# 4

# Flood risk



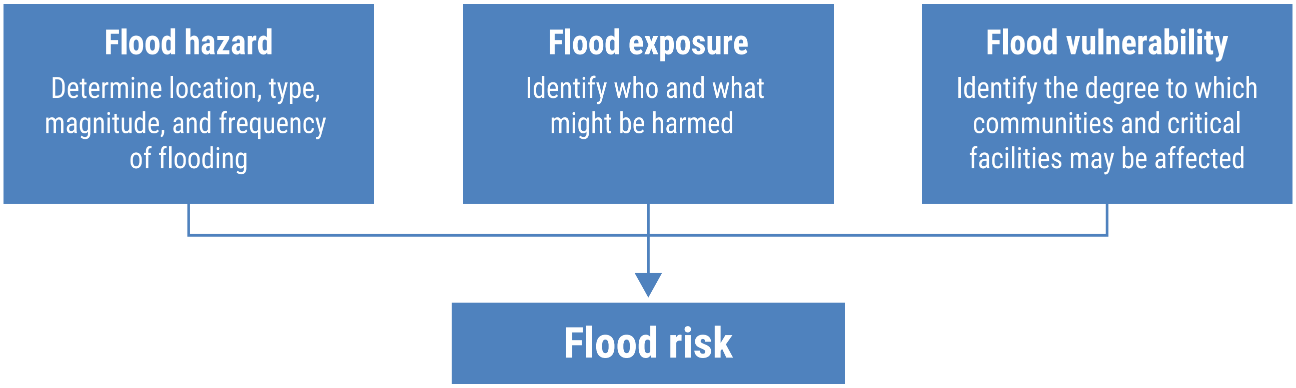
# QUICK **FACTS**

- Approximately 21 percent (56,053 square miles) of Texas' land area (268,597 square miles) is within the 1 percent (100-year) annual chance floodplain.
- Approximately one in every six people in Texas lives or works in known flood hazard areas, including in the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.
- Approximately 2.4 million people live or work in the 1 percent (100-year) annual chance floodplain, and an additional 2.8 million people are in the 0.2 percent (500-year) annual chance floodplain.
- Regional flood planning groups identified 9,322 low water crossings within flood hazard areas.
- Regional flood planning groups identified approximately 878,100 buildings within the 1 percent (100-year) annual chance floodplain, and an additional 786,100 buildings within the 0.2 percent (500-year) annual chance floodplain.
- Planning groups identified 6,258 hospitals, emergency medical services, fire stations, police stations, and schools within the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.
- The projected future conditions 1 percent (100-year) annual chance floodplain is estimated to increase by 11 percent over the existing flood hazard area to a total of 62,245 square miles.
- The regional flood planning groups project an increase of approximately 2.6 million people and 740,000 buildings in the 1 percent annual chance floodplain under projected future condition flood hazard.
- Regional flood planning groups estimate approximately 10,243 low water crossings will be within future condition flood hazard areas.
- An estimated 10,007 hospitals, emergency medical services, fire stations, police stations, and schools are projected to be within the future 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.

Texas unfortunately leads the nation in flood-related property damage and fatalities. The cost of Hurricane Harvey alone is estimated at more than $125 billion (2017 U.S. dollars) in damage, primarily from catastrophic rainfall-triggered flooding in the Houston metropolitan area and Southeast Texas (NOAA, 2024). From 1959 to 2019, there have been 1,069 flood-related deaths in Texas, 570 of which are vehicle-related flood fatalities (Han and Sharif, 2020). Planning for future flood hazards by analyzing flood risk is a highly cost-effective way to identify solutions that will reduce current flood risk and avoid increasing future flood risk.

**Flood risk** is a function of three factors: the specific flood *hazard* (where is it going to flood), the potential *exposure* of people and property to that

*Figure 4-1. The three components of flood risk: hazard, exposure, and vulnerability*




hazard (who and what might flood), and the *vulnerability* of the people and property exposed to that flood hazard (the degree to which a community and/or critical facilities are affected and how quickly and easily they may recover after a flood event). For the purposes of the regional and state flood planning efforts, flood risk analyses comprised a three-step assessment of flood hazard, flood exposure, and vulnerability analyses (Figure 4-1). The greater each component, the greater the overall flood risk. By understanding and addressing each component, we can better manage and reduce flood risk.

The initial round of regional flood planning was the first comprehensive evaluation of flood risk for Texas. While some flood planning regions (Flash Flood Alley and some coastal areas) already had substantial flood hazard data, there were several regions in the Texas Panhandle and West Texas where much of the flood hazard was either unmapped or based on outdated maps. As a result, most of the flood risk across these regions was not well quantified, meaning lives and property were unknowingly within harm's way.

Each of the 15 planning groups completed a comprehensive assessment of flood risk in their regions. Each region performed flood risk analyses for existing conditions, as well as a future conditions scenario that considered potential changes in flood hazards over a 30-year planning horizon.

As reported in the 15 regional flood plans, approximately 21 percent of the state (56,053 square miles) falls within the extent of the 1 percent (100-year) annual chance floodplain, and an additional estimated 4 percent (10,778 square miles) falls within the 0.2 percent (500-year) annual chance floodplain. Approximately 8 percent of the state's population is located within the 1 percent (100-year) annual chance floodplain, and an additional estimated 9 percent is within the 0.2 percent annual chance floodplain (Table 4-1). The planning groups identified 9,322 low water crossings across the state.

## 4.1 Existing flood risk

Recognizing the degree and extent of existing flood risk faced by communities is a fundamental component of comprehensive flood planning; it is impossible to mitigate a risk without understanding or awareness of the possible danger. Using best available information, the regional flood planning groups were required to identify and compile existing flood hazards in their regions, including riverine flooding, urban flooding, coastal flooding, playa flooding, and possible flood prone areas of risk. This required each planning group to consider existing conditions and perform

*Table 4-1. Estimated existing flood risks identified within Texas**

| Flood exposure | 1 percent (100-year) annual chance floodplain | 0.2 percent (500-year) annual chance floodplain[a] | Total |
|---|---|---|---|
| Population | 2,408,600 | 2,811,300 | **5,219,900** |
| Buildings[b] | 878,100 | 786,100 | **1,664,200** |
| Residential buildings | 662,100 | 633,600 | **1,295,700** |
| Hospitals, emergency medical services, fire stations, police stations, and schools | 2,924 | 3,334 | **6,258** |
| Roadway miles | 43,400 | 20,500 | **63,900** |
| Agricultural area (acres) | 10,200,000 | 2,454,000 | **12,654,000** |

** Compilation of data as reported by the regional flood planning groups; statistics are rounded.*

*[a] In addition to flood risk in 1 percent annual chance floodplain.*

*[b] Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown.*

1. flood hazard analyses that determine location, type, magnitude, and frequency of flooding;
2. flood exposure analyses to identify who and what might be harmed within the region; and
3. vulnerability analyses to identify vulnerabilities of communities and critical facilities.

To accomplish this, the planning groups first collected and considered flood hazard information of varying quality and age from a wide variety of sources and, when possible, enhanced the data with additional local stakeholder input. The planning groups then built a comprehensive existing flood hazard dataset based on the collected assortment of information.

Then they used the existing flood hazard dataset to identify who and what may be exposed to those existing flood hazards as well as the vulnerabilities of those communities.

### 4.1.1 Existing condition flood hazard

The Texas Water Development Board (TWDB) provided a foundational flood hazard dataset for the planning groups using a variety of existing condition flood hazard information, including Federal Emergency Management Agency (FEMA) regulatory effective products, base level engineering floodplains, and cursory (approximate) floodplain information developed for the TWDB. The planning groups identified additional flood prone areas based on local knowledge of previous flood events acquired from public meetings, online surveys, and other outreach efforts.

To support and accelerate the new regional planning process, the TWDB developed a **floodplain "quilt"** and provided this to the planning groups as a common starting point for riverine and coastal flood risk data within their regions. While the TWDB also provided an initial ranking, or hierarchy, of these flood planning datasets within the quilt, each flood planning group was expected to confirm, modify, and/or otherwise enhance the initial floodplain quilt information as appropriate to support its flood risk analyses. The following floodplain quilt datasets were made available to the planning groups and others through the TWDB's Flood Planning Data Hub:[28]

- **FEMA mapping**: The floodplain quilt utilizes FEMA's **National Flood Hazard Layer**, including effective, pending, and preliminary flood hazard data known as **Flood Insurance Rate Maps**, as the best available dataset, where available. The National Flood Hazard Layer is made from effective flood maps and covers more than 90 percent of the U.S. population (FEMA, 2021). According to FEMA's National Flood Hazard Layer data, out of the 254 counties in Texas, 133 counties have Flood Insurance Rate Maps (FEMA, 2024).

[28] www.twdb-flood-planning-resources-twdb.hub.arcgis.com/

- **Base level engineering**:[29] An automated riverine hydrologic and hydraulic modeling approach that builds on lessons learned to produce a baseline understanding of a community's flood risk. Where available, base level engineering is meant to complement the current effective Flood Insurance Rate Map data but not replace it.
- **Digitized paper Flood Insurance Rate Maps**: Dataset that covers portions of the state where no digital Flood Insurance Rate Map data has been created and is not available on the National Flood Hazard Layer.
- **Cursory floodplain data**: The TWDB acquired statewide cursory floodplain data through a contract with Fathom that filled any remaining data gaps. This flood risk data includes complete, but approximate, flood risk coverage for Texas developed from very large nationwide 2-D hydrodynamic modeling data. A publicly available early derivative of this data, called Flood Factor, is published by First Street Foundation.[30]

Planning groups also used the following additional datasets to support flood hazard analysis:

- **Local studies**: Regional or local flood risk data not currently available to the TWDB and therefore not included in the floodplain quilt datasets. There are many parts of Texas where regional or local entities have better-quality flood risk data than any other listed sources.
- **U.S. Army Corps of Engineers or other federal data**
- **Land cover data**: Watershed runoff is greatly impacted by land cover conditions, including development and soil information. Soil properties influence the relationship between rainfall and runoff because different soils have varying rates of infiltration. Land use affects such hydrologic processes as evapotranspiration, interception, and infiltration. As urban development (impervious cover) is added to a watershed, the hydrologic response is changed, and surface runoff often increases. While not as prolific as urban development, cultivated agricultural and grazed land use results in increased levels of runoff in a watershed and, therefore, increased existing flood risk, as compared to natural forested and woodland ground cover. The rate of development and land use change in Texas necessitates updated floodplain modeling to adequately estimate flood risk.
- **Rainfall data**: Accurate rainfall data is crucial to mapping the existing flood risk condition. The TWDB recommended that **Atlas 14** rainfall data be used for flood modeling associated with the state flood planning efforts. When applicable, each planning group utilized the Atlas 14 rainfall dataset to inform its flood hazard areas based on the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood events. Atlas 14 indicates that the 1 percent annual chance 24-hour rain event may be greater than what we previously considered in many areas. The greatest rainfall changes occur along the Texas coast and in Central Texas.

Using these datasets, the planning groups were required to consider the following for their flood hazard analyses:

1. **Riverine flooding** caused by bank overtopping when the flow capacity of rivers 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.
2. **Pluvial flooding**, including 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 carry it away. The inflow of stormwater results from (a) heavy rainfall, which can collect on the landscape (pluvial flooding) or cause rivers and streams to overflow their banks and

[29] https://webapps.usgs.gov/fema/ble_firm/

[30] https://firststreet.org/methodology/flood

inundate surrounding areas; or (b) storm surge or high tides, which push water onto coastal cities. Floodwater inundation and movement are influenced by (a) land development, which disturbs natural drainage patterns and creates hardened, impervious surfaces that inhibit infiltration of stormwater; and (b) stormwater systems that are undersized for current needs and thus increase exposure to drainage hazards.

3. **Coastal flooding**, which occurs when normally dry, low-lying land is flooded by seawater. Coastal flooding can be caused by high-tide events, storm surges, and wind-driven waves. Relative sea level rise exacerbates these drivers, leading to more frequent coastal inundation and more destructive flooding events (Sweet and others, 2014).
4. **Other possible flood prone areas** are areas that have not been previously identified as mapped flood hazard areas but that were captured in the regional flood planning process through other means, including local knowledge of historic flooding. To collect this information from stakeholders, planning groups utilized interactive web maps and information gathered during public meetings to identify flood prone areas. Additional methods for collecting this information included the following:
    - Delineation of low water crossings outside of the known and mapped 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.
    - The use of historical flood data to identify flood prone areas outside of known and mapped 1 percent and 0.2 percent annual chance floodplains.
    - Identification of areas subject to inundation from reservoirs and levees. Dam breach inundation areas (downstream) were also included where data was publicly available.

The flood hazard analyses revealed the locations and extent of flood hazard areas that are subject to flooding during 1 percent (100-year) and 0.2 percent (500-year) annual chance flood events (Figure 4-2) and known flood prone areas (Figure 4-3). This flood hazard analysis shows that the flood risk across Texas is significant and widespread with almost one-fourth of Texas' land area (66,831 square miles) in either the 1 percent or 0.2 percent annual chance flood hazard areas, with approximately 21 percent of the land area (56,053 square miles) within the 1 percent annual chance flood hazard areas. An additional 603 square miles are identified as flood prone areas through stakeholder feedback where the annual chance of flooding is reported as unknown (Table 4-2).

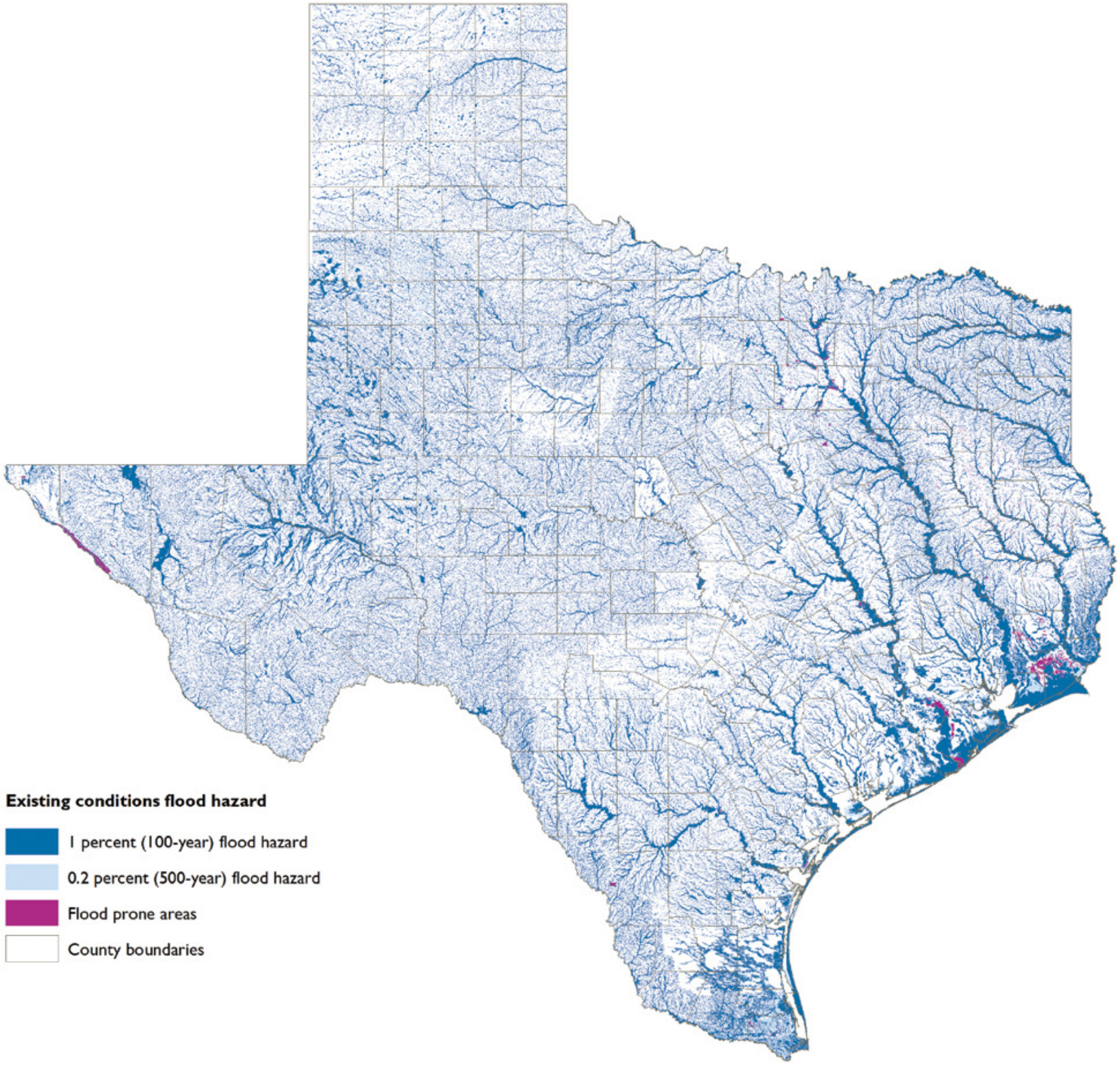
This effort is not regulatory in nature, and the results of this evaluation have no impact on National Flood Insurance Program insurance requirements or premiums. Rather, this exercise is intended to gather a comprehensive set of best available information reflecting actual, statewide flood risk to improve communities' understanding of their current risks and to better prepare for future flood events.

### 4.1.2 Gaps in available flood risk data

Once planning groups completed flood hazard analysis, including collecting all known flood hazard locations and previously documented flood prone areas, they could determine the geographic areas that represented gaps or need for additional analyses in flood hazard information. They did this primarily through stakeholder input. The gap analyses identified areas that had outdated or non-existent modeling and/or mapping, which the planning groups later utilized to identify potential flood management evaluations, described in Chapter 7 of this plan.

Not surprisingly, gap analyses revealed that some flood planning regions are far more "data rich" than others, meaning up-to-date mapping and modeling are available for most of the key areas in the region. These regions include Region 6 San Jacinto, Region 11 Guadalupe, and Region 12 San Antonio. By contrast, other planning regions,

*Figure 4-2. Locations of flood hazards under existing conditions*




including those in the Texas Panhandle, West Texas, and East Texas, have significantly more data gaps (Figure 4-4).

Floodplain data gaps generally included the absence of detailed hydraulic and hydrologic modeling, modernized data, and broad coverage of digitized flood hazard information from previously published sources. Outdated information included studies over 10 years old, approximate data, outdated modeling software, base level flood elevation data, outdated FEMA maps, and inadequate flood risk mapping. According to FEMA's National Flood Hazard Layer data, of the 133 counties that do have Flood Insurance Rate Maps, four are only partially mapped. There are 121 counties in Texas that do not have any effective Flood Insurance Rate Maps (FEMA, 2024).

Updates were also needed for significant land use changes, new flood control structures, alterations in channel geometry, or changes in rainfall pattern based on Atlas 14 data.

