Proactively Integrating Transportation and Stormwater Infrastructure in North Texas

North Central Texas Council of Governments

Matt Lepinski, P.E.

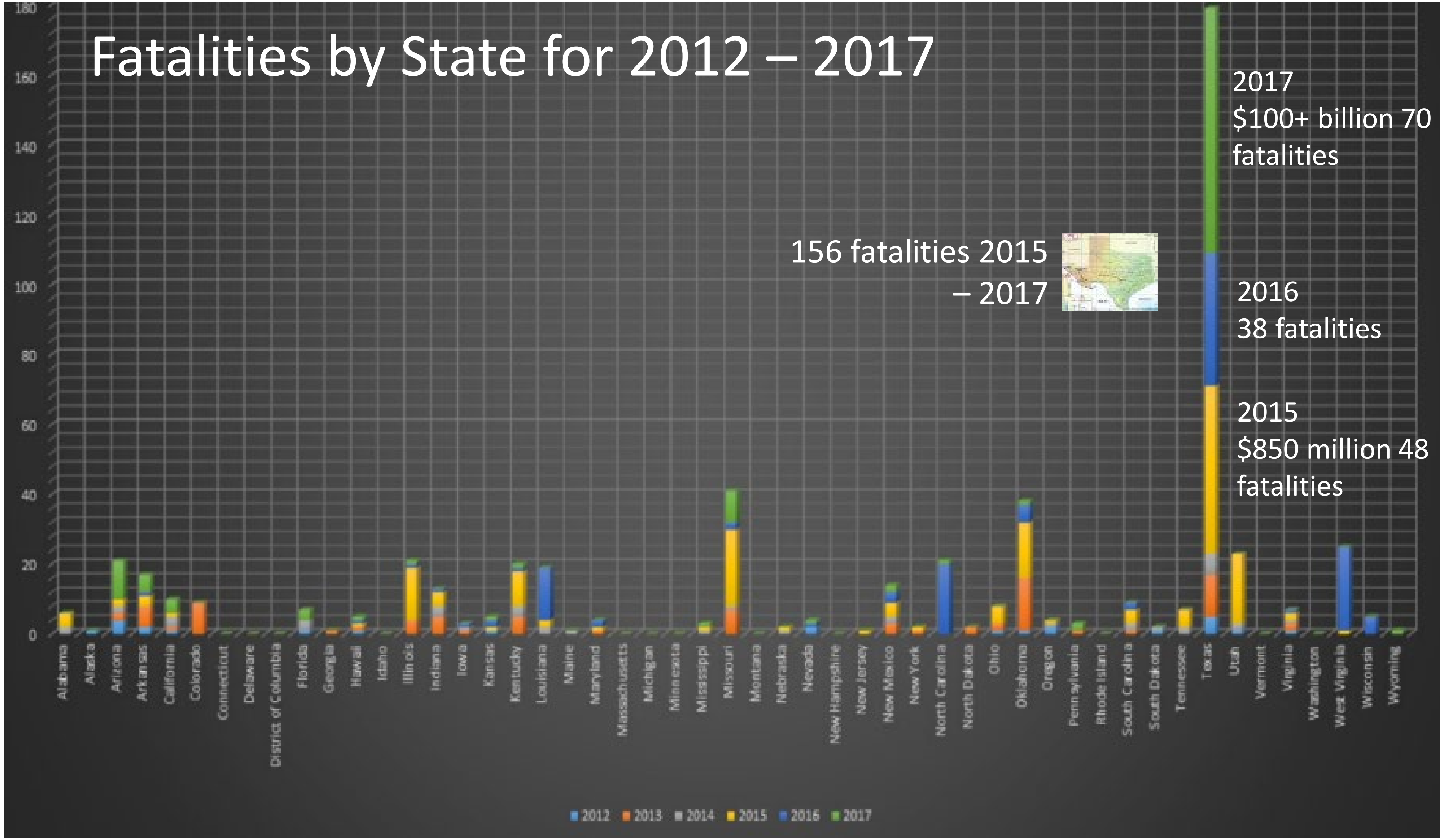
U.S. Army Corps of Engineers, Fort Worth District

SAME Transportation Resiliency Forum

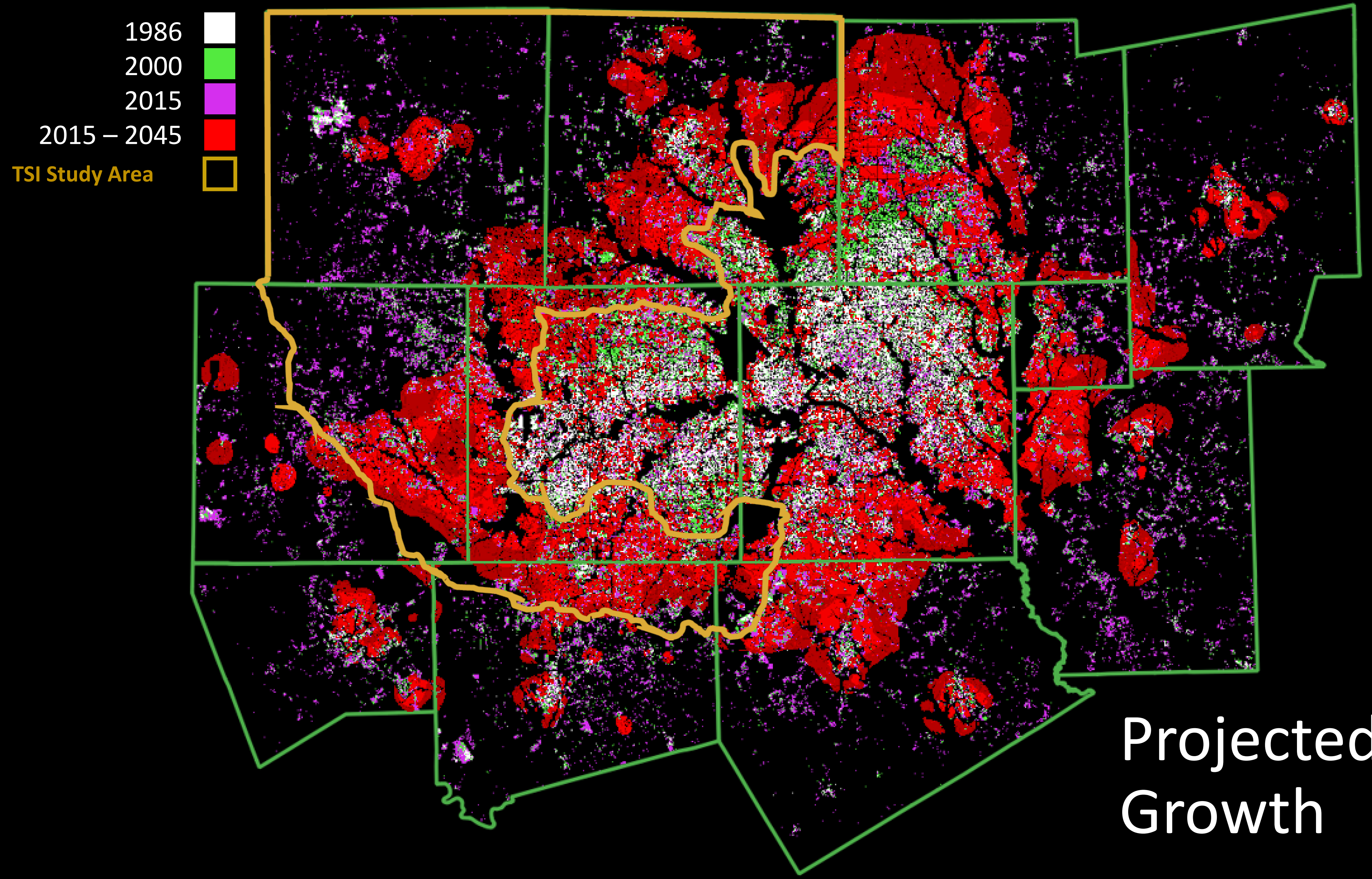
August 19th, 2024

Flooding Fatalities and Damages

Texas far outpaces other states in flood-related fatalities and flood-related damages

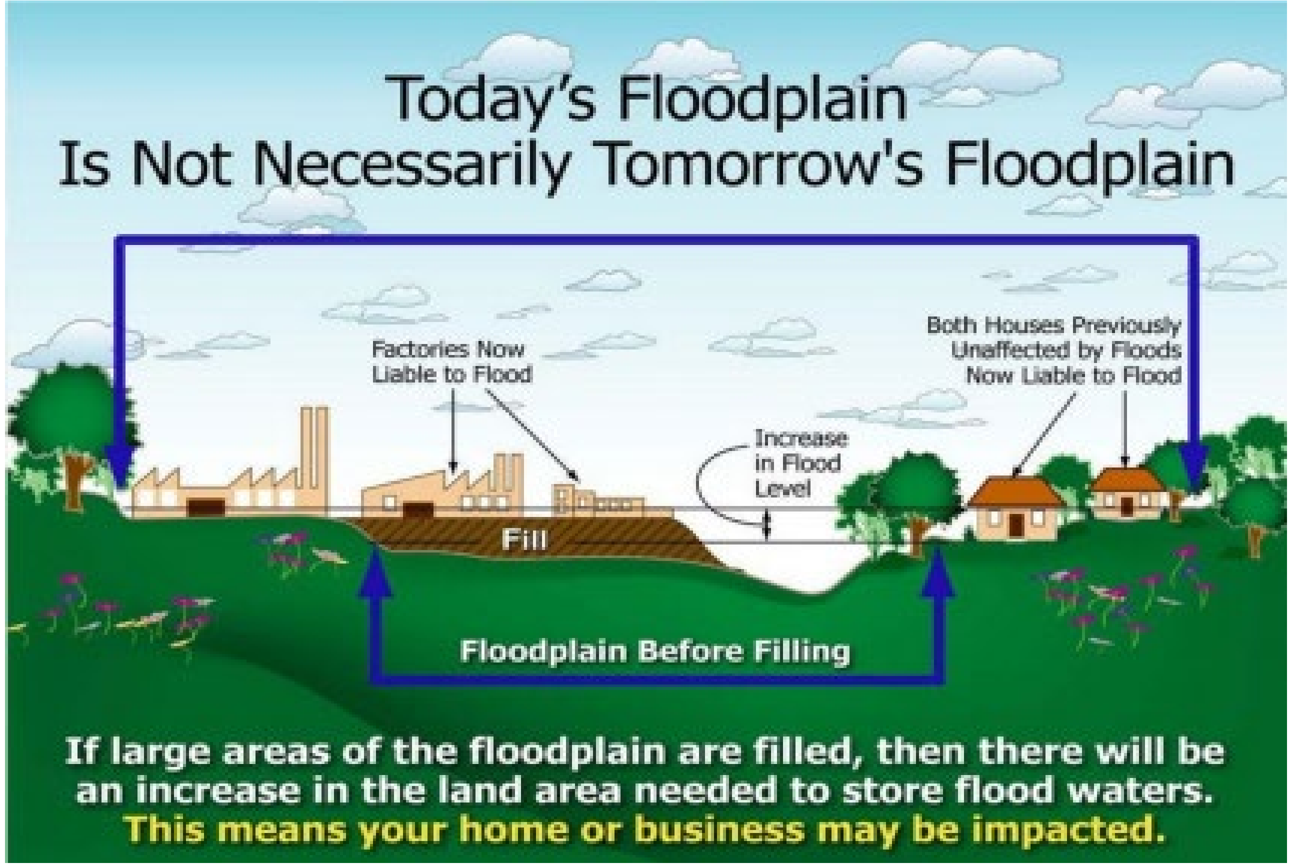


Source: Gregory Waller, Service Coordination Hydrologist, NWS – West Gulf River Forecast Center, http://www.nws.noaa.gov/om/hazstats.shtml, 11/18 TFMA

