Bandera Well Longevity Model Results

02/14/2022

Outline

- Study Objective
- Background
  - The lower Trinity aquifer in Bandera County
  - The City of Bandera Public Supply Wells
- Methodology:
  - Analytical Solution
  - Numerical Model
- Model Discussion
- Next Steps

What is required to move the City of Bandera ASR project forward?

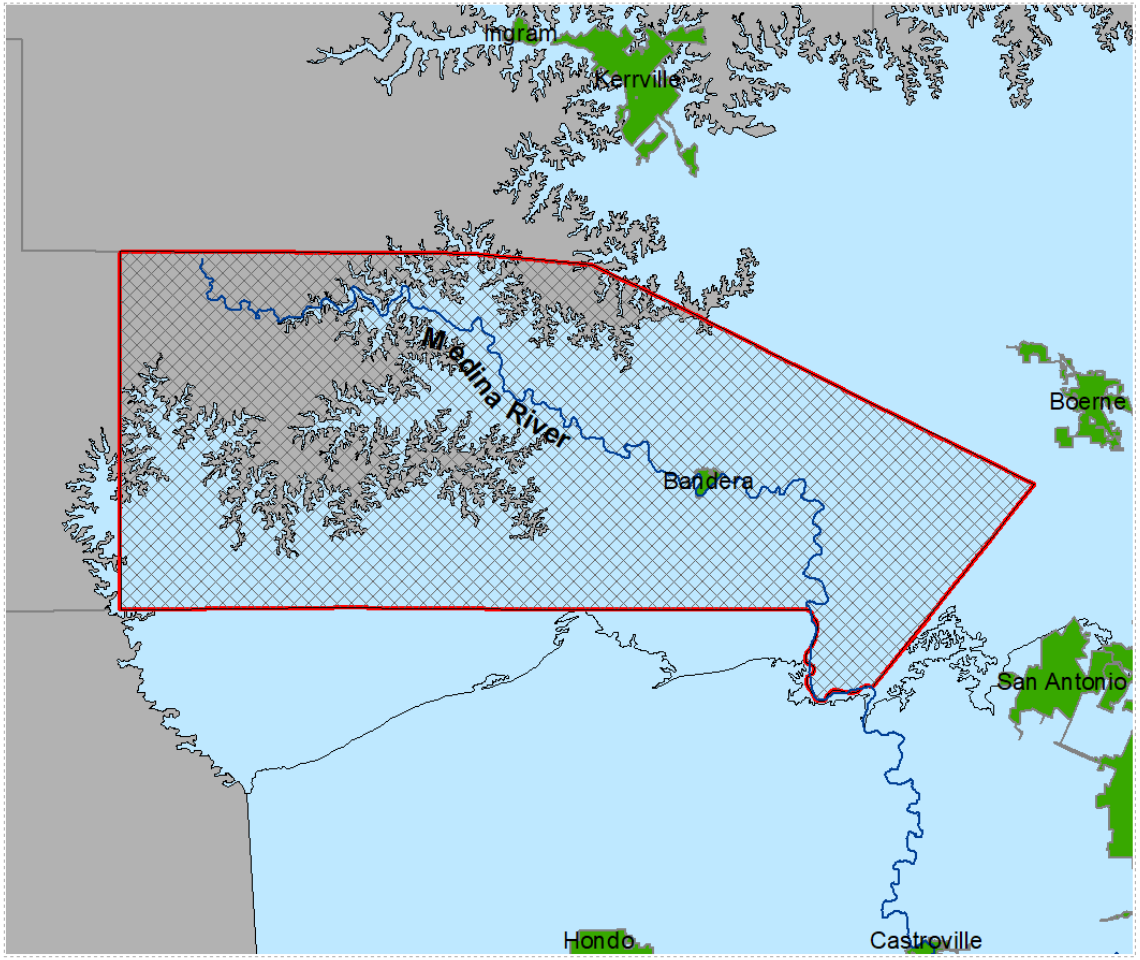
Challenges: Lower Trinity aquifer water level declines, water supply resiliency

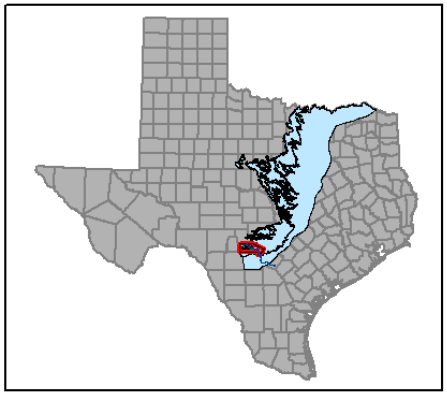
Objective: Predict longevity of the city's lower Trinity wells

Methodology: Test how the wells would respond to producing the entire existing water supply listed in the state water plan

Study Area

Longevity Assessment for City of Bandera Wells



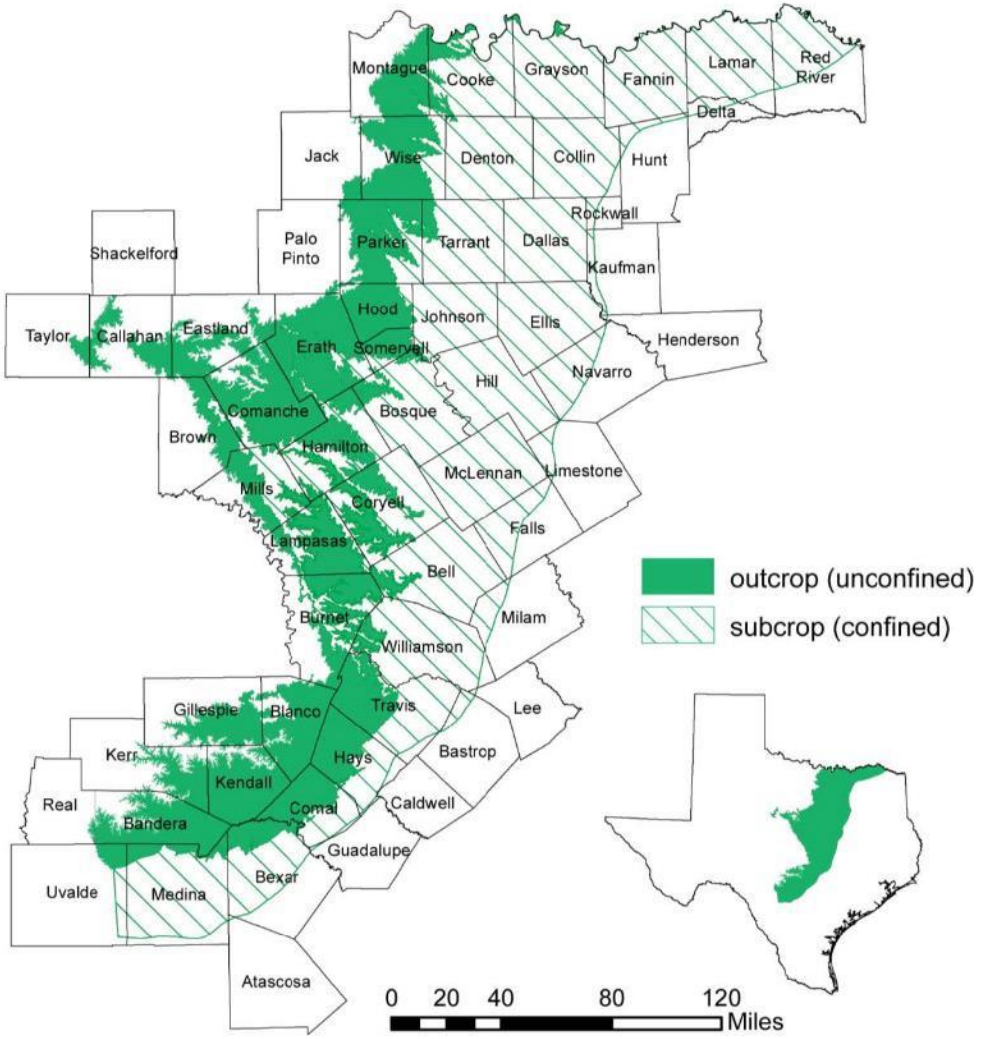


Urban Areas
BRACD
Bandera County
Trinity Aquifer

Texas Water Development Board 02/14/2022

Trinity Aquifer

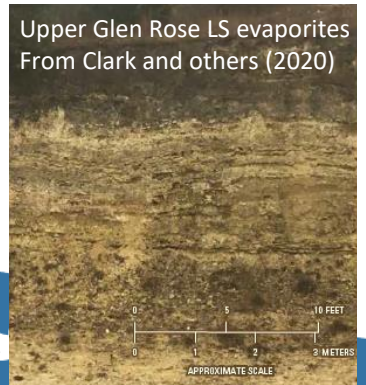
- The Trinity Aquifer is contained within the Trinity Group, which is found across most of south-central Texas
- Complex and contains both carbonate and siliciclastic units
- Subdivided into three hydrogeological units
  - Upper Trinity aquifer
  - Middle Trinity aquifer
  - Lower Trinity aquifer