*Figure 4-3. Example of known flood prone areas*

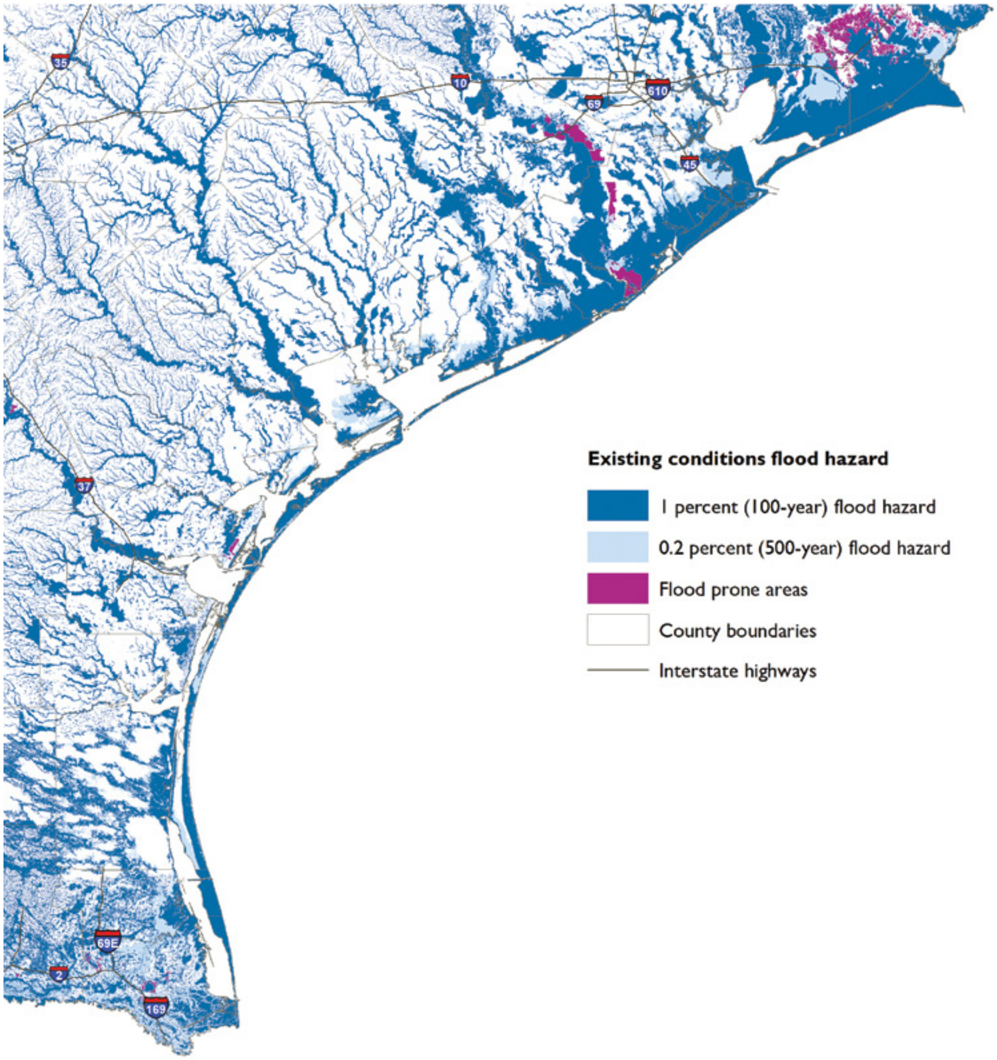
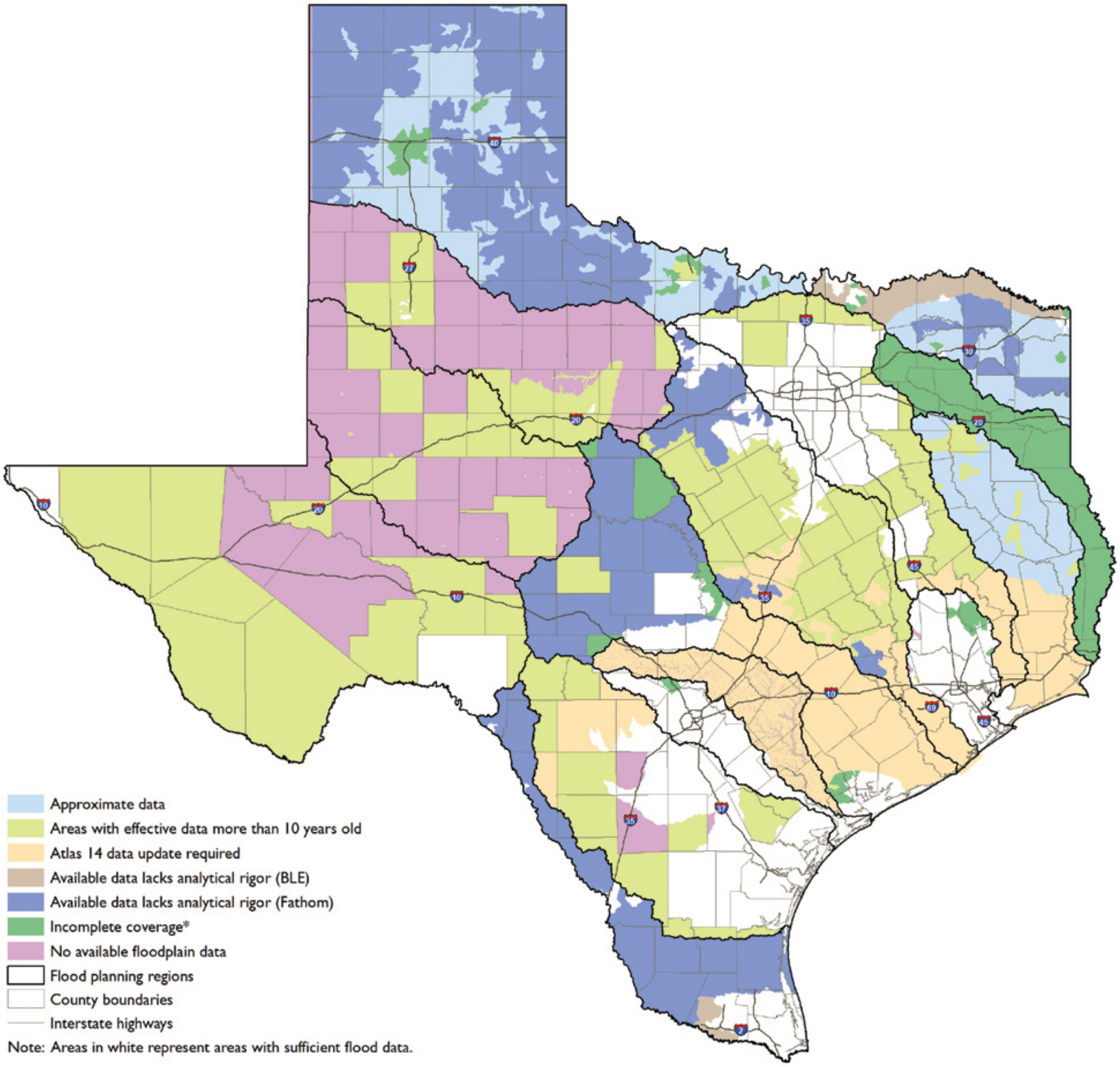



*Table 4-2. Identified existing flood hazard areas (square miles) by flood planning region*

| Region | 1 percent (100-year) annual chance floodplain | 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) | Total |
|---|---|---|---|---|
| 1 | 4,305.21 | 929.65 | 0.24 | **5,235.10** |
| 2 | 2,820.71 | 115.16 | | **2,935.87** |
| 3 | 4,882.12 | 451.21 | 103.91 | **5,437.24** |
| 4 | 2,310.67 | 176.21 | | **2,486.88** |
| 5 | 3,078.52 | 374.32 | 261.91 | **3,714.75** |
| 6 | 1,485.56 | 471.48 | 1.25 | **1,958.29** |
| 7 | 3,634.37 | 1,393.99 | | **5,028.36** |
| 8 | 4,688.02 | 485.21 | 106.18 | **5,279.41** |
| 9 | 4,521.09 | 1,127.23 | | **5,648.32** |
| 10 | 4,514.84 | 723.23 | | **5,238.07** |
| 11 | 985.62 | 182.84 | 1.27 | **1,169.73** |
| 12 | 800.20 | 124.34 | 0.05 | **924.60** |
| 13 | 4,577.86 | 1,287.41 | 8.32 | **5,873.59** |
| 14 | 9,284.72 | 1,755.47 | 98.58 | **11,138.77** |
| 15 | 4,163.14 | 1,180.61 | 21.38 | **5,365.12** |
| **Total** | **56,052.64** | **10,778.35** | **603.09** | **67,434.09** |

*Figure 4-4. Flood map gaps and data quality identified by the planning groups*




** "Incomplete coverage" is composed of several map coverage deficiencies identified by the regions, including: <50 percent detailed study; additional reach floodplain modeling recommended by the client; detailed FEMA mapping is only associated with the main reach for the watershed; detailed study covers less than half of watershed; incomplete coverage of recent, detailed mapping; lacks effective FEMA mapping near areas of recent development or floodplain road crossings; no 0.2 percent (500-year) exists.*

### 4.1.3 Existing condition flood exposure

After identifying flood hazard locations based on the best available information, the planning groups developed analyses to identify who and what might be in harm's way and to determine if they are located within any flood risk or flood prone areas.

All structures and populations located within the 1 percent (100-year) annual chance floodplain, 0.2 percent (500-year) annual chance floodplain, and flood prone areas were determined by intersecting the flood hazard layer with GIS data features, including buildings, roadways, population estimates, agricultural areas, etc.

*Table 4-3. Summary of statewide existing condition flood exposure*

| Flood exposure | 1 percent (100-year) annual chance floodplain | 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) | Total |
|---|---|---|---|---|
| Population | 2,408,561 | 2,811,347 | 665,911 | **5,885,819** |
| Buildings[a] | 878,098 | 786,132 | 125,610 | **1,789,840** |
| Residential buildings | 662,107 | 633,563 | 106,305 | **1,401,975** |
| Roadway stream crossings (including low water crossings) | 69,839 | 7,669 | 1,012 | **78,520** |
| Roadway miles | 43,444 | 20,468 | 1,856 | **65,768** |
| Agricultural areas (acre) | 10,200,323 | 2,453,832 | 51,695 | **12,705,850** |
| Critical facilities[b] | 6,153 | 8,252 | 693 | **15,098** |
| Hospitals, emergency medical services, fire stations, police stations, and schools | 2,924 | 3,334 | 401 | **6,659** |

*Note: All values are counts unless otherwise labeled.*

*[a] Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown.*

*[b] Critical facilities include hospitals, emergency medical services, fire stations, police stations, schools, shelters, power generation, and water and wastewater treatment plants.*

The exposure analyses performed by the regional flood planning groups identified all buildings located in the flood hazard areas; however they did not take the finished floor elevation of a building and flooding depth into account. Therefore, the number of buildings within flood hazard areas identified by the flood planning groups using two-dimensional analyses may be higher than the number of buildings identified using flood elevation (three-dimensional analyses). Therefore, the number of buildings at risk of flooding during a particular storm event is lower than the number of buildings located in the flood hazard area.

The TWDB is currently working to generate statewide damage estimates from these flood risk assessments as a part of a new, broader flood analytics initiative seeking to leverage new statewide flood hazard data. These hazard datasets include information such as water surface elevation, flood depths, and flood extents for a variety of annual chance flood events (10-year through 500-year). By combining these datasets with exposure datasets such as building footprints, flood risk can be expressed in monetary terms such as average annualized losses. While the overall initiative is envisioned to be ongoing and longer-term, the TWDB has conducted some initial testing on software tools to assess their capabilities and feasibility of developing statewide flood risk assessments.

This preliminary analysis was performed on the entire state of Texas using the 1 percent (100-year) flood fluvial depth grid from the cursory floodplain dataset. The estimated flood damage statewide is about $32 billion. This effort identified about 410,000 buildings within the 1 percent annual chance floodplain that may experience flood damage. Damage to residential buildings accounts for about 81 percent of the total flood damage amount. These results should be considered as very preliminary and subject to change and are being provided for general informational purposes. Being exposed to a hazard does not automatically mean harm will occur, but identifying flood hazard exposure helps determine the overall flood risk. For example, a building located within a 0.2 percent (500-year) annual chance floodplain may be exposed to but not vulnerable to a flood hazard if it is elevated and fortified specifically against the threat of flooding.

The flood exposure analyses considered available datasets and different types of developments within flood hazard areas to estimate the existing flood hazard exposure (Table 4-3), including the following:

*Table 4-4. Populations within existing flood hazard areas by flood planning region**

| Region | Population within 1 percent (100-year) annual chance floodplain | Population within 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) population | Total |
|---|---|---|---|---|
| 1 | 29,996 | 38,834 | 161 | **68,991** |
| 2 | 37,963 | 4,610 | | **42,573** |
| 3 | 241,489 | 444,808 | 319,858 | **1,006,155** |
| 4 | 65,006 | 25,551 | | **90,557** |
| 5 | 65,717 | 92,558 | 89,118 | **247,393** |
| 6 | 785,857 | 919,945 | 2,204 | **1,708,006** |
| 7 | 63,447 | 54,412 | | **117,859** |
| 8 | 129,887 | 133,705 | 197,630 | **461,222** |
| 9 | 83,020 | 40,357 | | **123,388** |
| 10 | 155,127 | 97,279 | | **252,406** |
| 11 | 63,857 | 52,575 | 696 | **117,128** |
| 12 | 67,738 | 22,812 | 26 | **90,576** |
| 13 | 144,054 | 100,356 | 9,090 | **253,500** |
| 14 | 115,530 | 47,985 | 35,740 | **199,255** |
| 15 | 359,873 | 735,560 | 11,388 | **1,106,821** |
| **Total** | **2,408,561** | **2,811,347** | **665,911** | **5,885,819** |

*Note: Blank cells do not always signify the absence of populations within flood hazard areas; they may indicate that such populations were not identified or reported by the regional flood planning groups.*

** Values represent the maximum daytime or nighttime population provided by the regional flood planning groups.*

1. Population
2. Buildings, including residential and nonresidential
3. Critical facilities
4. Roadways, including the estimated number of roadway stream crossings, low water crossings, and the total length of roadway
5. Agricultural areas, including the total area of farms and ranches

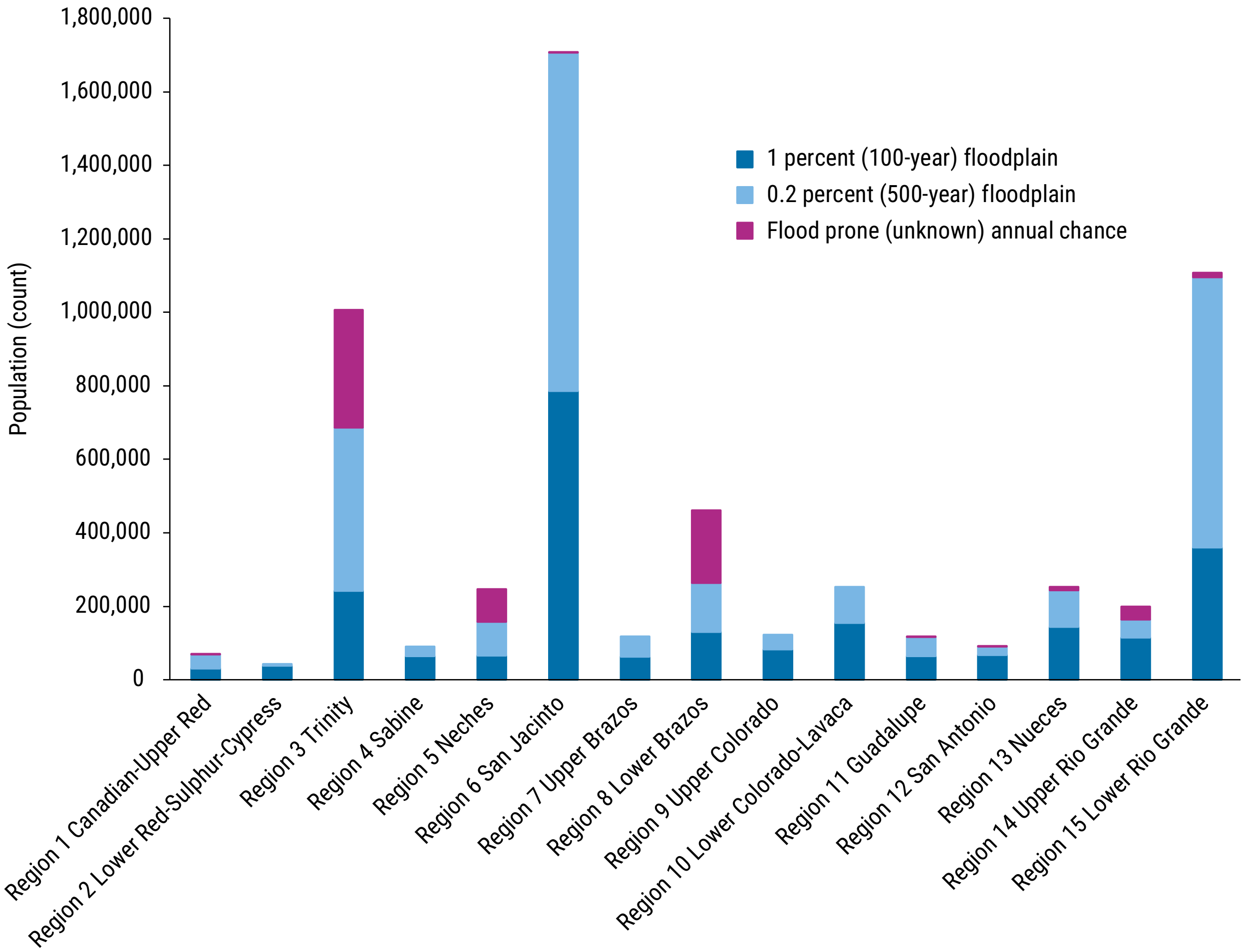
## Population

All planning groups were required to include daytime and nighttime population estimates located within the 1 percent (100-year) annual chance floodplain, 0.2 percent (500-year) annual chance floodplain, and flood prone areas. The higher of the day and night estimates per county was utilized in estimating the total population potentially exposed to flood hazards. The regional planning groups calculated that an estimated 5,885,830 people are potentially exposed to existing flood hazards. Of those, 2,408,561 people were identified within the 1 percent, 2,811,347 within the 0.2 percent, and 665,911 within the flood prone areas (Table 4-4). Figure 4-5 and Figure 4-6 illustrate the populations potentially exposed to flood hazard areas by flood planning region and county, respectively.

## All buildings

The existing flood exposure analyses identified an estimated 1,789,840 buildings within identified flood hazard areas, of which 878,098 were identified within the 1 percent (100-year) flood hazard area, an additional 786,132 within the 0.2 percent (500-year) flood hazard area, and 125,610 more within the flood prone area (Table 4-5, Figure 4-7, and Figure 4-8). Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown. A high number of agricultural buildings are located in flood hazard areas throughout the state, including barns, livestock operations, and grain silos, etc.

*Figure 4-5. Populations within existing flood hazard areas by flood planning region*




## Residential buildings

Planning group analyses of existing flood exposure differentiated residential buildings from other types of structures within the 1 percent (100-year) annual chance floodplain, 0.2 percent (500-year) annual chance floodplain, and flood prone areas. The planning groups identified 662,107 residential buildings within the 1 percent, 633,563 additional residential buildings within the 0.2 percent, and 106,305 more in the flood prone areas (Table 4-6, Figure 4-9, and Figure 4-10).

## Roadways/transportation at flood risk

Approximately 70 percent of flood-related fatalities occur on roadways (TXDOT, 2024). Flooded roadways pose a direct threat to motorists, as demonstrated by the number of flood-related fatalities that have occurred when vehicles are driven into hazardous floodwaters. Texas consistently leads the nation in flood deaths, and the majority of those deaths are in vehicles. Inundated roadways pose indirect threats to those attempting to escape from flooding, first responders, and flood victims trying to reach critical facilities. Many accidents, rescues, and deaths occur at low water crossings, and most occur at night. Determining the roadway crossings located in flood hazard areas required considering the water surface elevations during storm events and the deck elevation of the roadway crossing. The regional flood planning groups identified the number of low water crossings amongst all the roadway crossings in 1 percent (100-year) annual chance floodplains.

