PRESENTATION TO GMA-12: Consideration for Environmental Impacts

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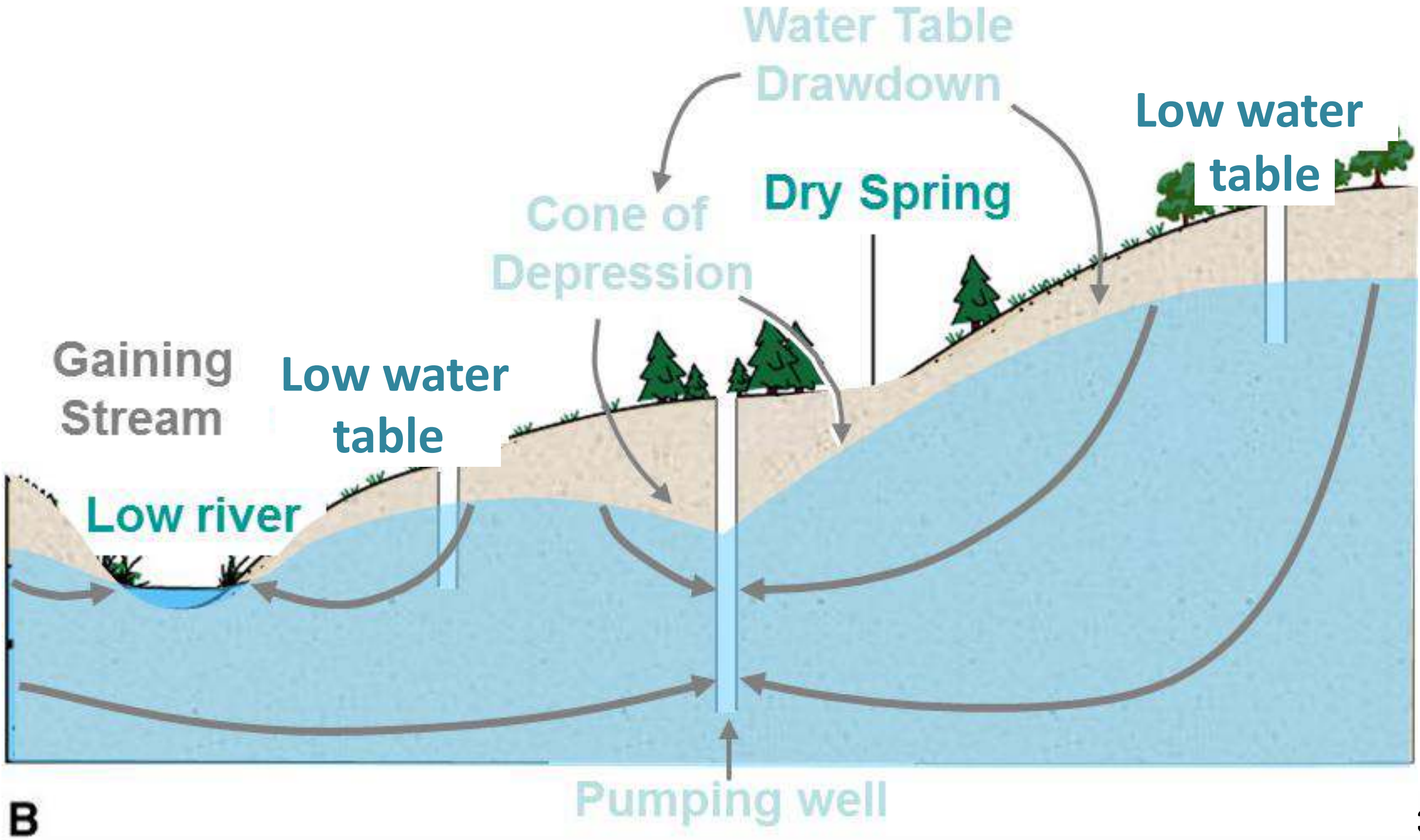
OUTLINE FOR CONSIDERATIONS FOR ENVIRONMENTAL IMPACTS