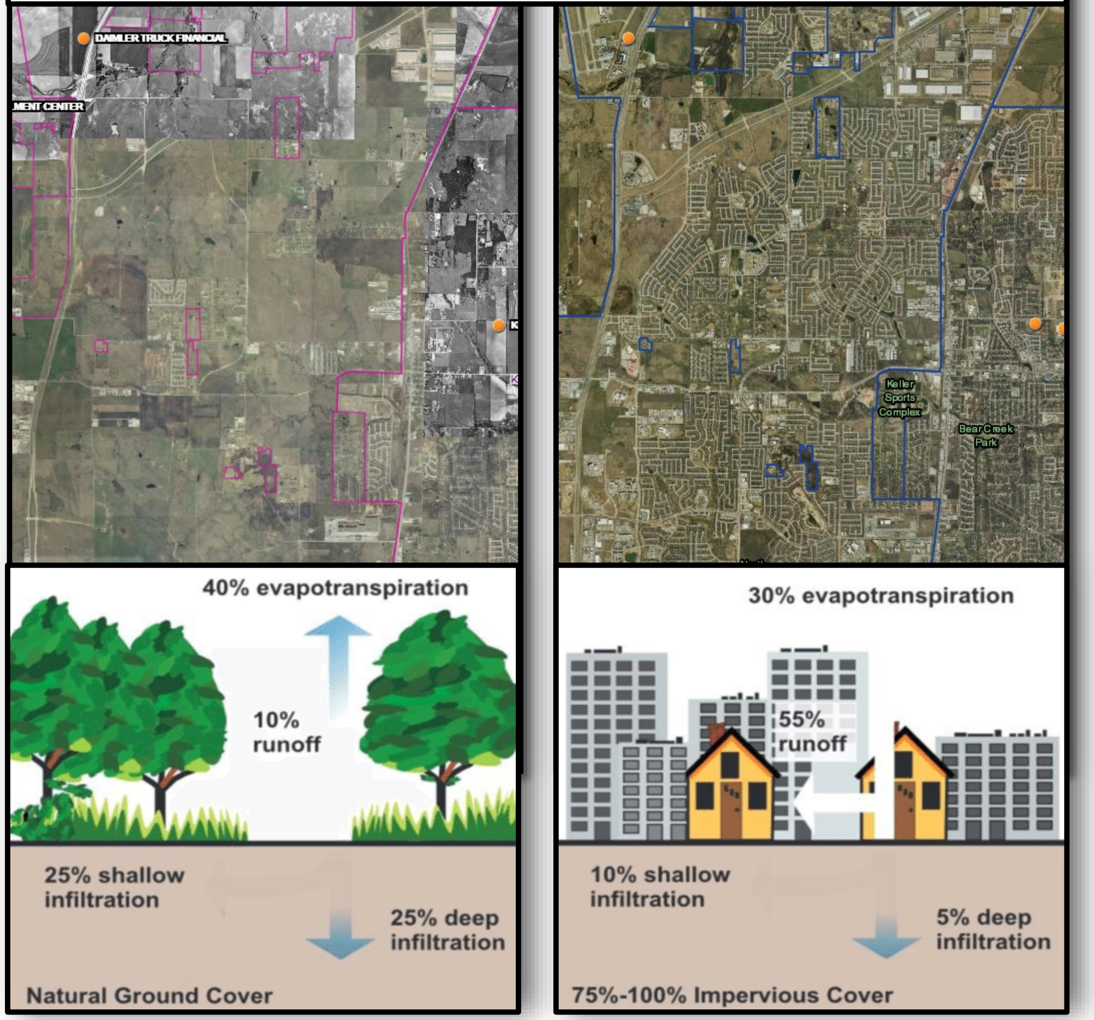


Projected Growth

Urbanization Challenges



Case Study: Development in Fort Worth, TX (North)



BEFORE

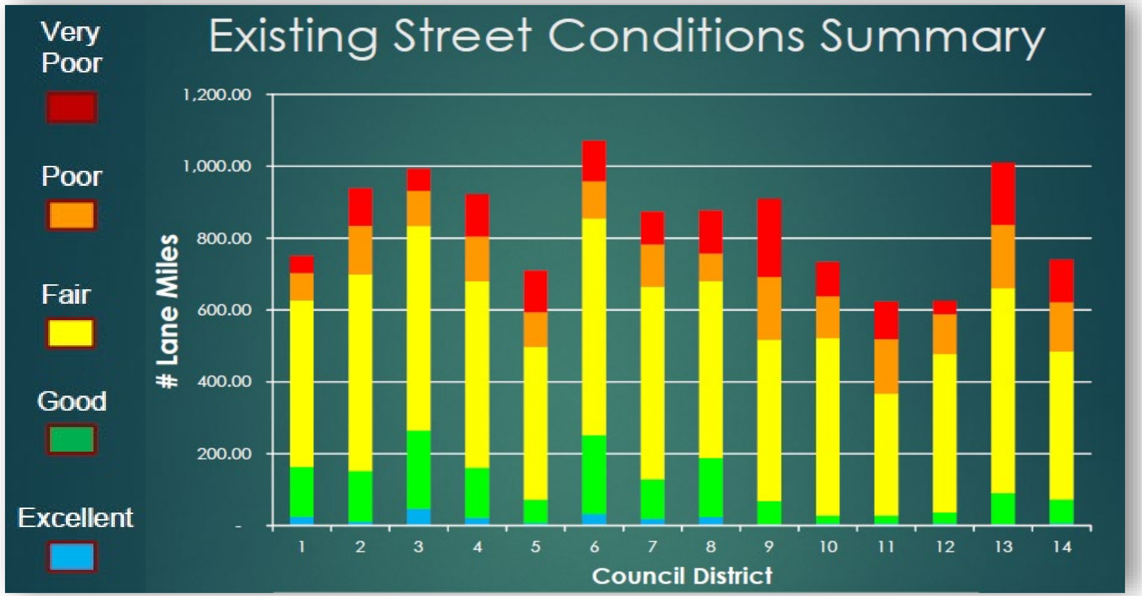
AFTER

Stormwater Challenges

- No regionwide data
- Piece-meal/lacks connectivity
- Updated rainfall estimates
  - Precipitation data required for infrastructure design, planning, and delineation of flood risk
  - NOAA Atlas 14 published for Texas in 2018
    - The 2022 FLOODS Act requires updates to this every 10 years

Transportation Challenges

- Transportation spending is high and growing
- Rate of deterioration for transportation infrastructure increasing
- Needs far outweigh resources



Source: Dallas 2017 Bond Program – http://www.dallasbond.com/

Exhibit 2-4: Major Expenditures

Mobility 2045 Update Planning Approach	
Infrastructure Maintenance*	$42.8
Management and Operations	$9.6
Growth, Development, and Land Use Strategies	$1.5
Rail and Bus**	$44.9
HOV/Managed Lanes + Freeways/Tollways and Arterials	$49.5
Total, Actual $, Billions	**$148.3**

Values may not sum due to independent rounding
*Includes transit system maintenance
**Transit capital expenditures, including those using innovative revenue sources such as public-private partnerships

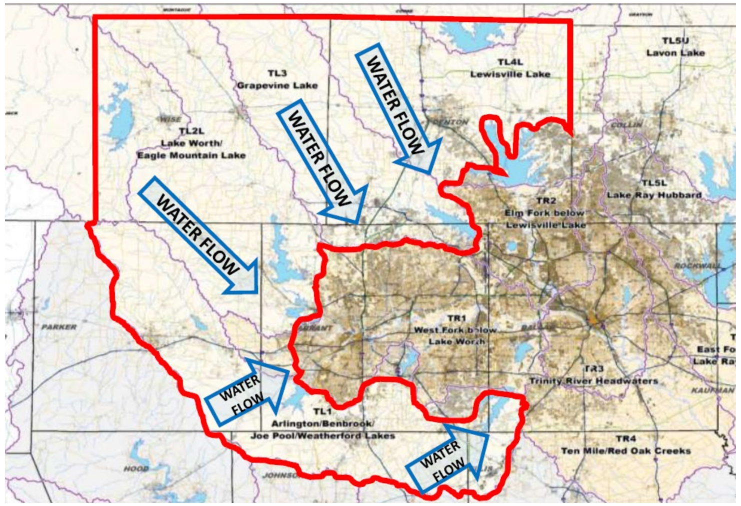
Source: NCTCOG, Mobility 2045 Update

integrating **Transportation & Stormwater Infrastructure**

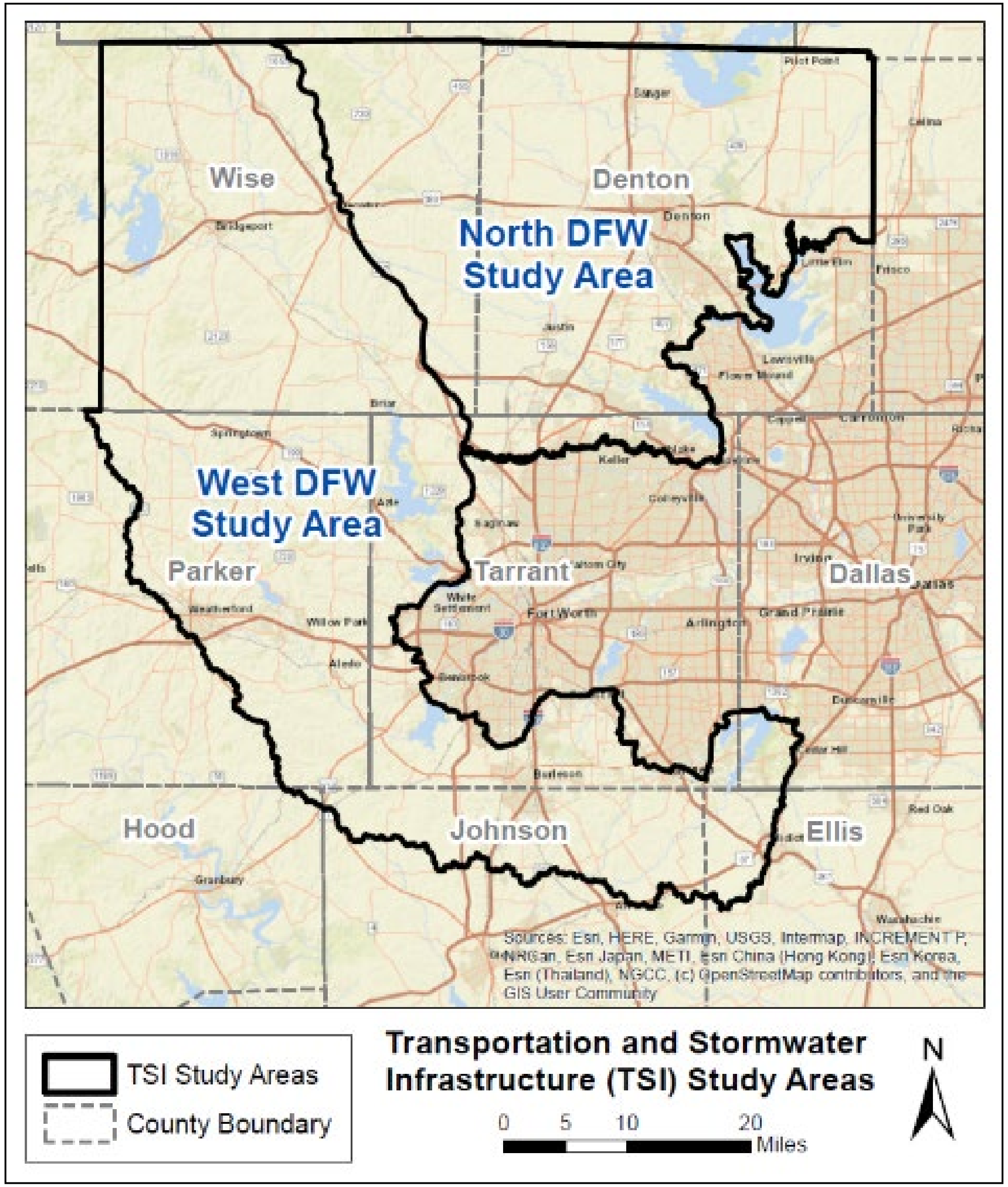
Integrated Transportation and Stormwater Infrastructure (TSI) Study Overview

Intent:

- Integrate regional planning for transportation, stormwater management, urban development, and environmental features
- *Proactively vs. Reactively* reduce flood risk
- Minimize overall life cycle costs of infrastructure
- Reduce impacts to the natural environment in the rapidly developing study area



