Chapter 1: Planning Area Description

Figure 1.1: Image of Flooded Gas Station in Grand Prairie, TX in 1976

Source: United States Army Corps of Engineers (USACE)

Origins of the State Flood Planning Process

In Texas, the billion-dollar flood disaster is becoming a regular occurrence (see ***Figure 1.1***). Between 2015 and 2017, flooding alone caused nearly $5 billion in damages to Texas communities. When considered in conjunction with the impact of Hurricane Harvey, the total cost in 2017 approached $200 billion in financial losses (NOAA, 2021) and nearly 100 deaths. As the state grappled with how to better manage flood risk and reduce loss of life and property from future disasters, the Texas Water Development Board (TWDB) prepared the first ever statewide flood assessment which described Texas' flood risks, provided an overview of roles and responsibilities, included an estimate of potential flood mitigation costs, and summarized entities' views on the future of flood planning. This plan was prepared because:

- Flood risks, impacts, and mitigation costs had never been assessed at a statewide level
- Flood risks pose a serious threat to lives and livelihoods
- Much of Texas is unmapped or uses out-of-date maps (Peter M. Lake, 2019)

The TWDB presented its findings to the 86th Texas legislative session in 2019. Later that year, the Legislature adopted changes to Texas Water Code §16.061 which established a regional and state flood planning process led by the TWDB. The legislation provided funding to improve the state's floodplain mapping efforts and to develop regional plans to mitigate the impact of future flooding. Regional flood plans for each of the state's 15 flood planning regions must be submitted to the TWDB by January 10, 2023. An updated version of the regional flood plans will be due every five years thereafter. (TWDB Flood Planning Frequently Asked Questions, 2021)

Overview of the Planning Process

Given the diverse geography, culture, and population of the state, the planning effort is being carried out at a regional level in each of the state's major river basins. The Region 3 (Trinity Region) is one of 15 flood planning regions where a regional flood plan will be developed. When complete, the TWDB will compile these regional plans into a single statewide flood plan and will present it to the Legislature in 2024. Regional flood plans are required to be based on the best available science, data, models, and flood risk mapping. The Legislature allocated funding to be distributed by the TWDB for the procurement of technical assistance to develop the flood plans.

Who's Preparing the Plan?

The TWDB has appointed Regional Flood Planning Groups (RFPGs) for each region and has provided them with funding to hire technical consultants to help prepare their plans. Because it is not a political subdivision, the RFPG cannot enter into a contract with the TWDB to receive the funding to develop the plan. Therefore, each RFPG selects a political subdivision to handle contract administration. Trinity RFPG chose the Trinity River Authority (TRA) to serve as its sponsor. The sponsor's role is to provide support for meetings and communications and to manage the technical consultant contract.

The RFPG's responsibilities include directing the work of their technical consultant; soliciting and considering public input; identifying specific flood risks; and identifying and recommending Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs) to reduce risk in their regions. To ensure a diversity of perspectives are included, members represent a wide variety of entities potentially affected by flooding, including:

- Agriculture
- Counties
- Electric Generation Utilities
- Environmental Interests
- Flood Districts
- Industry
- Municipalities
- Public
- River Authorities
- Small Businesses
- Water Districts
- Water Utilities

The TWDB provided detailed specifications to guide the preparation of the flood plans for each region. When complete, the 15 regional flood plans will be rolled up into the State Flood Plan that will provide a path forward to reduce existing risk to life and property and improve floodplain management data and practices. They will also identify potential FMEs, FMSs, and FMPs which may be appropriate for future studies and funding.

Data Sources

To ensure that flood plans are based upon consistent and reliable information in every region, the TWDB compiled Geographic Information System (GIS) data resources in the Texas Flood Planning Hub GIS layers are provided for:

- Critical infrastructure
- Flood infrastructure
- Flood risk
- Hydrology
- Jurisdiction boundaries
- Parks
- Population
- Property
- Terrain
- Transportation

The RFPG's dedicated GIS experts organized and analyzed this data for the Trinity Region, identified additional data sources needed to meet the TWDB's objectives, and used the data to prepare the illustrative maps included in this report.

To supplement the data provided by the TWDB, the RFPG also developed a data collection tool (survey) for entities with flood-related responsibilities. At least three recipients in flood-related roles from each community received this detailed survey to increase community response rates. Respondents provided contact information and their flood-related responsibilities, verified flood information that had already been collected, responded to questions to support the development of the regional flood plan, and verified and provided geospatial data through data uploads. An interactive web map allowed survey respondents to draw in problem areas and proposed projects that were not included in other information about the region.

Public Outreach

Almost 800 individuals representing the regional entities received the survey in July 2021. Postcards and emails were distributed to introduce the flood planning process and to provide the survey link. ***Figure 1.2*** illustrates the types of entities that were included in the data collection effort. ***Figure 1.3*** illustrates the various methods used to contact entities and the number of entities reached by each effort.

Figure 1.2: Outreach Efforts and Contacts Made

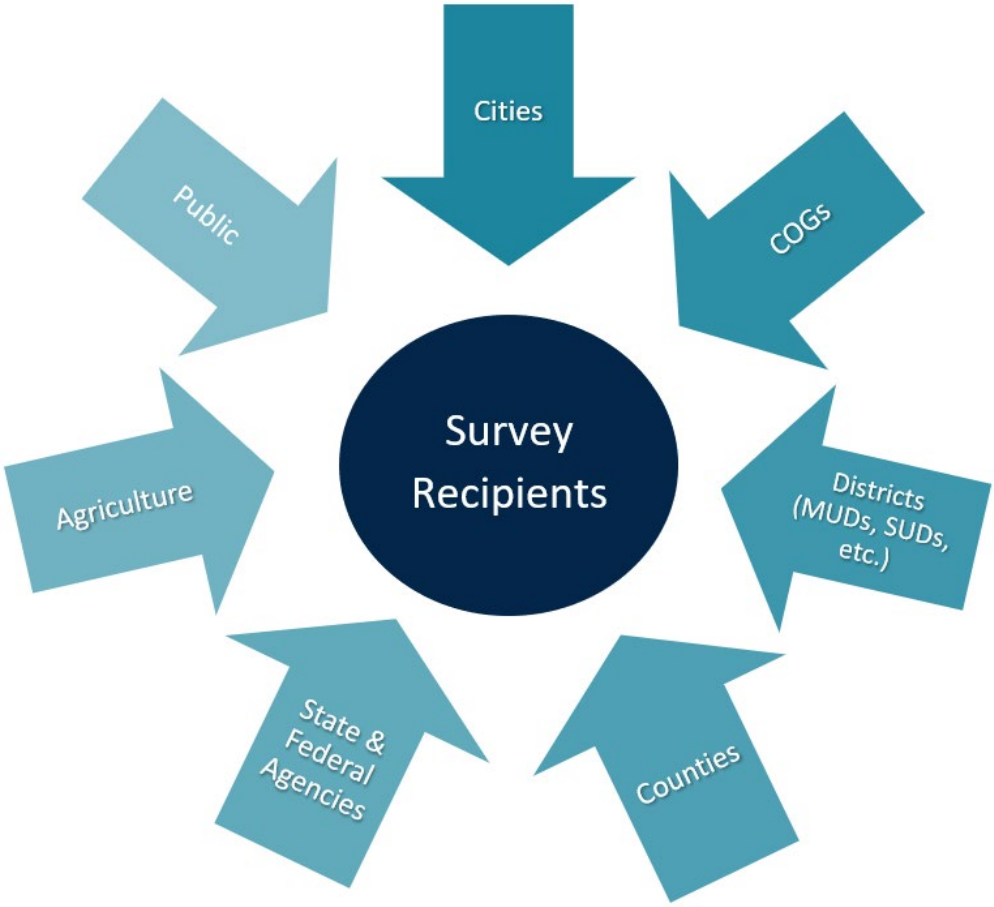
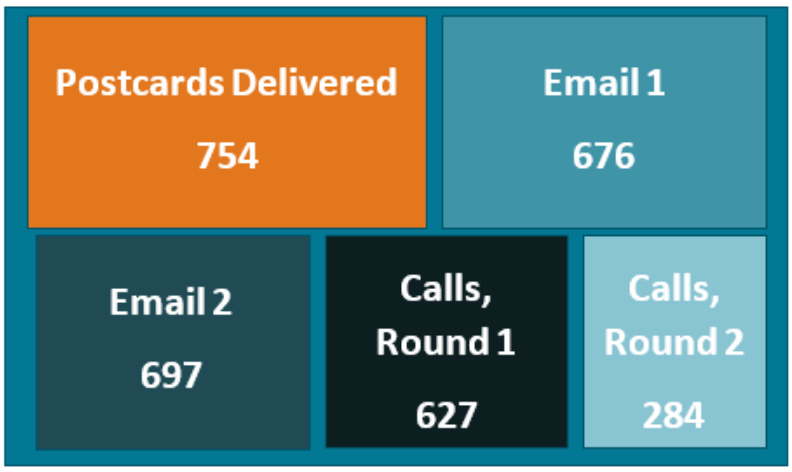


Figure 1.3: Outreach Efforts to Trinity Region Entities



To encourage participation, the RFPG followed up via email a week later. Calls went out to 627 recipients who had not yet responded, and a second round of calls was made to 284 recipients. The result of this effort was a response rate of approximately 30 percent. Survey results are included throughout ***Chapter 1*****,** and the chapters to follow.

Funding Sources

To fund projects identified by these plans, the legislature created a new flood financial assistance fund and charged the TWDB with administering the fund. The Texas Infrastructure Resiliency Fund, approved by Texas voters in November 2019, is being used to finance the preparation of these plans and will also be used to finance the recommended flood-related studies and projects. Communities who identify future projects aimed at flood mitigation will be eligible for financial assistance in the form of grants and loans from the TWDB. Additional discussion of funding sources available for flood mitigation activities, including federal and state funding, will be discussed in ***Chapter 4, Task 4B*** of this plan.

Characterizing the Trinity Region

Stretching from Gainesville, near the Oklahoma border, to Anahuac which meets the Trinity Bay at the Gulf of Mexico, the Trinity Region encompasses a wide variety of landscapes and communities and includes approximately 15,855 stream miles with a total drainage area of approximately 17,800 square miles. The total context of the Trinity Region with respect to the State of Texas is illustrated in ***Figure 1.4***. It is bounded to the north by the Red River Basin; to the east by the Sabine and Neches River Basins; and to the west and south by the Brazos and San Jacinto River Basins. From arid to subtropical, agricultural to urban, the flood risks faced by communities and landowners vary widely as well.

To better understand the nature of that flood risk, this section will discuss people, types, and locations of development; economic activity; and sectors at greatest risk of flood impacts. ***Table 1.1*** summarizes key elements of the primary streams and tributaries of the Trinity River system. ***Figure 1.5*** provides a map of those streams and tributaries described in ***Table 1.1***.

Social and Economic Character

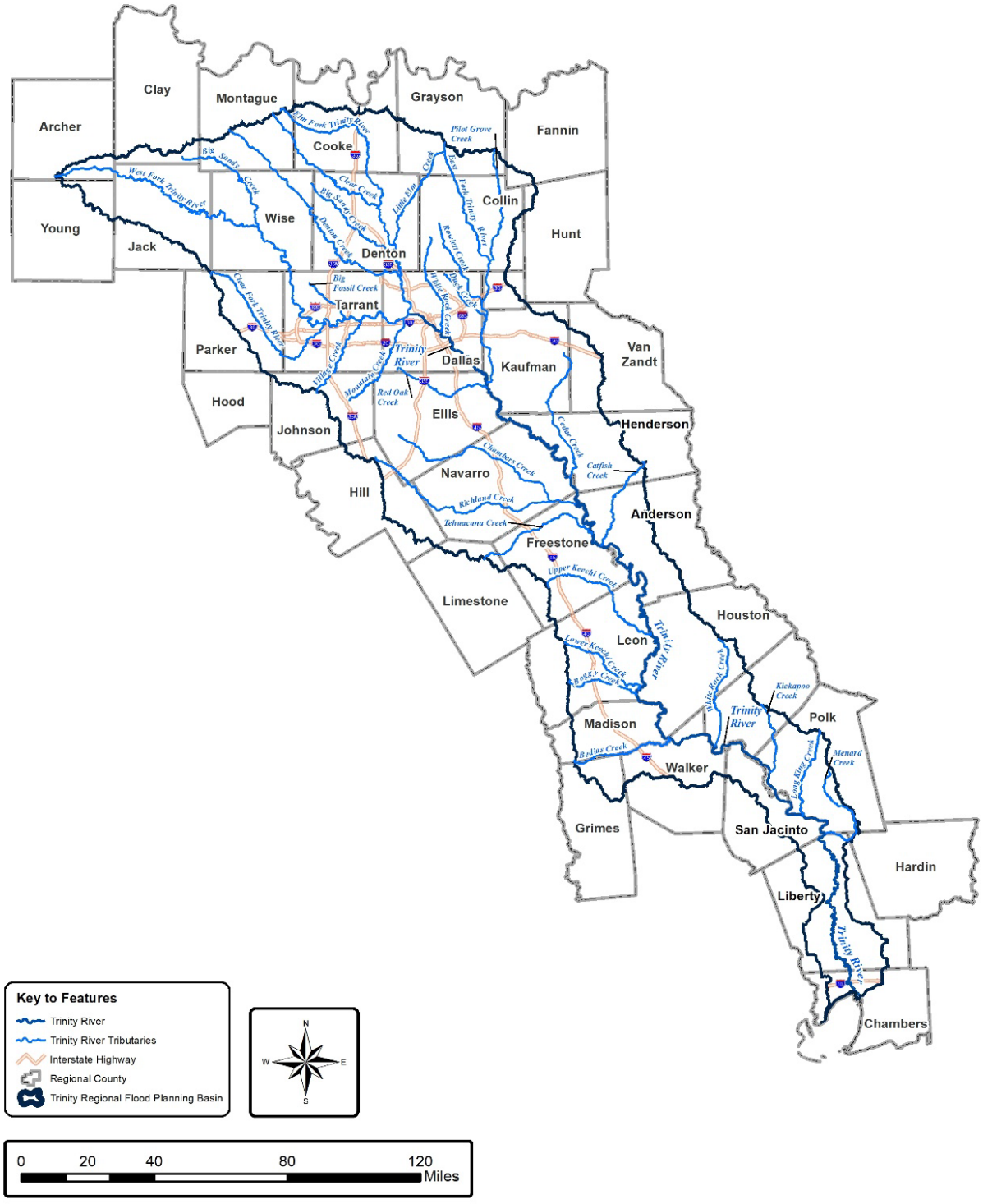
As the Trinity Region grows in population, many communities are expanding outward to accommodate this growth. Texas as a whole grew approximately 15 percent in the last decade, and research by the Texas Land Trends by Texas A&M Natural Resources Institute project found that in the Trinity Region alone, population grew by almost three million residents between 1997 and 2017.

Figure 1.4: Trinity Region Flood Planning Area

Table 1.1: Primary Streams and Tributaries of the Trinity River System

Stream Name	Length (River Miles)	Drainage Area (Square Miles)
West Fork of Trinity River	326	3,470
Clear Fork of Trinity River	66	524
Big Sandy Creek	53	353
Mountain Creek	40	295
Village Creek	36	191
Big Fossil Creek	20	56
Elm Fork of Trinity River	123	2,611
Denton Creek	107	719
Clear Creek	70	351
Little Elm Creek	39	261
Hickory Creek	46	179
White Rock Creek (Collin and Dallas counties)	38	135
East Fork of Trinity River	105	1,303
Pilot Grove Creek	49	443
Rowlett Creek	39	219
Duck Creek	23	43
Richland Creek	94	1,960
Chambers Creek	69	1,109
Cedar Creek	27	1,065
Tehuacana Creek	59	433
Catfish Creek	44	293
Red Oak Creek	40	232
Menard Creek	58	166
Boggy Creek	40	150
Kickapoo Creek	30	147
Upper Keechi Creek	67	511
Lower Keechi Creek	57	187
Bedias Creek	57	604
White Rock Creek (Houston and Trinity counties)	57	509
Long King Creek	39	225

Figure 1.5: Primary Streams and Tributaries of the Trinity River



Although growth has largely occurred in the Dallas-Fort Worth (DFW) metroplex, its effects can be felt downstream, as land that was once reserved for cropland or grazing declined during this period, with over 350,000 acres (about twice the area of Austin, Texas) of cropland and 120,000 acres of rangeland being converted to other uses. (Texas A&M Natural Resources Institute, 2021) As shopping centers occupy former pastures and row crops are replaced by subdivisions, the increase in paved surfaces reduces the absorption of rainwater. Urban drainage networks may also tax the capacity of the Trinity River's creeks and tributaries. Population growth and the outward expansion of metropolitan areas into what was formerly open space has increased the pressure on the region's flood control network and is exposing a growing number of residents to flood risk.

Population and Future Growth

Current Conditions

The Trinity Region is one of the state's most populated flood planning areas, with an estimated 7,854,000 residents living within a 17,800-square-mile area. The vast majority live in the counties that make up the DFW metroplex in the northern area of the region, with multiple smaller population centers interspersed with farms, ranches, forests, and other "working lands" as the river moves southward. In the central region of the basin, the communities of Corsicana, Trinidad, and Athens are located along an east-west axis that borders both Cedar Creek and Richland-Chambers Reservoirs, with Crockett and Palestine to the south and southeast. As the river moves southward toward Lake Livingston, it approaches the communities of Livingston and Liberty. The southern tip of the region borders the Trinity Bay and the Anahuac National Wildlife Refuge. Although not densely populated, the southernmost portion of the region attracts tourists engaged in birdwatching and fishing activities year-round.

Urbanized Areas

The 2019 Five-Year American Community Survey (United States Census Bureau, 2020) estimates, 27 percent of Texas residents currently reside in the Trinity Region. Within the region, there are 38 counties and 286 local communities, 52 of which have an estimated population of 25,000 or greater. Most of these communities are located within Dallas, Tarrant, Denton, and Collin counties.

Cities in the Trinity Region with an estimated population of 25,000 or greater include:

- Allen
- Arlington
- Balch Springs
- Baytown
- Bedford
- Benbrook
- Burleson
- Carrollton
- Cedar Hill
- Colleyville
- Coppell
- Corsicana
- Dallas
- Denton
- DeSoto
- Duncanville
- Euless
- Farmers Branch

- Flower Mound
- Forney
- Fort Worth
- Frisco
- Garland
- Grand Prairie
- Grapevine
- Haltom City
- Huntsville
- Hurst
- Irving
- Keller
- Lancaster
- Lewisville
- Little Elm
- Mansfield
- McKinney
- Mesquite
- Midlothian
- North Richland Hills
- Plano
- Prosper
- Richardson
- Rockwall
- Rowlett
- Sachse
- Saginaw
- Southlake
- The Colony
- University Park
- Watauga
- Waxahachie
- Weatherford
- Wylie

Only two larger communities are located outside the metroplex. The population of Huntsville in Walker County (which is only partially located within the planning area) was estimated at approximately 43,000 in 2019. Another larger community in the region includes Corsicana, (Navarro County) in the central Trinity Region.

