in Sea Level: Engineering Implications* – The NRC study developed sea level rise (SLR) / change (SLC) scenarios. This study was leveraged by USACE and National Oceanic and Atmospheric Administration (NOAA) and is the main resource for all present-day estimates
- National Oceanic and Atmospheric Administration (*NOAA) 2017 – Global & Regional Sea Level Rise Scenarios for the United States (TR NOS CO-OPS 083)* – NOAA has developed a tool to calculate the approximate SLR computed from the most recent Intergovernmental Panel on Climate Change (IPCC) and modified NRC projections. NOAA computed five scenarios including “high,” “intermediate-high,” “intermediate,” “intermediate-low,” and “low.” These SLR scenarios are presented in Figure 2-19. This data can be extrapolated from graphs and applied to a digital terrain model.
- *NOAA 2022 – Sea Level Rise Technical Report - Update to 2017 report and data.*
- *U.S. Army Corp of Engineers (USACE) 2013 - Incorporating Sea Level Change in Civil Works Programs (ER 1100-2-8162)* – This source provides design guidelines for incorporating the direct and indirect physical effects of projected future sea level change across the project life cycle in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects.
- *USACE Sea-Level Change Curve Calculator (Version 2021.12)* – The USACE developed a tool to calculate the approximate SLR for three scenarios including “high”, “intermediate”, and “low”.
- *General Land Office (GLO) Coastal Texas Protection and Restoration Feasibility Study Final Report (2021) (Coastal Texas Study)* - Uses the NOAA 2017 data and prepared inundation mapping for entire coast of Texas. The inundation mapping is based on various scenarios, including: 1% and 0.2% annual chance storm events modeled and future conditions with no mitigation (i.e., a “no action”) scenarios available for years 2035 and 2085.

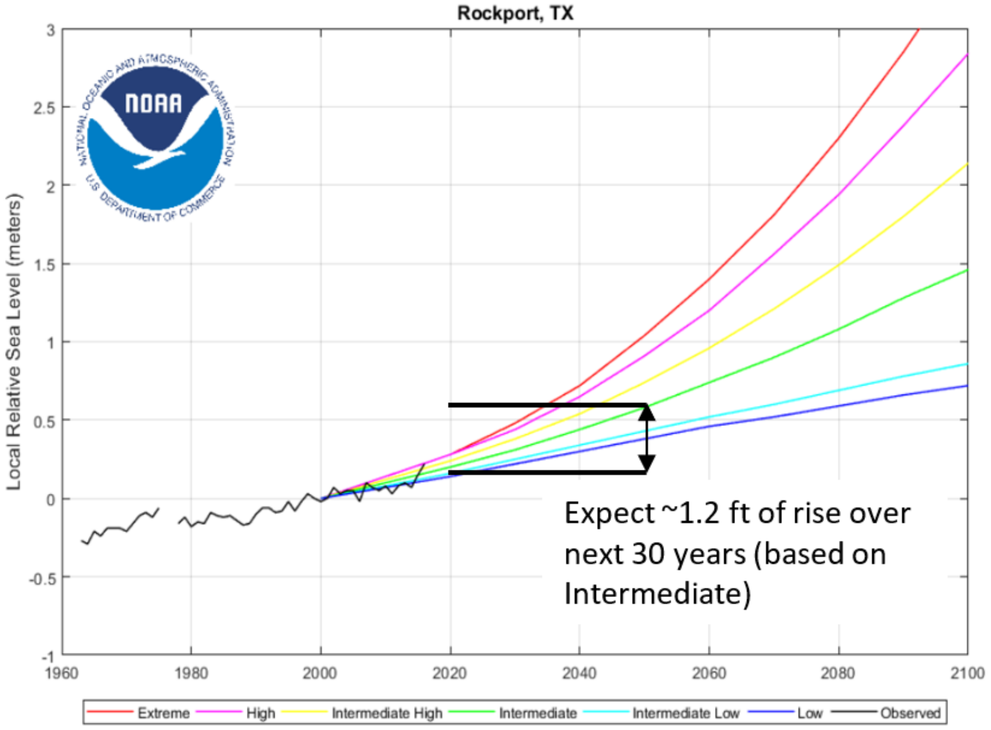
Both NOAA and USACE SLR estimates are computed from the same sources resulting in similar scenarios. For reference, a comparison of SLR categories is shown in Table 2-2 with brief descriptions of background assumptions.

