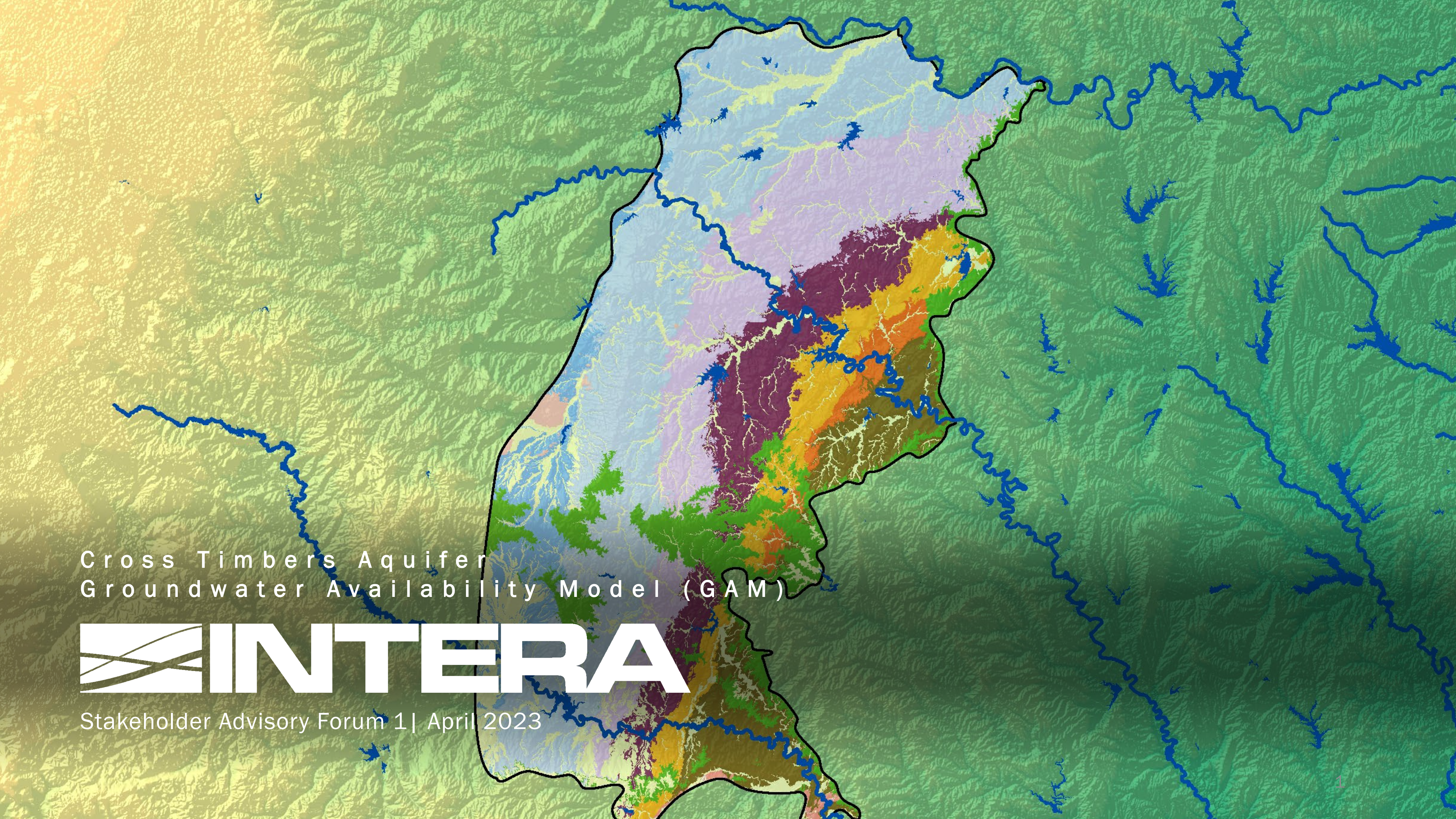

Cross Timbers Aquifer Groundwater Availability Model (GAM)

INTERA

Stakeholder Advisory Forum 1| April 2023

Project Team & Responsibilities

Texas Water Development Board

The INTERA Team
[1] INTERA
[2] LRE Water

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*Texas licensed professional

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Micaela Pedrazas[2]
Michelle Pedrazas[1]
Hai Pham, PhD[1]

INTERA

- Prime Contractor
- Project manager and technical coordination
- Technical Lead for model structure, recharge and surface water, calibration, and sensitivity analysis

LRE WATER
CONNECTING WATER TO LIFE

- INTERA Subcontractor
- Technical lead on development of pumping dataset

Study Objectives

1. Improve conceptual understanding of the Cross Timbers Aquifer and its future

2. Provide tool for assessing desired future condition of the aquifer (DFC)/modeled available groundwater (MAG)

3. Create a numerical model which can be used for water planning by both public and private entities

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

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

Groundwater Availability:

Where Policy Meets Science

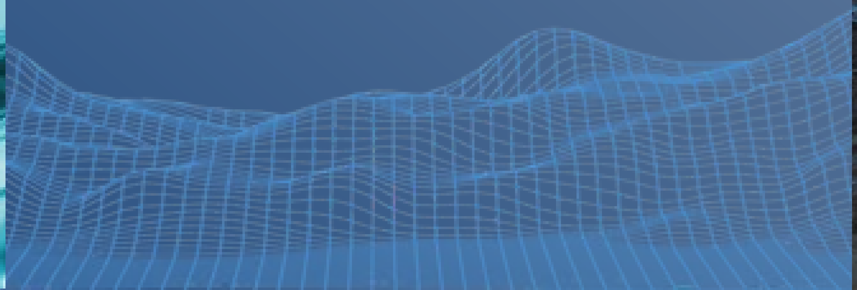
Desired Future Conditions (DFCs)

+

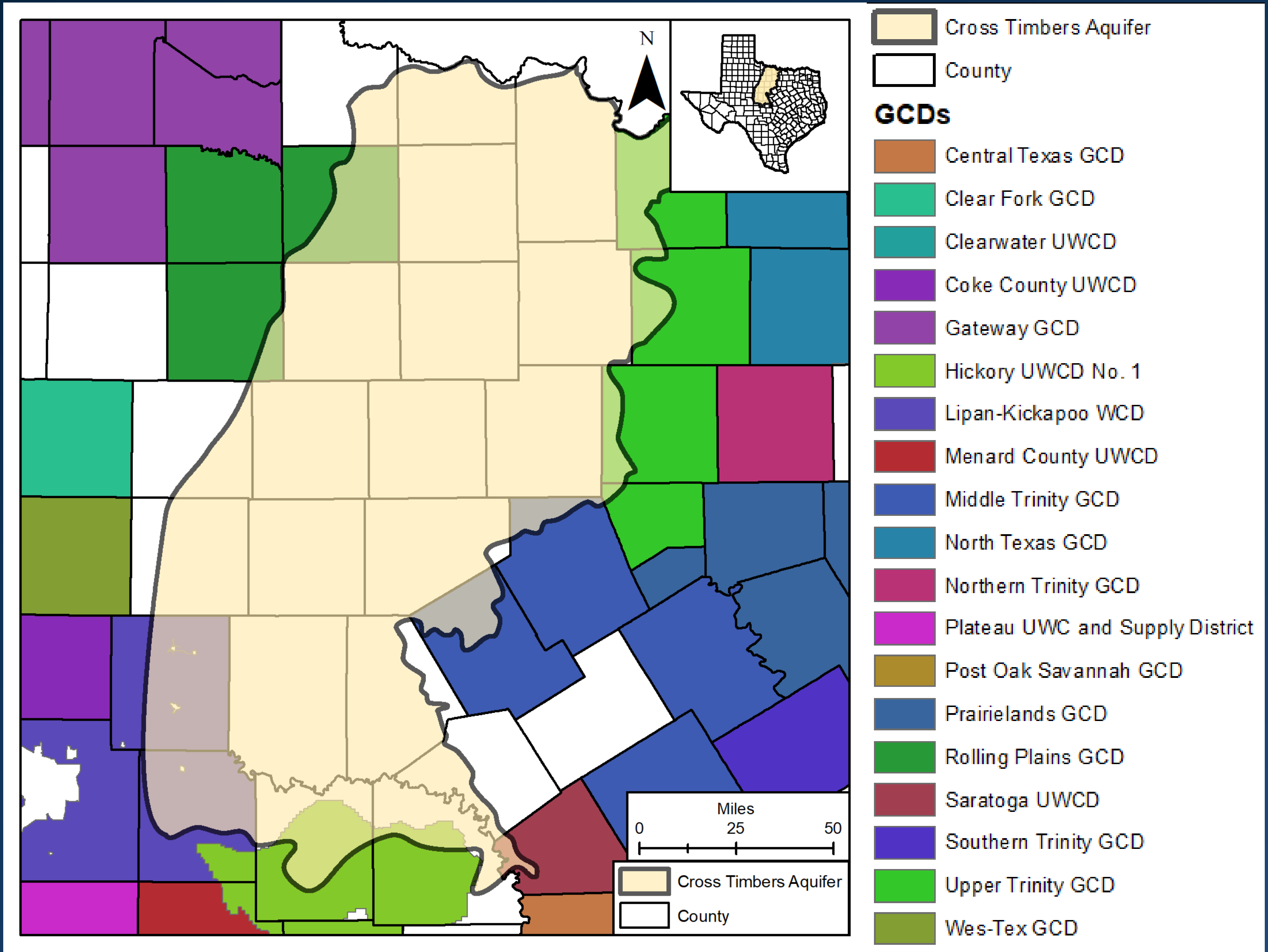
Groundwater Availability Model (GAM)