*Figure 4-6. Populations within existing flood hazard areas by county*

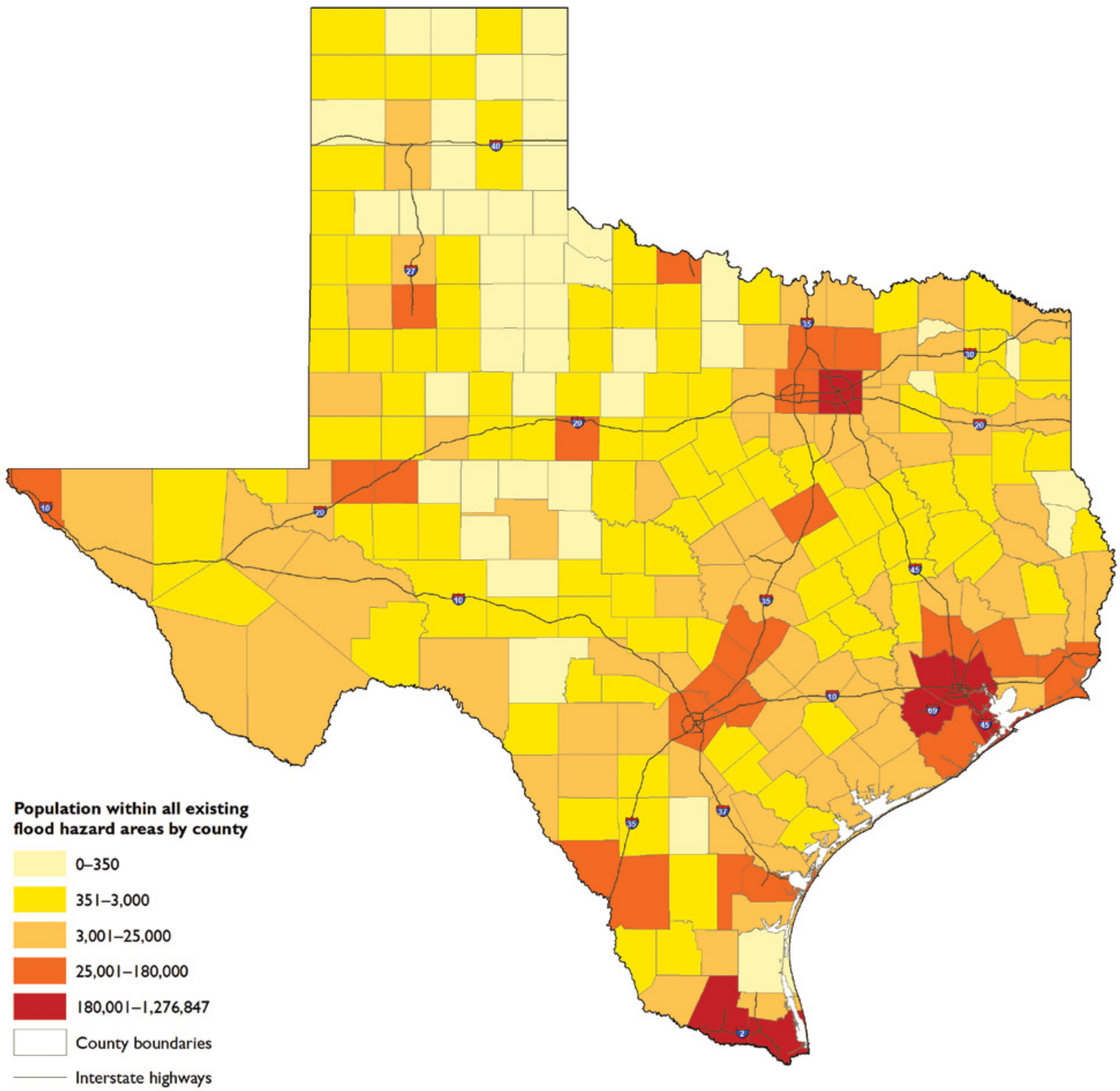


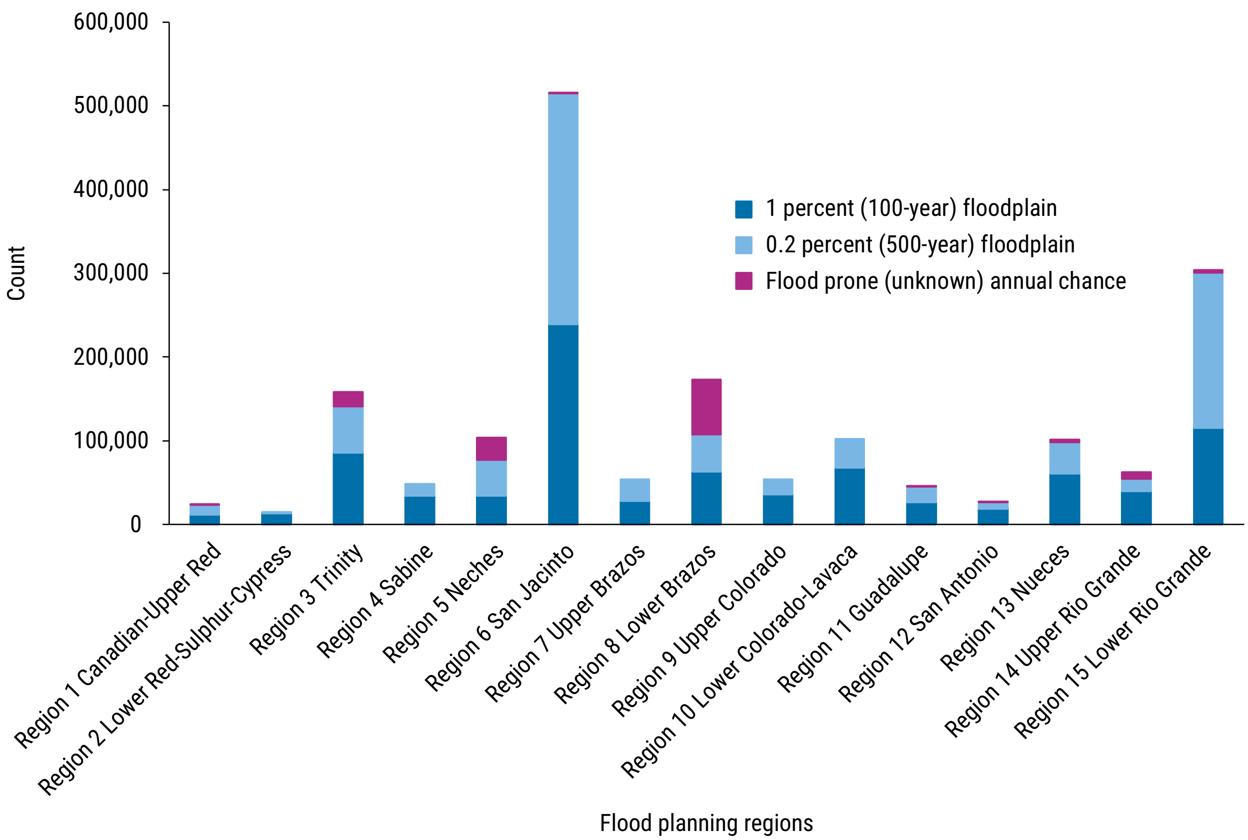
*Table 4-5. Buildings within existing flood hazard areas by flood planning region**

| Region | Buildings within 1 percent (100-year) annual chance floodplain | Buildings within 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) buildings | Total |
|---|---|---|---|---|
| 1 | 11,544 | 12,170 | 88 | **23,802** |
| 2 | 13,438 | 1,585 | | **15,023** |
| 3 | 85,859 | 55,581 | 16,839 | **158,279** |
| 4 | 34,592 | 14,111 | | **48,703** |
| 5 | 34,624 | 42,901 | 26,524 | **104,049** |
| 6 | 239,484 | 275,283 | 827 | **515,594** |
| 7 | 28,531 | 25,555 | | **54,086** |
| 8 | 63,056 | 44,662 | 65,586 | **173,304** |
| 9 | 36,333 | 17,269 | | **53,602** |
| 10 | 67,824 | 34,477 | | **102,301** |
| 11 | 27,069 | 18,447 | 285 | **45,801** |
| 12 | 19,113 | 7,529 | 10 | **26,652** |
| 13 | 60,934 | 37,147 | 3,591 | **101,672** |
| 14 | 40,121 | 14,290 | 8,426 | **62,837** |
| 15 | 115,576 | 185,125 | 3,434 | **304,135** |
| **Total** | **878,098** | **786,132** | **125,610** | **1,789,840** |

*Note: Blank cells do not always signify the absence of buildings within flood hazard areas; they may indicate that such buildings were not identified or reported by the regional flood planning groups.*

** Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown.*

*Figure 4-7. Buildings within existing flood hazard areas by flood planning region**




** Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown.*

*Figure 4-8. Locations of buildings and other resources within existing flood hazard areas*

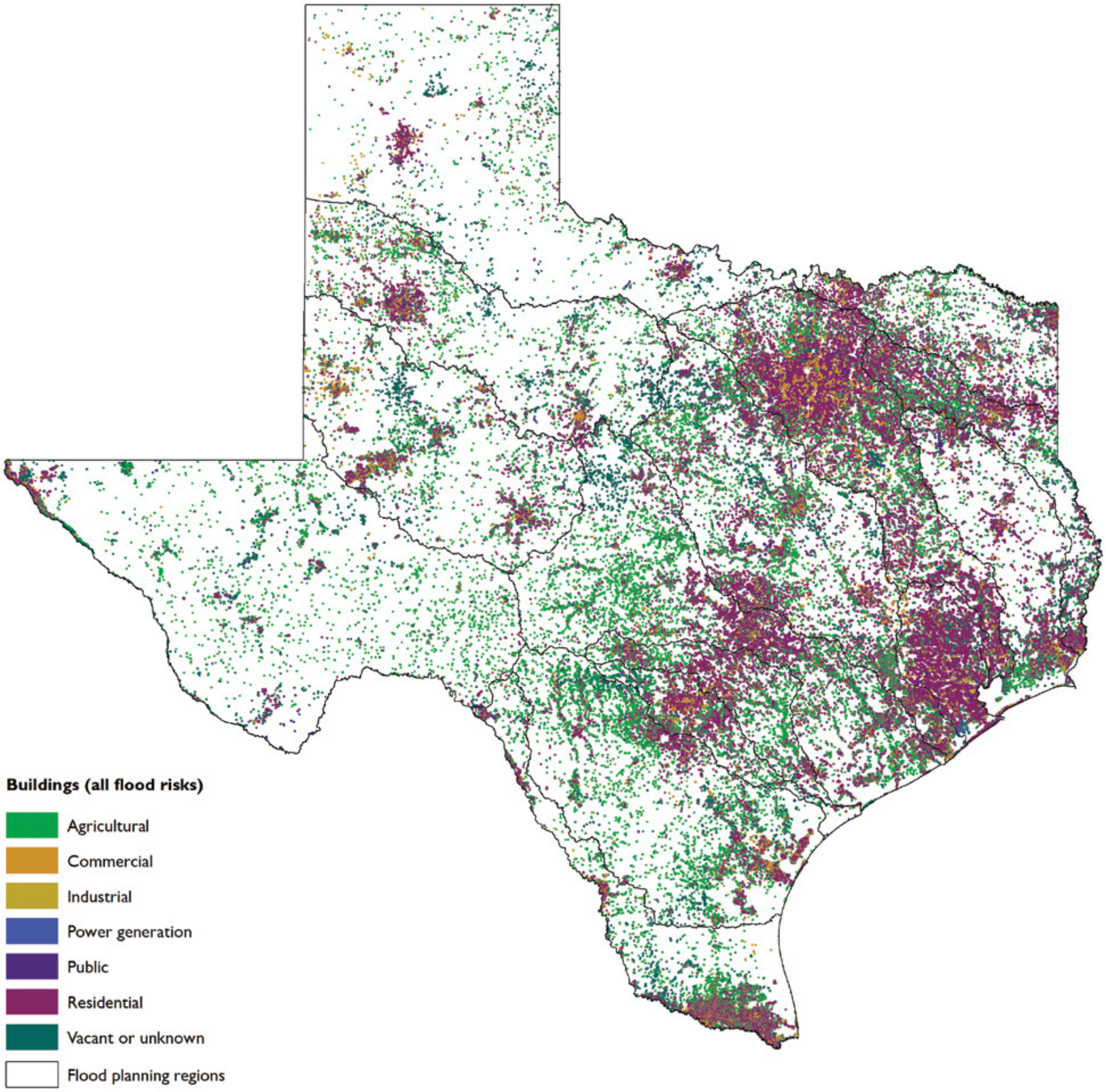


*Table 4-6. Residential buildings within existing flood hazard areas by flood planning region*

| Region | Residential buildings within 1 percent (100-year) annual chance floodplain | Residential buildings within 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) residential buildings | Total |
|---|---|---|---|---|
| 1 | 6,885 | 8,622 | 61 | **15,568** |
| 2 | 8,069 | 1,012 | | **9,081** |
| 3 | 72,930 | 36,454 | 12,636 | **122,020** |
| 4 | 24,066 | 10,773 | | **34,839** |
| 5 | 25,145 | 35,176 | 21,563 | **81,884** |
| 6 | 199,789 | 242,715 | 760 | **443,264** |
| 7 | 19,838 | 17,170 | | **37,008** |
| 8 | 42,646 | 36,523 | 59,595 | **138,764** |
| 9 | 23,637 | 11,848 | | **35,485** |
| 10 | 45,799 | 25,444 | | **71,243** |
| 11 | 18,879 | 12,952 | 271 | **32,102** |
| 12 | 13,692 | 5,519 | 8 | **19,219** |
| 13 | 42,976 | 27,730 | 2,319 | **73,025** |
| 14 | 24,931 | 9,106 | 6,168 | **40,205** |
| 15 | 92,825 | 152,519 | 2,924 | **248,268** |
| **Total** | **662,107** | **633,563** | **106,305** | **1,401,975** |

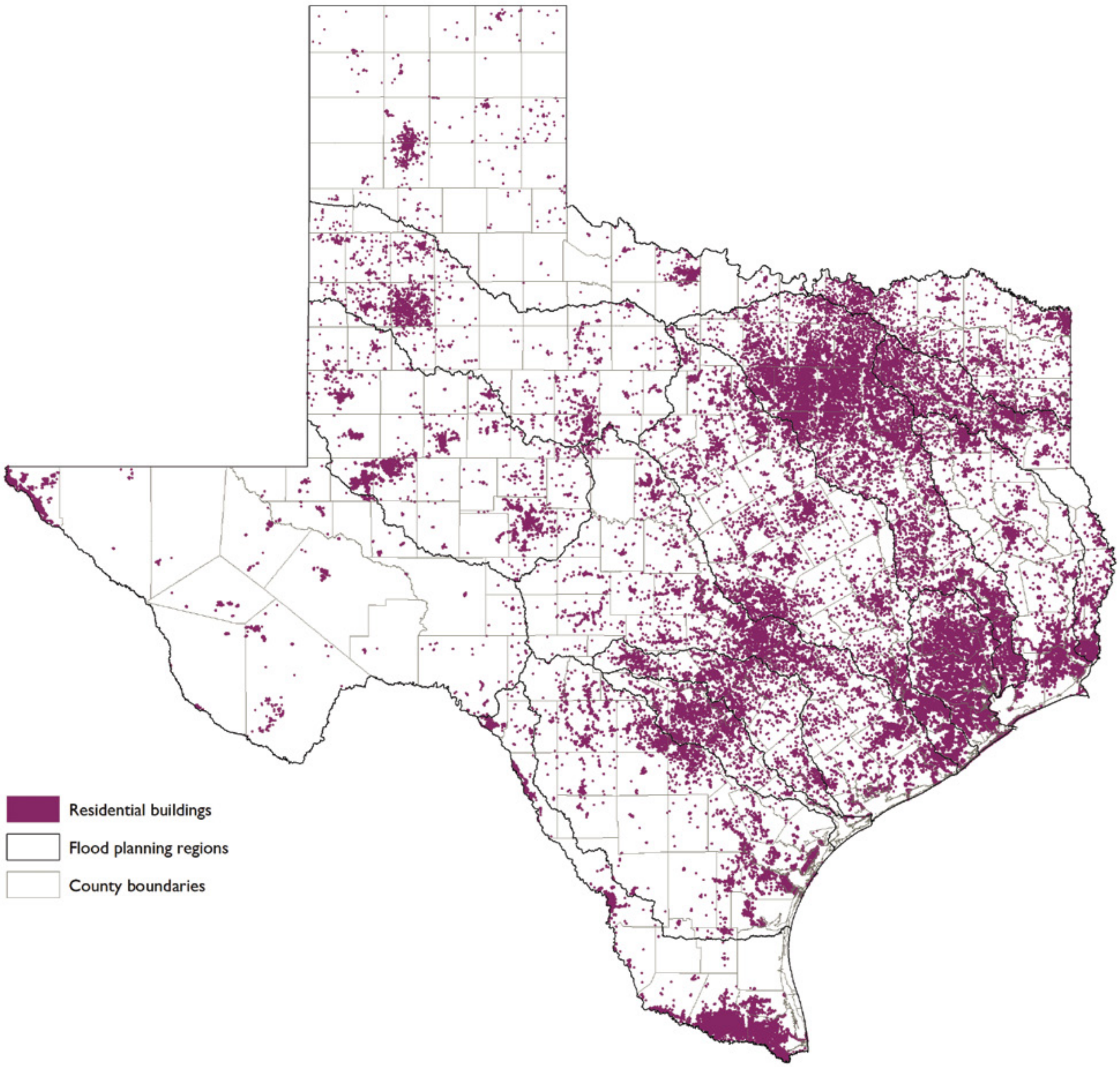
*Note: Blank cells do not always signify the absence of structures in the floodplain; they may indicate that such structures were not identified or reported by the regional flood planning groups.*

Some planning groups used roadway data from the Texas Department of Transportation and other sources to assess the potential impacts on transportation infrastructure in their regions that could result from 1 percent (100-year) or 0.2 percent (500-year) annual chance flood events. The Region 3 Trinity planning group used remote sensing, or LiDAR data, to determine bridge deck elevation and estimate flood exposure of road and railroad bridges at stream crossings. During the first planning cycle, most regional flood planning groups did not consider the deck elevation of the roadway crossing in determining whether it is in the flood hazard area. The results of the planning groups' analyses on roadways are presented in Figure 4-11.

**Roadway stream crossings**: The planning groups identified each instance of roadway stream crossing by intersecting the roadway layers with streams and flood hazard layers, and they reported the roadway stream crossings within the 1 percent (100-year) annual chance floodplain, 0.2 percent (500-year) annual chance floodplain, and flood prone areas. The roadway stream crossings may or may not have been classified as low water crossings. A roadway stream crossing is any instance where a road crosses a stream, regardless of roadway elevation or structure type. This can include elevated bridges, box culverts, and traditional low water crossings. The flood planning groups identified 69,839 roadway crossings in the 1 percent annual chance floodplain, 7,669 in the 0.2 percent annual chance floodplain, and 1,012 in flood prone areas.

