# Numerical Model of Groundwater Flow in the southern portion of the Trinity Aquifer

## Stakeholder Advisory Forum #1

Thank you for signing in early.

The meeting will begin at 1:00 pm, Central Daylight Time

Please stay muted during the meeting and use the chat box to submit questions

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# Meeting Information

- An audio and video recording of the meeting, presentation, and the report summarizing the meeting will be made available on the project's TWDB website

- http://www.twdb.texas.gov/groundwater/models/gam/trnt_h/trnt_s.asp

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# Agenda

- Groundwater Modeling Program Introduction
- Numerical Model for the southern portion of the Trinity Aquifer
- Question and Answer

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# Groundwater Modeling Program

Dynamic tools for water planning in Texas

### Purpose

To develop tools that can be used to help Groundwater Conservation Districts, Regional Water Planning Groups, and others understand and manage their groundwater resources.

### Periodically Updated

GAMs are updated when new relevant data becomes available

### Freely Available

GAM reports are available online and all models are standardized and well documented

### Public Process

Transparent development process where model development is recorded in steps

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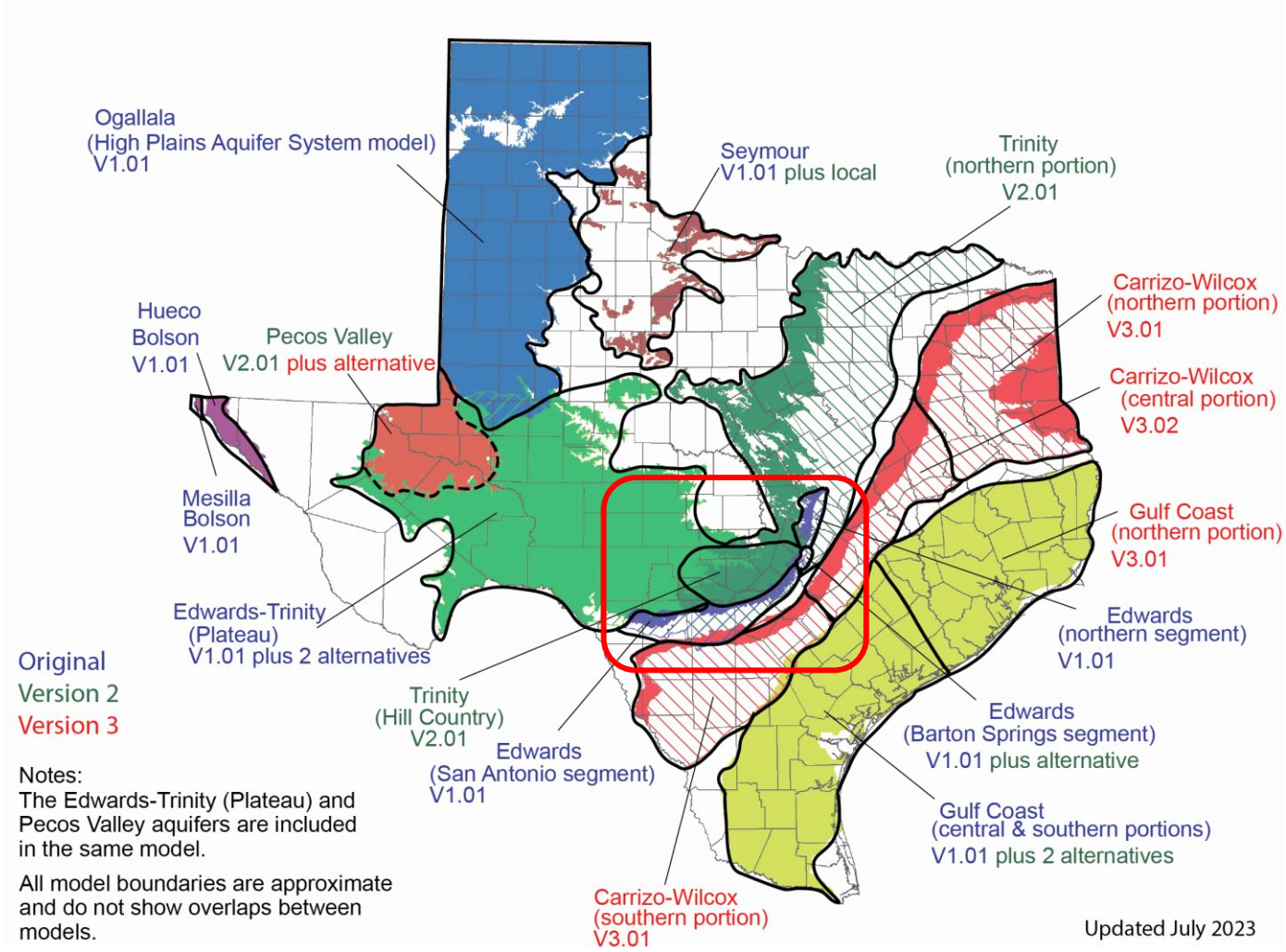
# GAMs for Major Aquifers

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# Why Stakeholder Advisory Forums?

Keep stakeholders updated about progress of the modeling project

Inform how the groundwater model can, should, and should not be used

Provide stakeholders with the opportunity to provide input and data to assist with model development

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# Contact Information

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**512-475-0470**
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**Texas Water Development Board**
**P.O. Box 13231**
**Austin, Texas 78711-3231**

**Web information:**
http://www.twdb.texas.gov/groundwater/models/gam/trnt_h/trnt_s.asp

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# Southern portion of the Trinity Aquifer

## Regional Overview

Lead Modeler : Jevon Harding, P.G.

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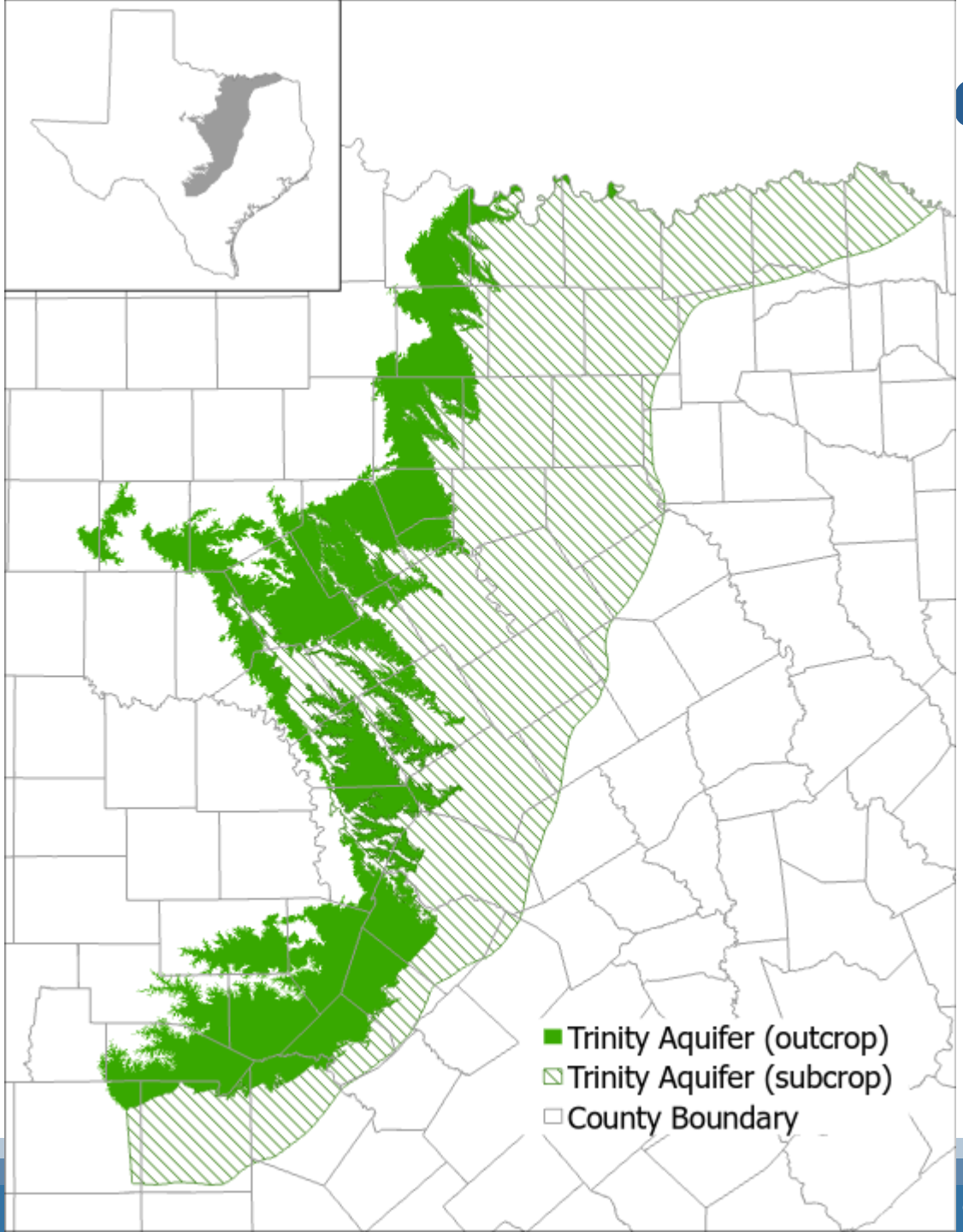
# e on Naming

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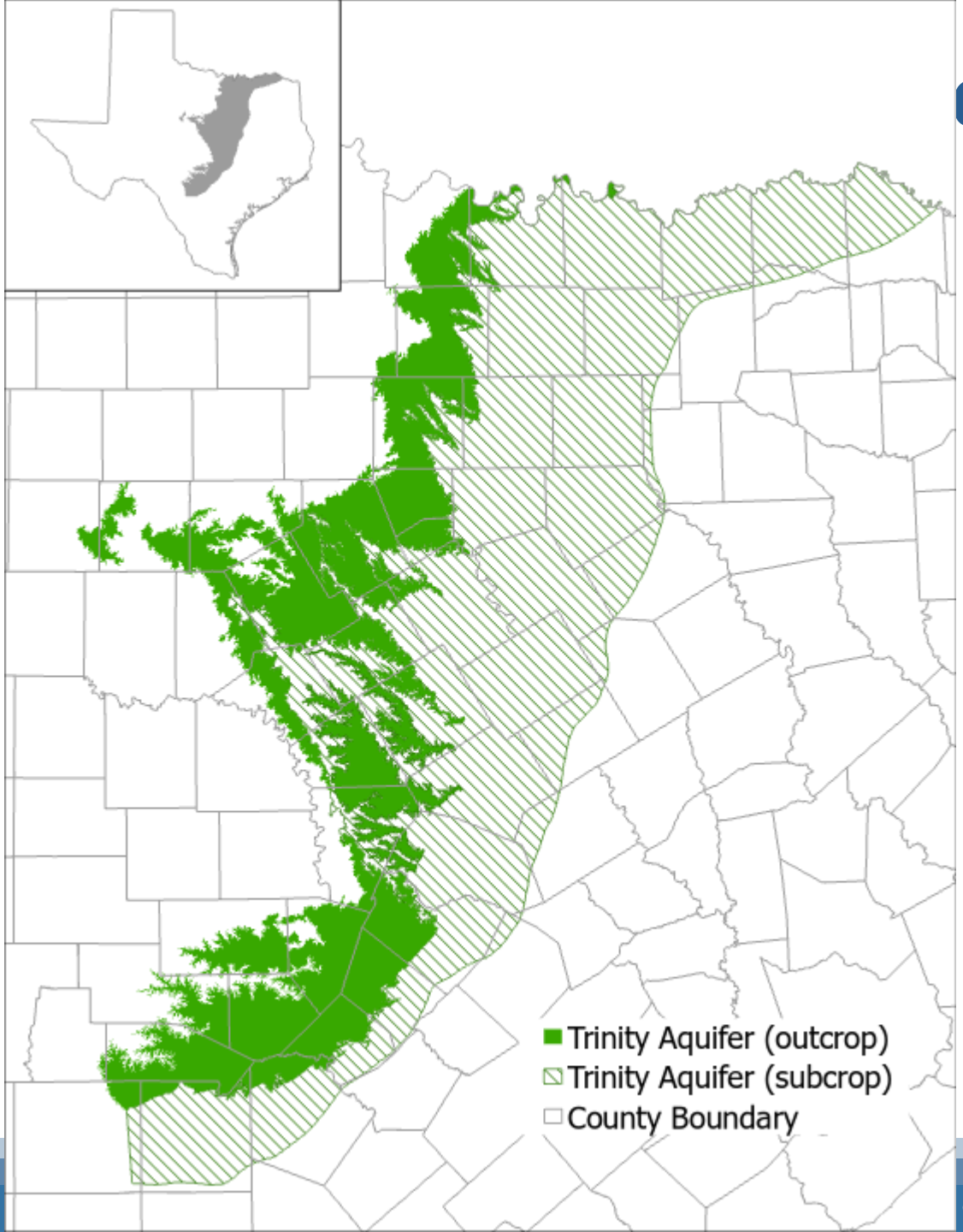
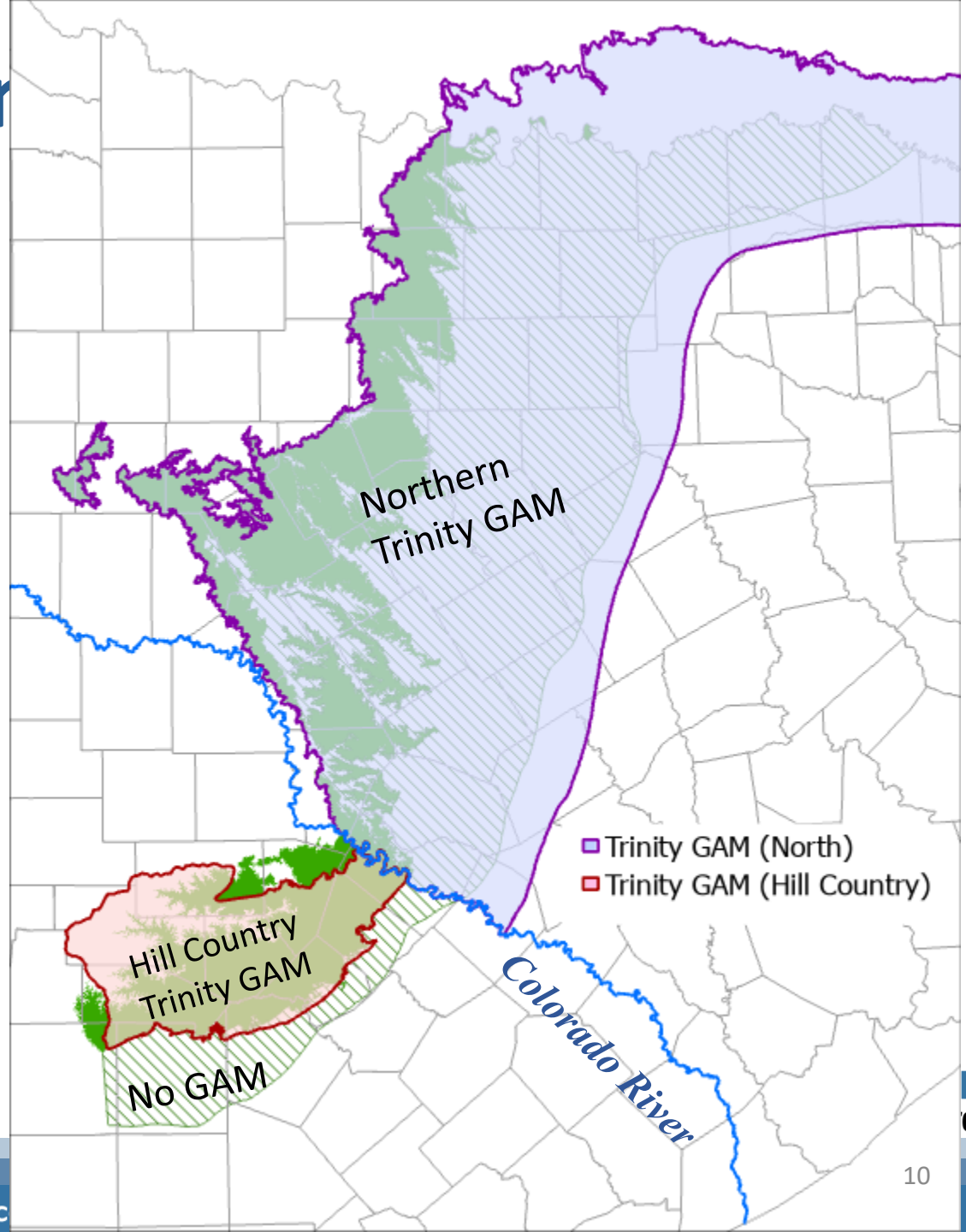
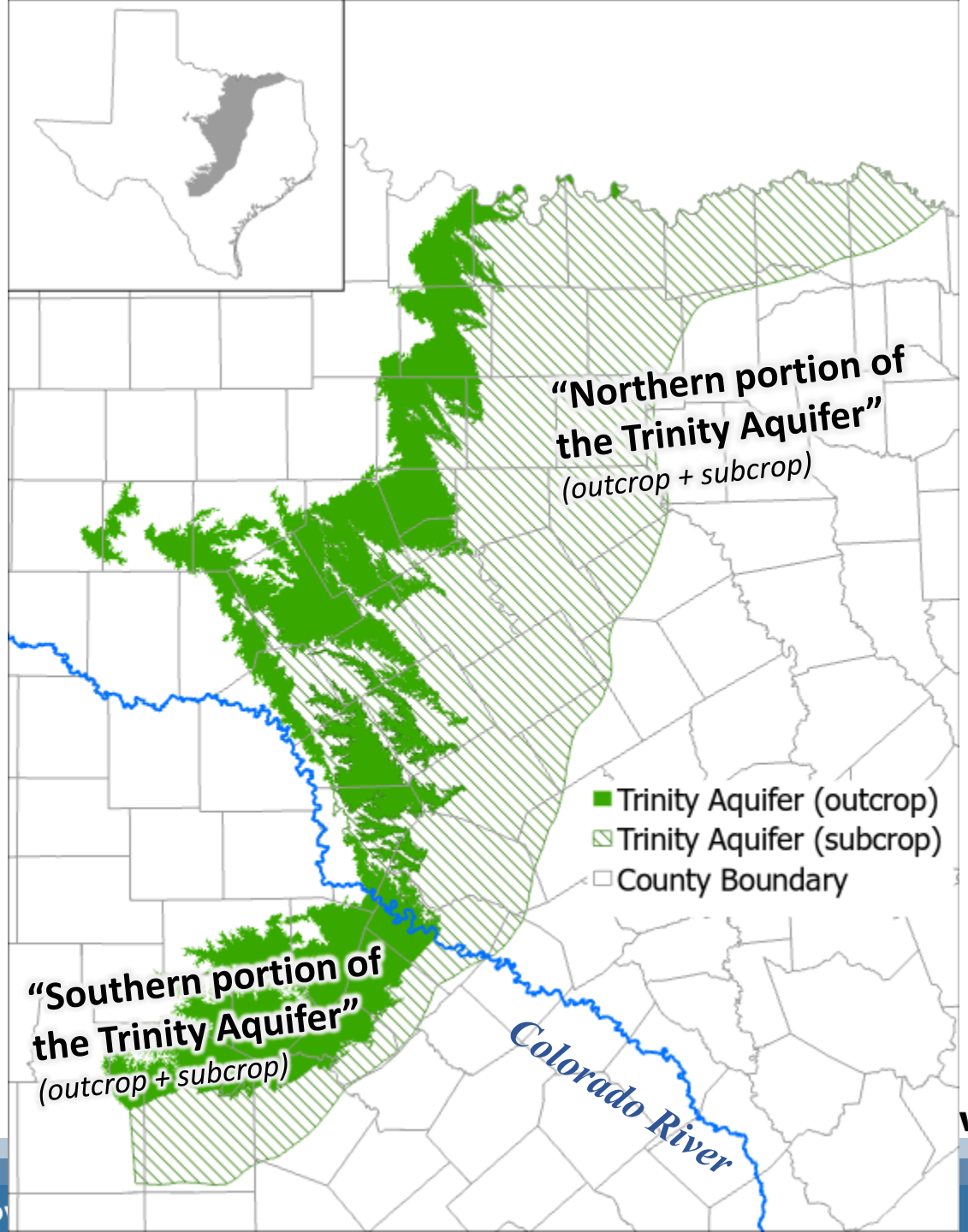
# e or

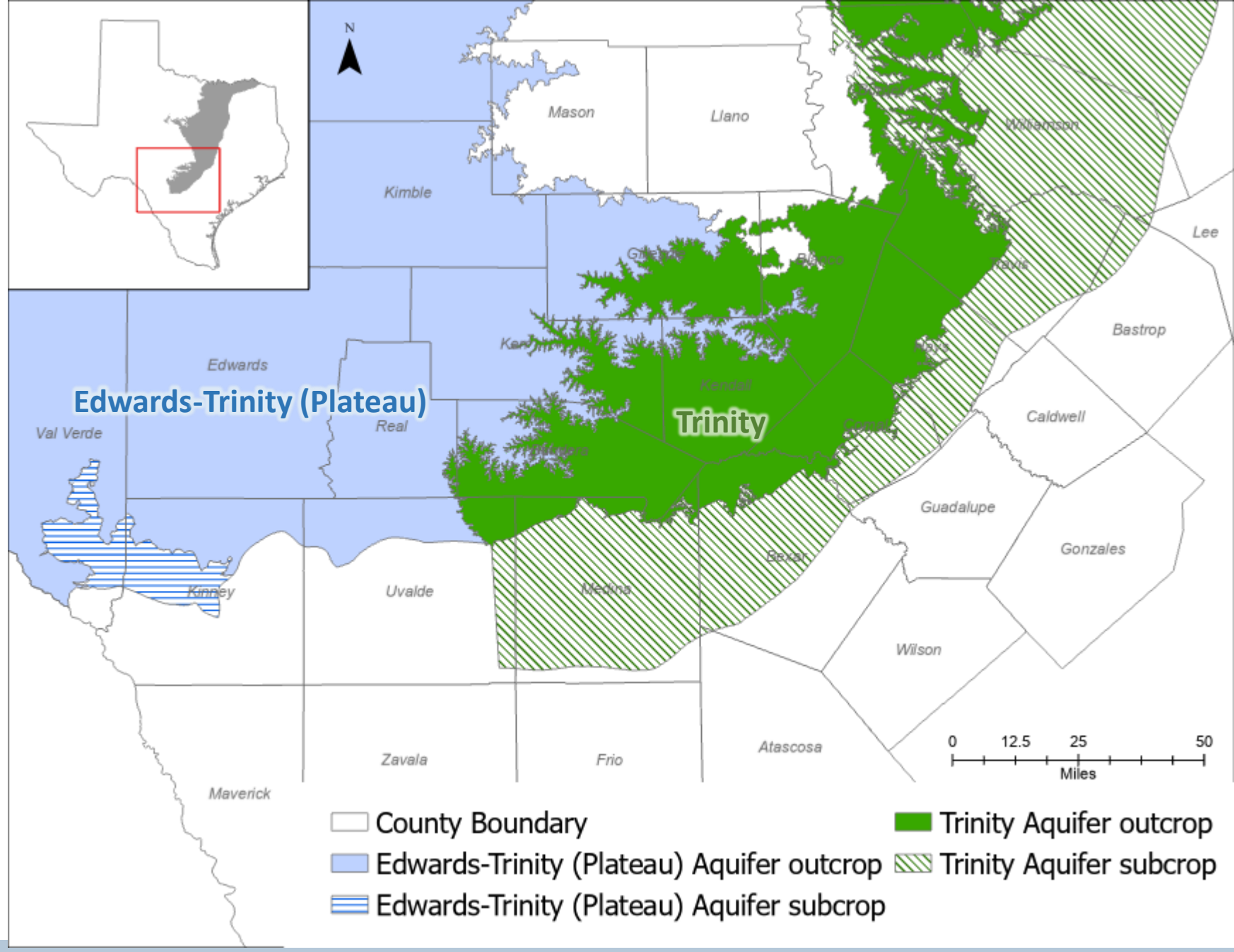

Trinity Aquifer (outcrop)
Trinity Aquifer (subcrop)
County Boundary


Northern
Trinity GAM
Trinity GAM (North)
Trinity GAM (Hill Country)
Hill Country
Trinity GAM
No GAM
Colorado River