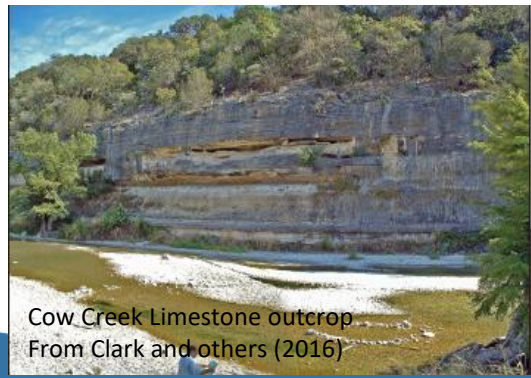
Upper and Middle Trinity aquifers

- Upper Trinity aquifer
  - contained in the Upper Glen Rose Limestone
  - subdivided into 5 hydrostratigraphic units
  - Primarily argillaceous limestone and carbonate mud with some evaporties
  - Fluid flow is directed through faults and factures and is particularly high within evaporite beds
  - Primarily used for residential and local irrigation in Bandera County
- Middle Trinity aquifer
  - contained within the Lower Glen Rose Limestone and the upper portion of the Pearsall Formation
  - Complex: Contains both carbonate units with fracture and karstic porosity as well as the sand and dolomite Hensell Sand
  - Less transmissive than the upper Trinity aquifer and contains few evaporties
  - Primary source of groundwater for most residential and municipal entities in the county

Epoch	Age	Group	Formation	Member	Hydrostratigraphic unit	Aquifer
Lower Cretaceous	Albian	Edwards	Fort Terrett	Basal Nodular	VIII *Transmissive*	Edwards
		Trinity	Glen Rose Limestone	Upper Glen Rose Limestone	Cavernous *Transmissive*	Upper Trinity
					Camp Bullis *Semi-confining*	
					Upper Evaporite *Transmissive*	
					Fossiliferous *Semi-confining*	
					Lower Evaporite *Transmissive*	
	Aptian			Lower Glen Rose Limestone	Bulverde *Semi-confining*	Middle Trinity
					Little Blanco *Transmissive*	
					Twin Sisters *Confining*	
					Doeppenschmidt *Transmissive*	
					Rust *Confining*	
					Honey Creek *Transmissive*	
			Pearsall	Hensell Sand	Hensell *Confining*	
				Cow Creek Limestone	Cow Creek *Transmissive*	



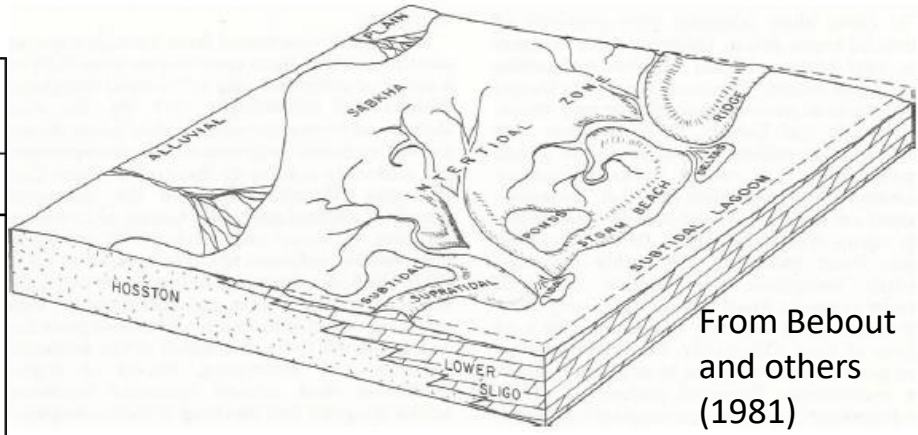
Upper Glen Rose LS evaporites
From Clark and others (2020)


Cow Creek Limestone outcrop
From Clark and others (2016)

Lower Trinity aquifer

- The lower Trinity aquifer is contained within the Hosston and Sligo formations
- Bounded above the Hammett Shale, which acts as a confining unit in most cases and limits interaction with the Middle Trinity aquifer
- The Sligo Formation is dolomitic and ~80 ft thick in southern Bandera County. It pinches out to the north near the center of the county
- The Hosston Formation is primarily coarse-grained sandstone and conglomerates.
- The Hosston Formation is ~280 ft thick in south Bandera County and thins northward, pinching out in Kerr County

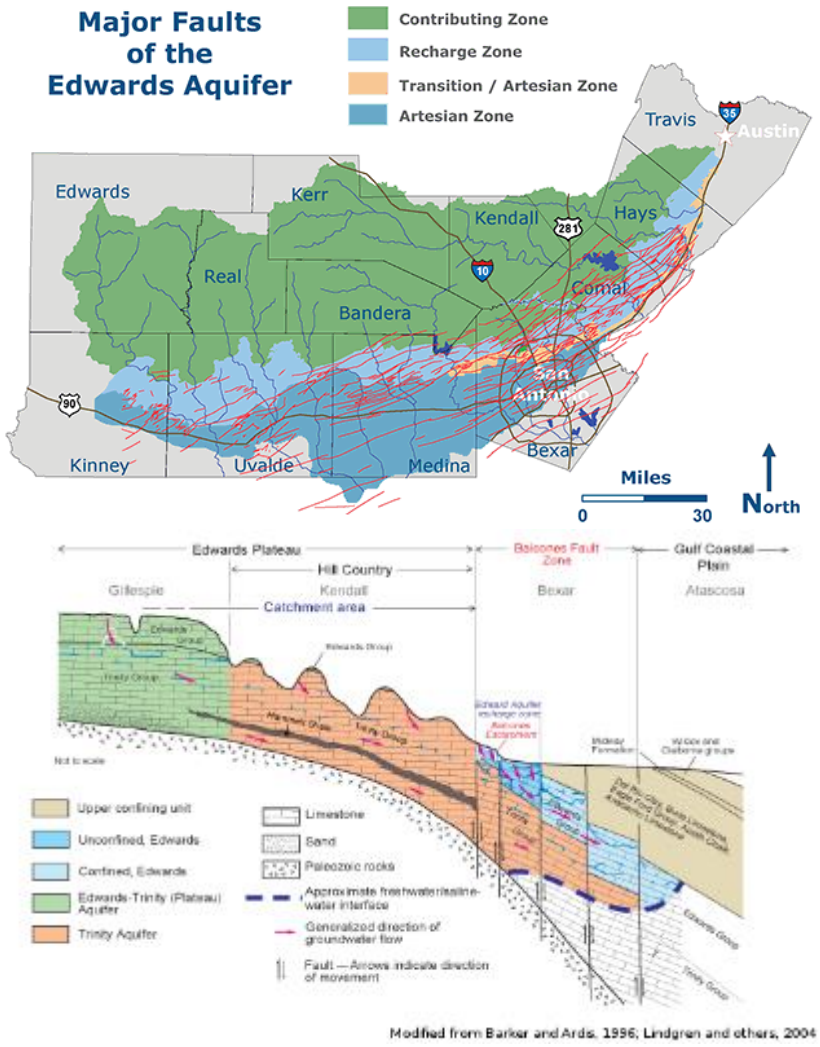
Epoch	Age	Group	Formation	Member	Hydrostratigraphic unit	Aquifer
Lower Cretaceous	Aptian		Pearsall	Hammett Shale	Hammett *Confining*	Confining unit
	Barremian		Sligo		Lower Trinity *Transmissive*	Lower Trinity
	Hauterivian		Hosston			



From Bebout and others (1981)

Balcones Fault Zone

- The Trinity Group was faulted during the Miocene
- The Balcones Fault Zone is a northeast–southwest trending zone of near-vertical faults extending from central to north Texas
- The hydrogeology in the Trinity aquifer is highly affected by faults, fractures, and geologic structures
- Recent studies show that there are likely more faults in Bandera County than previously mapped
- Some faults in Bandera County may have over 100 feet of offset, which may displace confining units such as the Hammett Shale