=

Modeled Available Groundwater (MAG)



Groundwater Conservation Districts



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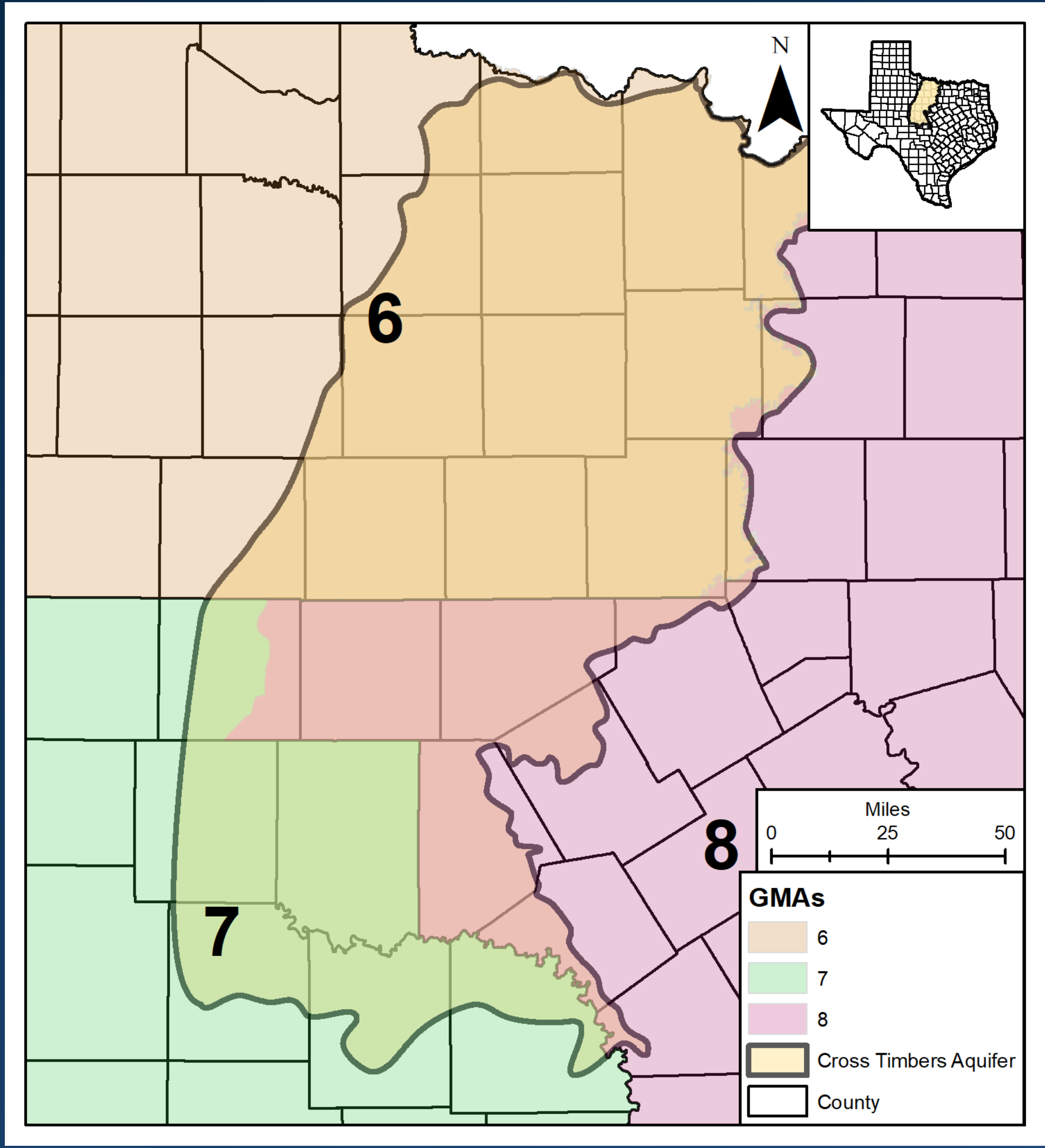
Groundwater Management Agencies



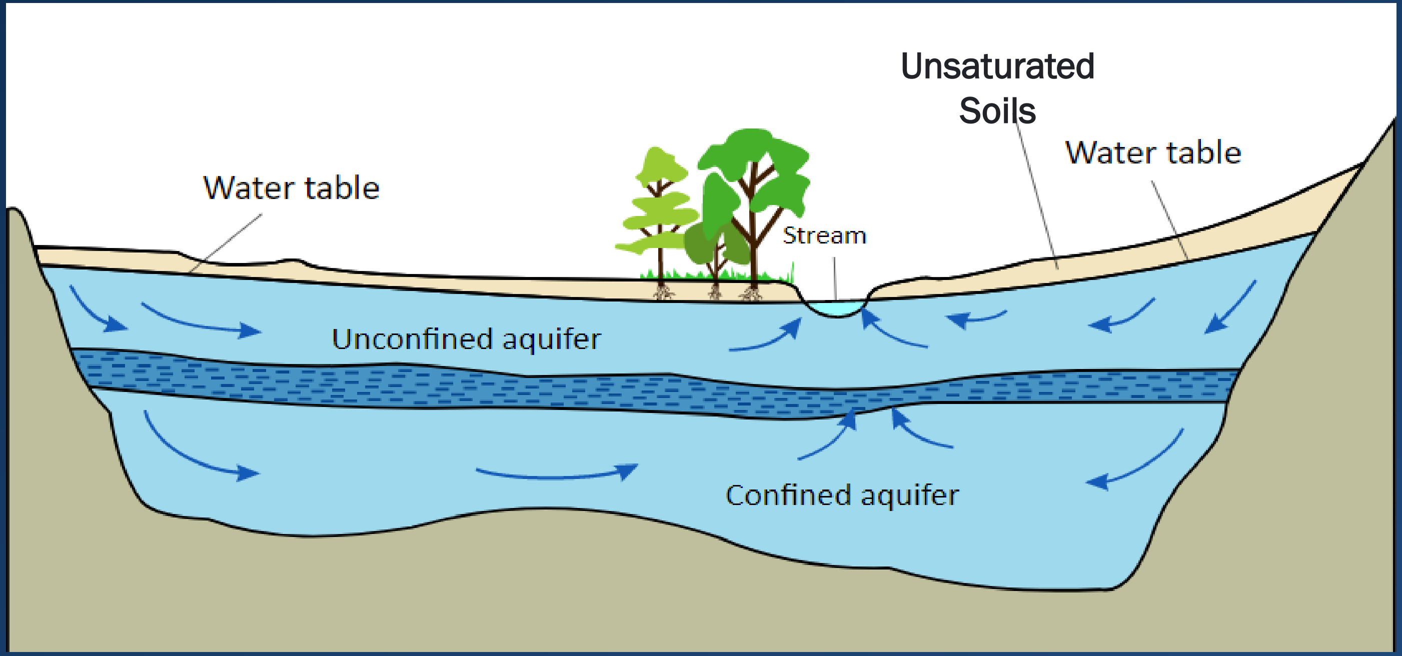
Groundwater Modeling

Aquifers and Confining Units

- An <u>aquifer</u> is a body of permeable rock which contains or transmits an economically viable quantity of groundwater

- Aquifers can be either <u>unconfined</u> (in communication with surface air pressure) or <u>confined</u> (isolated from surface air pressure)