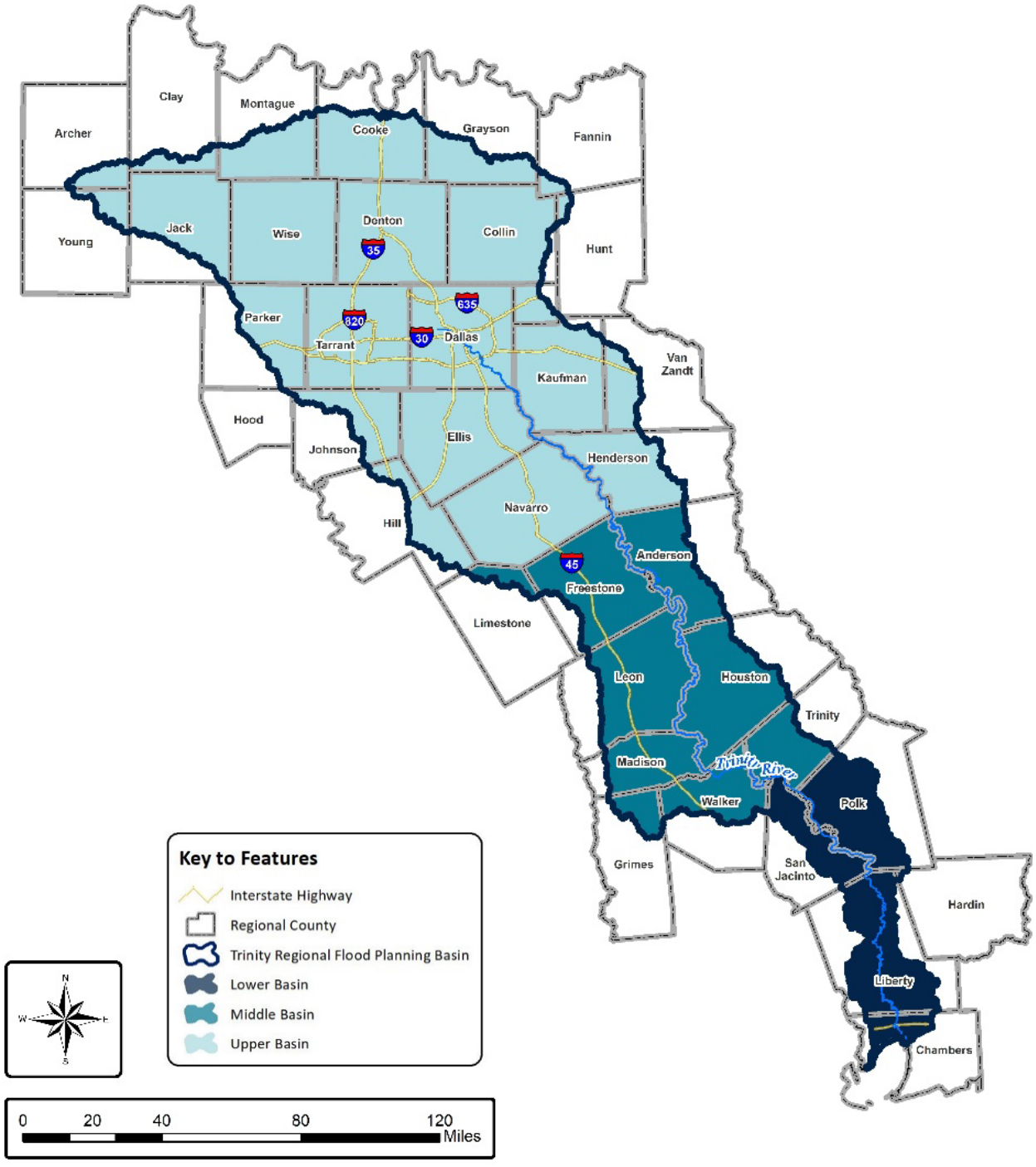
The Trinity Region also encompasses approximately 120 Municipal Utility Districts (MUDs) and Special Utility Districts (SUDs), 37 Water Control and Improvement Districts (WCIDs), and 10 Levee Improvement Districts (LIDs), many of which also have a role in flood protection.

Projected Growth within the Region

The current growth patterns in the Trinity Region are generally projected to continue over the next 30 years, with greater concentration in urban areas and even declining population in some rural counites. The analysis for this section was completed using the Water User Group and Hydrologic Unit Code (HUC)-8 population projections provided by the TWDB from the 2022 State Water Plan. From 2020 to 2050, the number of communities with populations over 25,000 is likely to increase to 64. The majority of these communities are within the DFW metroplex.

Due to the large area covered by the Trinity Region, the population projection analysis will be divided into three subregions (upper, middle, lower) that are generally divided by growth patterns, as illustrated in ***Figure 1.6***. These thresholds separate the communities into categories of similar size. The upper subregion contains those counties north of Navarro and Henderson, the middle subregion contains those counties north of Walker and Trinity counties and south of the upper subregion, the lower subregion contains the rest of the counties south of the middle subregion. ***Figure 1.6*** illustrates the dividing line between these subregions.

Figure 1.6: Trinity River Basin Sub-Regions



To determine growth patterns and population throughout the region, the team prepared ***Figure 1.7*** in which shading on the map indicates the population per community divided into five categories: 0-15,000; 15,001-50,000; 50,001-150,000; 150,001-350,000; 350,001+.

Upper Trinity

The upper portion of the Trinity Region encompasses the DFW metroplex and surrounding counties. A distinctive pattern within this subregion is an intense urban aggregation driven by the rapid acceleration of population growth. In fact, according to the TWDB's Water User Group projections, the top 10 fastest growing communities from 2020 to 2050 in the Trinity Region are within the upper subregion, all of which display over 250 percent increases in their population as shown in ***Table 1.2***. While Dallas, Fort Worth, and Arlington do experience large growth nominally, the higher extreme percentages happen in suburban communities in areas that are currently agricultural or ranching areas, as displayed in ***Table 1.2***. Generally, the fastest pace growth is in the northern portions of the DFW metroplex, specifically north and northeast of the City of Dallas.

Table 1.2: Top 10 Fastest Growing Communities in the Upper Trinity Subregion

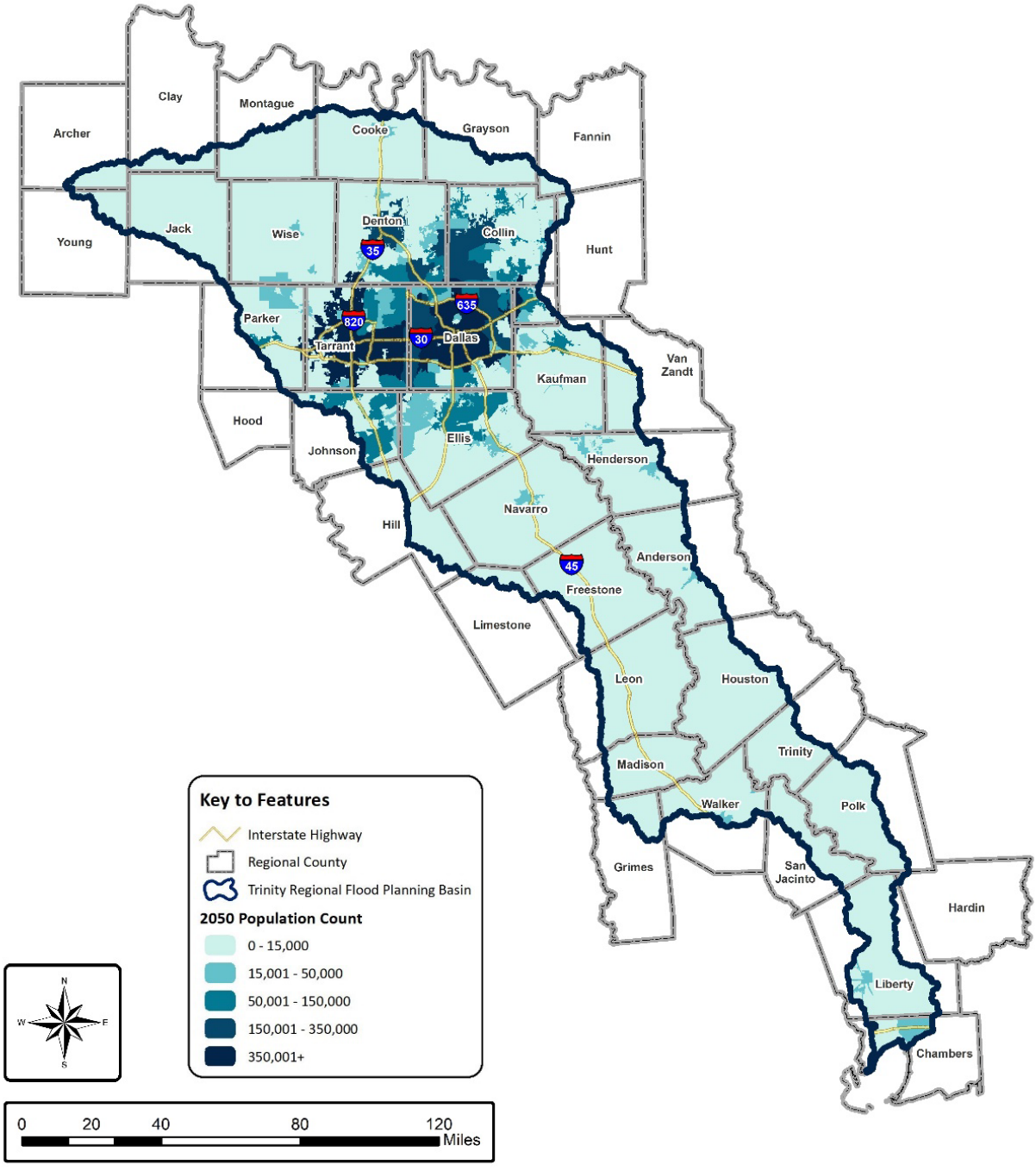
Community	Population 2020	Population 2050	Percent Change
Blue Ridge	2,425	81,703	3269%
Farmersville	8,660	75,393	771%
Princeton	11,047	91,943	732%
Haslet	1,750	14,000	700%
Celina	22,000	143,425	552%
Trenton	736	4,203	471%
Melissa	17,938	100,000	457%
Westlake	1,541	7,750	403%
Northlake	9,500	43,005	353%
Anna	15,037	53,553	256%

Source: TWDB Regional Water Plan, Water User Group Projections 2020-2070 (TWDB, 2020)

Middle Trinity

In the middle subregion, Navarro, Henderson, and Anderson counties feature communities with populations in the 15,000-50,000 range. However, none of these communities is anticipated to experience enough growth to move up to the next population category. Growth will continue to occur in and around larger urban areas. Of the larger communities in the middle subregion, Athens is projected to grow 34.05 percent, Corsicana increases in population by 32.94 percent, and Palestine will see a 4.48 percent increase in population.

Figure 1.7: Community Population Projections (2050)



Lower Trinity

The lower subregion of the Trinity Region's southernmost counties is within the Houston-Galveston Area Council region. Growth from the Houston area is expected to expand into these two counties and increase populations. While Huntsville remains within the 15,000-50,000 range, two communities within Liberty and Chambers counties are anticipated to rise into this range from the smaller category. According to the Water User Group projections of the largest communities, Huntsville will remain at the top with a projected growth rate of 11.5 percent, Dayton will surpass the City of Liberty with a growth percentage of 86.76 percent, and the City of Liberty will have a growth rate of 23.15 percent but will remain within the 0-15,000 category.

Economic Activity

Commercial Activity

To understand the economic risk that the region faces from flood events, this study identified the most significant industries within the region by three measures:

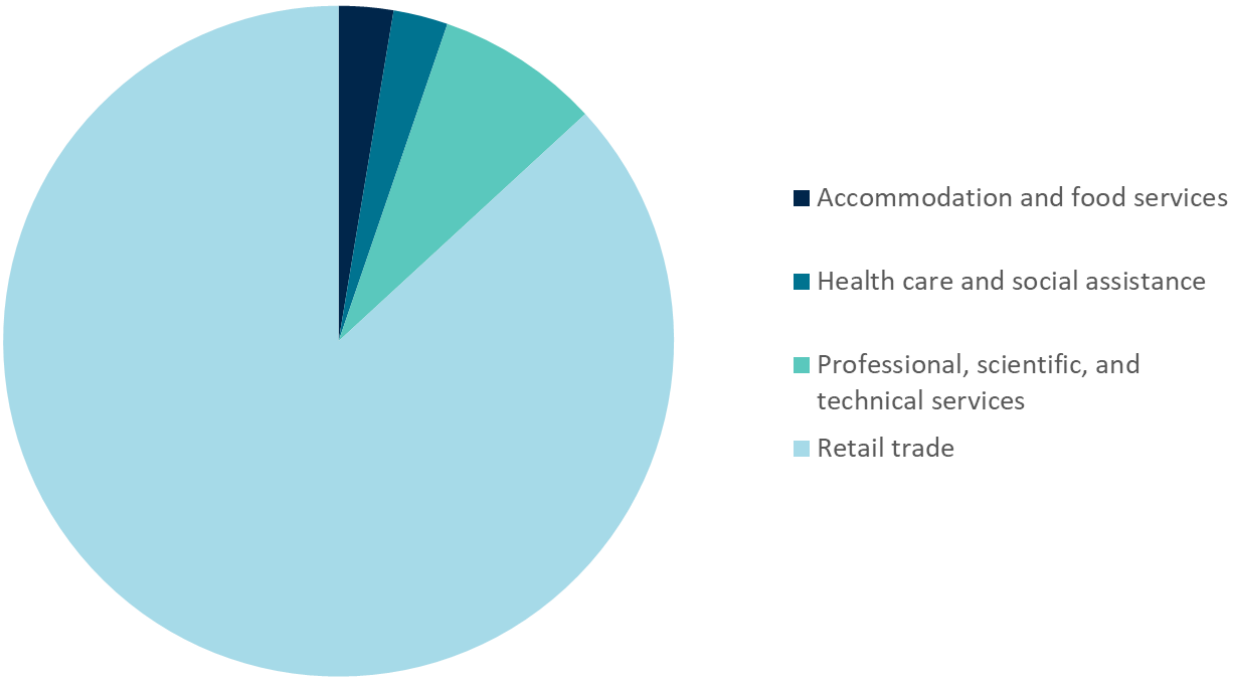
1. Number of establishments
2. Annual payroll
3. Total annual revenue

Data from the United States Census Bureau's Economic Census was used to identify the most predominant industries within the region. Industries were divided in accordance with the North American Industry Classification System (NAICS), which classifies all types of business sectors to facilitate the publication of statistical data related to the United States economy.

Number of Business Establishments

The total number of business establishments as of 2017 for every industry within the Trinity Region is approximately 196,600. As shown in ***Figure 1.8*****,** retail trade proved to be the predominant industry throughout the region. Retail trade was followed by professional, scientific, and technical services as the second most predominant industry within the region. Each business contributes to the tax base of their community, and most employ workers who depend on them as a sole source of income. If damaged or forced to close for an extended period of time, these businesses may each need financial and technical support to recover. The Federal Emergency Management Agency (FEMA) reports that roughly 40 percent to 60 percent of small businesses never reopen their doors following a disaster. The impact of business interruption on each individual business is significant. However, it is important to note the possibility that many of these retail establishments are smaller businesses and this measure may not fully capture the impact of a particular economic sector on the overall regional economy.

Figure 1.8: Major Industry by Number of Business Establishments



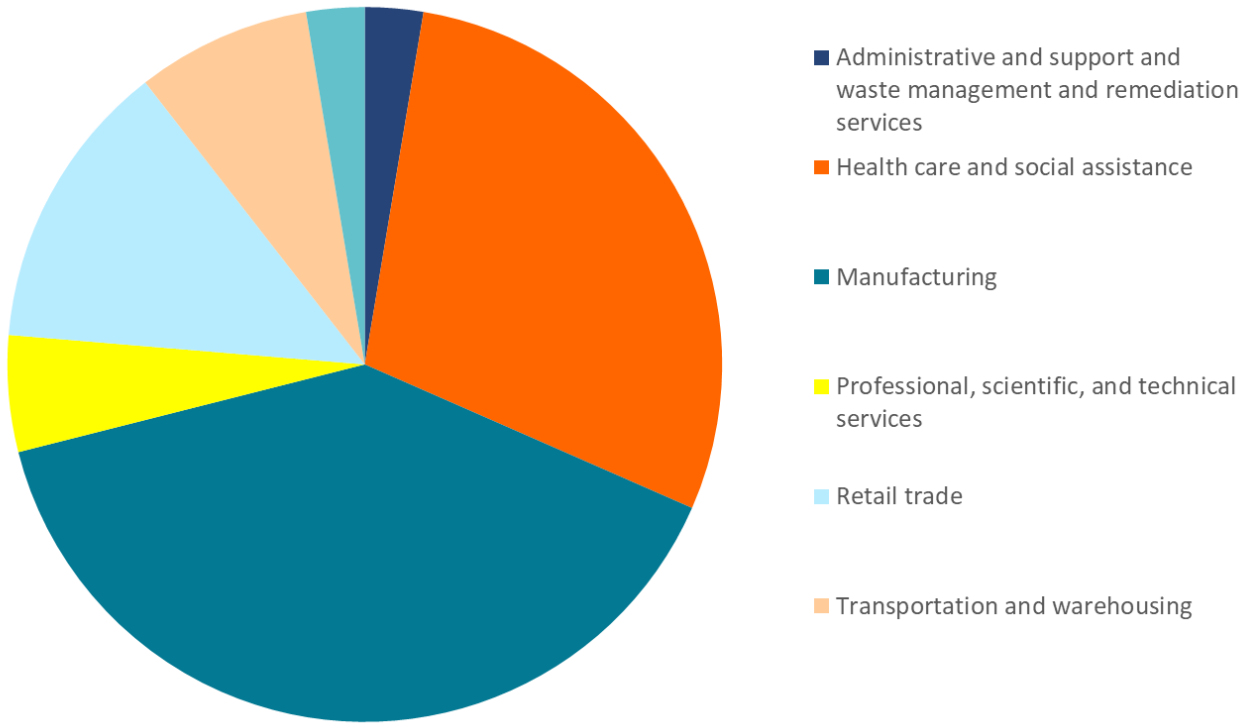
Source: United States Economic Census Table (United States Census Bureau, 2017)

Annual Payroll

The total annual payroll in the region as of 2017 is $178,500,918,000. The share of payroll by industry sector is showcased in ***Figure 1.9.*** Manufacturing and health care and social assistance represent the largest share of all industries by payroll. This is not surprising as both manufacturing and health care are among the highest-paying industries nationwide.