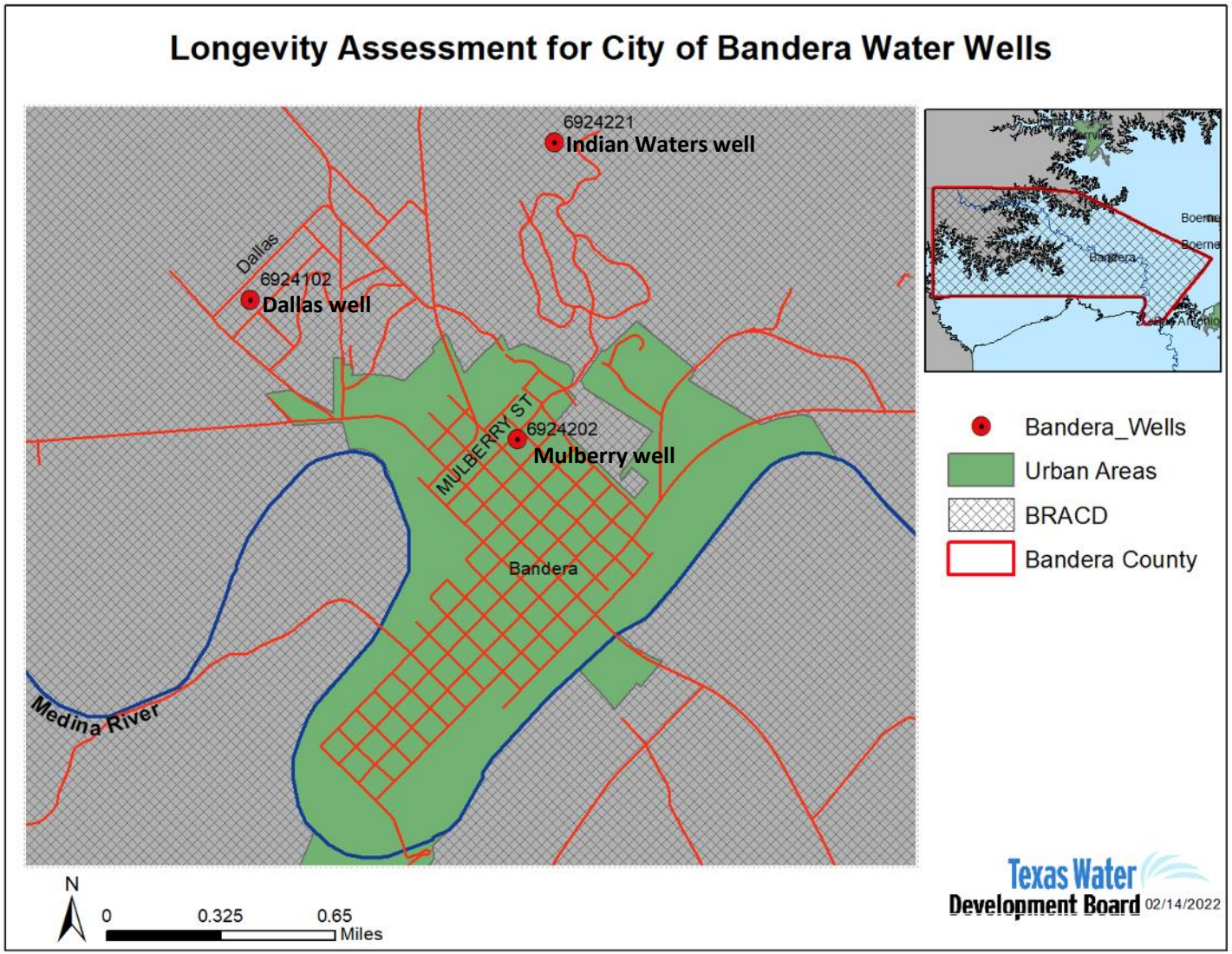


Modified from Barker and Ardis, 1996; Lindgren and others, 2004

It all starts with data…

- Major phase of the study
  - Data mining
  - Quality assurance and quality control
- A note of thanks to:
  - Heather Dodson, TWDB Groundwater Data Team Lead
  - Bandera River Authority and Conservation District
    - Dave Mauk, General Manager
    - Alysa Balzen, Groundwater Science Manager
  - City of Bandera
    - David Jordan, Public Water Director and
    - City of Bandera Admin Team

City of Bandera Wells



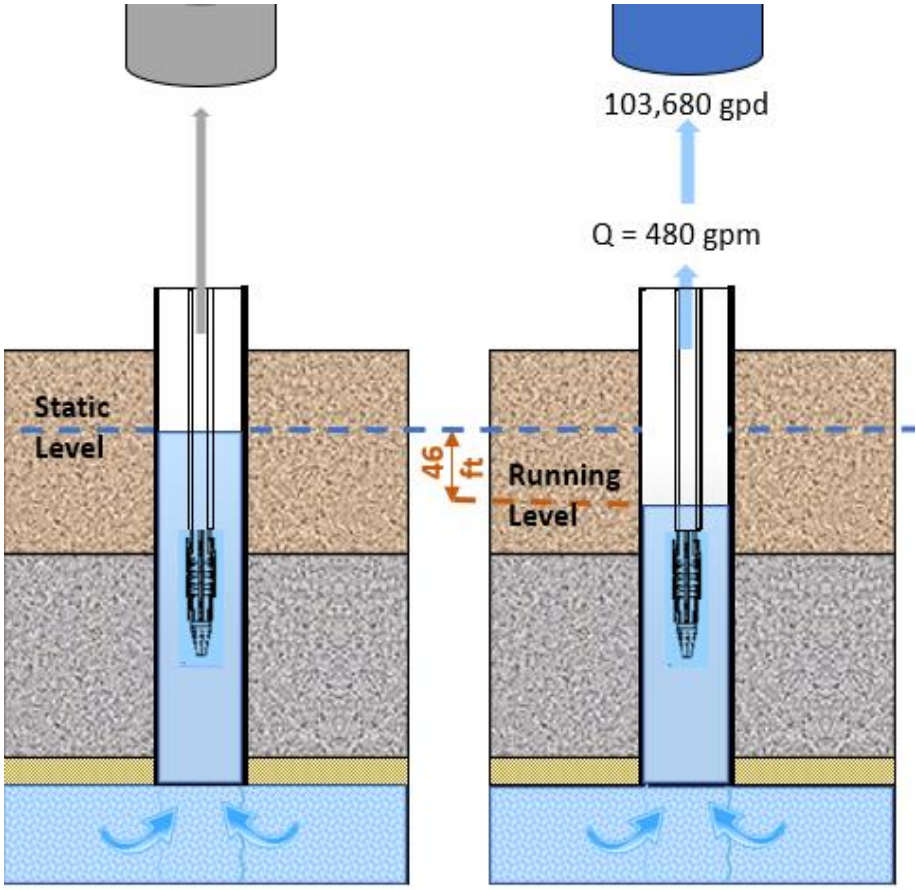
City of Bandera Wells

City of Bandera total production = 248,760 gpd (279 AFY)

Well Name	Well # 5a or Dallas St.	Well # 5 or Dallas St.	Well #4 or Mulberry St.	well #6 or Indian Waters
BRACS ID	88033	88432	52986	58742
SWN	6924116	6924102	6924202	6924221
PWS source #	1000012	G0100012C	G0100012B	G0100012D
Drill year	2017	1967	1953	1998
Well depth	480	805	842	770
Screen intervals	221-480	533-805	740-842	610-710
Well completion	Open Hole. Middle Trinity	Open Hole. Lower Trinity	Open Hole. Lower Trinity	Screened. Lower Trinity
Operation rate (gpm)	120	500	480	300
Average run time per day (hrs)	2.4	2.4	3.6	3.1
Average production per day (gallon)	17,280	72,000	**103,680**	55,800
Percentage of City of Bandera production	7%	29%	**42%**	22%
Static water depth (ft)	257	468	444	444
Running water depth (ft)	268	581	490	494
Drawdown (ft)	11	113	46	50
Aquifer Code (TWDB GWDB)	Middle Trinity	217HSTN- Hosston formation	217HSTN - Hosston formation	217HSTN- Hosston formation
Water level Measurements		19 measurements. 6 publishable winter values	20 measurements. 5 publishable winter values	3 measurements. 1 publishable winter value

City of Bandera Wells

Well Name	Well #4 or Mulberry St.
BRACS ID	52986
SWN	6924202
PWS source #	G0100012B
Drill year	1953
Well depth	842
Screen intervals	740-842
Well completion	Open Hole
Operation rate (gpm)	480
Daily average run time (hrs)	3.6
average production per day (gallon)	103,680
Percentage of City of Bandera production	42%
Static water depth (ft)	444
Running water depth (ft)	490
Drawdown (ft)	46
Aquifer Code (TWDB GWDB)	217HSTN - Hosston formation
Water level Measurements	20 measurements. 5 publishable winter values