- Introduction to Shallow Groundwater Flow Systems
  - Springs
  - GW-SW interaction
- Brazos River Alluvium Aquifer GAM
  - Model overview
  - Simulated SW-GW interaction for Brazos River
- Sparta/Queen City/Carrizo-Wilcox GAM
  - Model overview
  - Simulated SW-GW interaction for Brazos River and Colorado River
- Springs in GMA 12
- Summary of Environmental Issues or Topic

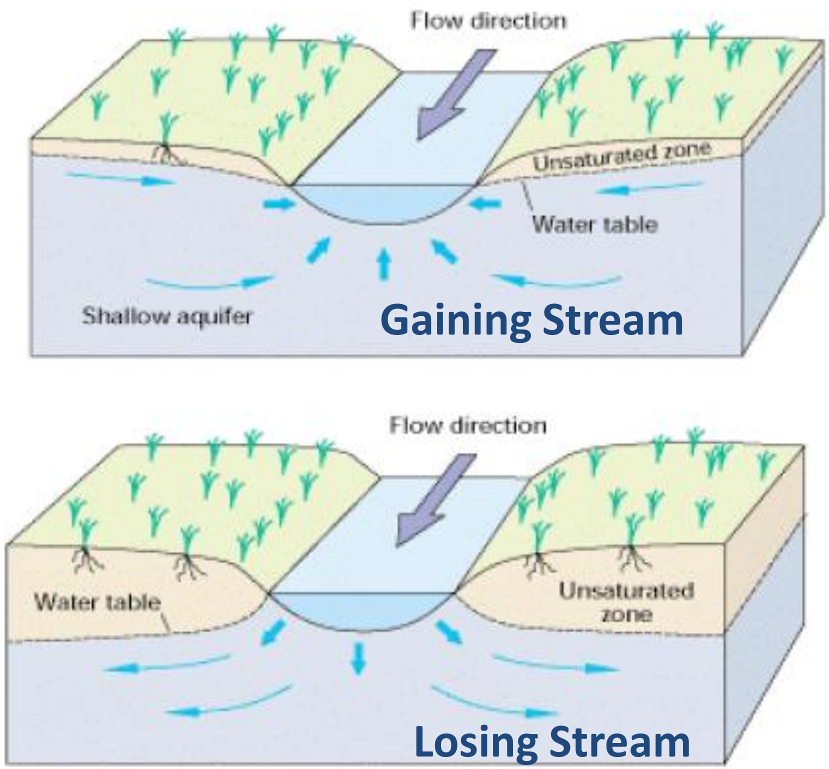
EXAMPLES OF HOW PUMPING CAN CAUSE ENVIRONMENTAL IMPACTS

- **Reduced flows to rivers**
- **Withdrawal from rivers (losing streams)**
- **Reduced spring flows**
- **Dried springs**
- **Lowered water table (vegetation impact)**

Caused by lower of water levels



CONCEPT OF GAINING AND LOSING STREAMS



USGS Circular 1186, 1999

- Gaining:
  - Net discharge of groundwater to surface water "base flow"
- Losing:
  - Net discharge of surface water to groundwater "recharge"

The TCEQ rules define baseflow as "*[t]he portion of streamflow uninfluenced by recent rainfall or flood runoff and is comprised of springflow, seepage, discharge from artesian wells or other groundwater sources, and the delayed drainage of large lakes and swamps.*