- A <u>confining unit</u> is an impermeable rock layer which prevents flow between rock layers



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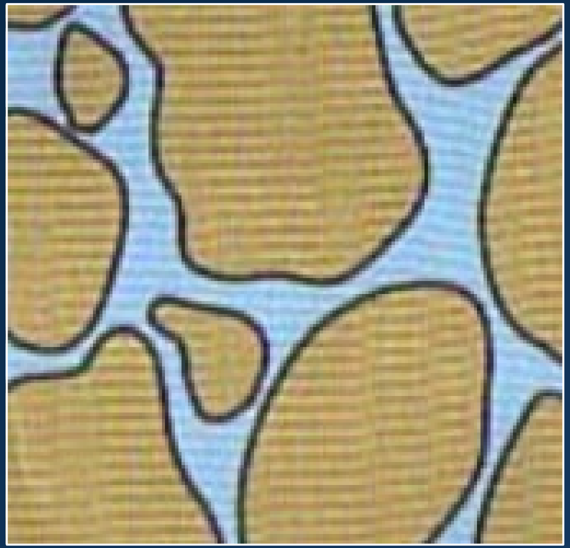
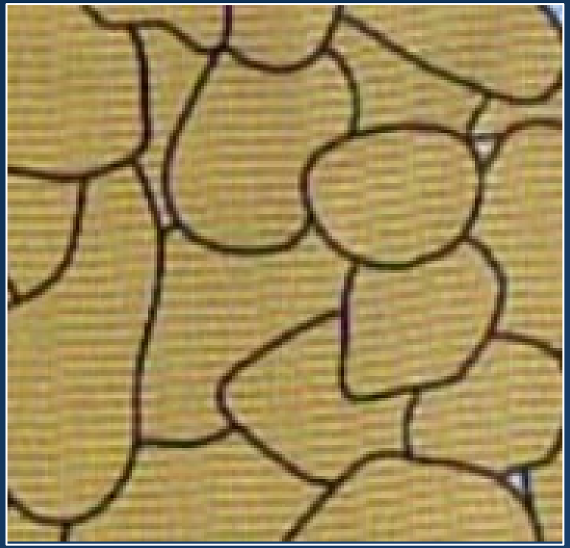
Aquifer Properties

- Hydraulic conductivity
  - the ease with which water is conducted through a porous material
  - related to permeability and transmissivity

Gravel and Coarse Sand



Finer Sands



Clay and Silt

More Permeable
Higher Conductivity

Less Permeable
Lower Conductivity

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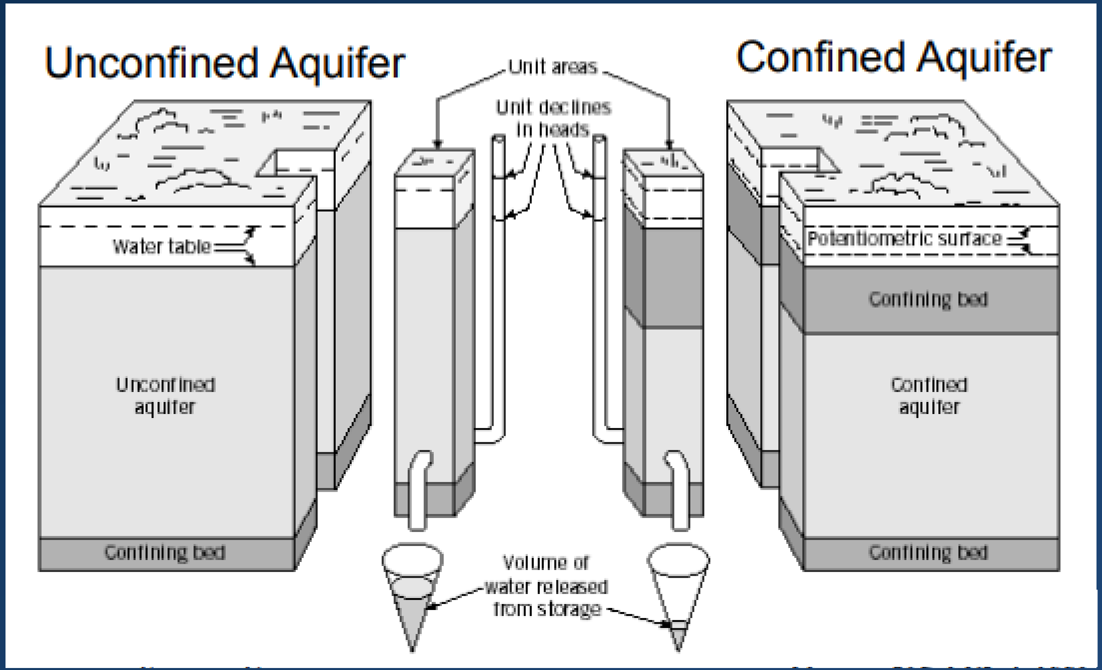
Aquifer Properties

- Storativity
  - The volume of water released from a confined aquifer per unit area of the aquifer and per unit reduction in hydraulic head

- Specific Yield
  - The volume of water released from an unconfined aquifer per unit area of the aquifer and per unit reduction in water table elevation

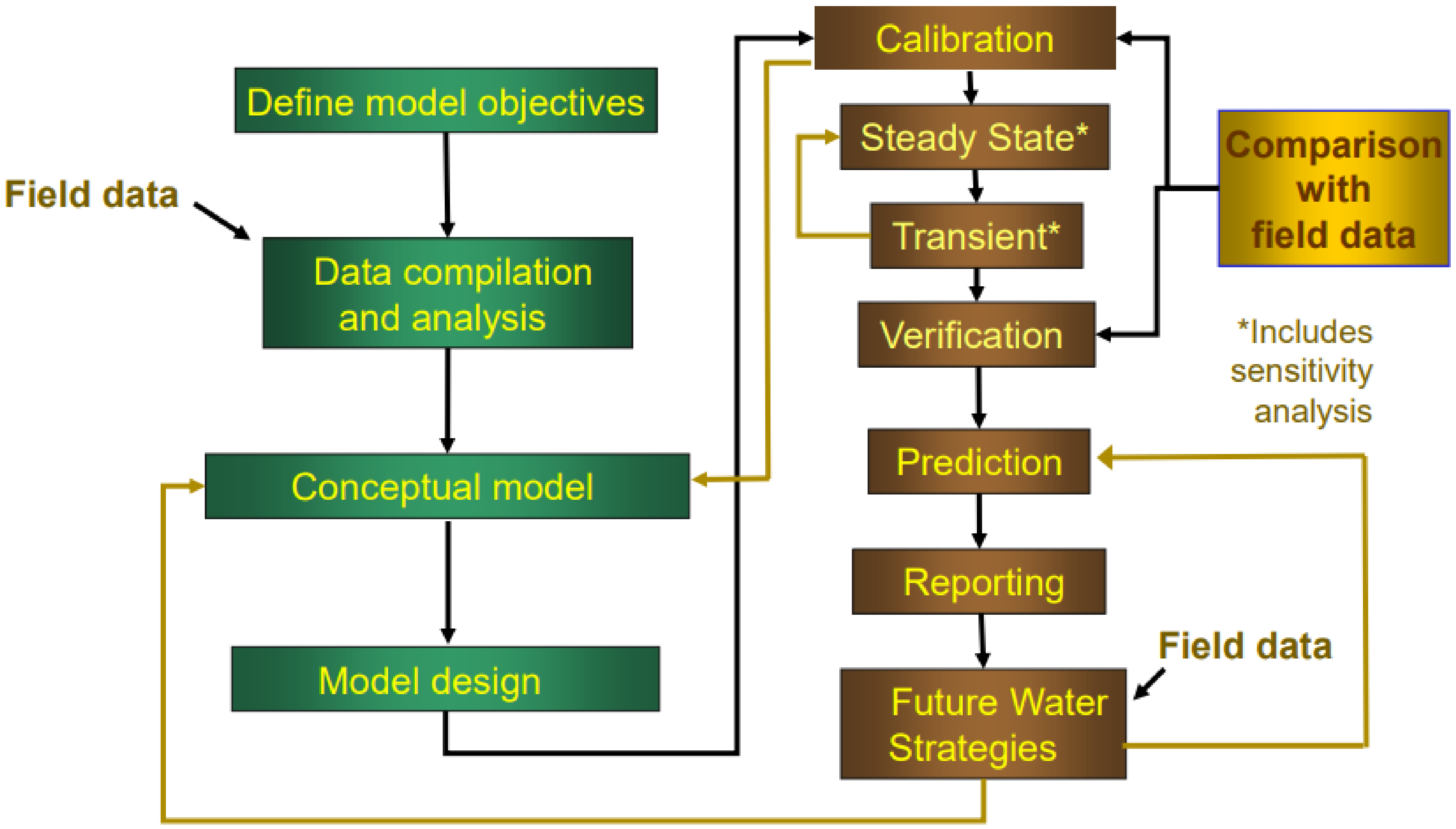


Heath (1983)