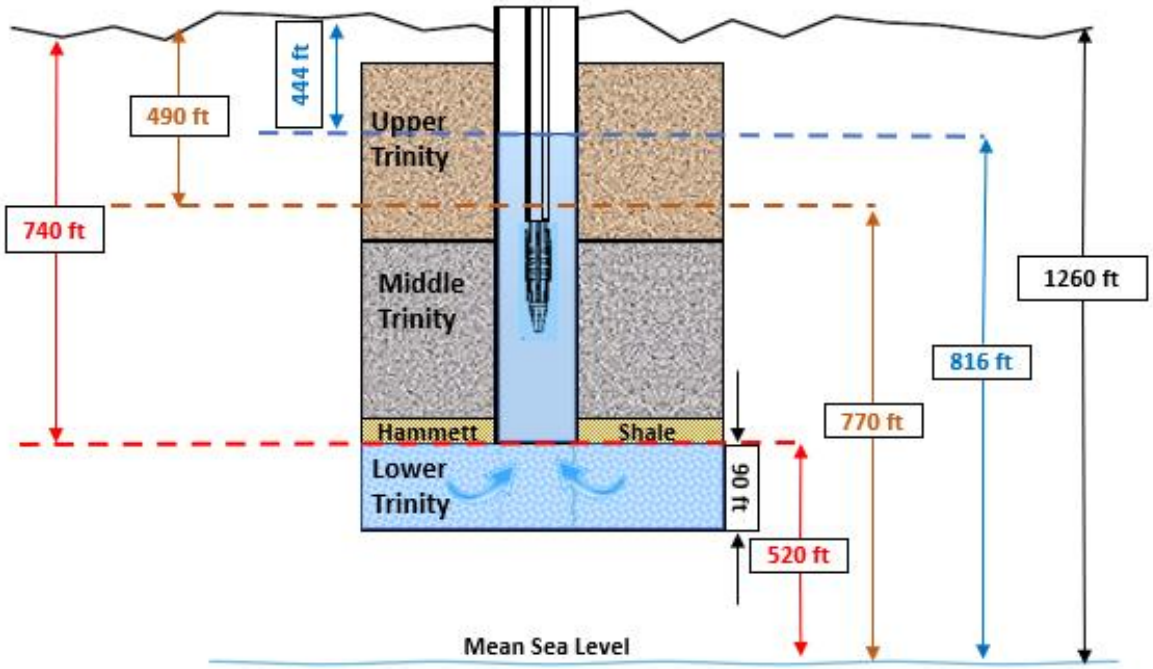
Current Static Condition (no pumping)

Current Running Condition (well can only run for 3.6 hours)

City of Bandera Wells

- Elevation above Mean Sea Level are used in analysis

Mulberry Street Well



Water Supply Challenges

- Trinity Aquifer is the sole supply source currently
- City of Bandera wells already reaching max drawdown
- There is very little redundancy in case of failure

Problem Solving

- What are the options for predicting the life span of a public water supply well based on water levels?

Investigate groundwater flow to that pumping well

Analytical Solution
- simple groundwater flow equation
- solve for drawdown at a point in time and space (fine resolution)
- has many assumptions

Numerical Modeling
- better at approximating complex systems
- fine or course resolution based on objective and computational capabilities
- effectively integrate assumptions

- We applied both for individual advantages

Problem Solving

- For predicting future water levels, what would be the worst-case scenario for the City of Bandera?

  Consume all existing groundwater supply for the city

- State Water Plan:

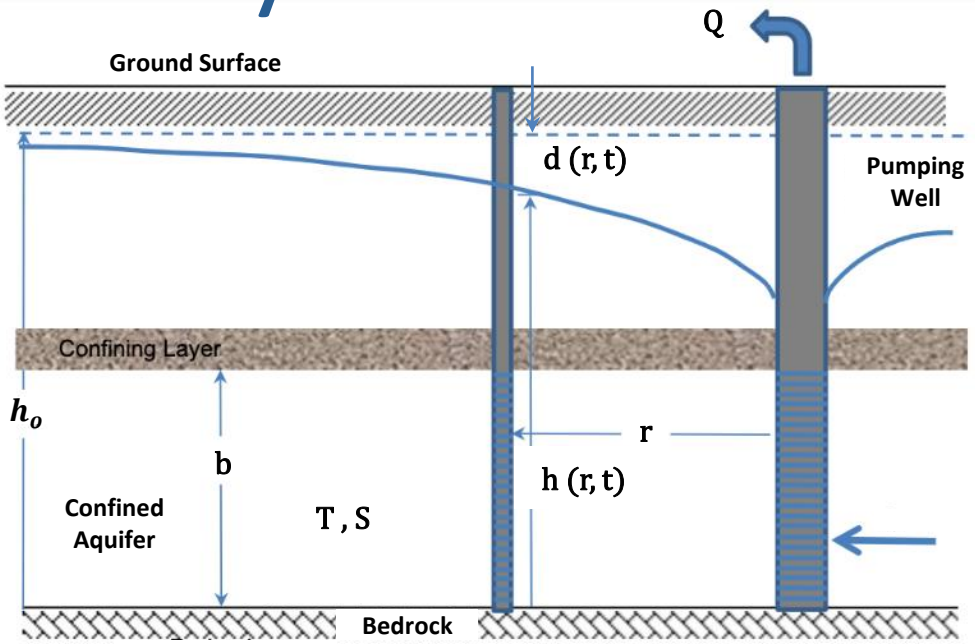
  Existing Trinity Aquifer supply for City of Bandera is 534 AFY (476,726 gpd)

- Existing supply is approximately 2 times the current city of Bandera production
- We used existing supply to predict future levels

Application: Analytical Solution

- Theis (1935) equation

$$d(r,t) = \frac{Q}{4\pi T} W\left(\frac{r^2 S}{4Tt}\right)$$



- Assumptions:

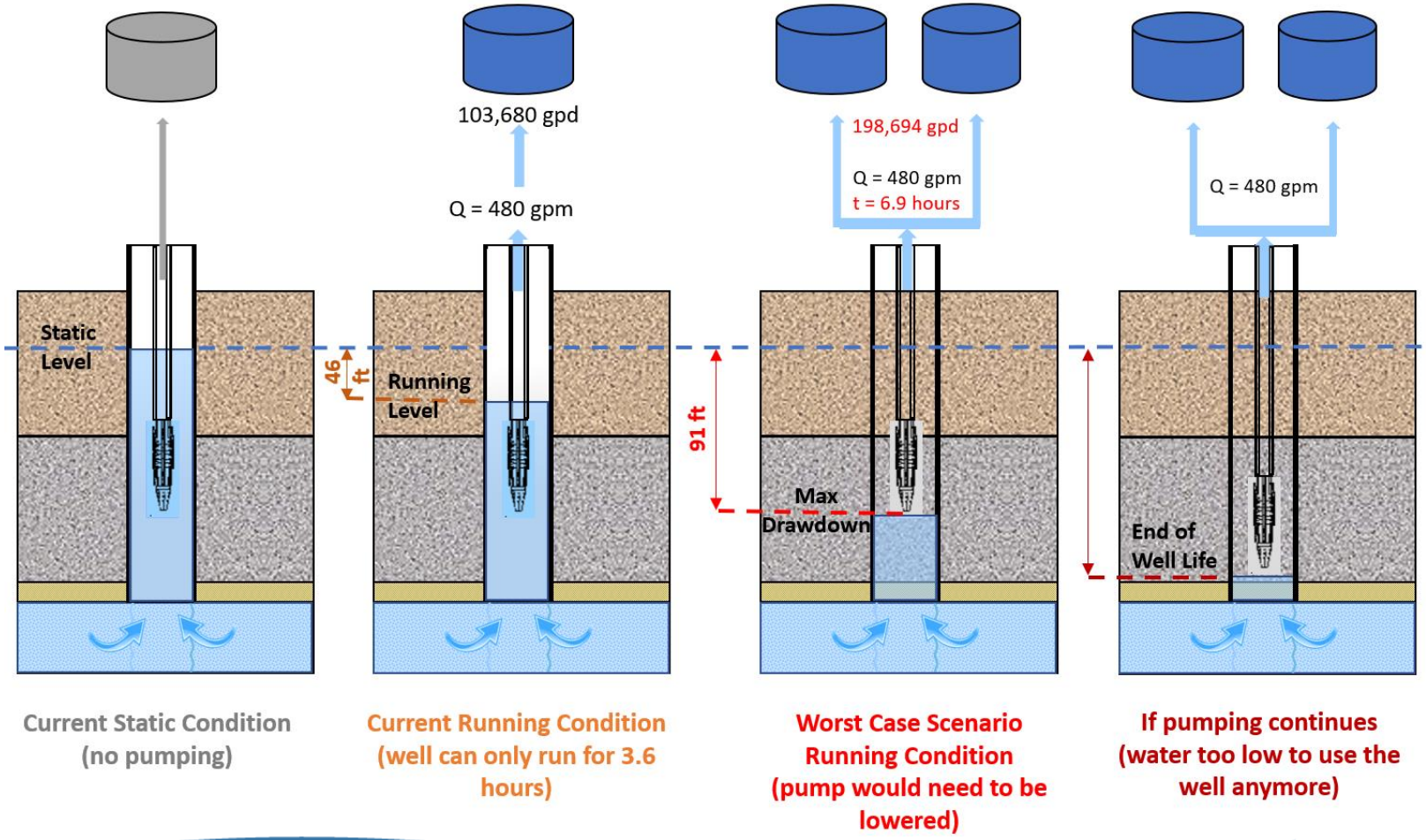
Aquifer
- confined
- infinite areal extent
- homogeneous
- uniform thickness