Table 2-2. Comparison of NOAA and USACE Sea Level Rise Scenarios

NOAA Scenarios	USACE Scenarios	Description
Low	Low	Linear historic sea level rise.
Intermediate-Low	Intermediate	NRC Curve I – Moderate Greenhouse Gas Emission
Intermediate	-	NRC Curve I – High Greenhouse Gas Emission
Intermediate-High	High	NRC Curve III – Moderate Glacier Melt
High	-	NRC Curve III – High Glacier Melt

Annual Mean Relative Sea Level Since 1960 and Regional Scenarios
8774770 Rockport, Texas

The figure will help to assess which scenario(s) the trajectory of sea level rise is following as well as the magnitude of year-to-year variability. A study on patterns and projections of high tide flooding shows the rise in local mean sea level will increase the annual occurrence of high tide flooding.



Expect ~1.2 ft of rise over next 30 years (based on Intermediate)

Figure 2-19. NOAA 2017 – Annual Mean Relative Sea Level Scenarios – Rockport, TX

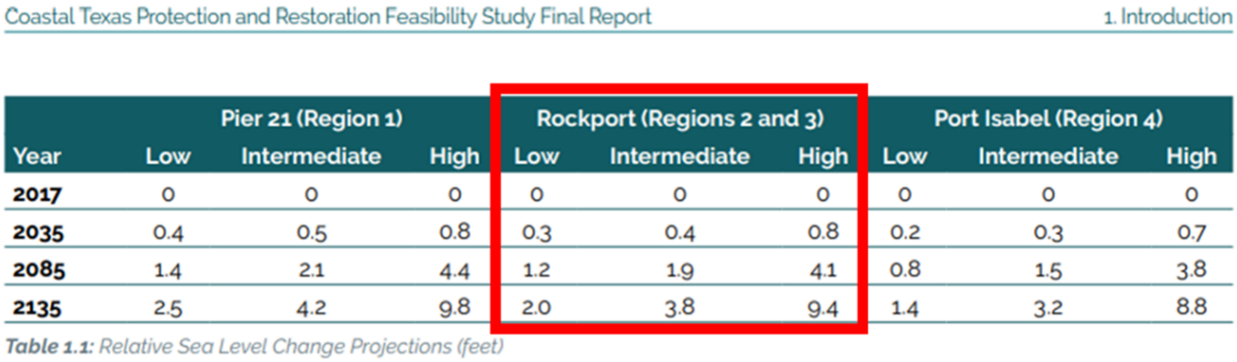
NOAA's *Global & Regional Sea Level Rise Scenarios for the United States* (2017 with 2022 update) provides the most relevant technical data related to SLR. When considering the various scenarios of SLR, the "intermediate-low" scenario has a high likelihood of occurrence based on predicted outcomes and includes scientifically reasonable considerations for increased greenhouse gas emissions, ocean thermal expansion, and land-based subsidence/uplift. However, the "intermediate" scenario is the most typical scenario selected for design. It includes considerations for past observed sea level trends and global effects due to moderate increases in greenhouse gas emissions. Table 2-3 compares the NOAA and USACE data to understand what the expected SLR is for the Nueces Region at the 30-year projected time frame.

Table 2-3. Water Surface Elevation Increase (ft) projected from 2020 to 2050

NOAA Scenarios	USACE Scenarios	USACE 2013[1]	NOAA 2017[2]	NOAA 2022[2]	Description
Intermediate-Low	Intermediate	0.7	0.9	1.0	NRC Curve I
Intermediate	-	-	1.2	1.1	
Intermediate-High	High	1.5	1.6	1.3	NRC Curve II

1. https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html
2. https://coast.noaa.gov/slr/

GLO's 2021 *Coastal Texas Protection and Restoration Feasibility Study Final Report* (Coastal Texas Study) used the NOAA 2017 data to prepare inundation mapping for the entire coast of Texas for several different scenarios and various projections into the future (see Figure 2-20). None of the modeled scenarios precisely match the 30-year projection required by the RFP. However, the Year 2035 "high" and Year 2085 "low" scenarios result in similar SLR values as was predicted by the NOAA 2022 intermediate and intermediate-low scenarios.