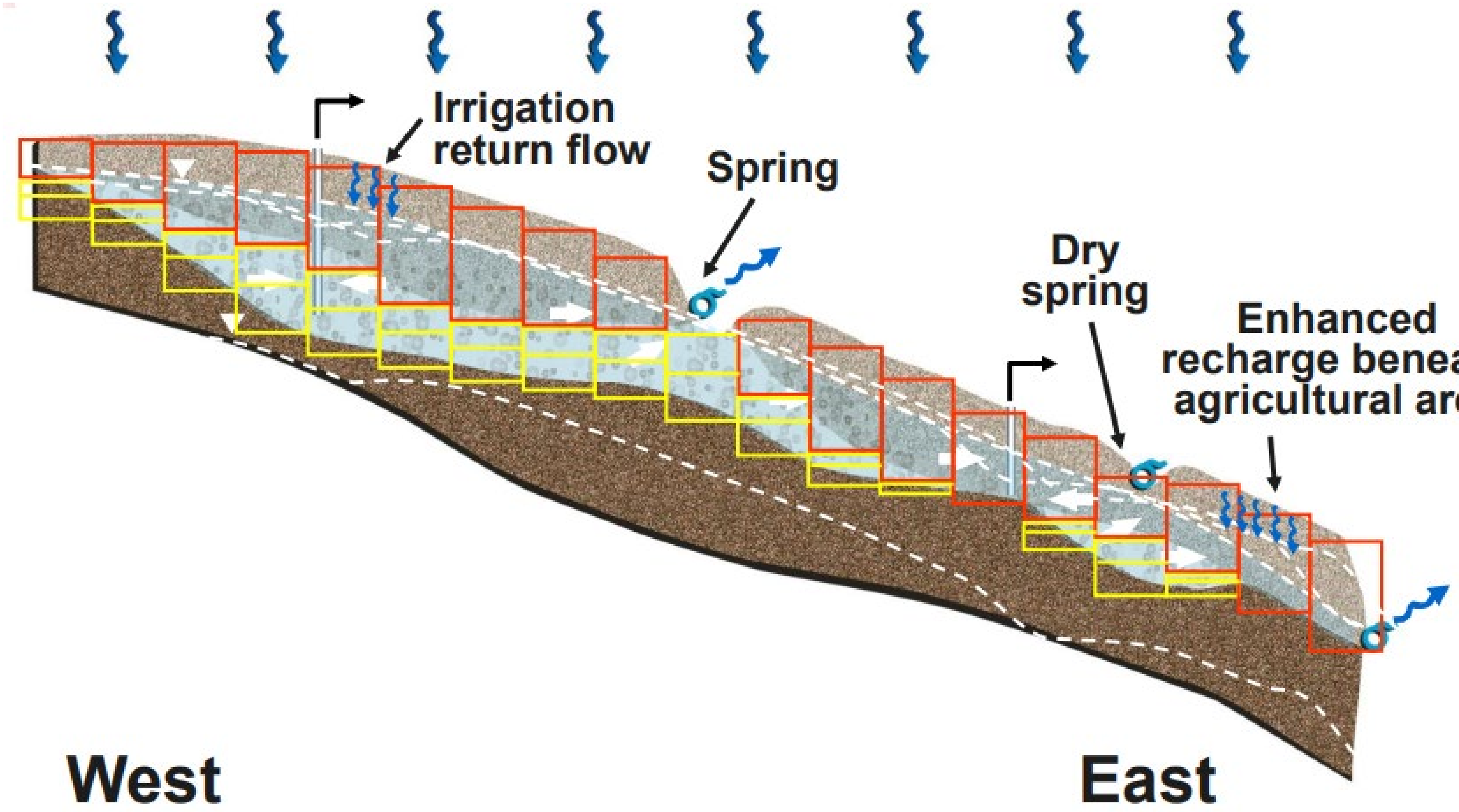
Why Groundwater Flow Models?

- Groundwater is more difficult to observe and measure than surface water
- Aquifers are complex, and predicting groundwater behavior depends on their physical properties
- Groundwater models are tools which aim to integrate dozens of variables dictating the flow within the aquifer(s) of interest
- The aim is to provide a comprehensive and accurate estimate of groundwater behavior through time

Modeling Protocol



Start with Conceptual Model, Divide into Cells



Technical Approach

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Efficient Workflows

- Reproducibility and transparency through scripting
- Iterative and incremental model building approach
- Parameter estimation and uncertainty analysis using PESTPP-IES
- MODFLOW 6 will be the basis for the Numerical Model

Efficient Workflows

Modeling Process

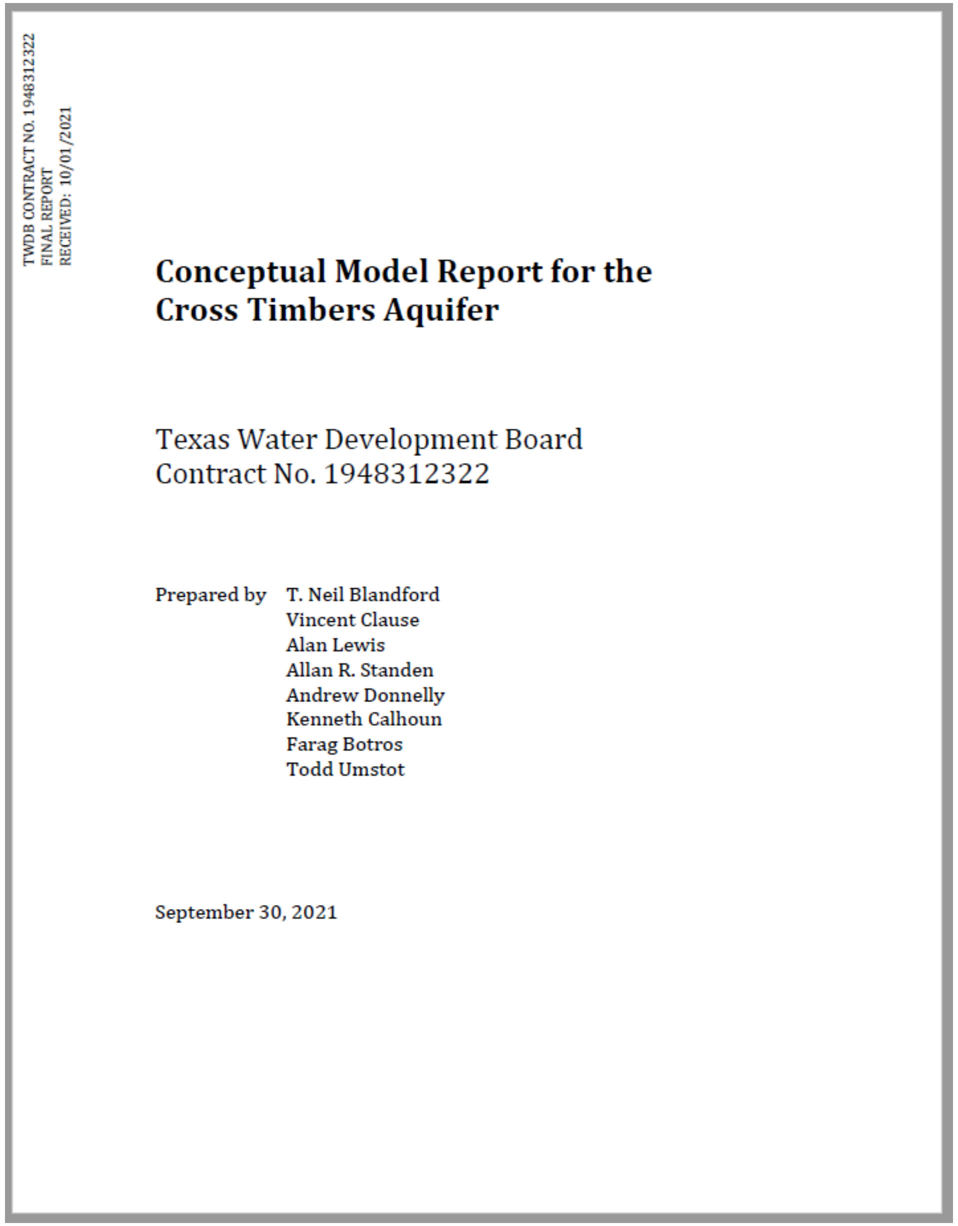
- Where science happens
  - Decisions and assumptions made **and tested**
- Open-source tools
- Scripting-driven approach
  - Rapid, reproducible, and robust
  - Self-documenting
- Incremental complexity
  - Objectively evaluate
    - Computational layering design
    - Spatial resolution
    - Temporal resolution
    - Boundary condition
  - How do these model elements influence simulated future water levels and groundwater fluxes?