By mitigating the impact of flooding on businesses, communities can become more economically resilient. One factor that is considered in this plan is social vulnerability, as measured by the Social Vulnerability Index (SVI), which accounts for loss of income as one of the greatest predictors of future vulnerability for individuals and communities. The Index (SVI) uses 15 different census variables to help identify communities that may need support before, during, and after a disaster. A severe flood event, which could affect income in these sectors, would heavily impact those vulnerable populations.

Figure 1.9: Major Industry by Payroll



Source: United States Economic Census Table (United States Census Bureau, 2017)

Total Annual Revenue

The analysis for total revenue by industry may provide the most useful insight into potential economic disruption of a major flood event by indicating the sectors most likely to be exposed to this risk. Total revenue indicates which industries have the greatest economic impact. While agriculture is an essential industry throughout the region, it provides a smaller amount of revenue in the region than some of the other categories. ***Figure 1.10*** demonstrates that retail trade remains the dominant industry in this area, followed by manufacturing, and wholesale trade. To extend this assessment to the county level, ***Figure 1.11*** identifies which industry sector makes up the largest share of annual revenue in each Trinity Region county, in order to provide some perspective on the benefit of developing FMSs that reduce future economic impact.

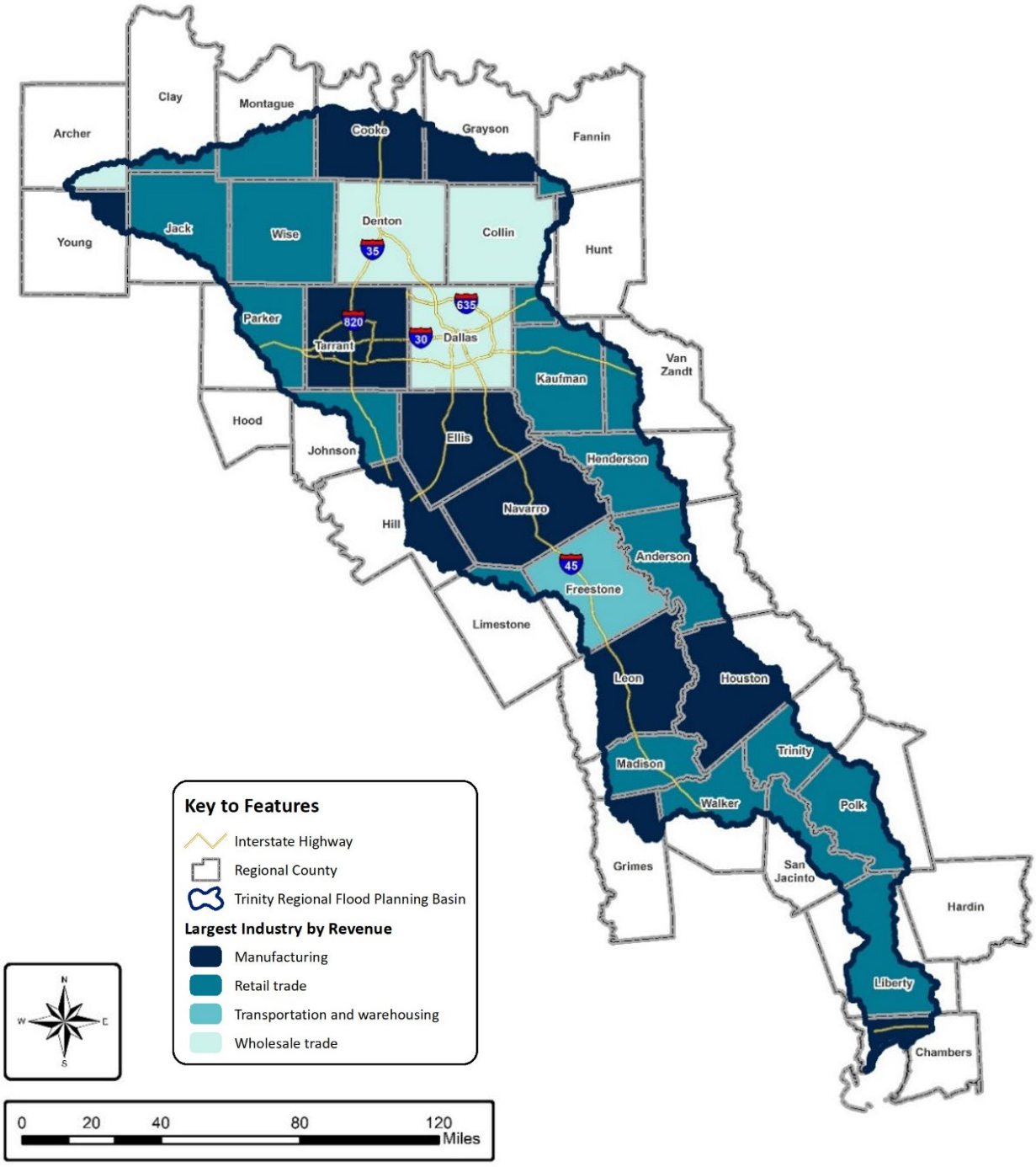
Figure 1.10: Major Industry by Revenue

Source: United States Economic Census Table (United States Census Bureau, 2017)

Agricultural and Ranching Activity

While the upper regions of the Trinity Region may draw attention due to the DFW metroplex, the waters of the Trinity River also traverse an extremely productive agricultural region with a rich farming and ranching heritage. Although the census did not record agriculture as being one of the top economic drivers in the region, it is still an integral component of the regional economy. Even though fewer people are exposed to flood hazards in these areas, the impact of flooding on agriculture, ranching, and forestry can be severe. Floods can delay the planting season, as they soak the fields and make them impassable for heavy equipment. This can lead to reduced crop size, lower yields, and reduced profits. When floods occur as crops mature in the fields, they may destroy a whole season's work and investment. Floods at harvest time can make it impossible for farmers to harvest mature crops and get them to market. Livestock may drown in floodwaters if there is no high ground for them to escape. Even if the animals are safe, damage may occur to barns and other structures, and cleanup of muck and debris can affect their feeding grounds. Forestry or orchard operations can lose trees to long periods of inundation, fast moving waters, and erosion, wiping out years of growth.

Figure 1.11: Major Industry by County



Source: United States Economic Census Table (United States Census Bureau, 2017)

To characterize the economic activity and character of Texas' rural spaces, this document employs the term "working lands", used by the Texas A&M Natural Resources Institute to describe rural economic activity. Working lands are privately owned farms or cropland, ranches, and forests and associated uses that make up the majority of economic activity in Texas' rural areas.

The distribution of these land uses across Texas is illustrated in ***Figure 1.12,*** which uses data from the United States Geological Survey (USGS) to help visualize how land is used across the region. The area dedicated to each use identified in ***Figure 1.12*** is as follows:

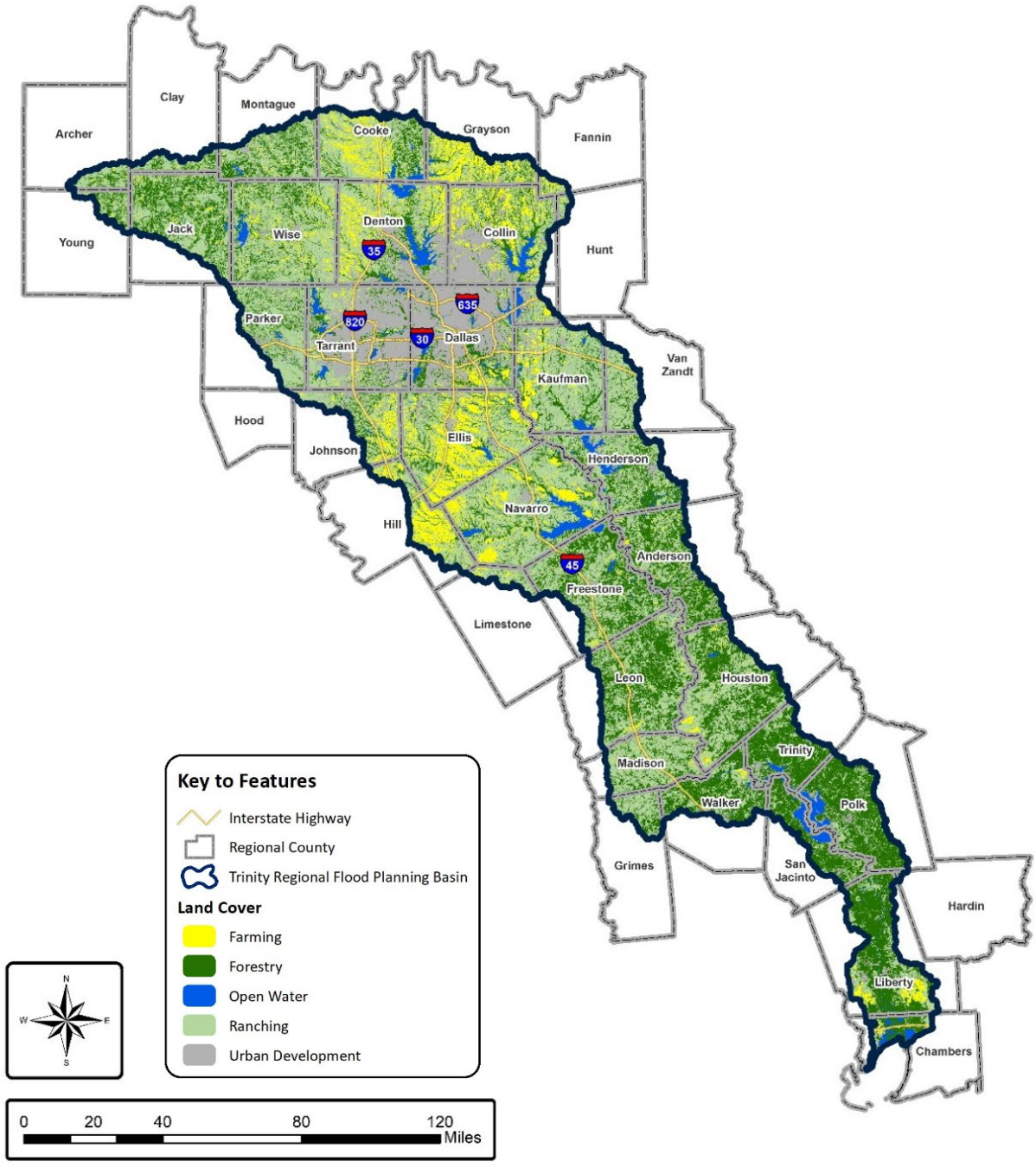
- **Ranching:** 4,882,000 acres
- **Forestry:** 3,415,000 acres
- **Farming:** 1,175,000 acres
- **Urban development:** 1,660,000 acres

Across Texas, the average acreage of farm and ranch operations is decreasing, and smaller parcel size may reduce the profitability of these enterprises. When combined with losses due to flooding, this could increase the likelihood of economic failure of a farming, ranching, or forestry operation.

Ranching and rangeland land uses predominate to the northwest of the Trinity Region in Wise, Parker, and the western half of Tarrant counties. Large landholdings in these counties may also be reflected in socioeconomic data, where census tracts far outside of urbanized areas have a very high median income. In the central portion of the flood planning area, Kauffman, Navarro, Henderson, and Madison counties are home to some of the largest concentrations of rangeland.

Farmland, symbolized in yellow, is the predominant use of working lands in the upper region. The Blackland Prairie Ecoregion in Grayson and Collin counties north of the metroplex, and Ellis, Johnson, Hill, and Navarro counties to the south are home to some of the state's most fertile croplands. Cooke and Denton counties also retain significant farmland in the Cross Timbers Ecoregion, although Denton County cropland continues to experience encroachment from urban areas. As the Trinity Region descends south toward the Gulf, farming activity resumes. According to the United States Department of Agriculture (USDA), major crops between 2015 and 2019 included sorghum, corn, and winter wheat, with rice in Liberty County and a small share of the state's cotton production. (USDA, 2021).

Figure 1.12: Working Lands in the Trinity Region by Land Cover



Source: USGS National Land Cover Database 2016 (USGS, 2016)

Economic Status of Population

Median Household Income (MHI) divides the data from the 2021 Environmental Systems Research Institute (ESRI) Census Tract data levels across the region in two equal halves to provide a good comparison for income levels across the region. The MHI can be affected by many factors, including education levels, opportunity of employment, and location. It is important to note that within any given area, there are residents that are outliers in both directions. The state MHI according to this measure is $63,500. Many communities near the downtown areas of Dallas and Fort Worth, as well as the inner ring suburbs of DFW are living on incomes below the state MHI. The lowest income tier is illustrated on ***Figure 1.13***. Suburban communities outside of these central areas in the northern suburbs have the region's highest median incomes. Another location with higher-than-average incomes is the southernmost portion of the region near the Trinity Bay. As the region moves south, the majority of census tracts have MHIs that are comparable with the state as a whole, however in many rural areas' household incomes are significantly lower than the state median.

Income Levels by Subregion

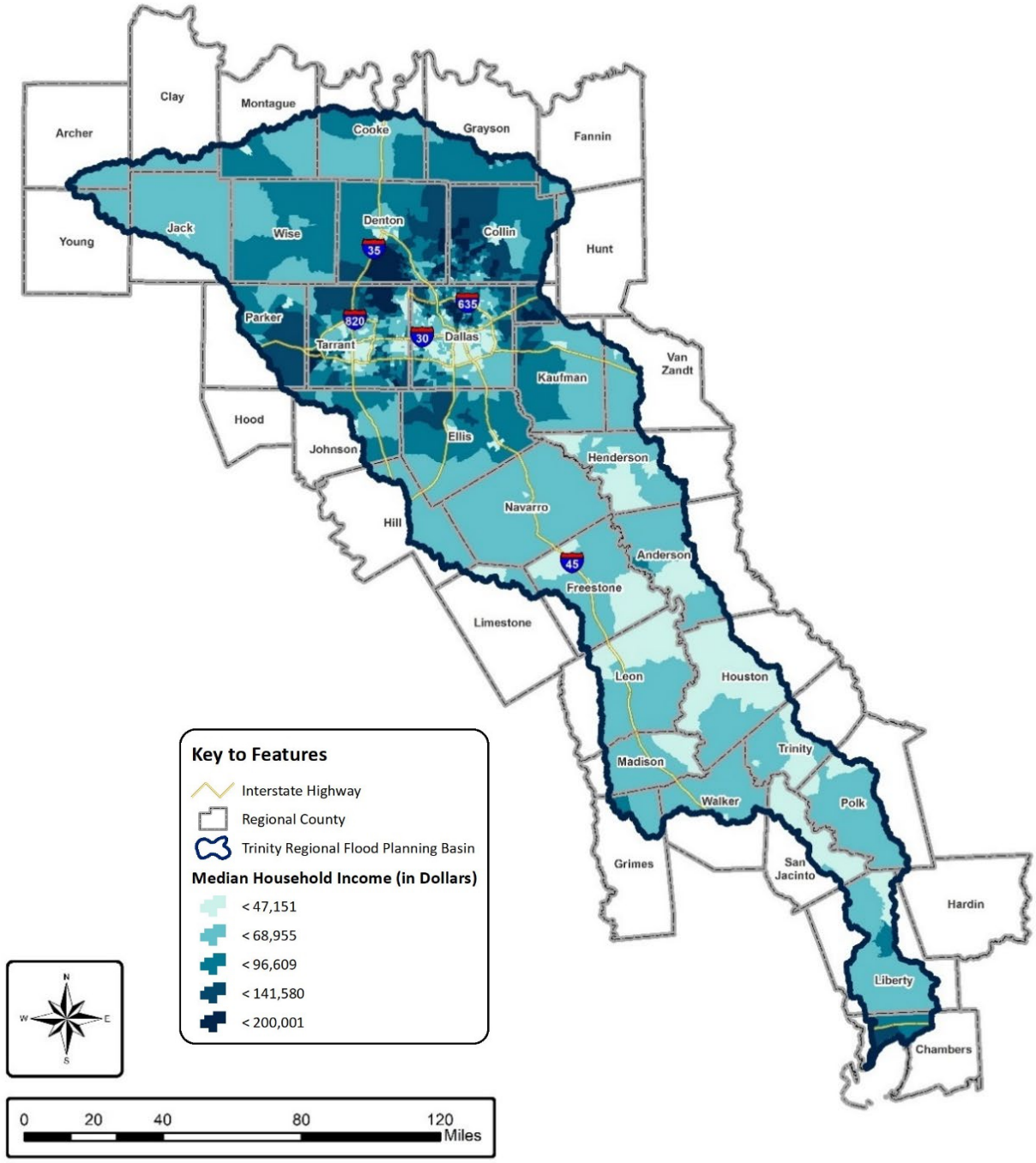
The upper subregion of the Trinity Region features the highest levels of household income, but still shows a wide diversity of incomes, with census tracts in every household income category. All of the region's highest annual income census tracts in the greater than $141,580 category lie within this subregion. The highest median income areas are within North Dallas, Southlake-Flower Mound area, near the Denton County – Collin County border, and to a lesser extent within Rockwall and Tarrant counties. All but one of the census tracts in the $96,609-$141,579 range are within the upper subregion.

As stated previously, many of these tracts lie on the outskirts and suburbs of Dallas and Fort Worth, predominantly in the northern suburbs of Dallas. The $68,955-$96,608 category comprises most of Ellis, Kaufman, and Wise counties and half of Denton County. The final two household income categories are mostly concentrated in the Dallas and Fort Worth area, with some tracts being in the more rural areas of the upper subregion. See ***Figure 1.13*** for more details on the distribution of income across the region.

The majority of the census tracts within the middle subregion have household incomes roughly equivalent to the state median income of $63,500. There is one census tract in the western portion of Anderson County that is within the $68,955-$96,608 category.

The lower subregion increases in household income as it nears the Trinity Bay and the influence of Houston. While there are many tracts in the lower two categories, there are a few tracts within Liberty, Chambers, and Grimes counties that are in the $68,955-$96,608 category. The tract bordering the Trinity Bay within Chambers County is within the $96,609-$141,579 category.