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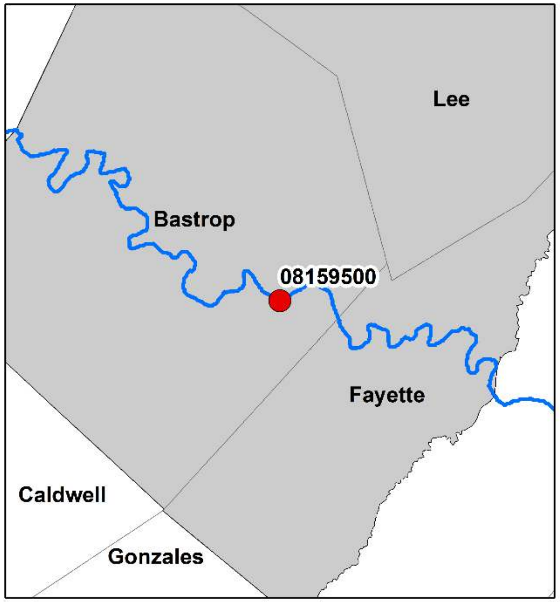
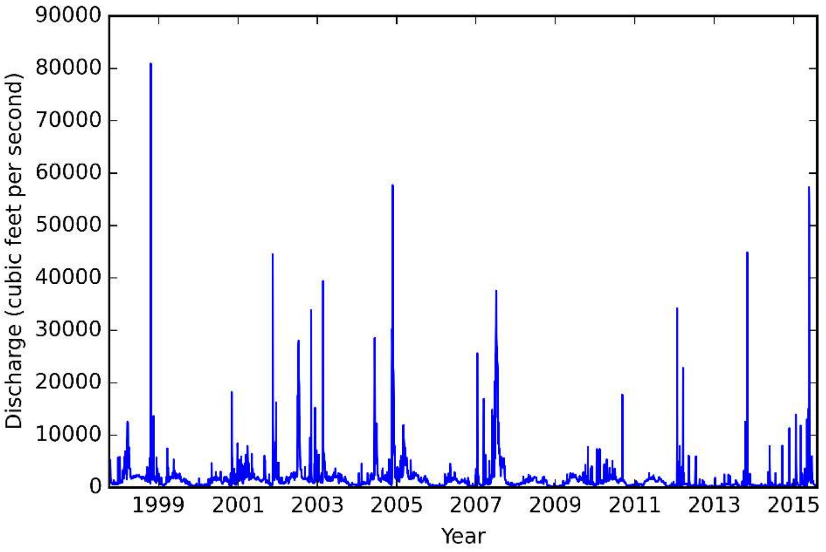
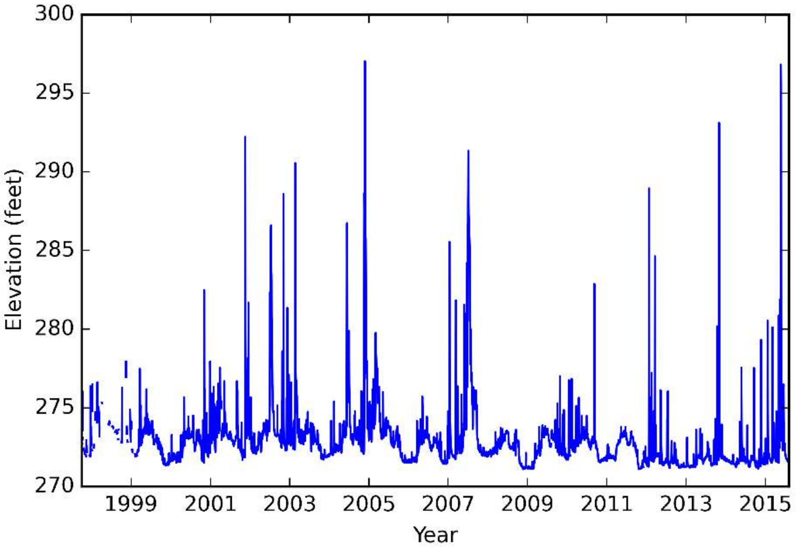
STREAM DATA FROM THE COLORADO RIVER