Open source utilities	
flopy mfsetup gis	Set up MODFLOW 6 model structure, properties, and boundary conditions
flopy pyemu	Setup PEST interface around the model: parameterization of model properties and boundary conditions; monitor outputs of interest
pyemu	Define prior parameter ensemble and likelihood/objective function
PEST++-IES pyemu	History matching using prior parameter ensemble and likelihood function
Matplotlib pyemu	Process results

Science: think critically about results, define hypothesis to test related to all steps above. Repeat as necessary

Concept to model

- Gridding and Layering:
  - Testing various grid resolutions and associated uncertainty related to cell sizes
  - Translating hydrostratigraphic layers to model layers
- Boundary condition assignments
  - Recharge, surface water and groundwater interaction, pumping (LRE), evapotranspiration
  - Subjective, introduces uncertainty
- Simulation periods
  - Calibration period: TBD–2022
  - Generic predictive period: 2022–TBD
    - “business as usual”


TWDB CONTRACT NO. 1948312322
FINAL REPORT
RECEIVED: 10/01/2021

Conceptual Model Report for the Cross Timbers Aquifer

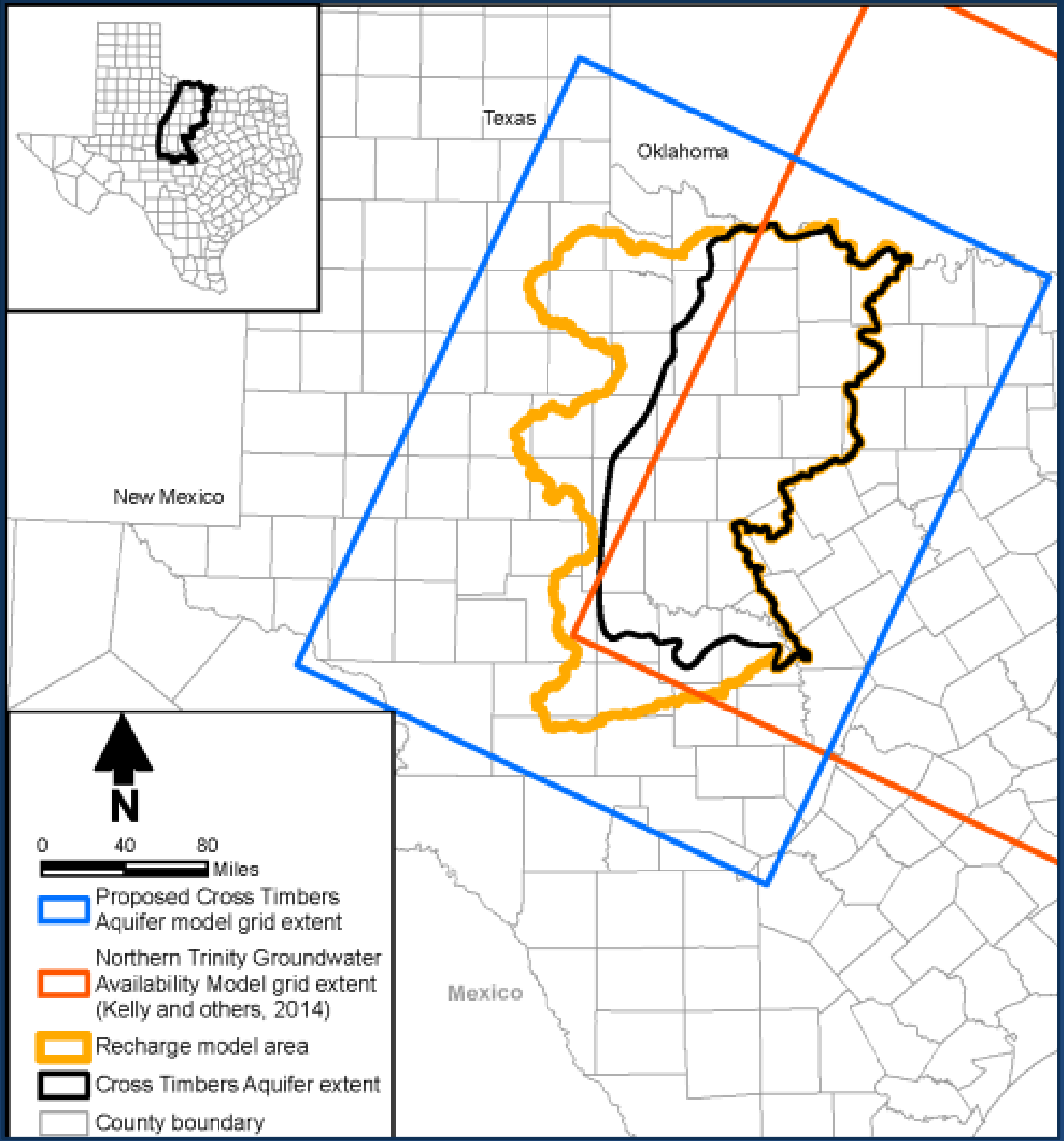
Texas Water Development Board
Contract No. 1948312322

Prepared by T. Neil Blandford
Vincent Clause
Alan Lewis
Allan R. Standen
Andrew Donnelly
Kenneth Calhoun
Farag Botros
Todd Umstot

September 30, 2021

Model Grid

- The model grid will cover the active extent of the study area
- Grid resolution will balance computational burden with grid resolution
- One-mile grid cells with refinement seems most likely
- Will be oriented on the same angle as the Northern Trinity Woodbine GAM



Conceptual Model Report for the Cross Timbers Aquifer (TWDB)

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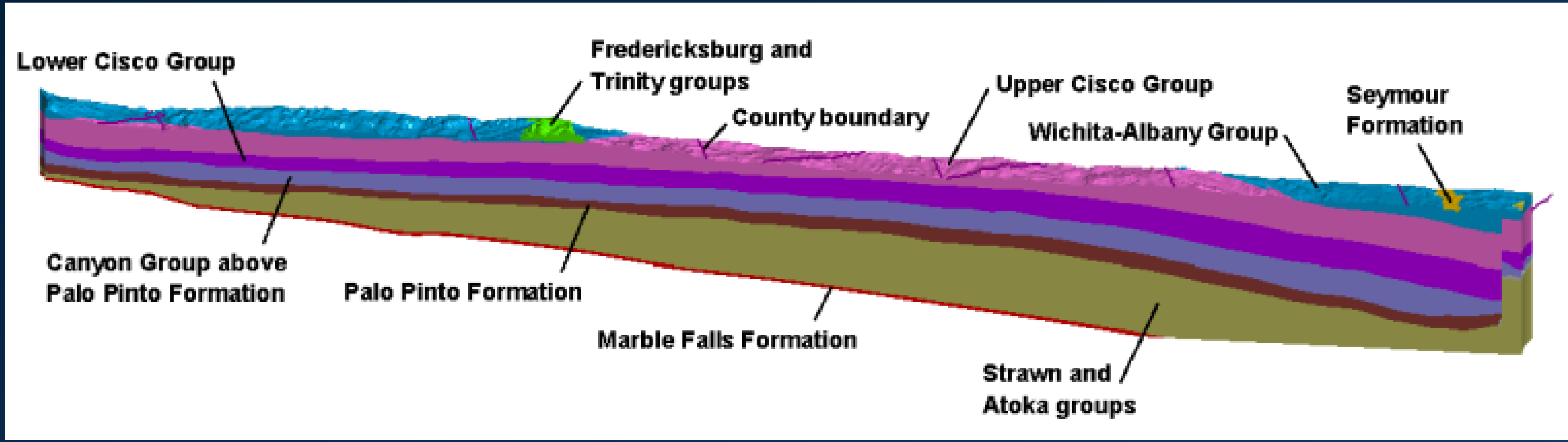
Model Layering