Figure 1.13: Median Income by Census Tract



Source: ESRI Business Analyst Census Tract Data (United States Census Bureau, 2021)

Social Vulnerability Analysis

When anticipating the likely extent of damages to a community from catastrophic floods, this assessment first considers "exposure" based on geographic location of people and property. Another important dimension to increasing the resilience of the communities in the Trinity Flood Planning Region is their relative "vulnerability" to floods when they do occur. Disasters affect different people or groups in different ways, which range from their ability to evacuate an area in harm's way, to the likelihood of damage to their homes and properties, to their capacity to marshal the financial resources needed to recover and rebuild after a storm. These factors are known as Social Vulnerability, or a person's or group's "capacity to anticipate, cope with, resist, and recover from the impacts of a natural hazard" based on their relative vulnerability. ***Figure 1.14*** is based upon an analysis of this region using the SVI – from the United States Department of Health and Human Services (HHS) Centers for Disease Control and Prevention (CDC). The Index is measured on a scale of 0-1, with 1 being the highest level of vulnerability and is used here to map social vulnerability in the region. The index focuses on a series of 15 demographic indicators:

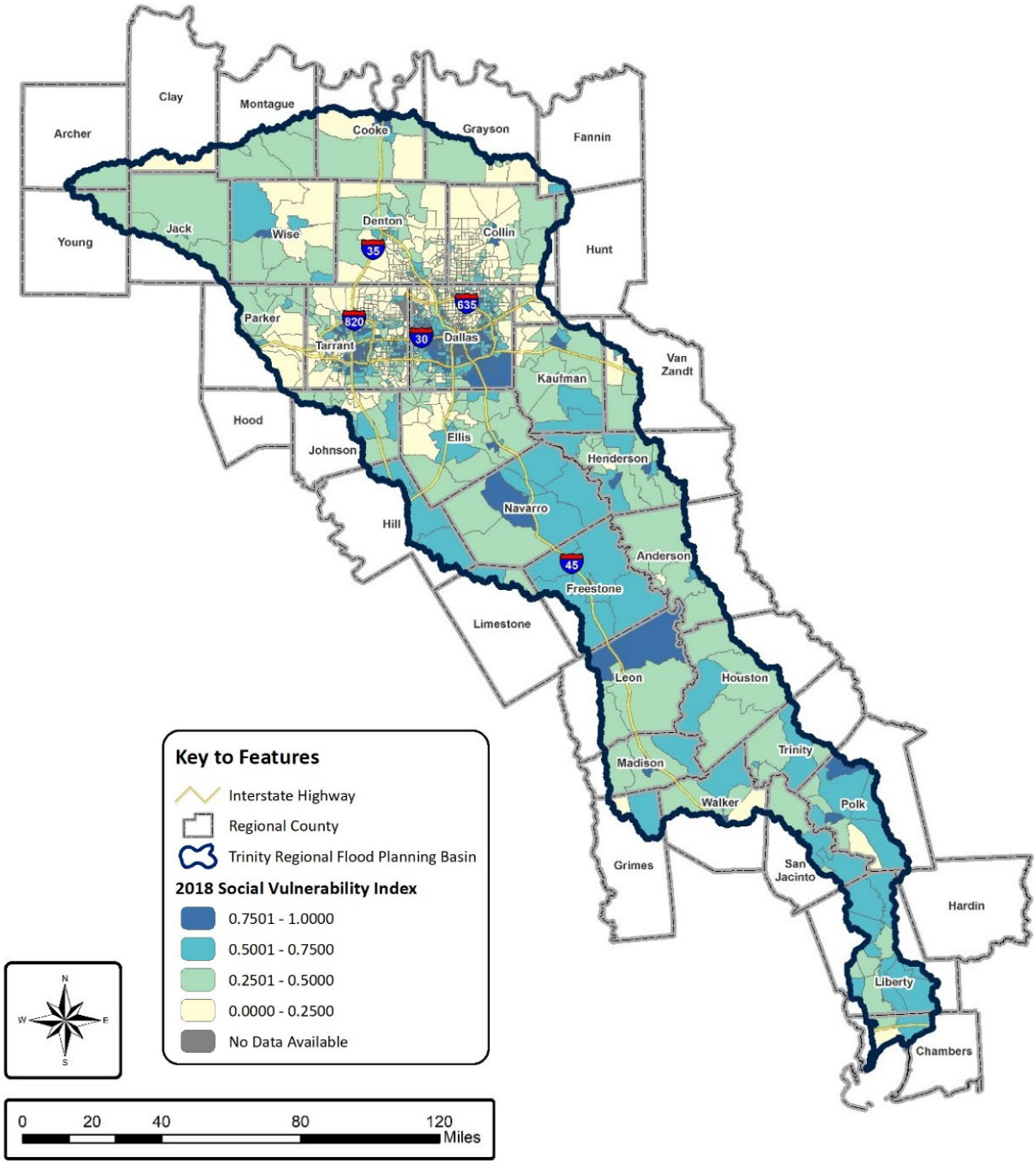
- Below poverty
- Unemployed
- Low Income
- No vehicle
- No high school diploma
- Aged 65 or older
- Aged 17 or younger
- Civilian with a disability
- Single-parent households
- Minority status
- Multi-unit structures
- Mobile homes
- Crowding
- Group quarters
- Language barriers

(Jaimie Hicks Masterson, 2014)

The presence of multiple factors above in a population, or even an individual household, have proven to be a reliable indicator of the long-term impact of a disaster. In ***Chapter 2***, this regional plan engages in a more detailed discussion about the location of high social vulnerability populations, the location of flood protection infrastructure and how future FMPs might reduce their vulnerability to injury and economic losses.

The level of social vulnerability varies widely even within a single county, which may contain both the most and least vulnerable populations. In the Trinity Region, the highest concentrations of social vulnerability, as shown in dark blue, are in the census tracts to the southeast of Dallas in Dallas County, Tarrant County south of Fort Worth, and small but densely populated census tracts in Wise, Collin, and Kaufman counties.

Figure 1.14: Social Vulnerability Index by Census Tract



Source: Social Vulnerability Index by Census Tract (United States Center for Disease Control, 2018)

Navarro County to the west of I-45 and two census tracts in Henderson County show evidence of high social vulnerability. In the middle subregion, the northernmost census tract of Leon County indicates high social vulnerability. Two census tracts in Polk County are the only areas to show the highest level of social vulnerability in the lower subregion, but as the Trinity River winds southward, there is an increasing likelihood that Counties and census tracts will show a modest to high level of social vulnerability, with a score of 0.5 to 0.75.

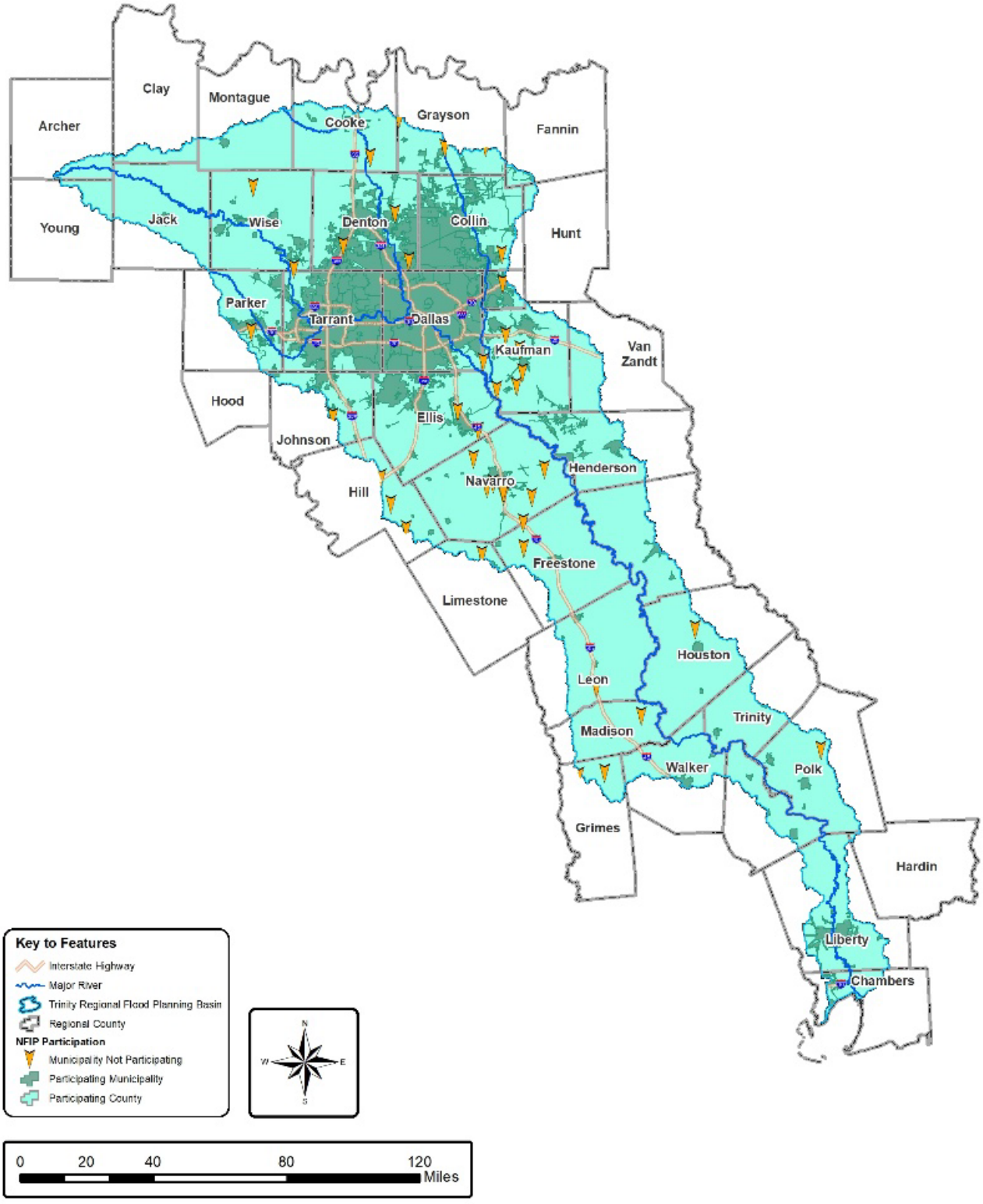
Flood-Prone Areas and Flood Risks to Life and Property

As Texas seeks to better manage flood risk to mitigate loss of life and property from flooding, this section establishes a baseline of what is known with respect to the area's exposure to flood hazards, as well as the vulnerability of the communities within the Trinity Region. This is a critical step in reducing the vulnerability of the Trinity Region's people and places to future flooding.

Today, a patchwork quilt of plans, regulations, and infrastructure provides Texans with limited protection from flooding. This planning largely takes place at a local level, with an inconsistent set of standards from community to community that makes it very difficult to quantify risk across the region. Fortunately, majority of the communities in the Trinity Region (87 percent) participate in the National Flood Insurance Program (NFIP). This is good news, as it improves their prospects for economic recovery in the event of a major flood and provides a system to reduce flood risk to new development. However, many communities are using maps that are decades old and may only tell part of the story. These maps may not reflect changing patterns of development and often fail to identify flood risks associated with changes in the topography and environment. Additionally, Flood Insurance Rate Maps are intended to identify and communicate risks in the watershed less than one square mile but do not always include all watersheds and may be greater than one square mile in many communities. ***Figure 1.15*** shows the participating communities within the Trinity region. While all the counties within the region participate in the NFIP, the same is not true of all the cities.

In the absence of a cohesive flood map that applies across the region, the following chapters of this assessment will piece together an intricate flood quilt, combining several data layers from FEMA, including effective detailed maps, effective approximate maps, Base Level Engineering (BLE) with data from other federal agencies, local and regional studies, and the commercially available data prepared by Fathom that was provided by the TWDB. (Additional information on the floodplain quilt is included in ***Chapter 2***.)

Figure 1.15: Participation in National Flood Insurance Protection Program



Identification of Flood-prone Areas

According to current FEMA mapping, approximately 20 percent of the total area in the region is within the 1% annual chance storm event. In the Trinity Region, more than 50 communities have over 20 percent of their land located in the floodplain. This only tells part of the story, because not all the floodplains within the Trinity Region have been mapped and modeled. While developing a comprehensive flood risk model of the region is beyond the scope of this planning effort, the TWDB provided a floodplain quilt for use in this plan. The quilt is a combination of various sources of data, providing comprehensive coverage of all known existing statewide flood hazard information.

Figure 1.16 shows the initial flood quilt information provided by the TWDB that served as the Trinity Region's starting point, providing an approximation of region-wide flood risk using currently available data. In subsequent chapters, this "quilt" is confirmed, updated, and otherwise enhanced as appropriate to prepare a larger flood risk assessment (TWDB, 2021). When complete, this regional flood quilt identifies gaps in information and more accurately estimates the distribution of flood risk across the region. A more comprehensive description of the identification of flood-prone areas is provided in ***Chapter 2***.

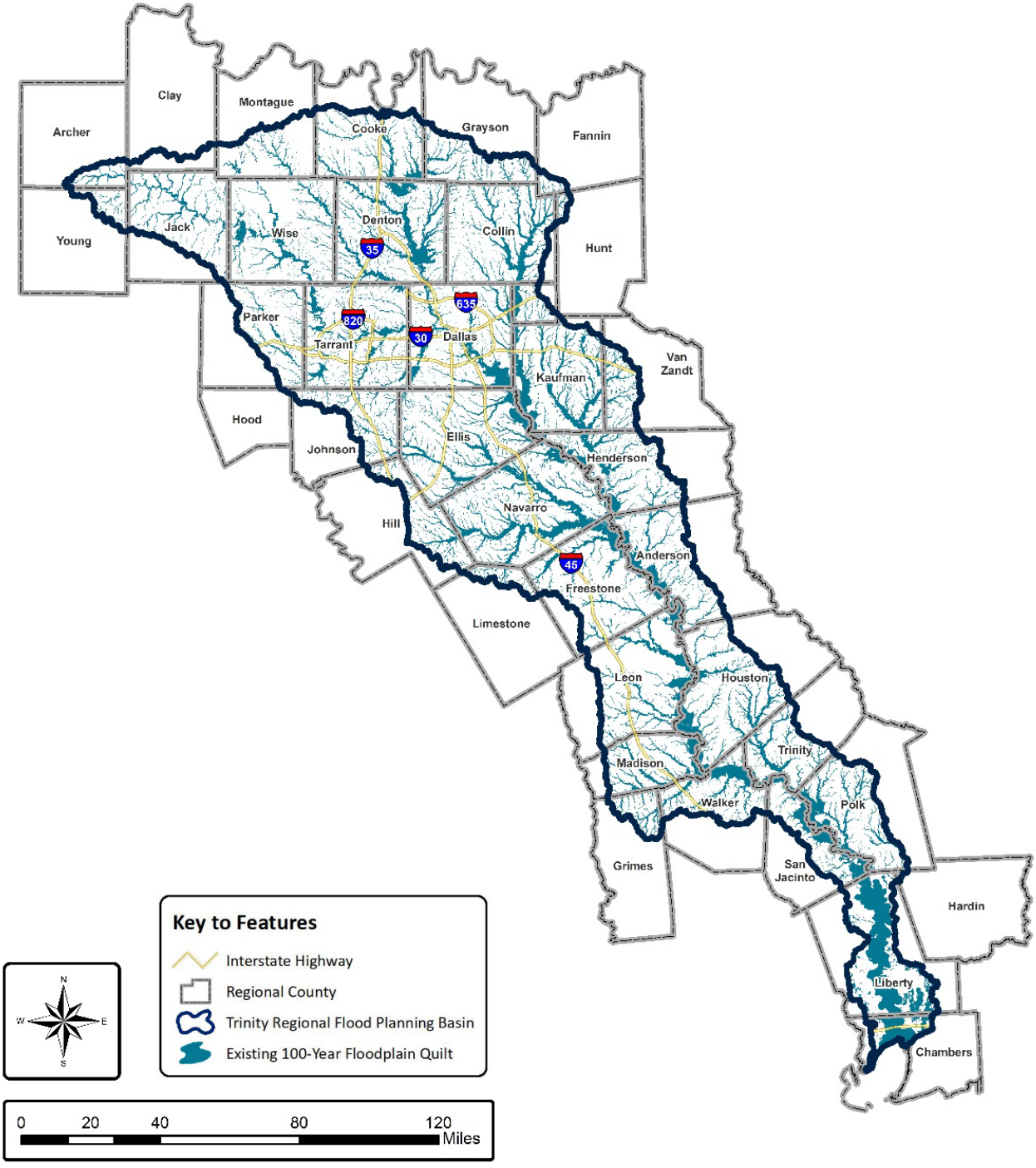
Key Historical Flood Events

The cycle of catastrophic disasters in the Trinity Region ebbs and flows year by year, but a long history of flooding has irrevocably shaped its communities, with flood control measures like dams and levees expanding the lands available for new development. Early historical Trinity River floods affected population centers located along the river and its major tributaries. The 1908 and 1942 floods in Dallas and Fort Worth resulted in the creation of the USACE Fort Worth District in 1950 (USACE, USACE Fort Worth District History, 2021) and spurred the construction of multiple dams for flood control purposes within the Trinity Region (Cotter & Rael, 2015). In the years since, these flooding concerns have been addressed by state and local efforts in addition to the USACE. ***Chapter 4*** includes more detailed information on historical flood events.

For example, one of the most significant storms was the May 1949 flood in the DFW Metroplex. The levee for the Clear Fork of Trinity River in Fort Worth failed, inundating hundreds of homes and businesses. ***Figure 1.17*** illustrates the impacts of this flooding in what are now some of the busiest commercial and residential areas of the City of Fort Worth.

Even though there are many years with no recorded disaster that reaches either the level of a Major Disaster Declaration (DR) or an Emergency Declaration (EM) the cumulative impact is great. Frequently, however, when one disaster occurs, it is followed by one or more catastrophic events during the same year, and perhaps even the same month.

Figure 1.16: Flood-Prone Areas



Source: TWDB Flood Quilt Data

Figure 1.17: Image of Flooded Wards Building and Rooftops, Fort Worth

Source: USACE (USACE, 1949)

Since 2000, there have been 125 EMs and 112 DRs within the Trinity Region (FEMA, 2021). A Presidential DR puts into motion long term federal recovery programs, some of which are matched by state programs, and designed to help disaster victims, businesses, and public entities. An EM is more limited in scope and without the long-term federal recovery programs of a DR.