Coastal Texas Protection and Restoration Feasibility Study Final Report — 1. Introduction

	Pier 21 (Region 1)			Rockport (Regions 2 and 3)			Port Isabel (Region 4)		
Year	Low	Intermediate	High	Low	Intermediate	High	Low	Intermediate	High
2017	0	0	0	0	0	0	0	0	0
2035	0.4	0.5	0.8	0.3	0.4	0.8	0.2	0.3	0.7
2085	1.4	2.1	4.4	1.2	1.9	4.1	0.8	1.5	3.8
2135	2.5	4.2	9.8	2.0	3.8	9.4	1.4	3.2	8.8

***Table 1.1:** Relative Sea Level Change Projections (feet)*

Figure 2-20. Coastal Texas Study Relative Sea Level Change Projections

The future coastal conditions flood hazard methodologies were discussed at the March 28, 2022 NRFPG meeting. Advantages and disadvantages of each methodology were presented for consideration, including NOAA and Coastal Texas data sources. The NRFPG approved use of the Year 2085 "low" model data for Rockport, Texas, from the Coastal Texas Study to use for development of the 2023 Nueces RFP. This model data assumes a 1.2-foot SLR. This is similar to the NOAA 2022 intermediate sea level rise of 1.1 foot. However, the Coastal Texas Year 2085 "low" model projection data was later found not to be available for use in the 2023 Nueces RFP. In lieu of using the Coastal Texas data, **the NRFPG proposes using the NOAA 2022 intermediate SLR of 1.1 foot and applying an appropriate offset to the existing 1% and 0.2% annual chance coastal flood inundation boundaries**.

To determine and apply an appropriate offset, the Nueces Region Coastal Zone is divided into five coastal zones as listed below and shown in Figure 2-21.

- Baffin Bay
- Baffin Bay – Bluff
- Corpus Christi
- Copano
- Barrier Island – Back Bay

The regions are divided by their primary river systems and then further divided based on observed topography. For instance, a sharp increase in elevation near the waterline was noted in the Baffin Bay – Bluff cross-sections.