Conceptual Model Report for the Cross Timbers Aquifer (TWDB)

- 10-layer model
- There will be a constant-thickness layer between Layers 1A,B and 2 representing the shallow, fresher portion the aquifer where most of the wells are completed
- The lower layers are mostly brackish and have little calibration data

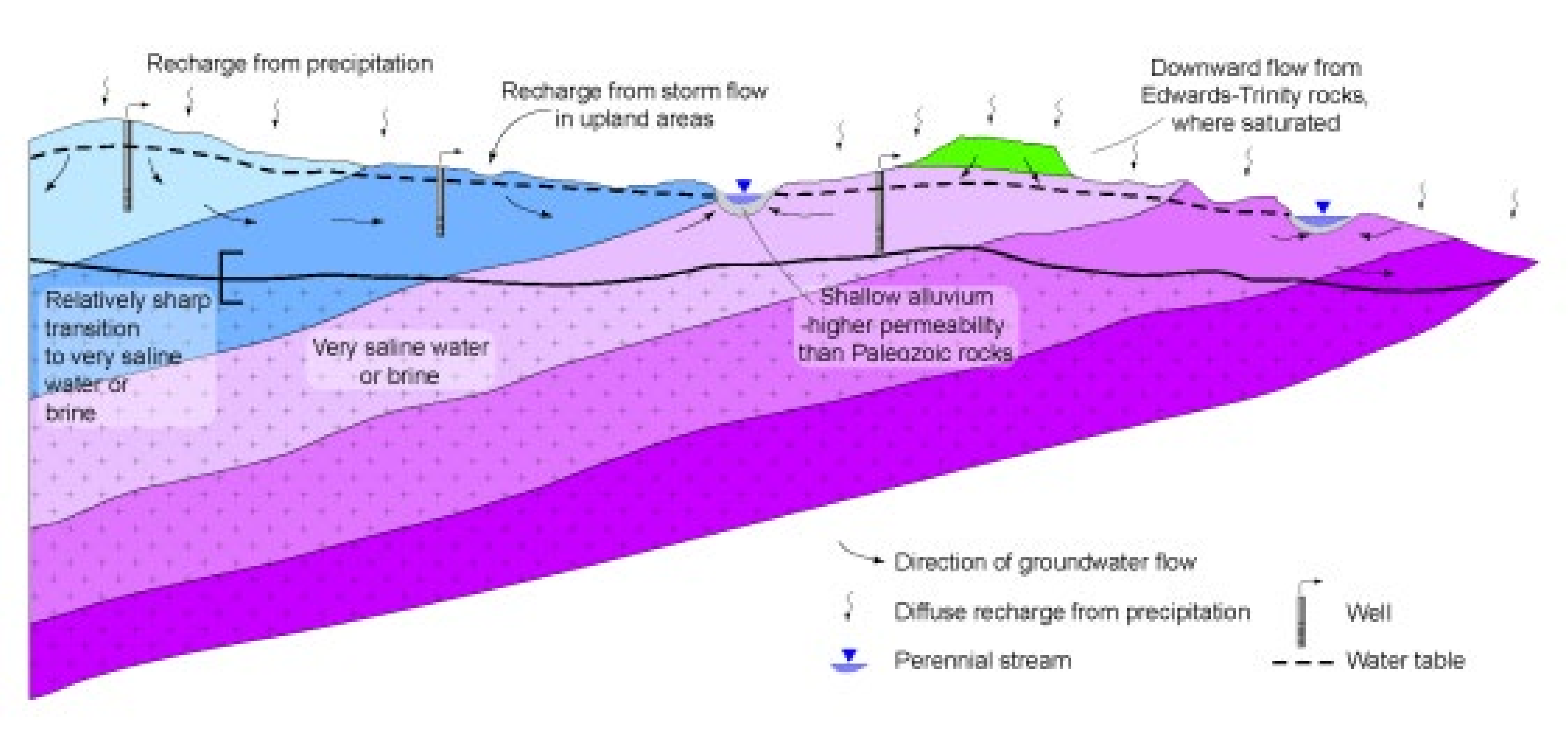
System	Series or Stage	Group	Formation	Model Layer
Quaternary - Pleistocene			Alluvium	1A
			Seymour	
Cretaceous		Fredericksburg	Edwards Comanche Peak Walnut	1B
		Trinity	Antlers; Paluxy Glen Rose Twin Mountains	
Permian	Leonard	Clear Fork	Choza	2
			Vale	
			Arroyo	
		Wichita - Albany	Lueders	3
			Clyde, Waggoner Ranch (GAT)	
	Wolfcamp		Belle Plains, Petrolia (GAT)	
			Putnam, Nocona (GAT)	
		Cisco	Santa Anna Branch	4
			Sedwick	
			Moran	
			Pueblo	
Pennsylvanian	Virgilian		Harpersville	
			Thrifty	5
			Graham	
	Missourian	Canyon	Caddo Creek	6
			Brad	
			Placid	
			Winchell	
			Wolf Mountain	
			Palo Pinto	7
		Strawn	Mineral Wells	8
	Desmoinesian		Brazos River	
			Mingus	
			Grindstone Creek	
			Lazy Bend	
	Atokian	Atoka	Smithwick	
	Morrowan	Morrow	Marble Falls	9

Surface-Groundwater Interaction

- Layer 1 will represent any of the shallow sediments overlying the Cross Timbers Aquifer

- These shallow alluvium sediments will be incorporated as a water-bearing unit

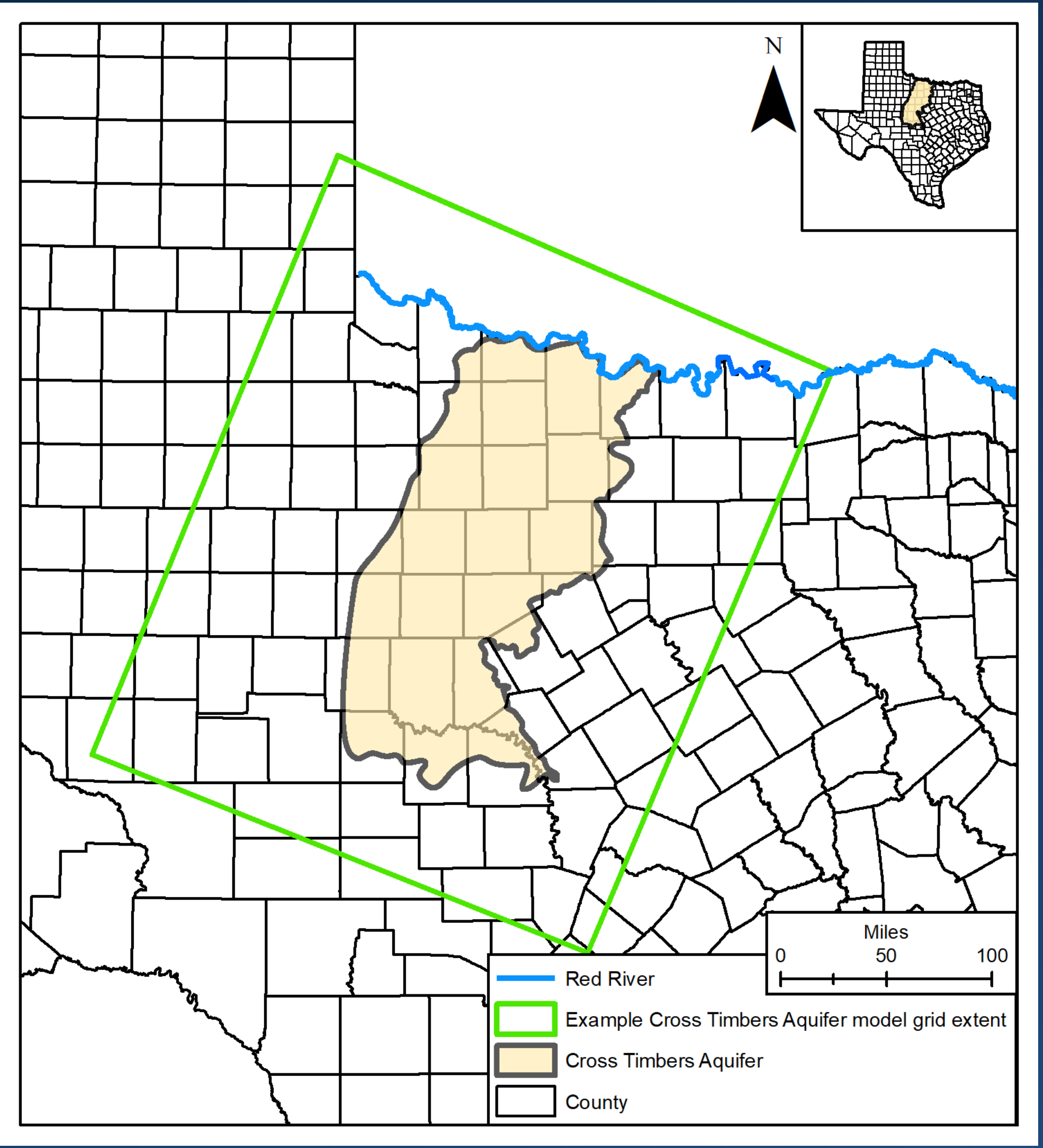
- Grid-refinement around surface water features