**Low water crossings** are a subset of roadway stream crossings that are subject to frequent inundation during storm events or subject to inundation during a 50 percent (2-year) annual chance storm event. During the first planning cycle, the regional flood planning groups had the flexibility to utilize the community's discretion to identify a roadway stream crossing as a low water crossing. Low water crossings have elevations where water overtops the roadway frequently, making the roadway impassable even during smaller storm events. In the flood exposure analyses, a

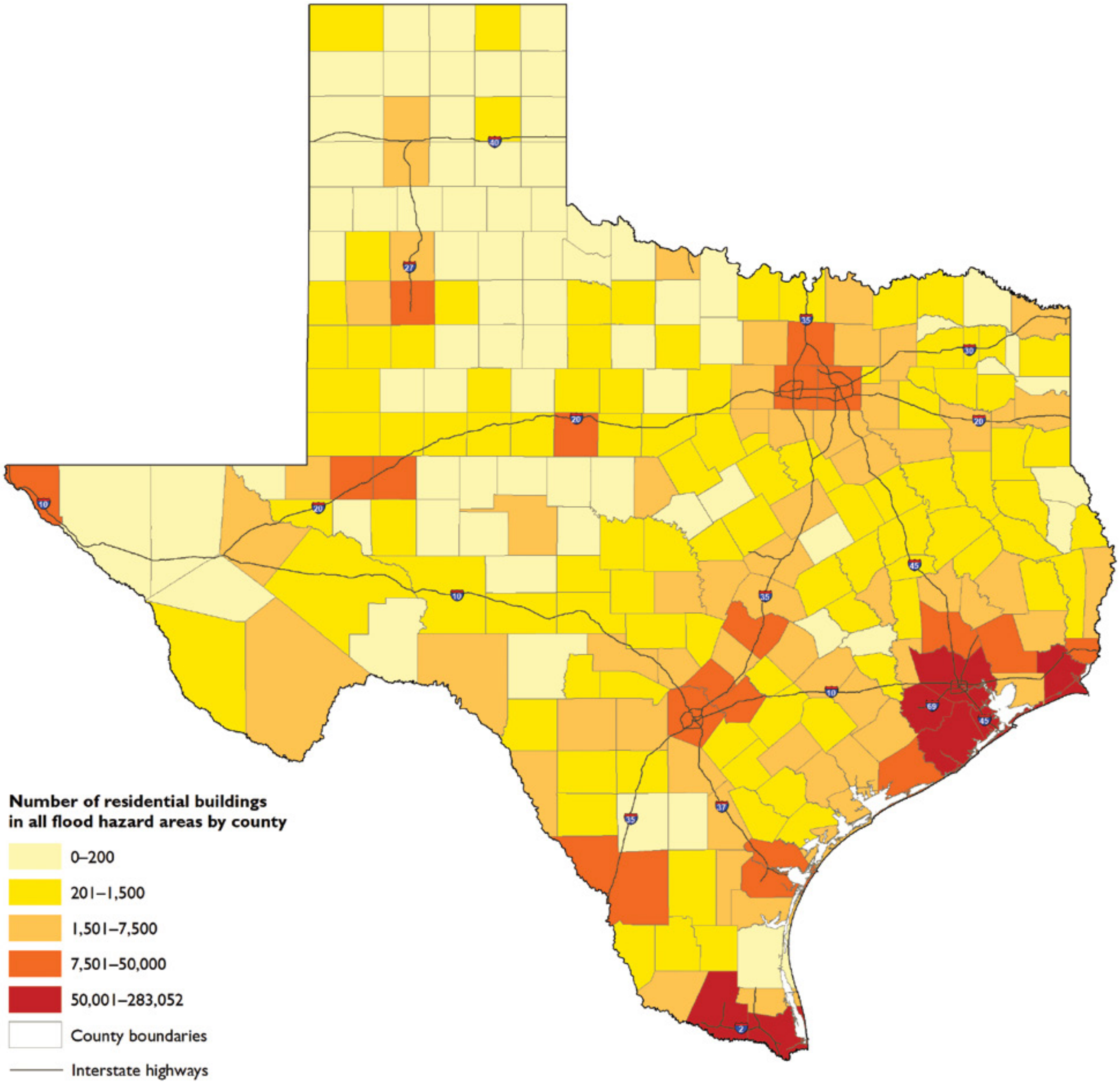
*Figure 4-9. Locations of residential buildings within existing flood hazard areas*




total of 9,322 low water crossings in flood hazard areas were identified by the regional flood planning groups. This number is lower than the 11,395 low water crossings identified by communities as existing flood infrastructure (Chapter 3). This may be due to some low water crossings being located outside identified flood hazard areas. Of the 9,322 low water crossings, 8,810 were identified in the 1 percent (100-year) annual chance floodplain, an additional 333 in the 0.2 percent (500-year) annual chance floodplain, and 179 more in flood prone areas (Table 4-7, Figure 4-12).

**Roadway miles**: The planning groups identified 43,444 miles of roadways in the 1 percent (100-year) annual chance floodplain, 20,468 miles in the 0.2 percent (500-year) annual chance floodplain, and 1,856 miles of flood prone roadways (Table 4-8 and Figure 4-1). Identified roadways within flood hazard areas are represented in total miles rather than the number of specific locations where roadways intersect with streams.

*Figure 4-10. Number of residential buildings within all flood hazard areas by county*




## Agricultural areas

While a natural phenomenon that can benefit land fertility, flooding of cultivated farmland can have significant negative impacts to agricultural production and rural economies. The planning groups identified 10,200,323 acres of working agricultural area within the 1 percent (100-year) annual chance floodplain, an additional 2,453,832 acres within the 0.2 percent (500-year) annual chance floodplain, and 51,695 acres more within flood prone agricultural lands (Figure 4-13).

## 4.1.4 Existing condition vulnerability

Following the analysis of existing flood exposure, the regional flood planning groups identified the populations and structures within existing flood hazard areas to determine their vulnerability to flooding. This task required identifying the critical infrastructure in each region during the flood exposure analysis and computing the U.S Centers for Disease Control and Prevention **Social Vulnerability Index** value for each structure identified.

*Figure 4-11. Locations of roadways/transportation within existing flood hazard areas*

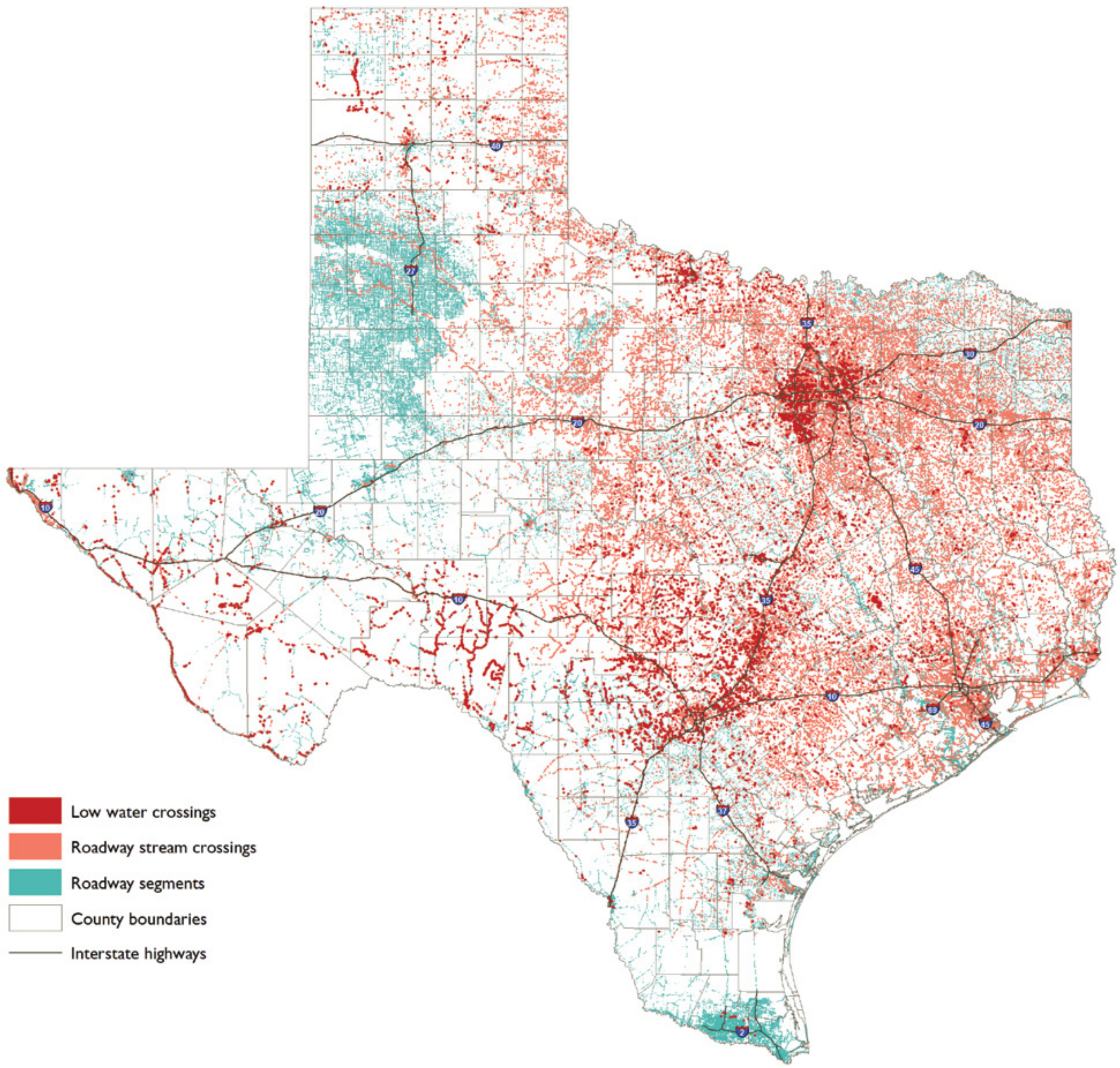


*Table 4-7. Low water crossings within flood hazard areas by flood planning region*

| Region | Low water crossings within 1 percent (100-year) annual chance floodplain | Low water crossings within 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) low water crossings | Total |
|---|---|---|---|---|
| 1 | 569 | 54 | 164 | **787** |
| 2 | 114 | 2 | | **116** |
| 3 | 1,626 | 110 | 1 | **1,737** |
| 4 | 107 | 6 | | **113** |
| 5 | 165 | 8 | 10 | **183** |
| 6 | 221 | 6 | | **227** |
| 7 | 284 | 8 | | **292** |
| 8 | 915 | 29 | | **944** |
| 9 | 243 | 12 | | **255** |
| 10 | 1,109 | 23 | | **1,132** |
| 11 | 636 | 25 | | **661** |
| 12 | 430 | 11 | | **441** |
| 13 | 503 | 23 | | **526** |
| 14 | 1,764 | 14 | 4 | **1,782** |
| 15 | 124 | 2 | | **126** |
| **Total** | **8,810** | **333** | **179** | **9,322** |

*Note: Blank cells do not always signify the absence of low water crossings within flood hazard areas; they may indicate that such features were not identified or reported by the regional flood planning groups.*

The planning groups were also required to determine the resilience of communities located in the flood prone areas.

Vulnerability and resilience are opposite sides of a coin. FEMA's definitions may be helpful:

- **Vulnerability** is susceptibility to physical injury, harm, damage, or economic loss. It depends on an asset's construction, contents, and economic value of its functions (FEMA, n.d.).
- **Resilience** is the capacity of individuals, communities, businesses, institutions, and governments to adapt to changing conditions and to prepare for, withstand, and rapidly recover from disruptions to everyday life, such as hazard events (FEMA, 2017).

## Critical facilities

The flood planning groups identified 6,153 critical facilities located in the 1 percent (100-year) annual chance floodplain, 8,252 facilities in the 0.2 percent (500-year) annual chance floodplain, and an additional 693 facilities within flood prone areas (Table 4-9, Figure 4-14).

Critical facilities provide valuable services and functions essential to a community, especially during and following a disaster. The State of Texas defines critical infrastructure as "all public or private assets, systems, and functions vital to the security, governance, public health and safety, economy, or morale of the state or the nation." According to FEMA (2020), "a critical facility should not be located in a floodplain if at all possible. If a critical facility must be located in a floodplain it should be provided a higher level of protection so that it can continue to function and provide services after the flood."

While the planning groups were given some flexibility in designating critical facilities in their regions, they generally identified the locations of hospitals, schools (K through 12), schools for children with special needs, fire stations, police stations, emergency shelters, water and wastewa-

*Figure 4-12. Locations of low water crossings within existing flood hazard areas*

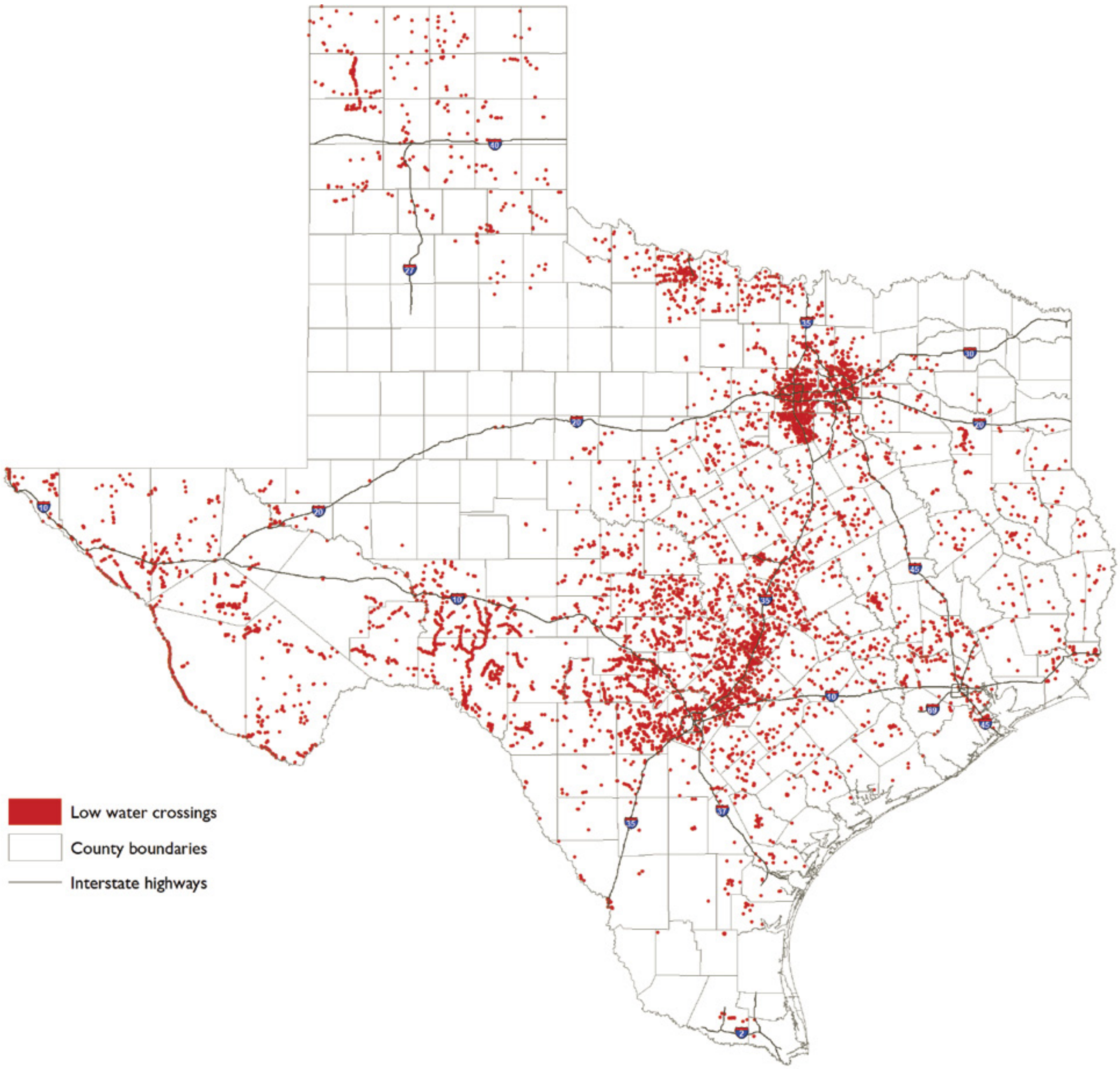


*Table 4-8. Roadway miles within existing flood hazard areas by flood planning region*

| Region | Roadway miles within 1 percent (100-year) annual chance floodplain | Roadway miles within 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) roadway miles | Total |
|---|---|---|---|---|
| 1 | 2,299 | 1,042 | 8 | **3,350** |
| 2 | 1,924 | 139 | | **2,063** |
| 3 | 3,945 | 1,936 | | **5,881** |
| 4 | 1,518 | 378 | | **1,897** |
| 5 | 1,505 | 949 | 615 | **3,069** |
| 6 | 4,350 | 3,635 | 13 | **7,998** |
| 7 | 5,944 | 3,597 | | **9,541** |
| 8 | 3,302 | 1,130 | 850 | **5,281** |
| 9 | 4,338 | 1,177 | | **5,516** |
| 10 | 2,374 | 911 | | **3,285** |
| 11 | 935 | 438 | 6 | **1,379** |
| 12 | 753 | 214 | 1 | **969** |
| 13 | 3,215 | 1,579 | 90 | **4,883** |
| 14 | 3,047 | 746 | 178 | **3,970** |
| 15 | 3,995 | 2,596 | 94 | **6,686** |
| **Total** | **43,444** | **20,468** | **1,856** | **65,768** |

*Note: Blank cells do not always signify the absence of roadways within flood hazard areas; they may indicate that such roadways were not identified or reported by the regional flood planning groups.*

ter treatment plants, power generating facilities, power facilities, assisted living facilities, and nursing homes. Of the total 15,098 critical facilities, 6,659 of these were identified as hospitals, emergency medical services, fire stations, police stations, and schools located within existing flood hazard areas (Figure 4-15).

## Communities

The U.S Centers for Disease Control and Prevention (CDC) uses a social vulnerability index as a means of helping local officials identify communities that may need the most support before, during, or after disasters (ATSDR, 2023). The CDC calculates the Social Vulnerability Index at the census tract level (roughly 4,000 people each) using 16 U.S. Census variables grouped into four related themes, including socioeconomic status, household composition, race/ethnicity/language, and housing/transportation (CDC, n.d.). These social factors help estimate the degree to which one's life and livelihood are at risk from flood and other events (Mah and others, 2023). The CDC's Social Vulnerability Index was employed as a reasonable proxy for community resilience during this first regional flood planning cycle.

Note that the TWDB has funded research to develop a social vulnerability index specifically related to the vulnerability of Texas communities facing flood hazards and anticipates making it available for the second cycle of regional flood planning.

The higher the social vulnerability index, the greater the vulnerability; the lower the social vulnerability index, the greater the resilience. The statewide average (calculated by census tract) social vulnerability index to all hazards is 0.48 on a scale of 0 to 1, with 0 being the lowest vulnerability and 1 being the highest. The TWDB considered a threshold of 0.75 to be a reasonable indicator for highly vulnerable areas. Vulnerable populations are spread across the state, with notably high densities in the west and south (Figure 4-16).