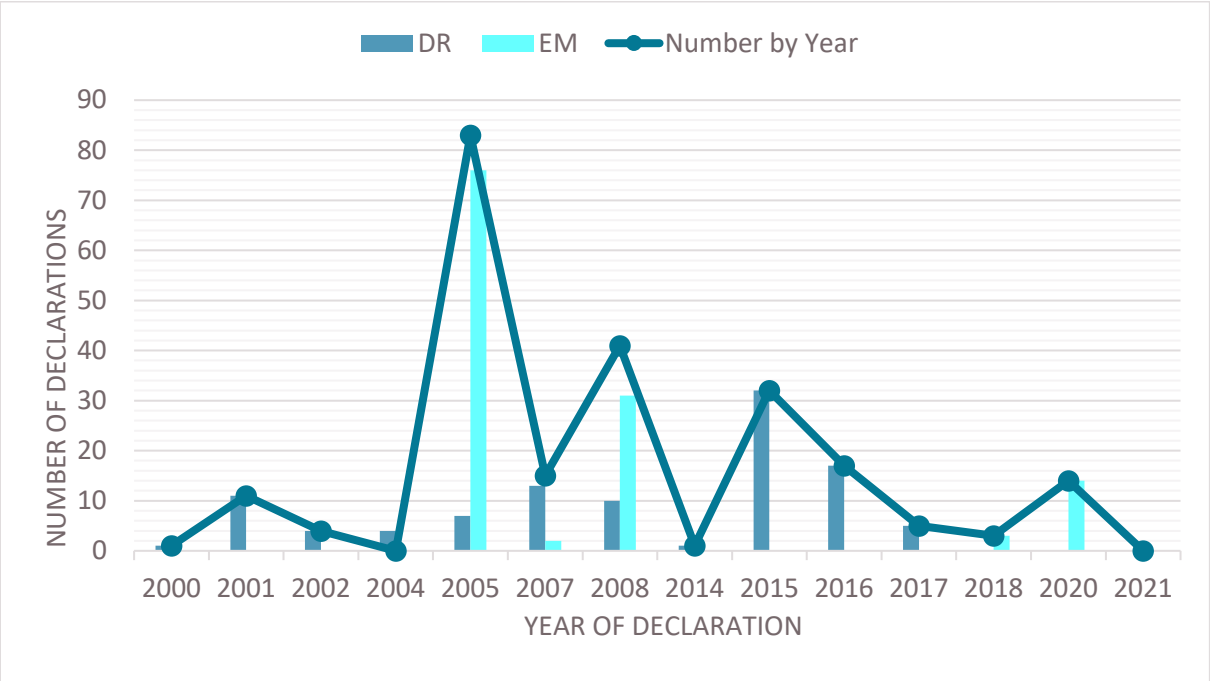
Generally, federal assistance and funding are provided to meet a specific emergency need or to help prevent a major disaster from occurring. Public Assistance (PA) is FEMA's largest grant program providing funds to assist communities responding to and recovering from major disasters or emergencies declared by the president. The program provides funding for emergency assistance to save lives and protect property and assists with funding for permanently restoring community infrastructure affected by a federally declared incident. Supplementally, PAs can be categorized for emergency work such as PA-A which is for debris removal and PA-B which is for emergency protective measures. Individual Assistance (IA) programs are made available under EMs and are limited to supplemental emergency assistance to the affected state, territory, or tribal government to provide immediate and short-term assistance essential to save lives, protect public property, health, and safety, or to lessen or avert the threat of a catastrophe. All IA programs may be authorized once a major disaster has been declared by the president. The approval of IA under a DR may also activate assistance programs provided by other federal agencies based on specific disaster needs.

Figure 1.18 charts the frequency of these declarations across the Trinity Region for the last 21 years. Some of the most significant events in that time period follow. To search for more information on EM of DR, FEMA provides a search tool found here: https://www.fema.gov/disaster/declarations.

EM-3216-TX, August 2005 (Hurricane Katrina)

Hurricane Katrina was a category five Atlantic hurricane that caused over 1,800 deaths and $125 billion in damage in late August 2005, particularly in the City of New Orleans and the surrounding areas. At the time, it was the costliest tropical cyclone on record and is now tied with 2017's Hurricane Harvey. The storm was the twelfth tropical cyclone, the fifth hurricane, and the third major hurricane of the 2005 Atlantic hurricane season, as well as the fourth-most intense Atlantic hurricane on record to make landfall in the contiguous United States. The State of Texas had an EM declared on September 2, 2005, for PA for 254 counties, including all the Trinity Region counties for emergency protective measures. Texas took in over 250,000 evacuees from Louisiana and other affected states.

Figure 1.18: Disaster Declarations within Trinity Region, 2000-2021



Source: Flood Events by County
(National Centers for Environmental Information, 2022)

EM-3261-TX, September 2005 (Hurricane Rita)

Hurricane Rita was the most intense tropical cyclone on record in the Gulf of Mexico. It moved westward through the Florida Straits, where it entered an environment of abnormally warm waters. Moving west-northwest, it rapidly intensified, achieving category five status on September 21. However, it weakened to a category three hurricane before making landfall in Johnson's Bayou, Louisiana, between Sabine Pass, Texas and Holly Beach, Louisiana. The timing of Hurricane Rita following on the heels of Hurricane Katrina compounded the disaster as Texas was still sheltering evacuees across the Trinity Region when Rita made landfall.

The impact of Rita on Southeast and East Texas included both wind and storm-surge damage. Due to the extensive damage, an EM for PA for 254 counties, including all the Trinity Region counties was made.

DR-1791-TX, September 2008 (Hurricane Ike)

On September 12, 2008, a DR was declared due to Hurricane Ike. This event had sustained winds of 110 mph upon landfall in Galveston Island making it a category two hurricane. Ike was of a severity and magnitude that the need for supplemental federal assistance was determined to be necessary. For 34 counties, 11 of which are in the Trinity Region, this declaration made IA

funding available to affected individuals and households. This declaration also made the PA program available to state and eligible local governments and certain private nonprofit organizations on a cost-sharing basis. A total of 50 counties qualified for PA with 13 of those counties being within the Trinity Region.

DR-4223-TX, May 2015

In the spring of 2015, the Trinity Region experienced several rounds of severe weather which culminated in supercell thunderstorms, dubbed the Memorial Day floods of 2015. Heavy rainfall leading up to the Memorial Day event saturated the soil, intensifying flooding. The National Weather Service recorded over 16 inches of rainfall at DFW International Airport signaling the wettest single month in the DFW Metroplex since 1982. While the flash flooding event was short lived, the cumulative impacts of the event, coupled with Tropical Storm Bill, taxed the basin's rivers and lakes. Several reservoir levels came within inches of breaking all time crest records recorded from a period of record spanning over 110 years. (NCTCOG, 2015) Another round of severe rainfall and subsequent flooding came in the fall of the 2015. This event particularly impacted the lower portion of the region within Liberty and Chambers County where the Trinity River rose above the flood stage.

On May 29, 2015, the State of Texas requested a DR due to severe storms, tornadoes, straight-line winds, and flooding which began on May 4, 2015, and continued through June 22, 2015. The requested declaration included IA for 22 counties including 17 Trinity Region counties, PA for 110 counties including 31 Trinity Region counties, and hazard mitigation for the entire State of Texas. Preliminary damage assessments were conducted in the requested counties to estimate damages immediately after the event and determine the need for additional assistance. On May 29, 2015, the president declared a Presidential Disaster Declaration in the State of Texas.

DR-4332-TX, August 2017 (Hurricane Harvey)

On August 23, 2017, Harvey was upgraded to a tropical depression. Over the next 48 hours Harvey would undergo a period of rapid intensification from a tropical depression to a category four hurricane. Harvey made landfall along the Texas coast near Port Aransas on August 25, 2017, as a category four hurricane and brought devastating impacts. As Harvey moved inland, its forward motion slowed and then meandered back offshore. Harvey continued to skirt the coastline as it made landfall a second time in the Harris County area on August 26th and then a third time just west of Cameron, Louisiana on August 30th.

Rain bands on the eastern side of the circulation of Harvey produced rapid flash flooding and devastating, widespread flooding as the storm moved into southeast Texas. All of this rainfall caused catastrophic flooding and drainage issues and caused rivers to rise and spill out of their banks. Approximately 46 percent of the river forecast points reached new record levels. Harvey

maintained tropical storm intensity the entire time while inland over the Texas coastal bend and southeast Texas.

The southern region of the Trinity Basin was once again severely impacted by flooding during Hurricane Harvey. From late August through early September, approximately 2.8-million acre-feet of water was released to the Galveston Bay from Harvey rainfall in the proximity of Liberty County. The City of Liberty, located in Liberty County, recorded 55 inches of rain during Harvey with damages over $11 million. (TRA of Texas, 2021) Overall, Harvey caused $125 billion in damages.

On August 25, 2017, the State of Texas requested an expedited DR due Hurricane Harvey. The DR request covered 60 counties with 10 Trinity Region counties included. The requested declaration included IA and direct federal assistance under the PA program for 41 counties, including seven Trinity Region counties and hazard mitigation statewide. On August 25, 2017, the president declared a major disaster for the State of Texas.

Past Casualties and Property Damage

In a major flood event, there are often losses incurred. In the Trinity Region, while there were no losses of life or injuries reported as being direct results of a storm event, there were multiple reported losses to property. From 1996 to present, property damage losses throughout the region amounted to $2,754,947,138 (see ***Table 1.3***) in 2021 dollars with the largest losses found in densely populated metropolitan areas that are prone to flash flooding, and in coastal areas that are subject to tropical storms and hurricanes.

Past losses for Farming

The Trinity Region accounts for much of the agricultural production in the State of Texas with much of the corn and cotton being produced in this area. According to the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information, the cumulative reported losses to crops due to flooding in the Trinity Region since 2000 amounted to $642,568,000 in 2021 dollars. As not every county fully reports the extent of agricultural damage, it is likely that even this multimillion-dollar tally of crop damage does not represent the full impact of flooding on agriculture in each county, nor does it include the losses of livestock. ***Table 1.4*** summarizes the crop damages by county within the Trinity Region from 2000 through 2021.

Table 1.3: Total Casualties and Property Damages Reported to National Oceanic and Atmospheric Administration

County	Total Events	Deaths Direct	Injuries Direct	2000-2021 Value Property Damage
Anderson	46	7	0	$3,991,491
Archer	28	0	0	$20,421
Chambers	45	0	0	$87,156,201
Clay	19	0	0	$0
Collin	86	0	0	$483,734
Cooke	68	4	4	$42,348,469
Dallas	215	8	1	$75,615,711
Denton	134	2	0	$15,960,546
Ellis	84	2	0	$9,315,832
Fannin	60	0	0	$876,374
Freestone	38	1	0	$2,432,522
Grayson	86	3	1	$31,441,079
Grimes	38	0	0	$3,274,253
Hardin	34	0	0	$689,456,762
Henderson	56	0	0	$2,015,682
Hill	53	0	0	$2,147,557
Hood	58	0	0	$91,273,610
Houston	41	0	0	$770,755
Hunt	89	0	0	$1,775,035
Jack	38	0	0	$2,417,143
Johnson	104	3	0	$4,021,570
Kaufman	65	0	0	$2,112,810
Leon	30	0	0	$703,321
Liberty	43	0	0	$121,849,147
Limestone	77	0	0	$2,027,384
Madison	25	0	0	$563,389
Montague	34	0	0	$8,430,685
Navarro	79	0	0	$31,014,730
Parker	64	0	0	$12,689,119
Polk	36	0	0	$340,687,942
Rockwall	23	0	0	$52,829
San Jacinto	39	0	0	$395,437,556
Tarrant	247	1	0	$90,479,567
Trinity	28	0	0	$410,671
Van Zandt	44	1	0	$1,082,444
Walker	37	1	0	$678,543,015
Wise	76	0	0	$1,707,134
Young	38	0	0	$360,648
TOTAL	**2182**	**33**	**6**	**$2,754,947,138**

Source: Flood Events by County (National Centers for Environmental Information, 2022)

Note: Some counties included in the table only have a small portion of the county within the Trinity Region.

Table 1.4: Total Crop Damage Value (2000-2021)

County	Total Events	2000-2021 Value Crop Damage
Anderson	46	$23,740
Archer	28	Not reported
Chambers	45	Not reported
Clay	19	Not reported
Collin	86	Not reported
Cooke	68	$644,500
Dallas	215	Not reported
Denton	134	$583,500
Ellis	84	Not reported
Fannin	60	Not reported
Freestone	38	$2,578
Grayson	86	$322,250
Grimes	38	$89,030
Hardin	34	Not reported
Henderson	56	Not reported
Hill	53	$1,697,000
Hood	58	$86,150
Houston	41	$169,700
Hunt	89	Not reported
Jack	38	Not reported
Johnson	104	Not reported
Kaufman	65	Not reported
Leon	30	Not reported
Liberty	43	$66,085
Limestone	77	Not reported
Madison	25	Not reported
Montague	34	$644,500
Navarro	79	Not reported
Parker	64	Not reported
Polk	36	$60,250
Rockwall	23	Not reported
San Jacinto	39	$96,130
Tarrant	247	$21,640
Trinity	28	Not reported
Van Zandt	44	Not reported
Walker	37	$23,330
Wise	76	Not reported
Young	38	Not reported
TOTAL	**2182**	**$4,507,053**

Source: Flood Events by County
(National Centers for Environmental Information, 2022)

Other Losses on Working Lands

When a major rain event occurs causing flooding, it can also cause heavy losses for livestock. The USDA National Agricultural Statistics Service estimates that Texas has 13 million head of cattle and calves as of January 1, 2020, (USDA National Agricultural Statistics Service , 2020). Much of the state's cattle is raised in the Trinity Region, with the largest cattle production in Fannin, Wise, Houston, and Van Zandt counties. If these operations are disrupted due to flooding, particularly if cattle are lost in the flood, it can trigger an impact on milk and beef production statewide.

Political Subdivisions with Flood-Related Authority

The RFPGs are tasked with identifying political subdivisions with flood control authority within their region. The TWDB provided a list of over 550 separate political subdivisions within the Trinity Region who were thought to potentially have some degree of flood-related authority. To collect the highest quality of information, the data collection survey conducted for this effort reached out to each entity, contacting multiple officials in each identified political subdivision.

State guidelines for "Flood Protection Planning for Watersheds" define political subdivisions with flood-related authority as cities, counties, districts, or authorities created under Article III, Section 52, or Article XVI, Section 59, of the Texas Constitution, any other political subdivision of the state, any interstate compact commission to which the state is a party, and any nonprofit water supply corporation created and operating under Chapter 67. Of the political subdivisions referred to above, the majority are municipal or county governments, both of which enjoy broad authority to set policy to mitigate flood risk.

State law also provides for limited purpose utility districts. These are known as MUDs, Municipal Water Districts (MWDs), Fresh Water Supply Districts (FWSDs), or SUDs. These districts may be located in or adjacent to cities or in the county and in some cases, may be involved in the reclamation and drainage of its overflowed land and other land needing drainage (Texas Legislature). During the data collection efforts, entities who responded that they did not have flood responsibilities or authorities were removed from the contact list.

Together, the entities outlined in ***Table 1.5*** constitute the primary flood mitigation entities in the Trinity Region by the numbers. Each of these entities received an invitation to participate in the data collection through the data collection tool and interactive web map located on the Trinity RFPG website.

Two additional types of districts bear more discussion, as they have a more direct relationship to flood management, as outlined in the State Water Code. The differing roles of WCIDs and LIDs are described in ***Table 1.6.***

Table 1.5: Political Subdivisions with Potential Flood-Related Authority

Entity	Number of Jurisdictions	NFIP Participants
Municipality	287	246
County	40	40
COGs	9	Not Applicable
River authority	7	Not Applicable
Water districts	3	Not Applicable
WSUDs (MUDs, FWSDs, MWDs, SUDs)	164	Not Applicable
Flood control entities (WCIDs, LIDs)	39	Not Applicable
Other	5	Not Applicable

Source: TWDB Data Hub (TWDB, 2021)

Table 1.6: Role of Water Control and Improvement Districts and Levee Improvement Districts

Entity	Statutory Authority	Flood Control Responsibilities
Water Control and Improvement Districts	State Water Code, Title 4, CHAPTER 51	(1) the improvement of rivers, creeks, and streams to prevent overflows and to permit navigation or irrigation
		(2) the construction and maintenance of pools, lakes, reservoirs, dams, canals, and waterways for irrigation, drainage, or navigation
		(3) the construction and maintenance control, storage, preservation, and distribution of water for flood control, irrigation, and power
Levee Improvement Districts	State Water Code, Title 4, CHAPTER 5	(1) to construct and maintain levees and other improvements on, along, and contiguous to rivers, creeks, and streams
		(2) to reclaim lands from overflow from these streams
		(3) to control and distribute the waters of rivers and streams by straightening and otherwise improving them
		(4) to provide for the proper drainage and other improvement of the reclaimed land

For political entities that participate in the NFIP program, Texas Water Code § 16.315 requires them to adopt a floodplain management ordinance and to designate a floodplain administrator who will be responsible for understanding and interpreting local floodplain management regulations and reviewing them for compliance with NFIP standards. Some of the rights and responsibilities granted under this authority of the Texas Water Code include:

- Applying for grants and financing to support mitigation activities
- Guiding the development of future construction away from locations threatened by flood hazards
- Setting land use standards to constrict the development of land which is exposed to flood damage and minimize damage caused by flood losses
- Collecting reasonable fees from citizens to cover the cost of administering floodplain management activities
- Using regional or watershed approaches to improve floodplain management
- Cooperating with the state to assess the adequacy of local structural and non-structural mitigation activities

Summary of Existing Flood Plans and Regulations

Approximately 30 percent of the entities who received an invitation to participate in the flood planning process via the Trinity RFPG data collection survey tool and interactive web map provided at least some measure of response at varying levels of detail. The tables that follow summarize the entities' responses to questions about their existing regulatory environment, as well as measures they may have in place to increase resilience. The information in these tables is strictly based on responses to the data collection survey.

Table 1.7 summarizes the number of survey participants who answered that they have a particular regulatory or planning measure in place. These plans and regulations were divided into four categories: drainage criteria manual/design manual, land use regulations, ordinances (floodplain, drainage, stormwater, etc.), Unified Development Code (UDC), and/or zoning ordinance with map. From the four types of regulations and plans, the largest number of respondents indicated that they had an active floodplain, drainage, and/or stormwater ordinance.

Table 1.7: Summary of Flood Plan and Regulations Provided via Survey

Type of Regulation	Count
Drainage Criteria Manual/Design Manual	37
Land Use Regulations	46
Ordinances (Floodplain, Drainage, Stormwater, etc.)	61
UDC and/or Zoning Ordinance with Map	32

Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

Table 1.8 provides a perspective on the relative complexity of each community's floodplain management approach by tallying the number of regulatory and planning measures for each responding community. This is self-reported data and reflects the knowledge and experience of the respondent. Many communities responded that they do not have any regulating documents that aid with flood management, or that just one is in place. The RFPG researched the flood planning measures taken by each community and determined that a higher level of preparedness than the survey results show. However, 24 respondents indicated they have all four of the measures described in ***Table 1.7*** and may even be taking additional measures to increase their authority to manage development and other activity that would impact flooding within their jurisdictions. A higher number of these measures indicates a greater degree of preparedness for flood management and appropriate regulation of development patterns.