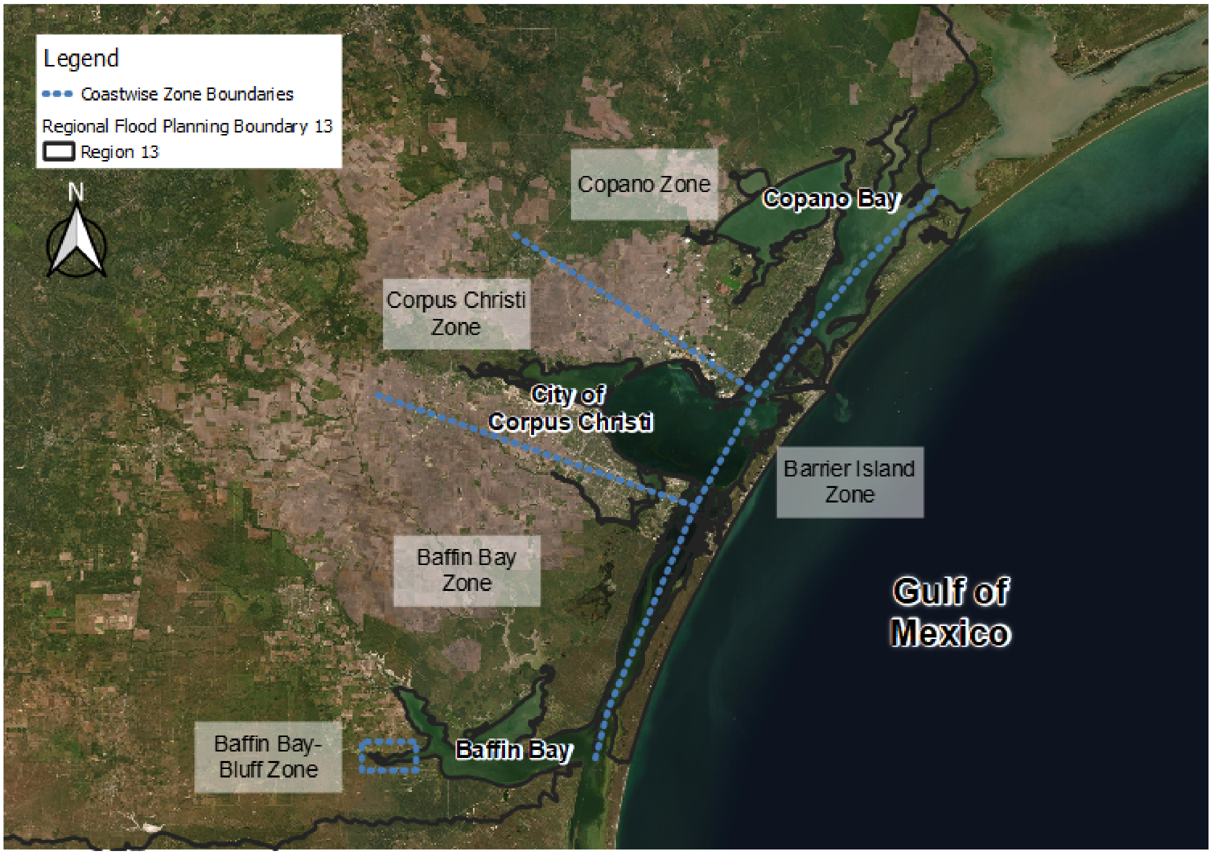


Figure 2-21. Coastal Zones used for applied Future Sea-Rise Buffer

Using the NOAA 2022 “intermediate” SLR estimate, a horizontal buffer was computed using the best available terrain data from transects of the coast to determine the average overland slope in each zone (see Table 2-4). The average overland slope for SLR was limited specifically to the coastal areas and does not include overland slopes further inland. All slopes were calculated from the waters line heading inland. The Barrier Island Zone slope was measured for the back bay, extending from the bay towards the Gulf of Mexico. This adjustment was made because the coastal dune system on the Gulf of Mexico side is considered bluffs for this analysis and the horizontal buffer is negligible. Based on the 1.1-foot vertical SLR and the average overland slope in each region, a horizontal buffer was calculated. This horizontal buffer is applied to the existing conditions 1% and 0.2% flood hazard layer within the Coastal Zone to become the future conditions flood hazard layer. However, due to the timing of the development of the above future coastal condition approach described above, the future coastal horizontal buffer is not applied to the future condition flood hazard layer in this first regional flood plan.

Table 2-4. Sea Level Rise Buffer Estimate

Buffer	Baffin Bay Zone	Baffin Bay - Bluff Zone	Corpus Christi Zone	Copano Zone	Barrier Island – Back Bay Zone
Average Overland Slope (%)	0.34%	2.40%	1.92%	0.16%	0.27%
Estimated Zonal Sea Level Rise Buffer (feet)	324	46	57	688	407

2.2.1.5 Changes to Existing Floodplain Functionality

Floodplains function in natural and beneficial ways by (1) providing storage and conveyance of stormwater, and (2) reducing flood velocities and flood peaks, wind and wave impacts, and soil erosion and sedimentation. Due to the lack of data, no anticipated changes to the existing floodplain functionality are included in this draft 2023 Nueces RFP.

2.2.1.6 Sedimentation in Flood Control Structures and Major Geomorphic Changes

Sedimentation in flood control structures results in the loss of floodplain storage and associated attenuation of flood flows. To understand the impacts on the future flood hazard from sedimentation detailed hydraulic modeling is required. Due to the lack of detailed modeling available in this first flood plan the impacts of sedimentation are not considered in the development of the future flood hazard.