*Figure 4-13. Locations of agricultural land within existing flood hazard areas*

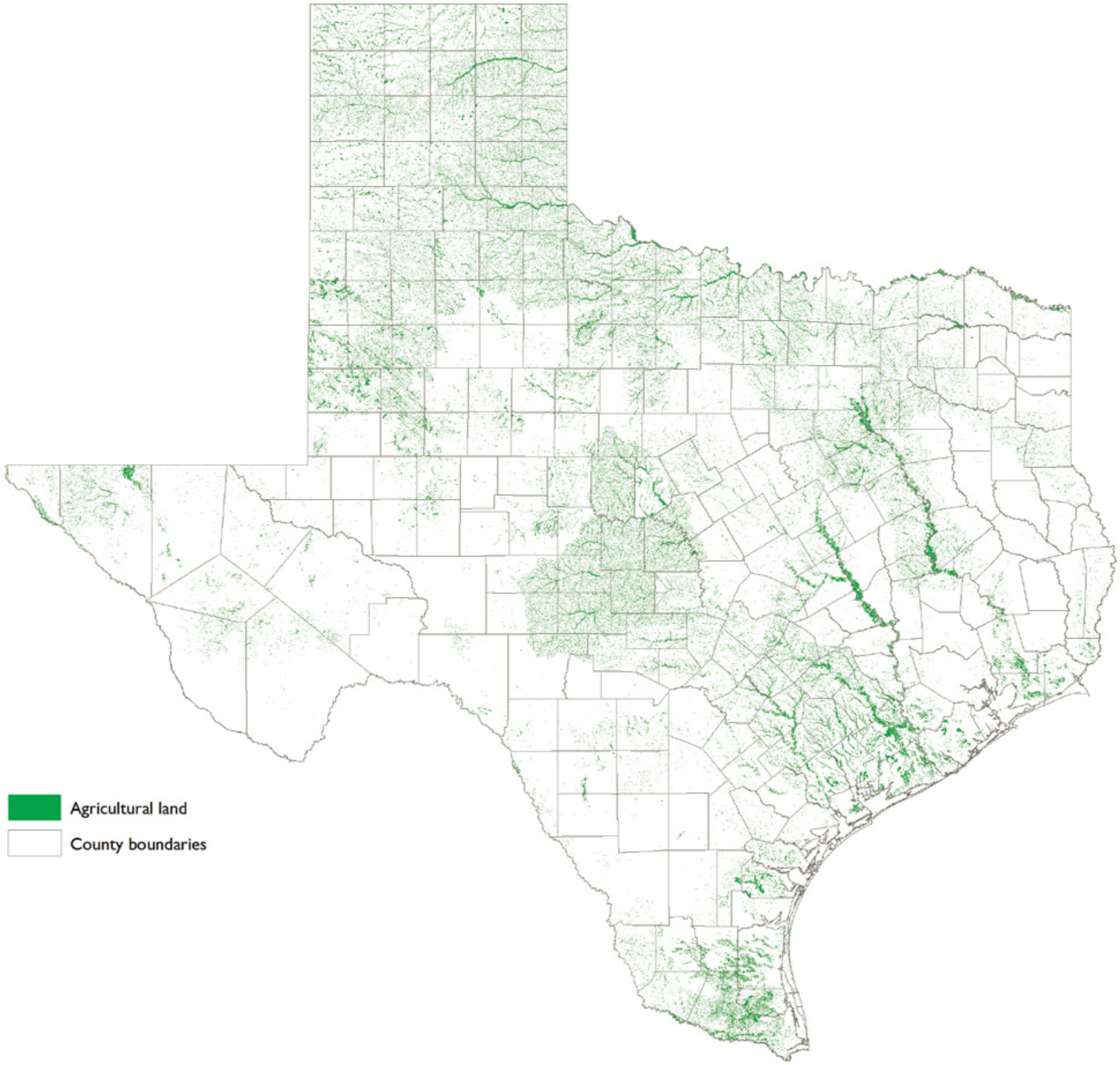


*Table 4-9. Critical facilities in existing flood hazard areas by flood planning region**

| Region | Critical facilities within 1 percent (100-year) annual chance floodplain | Critical facilities within 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) critical facilities | Total |
|---|---|---|---|---|
| 1 | 160 | 128 | | **288** |
| 2 | 147 | 3 | | **150** |
| 3 | 342 | 474 | 165 | **981** |
| 4 | 420 | 77 | | **497** |
| 5 | 479 | 1,603 | 291 | **2,373** |
| 6 | 3,185 | 4,552 | 5 | **7,742** |
| 7 | 45 | 64 | | **109** |
| 8 | 189 | 136 | 171 | **496** |
| 9 | 40 | 57 | | **97** |
| 10 | 99 | 59 | | **158** |
| 11 | 136 | 89 | | **225** |
| 12 | 203 | 31 | | **234** |
| 13 | 445 | 461 | 32 | **938** |
| 14 | 95 | 41 | 23 | **159** |
| 15 | 168 | 477 | 6 | **651** |
| **Total** | **6,153** | **8,252** | **693** | **15,098** |

*Note: Blank cells do not always signify the absence of critical facilities within flood hazard areas; they may indicate that such critical facilities were not identified or reported by the regional flood planning groups.*

** Critical facilities include hospitals, emergency medical services, fire stations, police stations, schools, shelters, power generation, and water and wastewater treatment plants.*

## 4.2 Future condition flood risk

Anticipating future flood risk is an essential component of comprehensive flood planning. As communities evolve, both in terms of population and infrastructure development, so can their susceptibility to potential flooding events. There is also an associated uncertainty regarding policy and development decisions that can impact future flood risk. For example, entirely limiting development within a high flood hazard area to avoid future flood risk as opposed to allowing some development within the floodplain may not only put the new development located in flood hazard areas but potentially increase the flood risk to downstream communities. With the added complexities of climate variability, shifting weather patterns, and increasing urbanization, it becomes imperative to not only understand the current flood risks but also to anticipate the challenges ahead.

During the first planning cycle, the regional groups were limited to using the best available data and resources for their respective regions to determine future condition flood risk. The planning groups were required to perform future condition flood risk analyses to determine the potential extent of both the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas looking ahead 30 years into the future (Figure 4-17). The future condition 1 percent (100-year) annual chance flood hazard area is projected to increase by 11 percent over the existing condition 1 percent (100-year) annual chance flood hazard area to an estimated total area of 62,245 square miles (Figure 4-18 and Figure 4-19).

As they did with the existing condition flood risk, the regional flood planning groups performed three analyses for future condition flood risk:

*Figure 4-14. Locations of critical facilities within existing flood hazard areas*

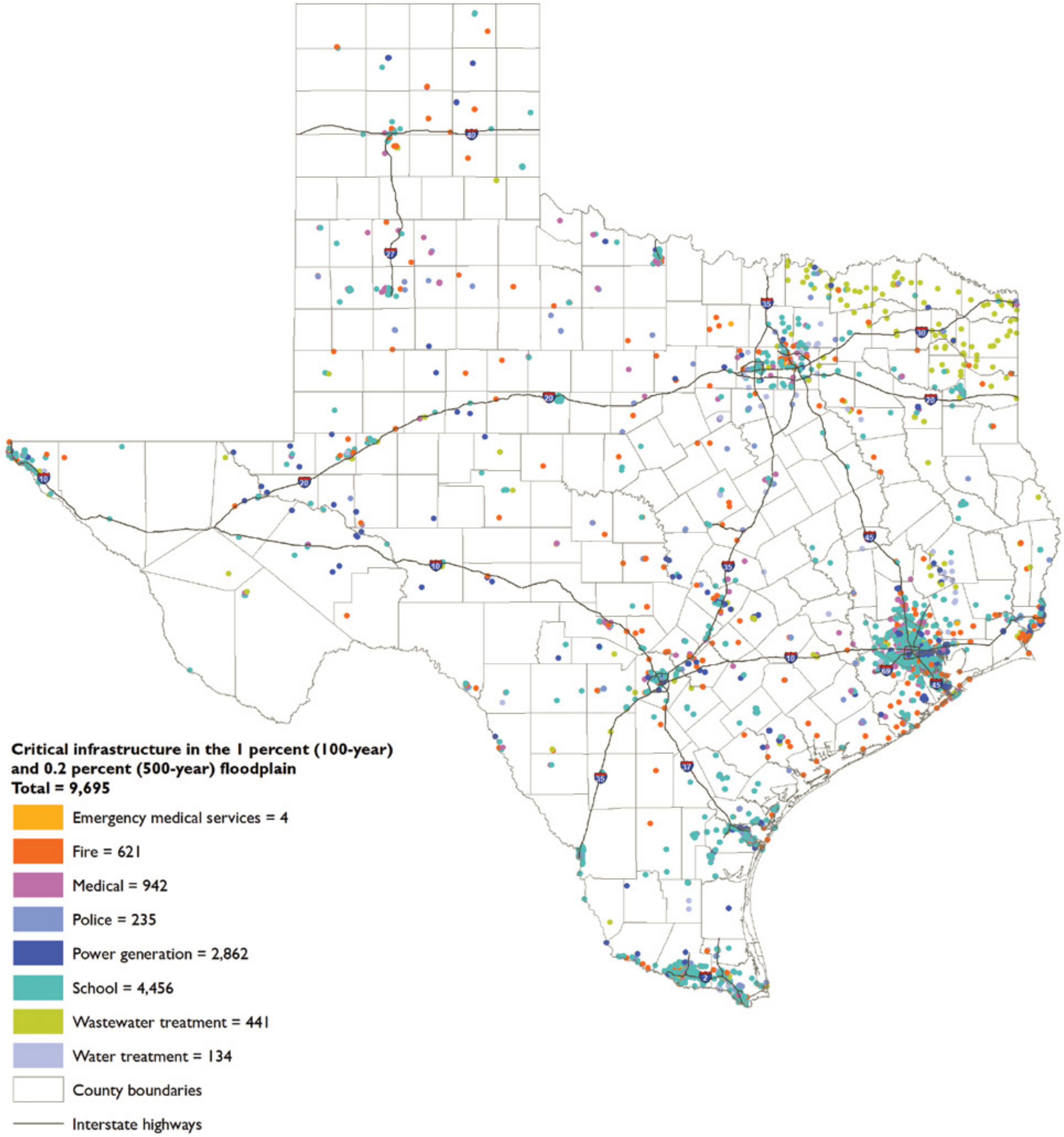
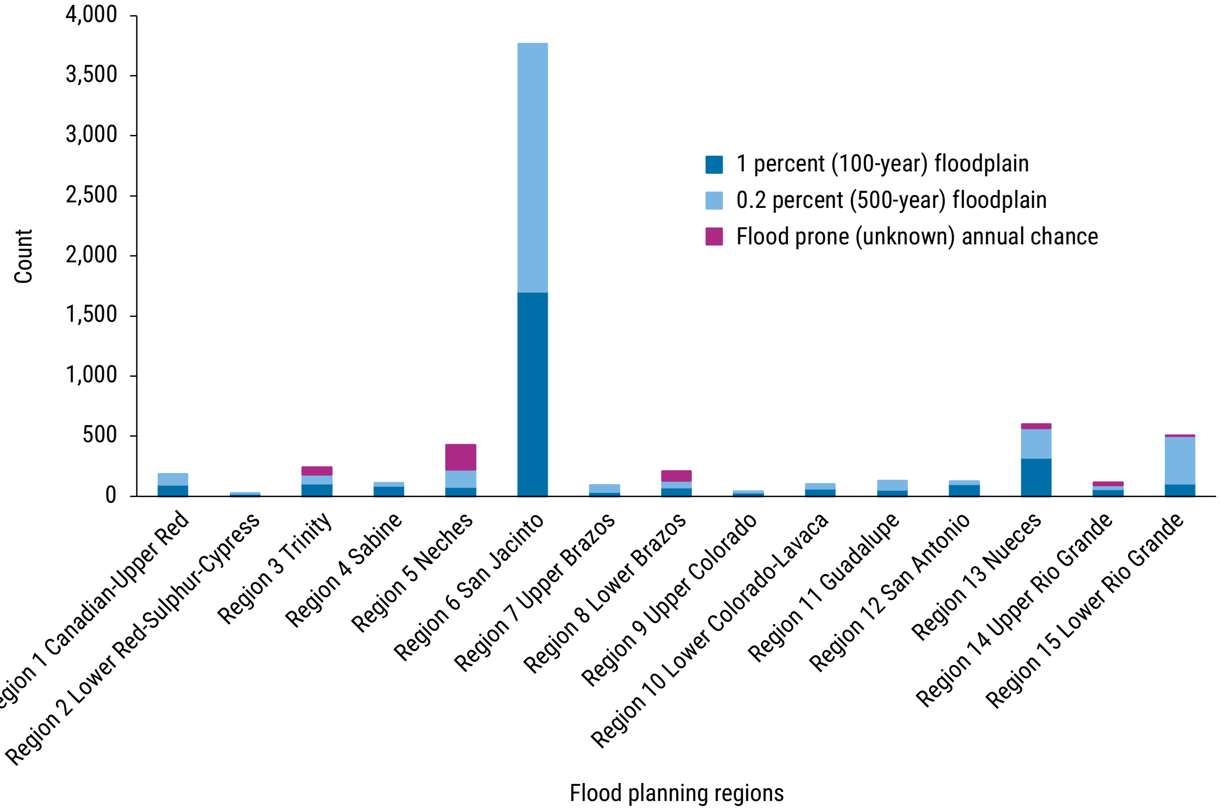


*Figure 4-15. Count of hospitals, emergency medical services, fire stations, police stations, and schools within existing flood hazard areas*




1. Flood hazard analyses that determine location, magnitude, and frequency of flooding
2. Flood exposure analyses to identify who and what might be harmed within the region
3. Analyses to identify vulnerabilities of communities and critical facilities

In addition to approximating the magnitude of potential future flood risk, these analyses are useful to better inform policy and long-term investment decisions.

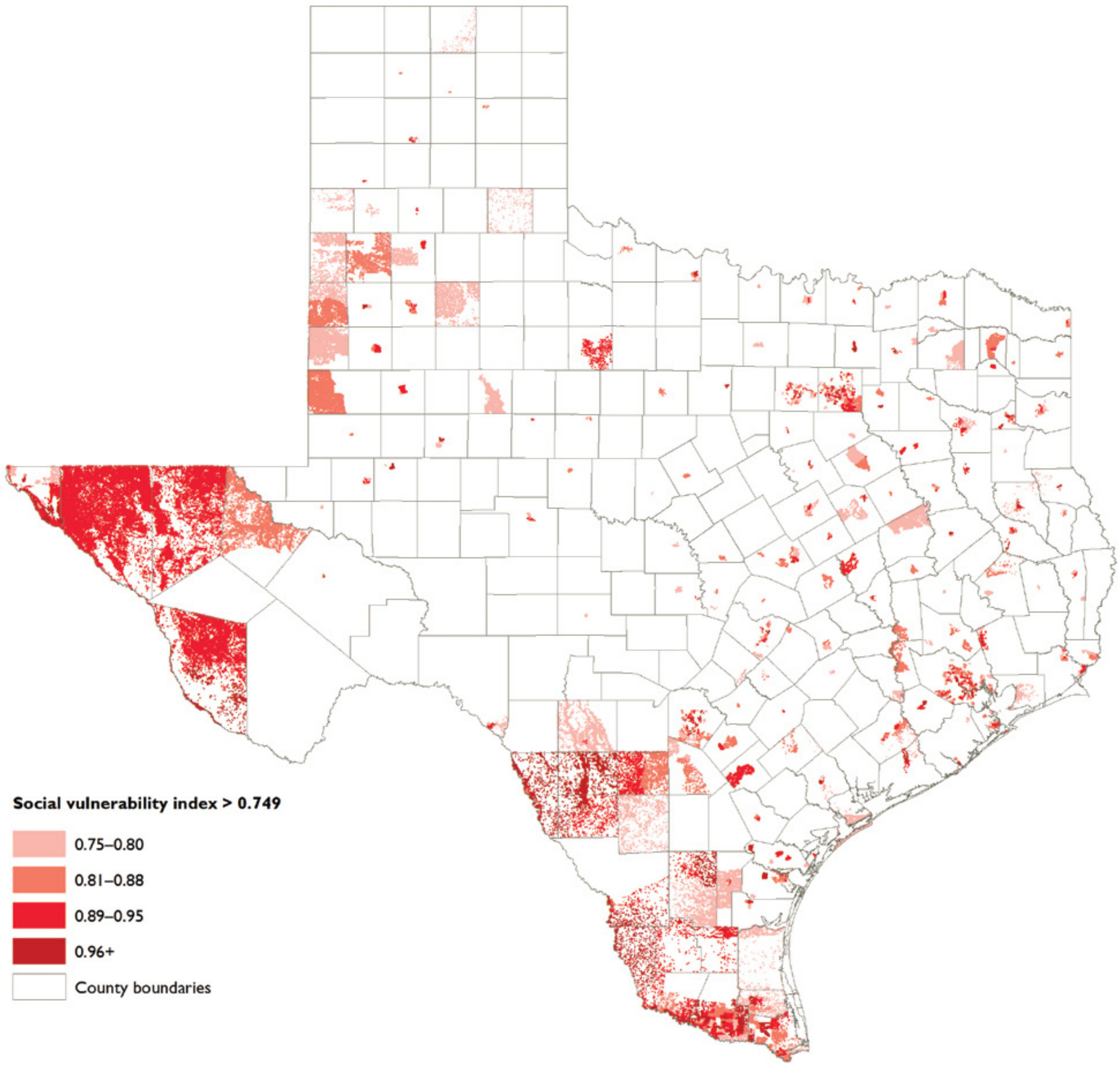
### 4.2.1 Future condition flood hazard

The first step in determining the future extent of both the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas was to identify areas within each region where future condition hydrologic and hydraulic model results and maps were available. For areas where future condition flood hazard data was not available, the TWDB provided four methods for performing future condition flood hazard analyses. The method selected depended on such factors as topography, growth types and rates, and development rates, and included the following:

1. Increasing water surface elevation based on projected percentage population increase (as proxy for development of land areas)
2. Utilizing the existing condition 0.2 percent (500-year) annual chance floodplain as a proxy for the future 1 percent (100-year) level
3. A combination of methods 1 and 2 or another method proposed by the planning group
4. Planning groups could request that the TWDB perform a desktop analysis

Each of the 15 regional flood planning groups determined the most appropriate methodology for performing future condition flood hazard

*Figure 4-16. Locations of Texas communities within 1 percent (100-year) annual chance flood hazard areas and who are considered vulnerable*

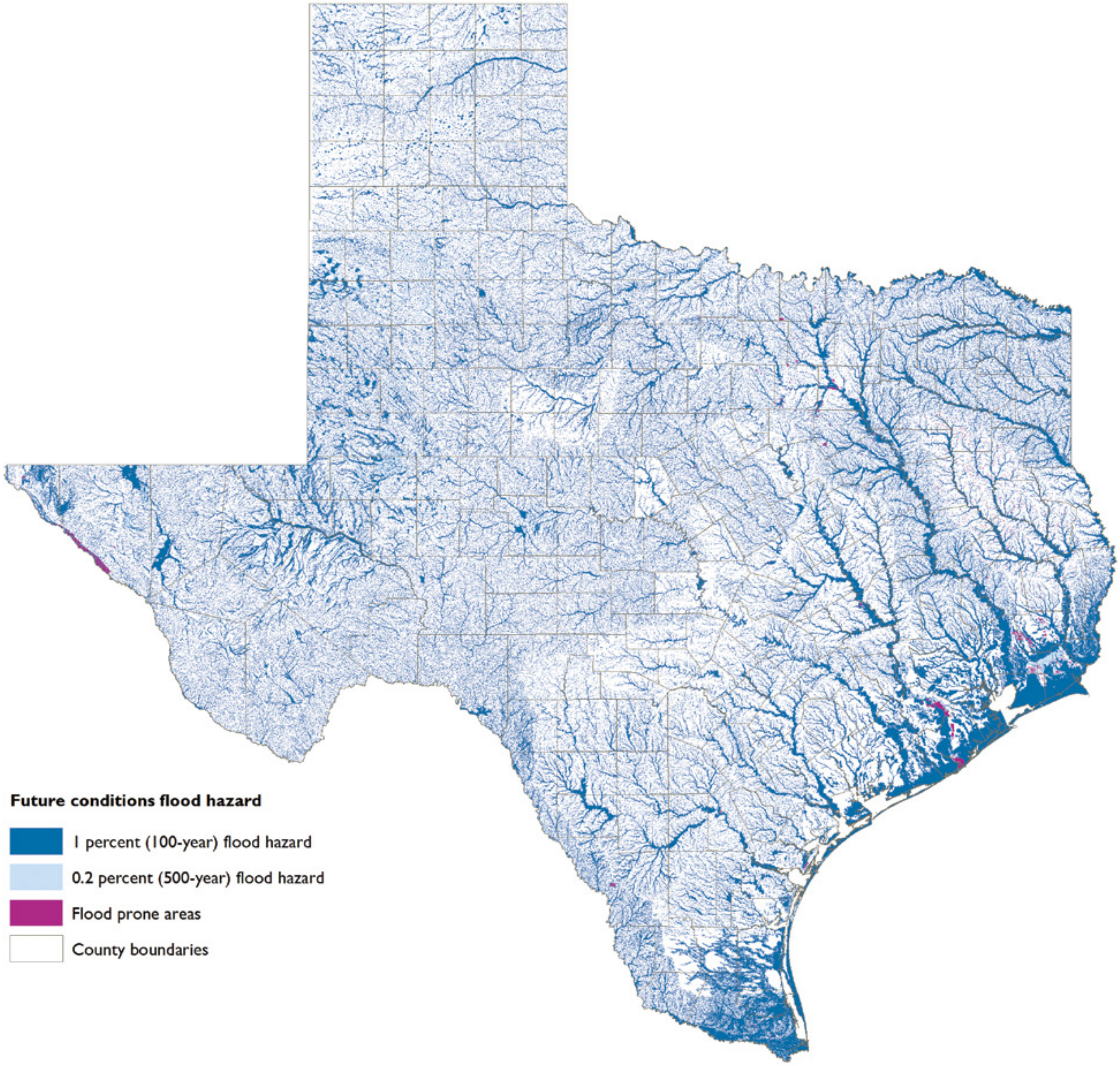



identification for its region. A summary of each region's approach is provided (Table 4-10). A full summary of each region's methodology is provided in Appendix A.