Objective: a 'roadmap' for communities



integrating **Transportation & Stormwater Infrastructure**

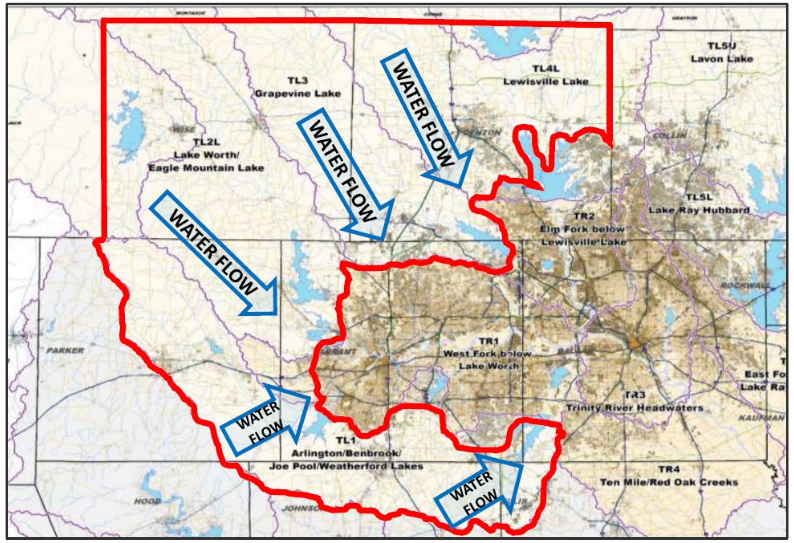
www.nctcog.org/tsi

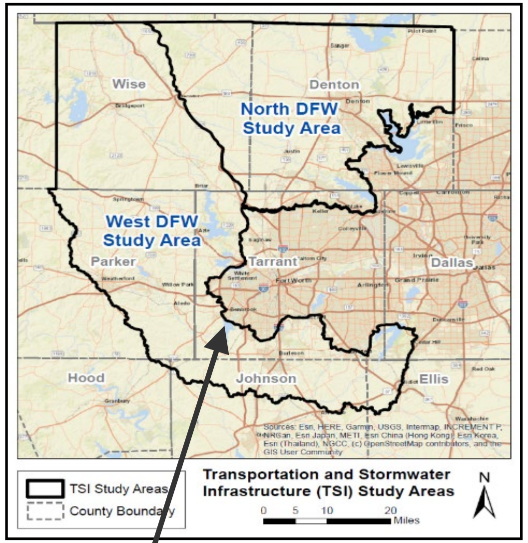
Response vs. Prevention

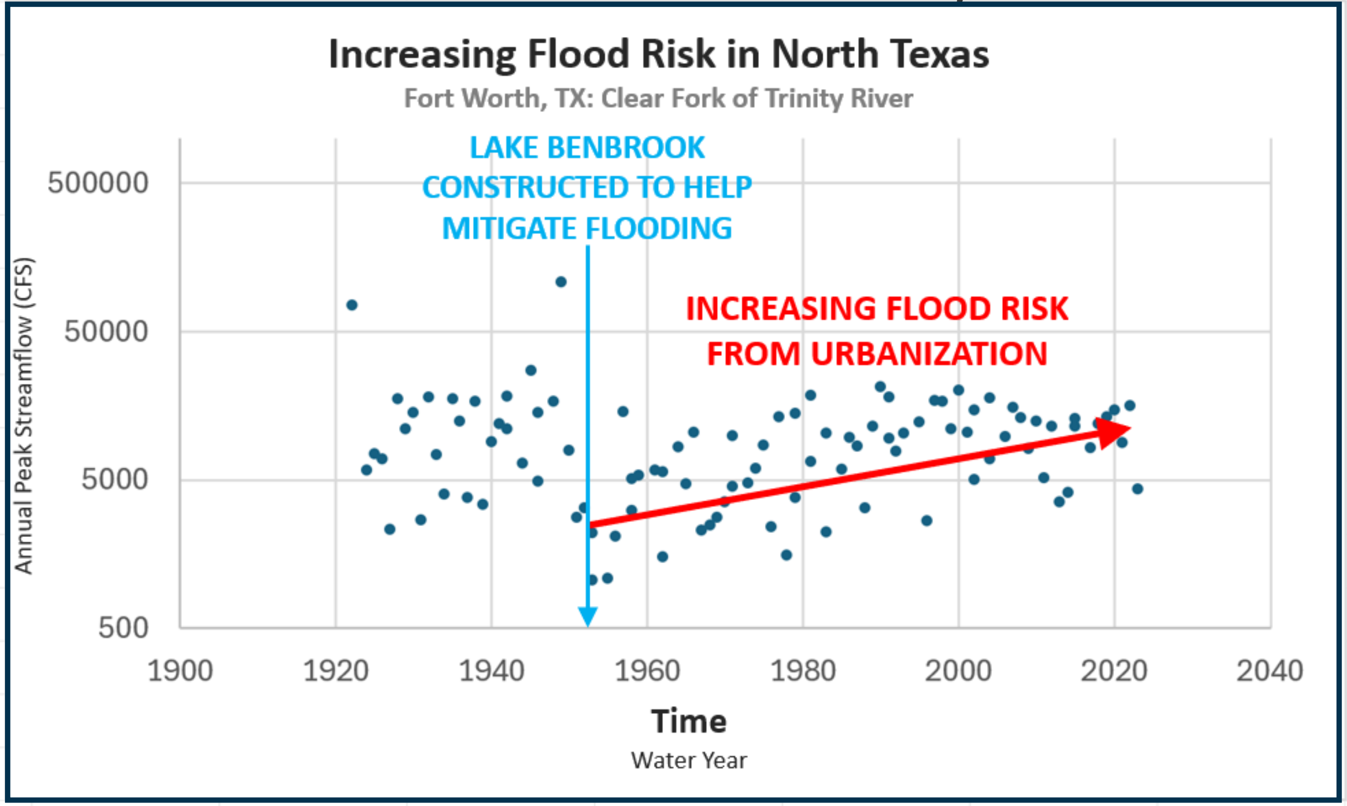
Sources: Flooded Area of Stores and Homes Near Downtown Fort Worth During Flood of 1949; https://texashistory.unt.edu/ark:/67531/metapth27965/: University of North Texas Libraries, The Portal to Texas History, https://texashistory.unt.edu; Tarrant County College NE, Heritage Room

Fort Worth – May 1949 (~11 inches of rain overnight):

- Levees breached, 10 deaths & $11M+ in damages
- *Resulted in extensive improvements to flood control infrastructure*
    - Water District (established in 1924)
    - USACE Fort Worth District (established in 1950)







integrating **Transportation & Stormwater Infrastructure**

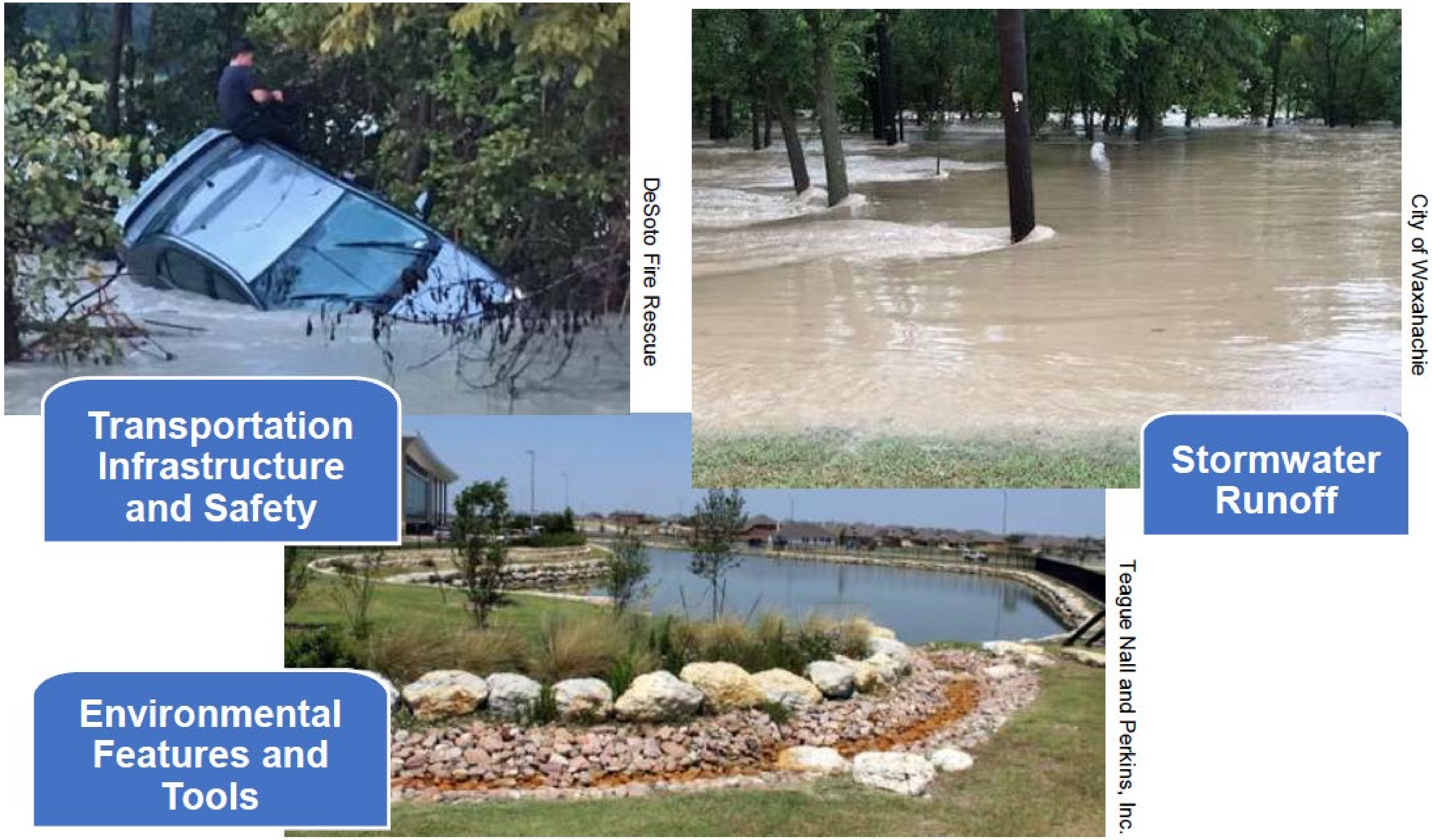
Project Area Details

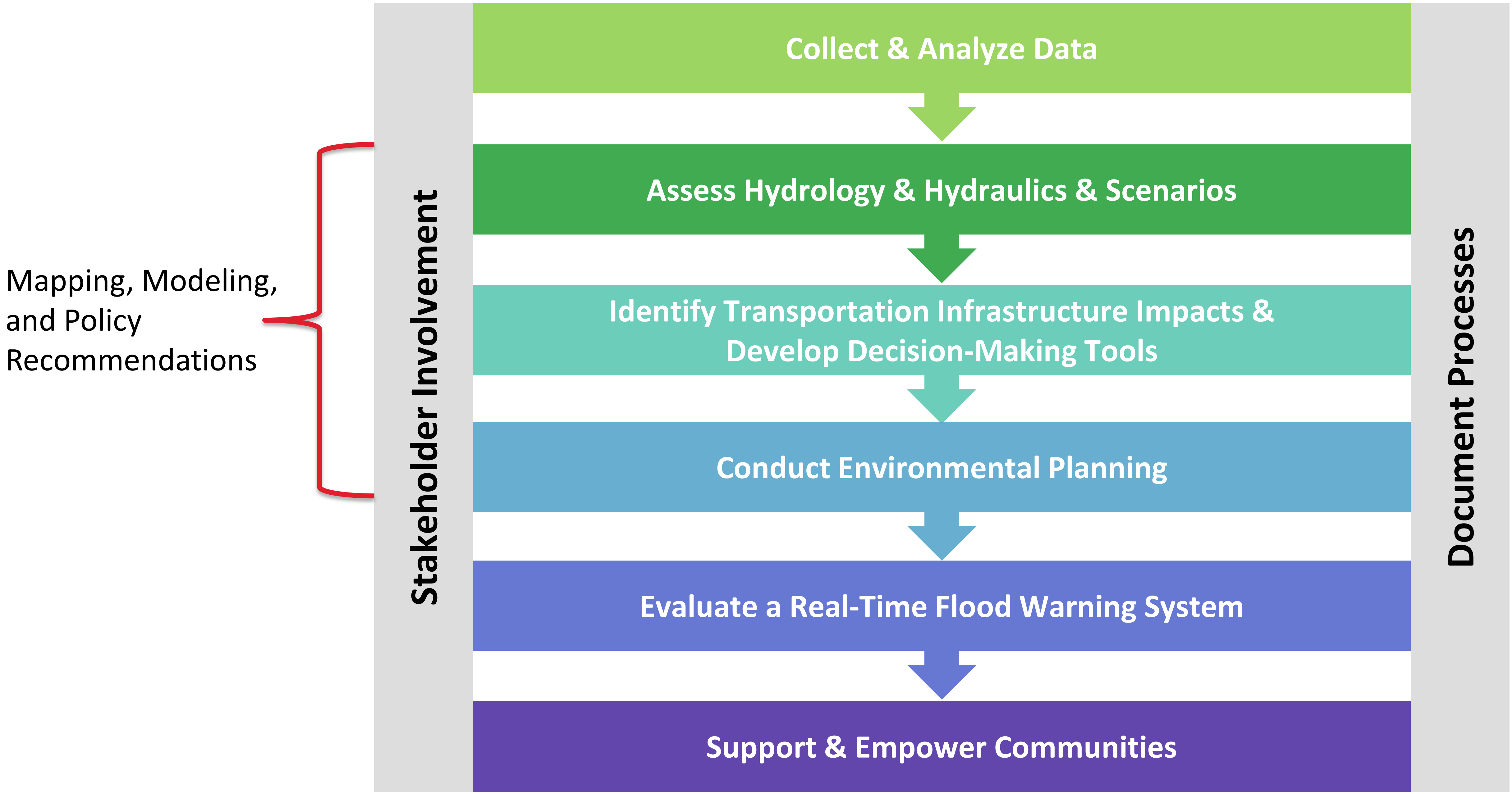
- 85 cities and portions of 8 counties
- 126% increase in population (2020 – 2045)
- 60% undeveloped (2015)
- 19% growth in impervious surface (2006 – 2016)
- > 7,000 miles of streams and > 274,000 acres of 100-year floodplain