Table 1.8: Number of Flood Plans and Land Use Regulations per Community

Regulations per Community	Count
0	43
1	24
2	6
3	12
4+	24

Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

Like the last two tables, ***Table 1.9*** includes data that was extracted from the data collection tool survey. In this instance communities identified the types of flood warning measures they were employing within their communities to mitigate the effects of flooding. These measures include regulations, information, education, and warning systems. The types of flood warning measures that are most widely used amongst survey respondents fall into the regulatory and flood warning categories. It is important to note that these results derive from the respondents to the survey and are not an exhaustive count of all flood warning measures being undertaken throughout the region. Resilient communities adapt to changing conditions, allowing people and places to recover quickly from disasters and thrive in the face of adversity.

Table 1.9: Types of Flood Warning Measures based on Survey

Flood Warning Measure	Count
Acquisition of flood-prone properties	12
Automatic low water crossing gates	1
Coordination with TxDOT message boards	2
Crew(s) set up barricades or close gates	5
Flood gauges	2
Flood readiness education and training	17
Flood response planning	23
Flood warning signs	2
Flood warning signs with flashing lights	1
Flood warning system	9
Higher Standards for floodplain management	32
Land use regulations that limit future flood risk	32
Outdoor siren/message speaker system	1
Participation in the Community Rating System	6
Participation in the NFIP	45
Portable/temporary traffic message boards	3
Public facing website	4
Reverse 911 system	2
Social media	7

Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

Using plans and policies to reduce the exposure of people and properties to flood risk is a form of non-structural flood control. By encouraging or requiring communities and developers to avoid developing in flood-prone areas altogether, or to take precautions such as increasing building elevation, preserving overflow areas through buffering and avoiding sensitive natural areas such as wetlands, communities can prevent new development from being located in harm's way.

Floodplain Ordinances, Court Orders, and Local and Regional Flood Plans

Floodplain ordinances and court orders dictate how development is to interact with or avoid a city's or county's floodplain. FEMA provides communities with flood hazard information upon which floodplain management regulations can be based. Floodplain ordinances and court orders are subject to the NFIP and ensure communities are taking flood hazards into account when making land use and land management decisions. Ordinances may include references to maps with Base Flood Elevations (BFEs), freeboard requirements, valley storage requirements, as well as criteria for land management and use. In addition, communities can regulate floodplains with higher or more restrictive standards.

Local and regional flood plans may go a step beyond the regulations laid out in an ordinance, enhancing a region's understanding of its flood risk, and establishing how that entity will manage or control floods in the future. They also outline the procedures for more sustainable flood risk management in the communities they serve. (Niki L. Pace, 2013)

Land Use Regulations and Policies: Zoning, Subdivision

Zoning ordinances regulate how property owners and developers are allowed to use their property. It is one of the most important tools that communities use to regulate the form and function of current and future development. Within the zoning ordinance, communities may incorporate a variety of tools, which may include, among others:

- Floodplain zones
- Stream buffers
- Setbacks from wetlands and other natural areas
- Conservation easements

Subdivision regulations get into a more focused regulation of the design and form of the building blocks of a city. They regulate platting processes, standards for design and layouts of streets and other types of infrastructure, the design and configuration of parcel boundaries, as well as standards for protecting natural resources and open space. While both cities and counties have subdivision ordinances, counties do not have zoning authority.

Comprehensive Plans and Future Land Use Plans

Comprehensive plans and their associated future land use plans provide legal authority for zoning regulations in the State of Texas and consider capital improvements necessary to support current and future populations and often consider social and environmental concerns the community wishes to address. To produce a comprehensive plan, communities undertake an extensive planning process that encourages discussion about topics such as risk from natural hazards, and may include recommendations regarding the location of development with respect to floodplains the need for future drainage improvements, etc.

In the Trinity Region, the Trinity RFPG has identified 124 future land use plans for municipalities, which are the only entities with the authority to develop and use such plans. The content of these plans varies widely in specificity but is frequently prepared in concert with a comprehensive plan, which establishes policies and program of action for long term growth and development of a community. These plans provide a guide for future areas of growth and development, as well as areas that are to be conserved in their natural state. According to the Texas Local Government Code, the comprehensive plan sets the groundwork that is necessary for a municipality to regulate the location and character of development through local zoning and land use ordinances. (Texas State Legislature)

Drainage Design Criteria

Drainage design criteria is required and developed to set the minimum standards for planners, architects, and engineers to follow when preparing plans for construction within the jurisdictions in which they serve. These could be for regional entities, such as the NCTCOG, for municipalities, or counties within the region. These criteria mitigate flood risk by promulgating a consistent set of standards for location and design criteria that mitigate future flood risk. Criteria may pertain to development and permit applications, right of way/easements, and hydrologic, and hydraulic standards.

Assessment of Existing Flood Infrastructure

This section provides an overview of natural and structural flood infrastructure in the Trinity Region that contribute to lowering flood risk. Because the Trinity River watershed connects communities from Archer County to Chambers County on the Trinity Bay, flood infrastructure in this region benefits the community where it is located but may also have substantial benefits for people and property downstream.

When assessing flood risk management infrastructure, the TWDB guidance directed the RFPG to consider the following types of natural and manmade features that contribute to risk reduction, not all of which are present in the Trinity Region:

Natural Features:

- Rivers, tributaries, functioning floodplains
- Wetlands and marshes
- Parks, preserves, natural areas
- *Playa lakes*
- *Sinkholes*
- *Alluvial fans*
- *Vegetated dunes*

Structural Features:

- Levees
- Dams that provide flood protection
- Local stormwater systems, including tunnels and canals
- Detention and retention ponds
- *Sea barriers, walls, and revetments*
- *Tidal barriers and gates*

Note: Features shown above in *italics* have not been identified as major components of the flood control system in the Trinity Region.

Flood infrastructure in the region is formed by a complex web of natural areas and built features which are owned and managed by entities ranging from the National Parks Service to individual landowners. Flood infrastructure may include non-structural measures, such as natural area preservation, buyout of repetitive flood loss properties, and flood warning systems, but also includes all major public infrastructure, such as regional detention. The TWDB provided several data sources to assist with the identification of flood management infrastructure in the Flood Data Hub. There were also a number of questions posed in the data collection survey that were used to complement the information provided by existing data sources to create a more complete picture of how communities in the region protect themselves from flood risk.

Information in the Inventory of Existing Flood Infrastructure summarized in this section refers to the ***TWDB-Required Table 1***, included in ***Appendix A*** of this plan and serves as the basis for several tables and charts.

Natural Features

When left in their natural state, many soils can be efficient at handling rainfall. As drops fall from the sky, they are intercepted by trees, shrubs or grasses which allow rain time to soak into the soil and slow the passage of runoff to the region's waterways. Wetlands and woodlands are most efficient at recycling rainfall, as the branches and undergrowth intercept water before it even reaches the ground, thus minimizing overland flow to tributaries and the river. Pastureland performs this function effectively as well, whereas croplands may shed a greater degree of water so as not to inundate the fields. Similarly, parklands in urban areas that are designed for dual functions can achieve nearly the same rate of capture of stormwater as lands in undeveloped areas (Marsh, 2010). For natural features to achieve maximum effectiveness at flood mitigation, they should form part of an interconnected network of open space consisting of natural areas and other green features that also protect ecosystem functions and contribute to clean air. This is sometimes known as green infrastructure, the practice of replicating natural processes to capture stormwater runoff (Low Impact Development Center, 2017). Even small changes in developed area can have significant impact on downstream flooding.

Natural areas can be managed to be even more efficient at these functions in a variety of settings:

- **Watershed or Landscape Scale**: Where natural areas are interconnected to provide opportunities for water to slow down and soak in, and to overtop the banks of creeks and channels when needed. These solutions often include multiple jurisdictions and restoration of natural habitat to achieve maximum effectiveness.
- **Neighborhood Scale**: Solutions built into corridors or neighborhoods that better manage rain where it falls. Communities establish regulatory standards for development that guide the use of neighborhood-scale strategies.

- **Coastal Solutions:** To protect against erosion, and mitigate storm surge and tidally influenced flooding, nature-based solutions can be used to stabilize shorelines and restore wetlands. (FEMA, 2021)

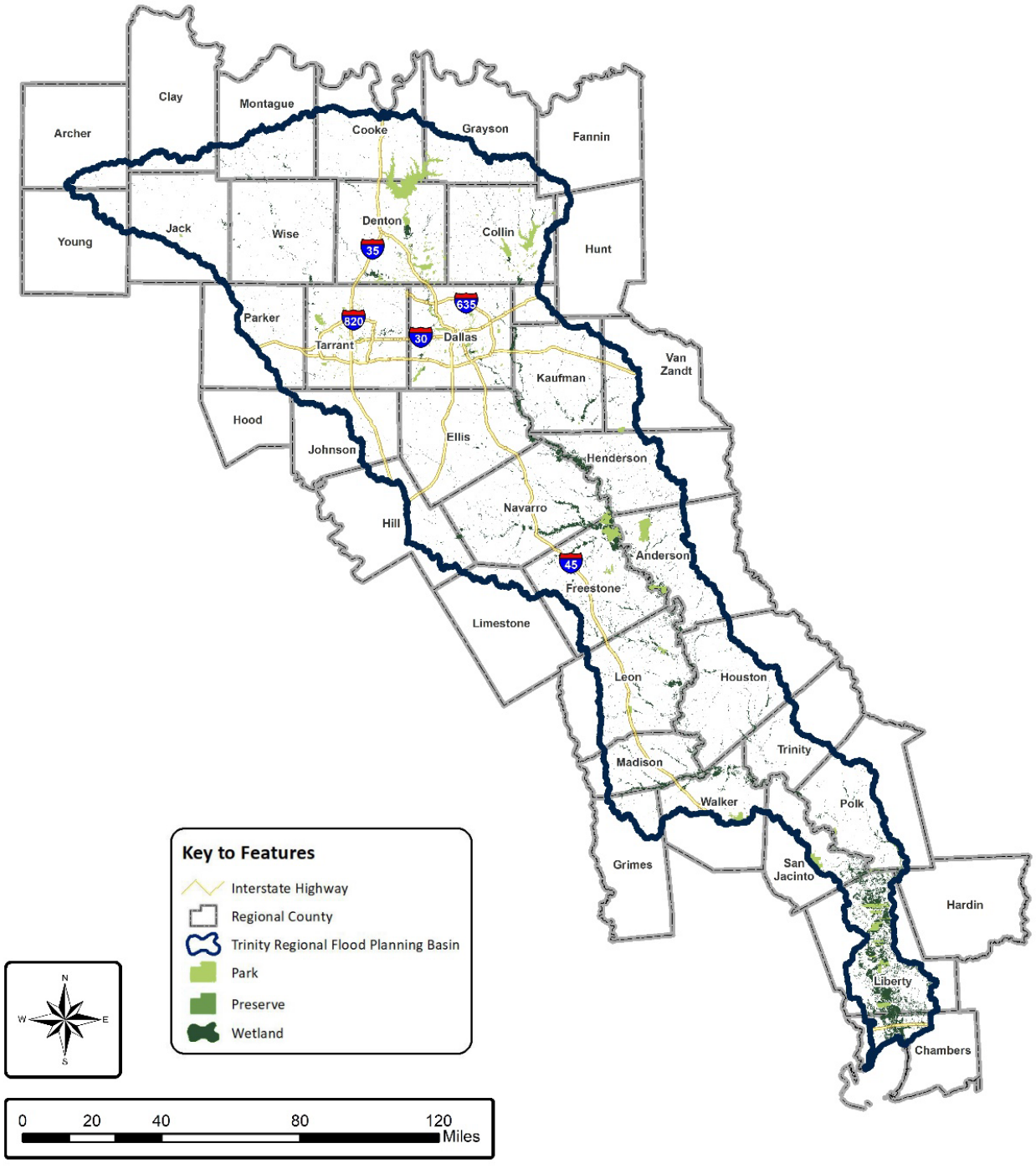
As forests and fields give way to urban development, the permeability of soil decreases. This makes land less efficient at the tasks of maintaining natural runoff velocities and allowing rainfall to soak into the ground and recharge the groundwater. In the 20 years between 1997 and 2017, the Texas Land Trends project found that the Trinity Region lost over 360,000 acres (about twice the area of Austin, Texas) of working land (crops, grazing lands, timber, and wildlife management) to urban and suburban development. While the population increased by more than 50 percent during that time, only 4 percent of the total acreage of natural areas were replaced with structures, roads, and parking lots. These types of hard surfaces can increase the potential for increased runoff unless flood mitigation is incorporated in the development. The acreage that remained as open space grew increasingly fragmented. In 1997, 1,044,255 landholdings consisted of parcels of more than 1,000 acres, whereas by 2017, the number of these larger parcels had declined dramatically. This trend was even more pronounced for landowners who held from 100-499 acres during the same time period. (Texas A&M Natural Resources Institute, 2021)

As the trend toward urbanization and fragmentation continues, the region should consider taking a more deliberate approach to managing its natural infrastructure in order to continue to receive the benefits of open spaces, something which the USACE addresses in its engineering with nature initiatives (USACE, 2022), which align natural and engineering processes to deliver economic, environmental, and social benefits efficiently and sustainably through collaborative projects. The TWDB also identified local, state, and national parks and wildlife management areas that form part of the region's natural infrastructure, all of which are illustrated in ***Figure 1.19.***

Rivers, Tributaries, and Functioning Floodplains

The natural flood storage capacity of all streams and rivers and the adjacent floodplains contribute greatly to overall flood control and management. The floodplain is a generally flat area of land next to a river or stream that stretches from the banks of the river to the outer edges of the valley. The first part of the floodplain is the main channel of the river itself, called the floodway, which may be dry for part of the year. Surface water, floodplains, wetlands, and other features of the landscape function as a single integrated natural system. Disrupting one of these elements can lead to effects throughout the watershed, which increase the risk of flooding to adjacent communities and working lands. Maintaining the floodplain in an undeveloped state provides rivers and streams with room to spread out and store floodwaters to reduces flood peaks and velocities. Even in urban areas, preservation of this integrated system of waterways and floodplains serves a valuable function, as even small floods resulting from a 20% or 10% annual chance storm event can cause severe flood damage.

Figure 1.19: Natural Flood Infrastructure



Source: TWDB Flood Planning Data Hub, (TWDB, 2021), State Wildlife Management Areas and Parks (Texas Parks and Wildlife Department, 2022), National Park Service Lands (USDOI, 2022), National Wetlands Inventory (USGS, 1998)

Depending on soil type and permeability, a single acre of floodplain land can significantly reduce risk to properties downstream. With over 20 percent of its land area located in the floodplain, the Trinity River and its tributaries cross through both rural and highly urbanized areas of Texas. In rural areas where more of the floodplain is preserved in an undeveloped state, the more natural form of the river and its many tributaries and floodplains contribute to flood risk reduction downstream as they meander southeast on their way south to the Gulf of Mexico. (FEMA, 2021)

In the upper basin of the Trinity Region, multiple entities participate in the Trinity Common Vision Corridor Development Certificate program for the purpose of stabilizing flood risk associated with floodplain development along the Trinity River within the DFW metroplex (NCTCOG, 2021). The program is a coordinated effort among NCTCOG, USACE, cities, counties, and others with flood control responsibilities along the corridor. USACE estimates that the Corridor Development Certificate program provides more than 1/3 of the flood protection capacity along the Trinity River in the North Texas area, which is more than any one of its flood-control dams (USACE, Trinity Common Vision Steering Committee Presentation, 2021). Additional information on this program is included in ***Chapter 2***.

Wetlands and Marshes

Wetlands are some of the most effective natural features at recycling water, by minimizing the overland flow and reducing the need for other types of flooding infrastructure. The USGS defines wetlands as transitional areas, sandwiched between permanently flooded deep water environments and well-drained uplands, where the water table is usually at or near the surface or the land is covered by shallow water. They can include mangroves, marshes, swamps, forested wetlands, coastal prairies, among other habitats and their soil or substrate is at least periodically saturated by fresh or salt water. There is a robust concentration of wetlands directly surrounding the Trinity River and as the Trinity River heads southward towards the coast, the concentration of wetlands increases. When left undisturbed by development, wetlands not only mitigate flooding from upstream, but also blunt the force of storm surges from the coast in the form of hurricanes and other tropical storms. According to the USGS National Wetlands Inventory, wetlands comprise 450,300 acres within the Trinity Region. This accounts for one of the largest types of natural infrastructure for the region.

Parks, Preserves, and Other Natural Areas

Parks and preserves serve as essential components of the ecosystem as they house a wide variety of local flora and fauna, as well as physical features that are necessary for the continued ecological health of the region. Parks include municipal, county, state, and national parks within the region, while preserves include the Texas Parks and Wildlife Department's (TPWD's) state wildlife management areas. These areas provide a sanctuary for the natural aspects impacted

by human activity. Additionally, these are essential components for water retention in the event of flooding and severe rainfall.

- Parks account for 127,000 acres
- Preserves make up 101,000 acres within the region

This acreage includes state and local parks, wetlands identified on the national wetlands inventory, as well as USACE properties. These types of natural flood infrastructure are generally located in or close to floodplain areas throughout the basin with higher concentrations of them being located along or close to the major rivers. The largest concentration of this infrastructure type is around Lake Ray Roberts between Denton and Cooke counties.