### Future condition flood hazard data gaps

The regional flood planning groups were asked to identify areas lacking future inundation boundary mapping after performing their future condition flood hazard analyses. They identified areas with, for example, clearly outdated future modeling and/or mapping, absence of future modeling and/or mapping, and areas with future modeling and/or mapping that require updates. In performing their analyses, several of the groups found that the flood hazard mapping and data gaps in their

*Figure 4-17. Future condition flood hazard areas*

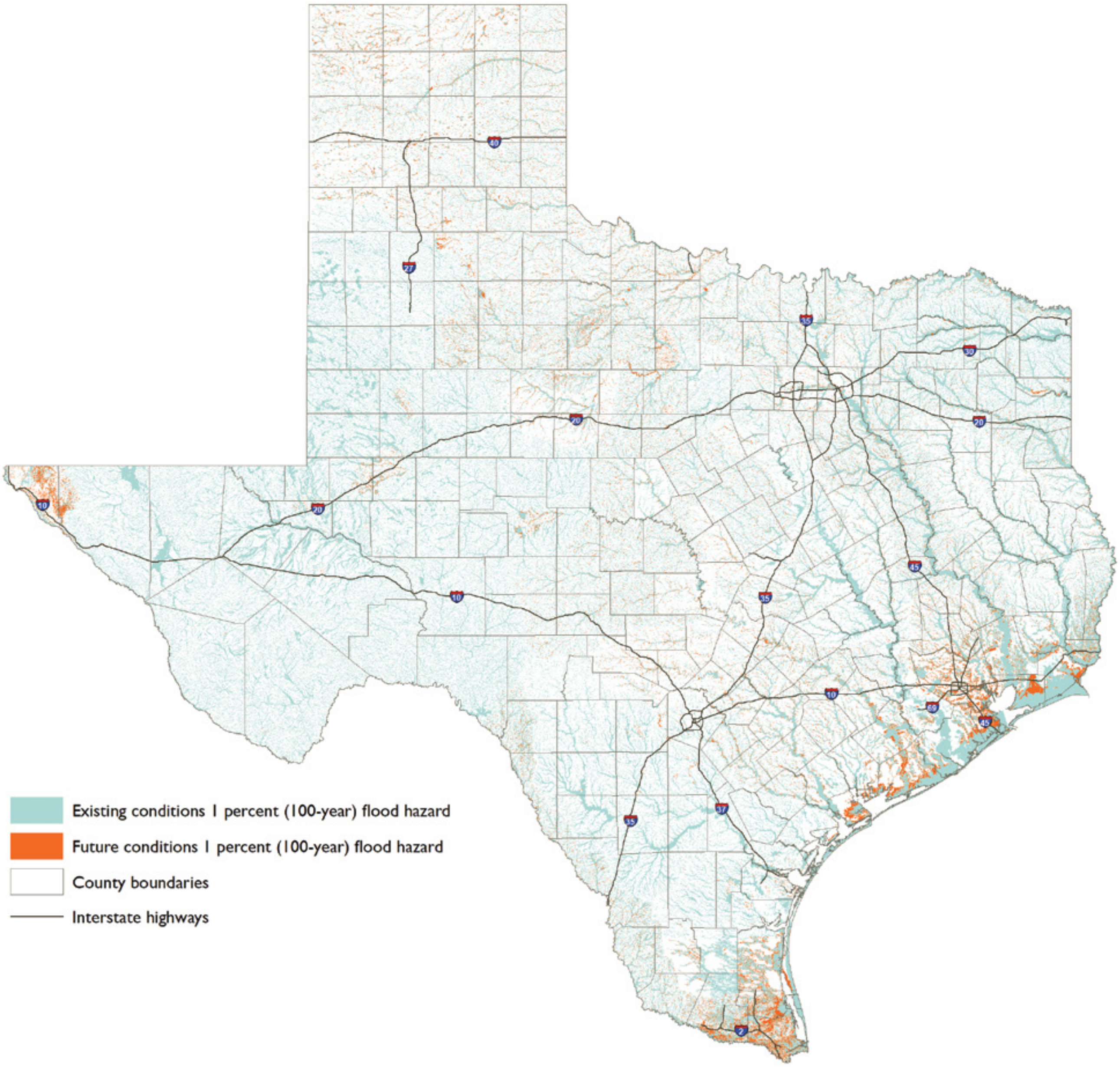



region coincided for both existing and future condition flood hazard boundaries. In general, the available future flood hazard mapping information was associated with heavily urbanized areas.

### 4.2.2 Future condition flood exposure

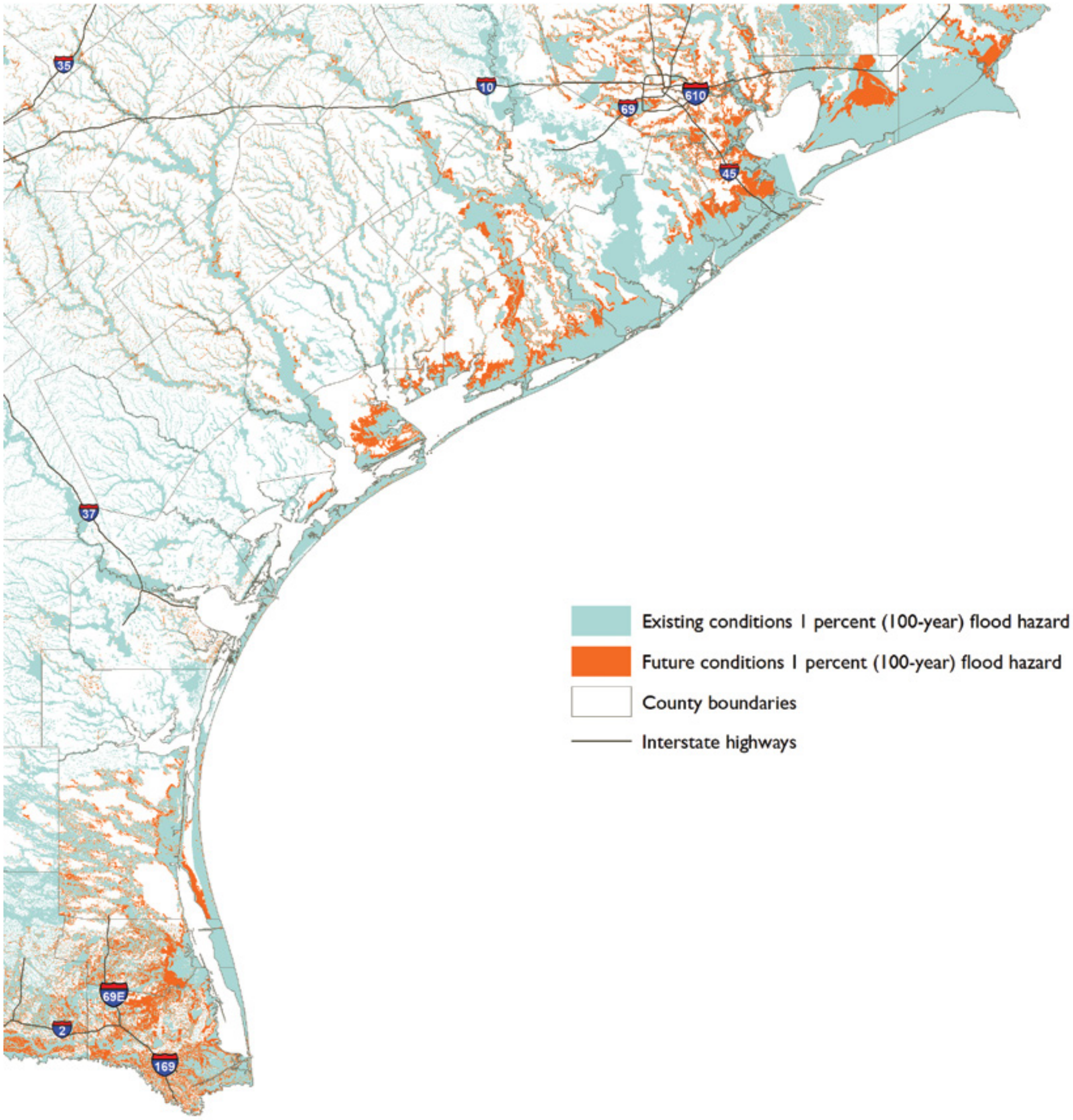
After identifying areas of future flood hazard in their regions, the planning groups were required to perform flood hazard exposure analyses to determine who and what may be harmed in the future 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas (Table 4-11). The flood exposure analyses considered exposure of different types of development within flood hazard areas:

*Figure 4-18. Comparison of existing and future conditions 1 percent (100-year) annual chance flood hazard area**




** Extent of the projected future conditions 1 percent (100-year) annual chance flood hazard area includes the existing conditions 1 percent (100-year) annual chance flood hazard area.*

*Figure 4-19. Comparison of existing and future conditions 1 percent (100-year) annual chance flood hazard area along the Texas coast**




** Extent of the projected future conditions 1 percent (100-year) annual chance flood hazard area includes the existing conditions 1 percent (100-year) annual chance flood hazard area.*

1. Population
2. Buildings, including residential and nonresidential
3. Critical facilities
4. Roadways, including the estimated number of roadway stream crossings, low water crossings, and the total length of roadway
5. Agricultural areas, including the total area of farms and ranches

## Population

The planning groups were required to include daytime and nighttime population estimates located within the future 1 percent (100-year) annual chance flood hazard area, 0.2 percent (500-year) annual chance flood hazard area, and flood prone areas. The higher of the daytime or nighttime estimates computed at each county level was utilized in estimating the total population in flood hazard areas. The planning groups identified an estimated 5,052,378 people within the future 1 percent, 3,124,151 people within the future 0.2 percent, and 655,838 people within future flood prone areas (Table 4-12 and Figure 4-20).

*Table 4-10. Summary of future condition flood hazard analyses by region*

| Region | Method 1 | Method 2 | Method 3 | Method 4 |
|---|---|---|---|---|
| 1 | | X | | |
| 2 | | X | | |
| 3 | | X | | |
| 4 | | X | | |
| 5 | | | X | |
| 6 | | | X | |
| 7 | | | X | |
| 8 | | X | | |
| 9 | | X | | |
| 10 | | X | | |
| 11 | | X | | |
| 12 | | X | | |
| 13 | | | X | |
| 14 | | | X | |
| 15 | | X | | |

*Table 4-11. Summary of statewide future condition flood exposure*

| Flood exposure | 1 percent (100-year) annual chance floodplain | 0.2 percent (500-year) annual chance floodplain | Flood prone (unknown annual chance) | Total |
|---|---|---|---|---|
| Population | 5,052,378 | 3,124,151 | 655,838 | **8,832,367** |
| Buildings[a] | 1,618,617 | 914,219 | 120,904 | **2,653,740** |
| Residential buildings | 1,298,772 | 750,754 | 110,260 | **2,159,786** |
| Roadway stream crossings (includes low water crossings) | 78,320 | 22,606 | 923 | **101,849** |
| Roadway miles | 59,190 | 27,564 | 1,506 | **88,260** |
| Agricultural areas (acres) | 12,011,680 | 3,903,956 | 24,289 | **15,939,925** |
| Critical facilities[b] | 14,581 | 7,395 | 545 | **22,521** |
| Hospitals, emergency medical services, fire stations, police stations, and schools | 6,182 | 3,825 | 286 | **10,293** |

*Note: All values are counts unless otherwise labeled.*

*[a] Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown.*

*[b] Critical facilities include hospitals, emergency medical services, fire stations, police stations, schools, shelters, power generation, and water and wastewater treatment plants.*

*Table 4-12. Populations within future flood hazard areas by flood planning region**

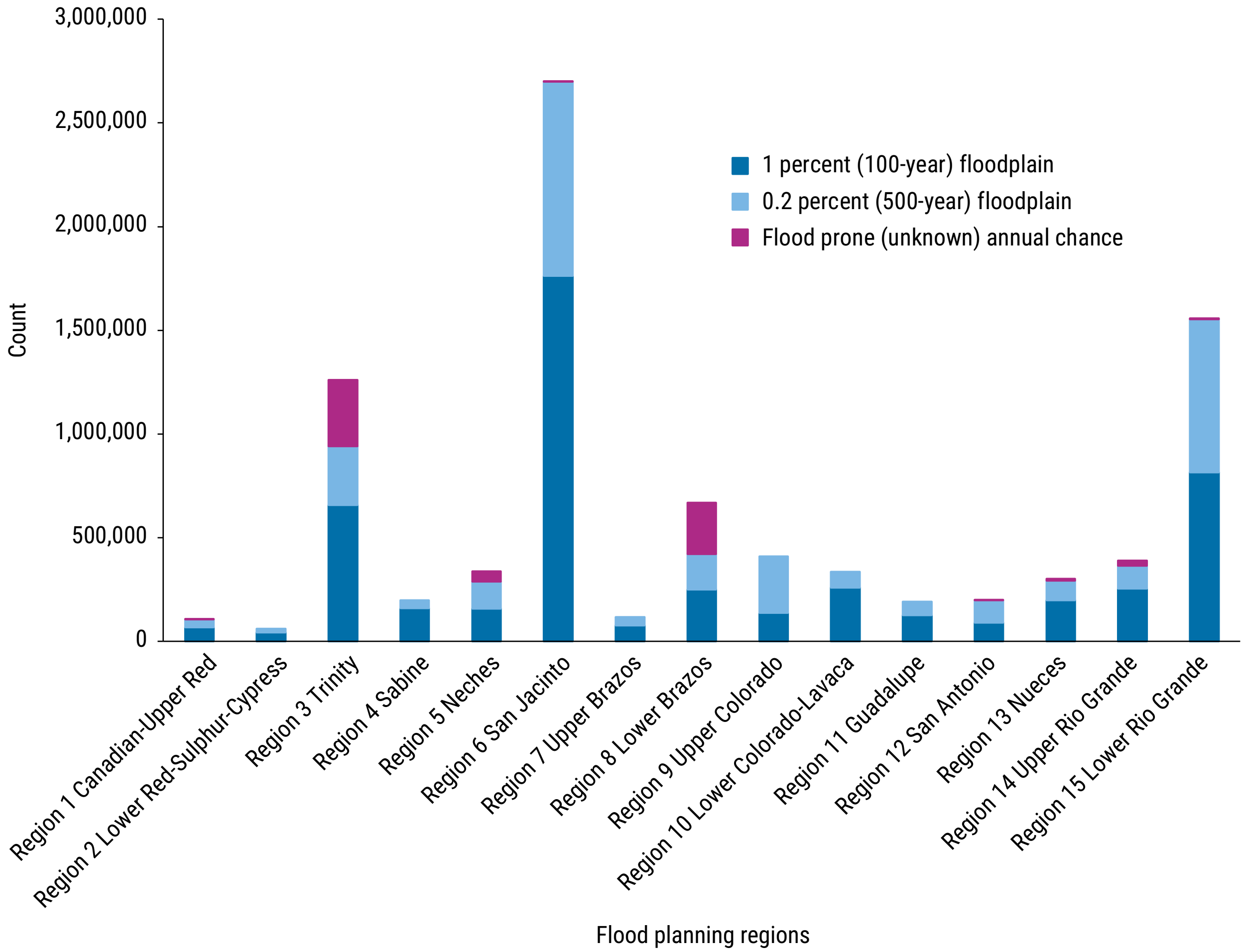
| Region | Population within future 1 percent (100-year) annual chance floodplain | Population within future 0.2 percent (500-year) annual chance floodplain | Future flood prone (unknown annual chance) population | Total |
|---|---|---|---|---|
| 1 | 66,927 | 39,356 | 139 | **106,422** |
| 2 | 41,858 | 19,663 | | **61,521** |
| 3 | 657,174 | 283,010 | 319,858 | **1,260,042** |
| 4 | 159,110 | 39,115 | | **198,225** |
| 5 | 157,903 | 131,028 | 48,471 | **337,402** |
| 6 | 1,763,356 | 935,884 | 1,515 | **2,700,755** |
| 7 | 75,459 | 41,637 | | **117,096** |
| 8 | 249,801 | 171,856 | 246,493 | **668,150** |
| 9 | 138,022 | 270,679 | | **408,701** |
| 10 | 258,485 | 76,776 | | **335,261** |
| 11 | 126,607 | 64,569 | | **191,176** |
| 12 | 90,379 | 107,296 | 26 | **197,701** |
| 13 | 198,921 | 94,370 | 8,715 | **302,006** |
| 14 | 253,678 | 110,302 | 25,760 | **389,740** |
| 15 | 814,698 | 738,610 | 4,861 | **1,558,169** |
| **Total** | **5,052,378** | **3,124,151** | **655,838** | **8,832,367** |

*Note: Blank cells do not always signify the absence of populations within flood hazard areas; they may indicate that such populations were not identified or reported by the regional flood planning groups.*

** Values represent the maximum daytime or nighttime population provided by the regional flood planning groups.*


*Low water crossing at Smithson Valley Road south of FM 1863 in San Antonio, Texas; photo courtesy of Roy Alaquinez*

*Figure 4-20. Populations within future flood hazard areas by flood planning region*




## Buildings

Through their future condition flood exposure analyses, the planning groups identified 1,618,617 buildings within the future 1 percent (100-year), 914,219 structures within the future 0.2 percent (500-year) annual chance flood hazard areas, and 120,904 buildings in future flood prone areas (Table 4-13, Figure 4-21, Figure 4-22). Buildings include all structures classified as residential, commercial, agricultural, industrial, public, or other. There appears to be a large number of agricultural buildings located in the flood hazard areas throughout Texas. These buildings include barns, livestock operations, and grain silos, etc.

## Residential buildings

The planning groups identified 1,298,772 residential buildings within the future 1 percent (100-year), 750,754 residential buildings within the future 0.2 percent (500-year) annual chance flood hazard areas, and 110,260 residential buildings in future flood prone areas (Table 4-14, Figure 4-23).