Photo courtesy of City of Newark

Why Collaboration is Important

- Dissolve silos
- Improve delivery of consolidated, adaptive infrastructure
- Get ahead of growth
- Reduce costs





integrating **Transportation**
& Stormwater Infrastructure

TSI Goals and Outcomes

Proactive Planning

- Reimagine transportation design to integrate stormwater, environmental, and flood reduction benefits
- Protect current and future infrastructure
- Develop model for replication

Reduce Flooding

- Reduce flooding downstream of rapidly growing upstream communities
- Increase resiliency to flooding disasters
- Inform decision-making
- Implement stormwater infrastructure with transportation infrastructure

Tools/ Resources

- Empower communities to adopt higher floodplain management standards
- Develop GIS based tools and resources
- Emergency management & flood warning recommendations

Local-Scale Innovation

- Enhance Trinity River Watershed Hydrology Assessment
- Enhance existing hydraulic models such as BLE
- Optimization study for drainage/flood control structures
- Develop flood susceptibility map

Community Roadmap

- Produce planning-level designs for transportation, stormwater detention, and environmental
- Integrate these layers to identify what needs to be built and achieved benefits
- Establish ways to fund planned infrastructure

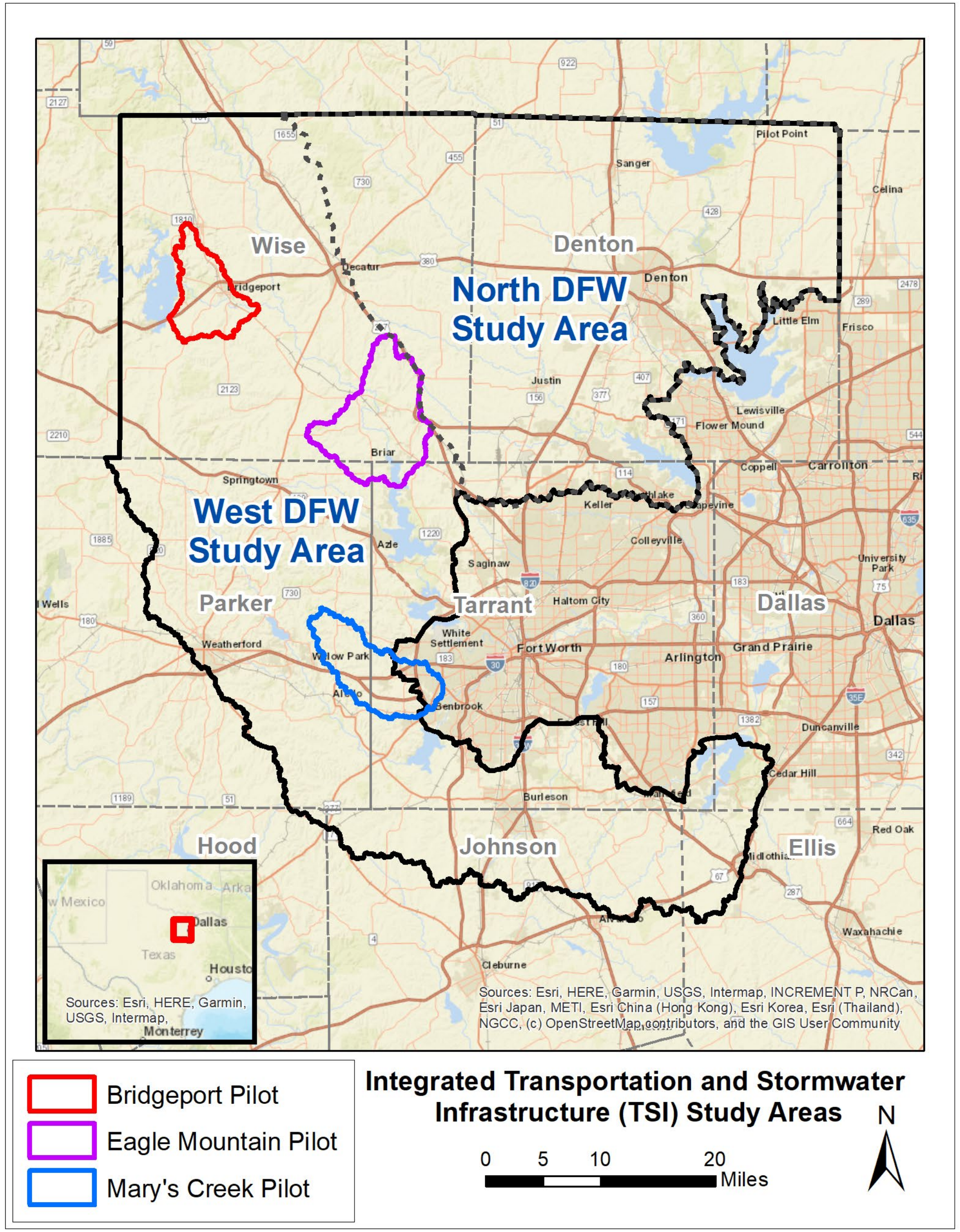
Result: A menu of options & integration where it makes sense

Note that these images are AI generated

TSI Pilot Study Overview

Pilot Study Locations and Updates:

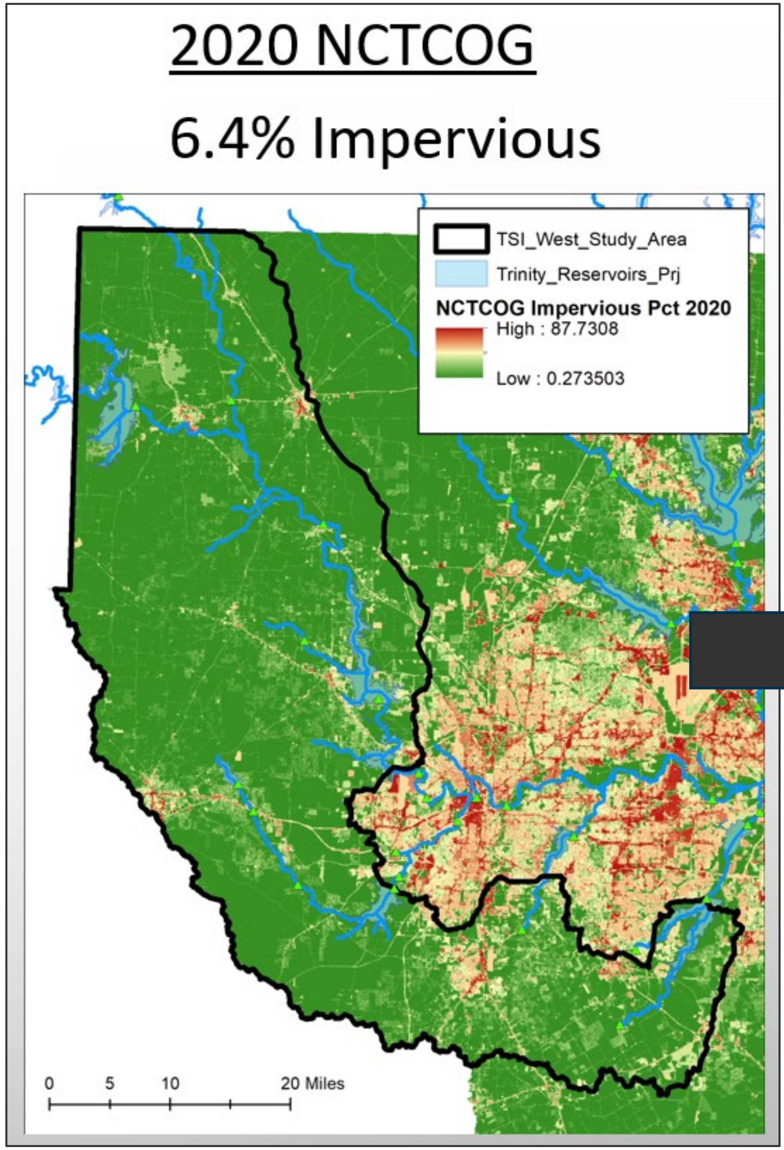
- **Intent:** to develop and test approach for larger effort
- Bridgeport:
  - Completed initial H&H pilot study in late 2023
- Eagle Mountain and Mary's Creek:
  - Completing more comprehensive H&H pilot studies, including:
    - Establishing current/future land use
    - Hydrology approach development and technical enhancements to WHA
    - Hydraulics approach development and technical enhancements to BLE
    - Optimization study and urban drainage methodology refinement
    - Identify flood-prone areas and model Green Stormwater Infrastructure (GSI)

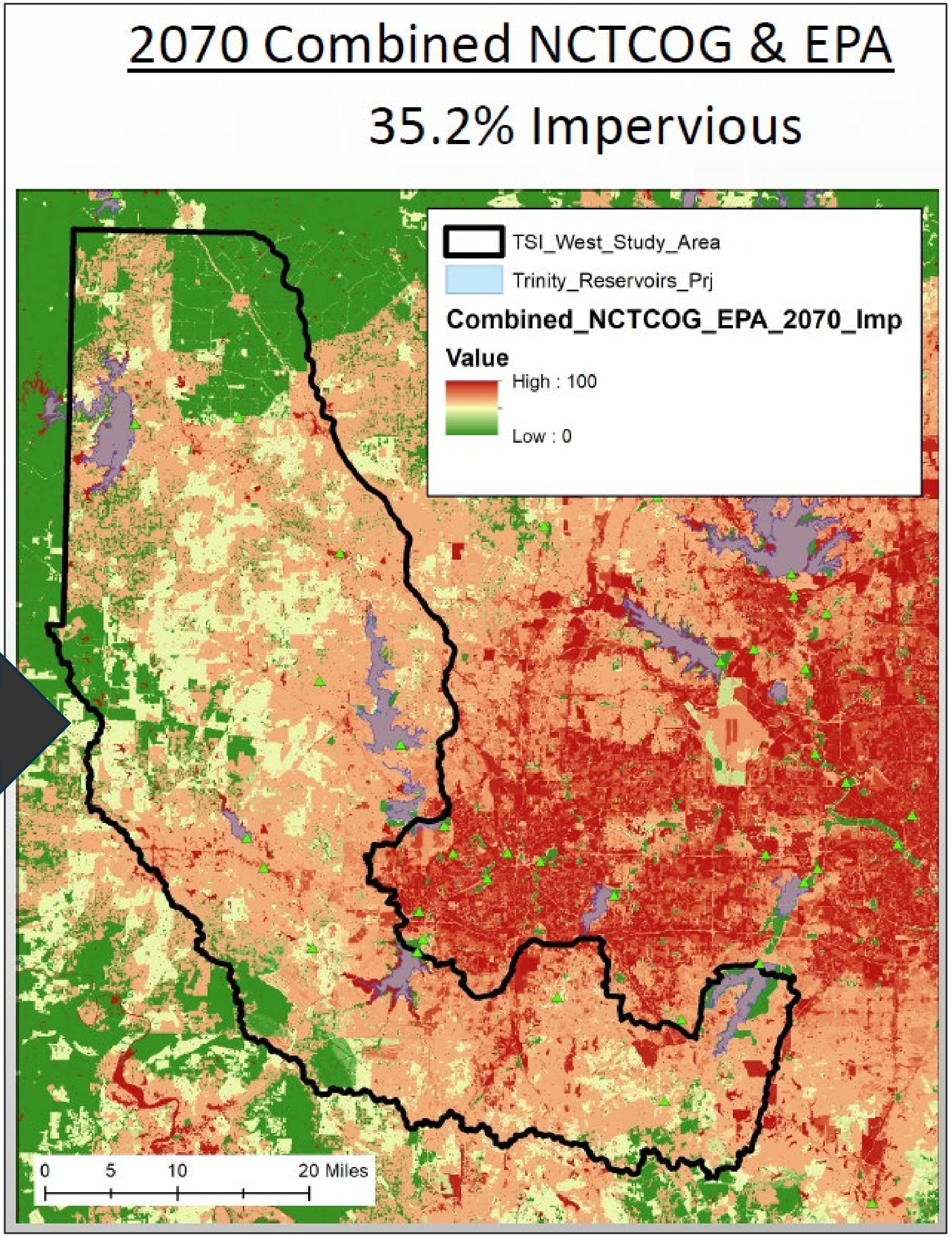


integrating **Transportation**
& Stormwater Infrastructure

TSI Land Use Approach

- Leverage available current (2020) and future (2070) land use data to inform:
  - Current conditions flooding
  - Future conditions flooding
  - Future conditions flooding with TSI