# Updated TWDB Naming Convention



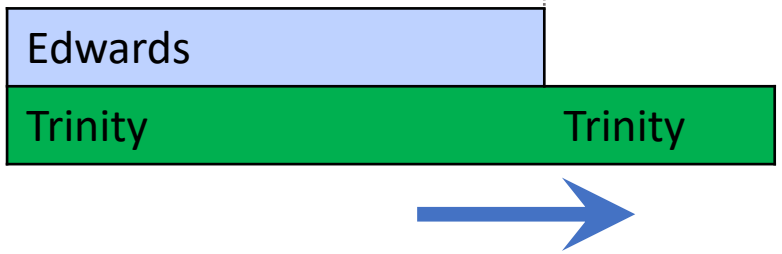
# Inter-Aquifer Flow

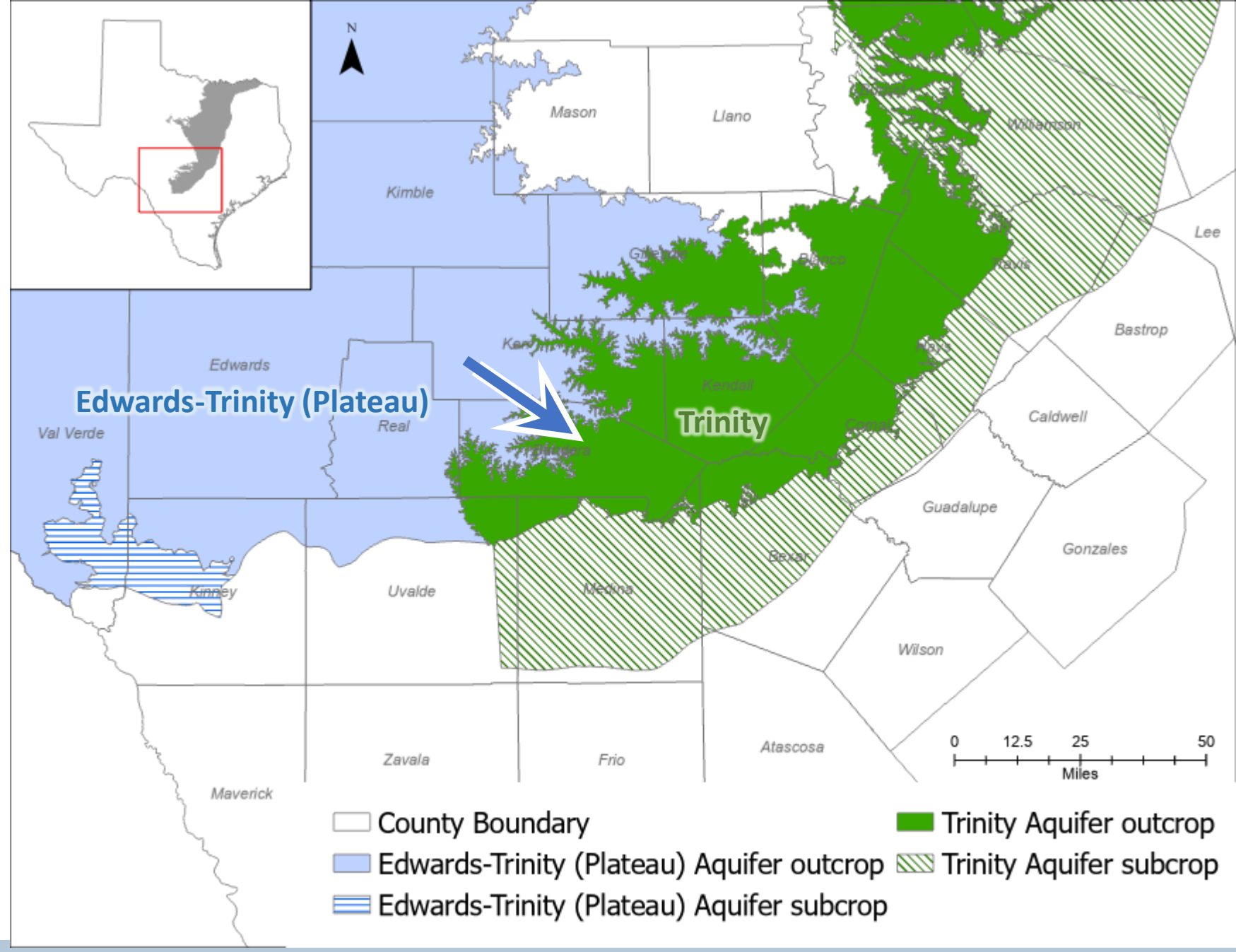


# Inter-Aquifer Flow

*Edwards-Trinity (Plateau)*

*Trinity*

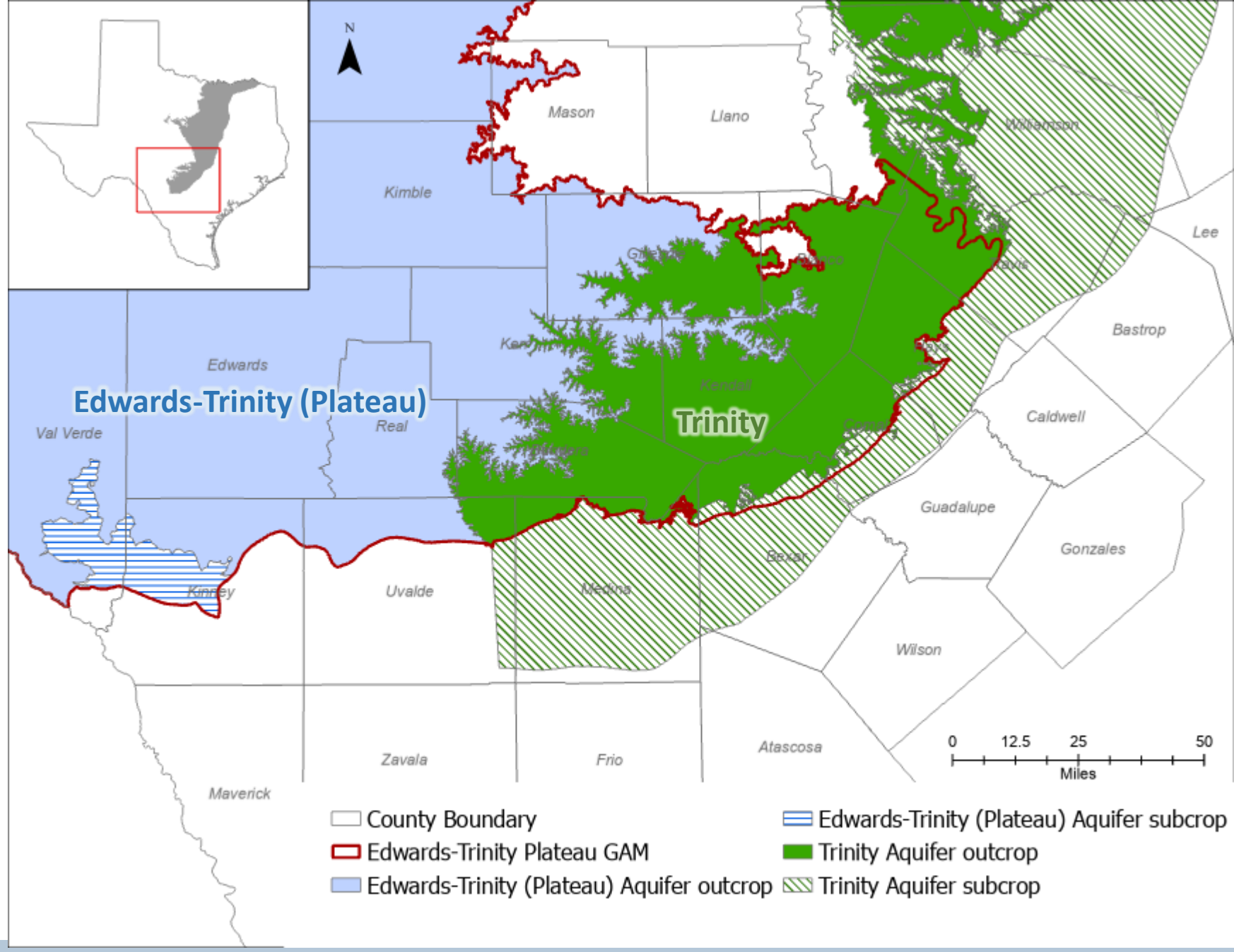


# Existing GAMs

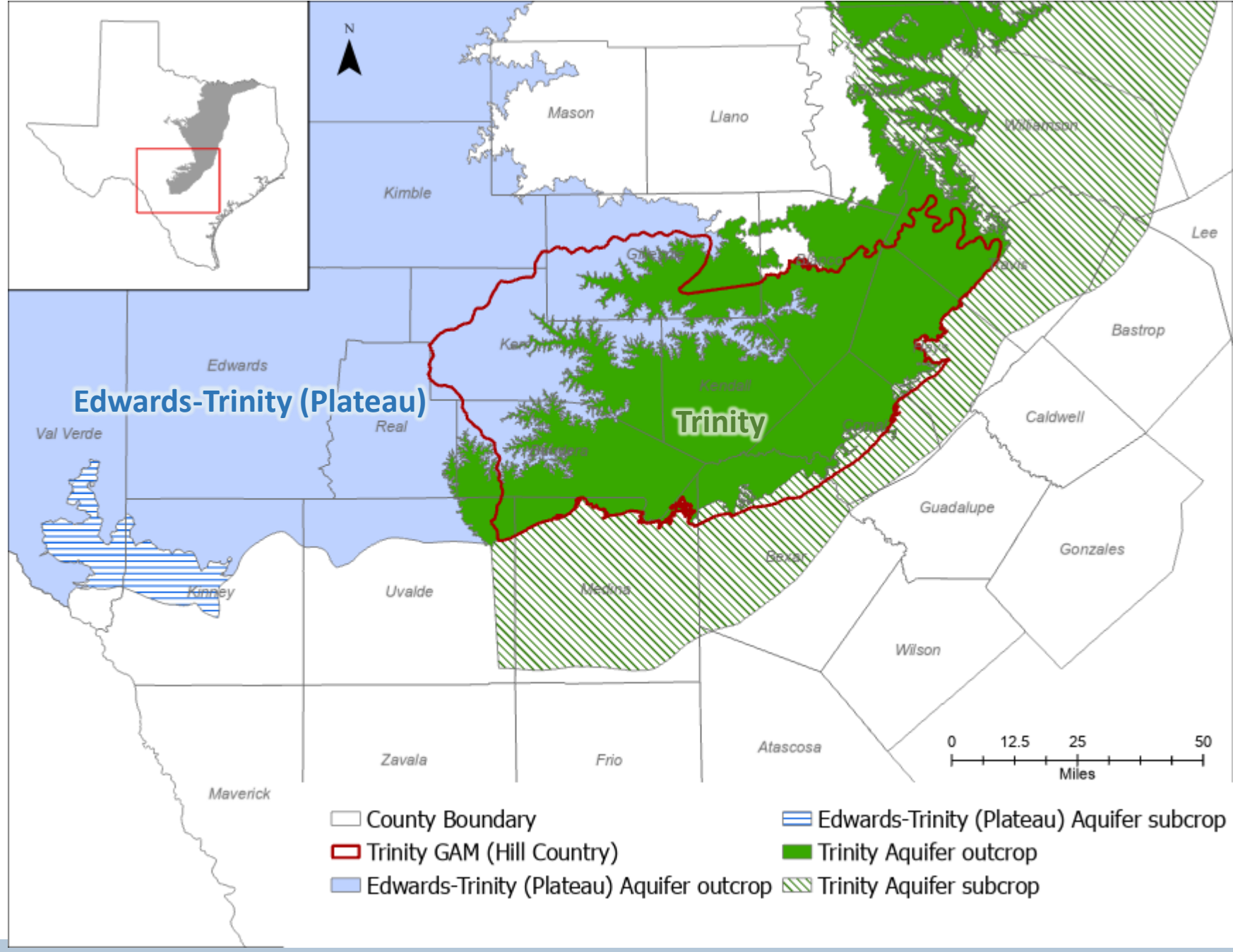
- Edwards-Trinity (Plateau) + Trinity GAM v1.01 [& alternative]
- 2 layers [1 layer]
- Updated in 2009 [2011]
- Calibrated to 2000 [2005]
- [Used in **GMA 7**]

** Note: Kinney County Alternative GAM used in GMA 7 & 10*

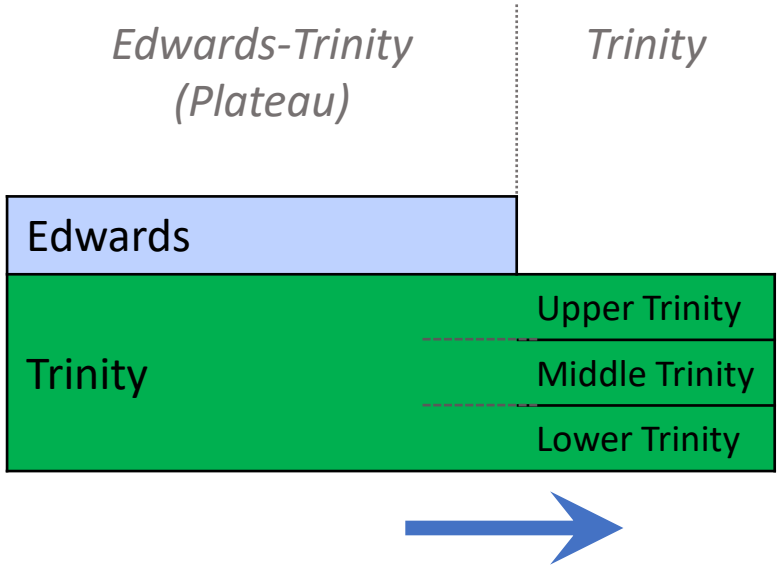


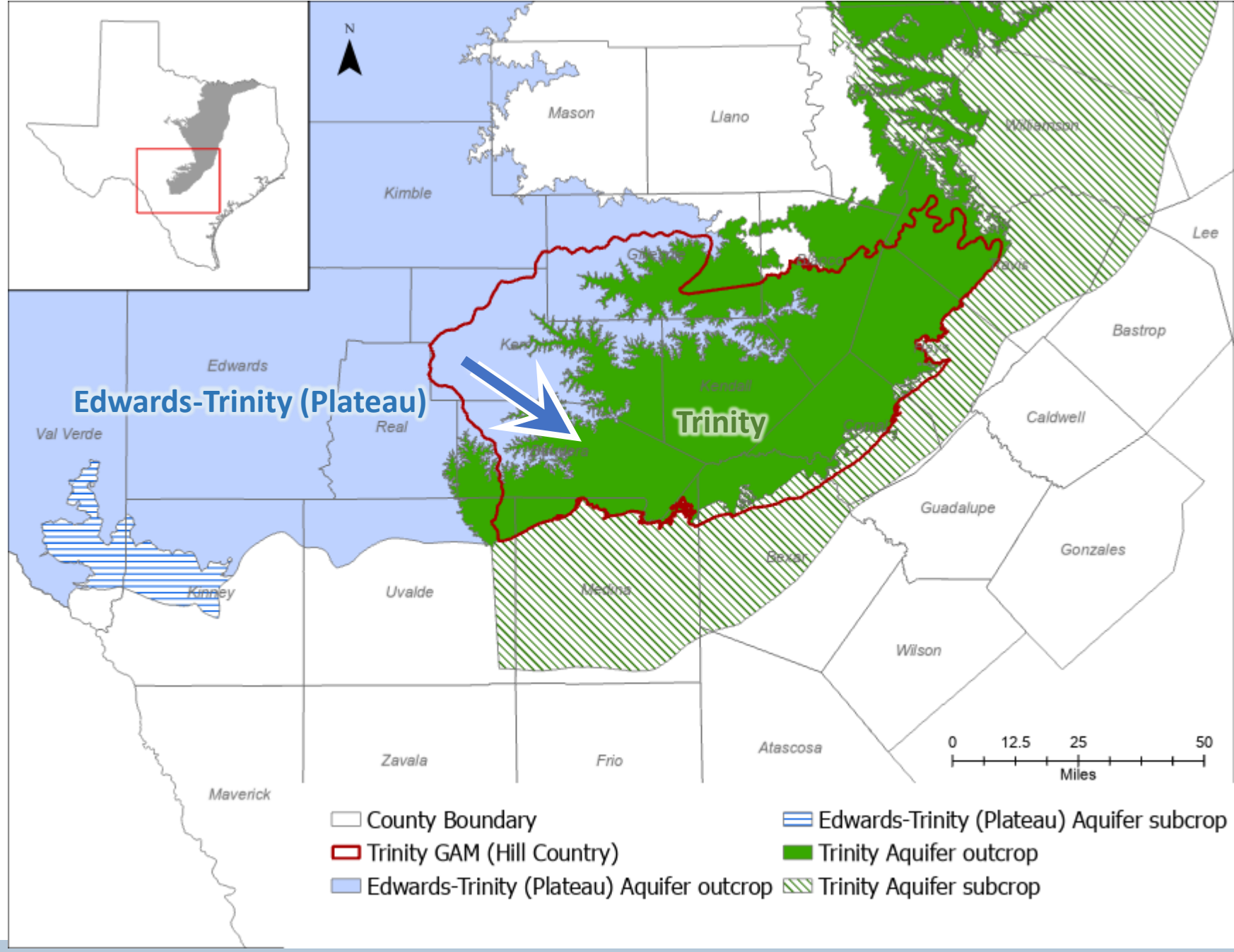
# Existing GAMs

- Trinity (Hill Country) GAM v2.01
- 4 layers
- Updated in 2011
- Calibrated to 1997
- Used in **GMA 9**



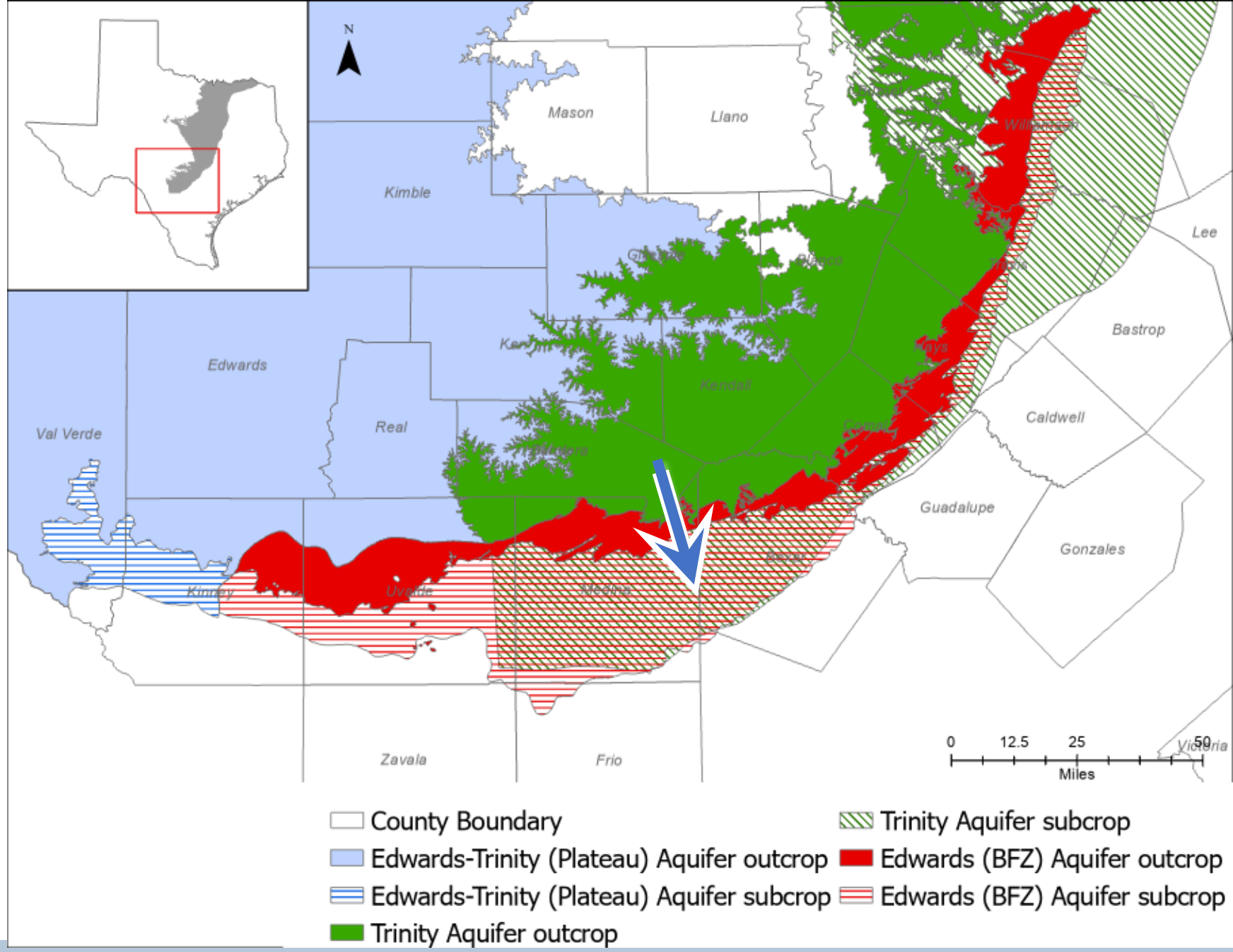
# Inter-Aquifer Flow



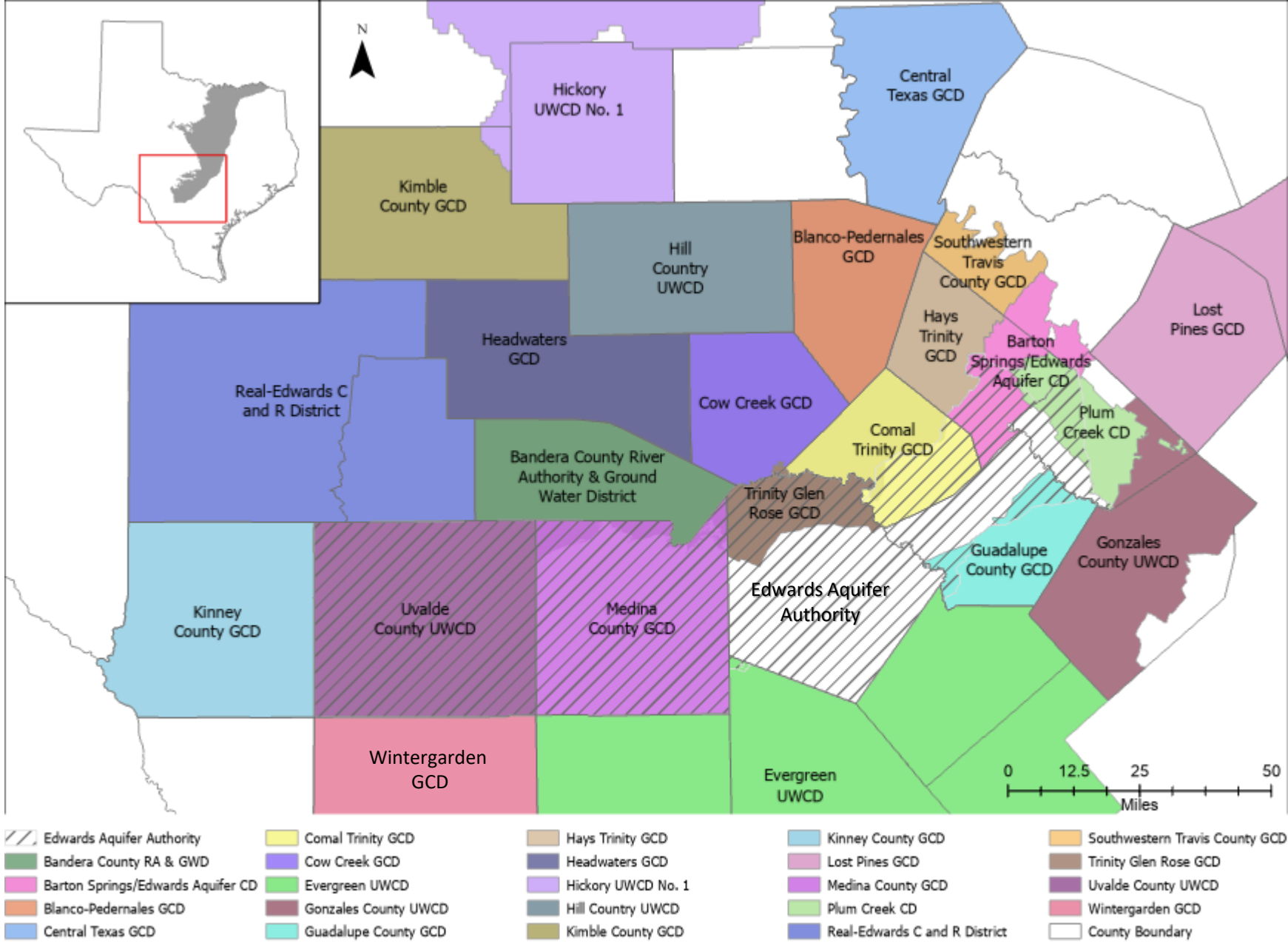



# Inter-Aquifer Flow

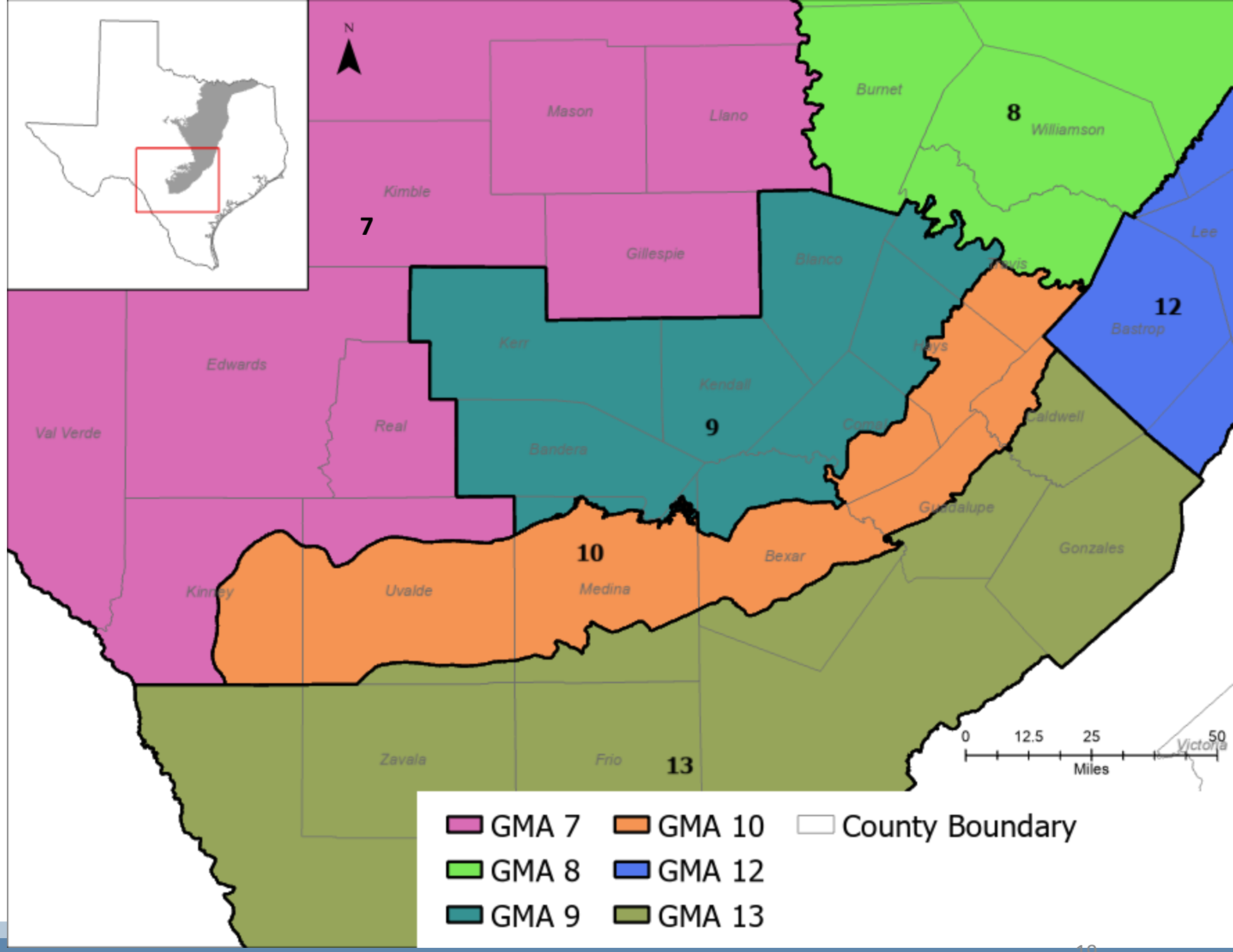
- **The current model is <u>NOT</u> intended to be used for modeling Edwards (BFZ) Aquifer**
- Edwards (BFZ) Aquifer will be treated as a boundary condition to account for inter-aquifer flow



# Groundwater Conservation Districts (GCD)



# Groundwater Management Areas (GMA)



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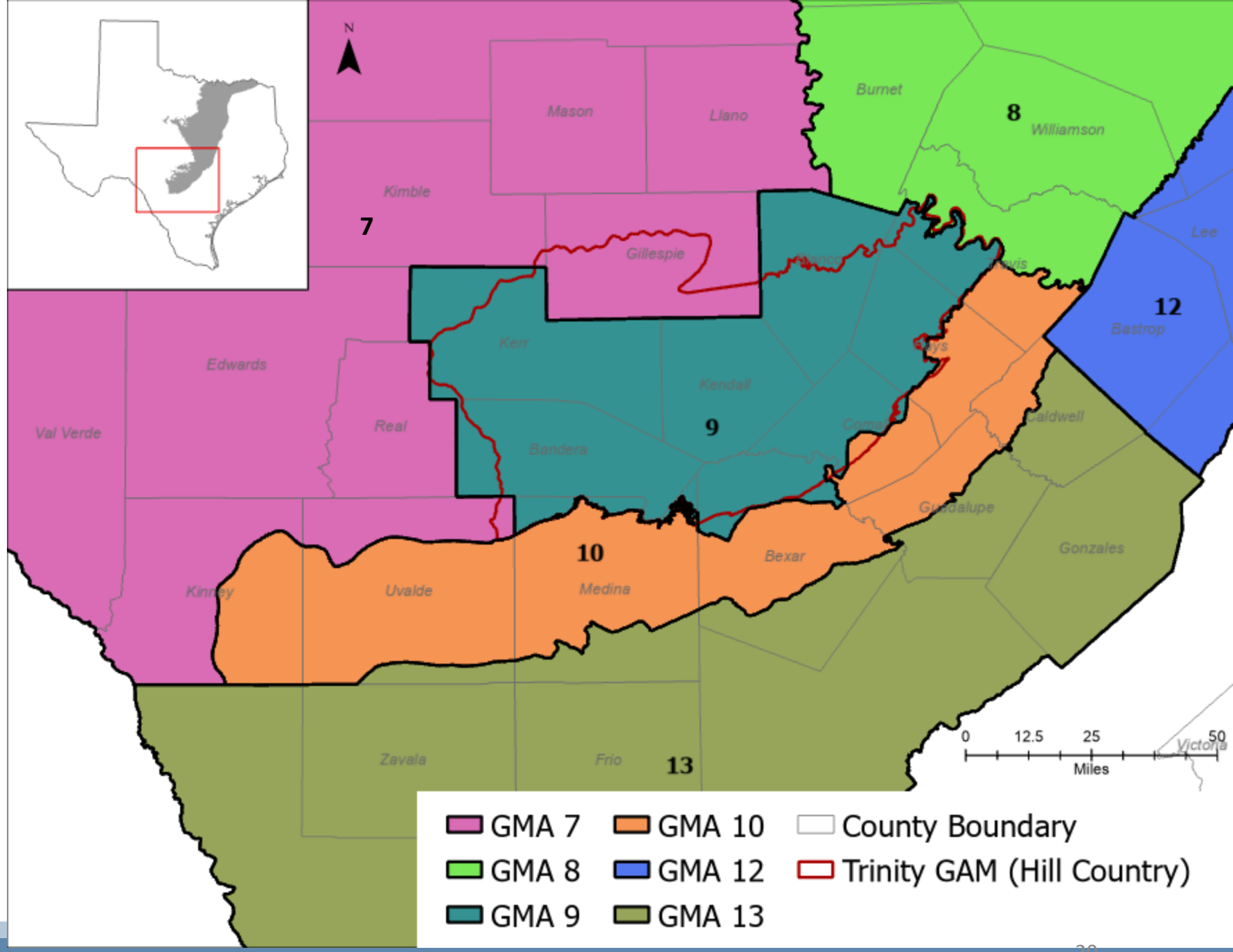

# Groundwater Modeling

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# Why Groundwater Flow Models?