River channels and their adjacent floodplains are dynamic systems that are in a constant state of flux and adjustment to changing patterns of streamflow, sediment loads, and riparian and aquatic ecosystems. Major geomorphic changes can include the migration of river meanders, or the widening or deepening of a river segment. Due to the lack of data, no geomorphic changes in riverine or coastal systems are assumed in the development of the future flood hazard.

2.2.1.7 Completion of Flood Mitigation Projects

The completion of flood mitigation projects has the potential to reduce the future flood hazard. However, the future condition does not include the completion of any flood mitigation projects currently under construction or that already have dedicated construction funding. This is due to the lack of information for flood mitigation projects currently underway in the basin.

2.2.1.8 Future Condition Hydrologic and Hydraulic Model Results

No future condition hydrologic and hydraulic model results have been identified during this draft 2023 Nueces RFP.

2.2.1.9 Future Flood Hazard Mapping

The future condition 1% and 0.2% annual chance flood inundation boundaries are provided in the geodatabase (i.e., FutFldHazard) and depicted on a subregion level in Appendix B8 – TWDB Map 8 - Future Condition Flood Hazard.

2.2.1.10 Future Flood Mapping Gap Analysis

BLE inundation boundary mapping is estimated to be completed for the entire Nueces basin in 2023 according to TWDB's BLE status update viewer. BLE mapping is considered approximate; however, based on the schedule for completion, it is unavailable for 2023 Nueces RFP consideration. No additional detailed modeling and mapping projects can be confirmed for inclusion in the future flood hazard risk layers. Thus, the future flood condition gap boundaries are assumed to be the same as the existing condition gap boundaries (refer to Figure 2-13).

2.2.1.11 Future Condition - Total Land Area at Flood Risk

This flood hazard analysis summarizes total area and agricultural area within the 1% and 0.2% annual chance flood risk under future conditions, which is summarized by county in Appendix A4 – TWDB Table 5 – Future Condition Flood Risk Summary Table. Total land area within the Nueces Flood Planning region at risk of 1% annual chance flood inundation under future conditions is summarized by county and flood risk type (riverine, fluvial, and coastal) in Figure 2-22. In total, 4,629 square miles of land (19.2% of all land in basin) is at risk of 1% annual chance flood inundation under future conditions, an increase of 52 square miles from existing conditions. An additional 1,283 square miles or 5,912 square miles of land (24.5% of all land in basin) is at risk of 0.2% annual chance flood inundation.