Pumping well
- fully penetrating
- small diameter

Flow
- horizontal
- unsteady

Analytical Solution Results

- Worst case Scenario: City of Bandera use all existing groundwater supply
- SWP: existing Trinity Aquifer supply for City of Bandera = **534 AFY (476,726 gpd)**
- Mulberry well production= 198,694 gpd (42%)

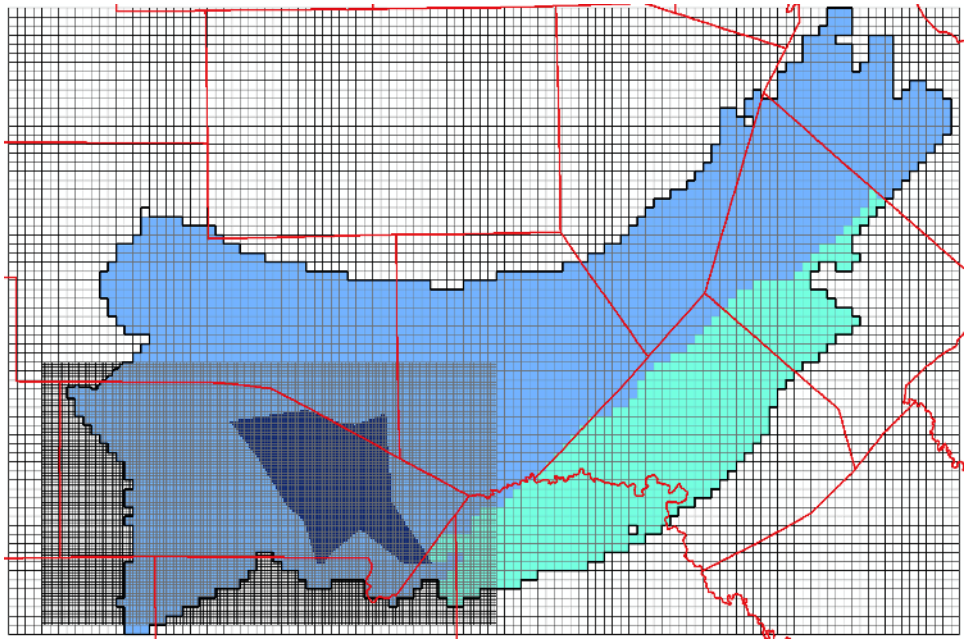


Analytical Solution Limitations

- The solution model becomes complicated and hard to solve as assumptions are not met
- Does not project future static levels
- Does not give 2-dimensional contours of water levels

Application: Numerical Model

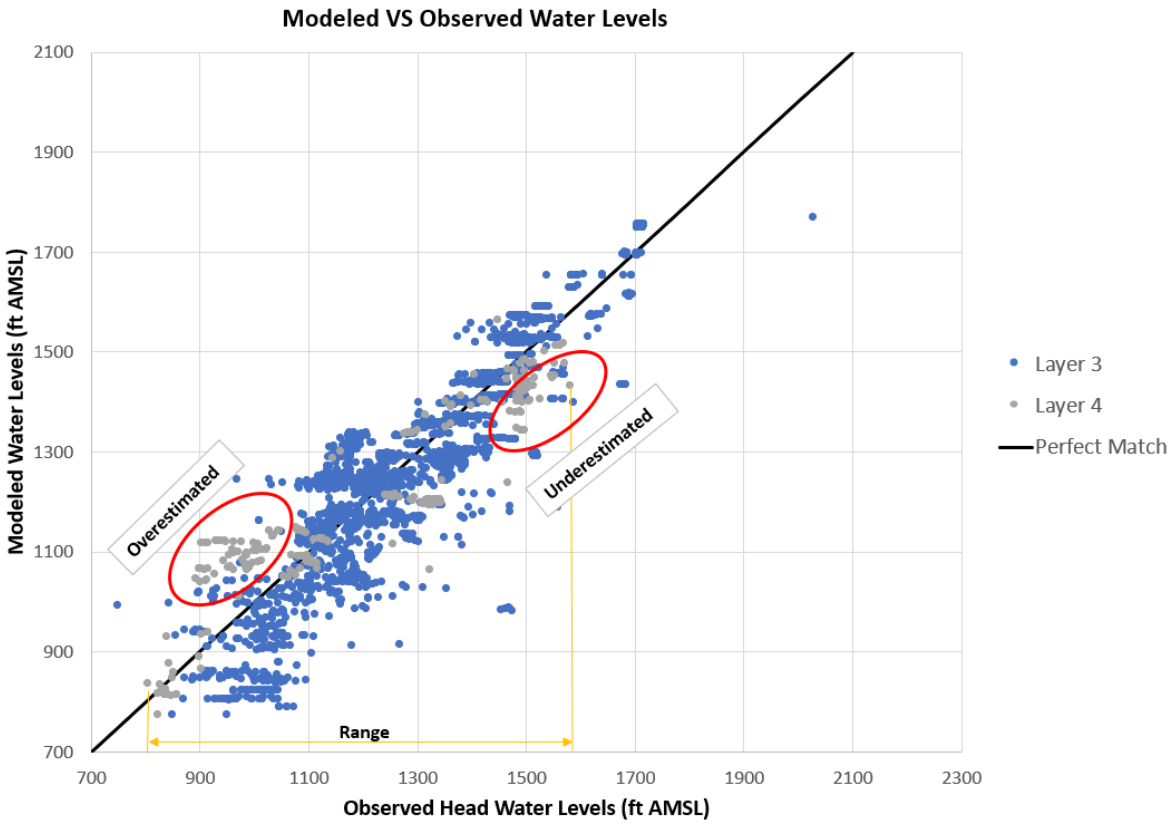
- Created Bandera Well Longevity Model
  - used existing GAM model frame
  - applied most recent aquifers surfaces
  - refined mesh to 0.25 mile in Bandera County area
  - added a new zone of hydraulic conductivity in Bandera County
- Collected data from:
  - TWDB Groundwater Database
  - TWDB historic use information
  - TCEQ Database
  - GCD Database



- Added Municipal and Irrigation use (1998-2018) in 6 counties
- Processed new model
- Verified historic water levels match
- Predicted water levels until 2079

Results: Historic Match

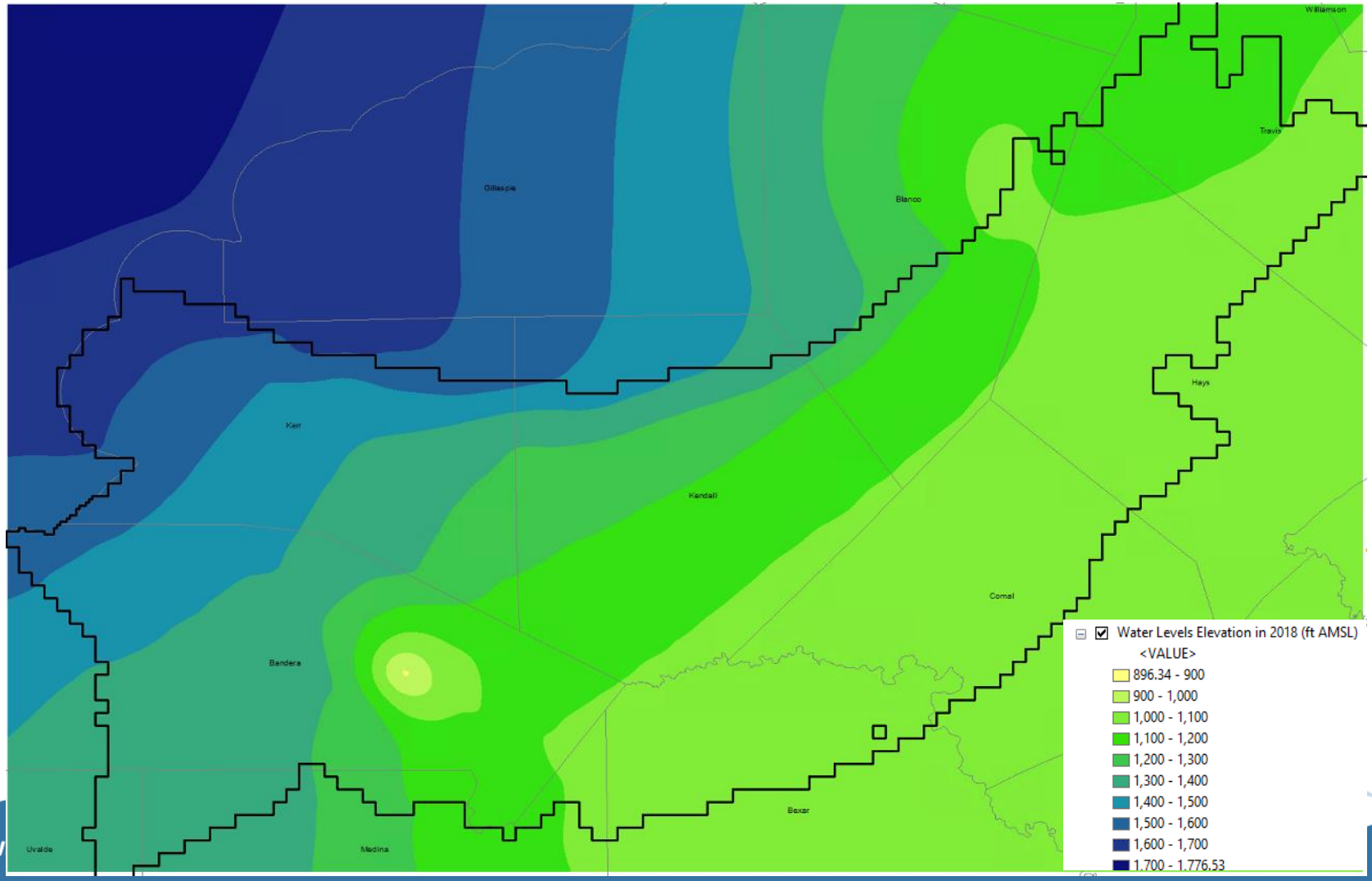
- Evaluate how well the model matched the observed water levels
- Residual = Observed - Modeled