- In contrast to surface water, groundwater flow is difficult to observe
- Aquifers are typically complex in terms of spatial extent and hydrogeological characteristics
- A groundwater model provides the only means for integrating available data for the prediction of groundwater flow at the scale of interest

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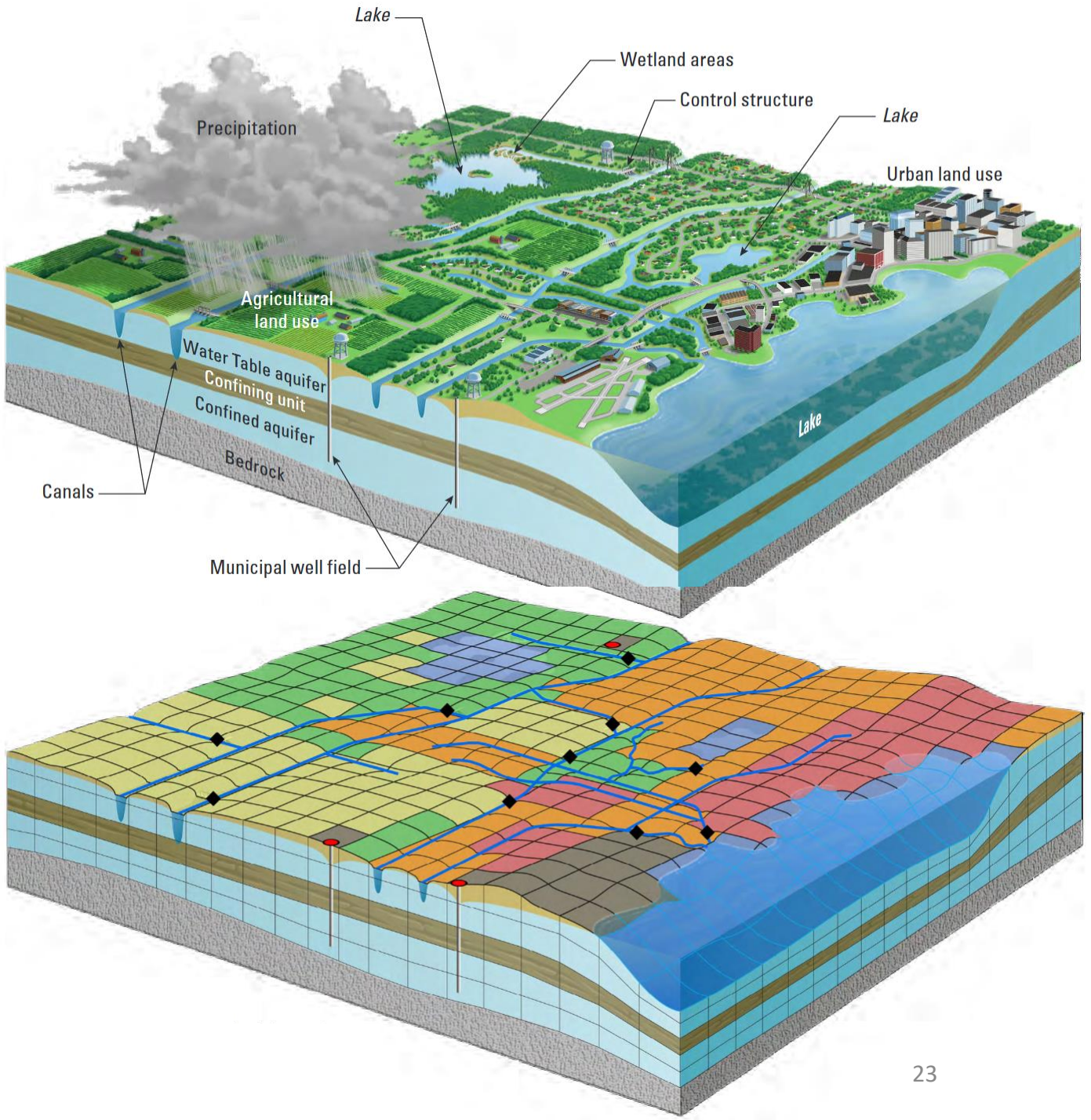
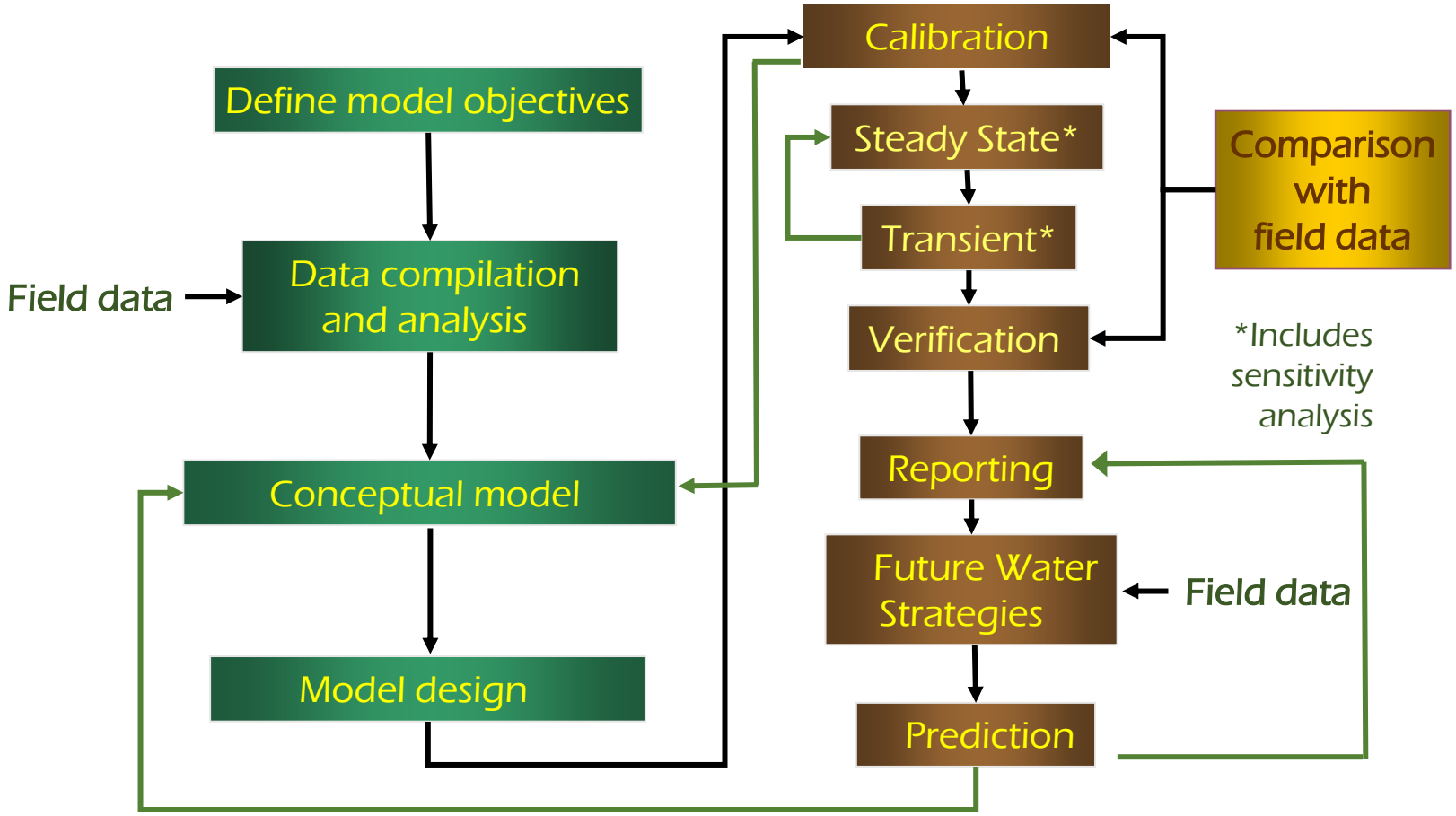
# Groundwater Modeling

- Simplification of complicated interconnected system
- Converts continuous information to discrete cells
- Approximates groundwater flow using equations




*https://pubs.usgs.gov/tm/6a40/pdf/Hughes_TM6-A40.pdf*

# Modeling Process

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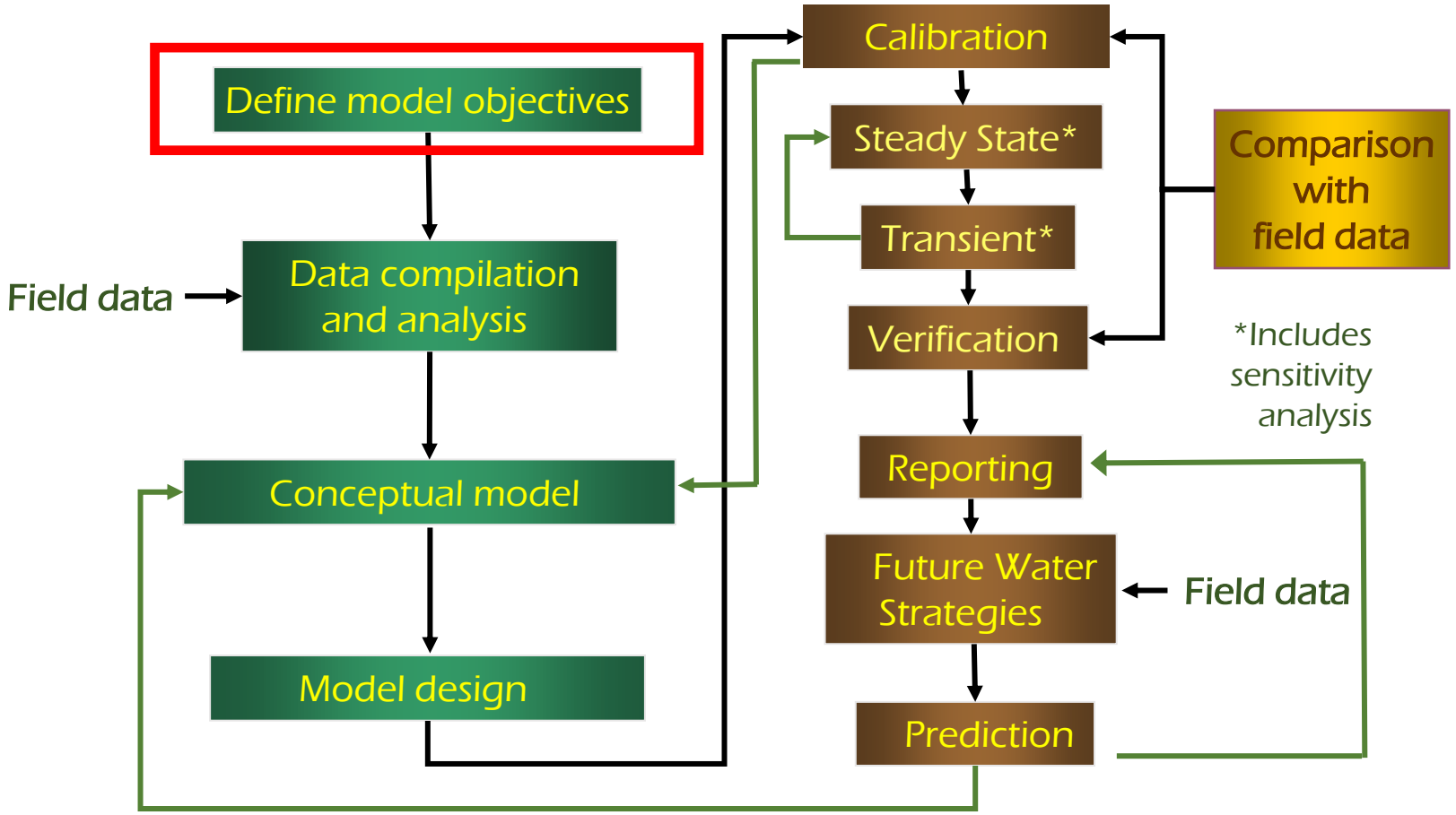
# Modeling Process

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# How we use Groundwater Availability Models

- Uses required by statute *(direct)*
  - Provide groundwater conservation districts with water budget data for their management plans.
  - Calculating Modeled Available Groundwater.
  - Calculating Total Estimated Recoverable Storage
- Uses required by statute *(indirect)*
  - HB 1232 Texas aquifer study
  - HB 30 potential brackish groundwater production area determination
- Other uses
  - Assisting groundwater management areas in assessing desired future conditions scenarios.

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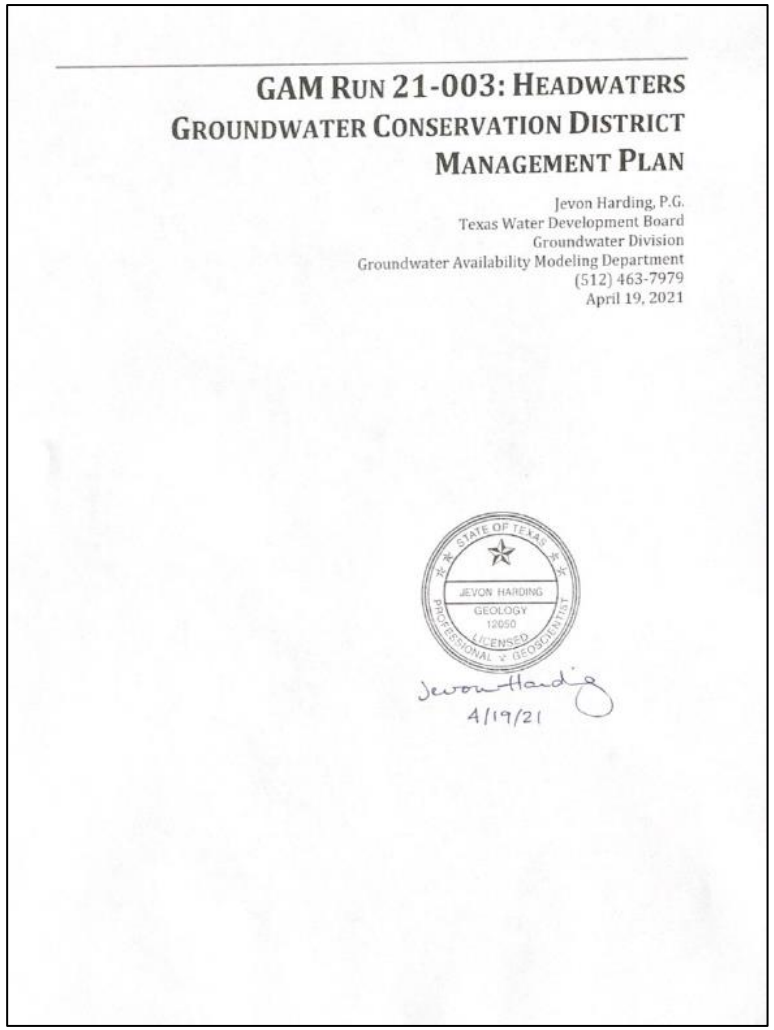
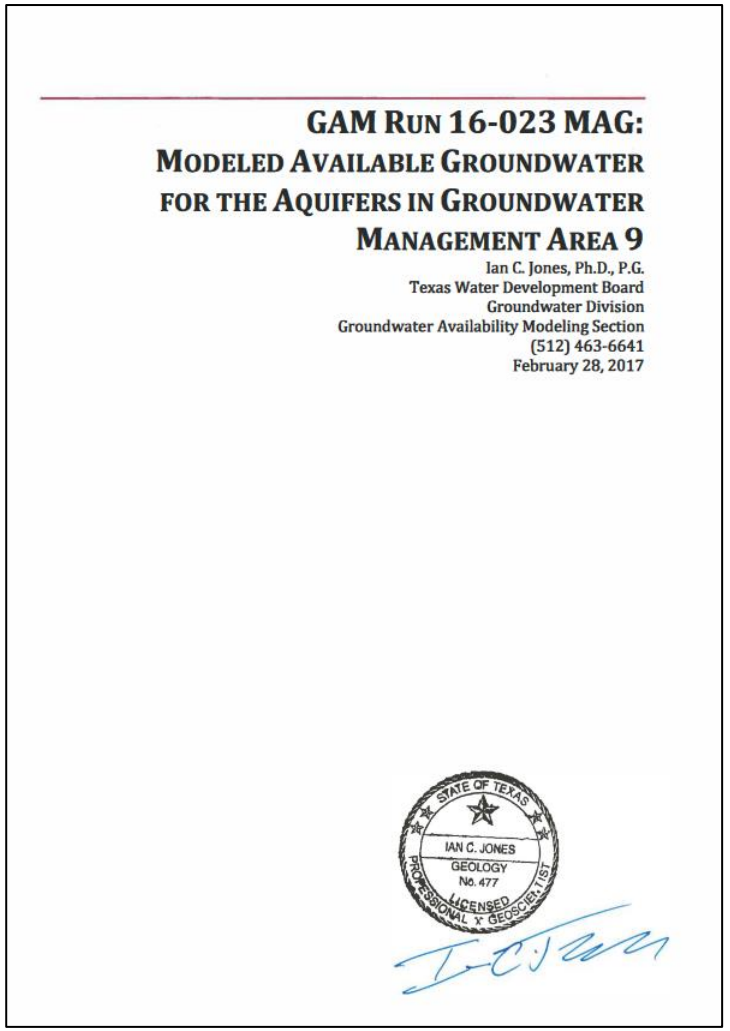
# How we use Groundwater Availability Models



GAM Run 21-003: Headwaters Groundwater Conservation District Management Plan

Jevon Harding, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
(512) 463-7979
April 19, 2021

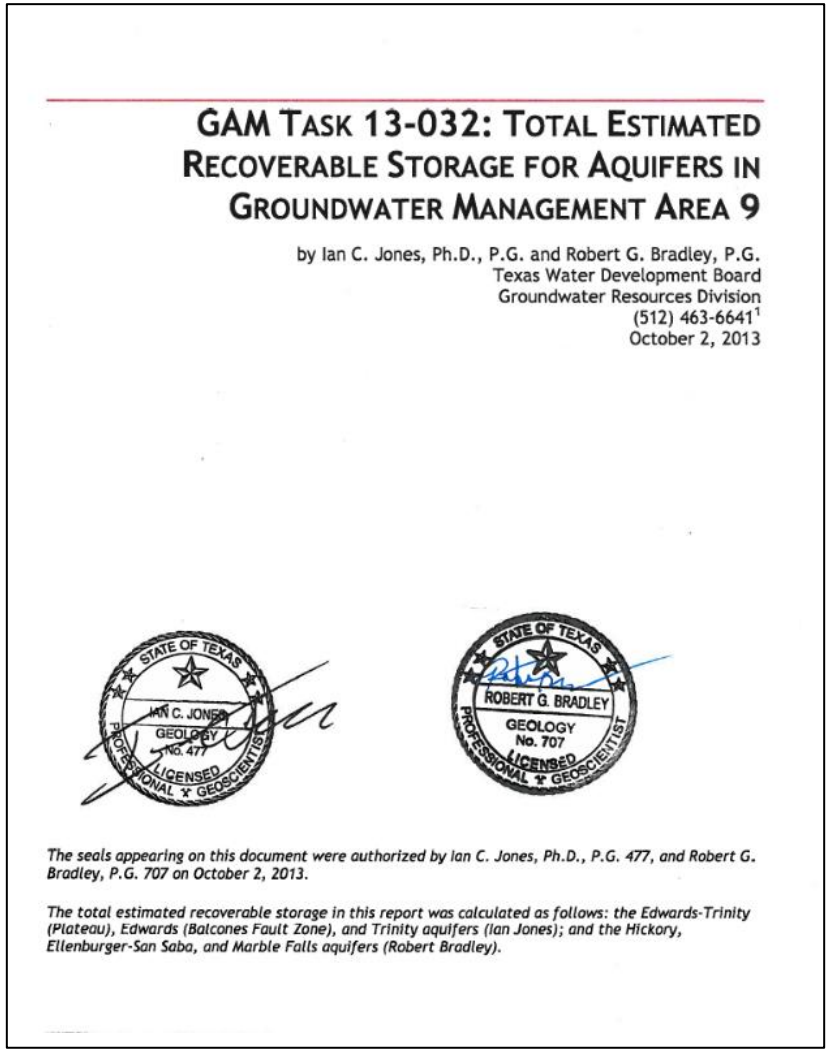
Example GAM Run for
GCD management plan



GAM Run 16-023 MAG: Modeled Available Groundwater for the Aquifers in Groundwater Management Area 9

Ian C. Jones, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Section
(512) 463-6641
February 28, 2017

Example GAM Run for
Modeled Available Groundwater



GAM Task 13-032: Total Estimated Recoverable Storage for Aquifers in Groundwater Management Area 9

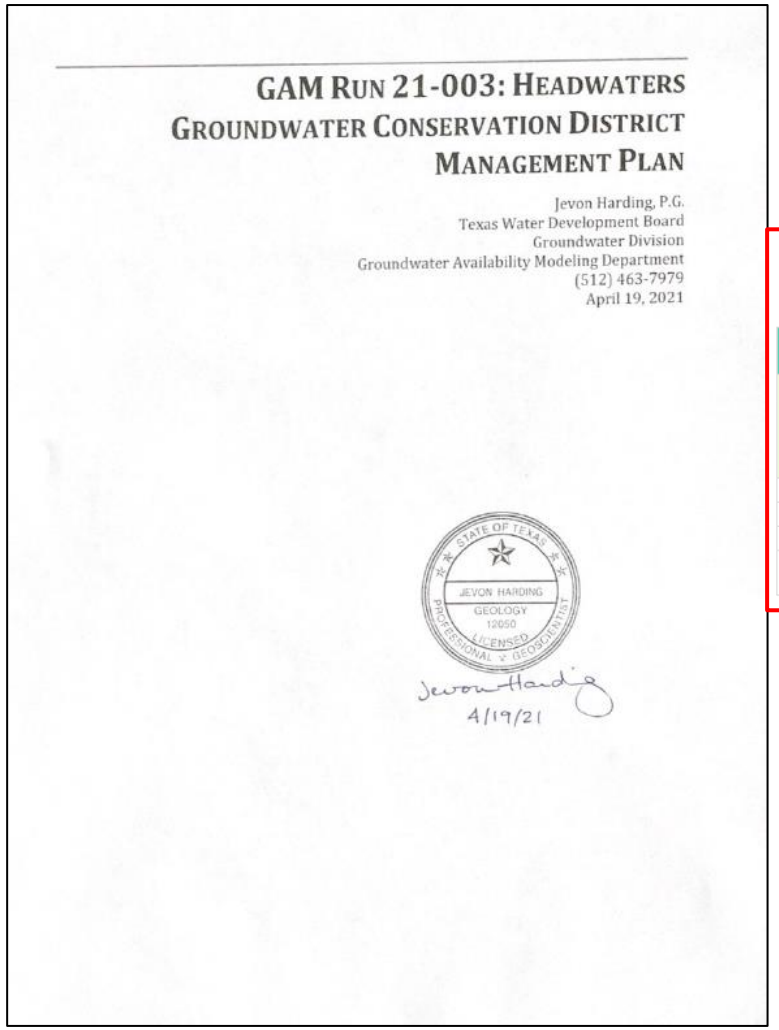
by Ian C. Jones, Ph.D., P.G. and Robert G. Bradley, P.G.
Texas Water Development Board
Groundwater Resources Division
(512) 463-6641[1]
October 2, 2013

*The seals appearing on this document were authorized by Ian C. Jones, Ph.D., P.G. 477, and Robert G. Bradley, P.G. 707 on October 2, 2013.*

*The total estimated recoverable storage in this report was calculated as follows: the Edwards-Trinity (Plateau), Edwards (Balcones Fault Zone), and Trinity aquifers (Ian Jones); and the Hickory, Ellenburger-San Saba, and Marble Falls aquifers (Robert Bradley).*

Example GAM Run for
Total Estimated Recoverable Storage

# How we use Groundwater Availability Models



GAM Run 21-003: Headwaters Groundwater Conservation District Management Plan

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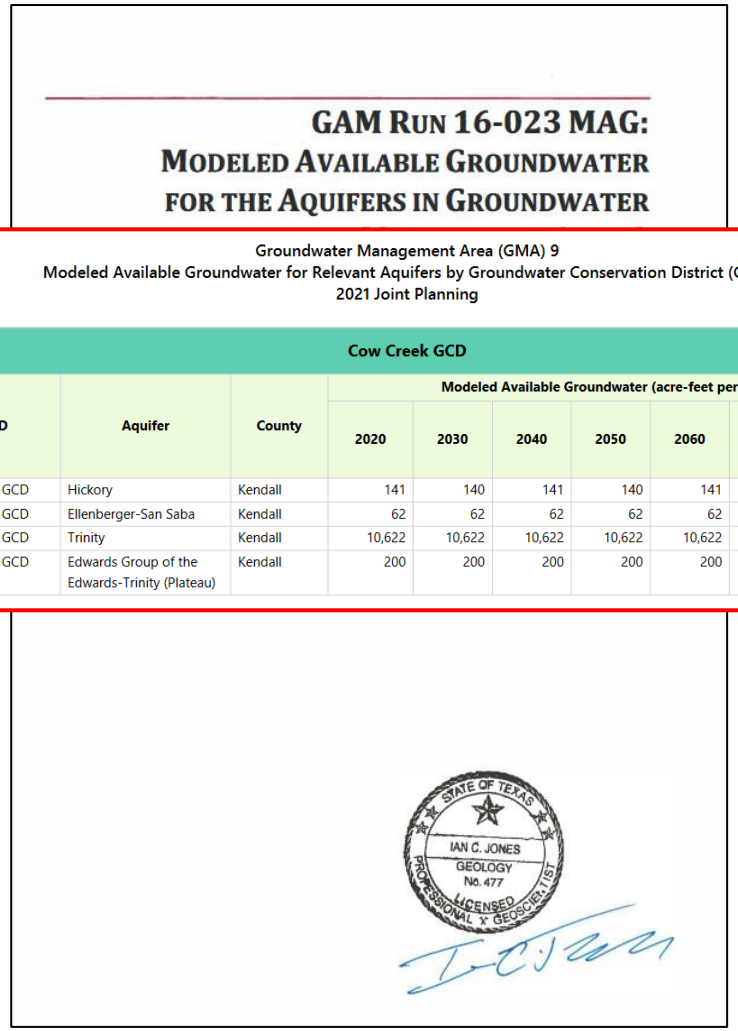
Groundwater Availability Modeling Department
(512) 463-7979
April 19, 2021

Example GAM Run for
GCD management plan

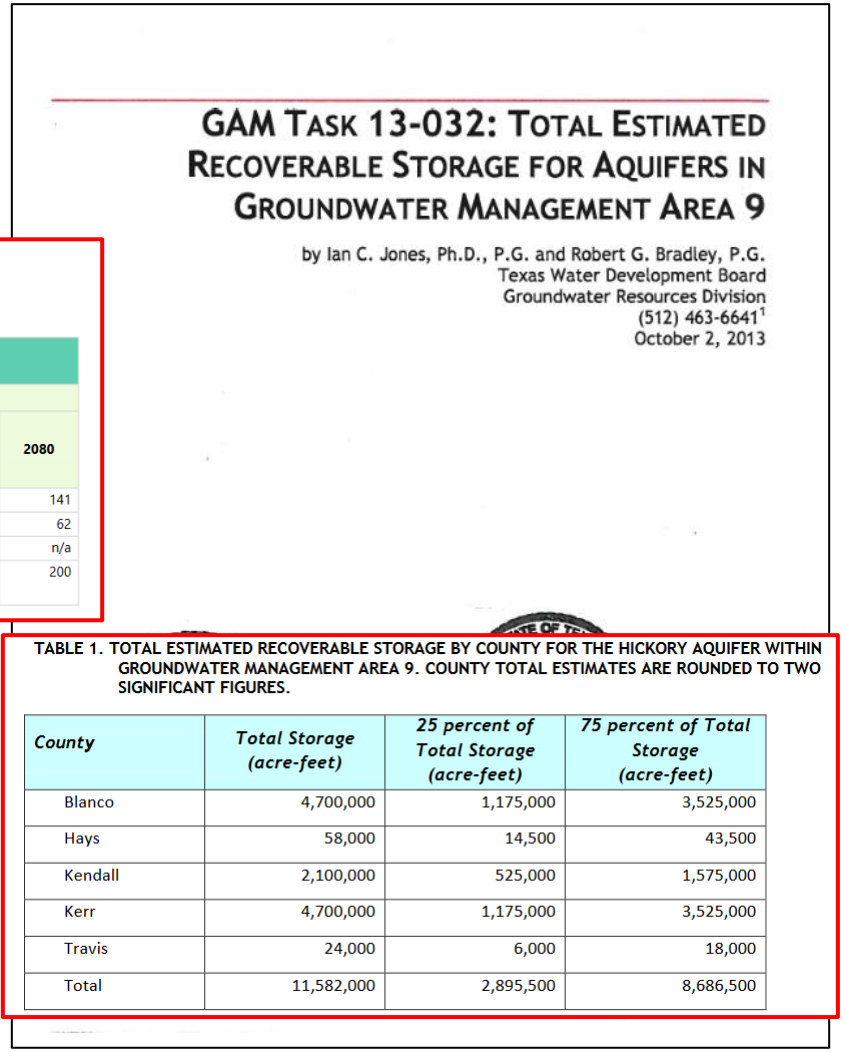


GAM Run 16-023 MAG: Modeled Available Groundwater for the Aquifers in Groundwater

Groundwater Management Area (GMA) 9
Modeled Available Groundwater for Relevant Aquifers by Groundwater Conservation District (GCD)
2021 Joint Planning

| Cow Creek GCD | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| GCD | Aquifer | County | Modeled Available Groundwater (acre-feet per year) | | | | | | |
| | | | 2020 | 2030 | 2040 | 2050 | 2060 | 2070 | 2080 |
| Cow Creek GCD | Hickory | Kendall | 141 | 140 | 141 | 140 | 141 | 140 | 141 |
| Cow Creek GCD | Ellenberger-San Saba | Kendall | 62 | 62 | 62 | 62 | 62 | 62 | 62 |
| Cow Creek GCD | Trinity | Kendall | 10,622 | 10,622 | 10,622 | 10,622 | 10,622 | n/a | n/a |
| Cow Creek GCD | Edwards Group of the Edwards-Trinity (Plateau) | Kendall | 200 | 200 | 200 | 200 | 200 | 200 | 200 |

Example GAM Run for
Modeled Available Groundwater



GAM Task 13-032: Total Estimated Recoverable Storage for Aquifers in Groundwater Management Area 9

by Ian C. Jones, Ph.D., P.G. and Robert G. Bradley, P.G.
Texas Water Development Board
Groundwater Resources Division
(512) 463-6641[1]
October 2, 2013

TABLE 1. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE HICKORY AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 9. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

| *County* | *Total Storage (acre-feet)* | *25 percent of Total Storage (acre-feet)* | *75 percent of Total Storage (acre-feet)* |
|---|---|---|---|
| Blanco | 4,700,000 | 1,175,000 | 3,525,000 |
| Hays | 58,000 | 14,500 | 43,500 |
| Kendall | 2,100,000 | 525,000 | 1,575,000 |
| Kerr | 4,700,000 | 1,175,000 | 3,525,000 |
| Travis | 24,000 | 6,000 | 18,000 |
| Total | 11,582,000 | 2,895,500 | 8,686,500 |

Example GAM Run for
Total Estimated Recoverable Storage

# How we use Groundwater Availability Models

- Uses required by statute *(direct)*
  - Provide groundwater conservation districts with water budget data for their management plans.
  - Calculating Modeled Available Groundwater.
  - Calculating Total Estimated Recoverable Storage
- Uses required by statute *(indirect)*
  - HB 1232 Texas aquifer study
  - HB 30 potential brackish groundwater production area determination
- Other uses
  - Assisting groundwater management areas in assessing desired future conditions scenarios.