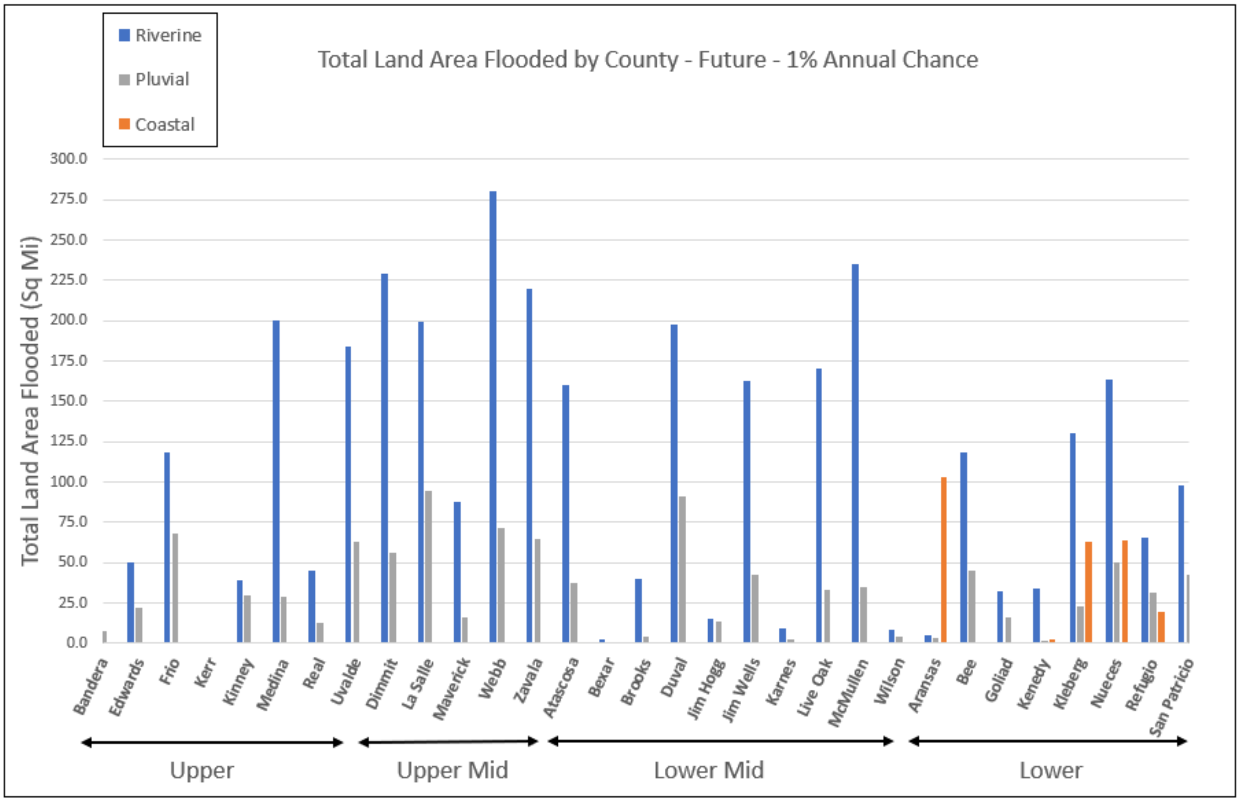


Figure 2-22. Total Land Area at Flood Risk of 1% annual chance storm by Type, County - Future Condition

2.2.2 Future Flood Exposure Analyses

The future flood exposure analysis is a high-level, region-wide, GIS-based analysis to identify who and what might be harmed by flooding. This includes identifying all structures located within both the 1% and 0.2% annual chance flood event and possible flood-prone area boundaries, as defined in the future flood hazard analysis. For additional details, see Appendix A4 – TWDB Table 5 – Future Condition Flood Risk Summary Table, which includes a summary of the land area, number of structures, population, roadway segments and crossings, agriculture area, and critical facilities that are exposed to the future condition 1% and 0.2% annual chance flood risk and possible flood-prone areas.

The future flood exposure analysis indicated approximately 78,000 structures and a population of 191,000 at potential risk of flooding from the 1% annual chance flood event, which is 17,000 more structures than in the existing condition. This grows to 112,000 structures and a population of

The existing condition flood exposure analysis indicated roughly 61,000 structures and a population of 137,000 at potential risk of flooding from the 1% annual chance flood event. This grows to 98,000 structures and a population of 283,000 at potential risk of flooding from the 0.2% annual chance flood event.

However, this does not include the potential construction of new structures built in the floodplain. A heat map illustrates where these structures are generally clustered in the Nueces Flood Planning Region (NFPR), as shown in Figure 2-23. The location of hot spots for flood exposure are similar to those identified in existing conditions.