Coastal Areas

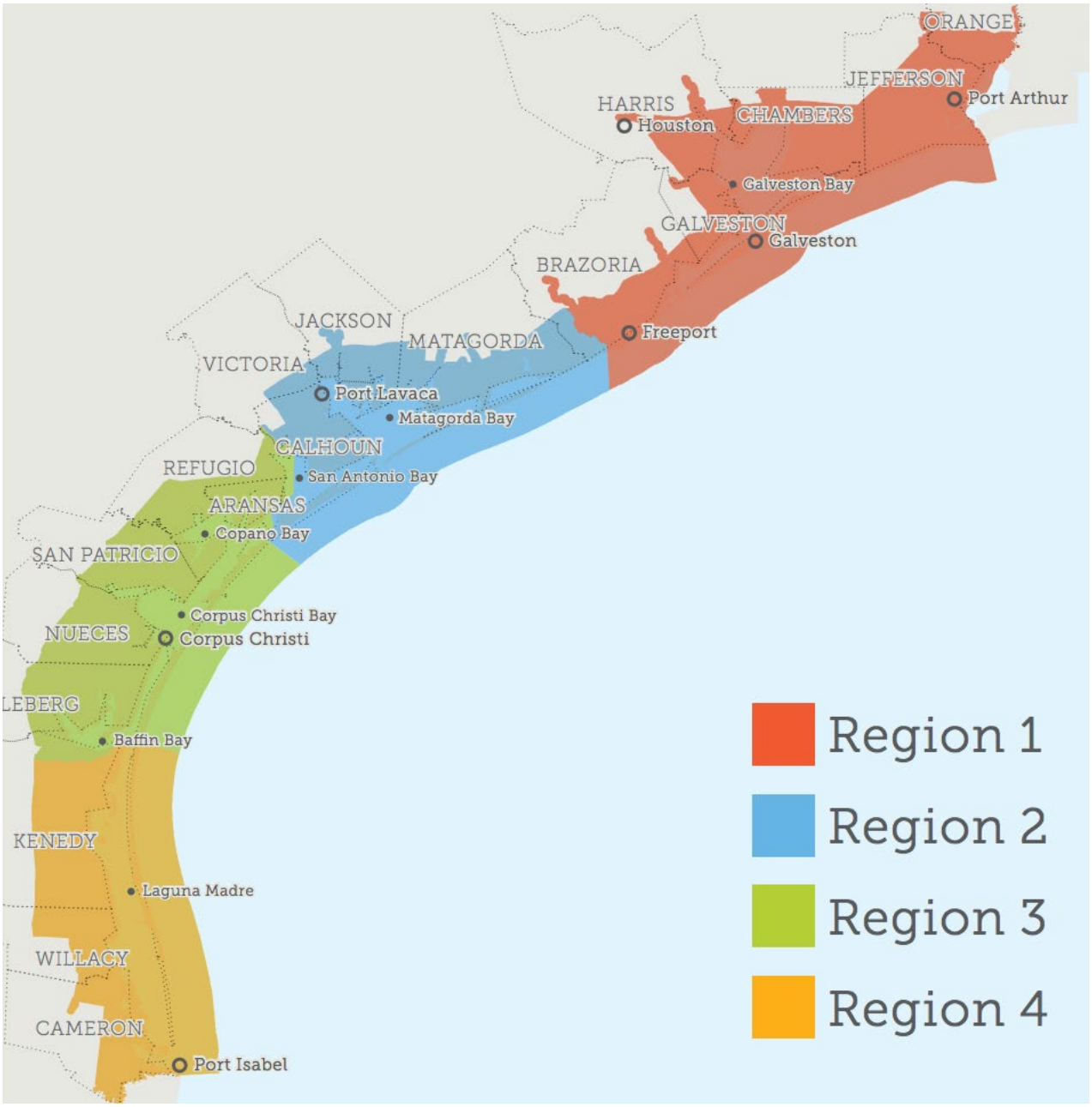
The National Coastal Zone Management Program is a voluntary partnership between NOAA and coastal states that was formed following the passage of the Coastal Zone Management Act of 1972.

In Texas, this program is managed by the Texas General Land Office (GLO) and implemented through the 2019 Coastal Resiliency Master Plan (CRMP). The geographic extent of the state's coastal zone is illustrated in ***Figure 1.20.*** The state divides the Texas coast into four regions for planning purposes based on approximate size, population centers, habitats, and environmental conditions. In the Trinity Region, only the southernmost area of Chambers County that touches Trinity Bay is in the Texas coastal zone, located in Region 1. The dynamics of flooding in coastal areas differ from riverine flooding, in that they are influenced by issues such as sea level rise, land subsidence, tidal flooding and storm surge as well as rainfall events. Mitigating coastal flooding is one of the primary objectives of the CRMP, and proposed solutions include:

- Elevating structures
- Incorporating green infrastructure into development
- Creating flood resilient parks and recreational spaces
- Retaining and restoring open space
- Maintaining/creating freshwater wetlands and coastal prairies

The state is in the process of updating the 2019 CRMP and anticipates the release of a new plan in 2023 that will include a list of Tier 1 projects in each region which will be priority projects for funding in the future years. (Texas GLO, 2019)

Figure 1.20: Texas Coastal Zone



Source: 2019 Texas CRMP

Constructed Flood Infrastructure/Structural Protections

A wide variety of structural measures are used by state and federal agencies, communities, and private landowners to protect development and agricultural areas from flooding. These may include flood control reservoirs, dams, levees, and local drainage infrastructure such as channels and detention areas. Dams and levees are some of the most frequently used defenses to achieve structural mitigation of future flood risk in this region and serve an established role of protecting people and property from flood impacts and will therefore be a primary focus of this section of this plan. ***Figure 1.21*** identifies the location of all known dams and levees in the Trinity Region.

Dams and Reservoirs

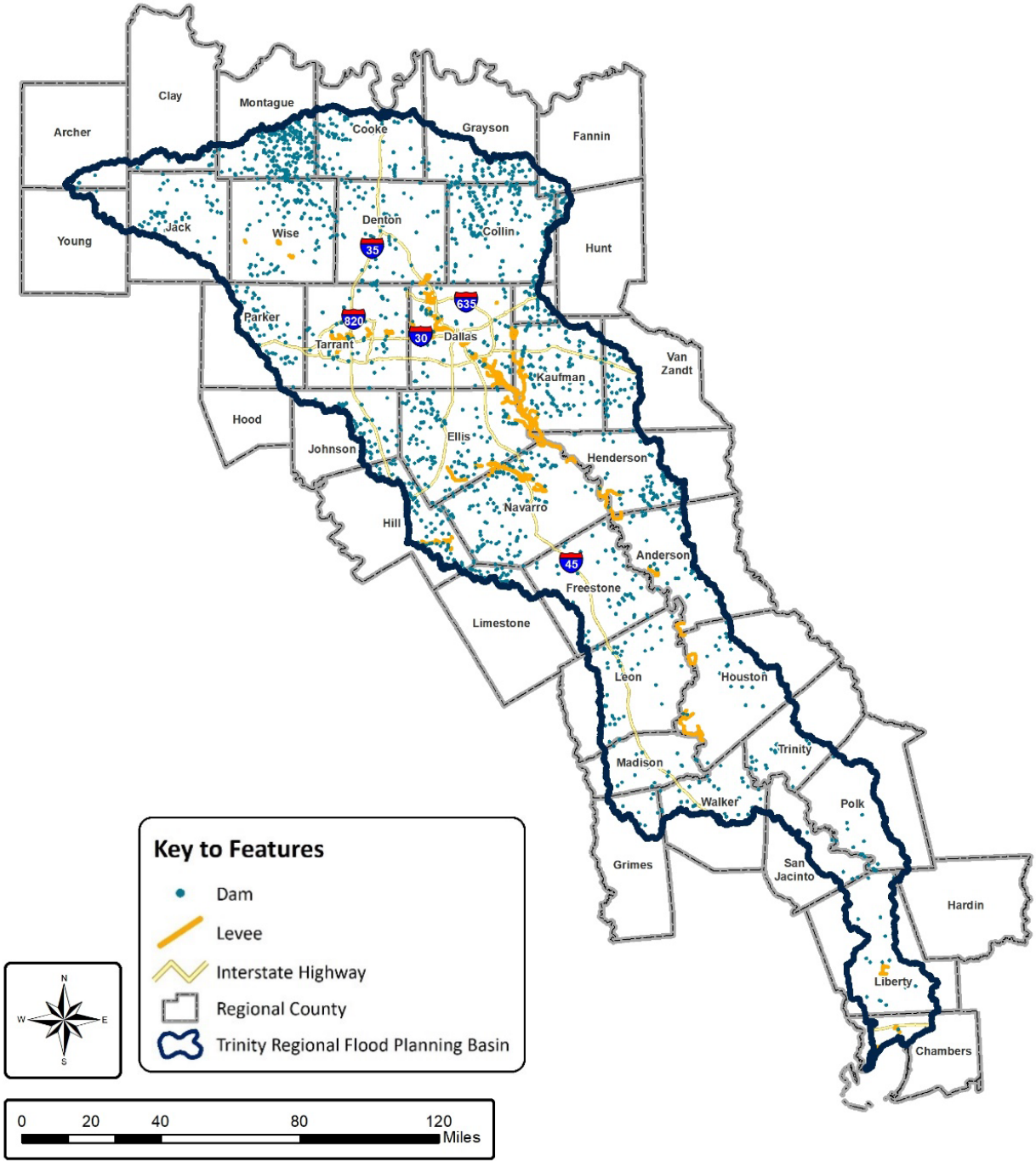
The TCEQ Dams Inventory, provided in September 2021 by the Texas Commission on Environmental Quality (TCEQ), contains a total of 2,037 dams in the Trinity Region. Dams in Texas serve a variety of purposes beyond flood control, including water storage for human consumption, agricultural use, power generation, industrial use, and recreation. Of the dams identified in the region, 1,409 are identified as having flood control as one of its purposes. The focus of this plan is flood control dams, which are associated with reservoirs (lakes) permitted for flood control purposes.

The USACE is responsible for the management of the region's largest dams and flood control reservoirs. Although residents may know them for their recreational, water supply, and power generation functions, these facilities are particularly important in mitigating the effects of flooding because of their scale and ability to store vast amounts of water. Their size allows them to serve as a repository for flood waters and hold, store, and slowly release these waters over time to manage downstream flooding. (TCEQ Dam Safety Program, Field Operations Support Division, 2009).

Reservoirs in the Trinity Region owned and operated by USACE with flood control as a purpose include:

- Bardwell Lake
- Benbrook Lake
- Grapevine Lake
- Joe Pool Lake
- Lake Lavon
- Lake Lewisville
- Navarro Mills Lake
- Ray Roberts Lake (USACE, 2021)

Figure 1.21: Constructed Flood Infrastructure/Structural Flood Protection



Sources: National Inventory of Dams (USACE, 2020), National Levee Database (USACE, 2022)

Figure 1.22: Flooding, Trinity River Levees

For all dams that have a flood control purpose but are not maintained by the USACE, ***Table 1.10*** provides the total number of registered flood control dams in each county. Many of these dams were designed and constructed by the Natural Resources Conservation Service (USDA-NRCS), with the private property owner providing the land, the federal government providing the technical design expertise and the funding, and local government responsible for maintaining them into the future. (Texas State Soil and Water Conservation Board, 2021)

These dams are owned and operated by a wide range of organizations and people, including state and local governments, public and private agencies, and private citizens. The TCEQ Dam Safety Program is involved with the permitting and inspections of these facilities, as well as maintaining hydrological data to establish standards for dam construction. However, the law provides for broad exemptions, which include private ownership, maximum capacity of less than 500 acre-feet, hazard classification, and location in a county with a population of less than 350,000 and/or outside City limits. Because of the diverse nature of ownership and capacity of dams, the frequency of inspection may vary widely as well. While high-hazard and large low-hazard dams are scheduled to be inspected every five years, small and intermediate size and low-hazard dams are only inspected at the request of an owner; as a result of a complaint; following an emergency such as a flooding event; or for determining the hazard classification. (Texas Commission on Environmental Quality, 2021). Even for dams that are not for flood control, however, breaches and overtopping could have significant downstream impacts.

Table 1.10: Number of Flood Control Dams by County

County	No. of Dams
Anderson	3
Clay	4
Collin	185
Cooke	77
Dallas	22
Denton	36
Ellis	141
Fannin	13
Freestone	1
Grayson	77
Henderson	7
Hill	81
Hunt	18
Jack	32
Johnson	39
Kaufman	127
Leon	2
Limestone	23
Madison	4
Montague	154
Navarro	119
Parker	41
Rockwall	50
Tarrant	8
Van Zandt	43
Wise	122
Young	1
Total	**1,430**

Within the Trinity Region, the TCEQ maintains hazard classifications of high, low, and significant for these 1,409 flood control dams, as illustrated in ***Table 1.11***. High-hazard potential dams may be associated with expected loss of seven or more lives or three or more habitable structures in the breach inundation area; excessive economic loss in or near urban areas where failure would be expected to cause extensive damage to:

- Public facilities
- Agricultural, industrial, or commercial facilities
- Public utilities
- Major highways and/or railroads

Table 1.11: Summary of Hazard Classification of Dams in the Trinity Region

	High	Significant	Low	Grand Total
Total	430	78	901	1,409

Source: TCEQ Total of dams in region by classification, provided September 2021

Dams categorized as having significant hazard potential may result in the loss one to six human lives or one or two habitable structures in the breach inundation area downstream of the dam; appreciable economic loss, located primarily in rural areas where failure may cause:

- Damage to isolated homes
- Damage to secondary highways or minor railroads
- Interruption of service or use of public utilities, including the design purpose of the utility

For low hazard dams, no loss of human life or damage to permanent habitable structures and minimal economic loss are anticipated in the breach inundation area (located primarily in rural areas where failure may damage occasional farm buildings, limited agricultural improvements, and minor highways. (Texas Administrative Code, 2009).

Levees

Levees are man-made structures that provide flood protection. More than one million Texans and $127 billion dollars' worth of property are protected by levees. The Texas 2018 Levee Inventory Report lists 51 USACE levee systems in the state (ASCE, 2021). These USACE levees are maintained and inspected to federal standards and provide a high standard of flood protection. Although not all are used for flood control purposes, failure of a single dam or levee could have multiple consequences for property and human safety downstream.

According to the National Levee Database, published in August 2020, there are 101 levees in the Trinity Region with 51 managed by the USACE. The Texas Water Code §16.236 requires that the design be based on the 1% annual chance storm event plus three feet of freeboard in urbanized areas. The water code also outlines a review and approval process for the construction and improvement of levees following the filing of an application and a set of preliminary plans for the levee that includes sufficient engineering detail for evaluation. Applications must include the location and extent of the structure, location of surrounding levees, reservoirs, dams, or other flood control structures which may be affected and the location and ownership of all properties lying within any proposed protected area or others which may be affected by the project's alteration of the flood flows. The preliminary plans must demonstrate the effects the proposed project will impose on existing flood conditions. (Texas Commission on Environmental Quality, 2005).

Table 1.12 provides the number of levees by county throughout the region. Dallas County has the largest number of levees in the region while Tarrant, Hill, and Ellis counties each have between 10 and 20 levees. In 2004, FEMA initiated remapping for both Tarrant and Dallas counties that included the Trinity River and the DFW levee system. Most USACE levees in Texas were designed to withstand a flood that exceeds the 0.2% annual chance storm event, plus an additional three to four feet of freeboard. (Melinda Luna, 2007)

Smaller, concrete-lined channels can be found in many communities across the Trinity Region. Hardened, structural alternatives are being systematically reduced in application due to impacts to the environment and the potential for increasing flooding downstream and loss of open space. Recent channel improvements tend to incorporate more natural features.

Stormwater Management System

Stormwater management systems serve to manage both the quantity and quality of the water that drains into the Trinity River and its tributaries. Although survey respondents provided limited information as to their own stormwater management systems, participants in the Texas Pollutant Discharge Elimination System (TPDES) which is managed by the TCEQ, are likely to have storm drainage infrastructure. Five cities in the region: Dallas, Fort Worth, Arlington, Irving, and Plano have a sophisticated drainage systems and are classified as Phase I Municipal Separate Storm Sewer Systems (MS4s). Small MS4s are communities located in urbanized areas as determined by the 2010 census.

Table 1.12: Number of Levees by County

County	Number of Levees
Anderson	1
Anderson, Henderson, Navarro	1
Anderson, Houston	1
Chambers	2
Cooke	1
Dallas	22
Dallas, Denton	1
Dallas, Ellis	1
Dallas, Kaufman	4
Denton	1
Ellis	10
Ellis, Navarro	3
Henderson	1
Henderson, Kaufman	1
Hill	12
Houston	5
Kaufman	6
Liberty	1
Navarro	6
Tarrant	16
Wise	5
Total	**101**

Source: (USACE, 2022)

Bridges and Culverts

Bridges and culverts are used to provide vehicular and pedestrian transportation across low points, including rivers, streams, and floodplains. Design criteria for these structures varies depending on the governing entity. The structure is required to convey the flow of surface and stream water through the embankment. Culverts and bridges can be overtopped by floodwaters if the design capacity of the structure is exceeded. This type of flooding can occur during or following prolonged periods of rainfall or during an intense rainfall that overwhelms the culvert or bridge, such as a flash flood event. Additional information on bridges and culverts in relation to low water crossings is included in ***Chapter 2*** of this plan.

Coastal Areas

As detailed above, there is a very small portion of the Trinity Region in the Texas coastal zone Region 1. The state's CRMP does not contain any projects within the Trinity Region, and a review of data provided by FEMA and the Texas Coastal Management Program did not include any sea barriers, walls, revetments, tidal barriers, or gates within the Trinity watershed.

Non-Functional/Deficient Flood Mitigation Features/Condition and Functionality of Infrastructure and Other Flood Mitigation Features

As the Trinity Region undertakes its first flood plan, information on the condition of the region's flood mitigation features is in short supply. Neither the State Flood Data Hub nor the participants in the Trinity Region data collection effort provided a great deal of information on this subject. However, throughout Texas, flood infrastructure is rapidly aging and in need of repair. In 2019, the Association of State Dam Safety Officials (ASDSO) estimated the cost to rehabilitate all non-federal dams in Texas at around $5 billion. The Texas State Soil and Water Conservation Board (TSSWCB) estimates about $2.1 billion is needed to repair or rehabilitate dams included in the Small Watershed Programs. (TSSWCB, 2021).

The USACE establishes a rigorous maintenance standard for its eight reservoirs to ensure that they perform to expectations. However, for the 1,409 flood control dams in the region that are not subject to USACE regulations, the consequences of dam failure downstream can be severe, with losses of life, agricultural resources and property.

According to the TCEQ's dam safety program, the primary reasons for dam failure include:

- Overtopping by floods
- Foundation defects
- Piping and seepage

(TCEQ, 2006)

Many Texas dams are exempt from dam safety requirements by state legislation which makes tracking their maintenance status extremely challenging. Condition-related data and associated risk for the region's levees is largely unknown because most of the levees in the state are built, inspected and/or maintained by local governing agencies who may not have the resources for routine assessment and performance tracking. According to the National Levee Database, the levee condition for all 122 levees within the Trinity region is "Unknown".

Recent increases in frequency and intensity of storms continue to test the capacity of the state's levees. Without a clearer picture of the state's levee infrastructure and concerted funding to assist private owners, the majority of the state's levees that are not managed and maintained by the USACE will remain in the presumed deficient status. (ASCE, 2021)

Functionality of Flood Infrastructure

The TCEQ Dam Inventory provides some insight into the functionality and condition of the region's infrastructure. For the majority of dams in the Trinity region, the condition is *Unknown*. However, of those dams that have been assessed, ***Table 1.13*** illustrates that the majority of those dams are in fair or good condition and are considered to be functional.