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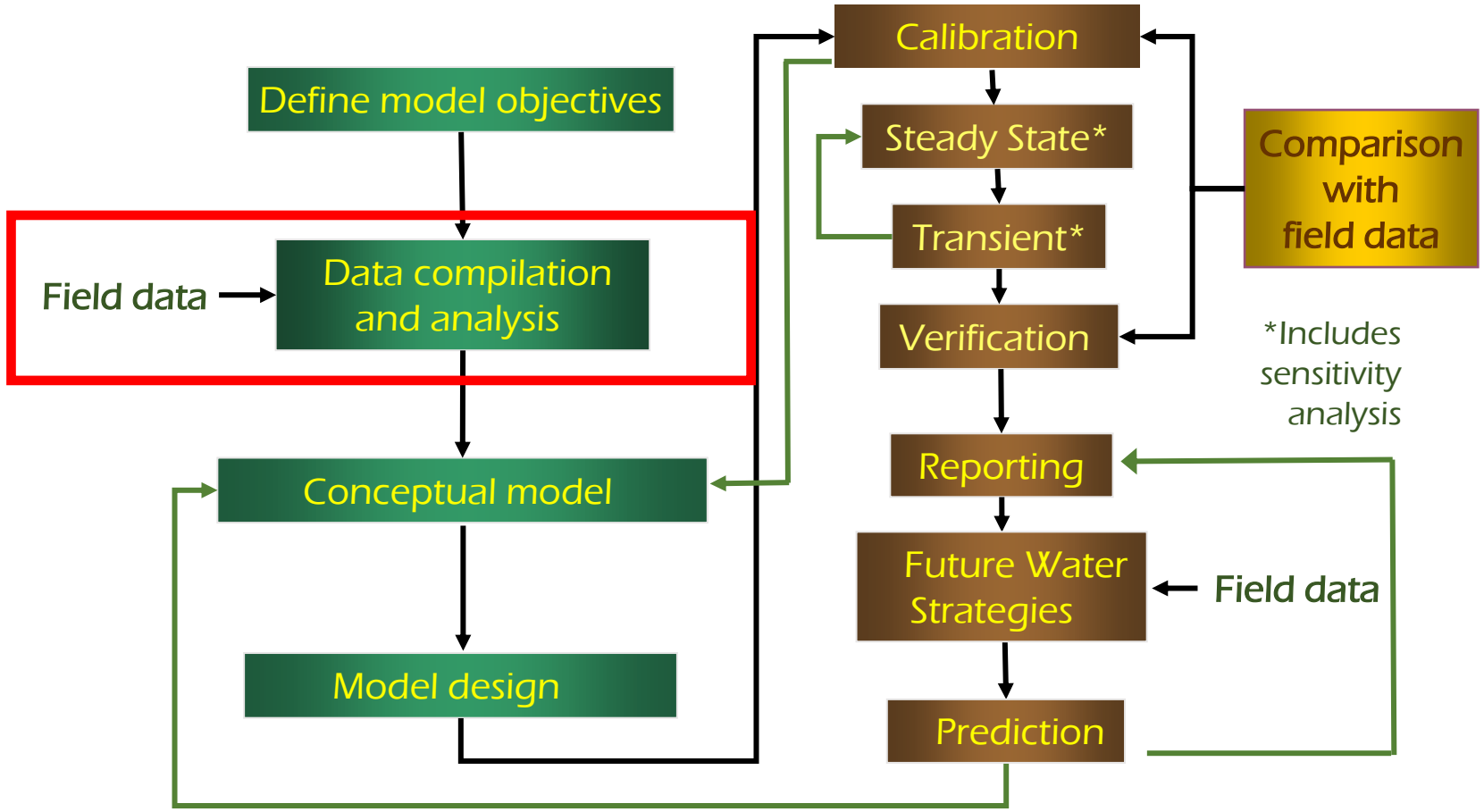
# Modeling Process

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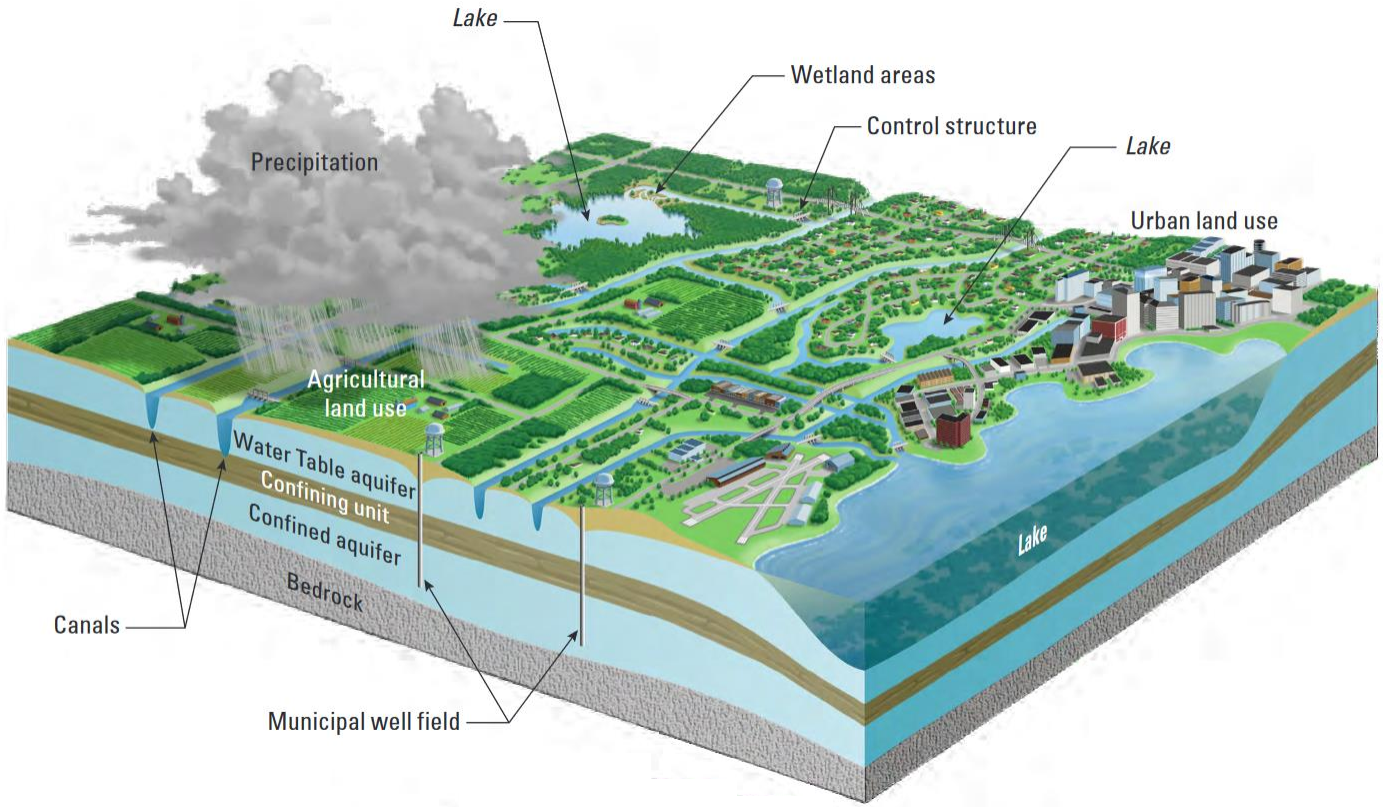


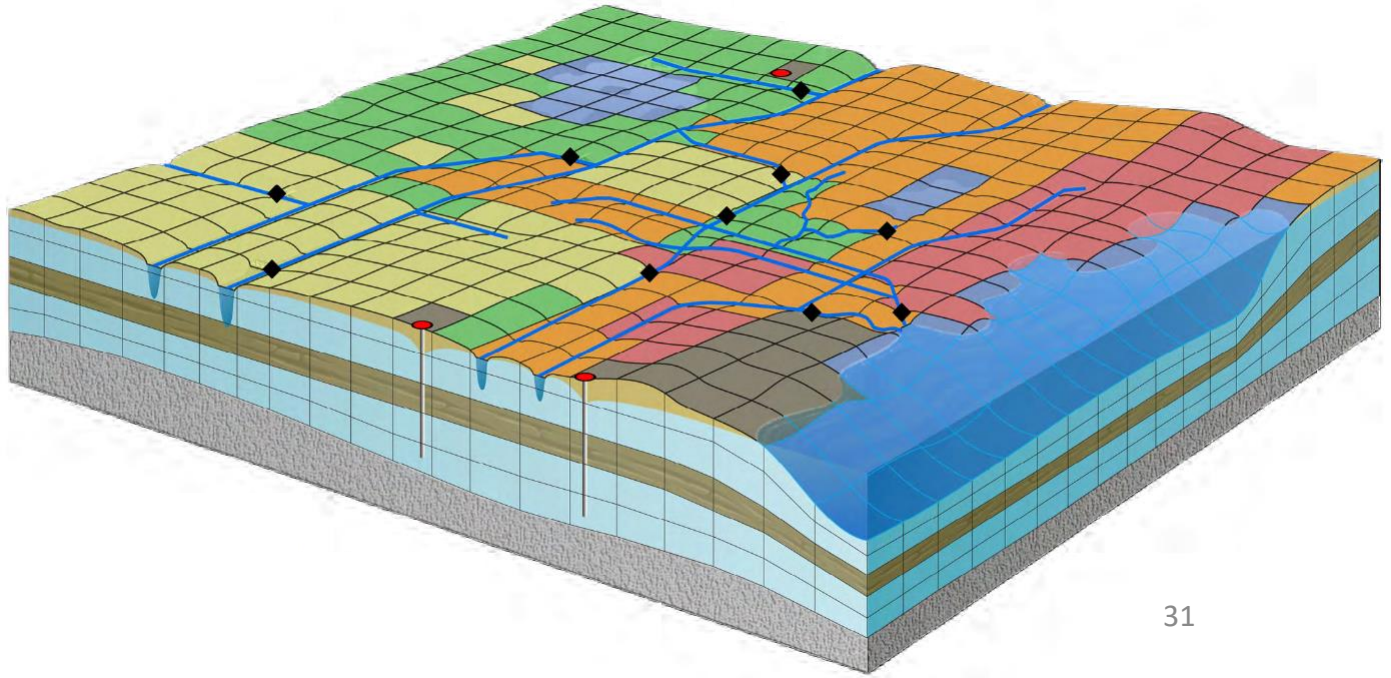

*https://pubs.usgs.gov/tm/6a40/pdf/Hughes_TM6-A40.pdf*

# Data Collection

| Data Types | Modeling Question to answer |
|---|---|
| Heads (Water Levels) | - Can the model match past AQUIFER levels? |
| Discharge (Springs, Pumping) | - How much water is leaving the AQUIFER and by what mechanism?<br>- Where is water leaving the AQUIFER? |
| Precipitation | - How much water is potentially available to recharge the AQUIFER? |
| Land Use | - Where can water infiltrate to recharge the AQUIFER?<br>- Where does pumping occur from AQUIFER? |
| Hydraulic properties | - How easily does water flow through the AQUIFER? |
| Geologic picks/maps | - What does the AQUIFER look like underground?<br>- Are there faults that can affect the flow through the AQUIFER? |
| Water quality | - Where are there environmental concerns or unusual geology/flow in the AQUIFER? |

# Data Collection

## Data Sources

- TWDB databases
- Historical County Reports *(predevelopment)*
- Railroad Commission Database
- GCDs
- Thesis work
- Other literature
- Stakeholders

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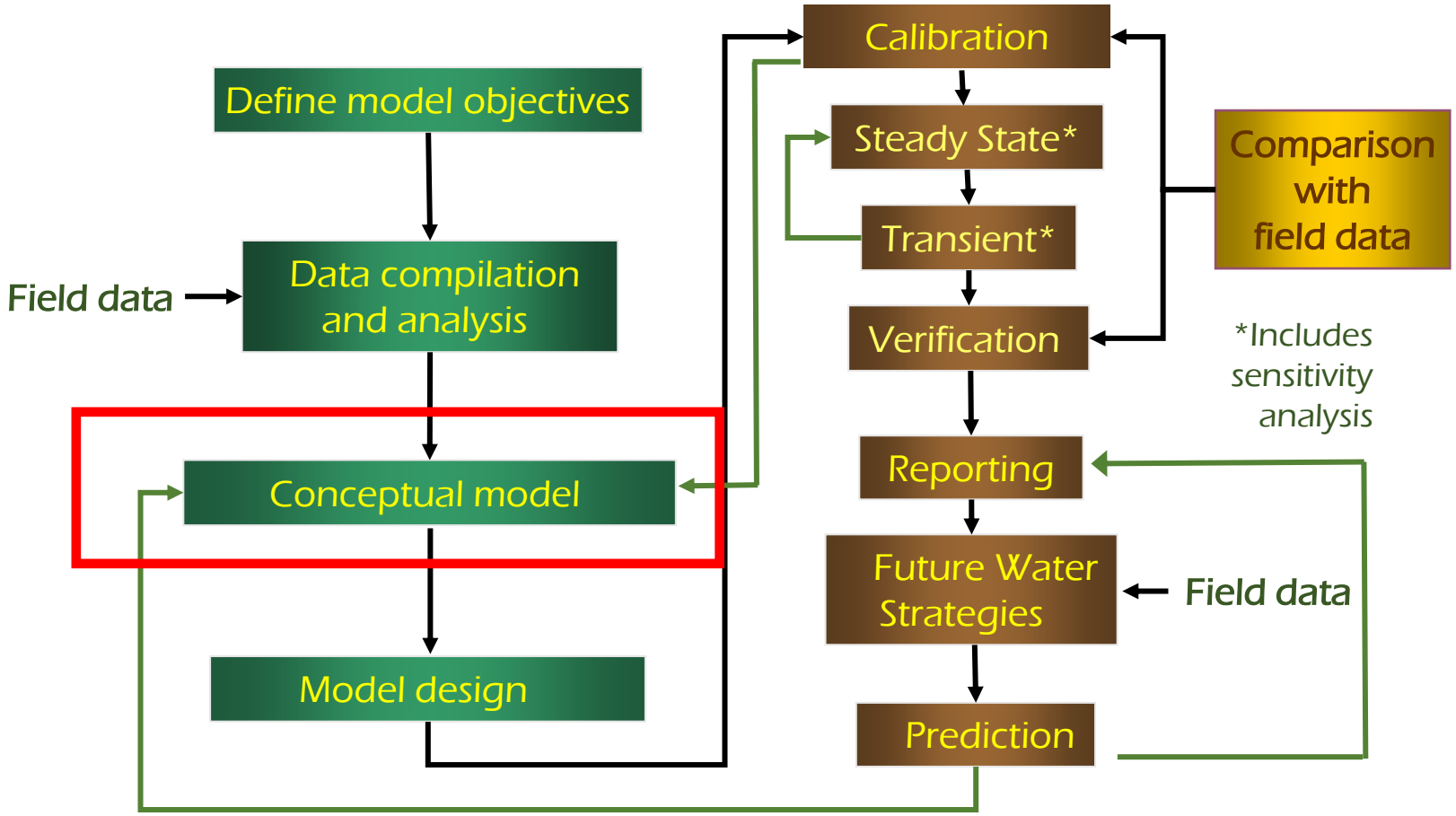
# Modeling Process

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# Conceptual Models

**Conceptual Model Report for the Hill Country Trinity Aquifer Groundwater Availability Model**

*Prepared by Editors*

Nate J. Toll
Ronald T. Green, Ph.D., P.G.
Ronald N. McGinnis
Leanne M. Stepchinski
Rebecca R. Nunu
Gary R. Walter, Ph.D.
*From* Southwest Research Institute®
Jevon Harding, P.G.
Neil E. Deeds, Ph.D., P.E.
*From* INTERA Incorporated

**2018**

*Contributors*

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*Prepared for:*

Texas Water Development Board
P.O. Box 13231, Capitol Station
Austin, Texas 78711-3231

May 31, 2018

https://www.twdb.texas.gov/groundwater/models/gam/trnt_h/

***A Conceptual Model of Groundwater Flow in the Pecos Valley and Edwards-Trinity (Plateau) Regional Aquifers***

**2022**

*By Ki Cha, Ph.D., Jevon Harding, P.G., Grayson Dowlearn, P.G., Ian Jones, Ph.D., P.G., and Roberto Anaya, P.G.*
*Texas Water Development Board*
*August 2022*

https://www.twdb.texas.gov/groundwater/models/gam/eddt_p/eddt_r.asp

Brackish Groundwater in the Hill Country Trinity Aquifer and Trinity Group Formations, Texas

Mark C. Robinson, P.G., Alysa K. Suydam, P.G., Evan D. Strickland, P.G., Azzah AlKurdi

Report 388
September 2022

Texas Water Development Board
www.twdb.texas.gov

**2022**

https://www.twdb.texas.gov/groundwater/bracs/studies/HillCountry_Trinity/index.asp

# Data Collection

*Primarily using 2018 Conceptual Model report, unless otherwise **noted***

| Data Types | Modeling Question to answer | Status |
|---|---|---|
| Heads (Water Levels) | - Can the model match past AQUIFER levels? | * Request post-2015 data |
| Discharge (Springs, Pumping) | - How much water is leaving the AQUIFER and by what mechanism?<br>- Where is water leaving the AQUIFER? | * Request % per Trinity unit |
| Precipitation | - How much water is potentially available to recharge the AQUIFER? | |
| Land Use | - Where can water infiltrate to recharge the AQUIFER?<br>- Where does pumping occur from AQUIFER? | |
| Hydraulic properties | - How easily does water flow through the AQUIFER? | * Request post-2015 data |
| Geologic picks/maps | - What does the AQUIFER look like underground?<br>- Are there faults that can affect the flow through the AQUIFER? | **2022 BRACS maps** |
| Water quality | - Where are there environmental concerns or unusual geology/flow in the AQUIFER? | |

* Request for GCD/stakeholder input

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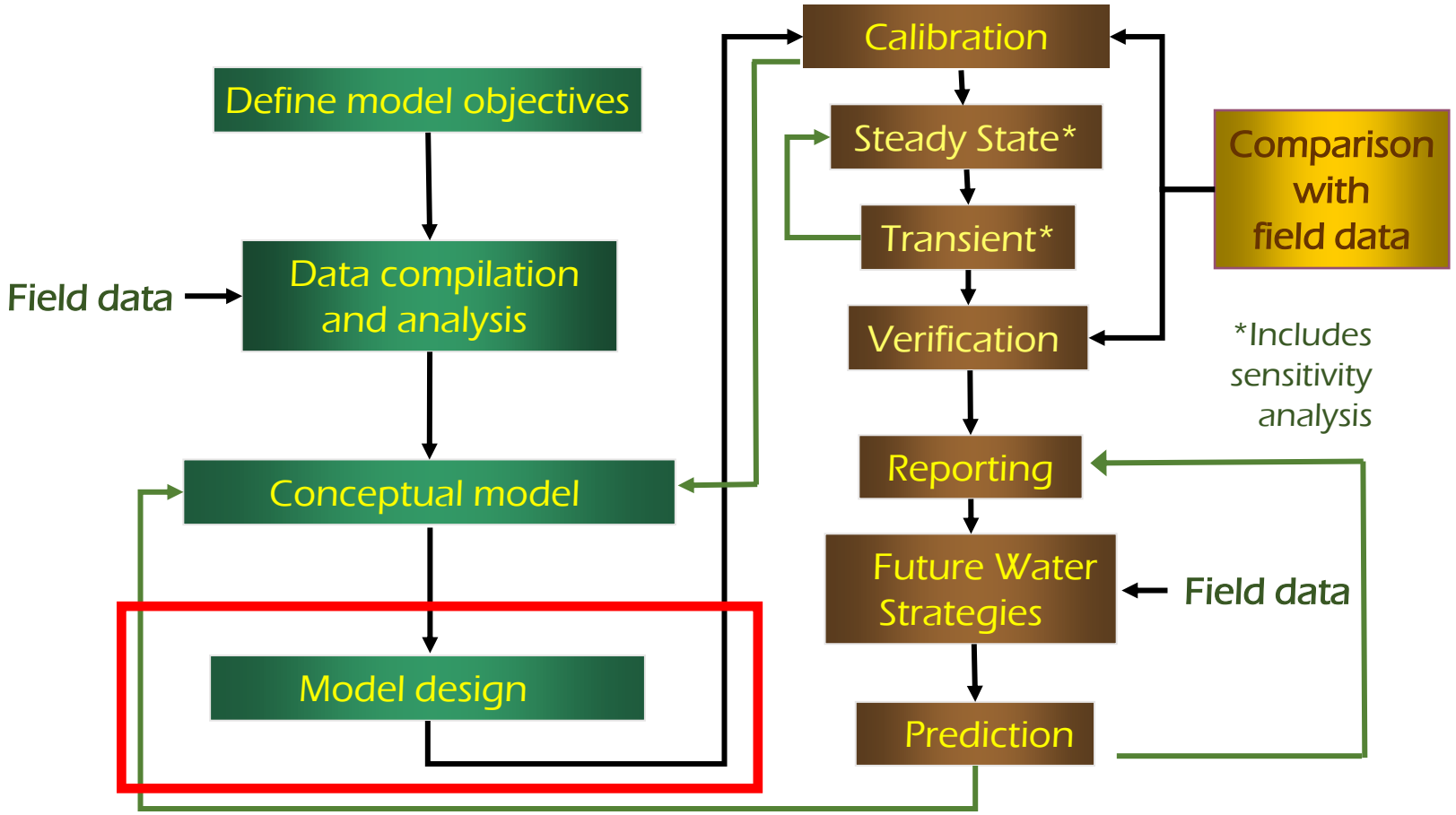
# Modeling Process

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# Model Design

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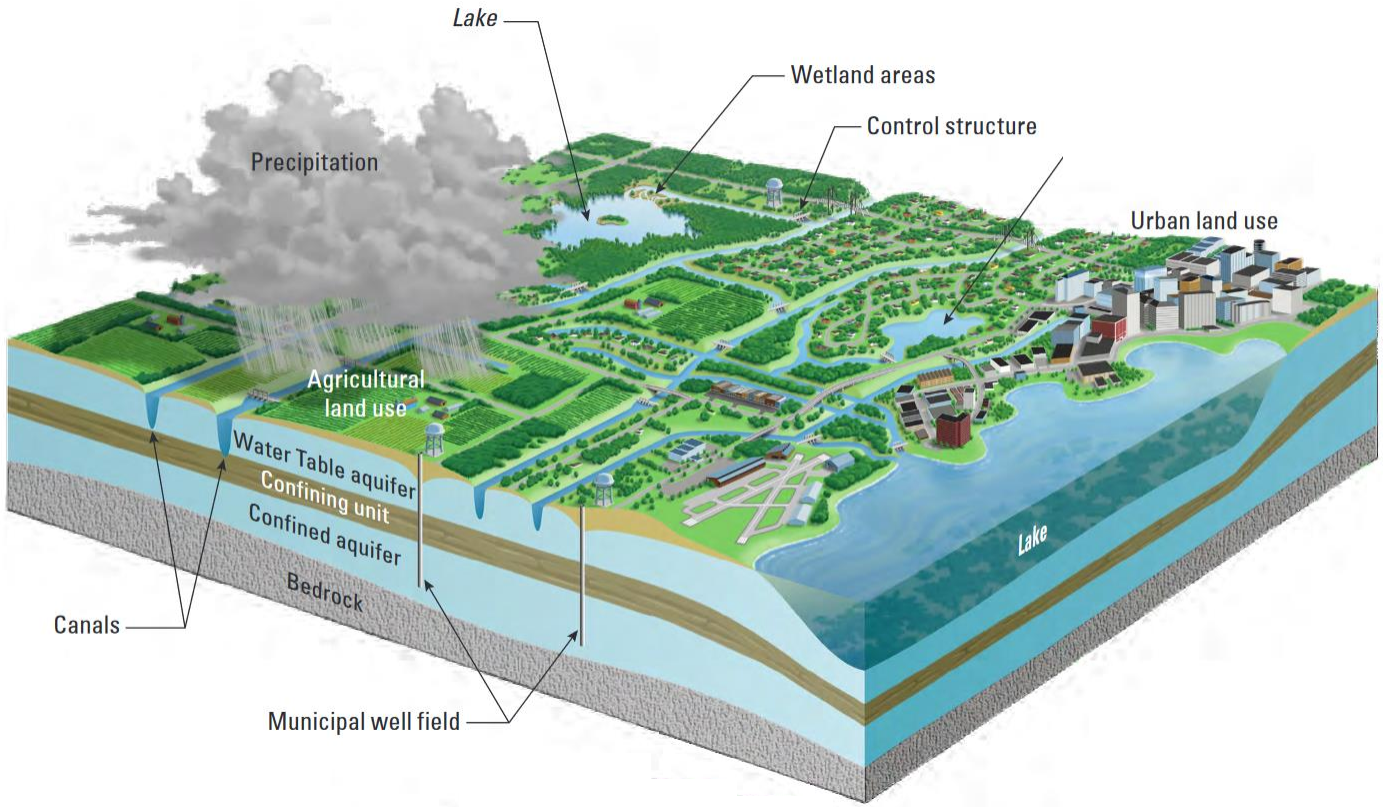


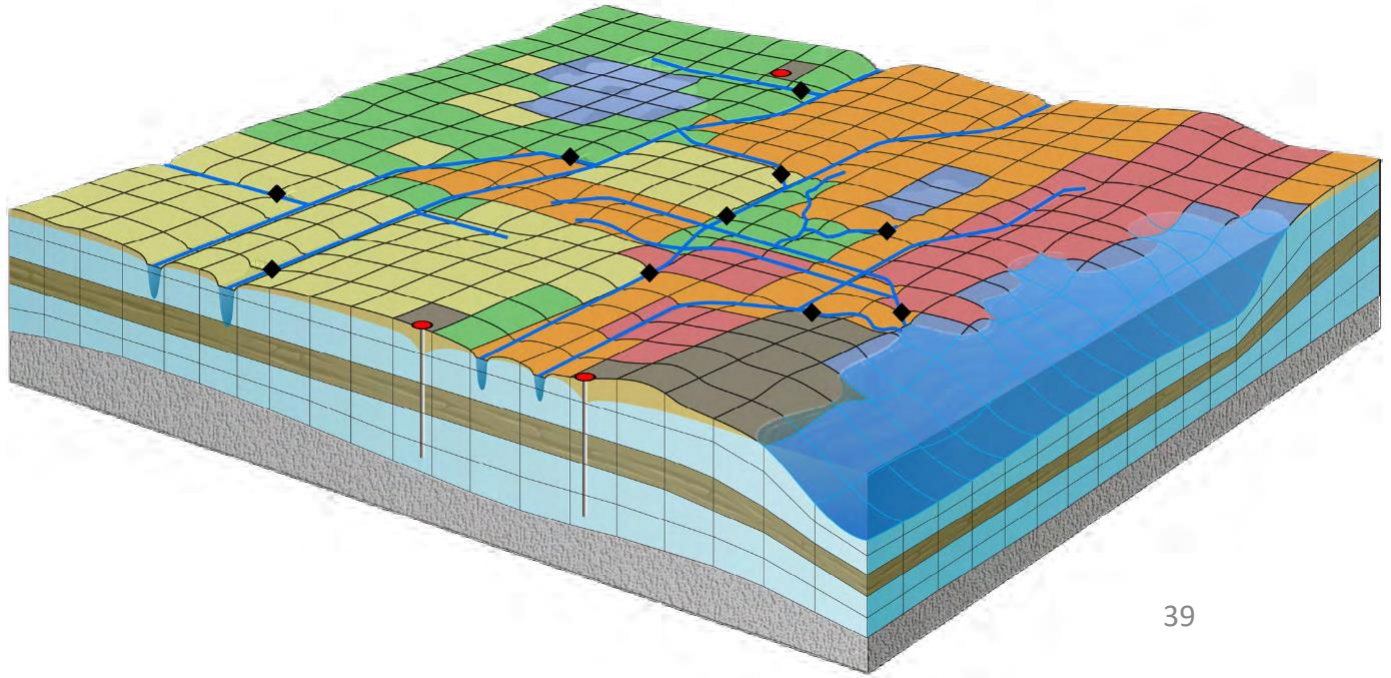

*https://pubs.usgs.gov/tm/6a40/pdf/Hughes_TM6-A40.pdf*

# Model Design

- MODFLOW 6
  - Open-source software from U.S. Geological Survey
  - Ability to automate model setup and analysis with “flopy” (Python)
  - Ability to add extra refinement to areas of interest (streams, springs, etc.)
  - Ability to run nested local models in future