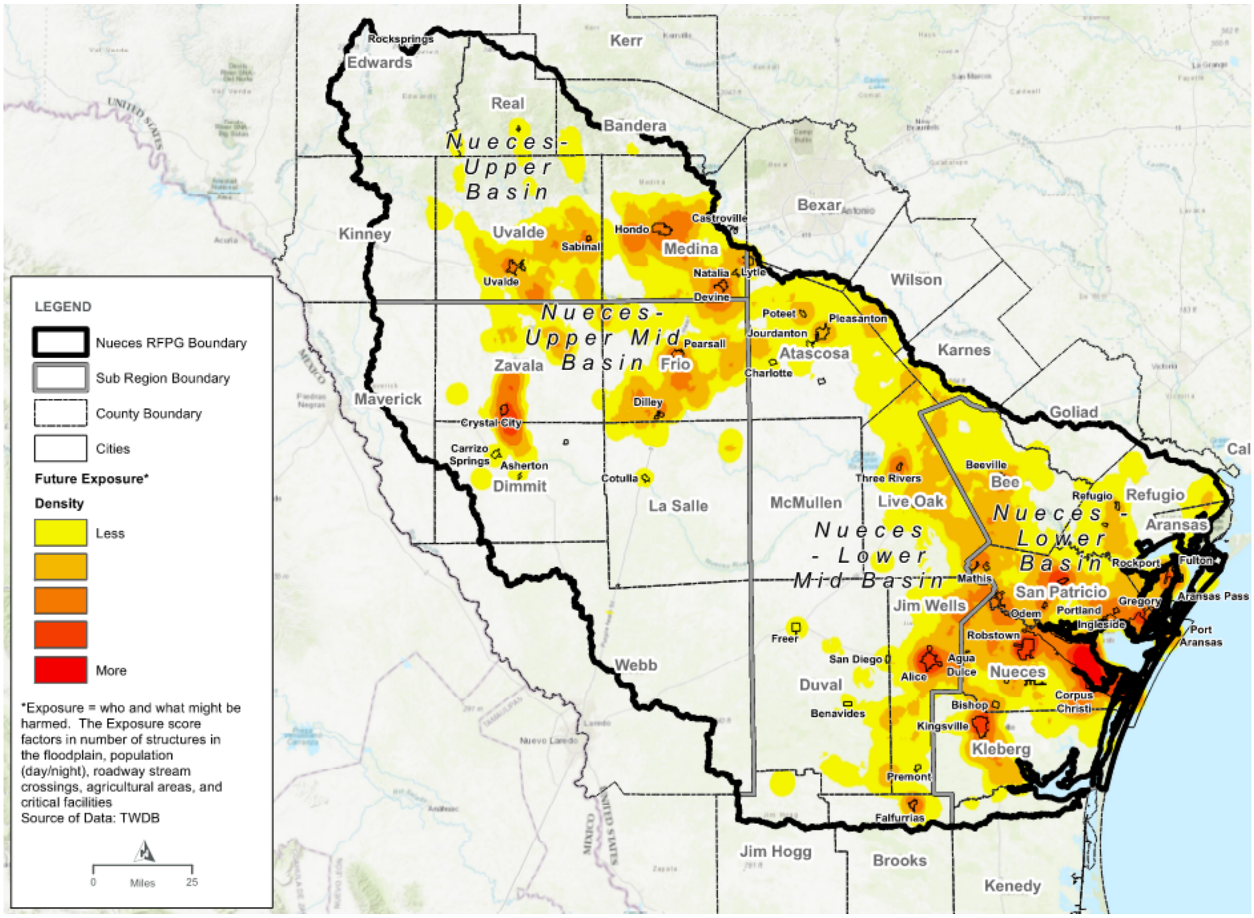


Figure 2-23. Future Condition Exposure Analysis (Map 11)

2.2.3 Future Vulnerability Analysis

The objective of this analysis is to identify critical infrastructure amongst the items identified in the future flood exposure analysis and to compute SVI for each structure identified during the flood exposure analysis.

2.2.3.1 Vulnerabilities of Critical Facilities

The future flood vulnerability analysis identified approximately 642 critical facilities in the 1% annual chance flood inundation. This is an increase of approximately 197 critical facilities when compared to existing conditions. This analysis does not include the potential construction of new critical facilities built in the floodplain. A heat map illustrates where these structures are generally clustered in the NFPR (Figure 2-24).