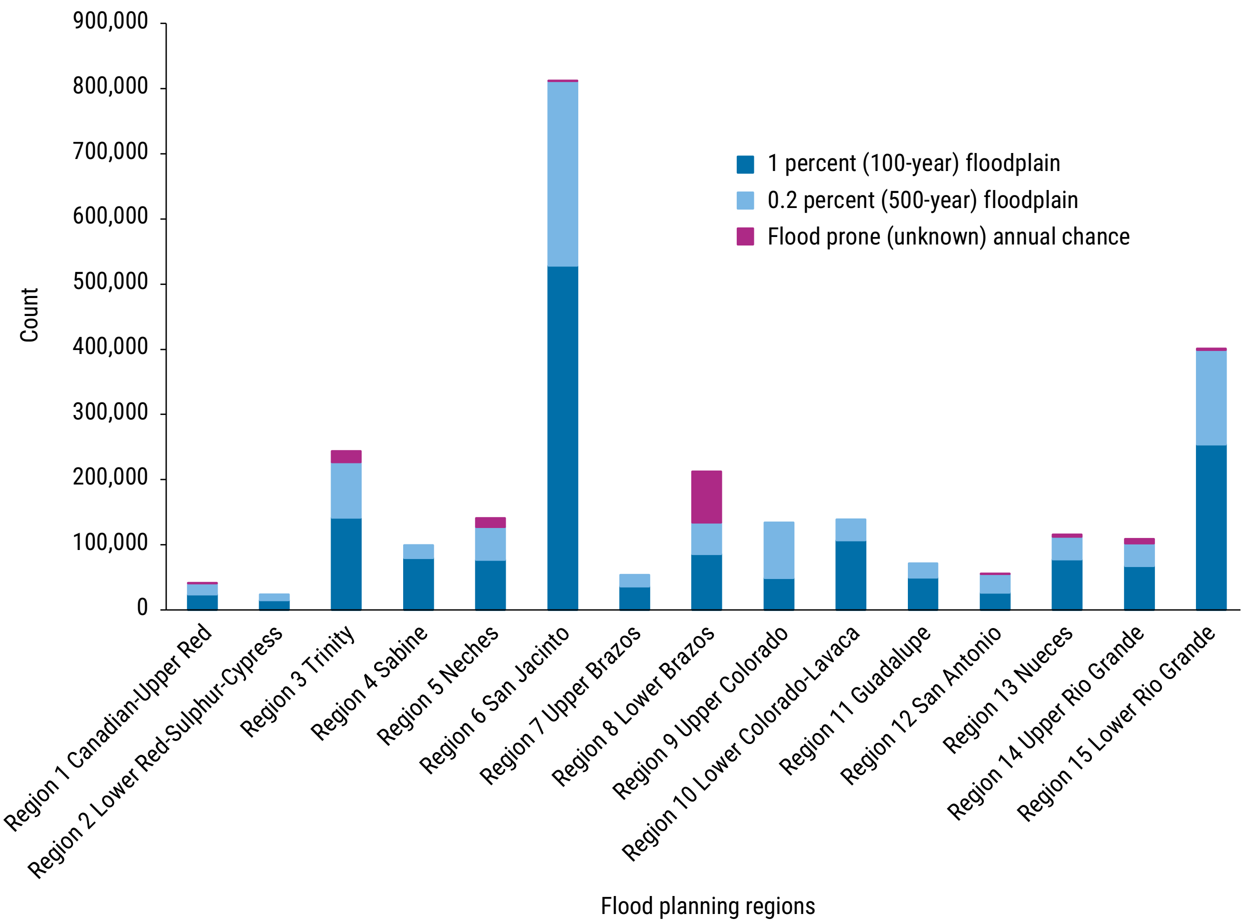
*Table 4-13. Buildings within future flood hazard areas by flood planning region**

| Region | Buildings within future 1 percent (100-year) annual chance floodplain | Buildings within future 0.2 percent (500-year) annual chance floodplain | Future flood prone (unknown annual chance) buildings | Total |
|---|---|---|---|---|
| 1 | 23,718 | 17,480 | 78 | **41,276** |
| 2 | 15,023 | 8,601 | | **23,624** |
| 3 | 141,440 | 85,410 | 16,839 | **243,689** |
| 4 | 79,674 | 19,576 | | **99,250** |
| 5 | 77,317 | 50,382 | 13,333 | **141,032** |
| 6 | 528,442 | 283,258 | 479 | **812,179** |
| 7 | 35,955 | 18,131 | | **54,086** |
| 8 | 85,738 | 48,481 | 78,326 | **212,545** |
| 9 | 49,218 | 84,697 | | **133,915** |
| 10 | 106,636 | 32,648 | | **139,284** |
| 11 | 49,736 | 21,765 | | **71,501** |
| 12 | 26,642 | 28,830 | 10 | **55,482** |
| 13 | 77,821 | 34,551 | 3,423 | **115,795** |
| 14 | 67,134 | 35,167 | 6,992 | **109,293** |
| 15 | 254,123 | 145,242 | 1,424 | **400,789** |
| **Total** | **1,618,617** | **914,219** | **120,904** | **2,653,740** |

*Note: Blank cells do not always signify the absence of buildings within flood hazard areas; they may indicate that such buildings were not identified or reported by the regional flood planning groups.*

** Includes all residential, agricultural, commercial, industrial, public, and vacant or unknown.*

*Figure 4-21. Buildings within future flood hazard areas by flood planning region**




** Includes all residential, agricultural, commercial, industrial, public, and vacant or unknown.*

*Figure 4-22. Locations of buildings by type within future flood hazard areas*

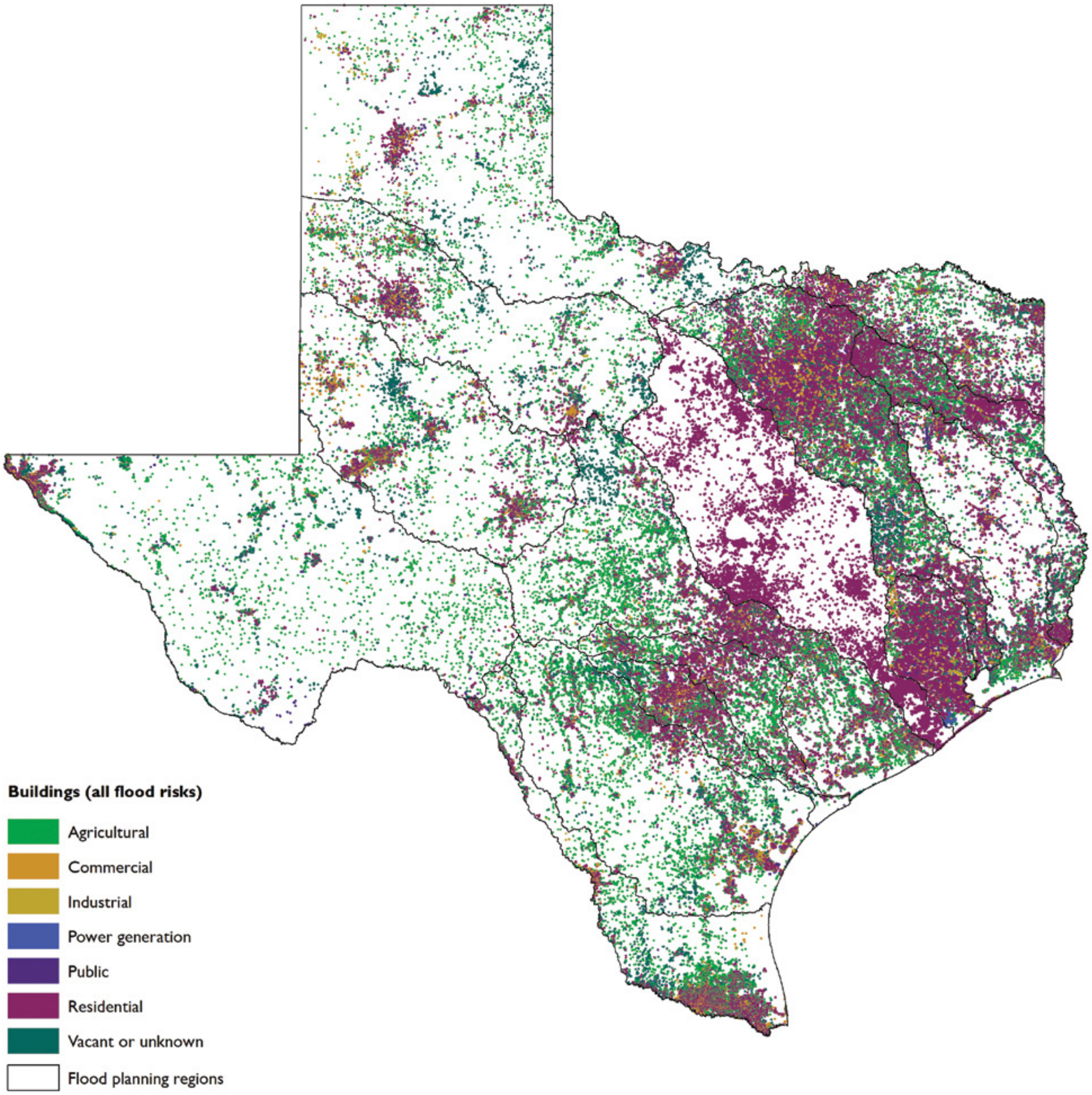


*Table 4-14. Residential buildings within future flood hazard areas by flood planning region*

| Region | Residential buildings within future 1 percent (100-year) annual chance floodplain | Residential buildings within future 0.2 percent (500-year) annual chance floodplain | Future flood prone (unknown annual chance) residential buildings | Total |
|---|---|---|---|---|
| 1 | 15,536 | 10,820 | 53 | **26,409** |
| 2 | 9,081 | 5,740 | | **14,821** |
| 3 | 109,384 | 70,067 | 12,636 | **192,087** |
| 4 | 65,689 | 15,050 | | **80,739** |
| 5 | 60,167 | 40,357 | 10,245 | **110,769** |
| 6 | 454,237 | 249,918 | 447 | **704,602** |
| 7 | 24,646 | 12,362 | | **37,008** |
| 8 | 85,629 | 48,395 | 78,249 | **212,273** |
| 9 | 33,105 | 62,990 | | **96,095** |
| 10 | 74,045 | 24,136 | | **98,181** |
| 11 | 36,035 | 16,981 | | **53,016** |
| 12 | 19,211 | 23,627 | 8 | **42,846** |
| 13 | 57,037 | 25,347 | 2,191 | **84,575** |
| 14 | 46,488 | 27,441 | 5,250 | **79,179** |
| 15 | 208,482 | 117,523 | 1,181 | **327,186** |
| **Total** | **1,298,772** | **750,754** | **110,260** | **2,159,786** |

*Note: Blank cells do not always signify the absence of buildings within flood hazard areas; they may indicate that such buildings were not identified or reported by the regional flood planning groups.*

## Roadways/transportation at future flood risk

The regional flood planning groups repeated their analyses on roadways and transportation systems at flood risk using the data generated in their future flood hazard analyses. The locations of roadways located in flood hazard areas are presented in Figure 4-24.

*Roadway stream crossings*

The groups identified 78,320 roadway stream crossings within the future 1 percent (100-year) annual chance flood hazard area, 22,606 within the future 0.2 percent (500-year) annual chance flood hazard area, and 923 in flood prone areas.

*Low water crossings*

The planning groups identified a total of 10,243 low water crossings at future flood risk. Of these, 9,456 were identified within the future 1 percent (100-year) annual chance flood hazard area, 653 within the future 0.2 percent (500-year) annual chance flood hazard area, and 134 in future flood prone areas (Table 4-15, Figure 4-25).

*Roadway miles*

The planning groups identified 59,190 miles of roadways in the future 1 percent (100-year) annual chance floodplain, 27,564 miles in the future 0.2 percent (500-year) annual chance floodplain, and 1,506 miles of future flood prone roadways (Table 4-16).

## Agricultural areas

The planning groups identified 12,011,680 acres of agricultural area in the future 1 percent (100-year) annual chance flood hazard area, 3,903,956 acres in the future 0.2 percent (500-year) annual chance flood hazard area, and 24,289 acres of future flood prone agriculture (Figure 4-26).

*Figure 4-23. Locations of residential buildings within future flood hazard areas*

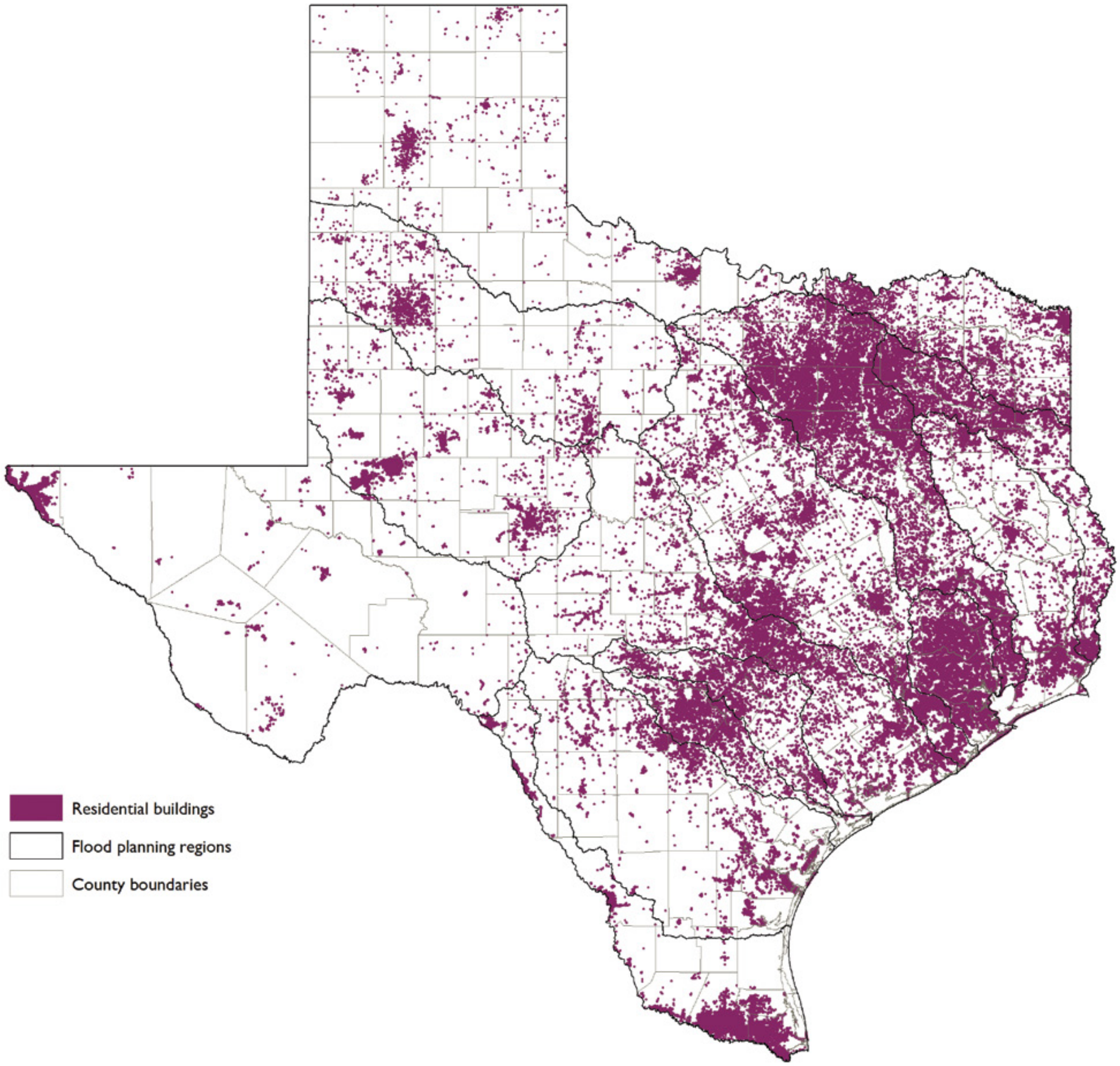


*Figure 4-24. Locations of roadways/transportation within future flood hazard areas*

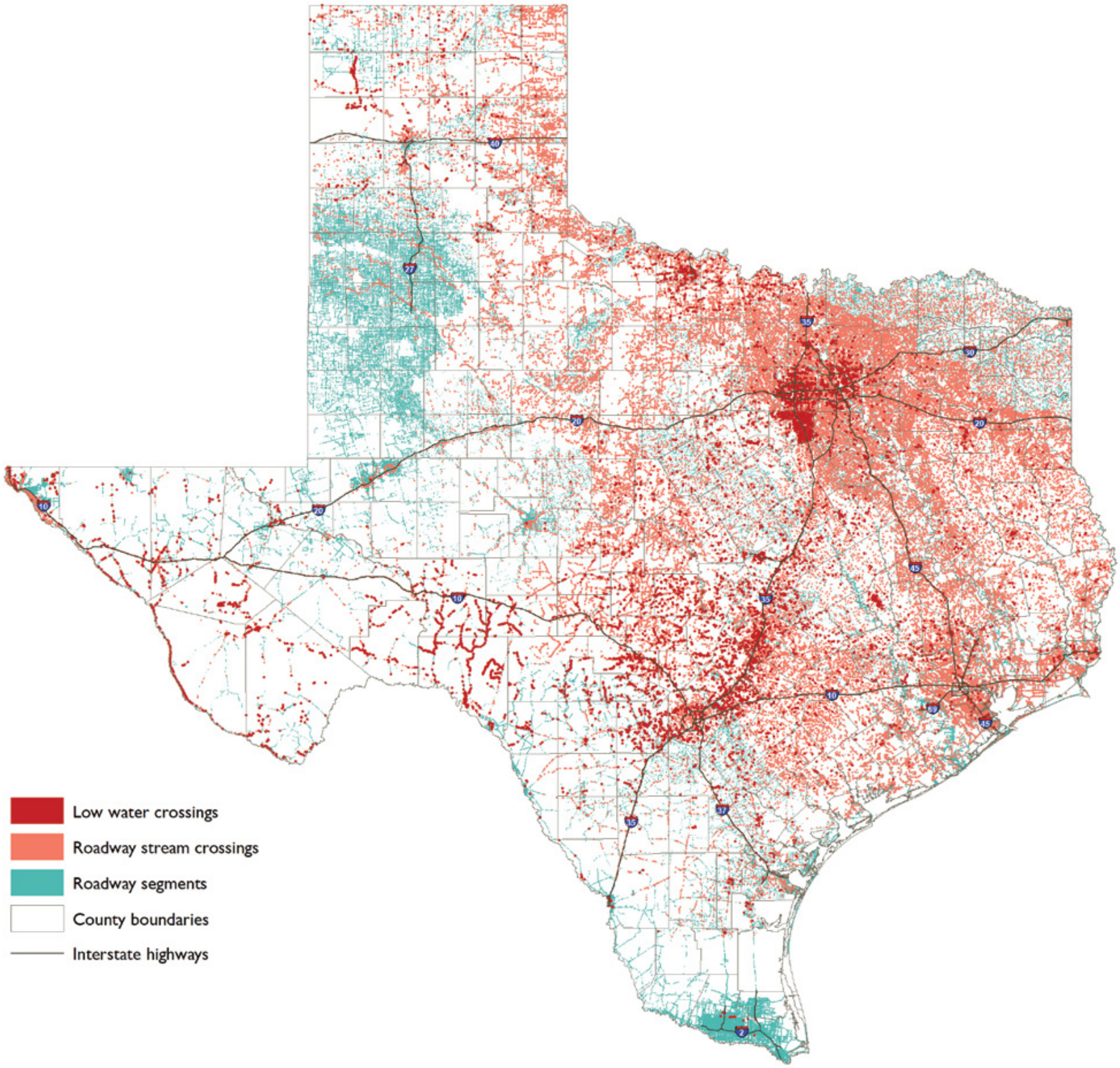


*Table 4-15. Low water crossings within future flood hazard areas by flood planning region*

| Region | Low water crossings within future 1 percent (100-year) annual chance floodplain | Low water crossings within future 0.2 percent (500-year) annual chance floodplain | Future flood prone (unknown annual chance) low water crossings | Total |
|---|---|---|---|---|
| 1 | 973 | 152 | 124 | **1,249** |
| 2 | 116 | 11 | | **127** |
| 3 | 1,736 | 332 | 1 | **2,069** |
| 4 | 113 | 4 | | **117** |
| 5 | 173 | 5 | 6 | **184** |
| 6 | 229 | 5 | | **234** |
| 7 | 290 | 2 | | **292** |
| 8 | 944 | 45 | | **989** |
| 9 | 244 | 9 | | **253** |
| 10 | 1,120 | 21 | | **1,141** |
| 11 | 661 | 15 | | **676** |
| 12 | 441 | 15 | | **456** |
| 13 | 509 | 17 | | **526** |
| 14 | 1,781 | 9 | 3 | **1,793** |
| 15 | 126 | 11 | | **137** |
| **Total** | **9,456** | **653** | **134** | **10,243** |

*Note: Blank cells do not always signify the absence of low water crossings within flood hazard areas; they may indicate that such features were not identified or reported by the regional flood planning groups.*

## 4.2.3 Future condition vulnerability

Once the future flood exposure analyses were completed, the regional flood planning groups were required to identify the resilience of communities located in those future flood prone areas. This task required them to identify the critical infrastructure amongst the items identified in the future flood exposure analyses and compute the social vulnerability index value for each structure.