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# Coordination with other TWDB Projects

- Edwards and Trinity Regional GAM *(in progress)*
- BRACS Hill Country Trinity geologic surfaces *(complete)*
- BRACS Edwards-Trinity (Plateau) geologic surfaces *(in progress)*

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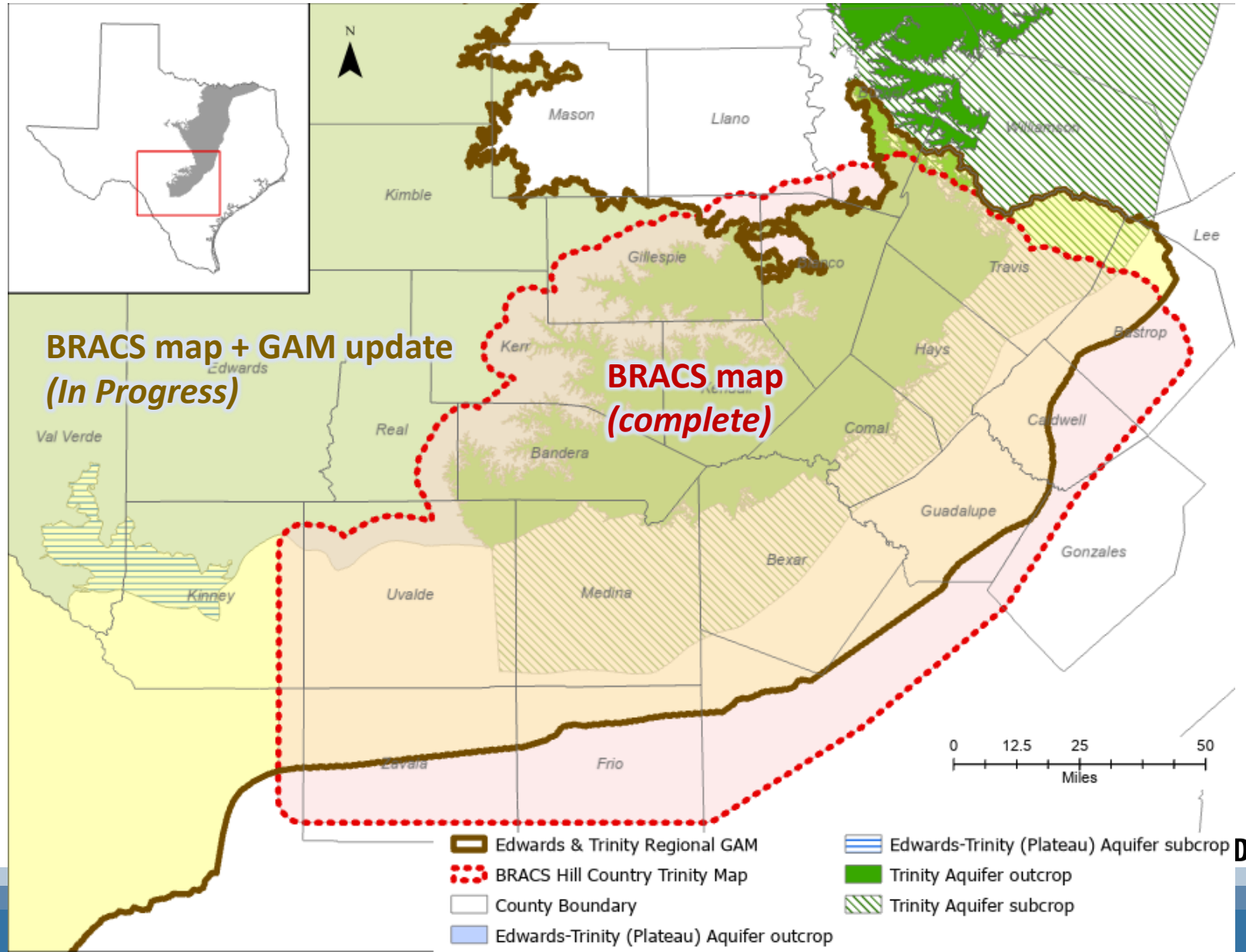
# Coordination with other TWDB Projects

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# Model Design: Layers

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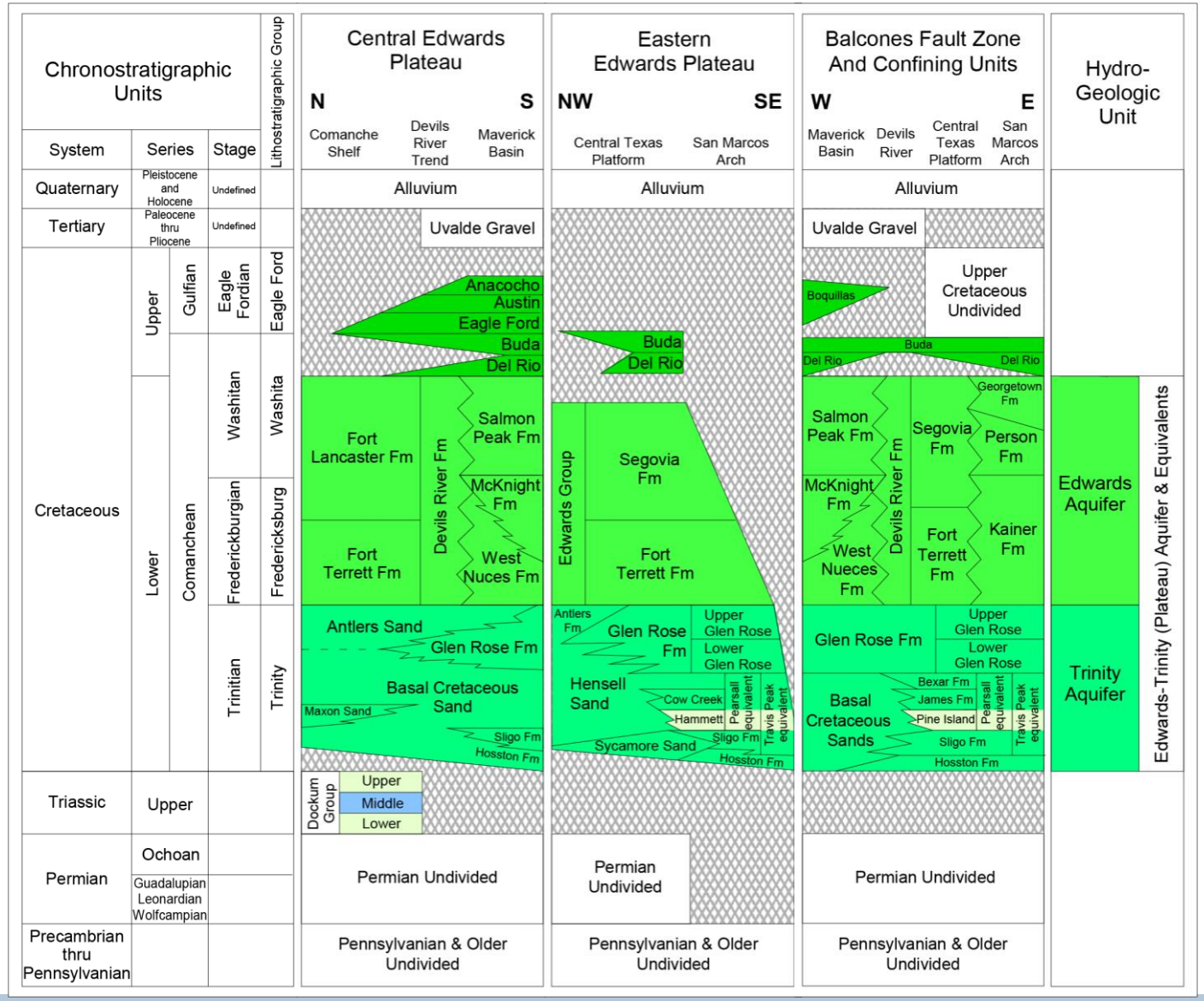
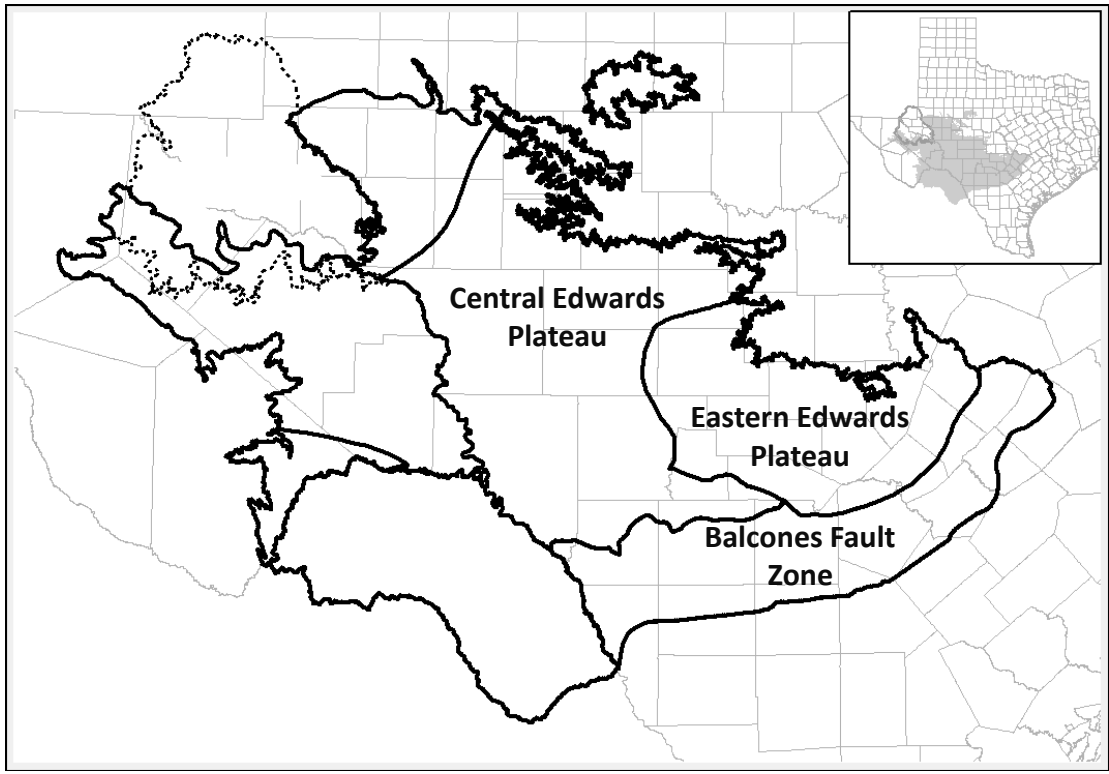
# Stratigraphy




*Edwards & Trinity Regional GAM Conceptual Model, 2022*

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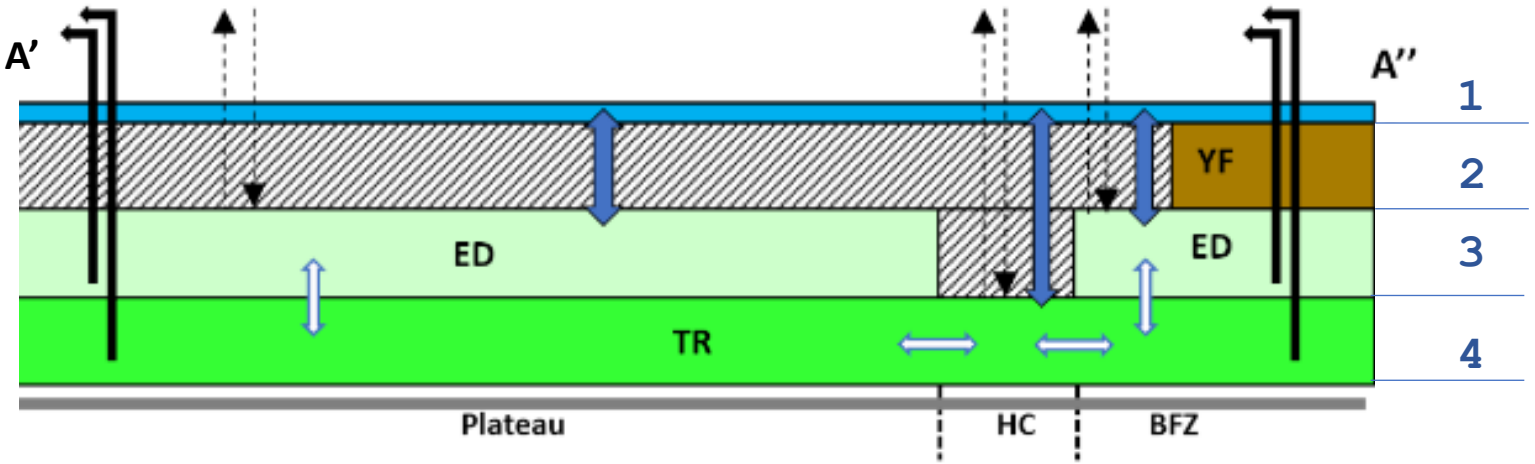
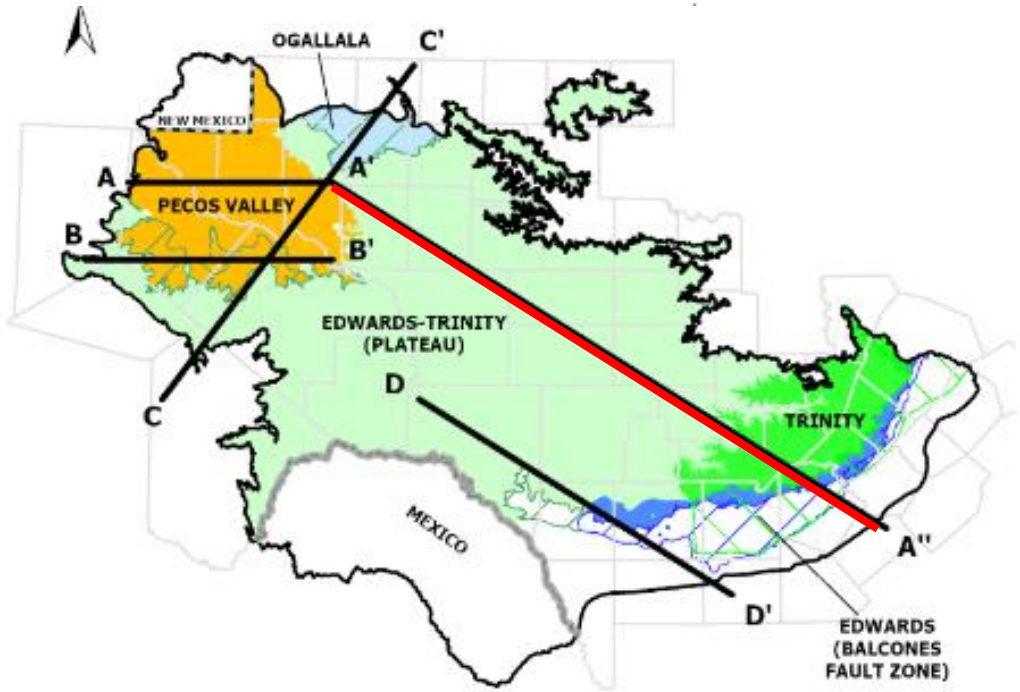
# Edwards & Trinity Regional GAM



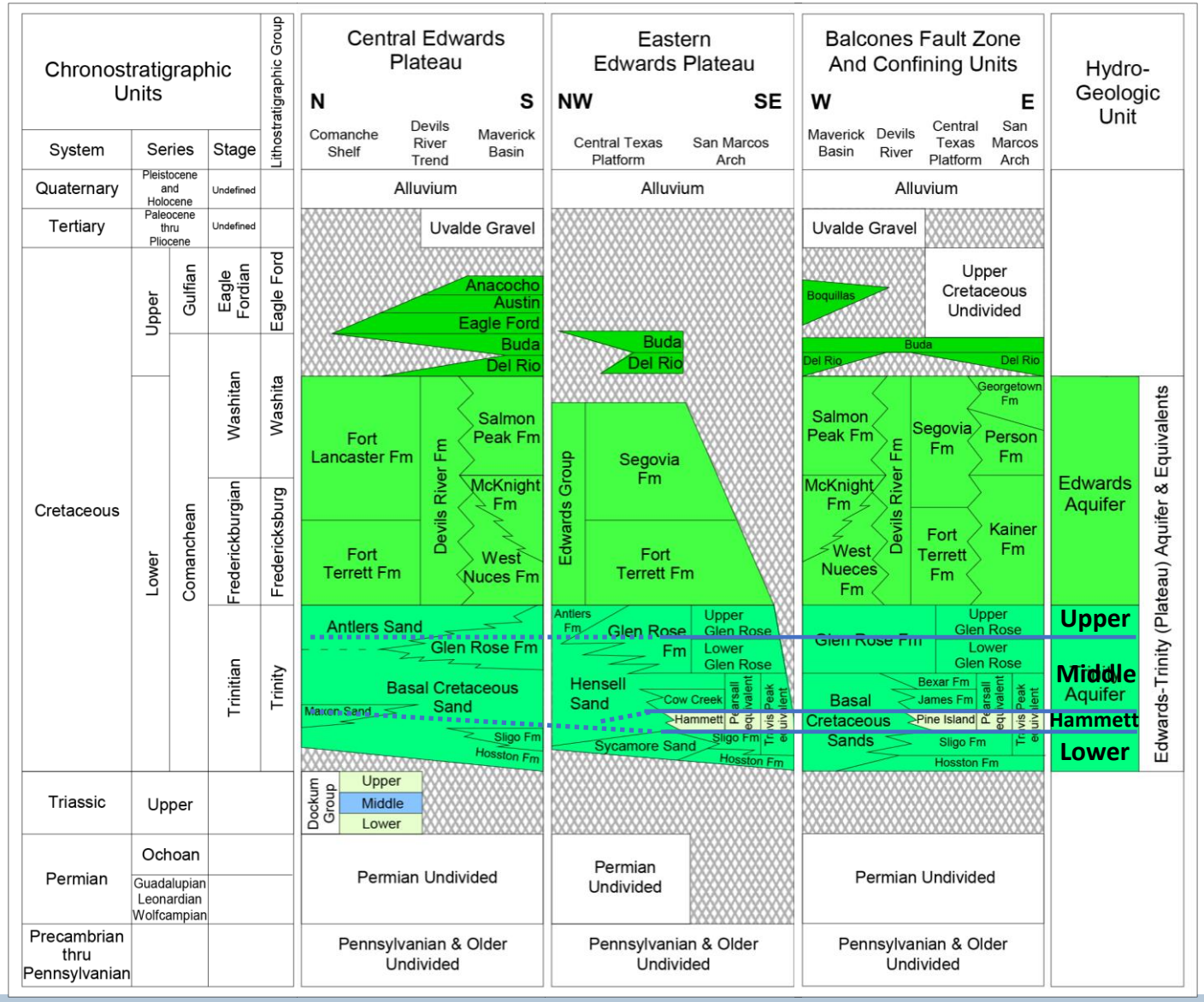

| Plateau (West) | Hill Country (Central) | Edwards BFZ (Southeast) | Model Layer |
|---|---|---|---|
| Rivers/Alluvium | Rivers/Alluvium | Rivers/Alluvium | 1 |
| | -- | Younger Units* | 2 |
| Edwards | -- | Edwards | 3 |
| Trinity | Trinity | Trinity | 4 |

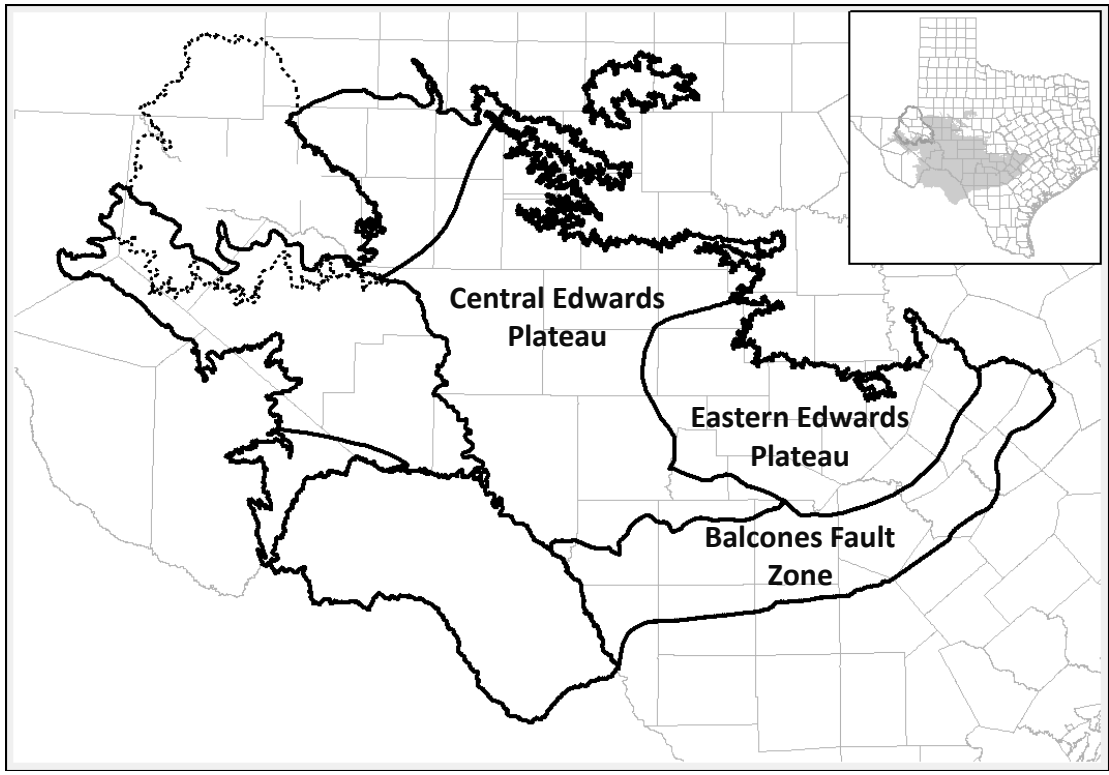
*Edwards & Trinity Regional GAM Conceptual Model, 2022*

**Upper Cretaceous + Overlying units*

Texas Water Development Board

# Stratigraphy




*Edwards & Trinity Regional GAM Conceptual Model, 2022*

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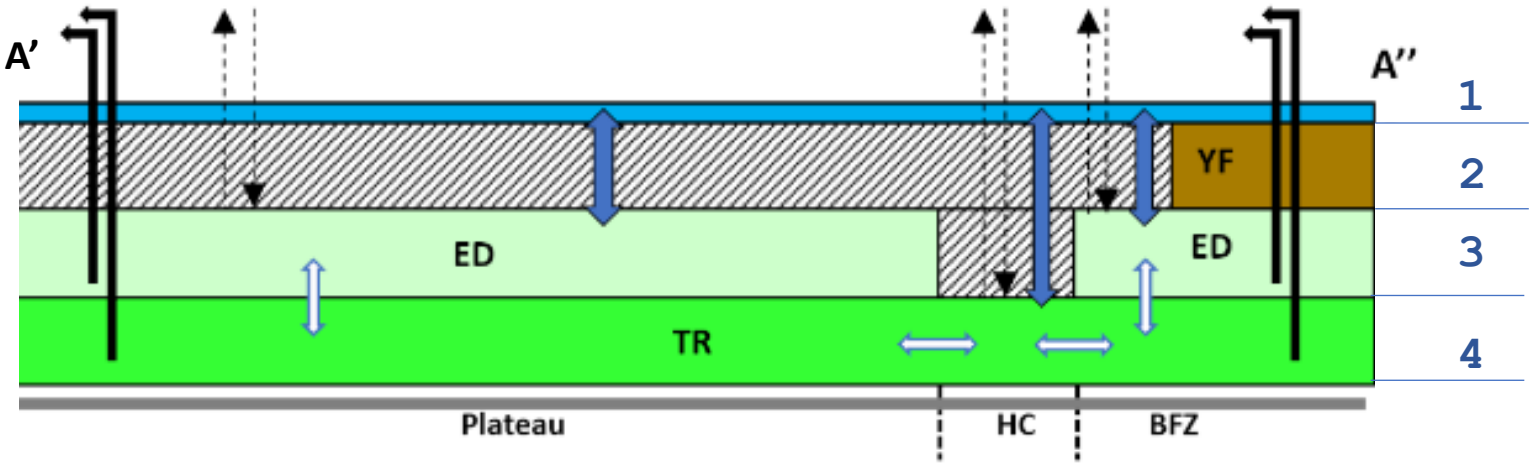
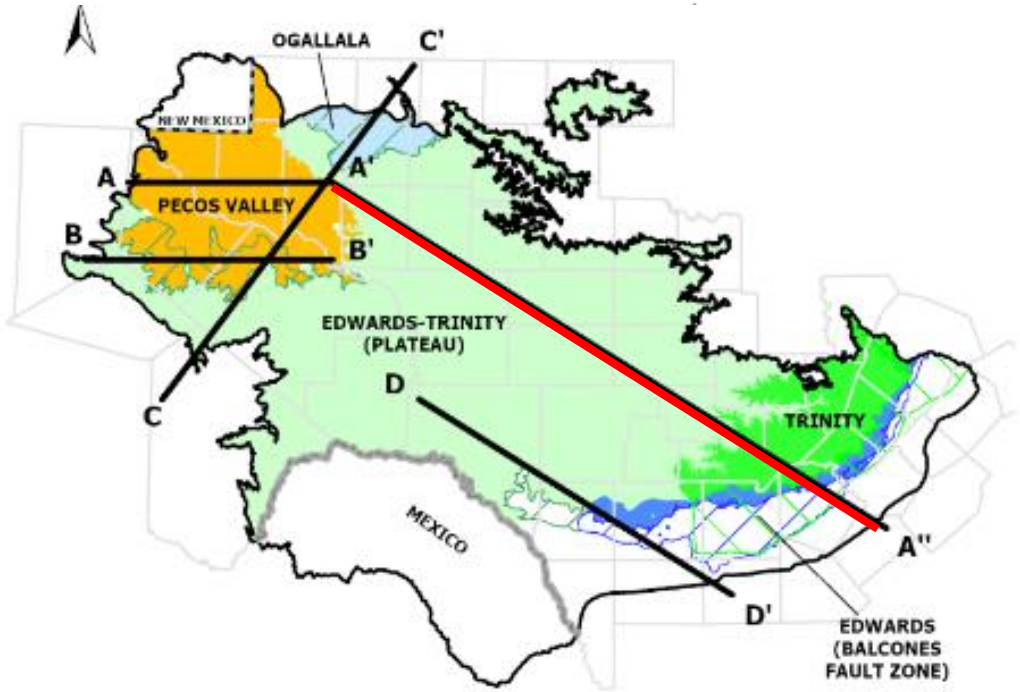
# Edwards & Trinity Regional GAM

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*Edwards & Trinity Regional GAM Conceptual Model, 2022*