Residual Mean (ft)	**2.86**
Residual Standard Deviation (ft)	91.41
Absolute Residual Mean (ft)	74.56
Range of Observations (ft)	775.4
Scaled Residual Standard Deviation	**0.096**

Results: Water Levels Surface

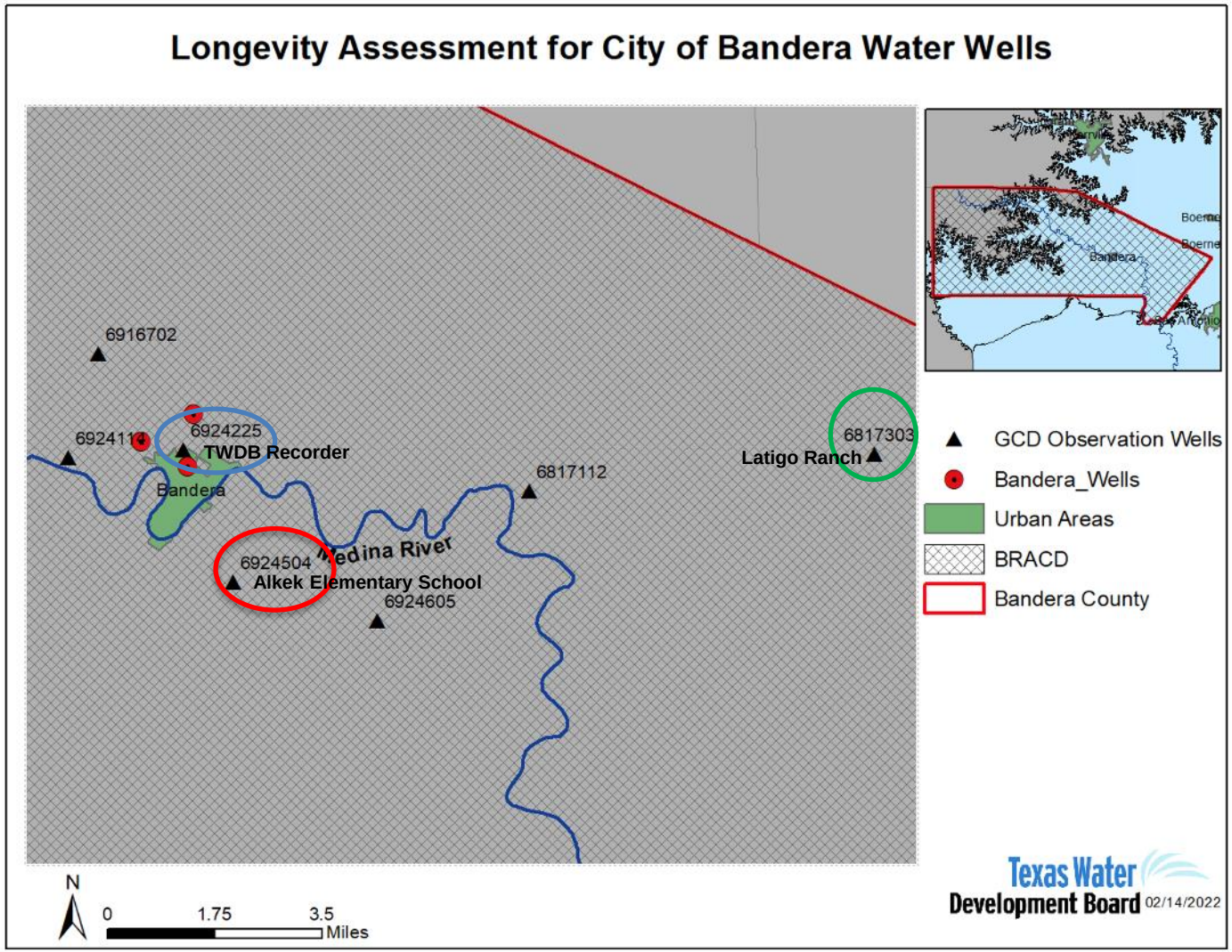
- City of Bandera cone of depression (Elevations: 890 ft - 1,000 ft)
- Observed water level elevations in the city of Bandera area (806 ft – 1100 ft)



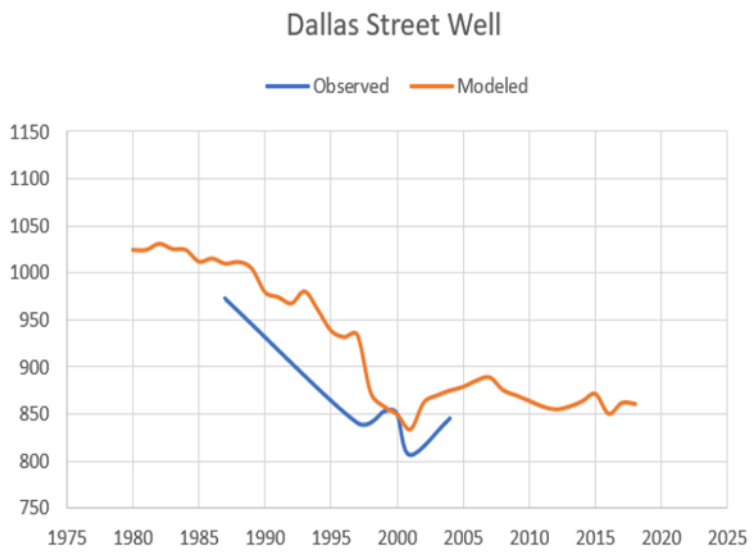
Results: Hydrographs

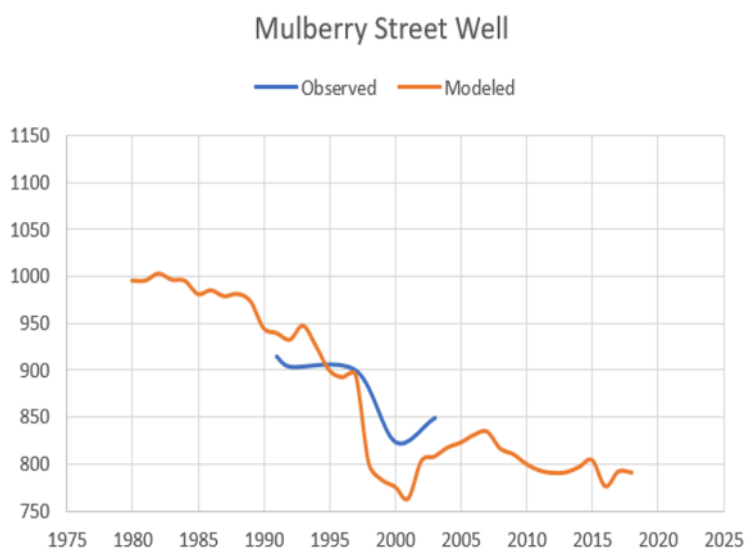
- Hydrographs show the pattern of modeled heads compared to observations

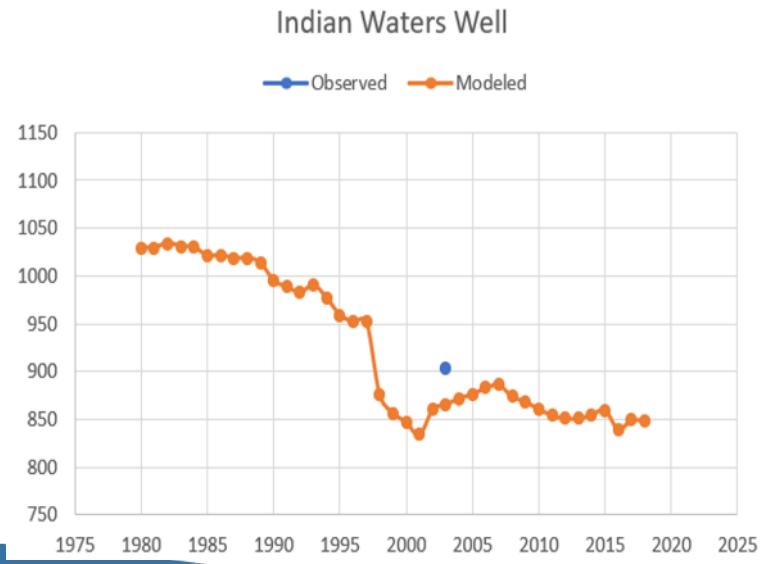
- Checked hydrographs for:
  - The City of Bandera 3 public wells
  - BRACD 7 observation wells