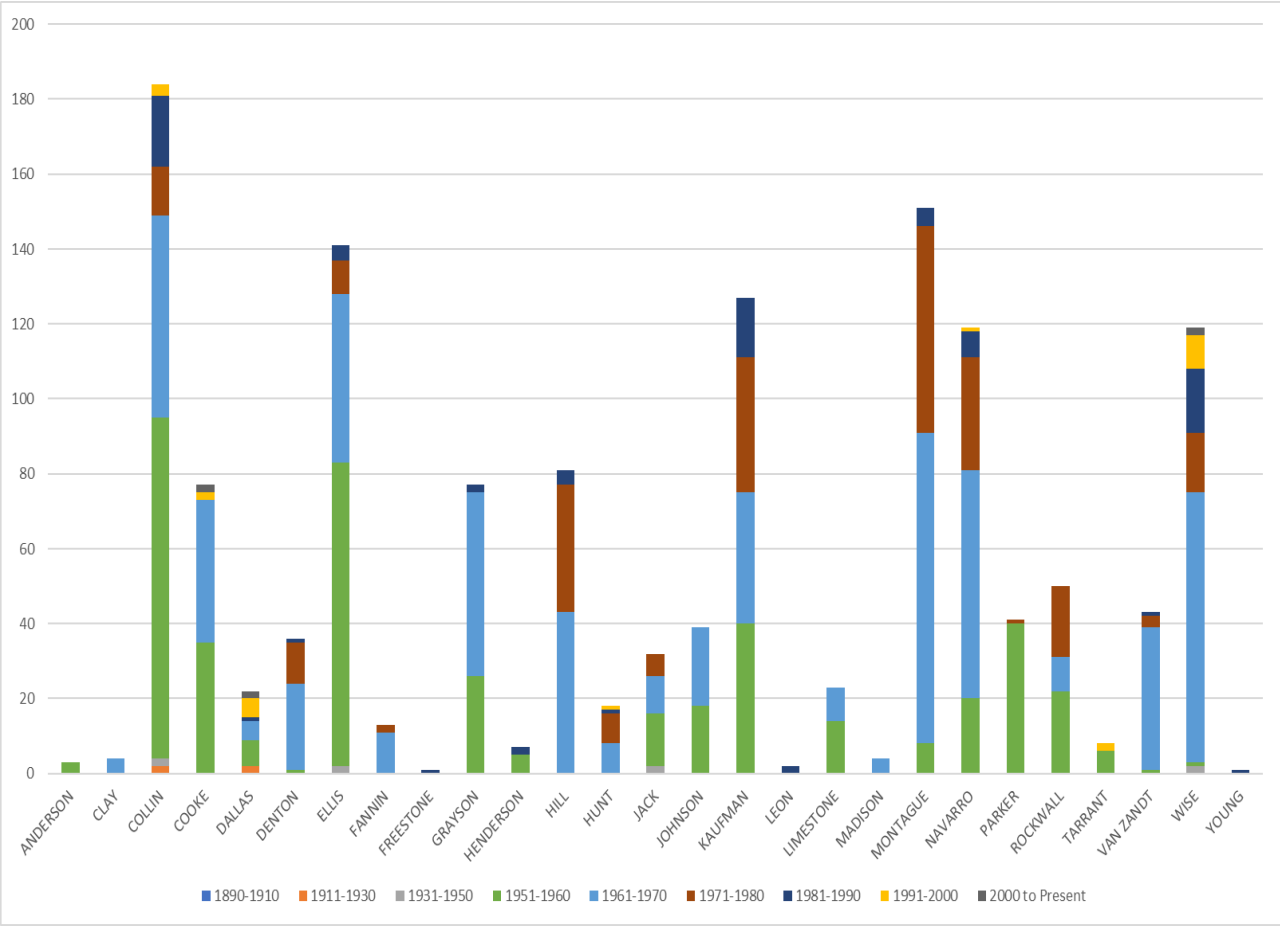
Table 1.13: Condition of Dams

	Functional	Non-Functional	Unknown	Total
Good	398			
Fair	258			
Poor		48		
Unknown			705	
Grand Totals:	**656**	**48**	**705**	**1,409**

Source: TCEQ Dam Inventory, provided September 2021

Although entity participants in the data collection effort provided little information about the nature of their dam infrastructure, TCEQ data on year of construction indicates that many may be due for maintenance, rehabilitation or even retirement. ***Figure 1.23*** provides cumulative totals of dams by county. The stacked colors represent the number of dams by decade of construction. According to the data provided by TCEQ, the majority of the region's dams were built between 1950 and 1980. This is because of federal funding, which provided funds for 50-year infrastructure, most of which has already surpassed this timeframe, creating age and funding challenges. Absent a full picture of the condition of the region's dams, this assessment considers year of construction, which is available for the majority of the dams. In the Trinity Region, over 90 percent of dams were built between 1951-1980. The 1960s were the most prolific period of dam building in the region, when over 43 percent were constructed. The percentage of dams built between 1951-1960 and 1971-1980 are the next largest, at about 30 percent and 17 percent, respectively.

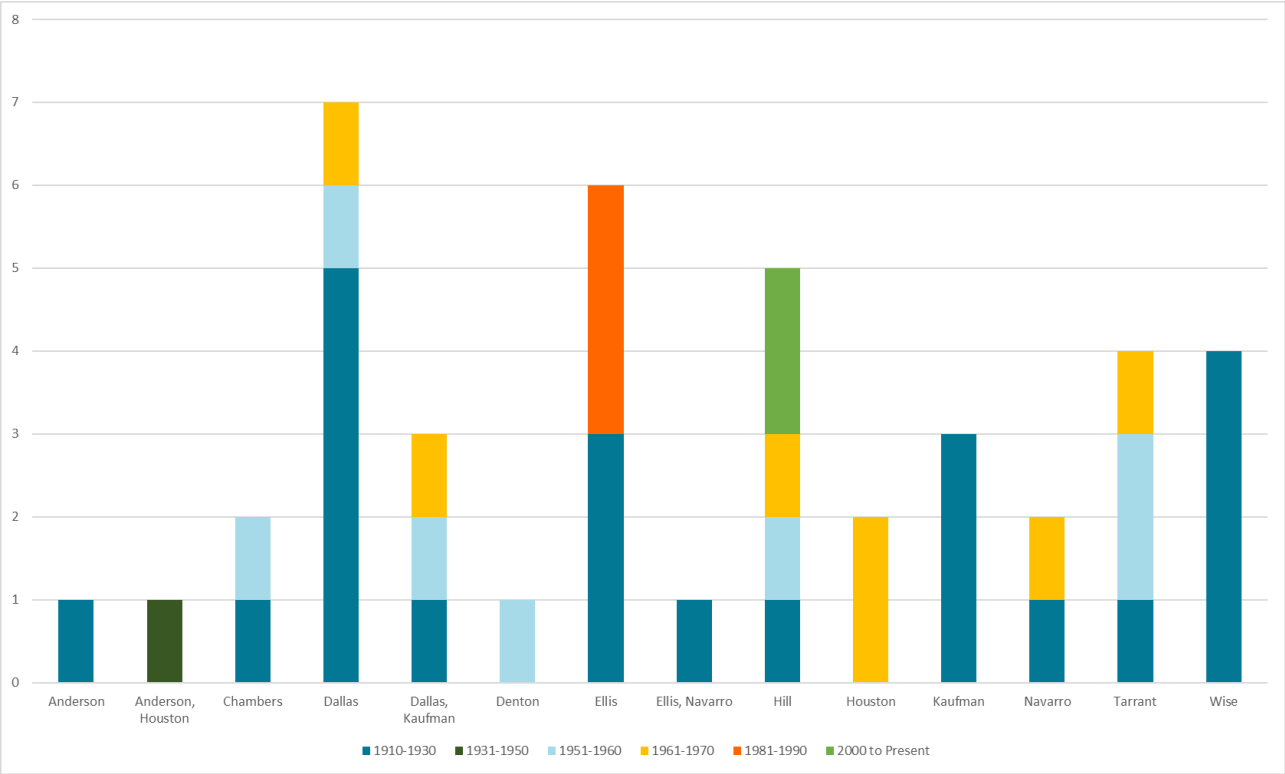
Figure 1.23: Dam by County by Year of Construction



Source: National Inventory of Dams: Local Dams (USACE, 2020)

With respect to levees, a 2021 assessment of the state's levee system by the ASCE continues to give the state's levees a grade of D and emphasizes that the lack of a state Levee Safety program means that few levees may be conducting regular safety inspections and preparing public evacuation plans for affected communities. (ASCE, 2021). There is much less information with respect to year of construction for levees than for dams, however, what is available indicates a substantial proportion of levees were built nearly a century ago, before 1930. Many of these older levees are agricultural in nature, and their primary purpose may be to provide a water supply and/or protect crops and rangeland from flooding. The National Levee Database did not provide a year of construction for all levees, but ***Figure 1.24*** charts the year of construction by county where provided.

Figure 1.24: Levees by County by Year of Construction



Sources: National Levee Database (USACE, 2022)

Deficient and Reasons for Deficiency

Inadequate data is available to assess the condition and functionality of the Trinity Region's infrastructure and other flood mitigation features. One of the reasons that infrastructure may not be maintained or repaired is a lack of funding, particularly for private landowners. The data collection survey requested this information from entities, however, no one self-reported having deficient structures. No further information from survey respondents or the TWDB is available to prepare an assessment of flood infrastructure deficiencies or the reasons for these deficiencies at this time.

Potential for Restoration

No information is currently available to assess the potential for flood infrastructure restoration. None of the survey participants provided any information regarding specific restoration needs for existing infrastructure. However, maintenance and restoration of existing infrastructure are important to maintain functionality.

Proposed or Ongoing Flood Mitigation Projects

The data for this section is derived from two primary sources. The first source of this data is the region's data collection survey, which was supplemented by direct outreach and interviews with entities. More detailed results are available in ***TWDB-Required Table 2*** in ***Appendix A***. The second source is existing Hazard Mitigation Plans (HMPs) in the region. There are also seven recently awarded Flood Infrastructure Fund (FIF) studies in the region.

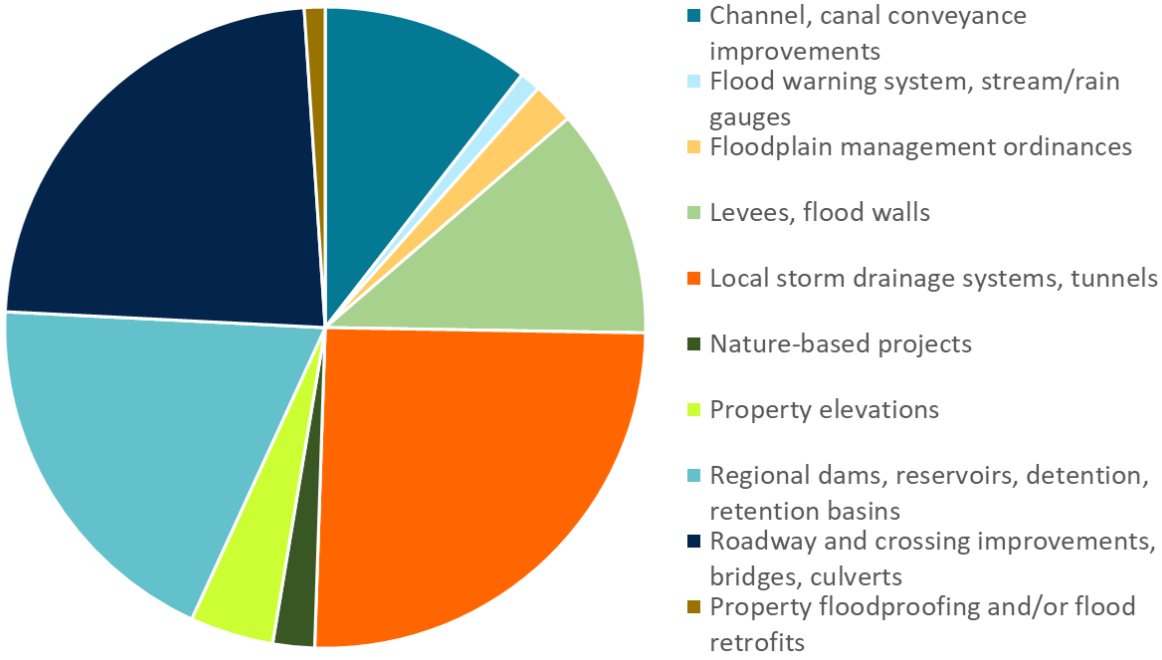
Ongoing or Proposed Projects Identified in Trinity Region Data Collection Tool and Web Map

Over 60 communities indicated in the survey that they planned to undertake FMPs in the coming years. However, there are a number of gaps in this dataset as little data was provided on individual projects. Only two respondents spoke about specific projects. Others indicated that they anticipated pursuing a variety of FMPs in the coming years. Respondents were allowed to select multiple alternatives.

Most respondents to this question indicated they intended to pursue more than one type of FMP. ***Figure 1.25*** represents all potential types of projects identified in the survey. Local storm drainage systems, roadway improvements and regional dams, reservoirs and detention, channel conveyance and levee improvements are among the most frequently cited FMPs for all responding jurisdictions. The topic of FMPs will be covered in greater detail in ***Chapter 4*** of this plan.

To accompany this chart, ***Table 1.14*** details the frequency with which communities plan on implementing a particular type of FMP. While several project types, like local storm drainage systems and roadway improvements may be local in nature, many other solutions are more regional in nature, such as regional dams and retention and even highway improvements that may involve state agencies.

Figure 1.25: Proposed or Ongoing Flood Mitigation Projects



Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

Table 1.14: Proposed Mitigation Projects by Type

Type of Projects	Count
Channel, canal conveyance improvements	10
Flood warning system, stream/rain gauges	1
Floodplain management ordinances	2
Levees, flood walls	11
Local storm drainage systems, tunnels	24
Nature-based projects	2
Property elevations	4
Regional dams, reservoirs, detention, retention basins	18
Roadway and crossing improvements, bridges, culverts	22
Property floodproofing and/or flood retrofits	1

Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

These proposed or ongoing FMPs are derived from the community survey responses throughout the basin. They are being completed by cities, counties, and additional entities throughout the basin. According to the self-assessment of survey respondents, about 25 percent of these projects are claimed to be over the 30 percent design mark, with only two projects being labeled as "nature based." The predominant types of projects being pursued are:

- Local storm drainage systems, tunnels
- Roadway and crossing improvements, bridges, culverts
- Regional dams, reservoirs, detention, retention basins

Of the projects with the lowest interest were those related to flood warning systems, ordinances, and flood retrofits. It is important to notice that there may be a larger number of projects than displayed, since entities submitted the categories of projects they were pursuing, but not the number of projects within each category. Potential funding sources for these projects that were identified by these entities include FEMA, GLO, CDBG-MIT, TWDB, TDEM, as well as local funding sources coming from the general fund, taxes, stormwater utility fees and other fees.

Structural Projects Under Construction

In the survey, 16 respondents noted that some of their proposed infrastructure or FMPs were at or above a 30 percent level of design. However, responses regarding projects under construction were insufficient to provide a complete answer to this question. ***Chapter 2*** includes more detailed assessment of projects under construction.

Nonstructural Flood Mitigation Projects Being Implemented

Information provided in response entity outreach is insufficient to provide a complete answer to this question. ***Chapter 2*** includes more information regarding nonstructural FMPs being implemented.

Structural and Non-Structural Flood Mitigation Projects with Dedicated Funding and Year Complete Funding Sources

Information provided in response entity outreach is insufficient to provide a complete answer to this question. However, several respondents to the survey who indicated that they did have projects at 30 percent level of design also indicated that Stormwater Utility Fees, Bond Programs, Ad Valorem Tax, and the General Fund were anticipated to be their primary source of revenue to complete these improvements. One respondent indicated that the entity would draw down funds from Special Tax Districts.

Non-local funding sources the entities intend to pursue to complete these projects include:

- Hazard Mitigation Grant Program (HMGP- FEMA/TDEM)
- Pre-Disaster Mitigation (FEMA)
- Cooperating Technical Partners (CTP) funds (FEMA)
- Flood Protection Planning Grants (TWDB)
- USDA NRCS
- Flood Mitigation Assistance (FEMA)

Plans Identified in Hazard Mitigation Projects

In addition to the plans identified via the survey conducted for this project, HMPs for the communities of the Trinity Region also served as an important source of information about future actions to promote flood mitigation. ***Table 1.15*** lists the types of FMPs and numbers of each subcategory type identified in the current HMPs in the Trinity Region. ***Chapter 4*** includes more information on specific projects identified in the HMPs.

Table 1.15: Flood Mitigation Projects by Hazard Mitigation Plan

Subcategory	Total Count
Infrastructure Improvement	220
Urban Planning and Maintenance	211
Education & Awareness for Citizens	145
Drainage Control & Maintenance	143
Equipment Procurement for Response	125
Flood Study/Assessment	121
Outreach and Community Engagement	81
Installation/Procurement of Generators	53
Buyout/Acquisition	52
Technology Improvement	35
Flood Insurance Education	34
Natural Planning Improvement	28
Erosion Control Measure	25

Flood Infrastructure Fund Projects

Of the applications to the FIF in 2021, seven projects in the Trinity Region received funding. These projects, awarded to the Trinity River Authority, Jackson County, Chambers County, Dallas County, Kaufman County, and Parker County Soil and Water Conservation District #558 are primarily for flood and drainage studies. The exceptions are Parker County, which received funding to assist with the preparation of an emergency action plan for dam breach and inundation.

These plans are prepared on a five-year cycle, so ***Table 1.15*** is best suited to provide evidence of the types of projects that will need funding in the future. Not every community provides a dollar value for future projects, so it is difficult to tally the total cost of need for mitigation. However, it is likely that a large need for structural improvement remains, given the projects referencing:

- Infrastructure improvement
- Drainage control

Given the 2021 winter storm, additional sources of funding may be available for the purchase of:

- Equipment for emergency response
- Generators

Many of the following non-structural initiatives can be accomplished with lower investment, while an ongoing program of buyouts and acquisitions may be a longer-term initiative:

- Education and citizen awareness
- Outreach and community engagements
- Urban planning and maintenance

Many of the FMPs identified by communities may have already been completed in the time since the HMP was adopted.

Potential Benefits of Planned Mitigation Projects

Although most communities did not provide detailed information about their intended projects, there does appear to be substantial awareness of the value of preparing for future flood events. Both survey responses and a review of HMPs indicate that substantial investments are being made in local drainage, roadway, and flood control infrastructure. An examination of HMPs indicated that 17 percent intended to adopt and/or update their non-structural measures, such as land use regulations that would help future development avoid being in conflict with areas of flood risk. Without greater detail as to the scale, complexity, and location of these projects, it is difficult to quantify the benefit received, but it is anticipated that the inventory of this information will continue to grow in future planning cycles.

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