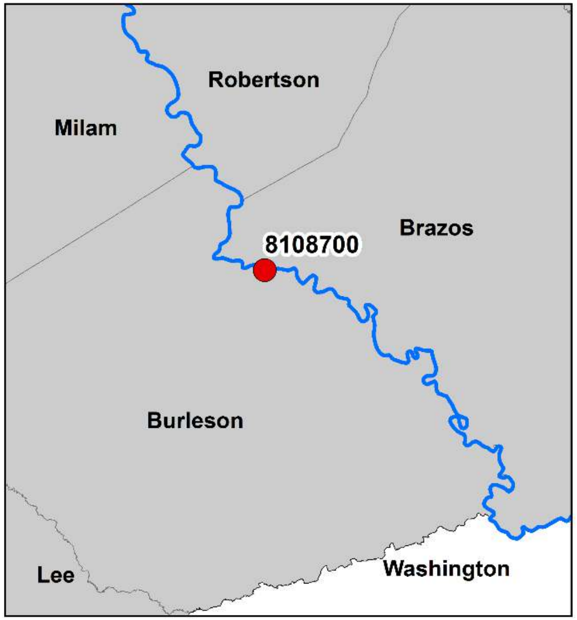


Example Gage on Colorado River



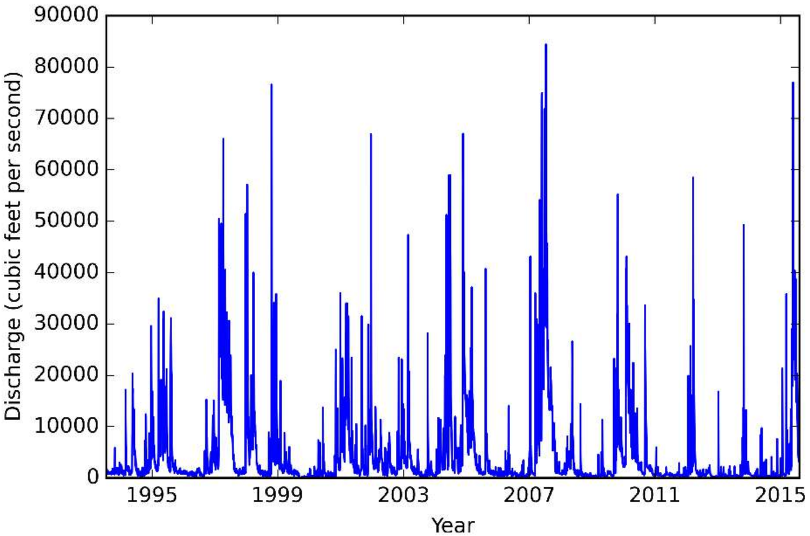
Average annual flow is 1.4 million acre-ft/yr
(~ 1,900 cfs)