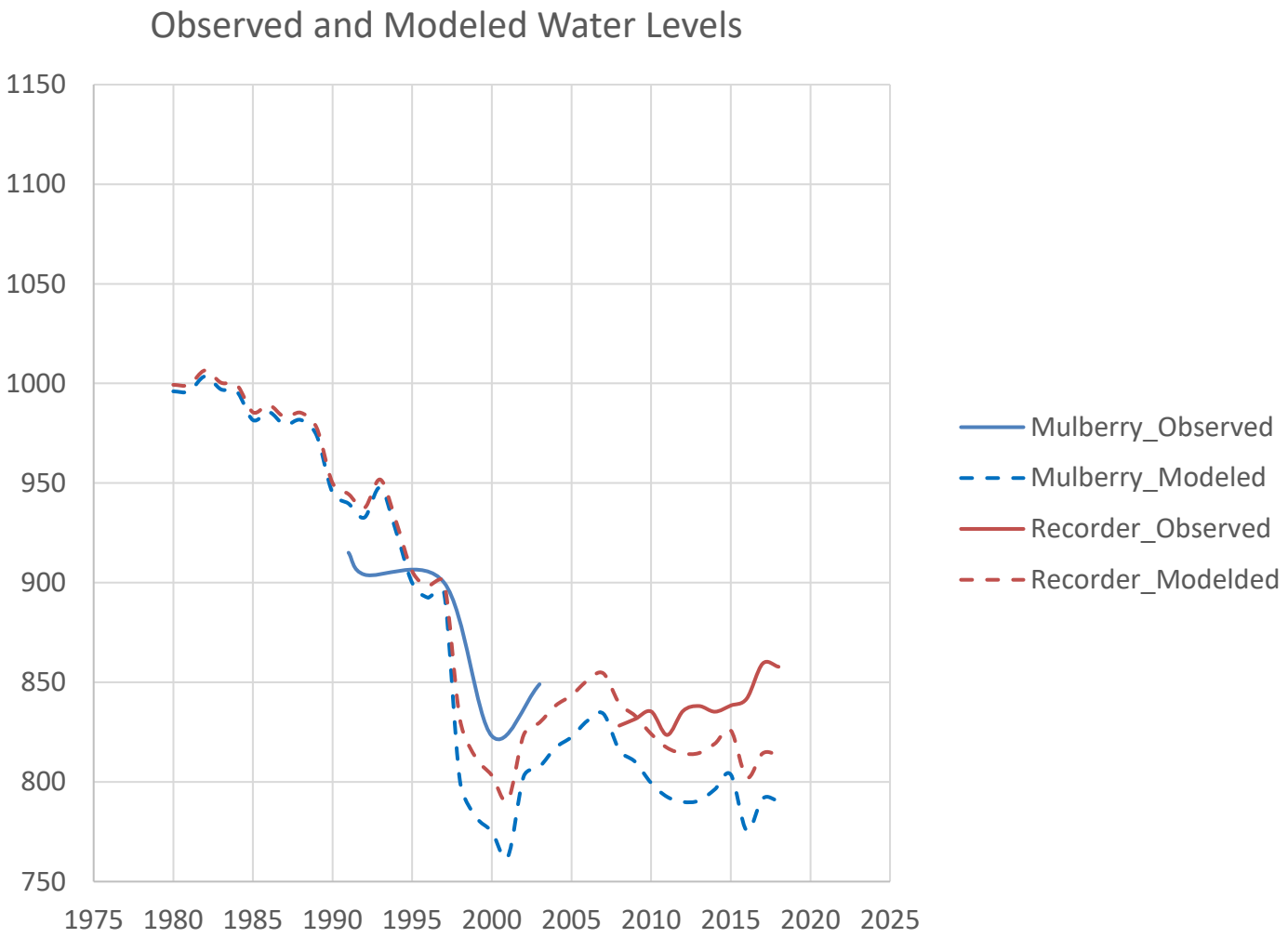
City of Bandera Wells



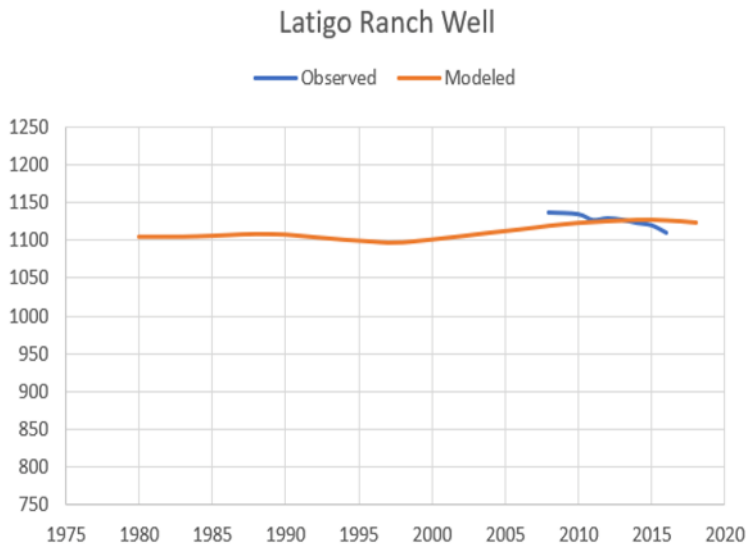


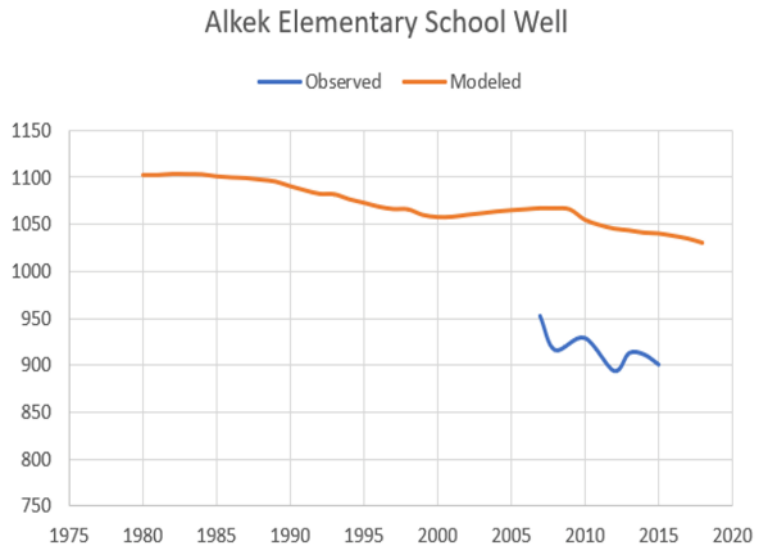


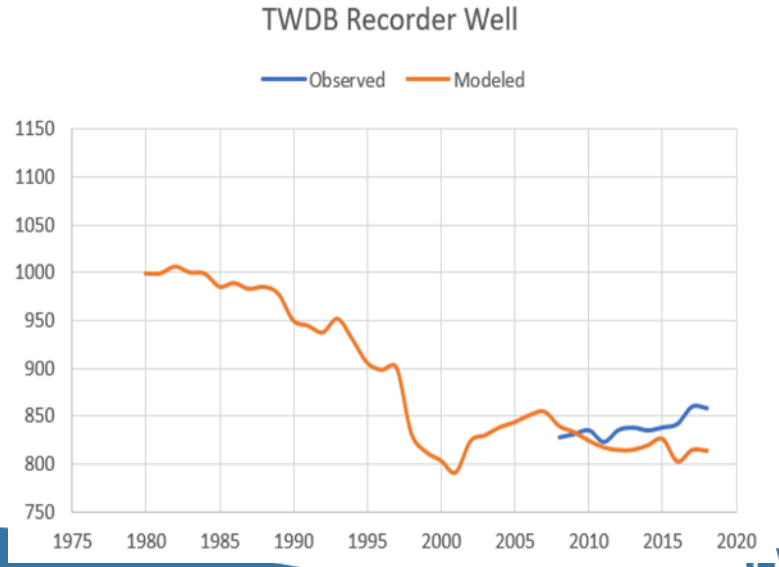
GCD Observation Wells



GCD Observation Wells







Predictive Model

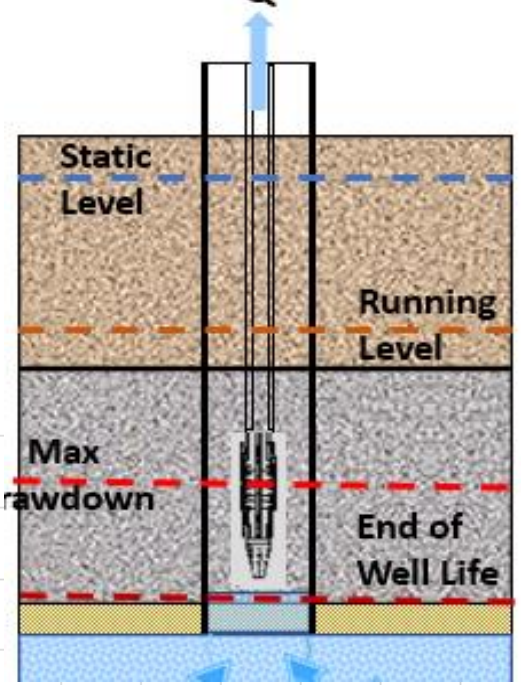
- Apply Bandera Well Longevity Model to predict future water levels based on worst case scenario for:
  - Municipal supply
  - Irrigation supply
- Existing supply from State Water Plan:

Bandera County			Existing Supply (AFY)					
WUG Name	Source Description	Basin	2020	2030	2040	2050	2060	2070
County Other	Trinity Aquifer	Nueces	399	399	399	399	399	399
Irrigation	Trinity Aquifer	Nueces	279	279	279	279	279	279
Bandera	Trinity Aquifer	San Antonio	534	534	534	534	534	534
Bandera County FWSD 1	Trinity Aquifer	San Antonio	75	75	75	75	75	75
County Other| Bandera River Ranch 1	Trinity Aquifer	San Antonio	69	69	69	69	69	69
County Other|Medina WSC	Trinity Aquifer	San Antonio	58	58	58	58	58	58
County Other	Trinity Aquifer	San Antonio	4356	4356	4356	4356	4356	4356
Irrigation	Trinity Aquifer	San Antonio	684	684	684	684	684	684

- Predict water levels until 2079

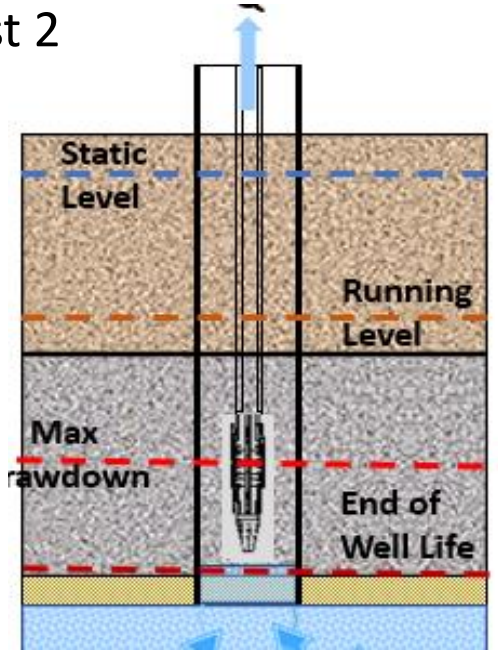
Predictive Model Results

- Based on worst case scenario
- Pump current elevation = Max drawdown
- Top of casing elevation = End of well life



Key Take-Aways

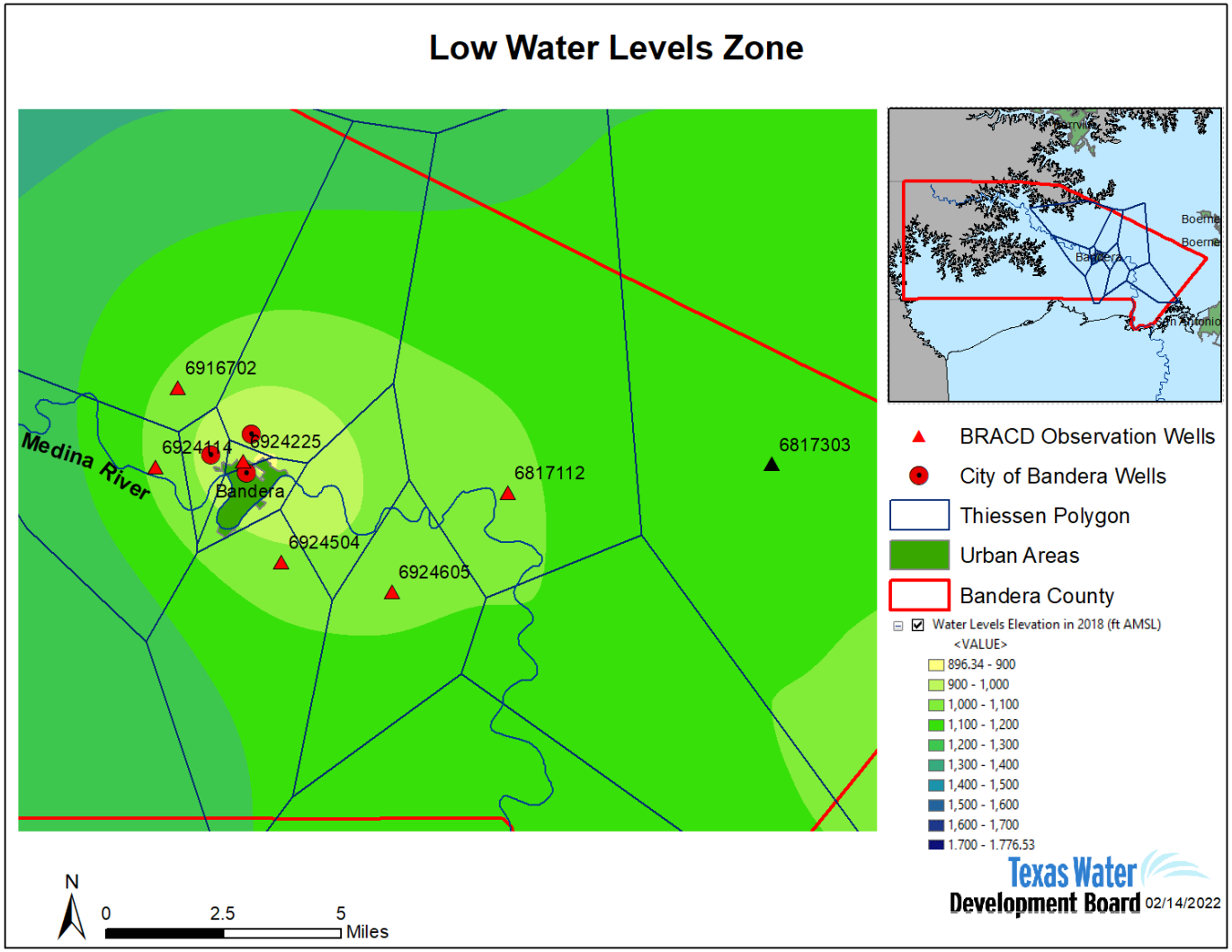
- The existing groundwater supply for City of Bandera is almost 2 times the current use



- The City of Bandera lower Trinity aquifer wells:
  - are reaching max drawdown with the current well configuration
  - will be no longer usable once the water levels reach the bottom of the casing
- Worst case scenario for the city of Bandera:
  - consume existing groundwater supply
  - Mulberry well would need to run for 6.9 hours, and drawdown would exceed current pump depth
  - wells will be no longer usable after 5 years when pumping at max supply
- Possible mitigation actions may be needed (ASR?)

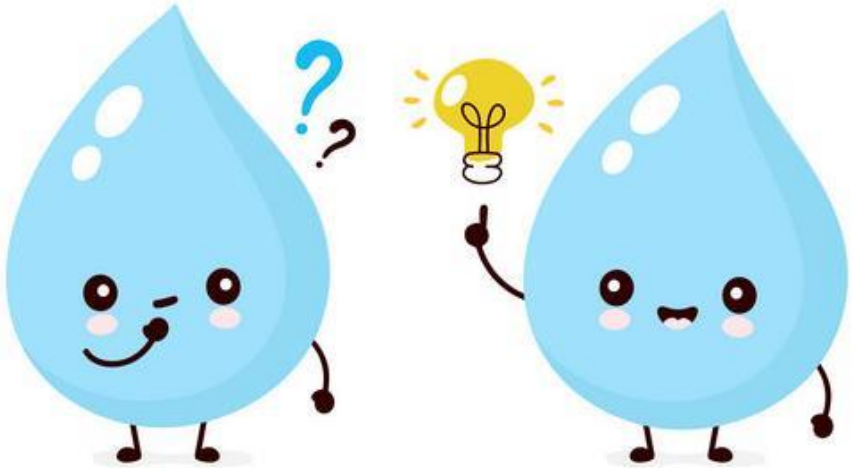
Additional Observations

- Low water levels zone (geology?)
- Limited data availability for the lower Trinity aquifer



Wrap up

- Draft report review by mid March
- Final report by Summer




Thank
you!