### Critical facilities

The flood planning groups identified 14,581 critical facilities in the future 1 percent (100-year) annual chance flood hazard area, 7,395 critical facilities in the future 0.2 percent (500-year) annual chance flood hazard area, and 545 critical facilities in future flood prone areas (Table 4-17, Figure 4-27). A total of 10,293 of these critical facilities were identified as hospitals, emergency medical services, fire stations, police stations, and schools within future flood hazard areas.

### Communities

Like the existing condition vulnerability analyses, the regional flood planning groups identified social vulnerability indices of all buildings located in the future condition flood hazard area. The statewide average estimate for the social vulnerability index for all buildings located in future condition flood hazard areas is 0.49—an increase of 0.01 over the existing social vulnerability index, as described under Section 4.1.4. The TWDB considered a threshold of 0.75 to be a reasonable indicator for highly vulnerable areas. Like the findings from the existing condition vulnerability analyses, the planning groups identified vulnerable populations with a social vulnerability index at or above 0.75 to be spread across the state, with high densities in the west and south (Figure 4-28).

*Figure 4-25. Locations of low water crossings within future flood hazard areas*

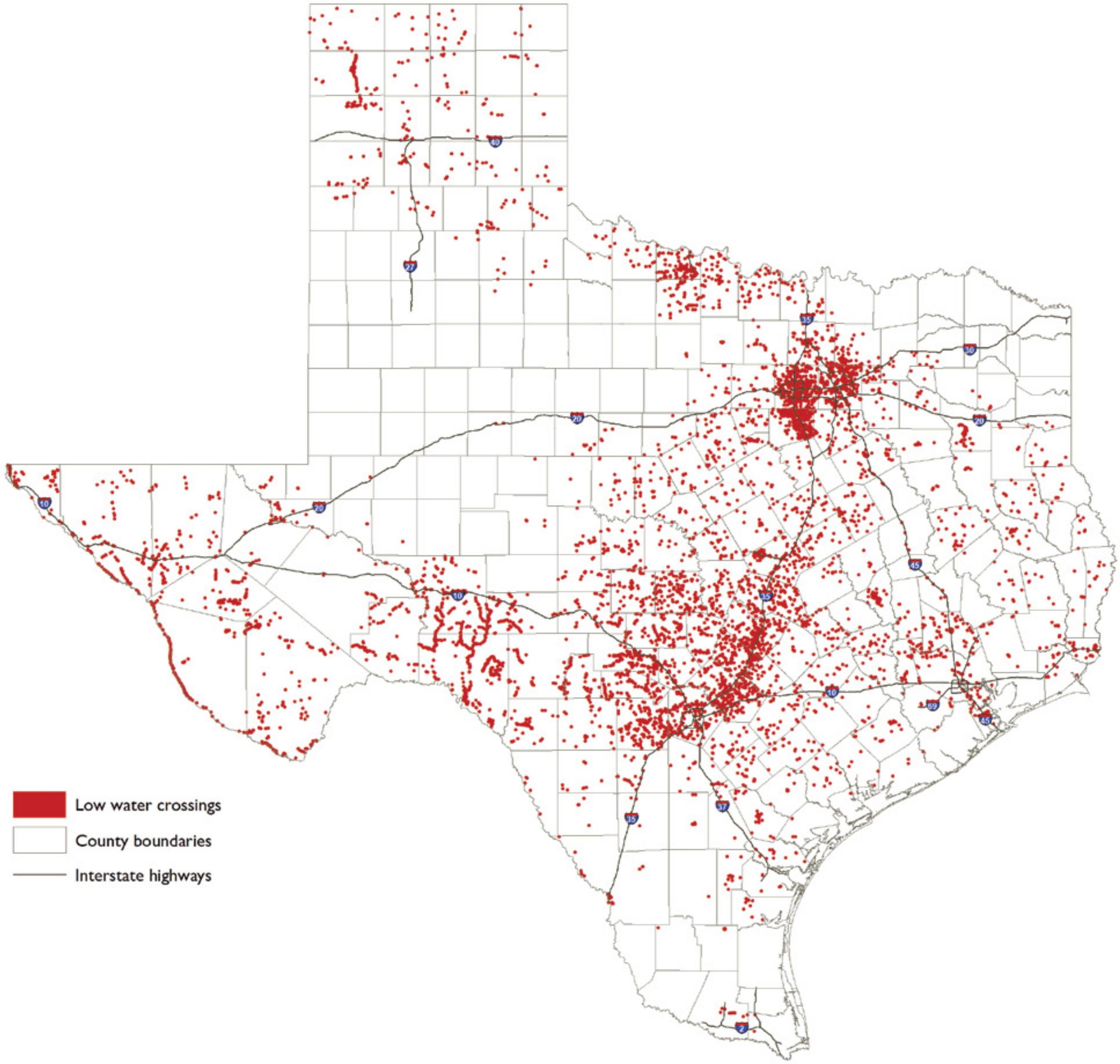


*Table 4-16. Roadway miles within future flood hazard areas by flood planning region**

| Region | Roadway miles within future 1 percent (100-year) annual chance floodplain | Roadway miles within future 0.2 percent (500-year) annual chance floodplain | Future flood prone (unknown annual chance) roadway miles | Total |
|---|---|---|---|---|
| 1 | 3,342 | 2,010 | 7 | **5,358** |
| 2 | 2,063 | 947 | | **3,010** |
| 3 | 5,588 | 3,305 | | **8,894** |
| 4 | 1,897 | 855 | | **2,752** |
| 5 | 2,444 | 1,167 | 378 | **3,988** |
| 6 | 8,147 | 3,701 | 9 | **11,858** |
| 7 | 6,439 | 3,103 | | **9,541** |
| 8 | 3,954 | 1,676 | 849 | **6,479** |
| 9 | 4,628 | 2,503 | | **7,131** |
| 10 | 4,353 | 1,246 | | **5,599** |
| 11 | 1,379 | 416 | | **1,795** |
| 12 | 968 | 604 | 1 | **1,573** |
| 13 | 3,537 | 1,560 | 85 | **5,183** |
| 14 | 3,846 | 1,035 | 139 | **5,020** |
| 15 | 6,605 | 3,437 | 38 | **10,079** |
| **Total** | **59,190** | **27,564** | **1,506** | **88,260** |

*Note: Blank cells do not always signify the absence of roadways within flood hazard areas; they may indicate that such roadways were not identified or reported by the regional flood planning groups.*

** All values are estimates rounded to the nearest whole number.*

*Flooding in the Rio Grande Valley following Hurricane Hanna in July 2020*

*Figure 4-26. Locations of agricultural land in future flood hazard areas*

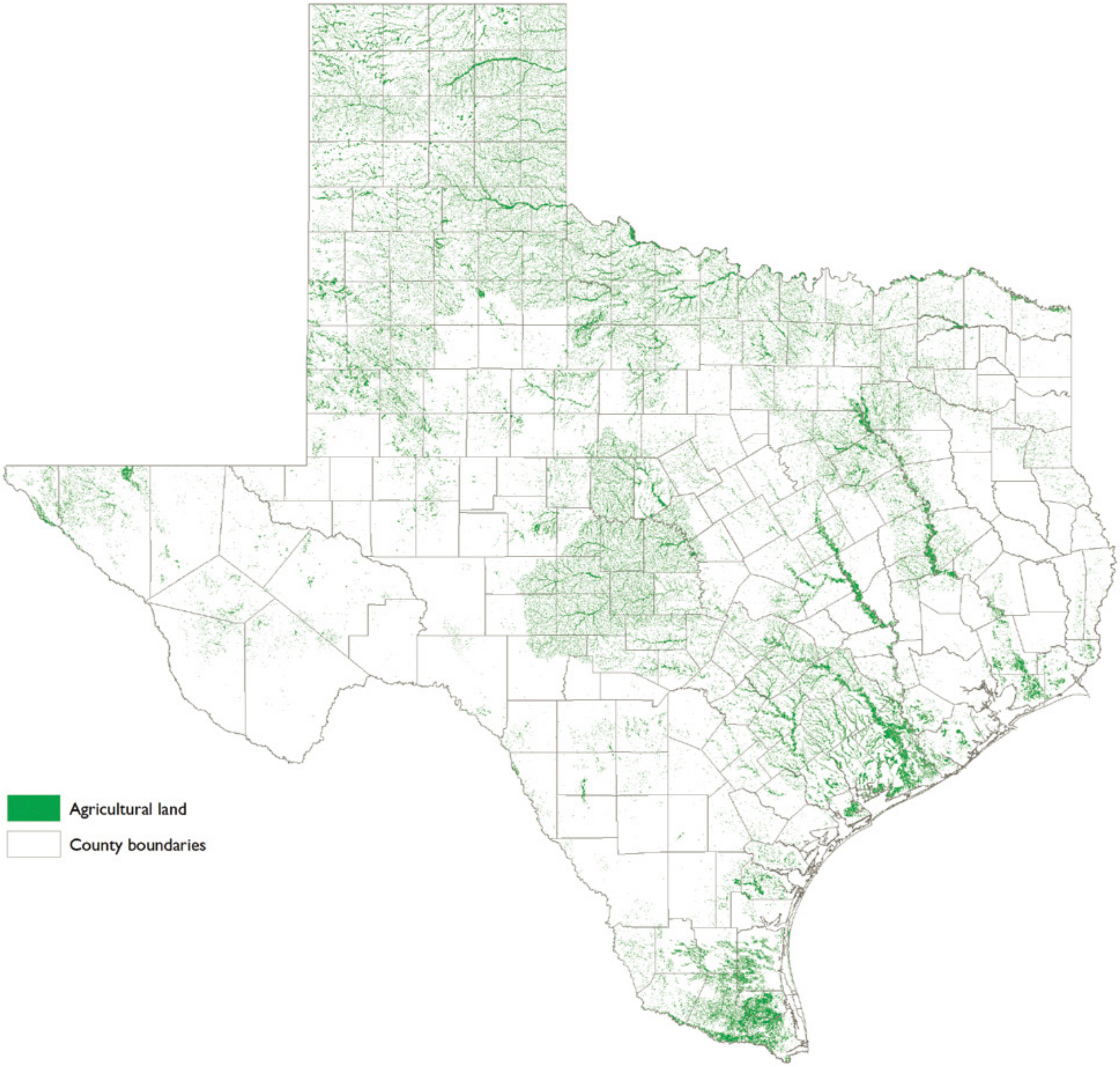


*Table 4-17. Critical facilities within future flood hazard areas by flood planning region**

| Region | Critical facilities within future 1 percent (100-year) annual chance floodplain | Critical facilities within future 0.2 percent (500-year) annual chance floodplain | Future flood prone (unknown annual chance) critical facilities | Total |
|---|---|---|---|---|
| 1 | 288 | 241 | | **529** |
| 2 | 150 | 24 | | **174** |
| 3 | 852 | 204 | 160 | **1,216** |
| 4 | 497 | 64 | | **561** |
| 5 | 2,082 | 1,307 | 152 | **3,541** |
| 6 | 8,311 | 3,524 | 1 | **11,836** |
| 7 | 64 | 45 | | **109** |
| 8 | 321 | 212 | 180 | **713** |
| 9 | 156 | 371 | | **527** |
| 10 | 177 | 33 | | **210** |
| 11 | 225 | 88 | | **313** |
| 12 | 234 | 185 | | **419** |
| 13 | 642 | 493 | 32 | **1,167** |
| 14 | 179 | 56 | 18 | **253** |
| 15 | 403 | 548 | 2 | **953** |
| **Total** | **14,581** | **7,395** | **545** | **22,521** |

*Note: Blank cells do not always signify the absence of critical facilities within flood hazard areas; they may indicate that such critical facilities were not identified or reported by the regional flood planning groups.*

** Critical facilities includes hospitals, emergency medical services, fire stations, police stations, schools, shelters, power generation, and water and wastewater treatment plants.*

*Residential flooding in the Houston area during Hurricane Harvey in 2017; photo courtesy of Royce Worrell*

*Figure 4-27. Locations of critical facilities within future flood hazard areas*

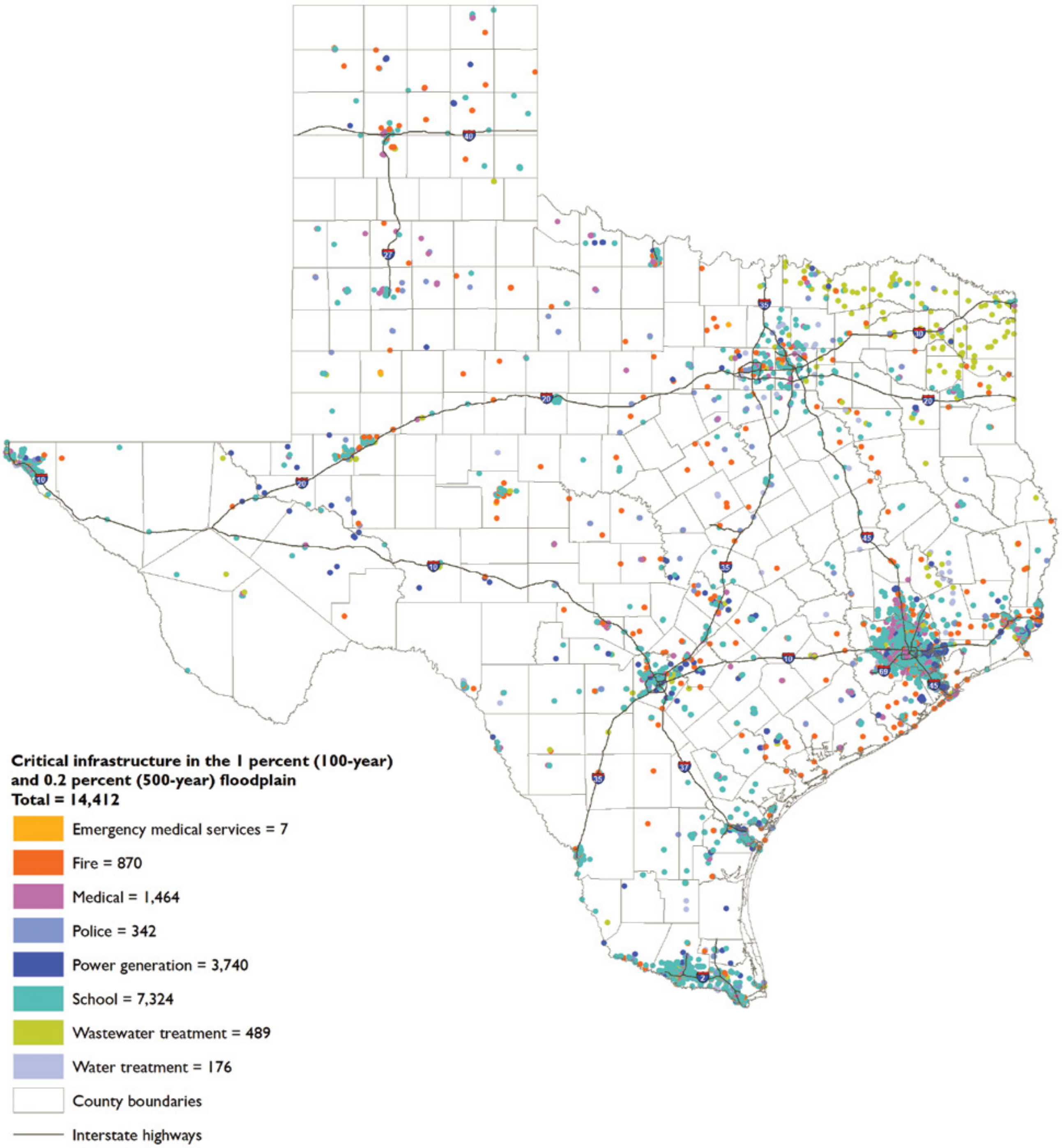
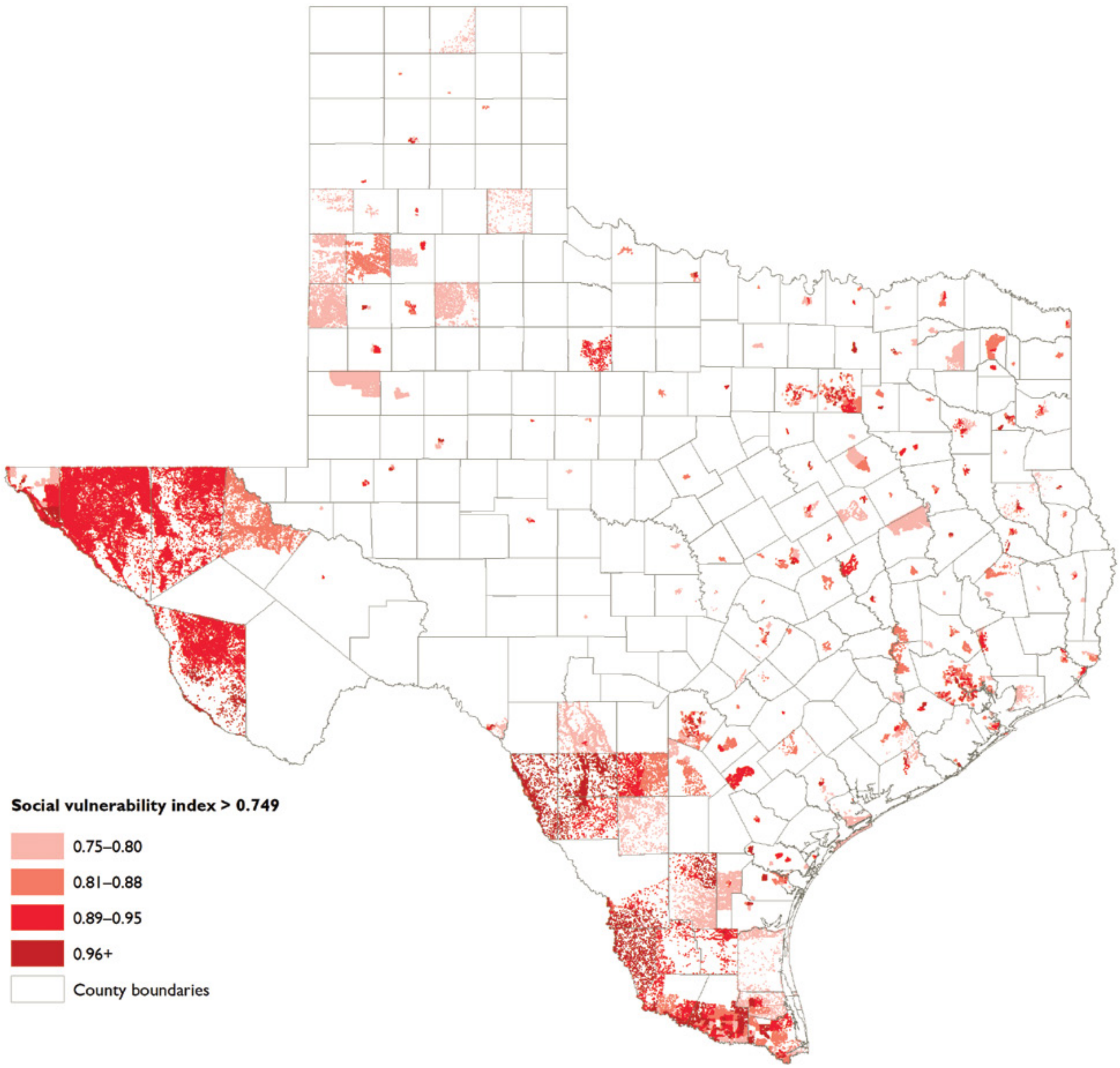


*Figure 4-28. Locations of Texas communities within future flood hazard areas (1 percent) that are considered vulnerable*



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