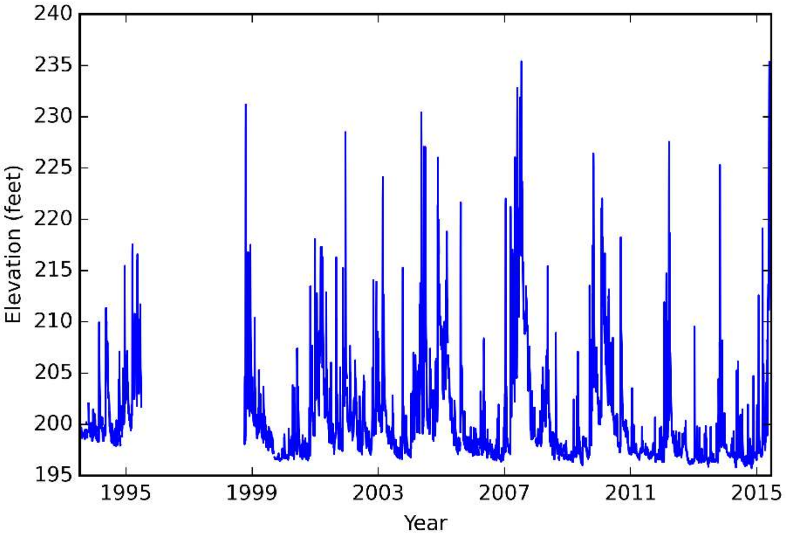
STREAM DATA FROM THE BRAZOS RIVER



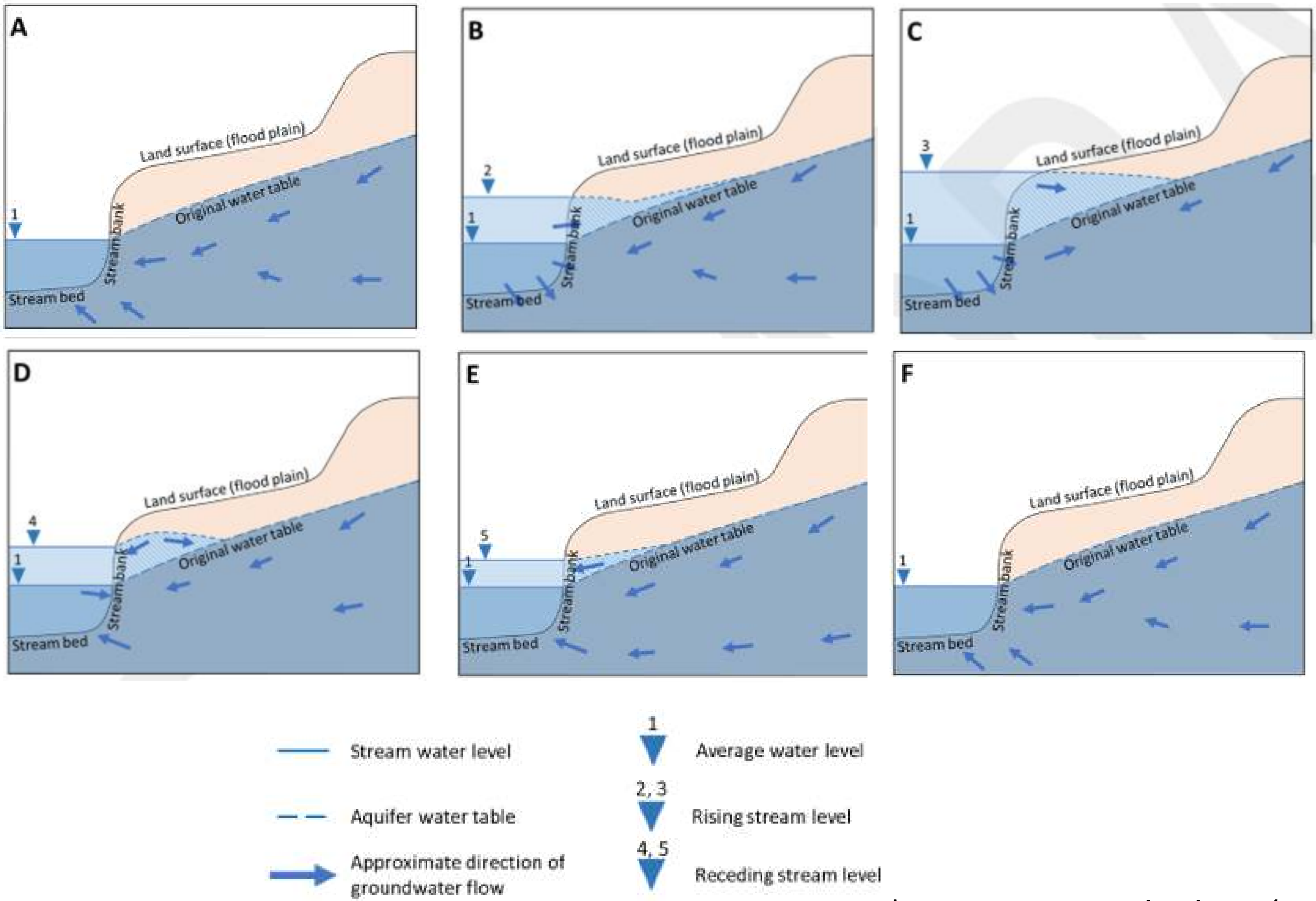
Example Gage on Brazos River

Average annual flow is 3.5 million acre-ft/yr
(~ 4,890 cfs)