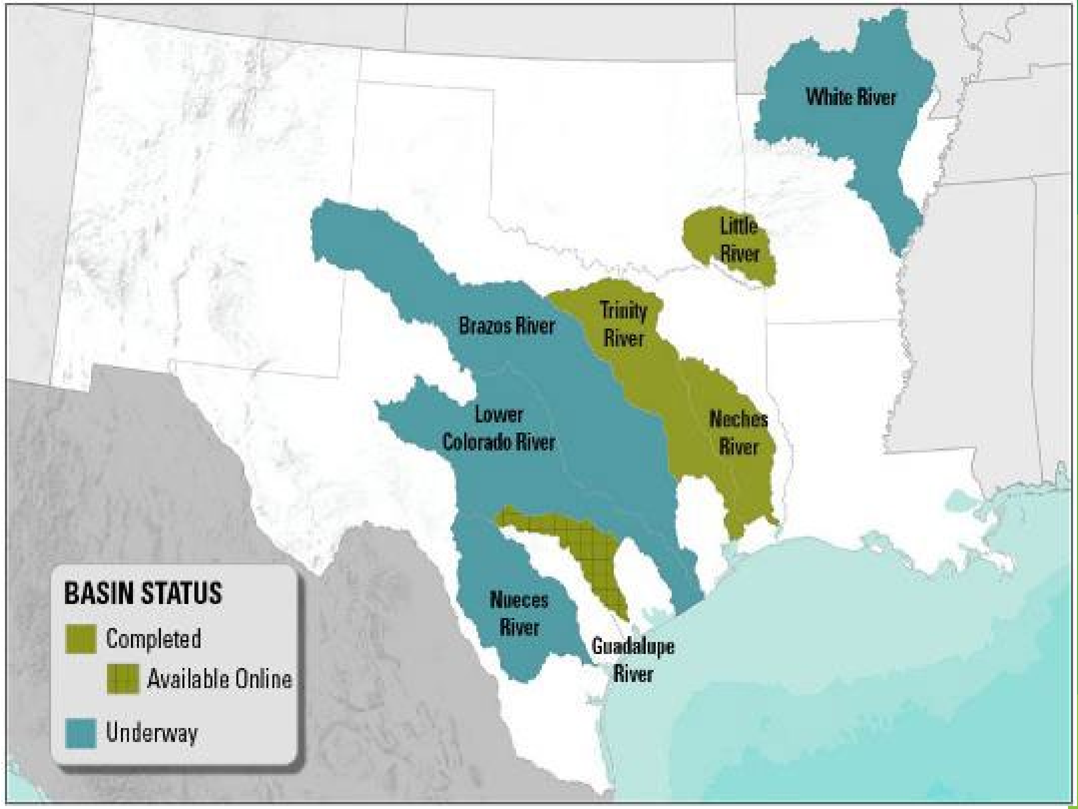




integrating **Transportation**
& Stormwater Infrastructure

Hydrology Data Source: Watershed Hydrology Assessment (WHA)

- **What?** State of the art estimate for the potential of flooding
  - Hydrology study (i.e., determines how much water) for large rivers and streams
  - Multi-method analysis to reduce **uncertainty**
  - Statistical data & numerical data is incorporated into larger modeling efforts
  - Incorporates NOAA Atlas 14 point-precipitation rainfall totals
  - Accounts for regulated flow from dams
- **Why?**
  - Hydrology remains the single largest source of **uncertainty** in our understanding of flood risk
  - Available hydrology information is generally dated and obsolete
- **Outcome:**
  - WHA produce consistent 100-yr and other frequency flows across the river basin, based on all available hydrologic information
  - Provides design data and suggests areas where flood hazard information may need to be updated
  - **Trinity River Watershed Hydrology Assessment**
    - Objective: Recently completed high quality hydrology study of 700-mile-long Trinity River Basin (18,000 square miles)
    - Outcome: Innovative and quality information for use in regional flood studies



https://webapps.usgs.gov/infrm/whav/

integrating **Transportation & Stormwater Infrastructure**

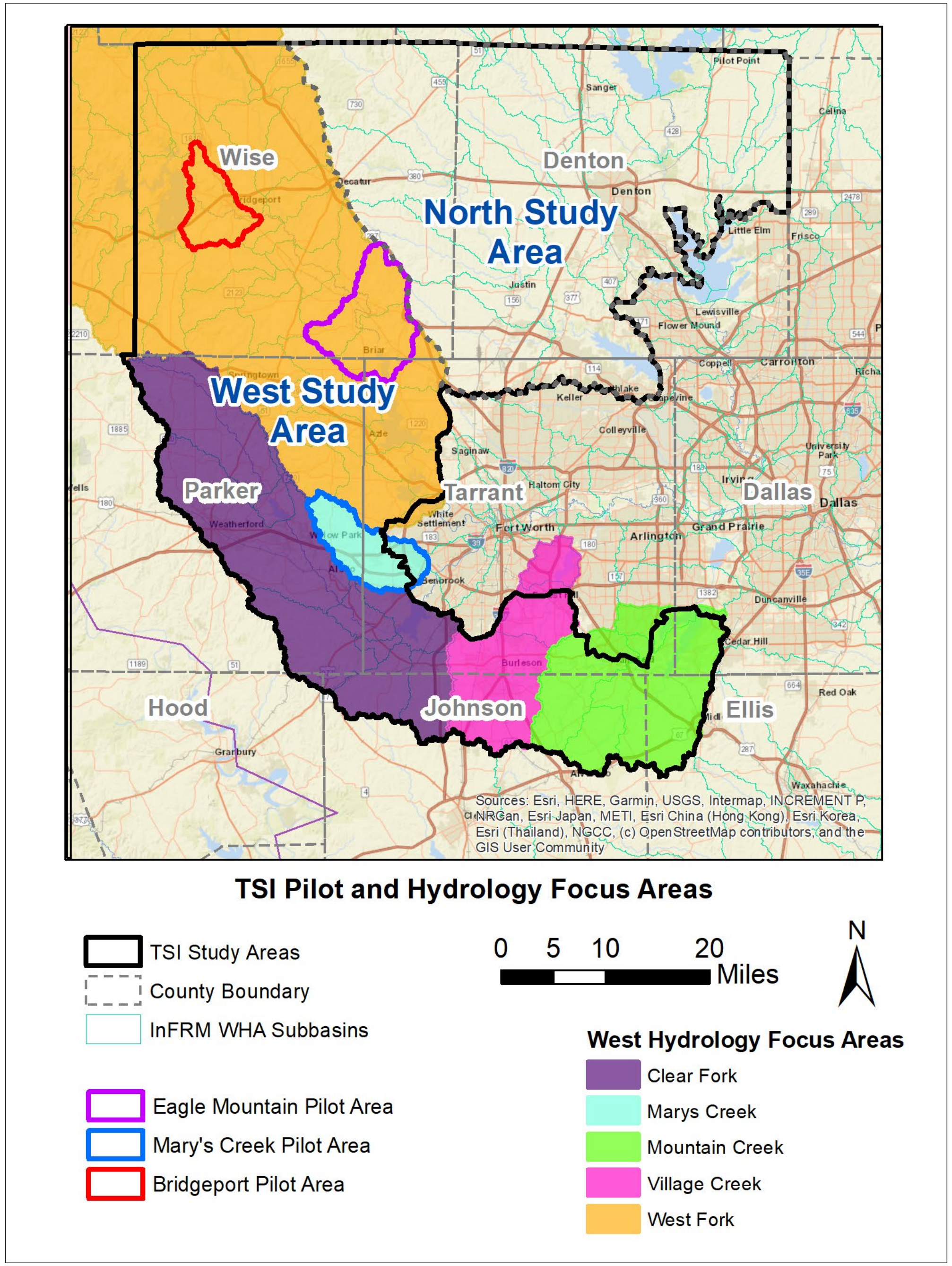
Hydrology Approach

- Developed SOP and enhancing hydrology (including new flow locations) in pilot areas and larger West area:
  - Mary's Creek
  - Village Creek
  - Mountain Creek
  - Clear Fork
  - West Fork