**Upper Cretaceous + Overlying units*

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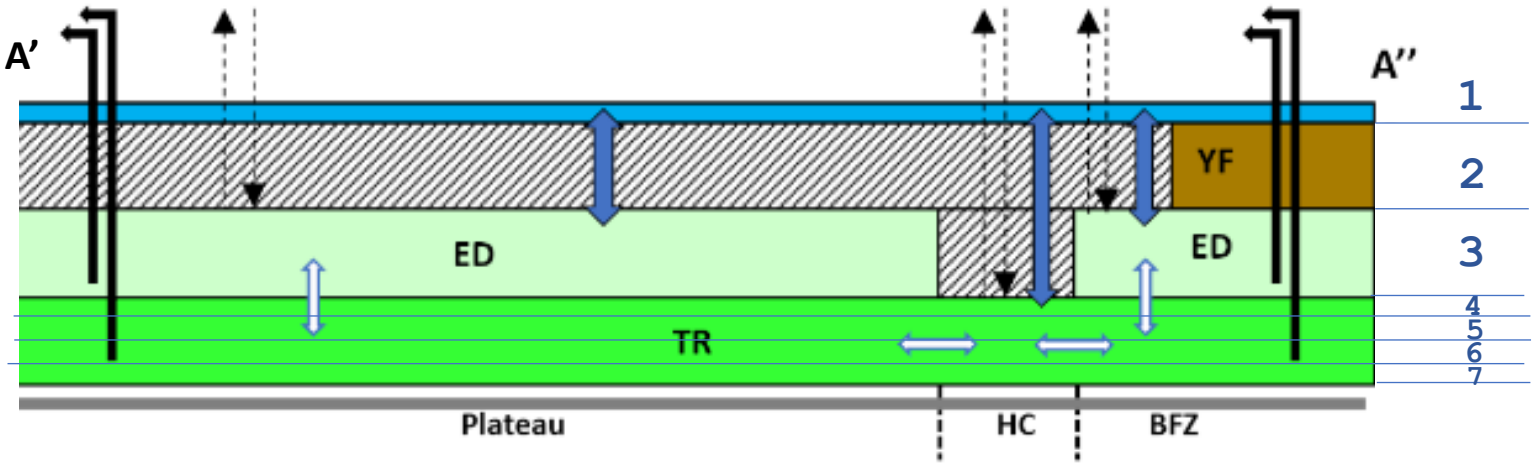
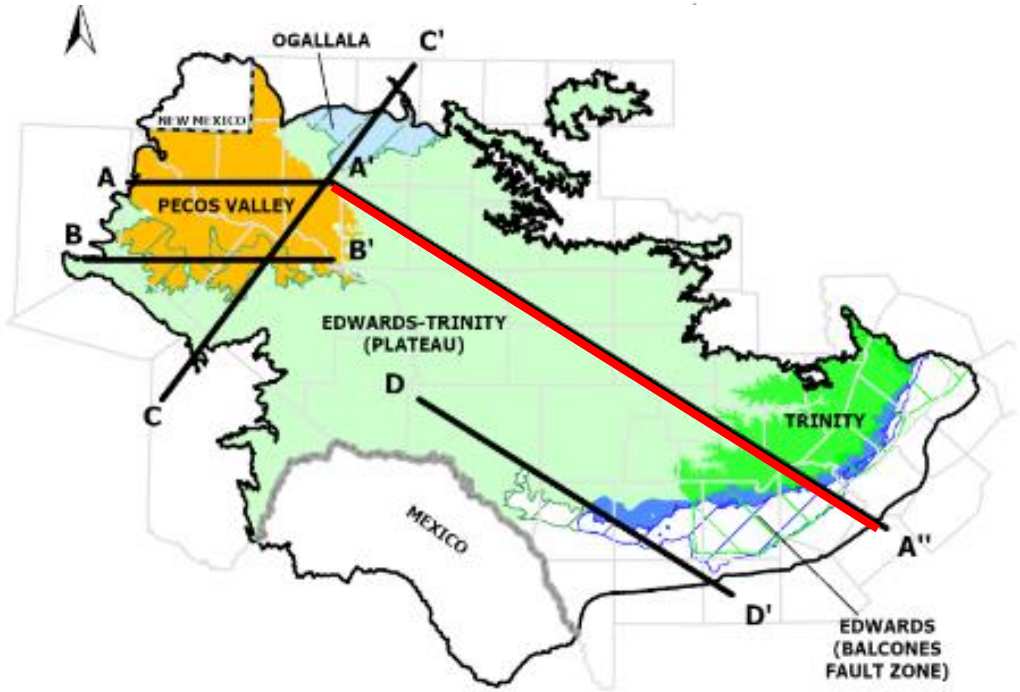
# Southern Trinity GAM

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| Edwards | -- | Edwards | 3 |
| Upper Trinity | Upper Trinity | Upper Trinity | 4 |
| Middle Trinity | Middle Trinity | Middle Trinity | 5 |
| Hammett Shale | Hammett Shale | Hammett Shale | 6 |
| Lower Trinity | Lower Trinity | Lower Trinity | 7 |

*Edwards & Trinity Regional GAM Conceptual Model, 2022*

**Upper Cretaceous + Overlying units*

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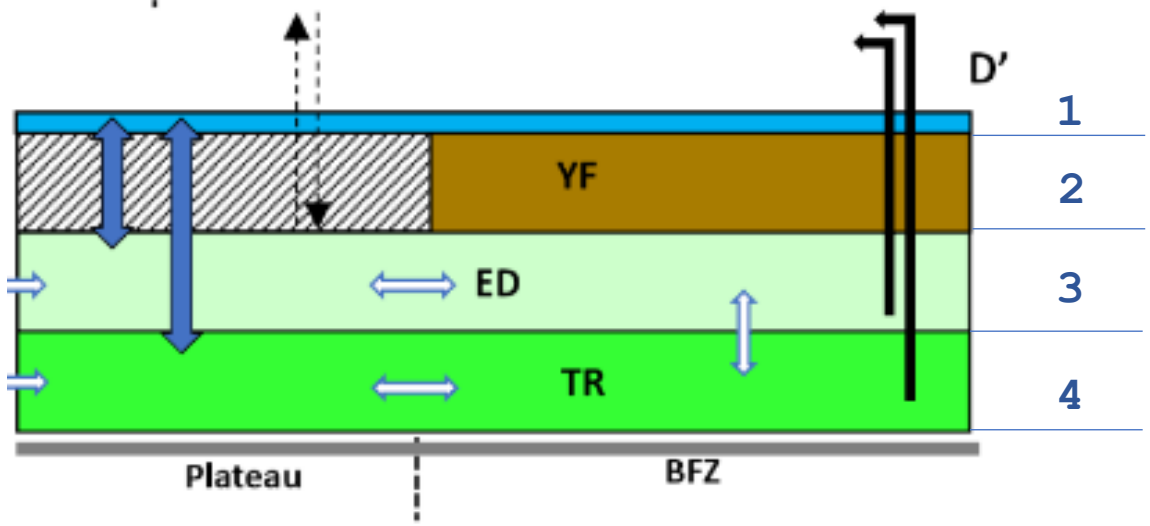
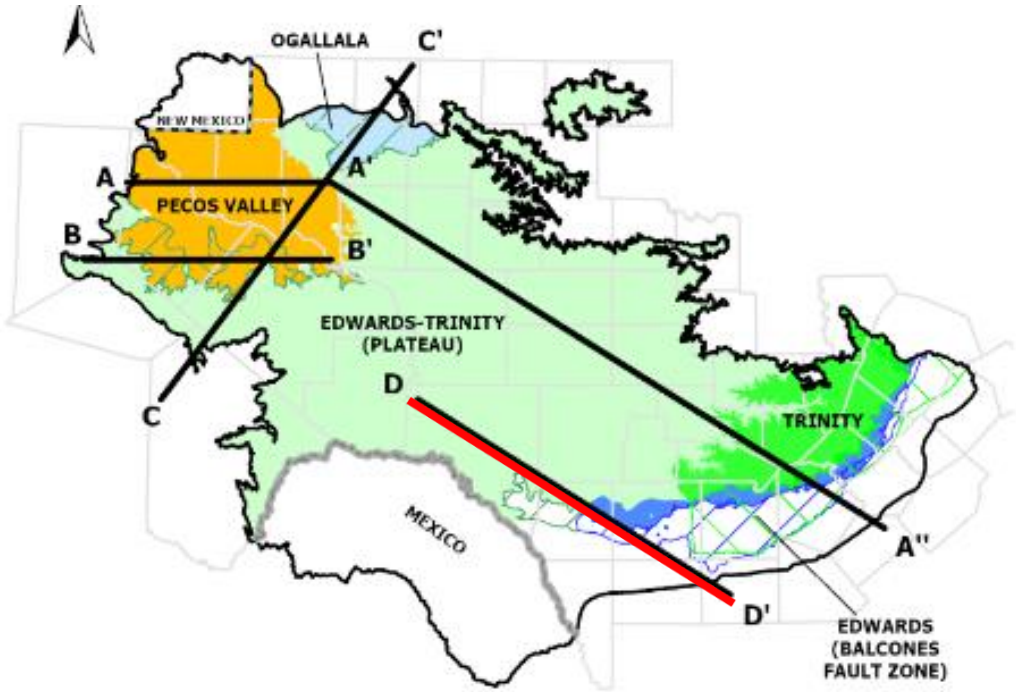
# Edwards & Trinity Regional GAM




*Edwards & Trinity Regional GAM Conceptual Model, 2022*

| Plateau (West) | Hill Country (Central) | Edwards BFZ (Southeast) | Model Layer |
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**Upper Cretaceous + Overlying units*

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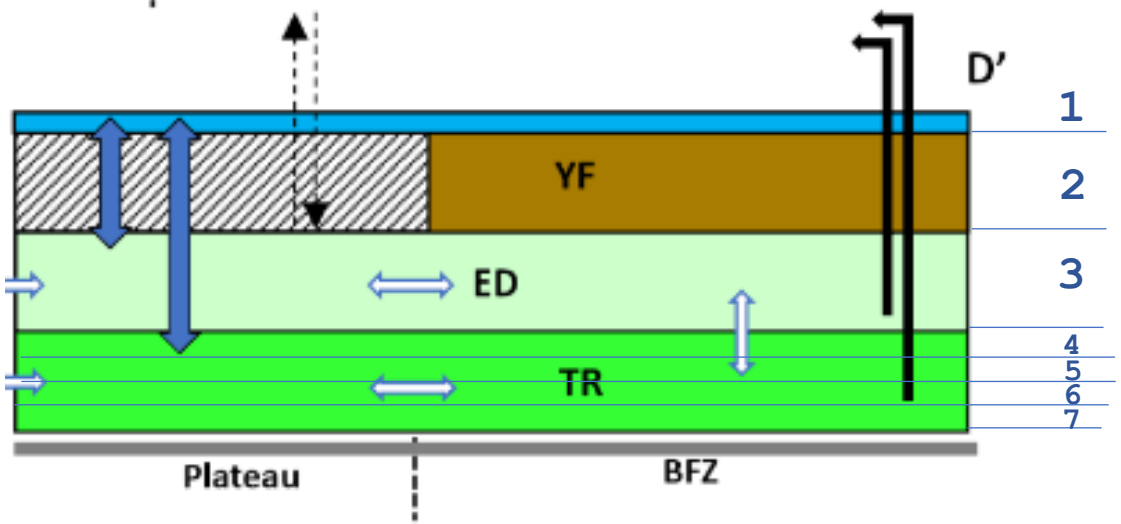
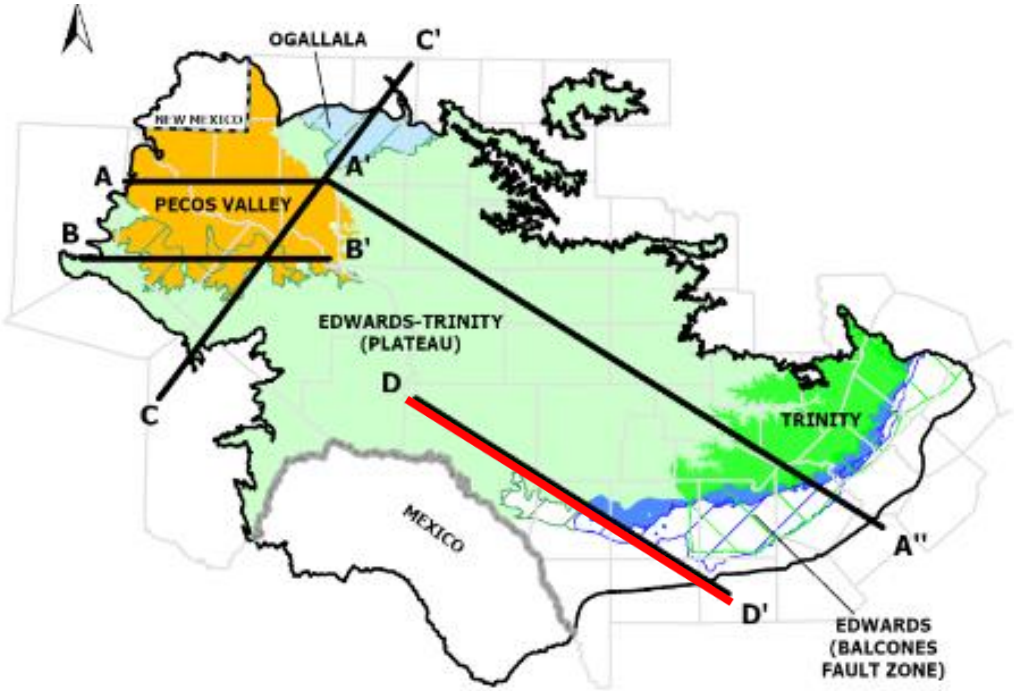
# Southern Trinity GAM




*Edwards & Trinity Regional GAM Conceptual Model, 2022*

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| Lower Trinity | Lower Trinity | Lower Trinity | 7 |

**Upper Cretaceous + Overlying units*

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# Model Design: Grid

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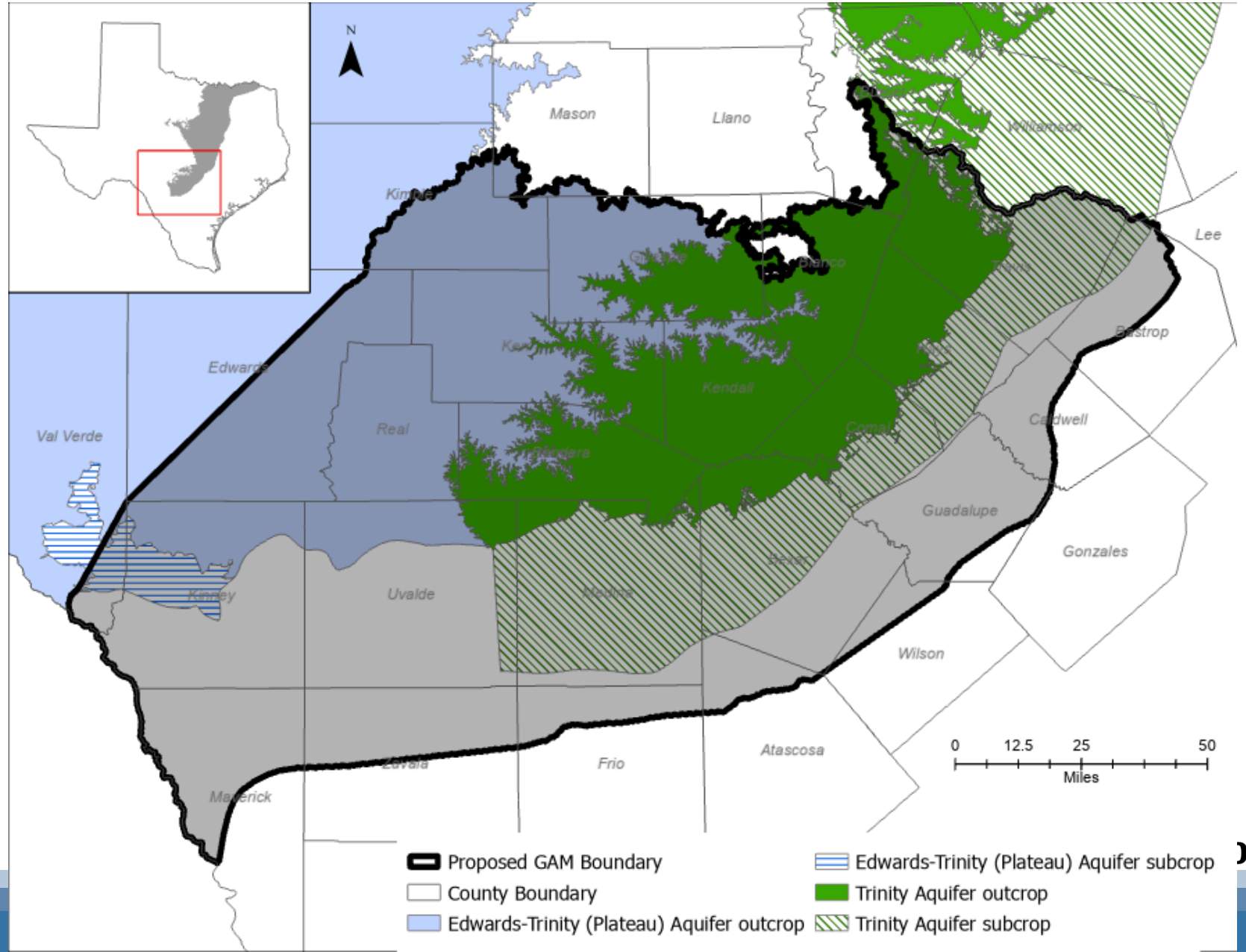
# Proposed Extent

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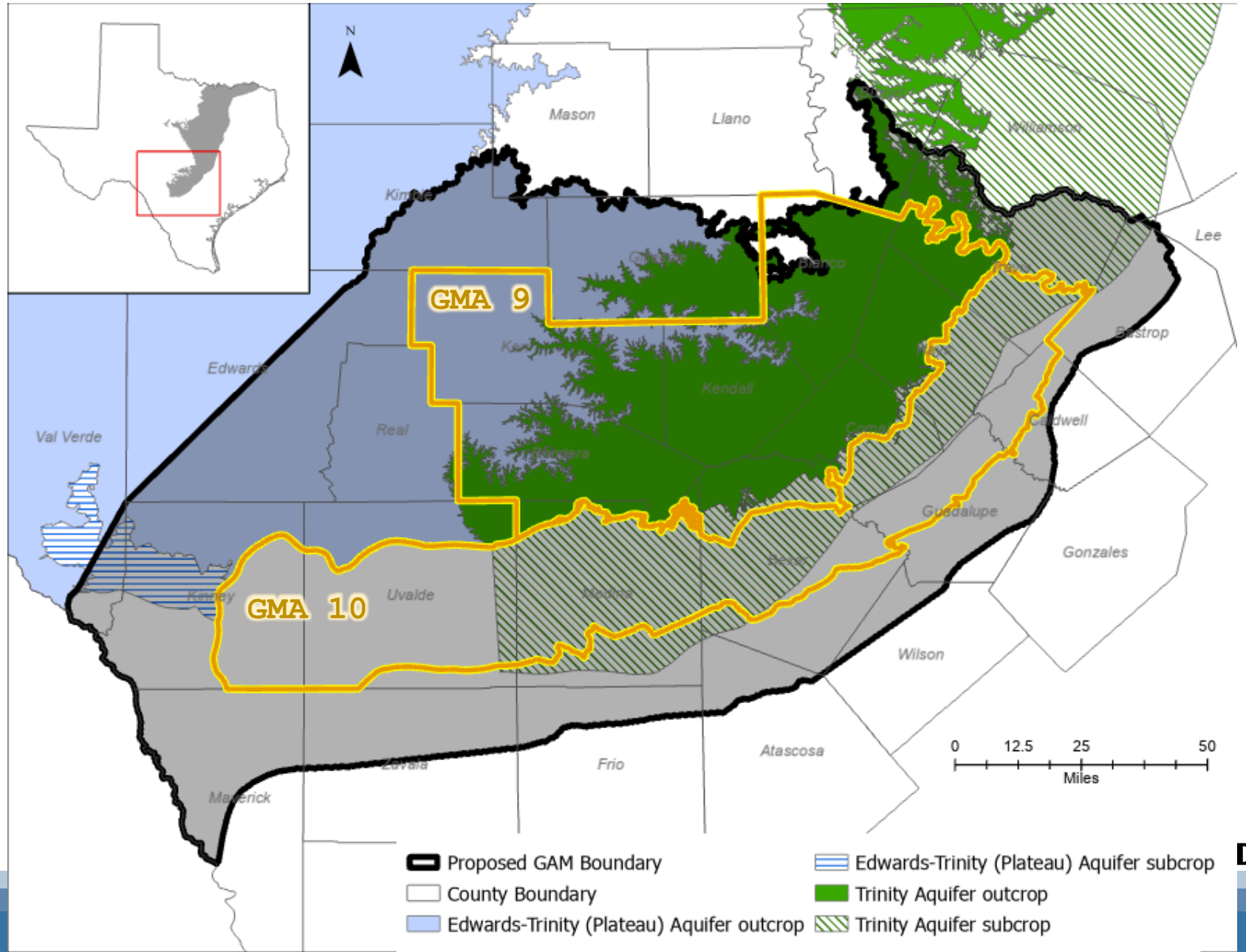
# Proposed Extent

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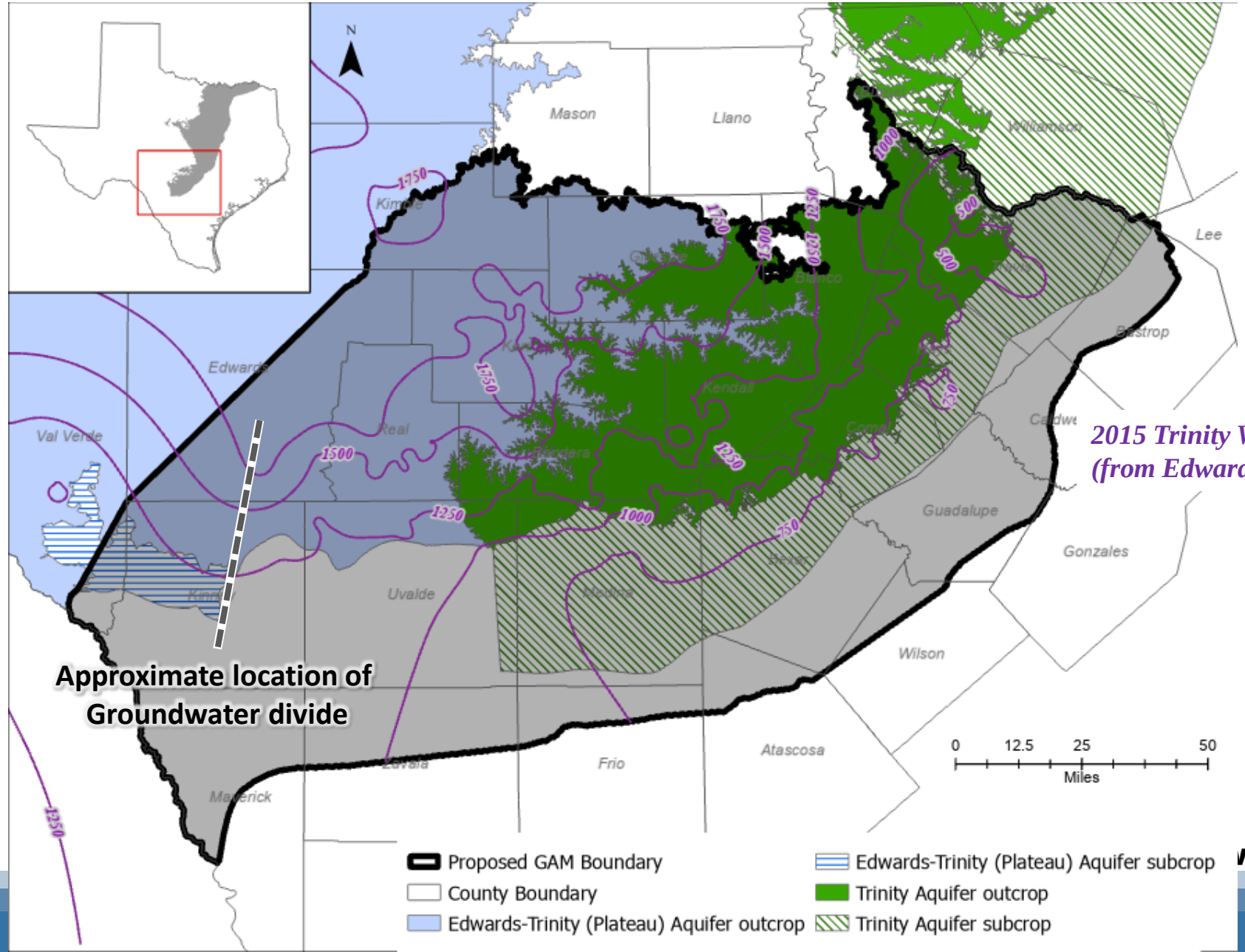
# Proposed Extent




*2015 Trinity Water Level (from Edwards & Trinity Regional GAM)*

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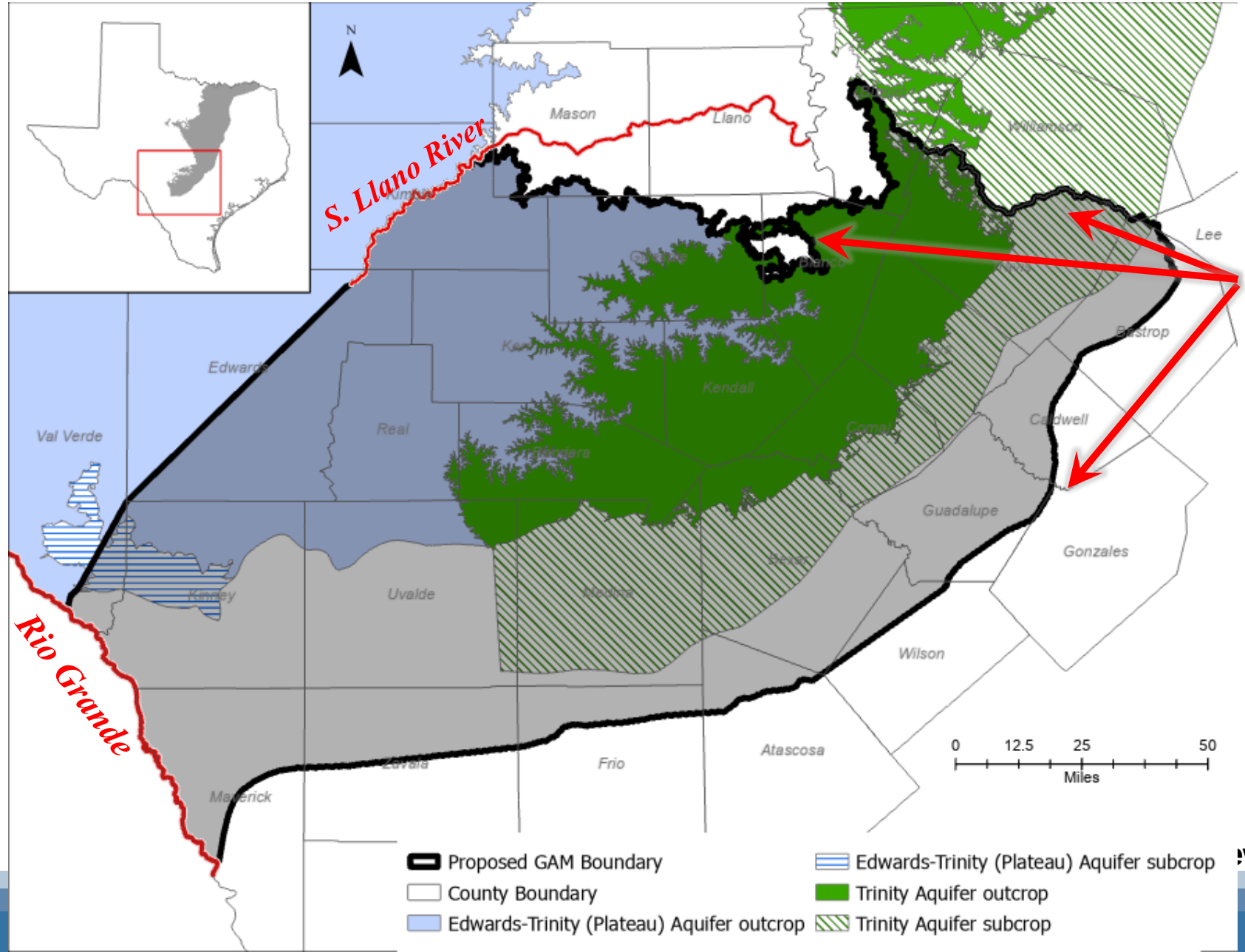
# Proposed Extent




***Boundary of Edwards & Trinity Regional GAM***

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# Proposed Layer Extents

| | | | |
|---|---|---|---|
| Rivers/Alluvium | Rivers/Alluvium | Rivers/Alluvium | 1 |
| | -- | Younger Units* | 2 |
| Edwards | -- | Edwards | 3 |
| Upper Trinity | Upper Trinity | Upper Trinity | 4 |
| Middle Trinity | Middle Trinity | Middle Trinity | 5 |
| Hammett Shale | Hammett Shale | Hammett Shale | 6 |
| Lower Trinity | Lower Trinity | Lower Trinity | 7 |