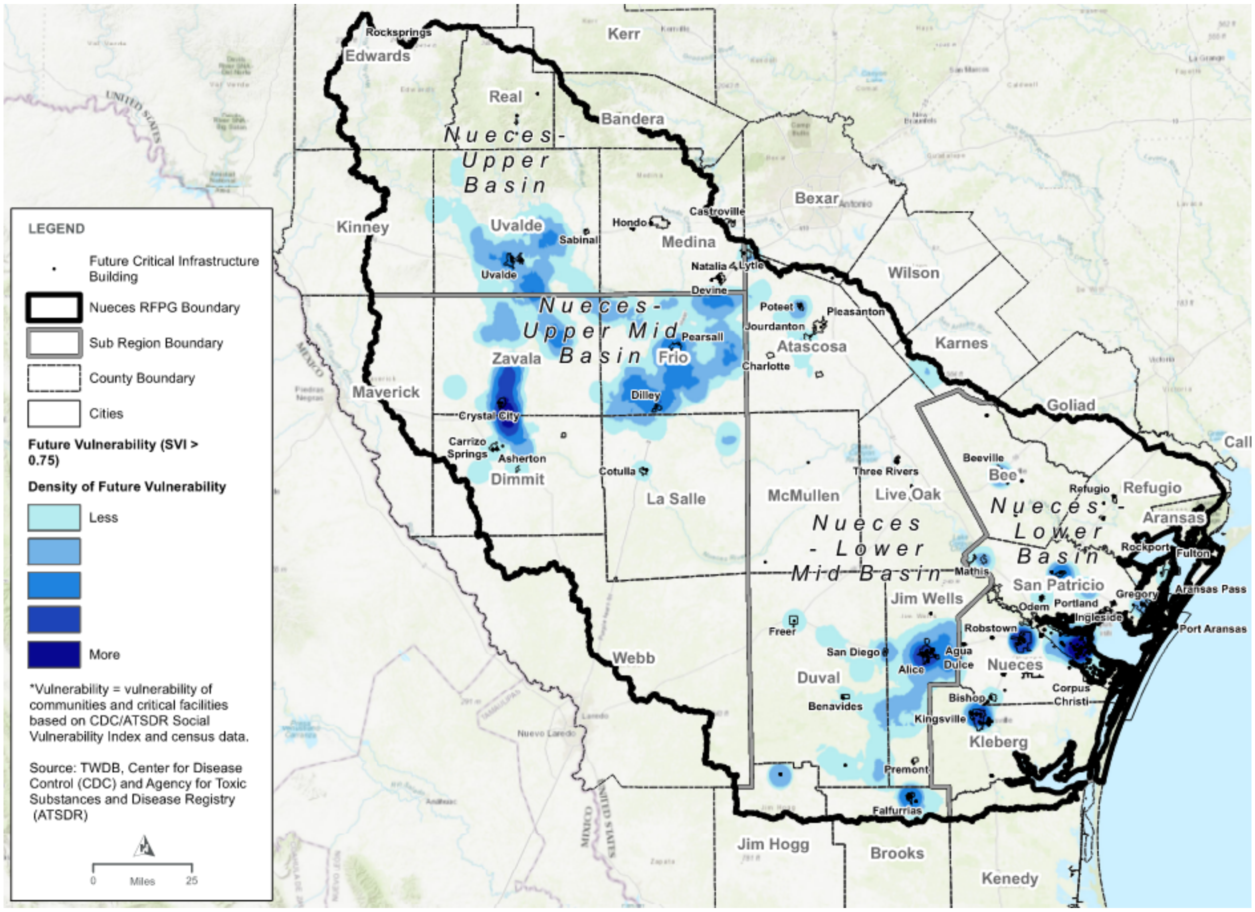


Figure 2-24. Future Condition Vulnerability Heat Map (Map 12)

2.2.3.2 Resilience of Communities in Flood-Prone Areas

Natural disasters, such as flooding, can pose a threat to the community's health and wellbeing. A number of factors, including socioeconomic, access to hospital systems, and crowded housing among others affects a community's resilience and ability to recover. The SVI developed by the CDC and Agency for Toxic Substances and Disease Registry (ATSDR) is a tool that uses U.S. census data to determine the social vulnerability by census tract. This information is then compiled into a database to help emergency response planners and public officials identify and map areas that are most likely to need support before, during, and following a flood event or natural disaster. The average SVI for the future condition floodplain or flood-prone areas per county is provided in Appendix A4 – TWDB Table 5 – Future Condition Flood Risk Summary Table**.** Locations of high SVI areas located in floodplains or flood prone areas are shown in Figure 2-24. The most vulnerable areas to flood risk are similar to those identified in the existing condition.