TSI Project
West Study Region
HEC-HMS Model Development SOP

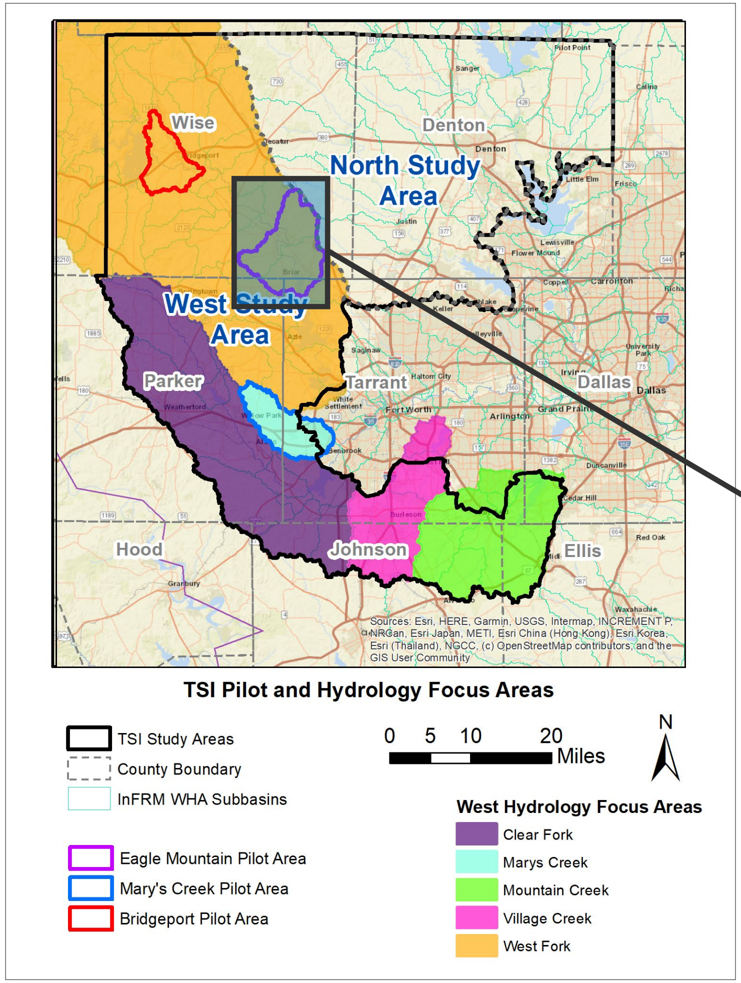
May 2024

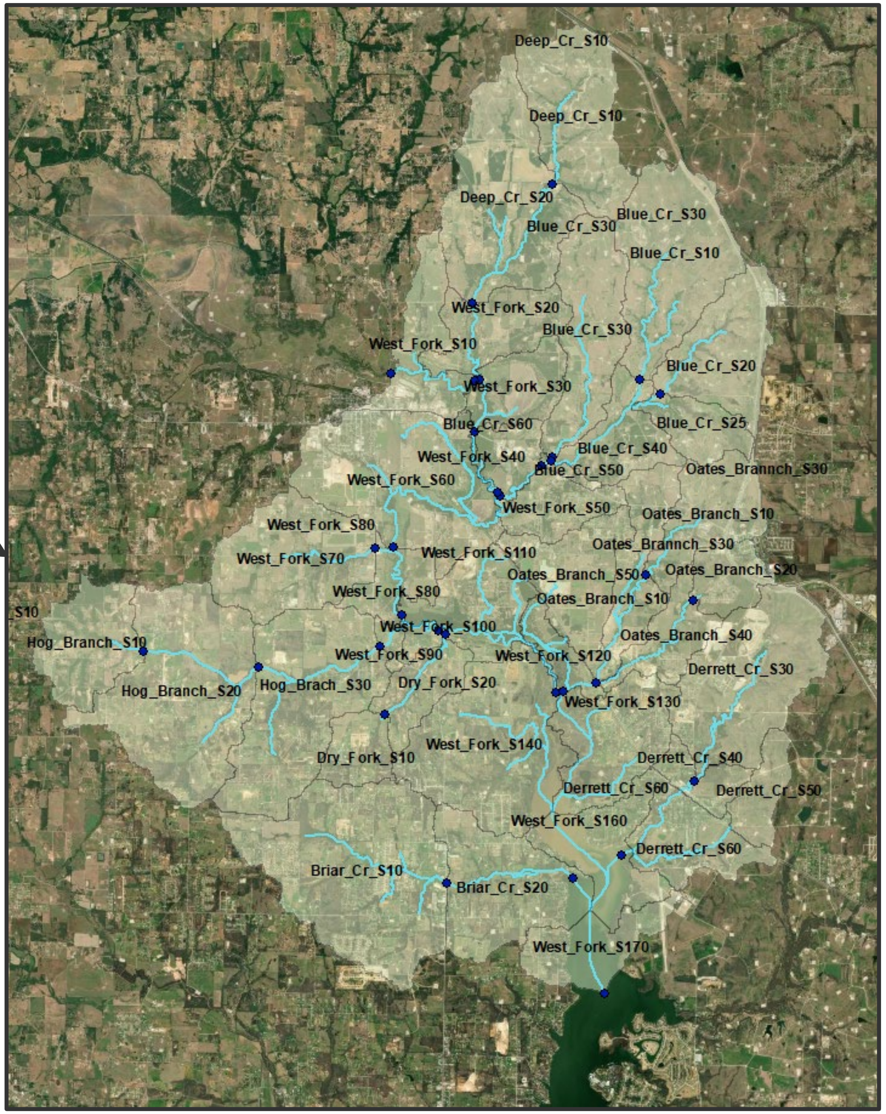
1. Delineate additional subbasins in HEC-HMS
2. Update HMS element names and descriptions
3. Calculate initial HMS parameters
4. Calibrate to InFRM WHA results
5. Update the HMS basin model for TSI current and future conditions
6. Run TSI storm scenarios
7. Model documentation
8. Submit final HMS model for review and use for team members



integrating **Transportation & Stormwater Infrastructure**

Hydrology enhancement example: Eagle Mountain Pilot



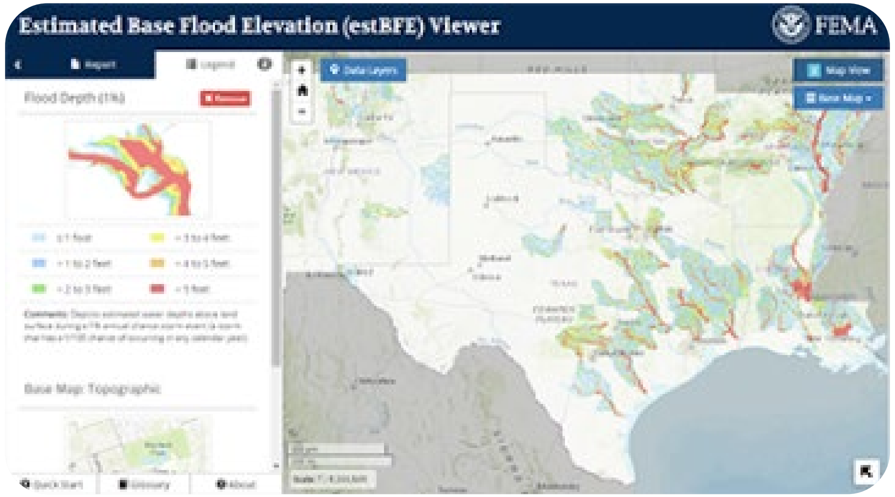


- Final hydrology delineation for TSI Eagle Mountain Pilot Area

integrating **Transportation & Stormwater Infrastructure**

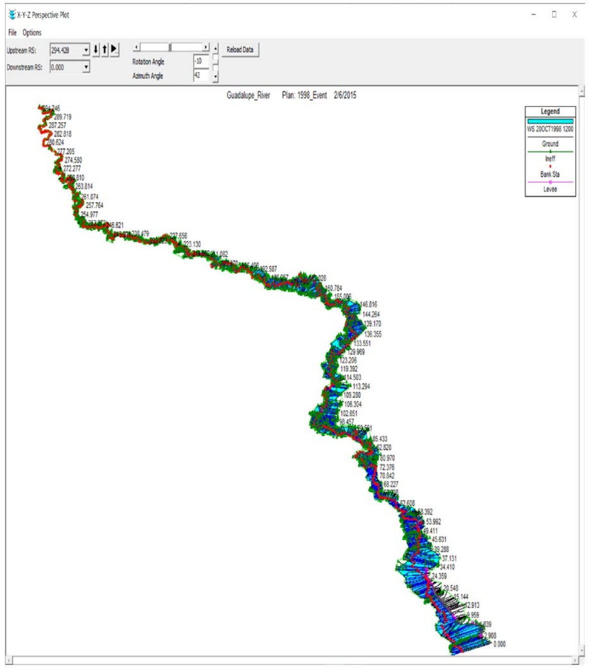
Hydraulics Data Source:
Base Level Engineering (BLE)

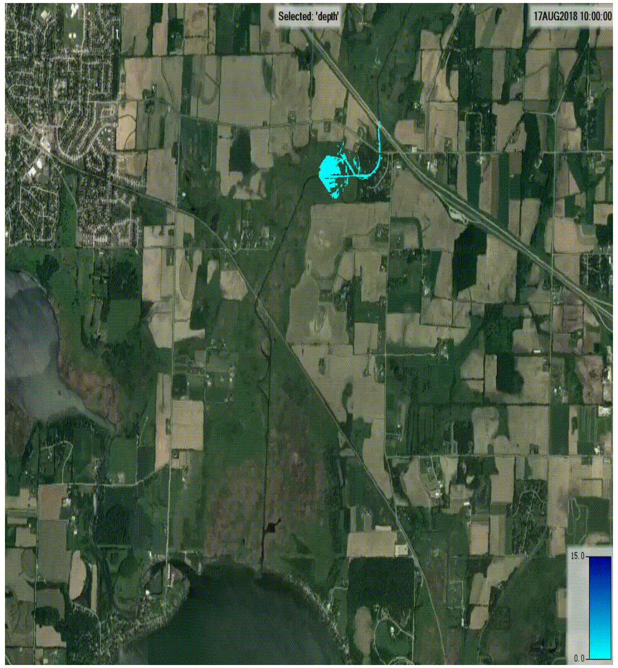
What?
Watershed-wide engineering modeling method that leverages high resolution ground elevation, automated model building techniques, and manual model review to prepare broad and accurate flood risk information.



Why?
Centralized and available flood hazard analysis to support floodplain management activities and development review, while increasing risk awareness for individuals.

Outcome:
- Quickly determine the flood risk for various events throughout multiple watersheds at various recurrence intervals (i.e., 10yr, 100yr, 500yr).
- Allows Federal, State, and local governments, as well as individuals, to access and use flood risk information.