Conceptual Model Report for the Cross Timbers Aquifer (TWDB)

Model Extent and Boundaries

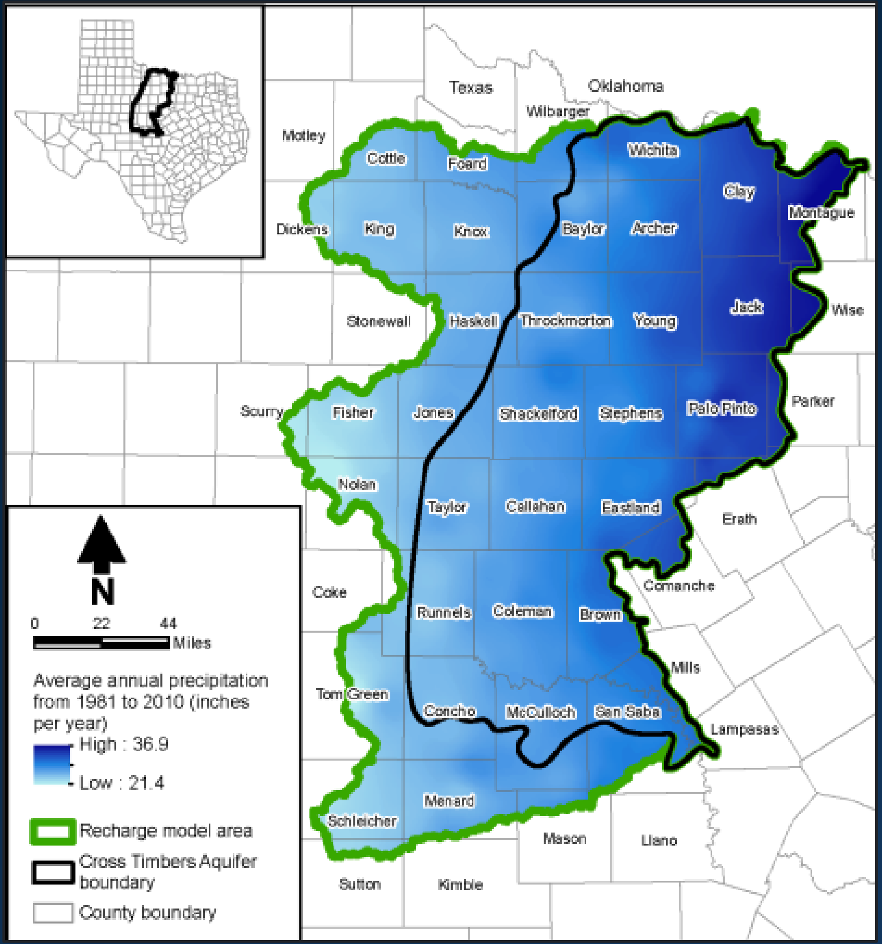
- Western boundary:
  - The aquifer boundary, with a larger western region considered to determine recharge
  - No-flow
- Northern boundary:
  - Red River
  - Head boundary in Layer 1, no-flow boundaries in deeper layers
- Eastern boundary:
  - Will closely follow the outcropping edge of the Northern Trinity Aquifer
  - General Head Boundary
- Southern boundary:
  - No-flow boundary

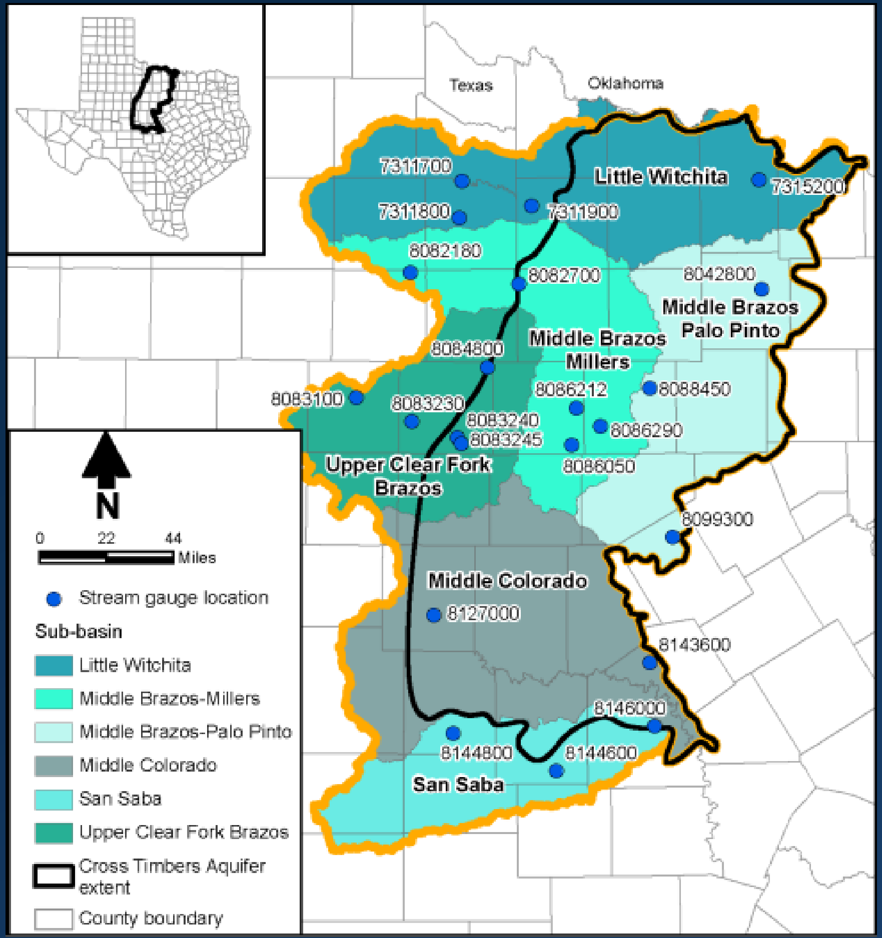


Hydrogeologic Parameters

- Initial hydraulic properties will be based on Section 4 of the Conceptual Model report (based on Specific Capacity Tests from driller reports)
- Hydraulic conductivities, and their relationships to anisotropy, will be calibrated
- Hydraulic conductivities of the major fault zones in the study area will also be calibrated

Recharge





Conceptual Model Report for the Cross Timbers Aquifer (TWDB)

- Conceptual Model used a Distributed Parameter Watershed Model (DPWM) which will be used as an initial estimate
- DPWM cells were ¼-mile by ¼-mile
- Recharge is cross-formational