**Upper Cretaceous + Overlying units*

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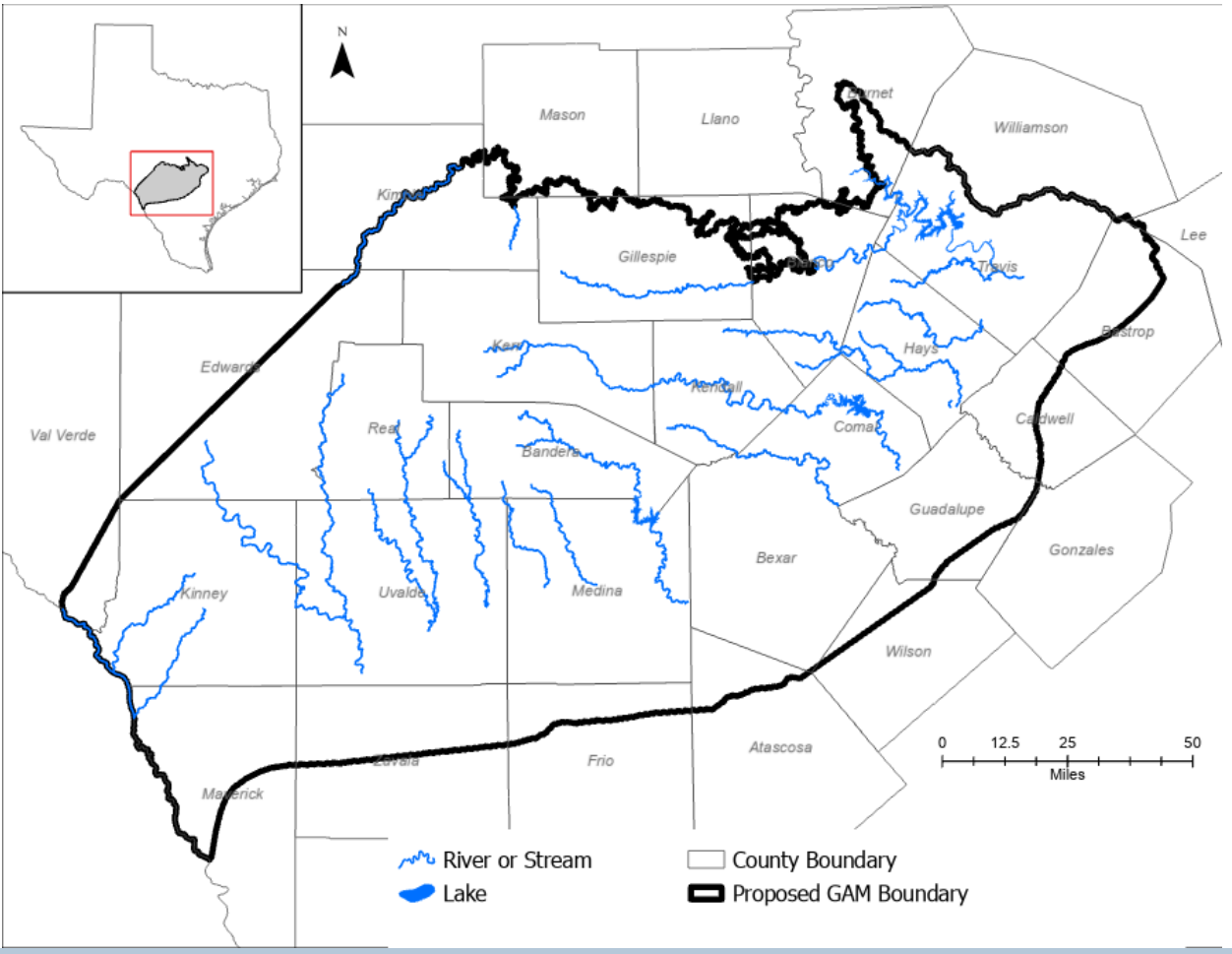
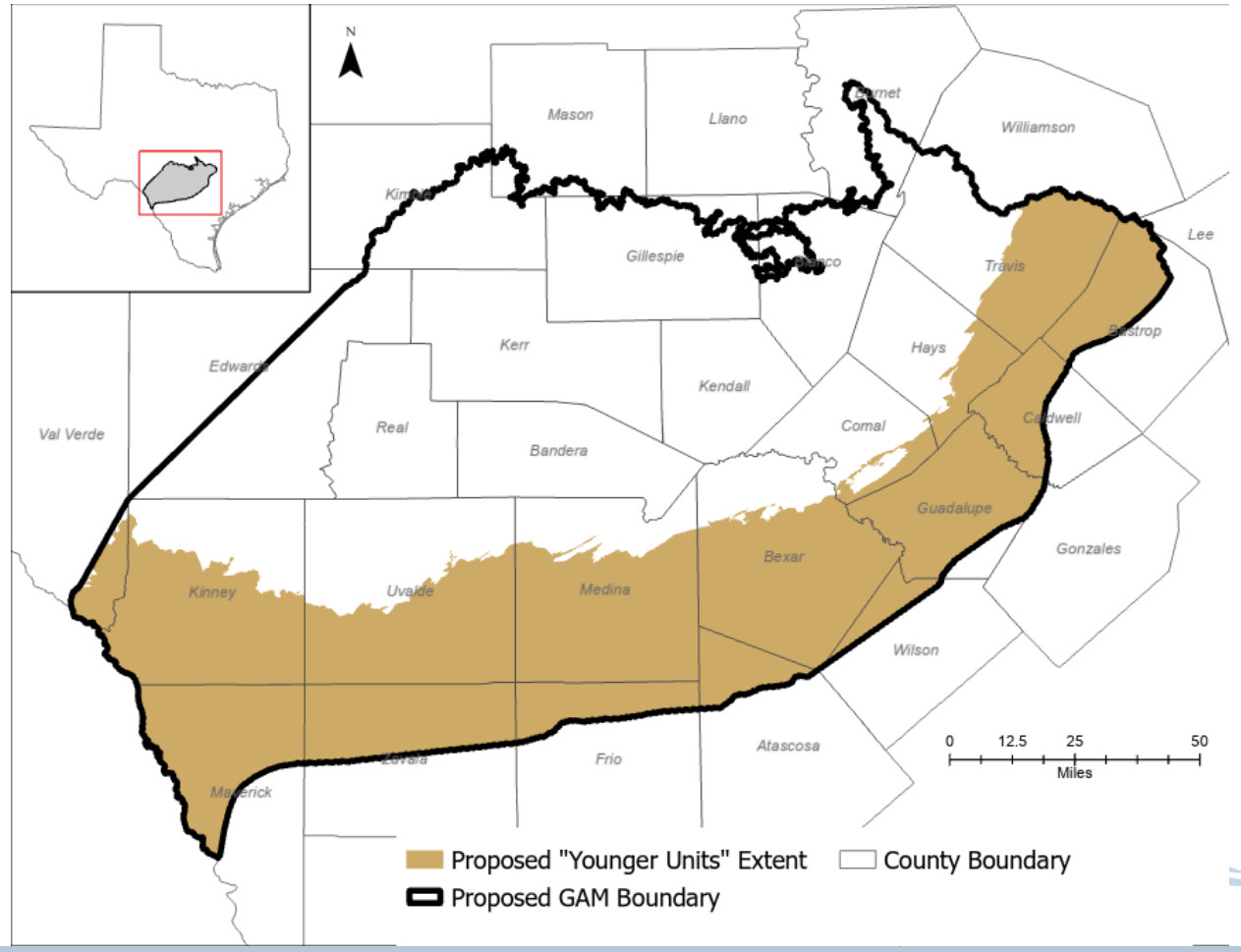
# Proposed Layer Extents

Layer 1 – Rivers and Alluvium

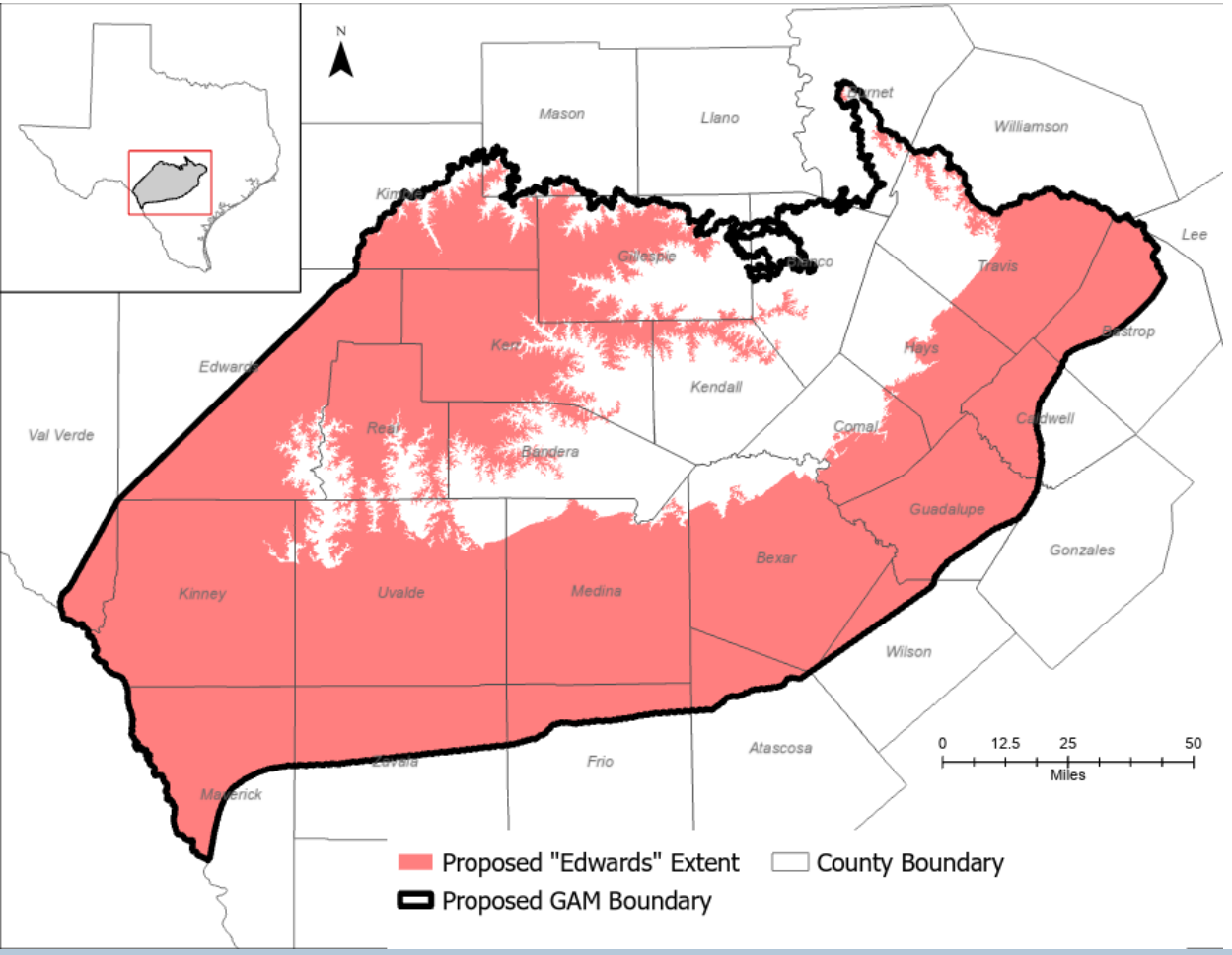



Layer 2 – Younger Units

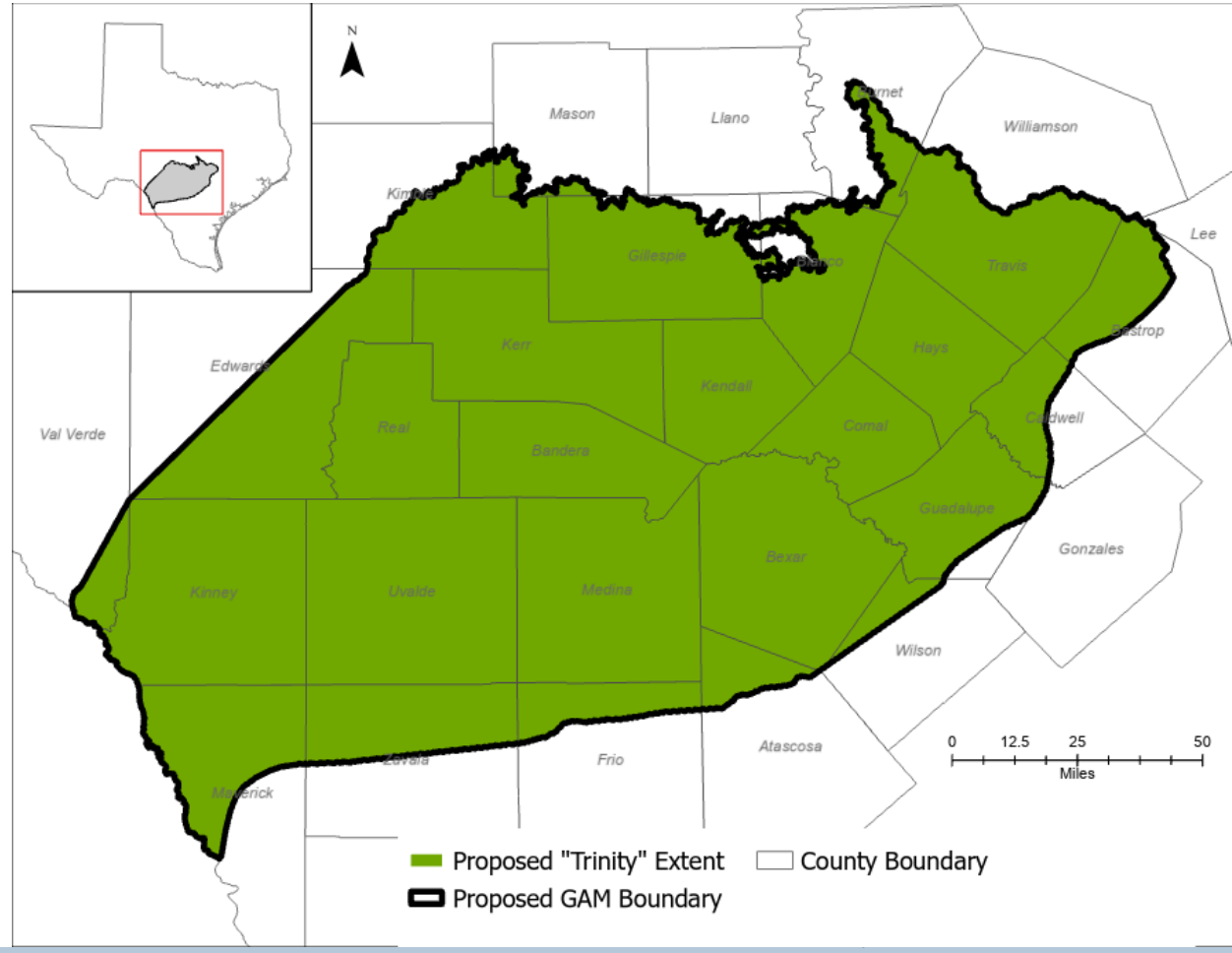


# Proposed Layer Extents

Layer 3 – Edwards

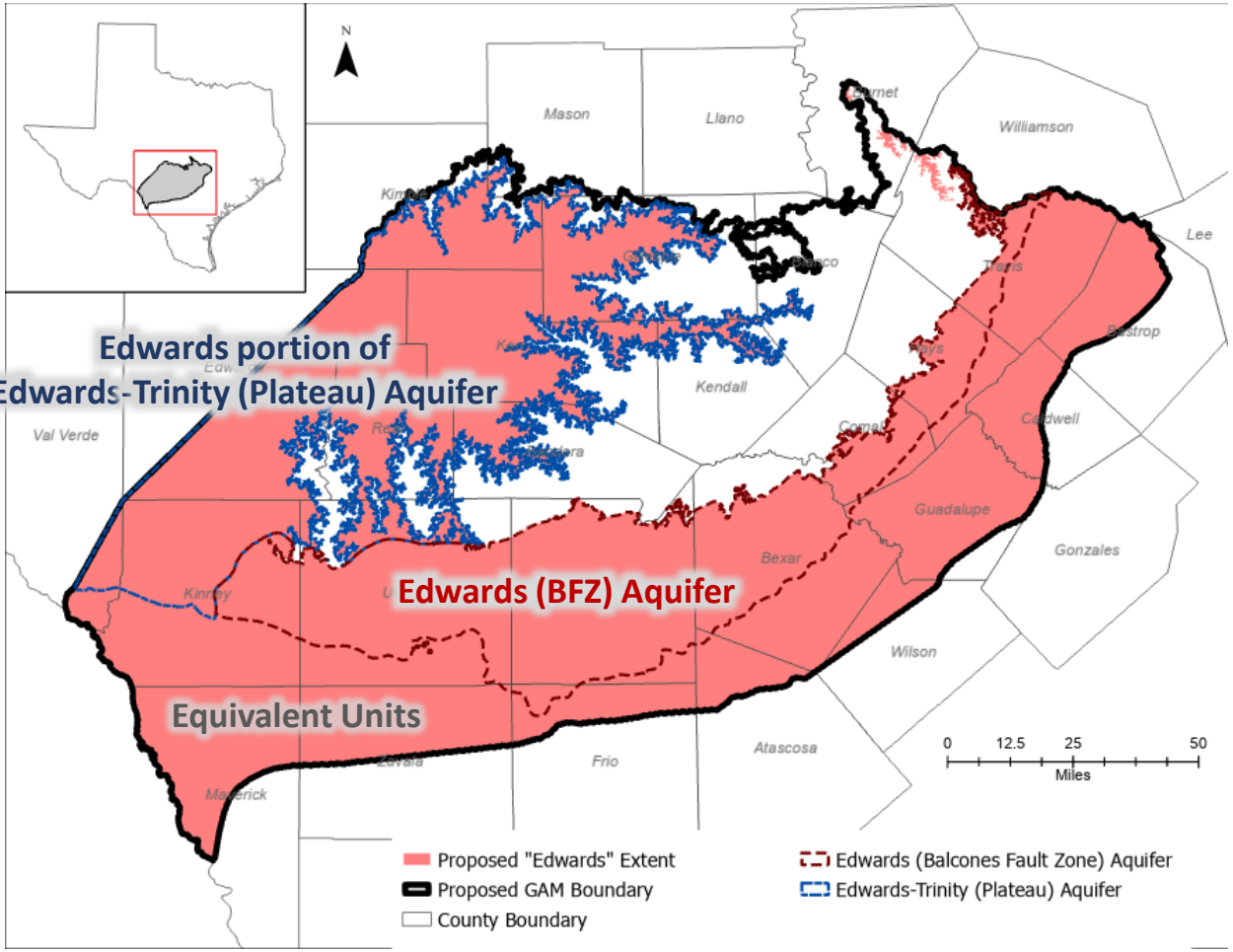



Layer 4 through 7 - Trinity

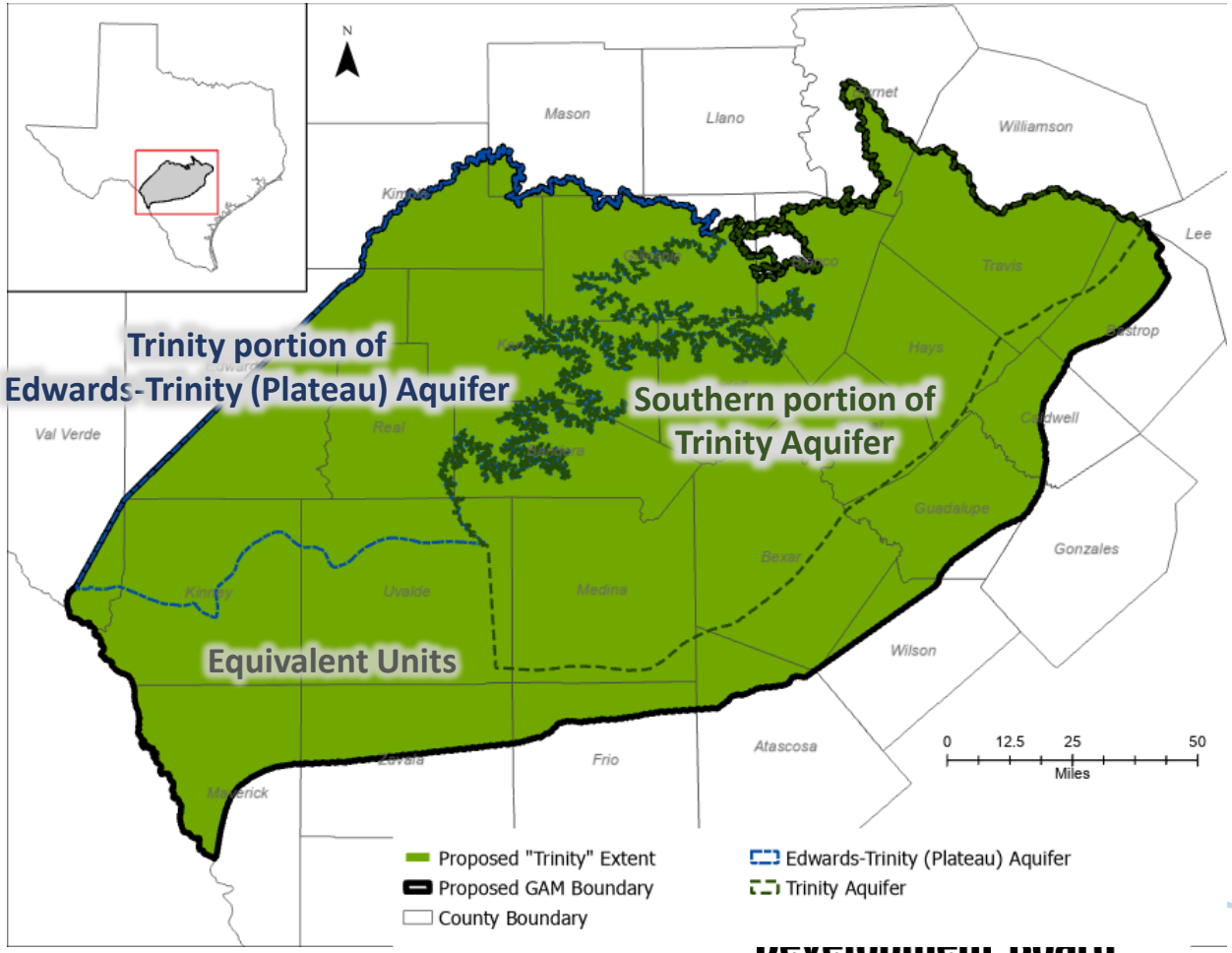


# Proposed Layer Extents

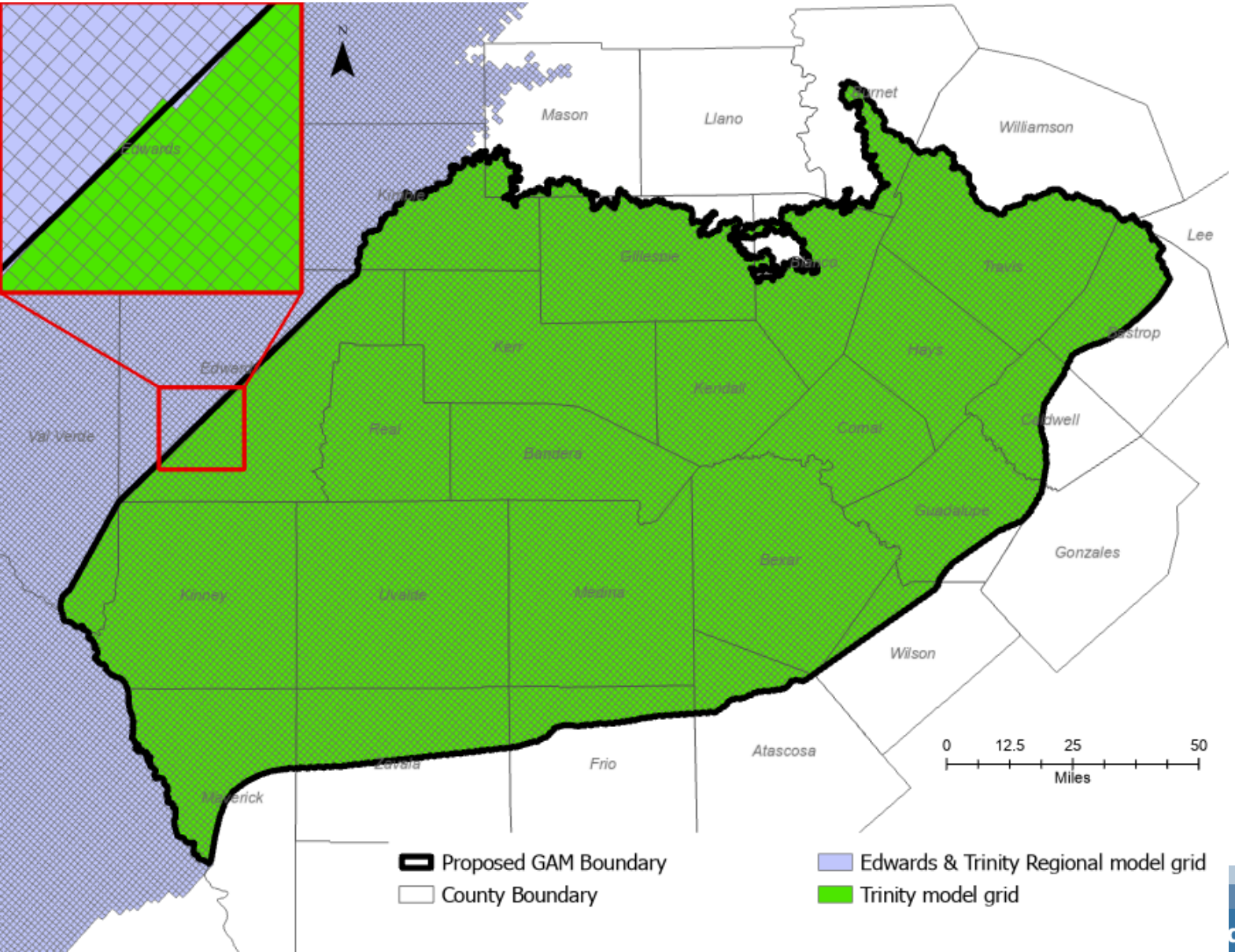
Layer 3 – Edwards




Layer 4 through 7 - Trinity

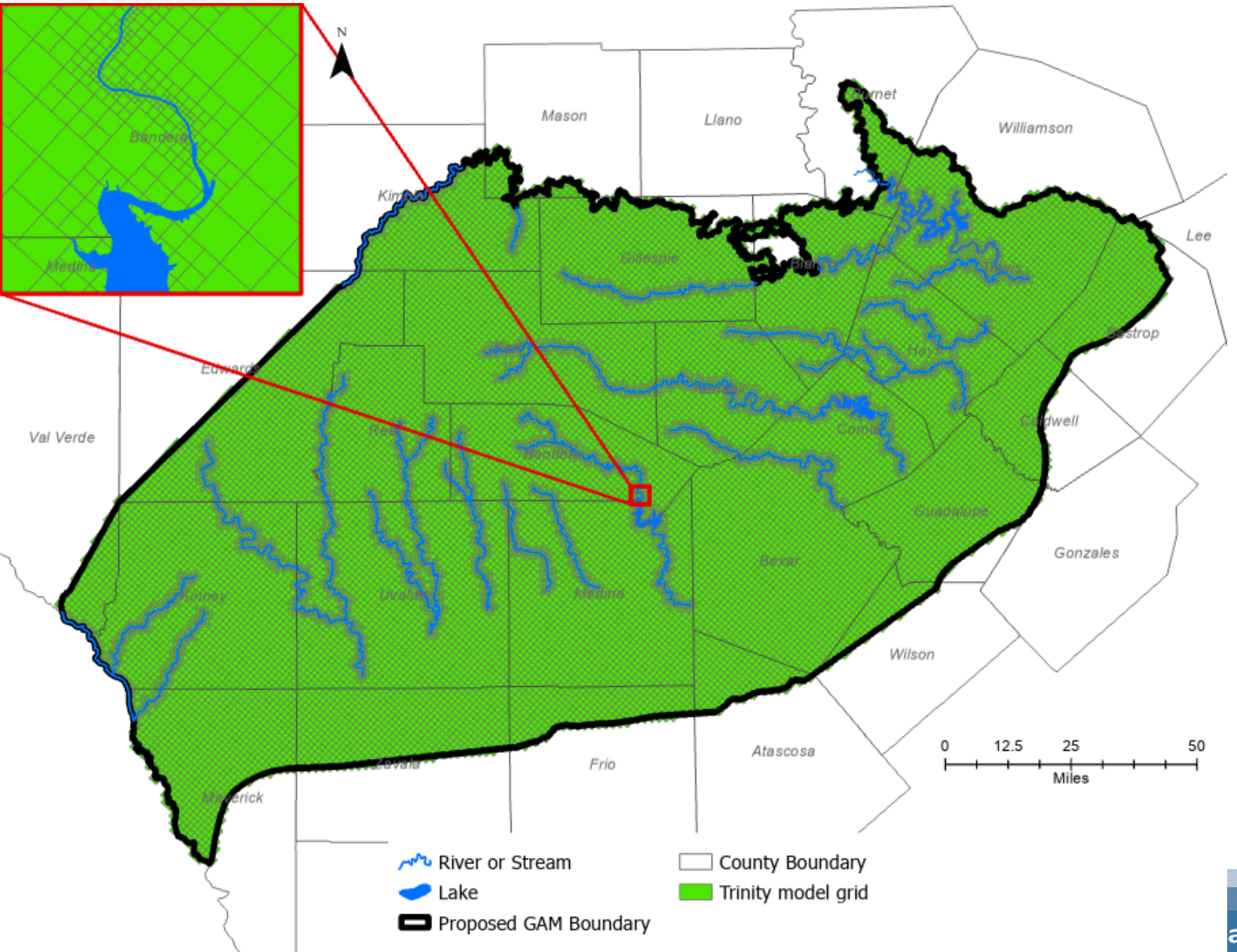


# Proposed Model Cell Size




- TWDB GAM standards require grid cell size no bigger than 1 square mile
- Grid will be oriented at the same angle as the Edwards and Trinity Regional GAM