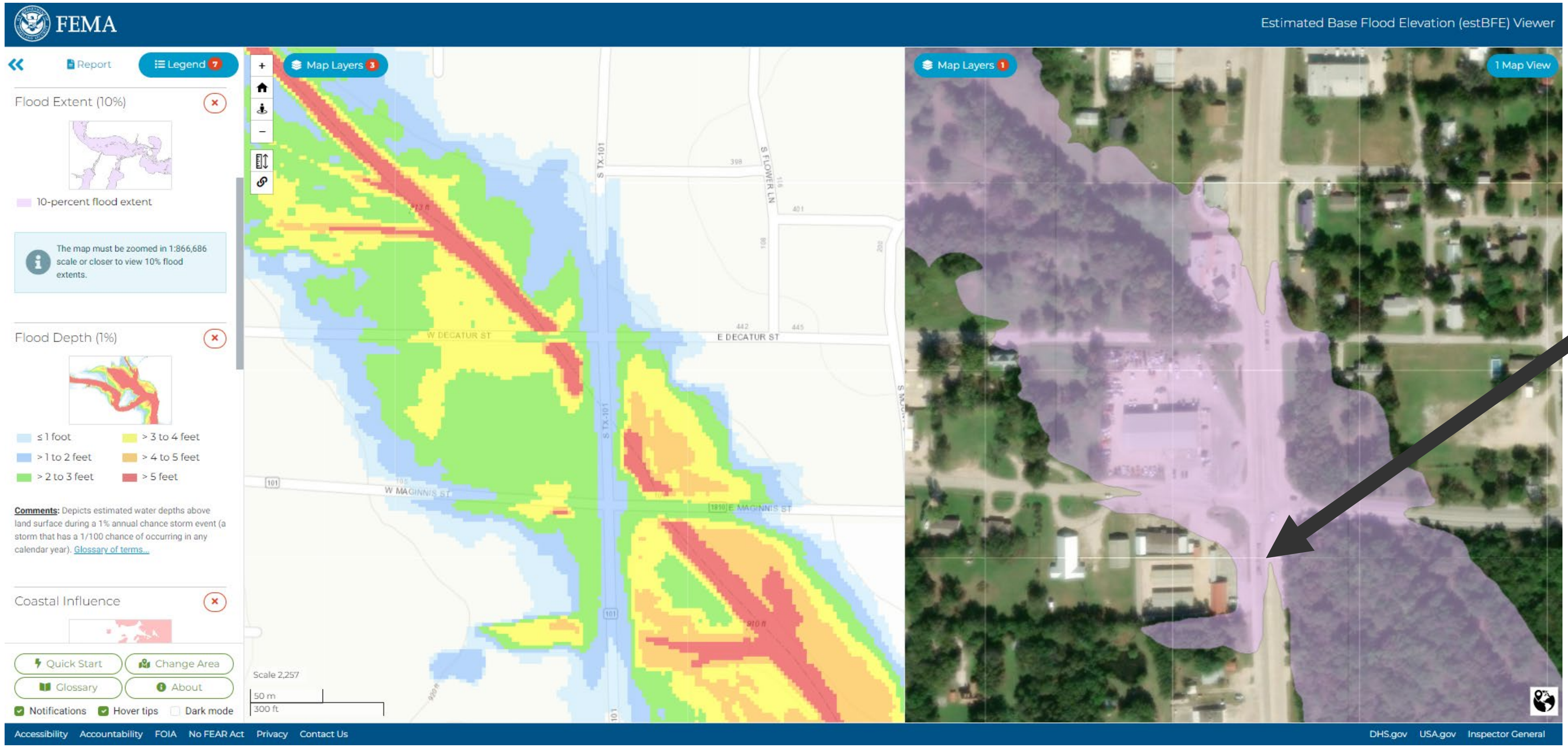


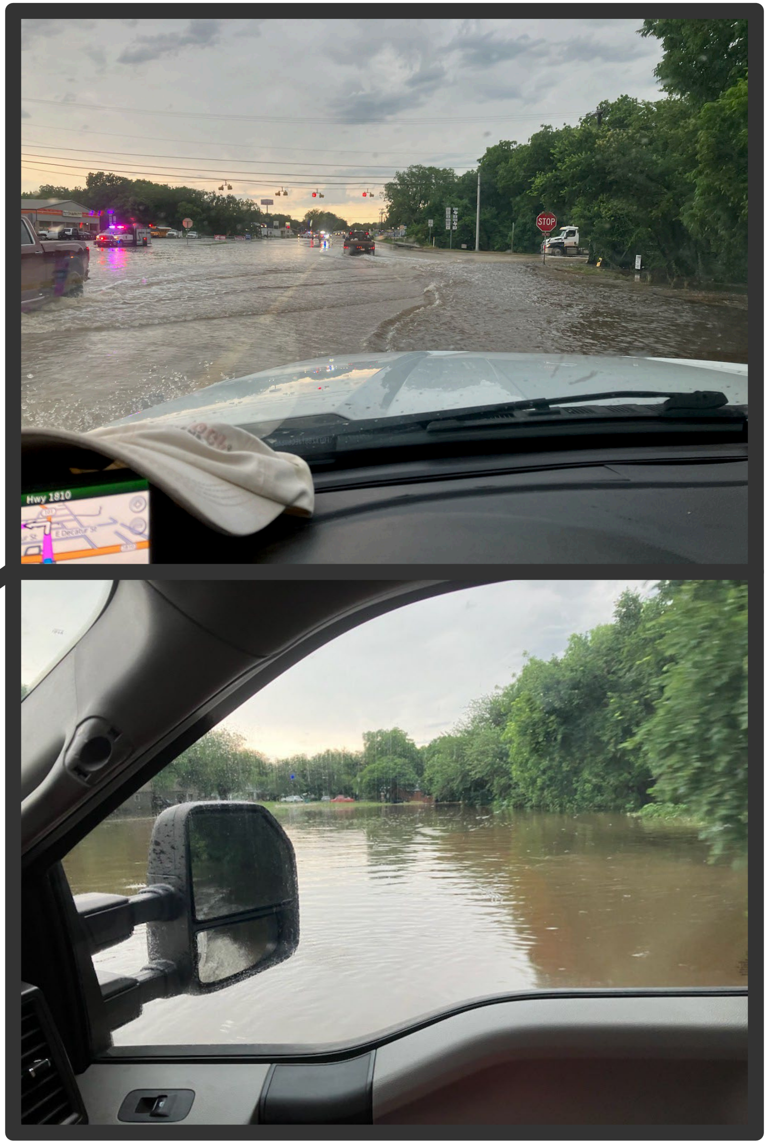


https://webapps.usgs.gov/infrm/estBFE/

integrating Transportation
& Stormwater Infrastructure

Hydraulics Example: TSI-Area Flooding with BLE (Chico, Texas)





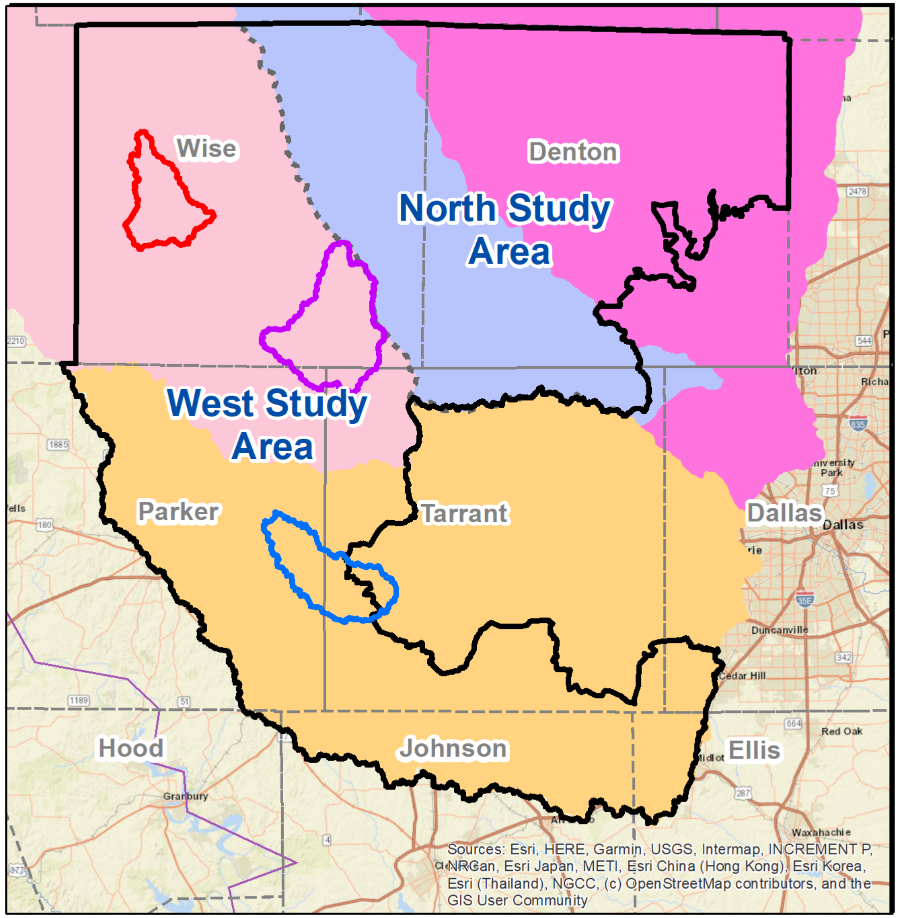
Dry Creek: May 28, 2024

Hydraulics Approach

- Developed SOP and enhancing hydraulic models to inform flooding considerations:
  - Defining approach for enhancing Base Level Engineering (BLE) & potentially other hydraulic models
    - Exploring 1D vs 2D model considerations
    - Testing approaches, adding detail, urban drainage, determining environmental constraints, establish recurrence intervals, incorporate current/future flows, optimization scripting, etc.

TSI Project
West Study Region
HEC-RAS Model Development
May 2024

Defining TSI HEC-RAS Modeling Process for:
1. 1D Individual Models
2. 1D Combined Models
3. 2D Modeling



TSI Pilot Areas with BLE (as of FEB 2024)

Eagle Mountain Pilot Area
Mary's Creek Pilot Area)
Bridgeport Pilot Area
Denton: BLE AVAILABLE ON VIEWER (1D STUDY)
Elm Fork Trinity: BLE AVAILABLE ON VIEWER (1D STUDY)
Lower West Fork Trinity: BLE COMPLETE & ON VIEWER SOON (2D STUDY)
Upper West Fork Trinity: BLE AVAILABLE ON VIEWER (1D STUDY)

0 5 10 20 Miles
N

BLE Viewer Link: https://webapps.usgs.gov/infrm/estBFE/

integrating **Transportation**
& Stormwater Infrastructure

TSI Optimization Study

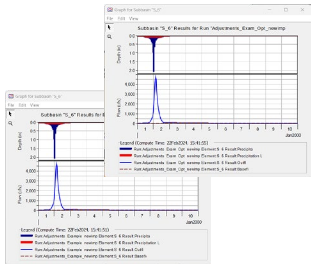
- The optimization study aims to model ideal **location and sizing** for detention ponds and consider potential alternatives (e.g., GSI/NBS) **to reduce downstream flows**.
- Utilizes the enhanced hydrology (HEC-HMS) models as a starting point.
- May incorporate transportation facilities at risk, regulatory tools, green infrastructure applications, scenario options, vulnerable areas, infrastructure integration options, and flood-prone and ideal GSI/NBS implementation areas where possible.
- Relies on the results of GSI and NBS suitability index based on geological, social, and environmental parameters and ranking of project types and locations.

TSI Optimization – Pilot Study Workflow

Obtain HEC-HMS models (“current conditions” and “future conditions”) for all pilot study areas.

→

Compare results from the “current conditions” and “future conditions” HEC-HMS models to identify subbasins with significant changes in peak flow and/or volume.

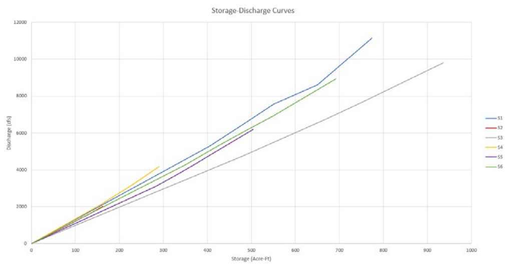


→

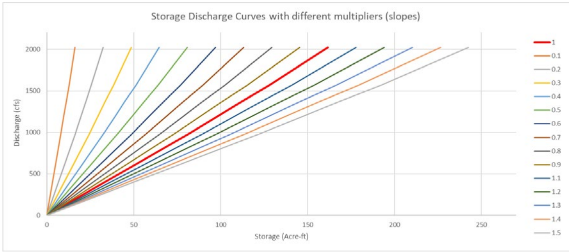
Modify the “future conditions” basin model by creating *Reservoir* elements downstream of each subbasin with associated Storage-Discharge Curves.

→

Develop a library of Storage-Discharge Curves (1) for detention ponds by generating per-subbasin ideal curves based on frequency storm results and (2) for GSI/NBS (from AgriLife).



→



Develop a python script to automate HEC-HMS and optimize, minimizing the change in peak discharge and/or volume by applying multipliers to the Storage-Discharge Curves.

→

Run the optimization script to minimize the impact of future conditions while considering constraints.

StDr1	StDr2	StDr3	StDr4	StDr5	StDr6	Sink	Total Storag
0.28	0.6	0.76	0.37	0.17	0	18001.76	979
0.74	0.32	0.39	0.23	0.38	0.17	18075.43	1117
0.82	0.64	0.47	0.44	0	0.17	17551.27	1165
0.24	1.1	0.81	0	0.17	0.51	18115.29	1257
0.8	0.48	0.49	0.17	0	0.5	17810.96	1262
0.92	1.25	0.41	1.03	0	0	17255.07	1305
1.04	1.33	0	0.26	0.31	0.52	17952.71	1320
1.1	0.45	0.54	0	0.26	0.13	17199.07	1349
0.53	1.46	0.65	0.54	0	0.4	17798.95	1362
1.28	1.18	0	0.13	0	0.75	17850.71	1421
0.59	0.94	0.96	0.24	0.34	0	17353.79	1423

Approach to Flood Risk Reduction
Flood susceptibility mapping

- Indicator method: Develop a flood susceptibility map using a GIS stacking model that includes four categories of conditioning factors: **Environmental, Socio-economical, Infrastructural, and Institutional**

Environmental

Topographical
- Elevation
- Slope
- LS factor
- Aspect
- Curvature
- TWI
- TRI

Meteorological
- Rainfall intensity
- Rainfall duration
- Rainfall frequency

Geological
- Geology (lithology)
- Soil hydrologic group

Hydromorphological
- SPI
- STI
- Stream order
- Distance from river
- Stream density
- Flow accumulation
- Flow direction
- Time of concentration
- Curve number

Land use/cover
- NDVI
- NDWI
- Imperviousness or NDBI

Socio-economical

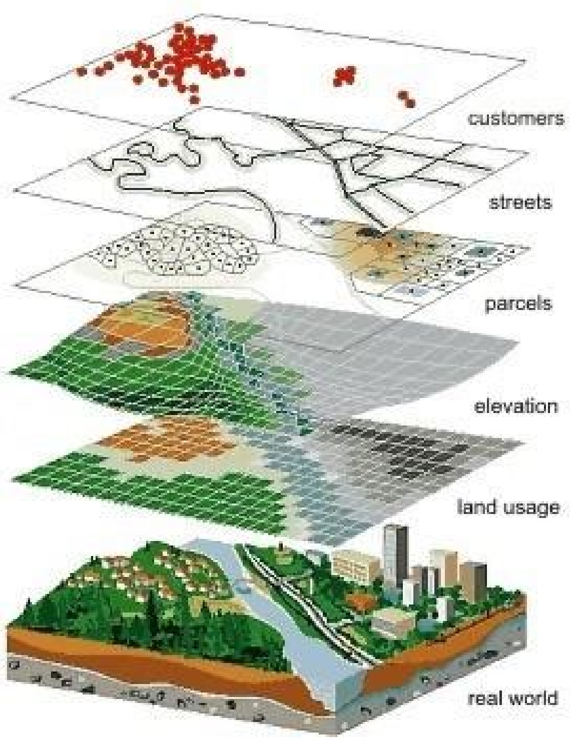
- Social vulnerability index
- Population density

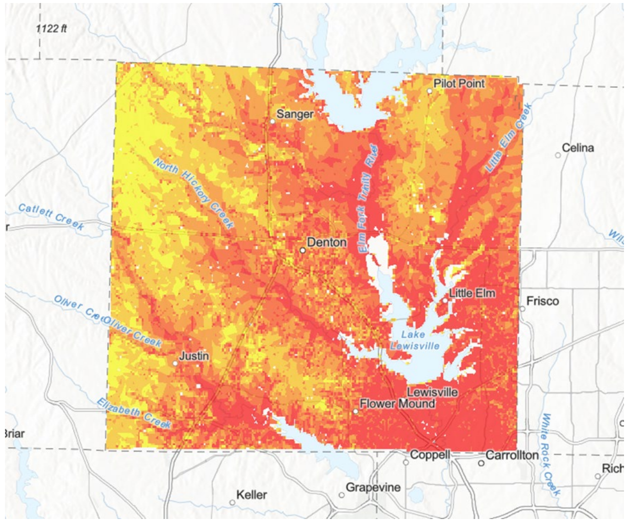
Infrastructural

- Distance from transportation network
- Distance from NRCS BMPs (ex. water harvesting catchment, pumping plant, roof runoff structure)