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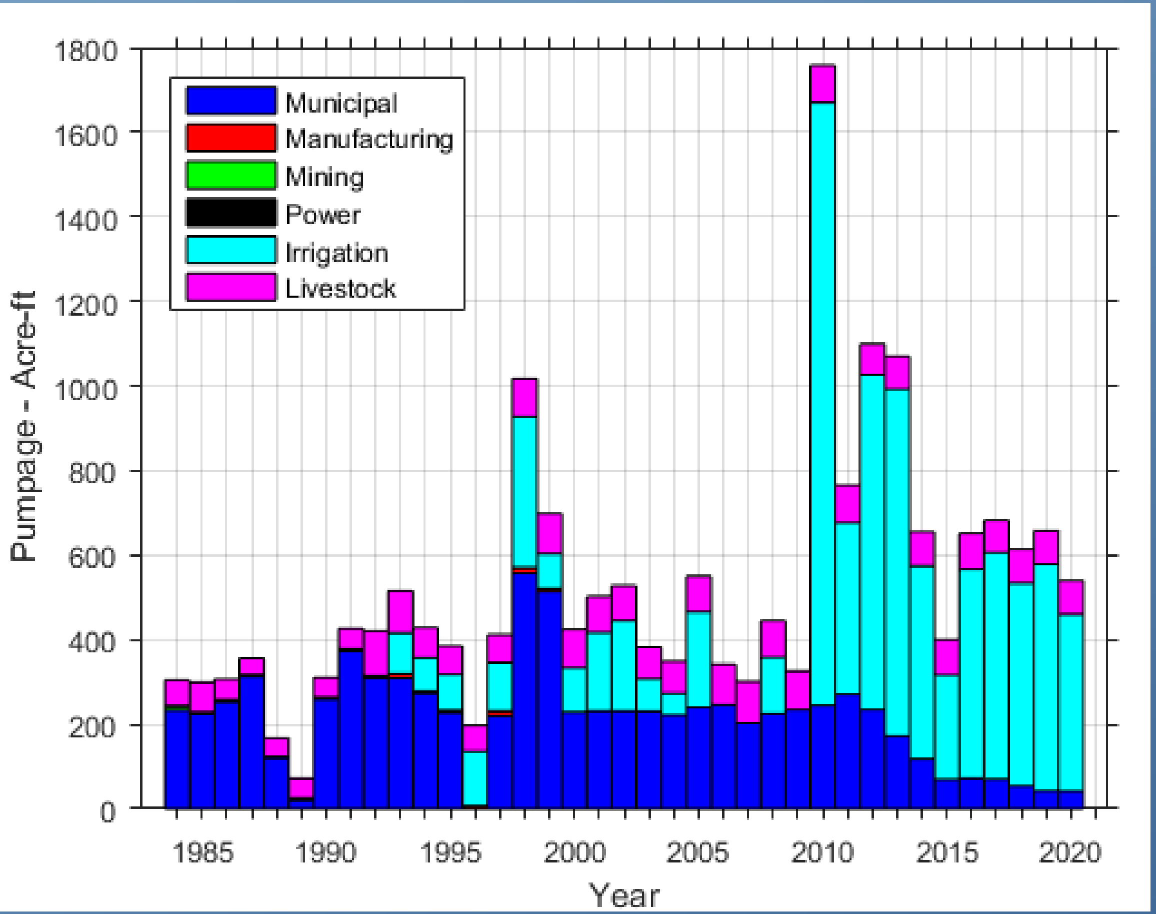
Pumpage Assessment



- TWDB Water Usage Survey
  - Improving Estimates
  - Assigning Pumpage to Cross-Timbers
    - Not “Other” or “Unknown”
- County by County Analysis
- Backward – Analysis from 1984 to 1900
- Spatial distribution
  - Across County
  - Create MODFLOW WEL Package

LRE WATER

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Model Calibration

- The process of assimilating and integrating information stored as historic state observations
  - We will primarily use water levels and estimates of baseflow to streams
- This information is transferred to the parameters, which are incrementally changed so that the model results more closely match the observations
- We will use an ensemble-based calibration process

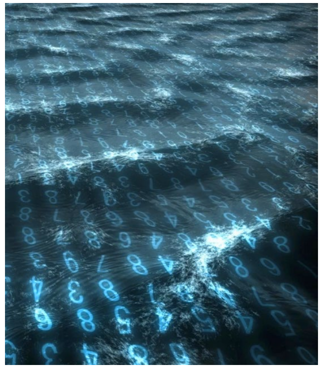
Model Calibration (cont.)

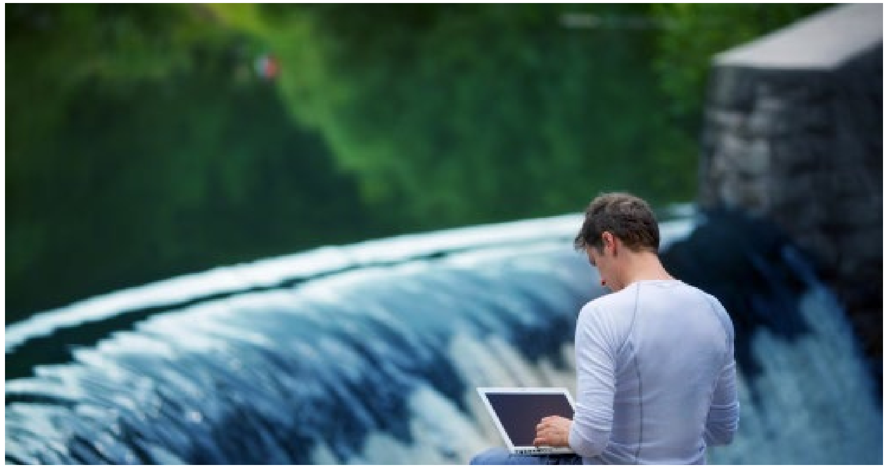
- Observations and Weighting
  - Weighting – assigning an importance factor to different aspects of the historical observation dataset

- Parameters and the Prior
  - Prior – A distribution which represents the model's best guess and the uncertainty of the model inputs (the parameters)

- We will use the Prior variance to generate an ensemble of uncalibrated hydraulic property fields which will span the range of uncertainty that exists in the properties before calibration

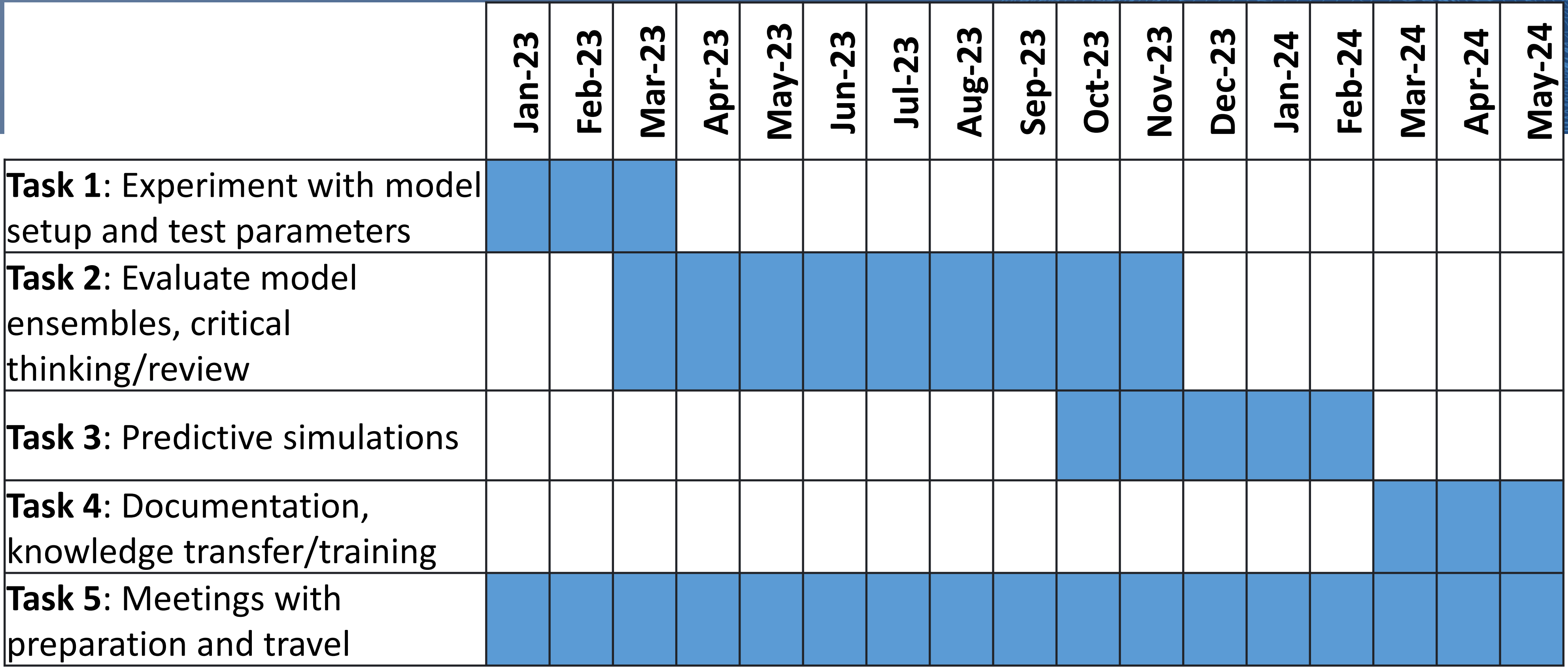
Data Request





- Any un-published data to support the model
  - Geophysical logs
  - Pump Tests
  - Water Levels
  - Interpreted Properties
  - Structural Picks
  - Production Information

Project Timeline



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Questions?