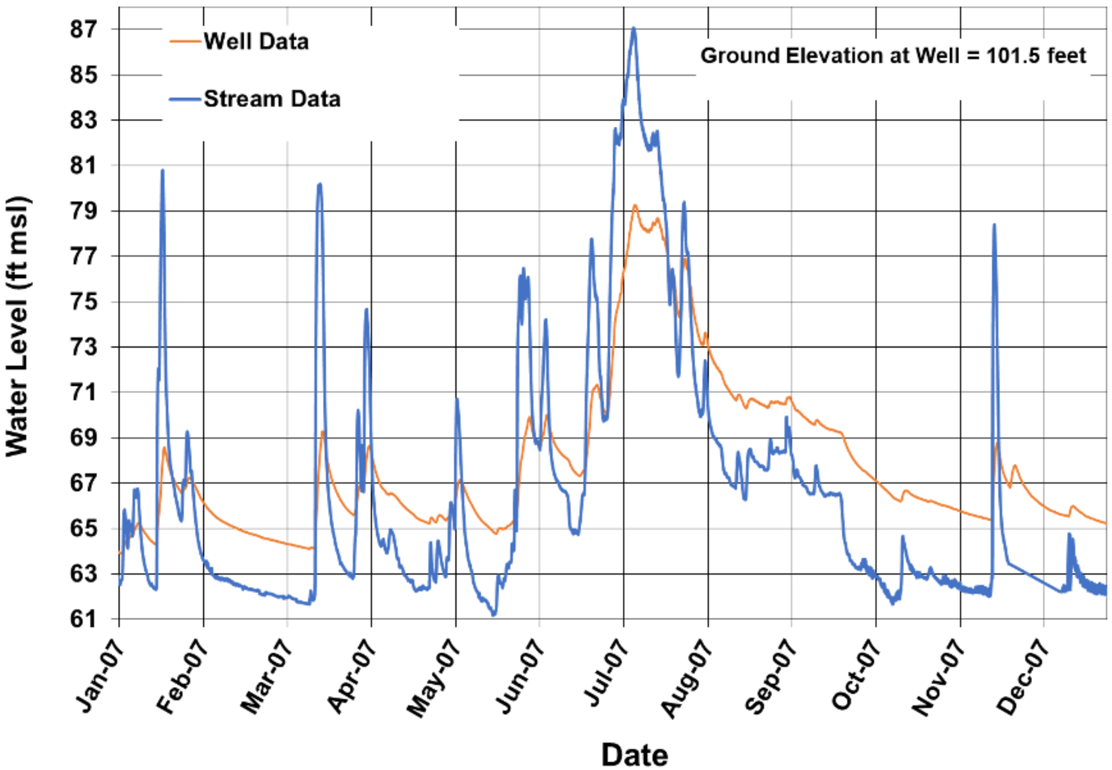
SCHEMATIC OF PROCESSES AFFECTING BANK STORAGE AND BANK FLOW



*From Young and others (2017)

EVIDENCE OF BANK STORAGE AND BANK FLOW IN ALLUVIUM

Comparison of water levels in river gauge and groundwater well near City of Wharton (Young and others, 2018)