Institutional

- Distance from USGS streamflow monitoring gauges



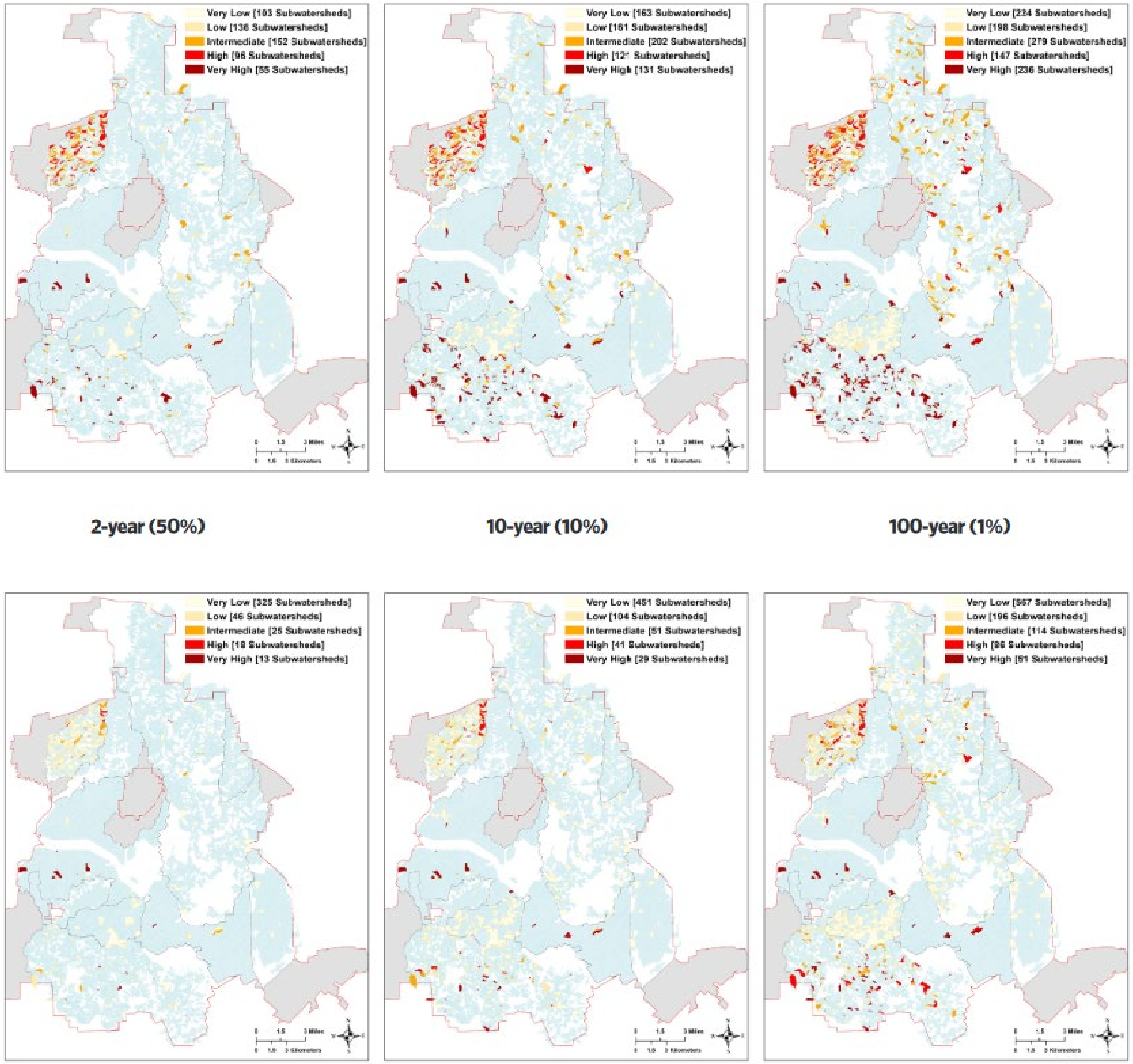


integrating **Transportation**
& Stormwater Infrastructure

Note: Factors are summarized based on a literature review from 30 peer-reviewed journal articles over the past three years. All these factors could be considered in TSI study according to the data availability.

Modeling GSI for Flood Control

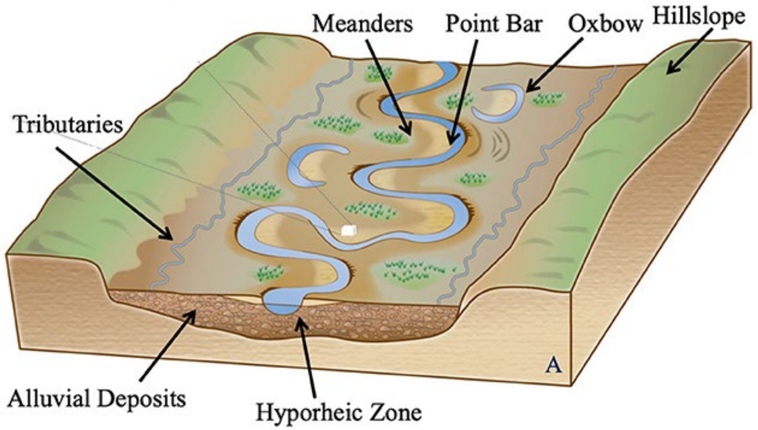
Before GSI



Dallas city study as an example

After GSI

- ❑ In high-risk flooded area, investigate hydrological response of incorporating GSI by running some watershed model (SWMM and/or SWAT)
- ❑ Watershed model will be linked to H&H Model
- ❑ Coupled model will be used for environmental constraints (e.g. minimum flows)



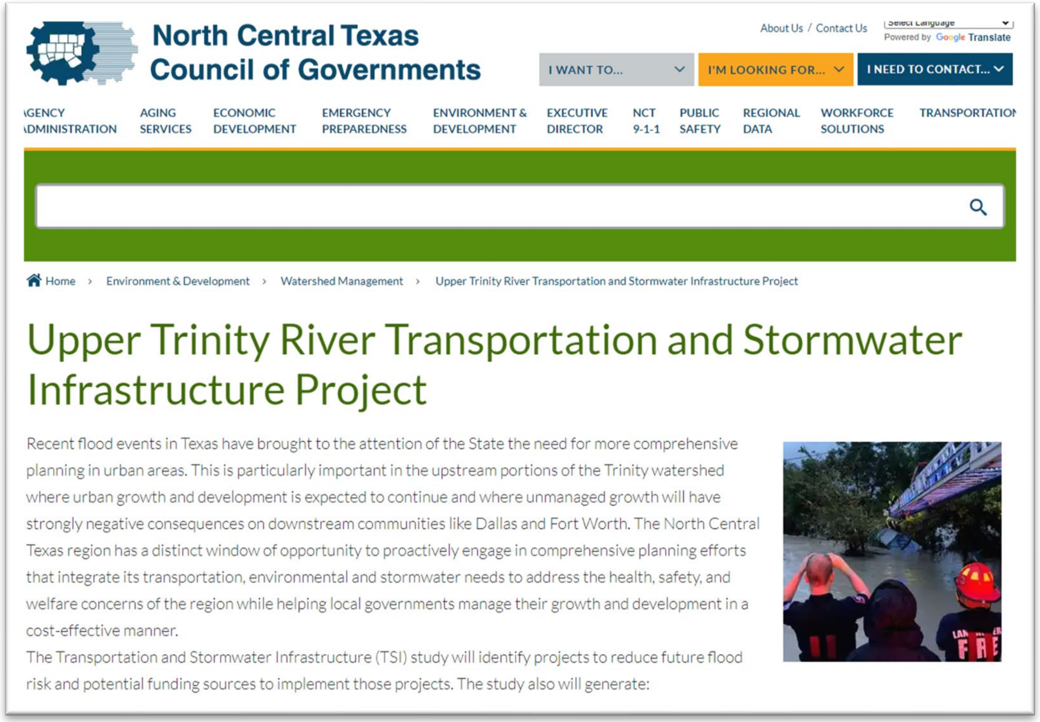
integrating Transportation & Stormwater Infrastructure

https://www.nature.org/dallasgsi

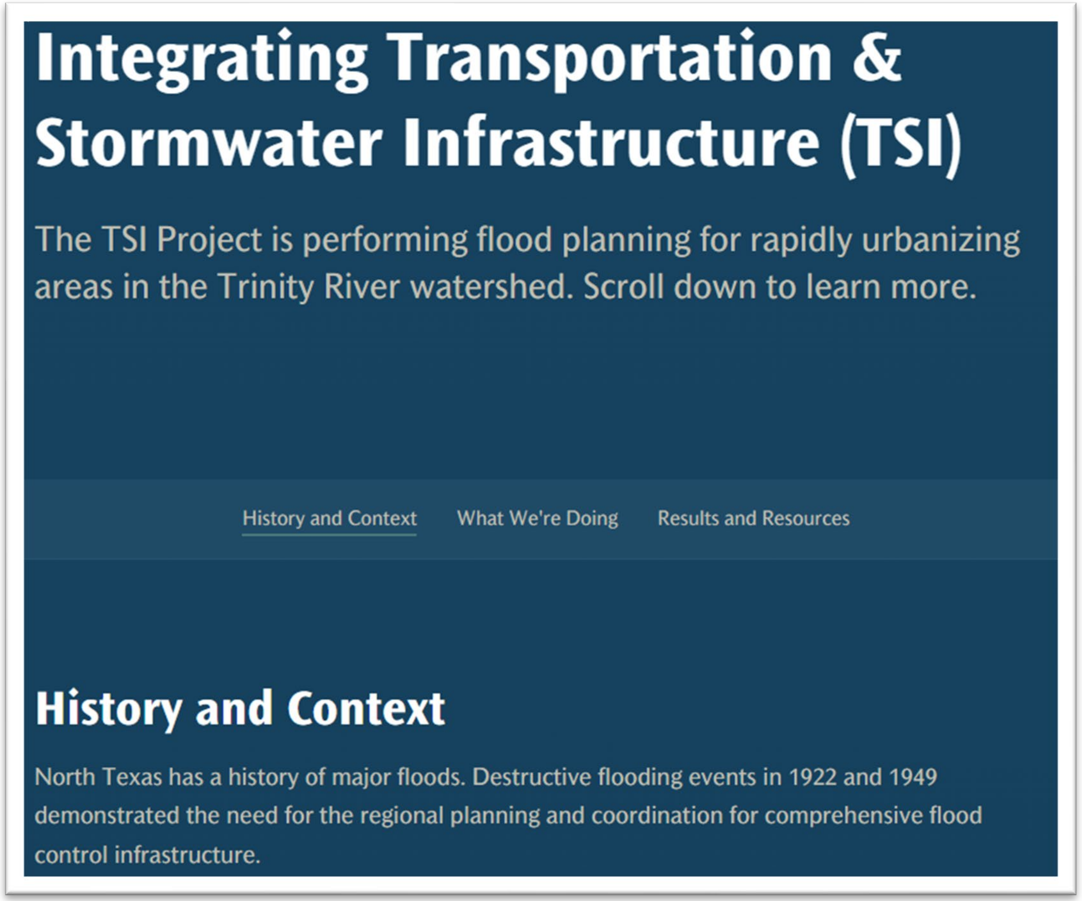
TSI Website and Story Map

Summary:

- The team developed a website and story map to assist in communicating and visualizing study results



https://nctcog.org/tsi



https://geospatial.nctcog.org/portal/apps/storymaps/stories/6b73437fc69643cb9b6f239831706191

integrating **Transportation & Stormwater Infrastructure**

Today's Presenter

Matthew Lepinski, P.E.

Lead Hydraulic Engineer
US Army Corps of Engineers
817.886.1683
Matthew.T.Lepinski@usace.army.mil

Funding Partners

- Texas Water Development Board
- Federal Highway Administration
- Texas Department of Transportation
- Federal Emergency Management Agency
- U.S. Army Corps of Engineers

Study Partners

- North Central Texas Council of Governments
- U.S. Army Corps of Engineers
- University of Texas at Arlington
- Texas A&M AgriLife
- Tarrant Regional Water District