# Proposed Refinement




- Quadtree refinement progressively divides cells into 4 equal parts
- Refinement around streams ($^1/_{16}$ mile) and lakes ($^1/_4$ mile)
- Facilitates local groundwater-surface water interaction projects in future

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# Future Steps

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# Future Steps - Grid

- Test various model extents, grid resolutions and refinement locations
- Convert hydrostratigraphic layers to model layers
  - ➢ Validate connections across steep elevation changes (faults, eroded valleys)
  - ➢ Optimize size/cell counts for computational efficiency

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# Future Steps – Model Packages

- Assign Boundary Conditions
  - Flow between aquifers : Edwards-Trinity [Plateau], Trinity, Edwards [BFZ]
  - Surface water/groundwater interaction

- Recharge
  - Compare 2018 report vs. new Recharge project (for 2022 Regional model)

- Discharge (pumping)
  - Compare 2018 report vs. new Pumping project (for 2022 Regional model)
  - Incorporate input from GMAs

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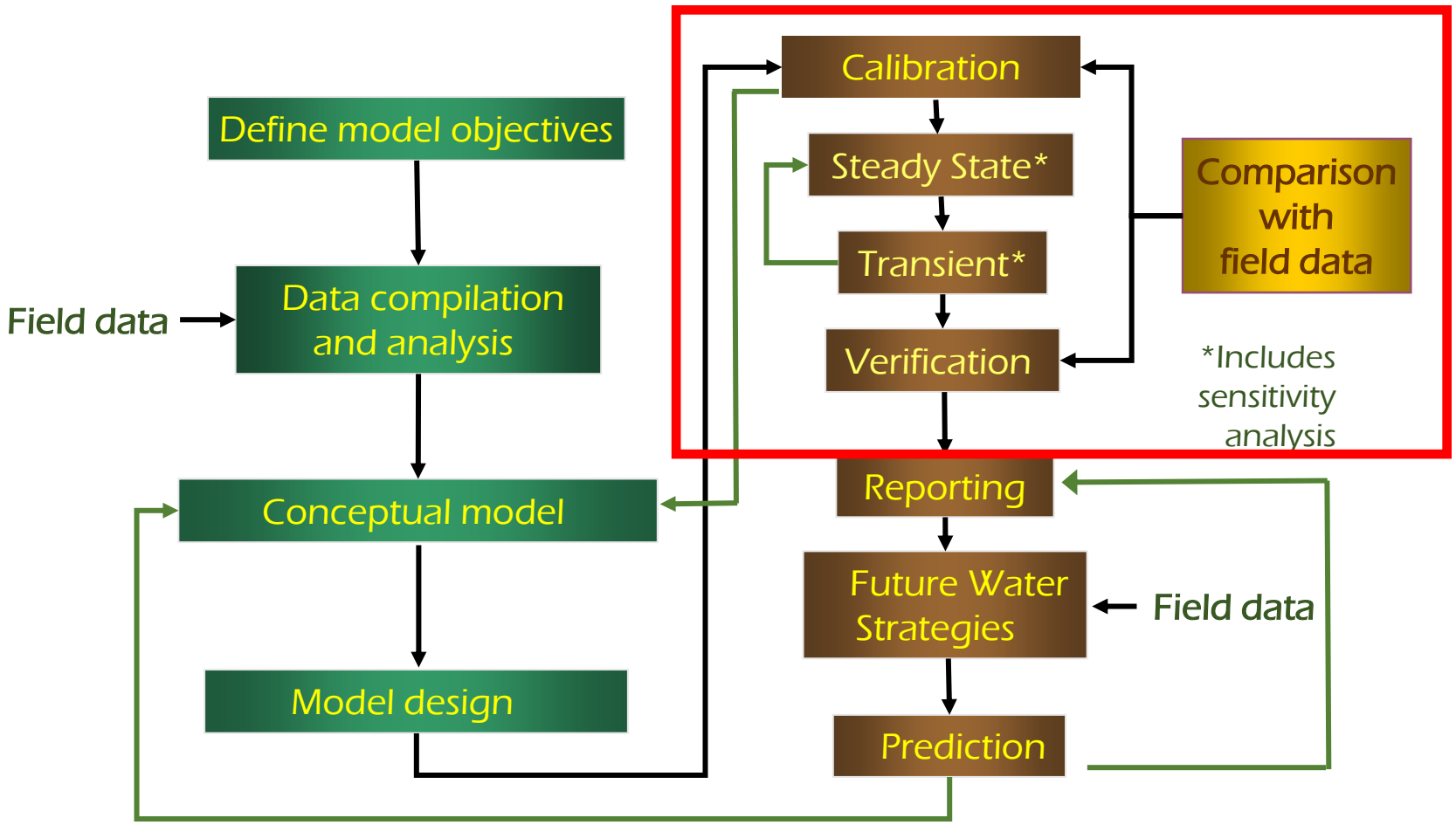
# Modeling Process



# Calibration

- Adjusting the model to best reproduce historical conditions
- Comparison of field observations to model results
  - Water levels
  - potentially baseflow/springflow
- Steady-state :
  - natural balanced condition
  - often used to represent pre-development conditions
- Transient:
  - Conditions changing over time
  - Proposed time period : **1980 – 2020**
  - Proposed stress periods: **annual**

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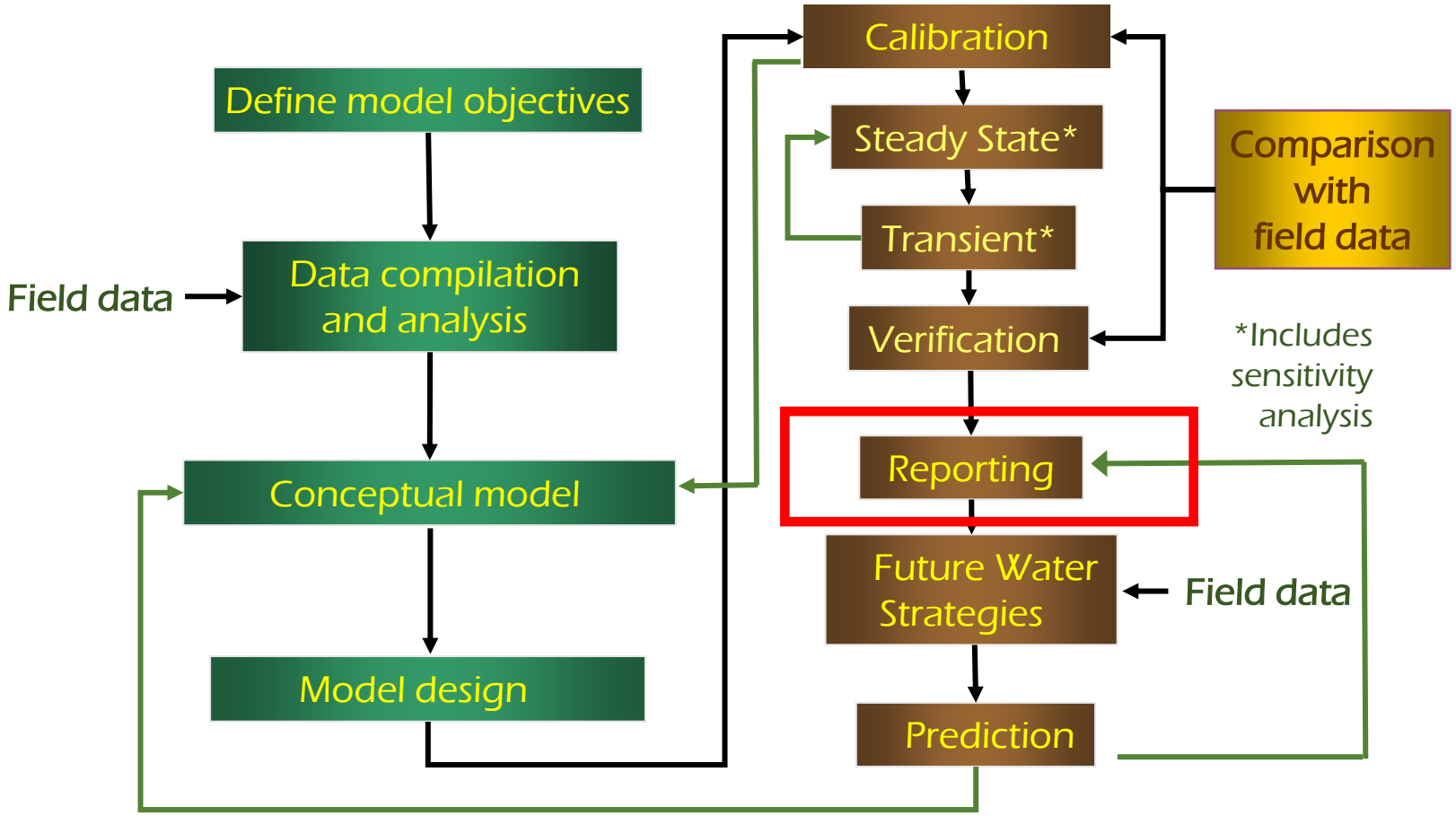
# Modeling Process




*** Last step in historical modeling process**

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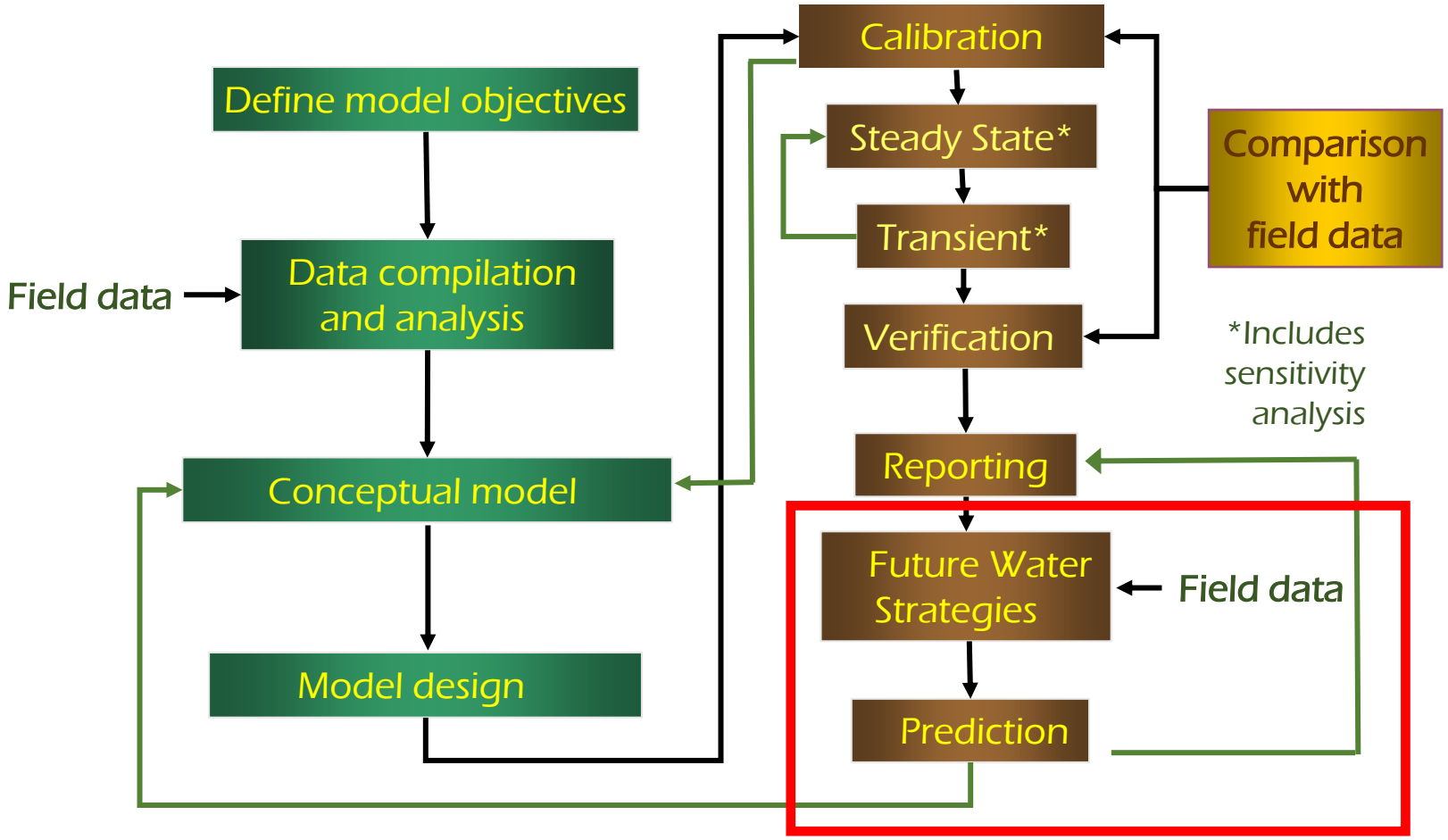
# Modeling Process

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# Predictive Model

- Predictive model is an extension of the TWDB historical model
- Usually, GMAs will independently construct their own predictive model for planning purposes
- Extending the model involves assumptions for model elements that change over time
- Predictive pumping files are hard to provide without in-depth information from the GMAs regarding scenarios to test (future water projects, pumping locations, etc.)
- If stakeholder interest, TWDB could provide some baseline predictive files for factors like recharge or streamflow.
  - Ex: drought scenario & average scenario

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# Stakeholder Input

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# Data Request

- Request:
  - Post-2015 unpublished data
    - Water levels
      - not in TWDB Groundwater database
      - Assigned to an aquifer (or with screen/depth information) and well location
    - Pump test results/ hydraulic property data
      - Hydraulic conductivity (permeability), Transmissivity, Storage
      - Example:  groundwater availability certifications for subdivisions
  - Review TWDB county estimates of Trinity pumping divided by unit
- Deadline:
  - **September 2023**

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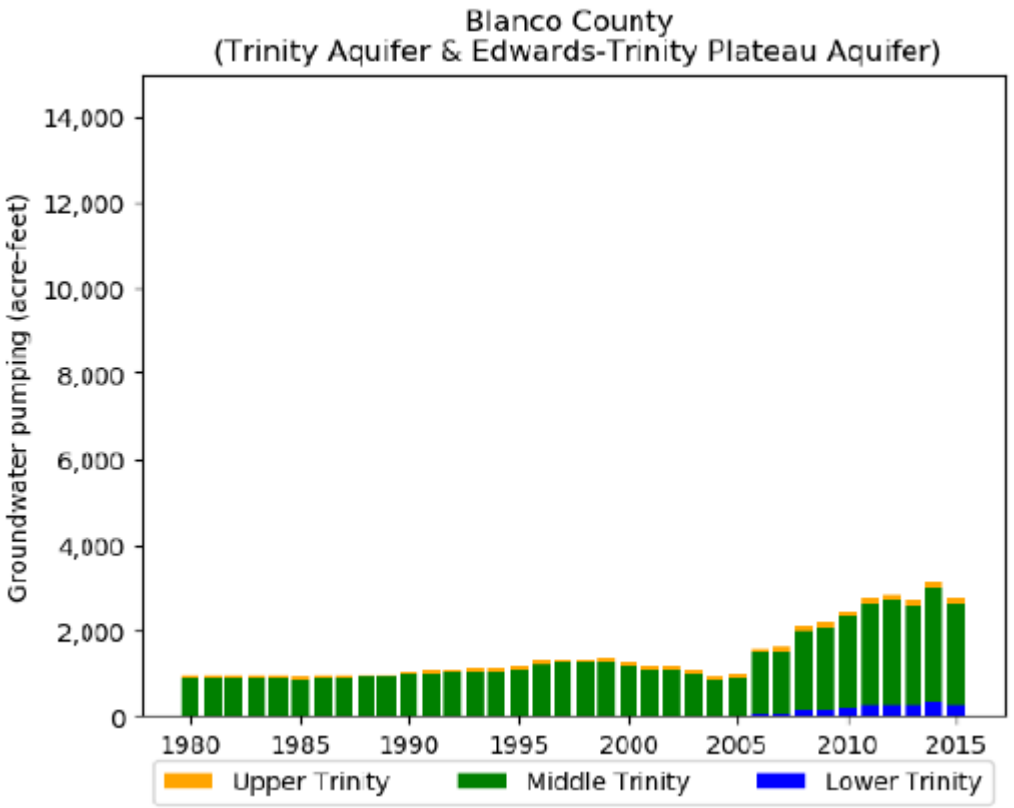
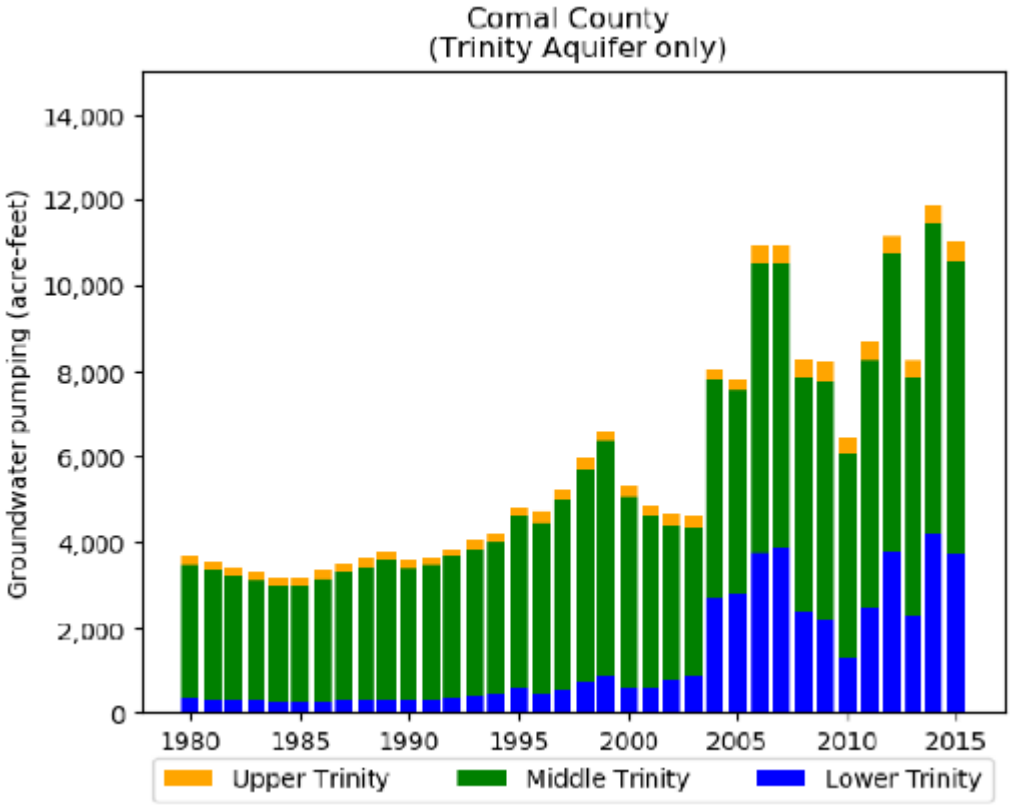
# Pumping Review

- Example of county pumping estimate

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# Pumping Review

- Example of county pumping estimate

| County | Year | Percent of Edwards-Trinity Plateau Aquifer pumping sourced from each hydrostratigraphic unit | | | Percent of Trinity Aquifer pumping sourced from each hydrostratigraphic unit | | |
|---|---|---|---|---|---|---|---|
| | | Upper Trinity | Middle Trinity | Lower Trinity | Upper Trinity | Middle Trinity | Lower Trinity |
| Blanco | 1980 | 25% | 75% | -- | -- | 97% | 3% |
| | 1990 | 25% | 75% | -- | -- | 98% | 2% |
| | 2000 | 25% | 75% | -- | -- | 97% | 3% |
| | 2010 | 8% | 83% | 8% | 0.4% | 86% | 14% |
| Comal | 1980 | -- | -- | -- | -- | 80% | 20% |
| | 1990 | -- | -- | -- | -- | 82% | 18% |
| | 2000 | -- | -- | -- | -- | 78% | 22% |
| | 2010 | -- | -- | -- | 0.1% | 47% | 53% |

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# Schedule

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# Project Tasks and Proposed Schedule

| Project Task | 2023 | | | | | | 2024 | | | | | | | | | | | | 2025 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M |
| 1.0 Project Management | | | | | | | | | | | | | | | | | | | | | | | |
| 2.0 Stakeholder Communication | | | | | | | | | | | | | | | | | | | | | | | |
| *2.1 Stakeholder Advisory Forums* | x | | | | | | | | | | | x | | | | | | x | | | | | |
| 3.0 Model Development | | | | | | | | | | | | | | | | | | | | | | | |
| *3.1 Data Collection and Conceptual Model* | | | | | | | | | | | | | | | | | | | | | | | |
| *3.2 Model Design* | | | | | | | | | | | | | | | | | | | | | | | |
| 4.0 Model Calibration | | | | | | | | | | | | | | | | | | | | | | | |
| *4.1 Steady-State Calibration* | | | | | | | | | | | | | | | | | | | | | | | |
| *4.2 Transient Calibration* | | | | | | | | | | | | | | | | | | | | | | | |
| *4.3 Sensitivity Analysis* | | | | | | | | | | | | | | | | | | | | | | | |
| 5.0 Documentation | | | | | | | | | | | | | | | | | | | | | | | |
| *5.1 Data Model Documentation* | | | | | | | | | | | | | | | | | | | | | | | |
| *5.2 Reporting* | | | | | | | | | | | | | | | | Draft | | | | | | Final | |

May 2026:
Proposed DFCs

Jan 2027:
Explanatory Report

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# Contact Information

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jevon.harding@twdb.Texas.gov

**Daryn Hardwick, Ph.D.**
Manager of Groundwater Modeling Department
512-475-0470
daryn.hardwick@twdb.texas.gov

Web information:
https://www.twdb.texas.gov/groundwater/models/gam/trnt_h/trnt_s.asp

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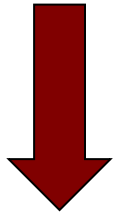
# What is Groundwater Availability?

Science + Policy = Groundwater Availability



GAM or other tool + Desired Future Conditions = Modeled Available Groundwater

**Goal: informed decision-making**

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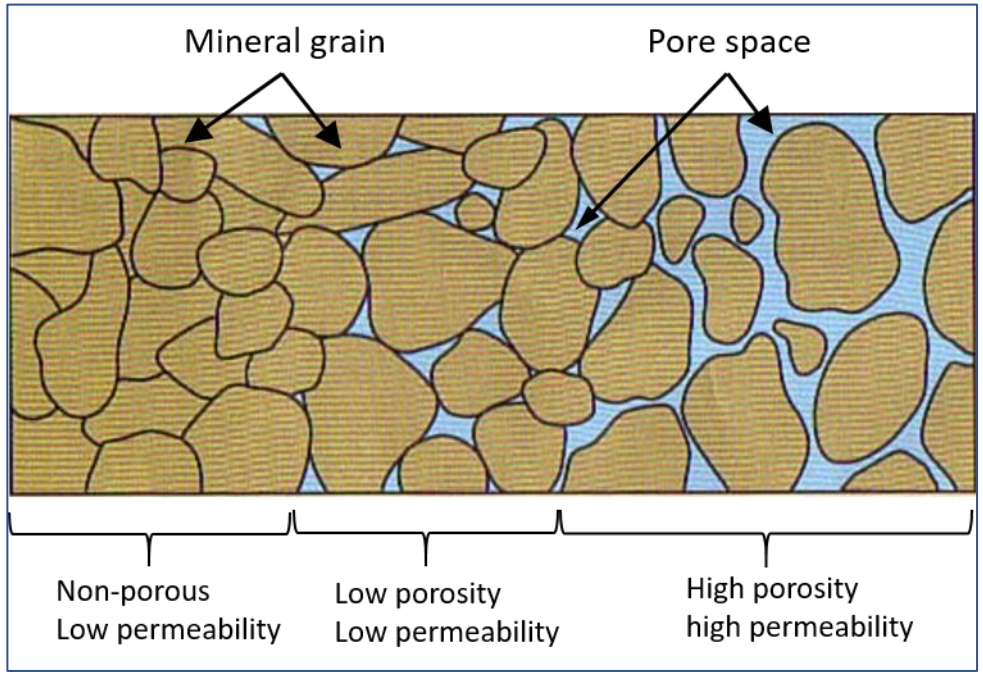
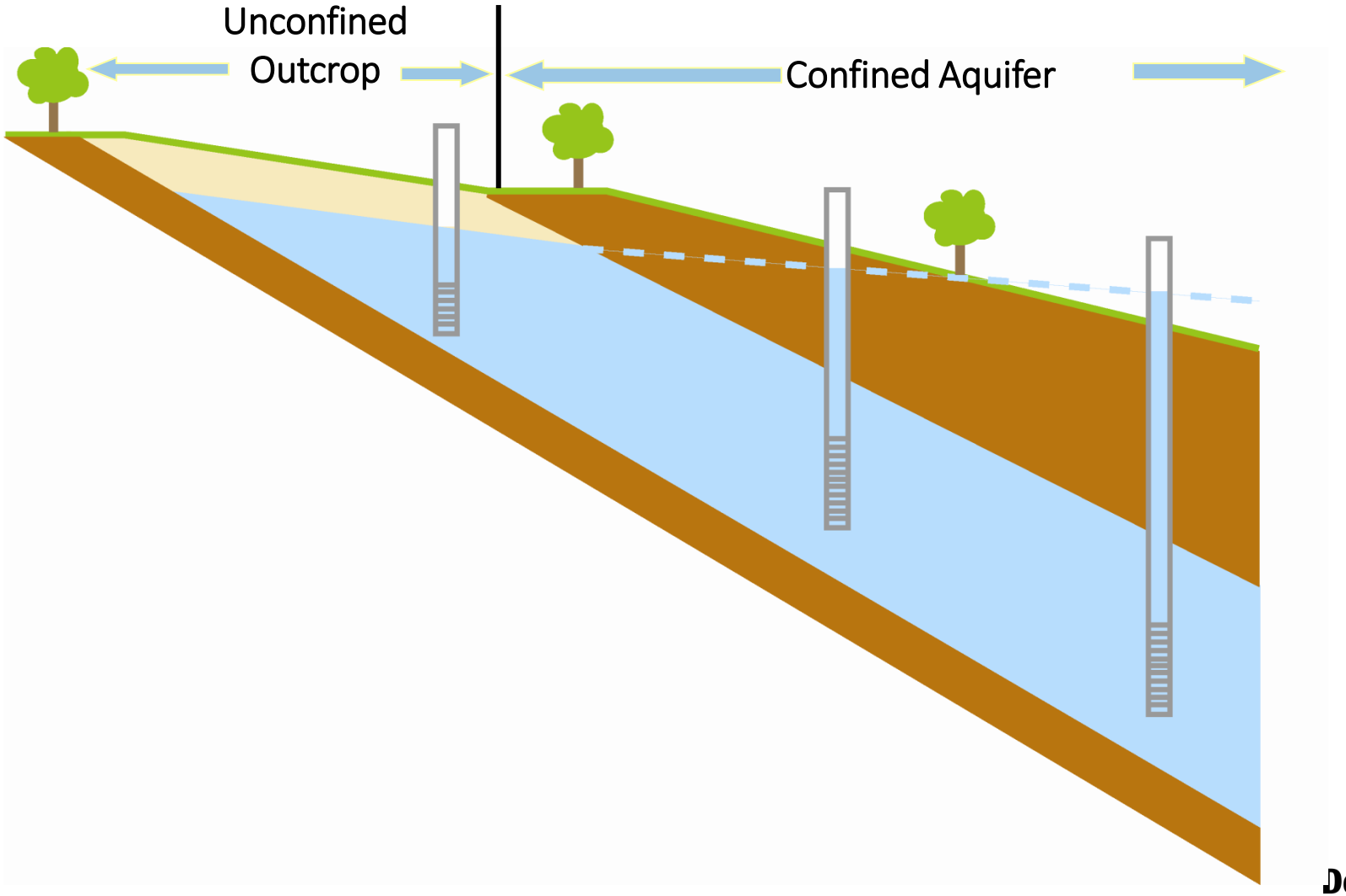
# Hydraulic Properties




**Clay & Silt → Fine Sand → Coarse Sand → Gravel**

*https://sta.uwi.edu/eng/chemical/geomechanics-and-rock-physics-research-opportunities-and-services*

# Confined/Unconfined Aquifer

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