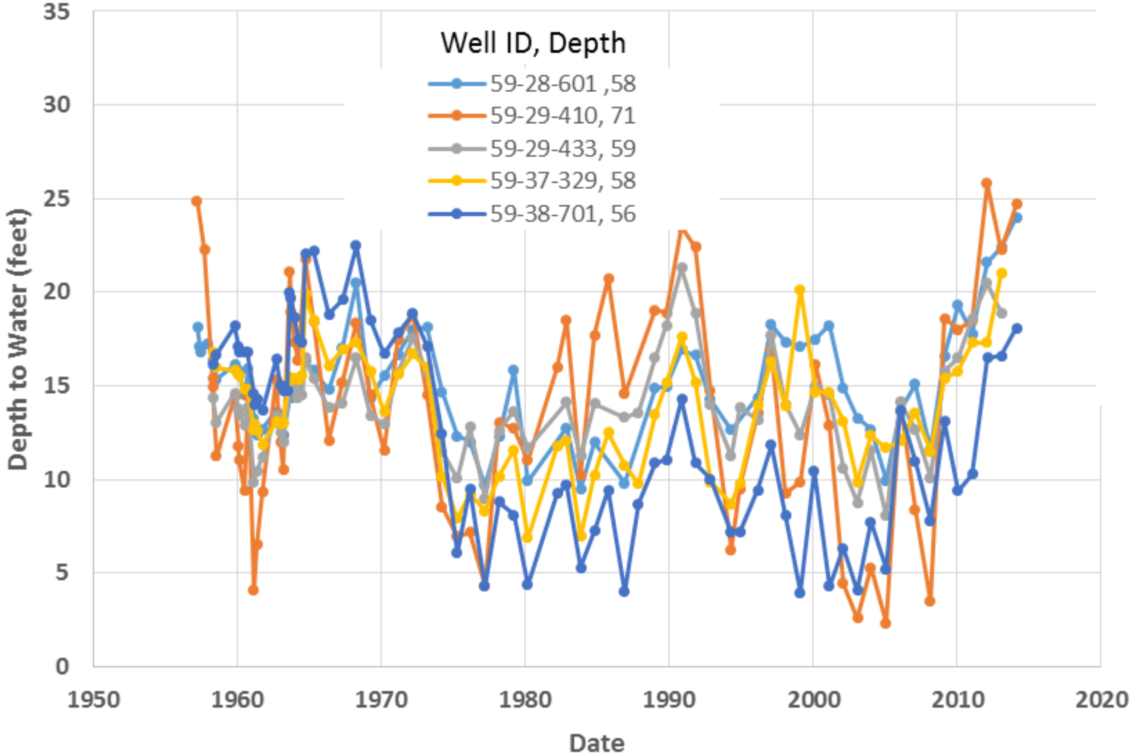


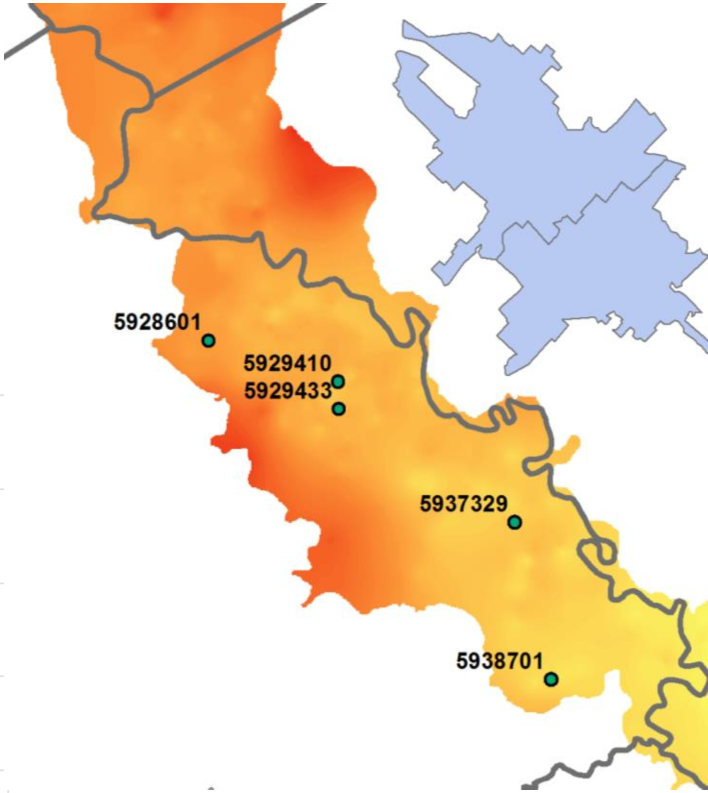
Note: well is located about 200 feet from river

Comparison of Isotopes in groundwater in Burleson County and surface water in Brazos River

This study involved the analysis of water levels and water quality in the Brazos River and groundwater in Burleson County. Over a four-month post-flood event period, Rhodes and others (2017) estimated that 96% of the groundwater that flowed to the Brazos River from the aquifer was from bank storage or water in temporary residence

EVIDENCE OF LIMITED PERSISTANCE FOR LOW WATER LEVEL CONDITIONS IN ALLUVIUM





POTENTIALLY IMPORTANT CHARACTERISTICS OF ALLUVIAL DEPOSITS AFFECTING GW-SW INTERACTION

- Transient and dynamic nature of water levels in rivers that occurs at time scales much smaller than 1 year
- Bank storage in alluvium during times of high river levels
- Bank flow from alluvium during after times of high river levels
- Short persistence (less than a few years) of low water levels in alluvium

APPLICATION OF THE BRAA AND SP/QC/CW GAMs FOR SIMULATING GW-SW EXCHANGE

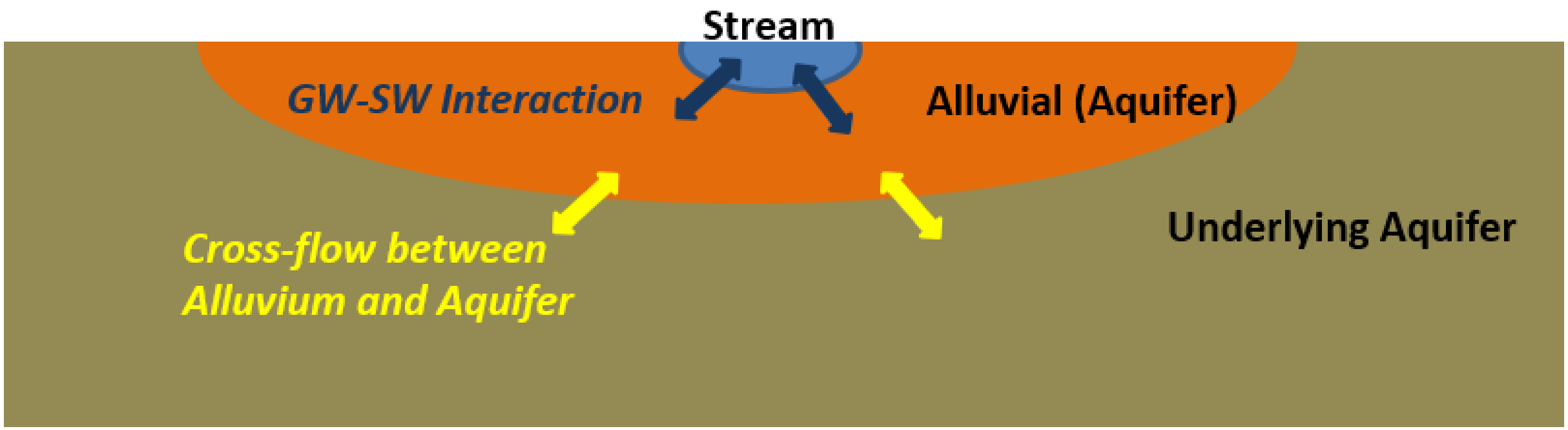
- Strengths
  - provide a better shallow ground flows zones than previous GAMs
  - explicitly account for the impact of alluvium on GW-SW interactions
  - grid refinement near streams to improve representation of river cells and wells
- Short-comings
  - Hydraulic properties of stream beds are largely unknown
  - Equations and do not account for potentially important processes such as unsaturated flow and bank flow
  - Input data and calibration targets are based on time intervals of 1-year, but GW-SW interactions are driven by processes that occur on time scale of hours to days
  - GAM predictions have not been validated with field data

APPLICATION OF THE BRAA AND SP/QC/CW GAMs FOR SIMULATING GW-SW EXCHANGE (con't)

- Given careful application and analysis, GAMs are suitable for developing some qualitative relationship between pumping and GW-SW exchange

- Without refinement in their representation of changing surface water levels and subsequent validation using measured field data, GAMs are not suitable for developing quantitative relationship between pumping and GW-SW exchange

WATER BUDGET FOR GW-SW EXCHANGE THAT IS SIMULATED BY THE GAMS

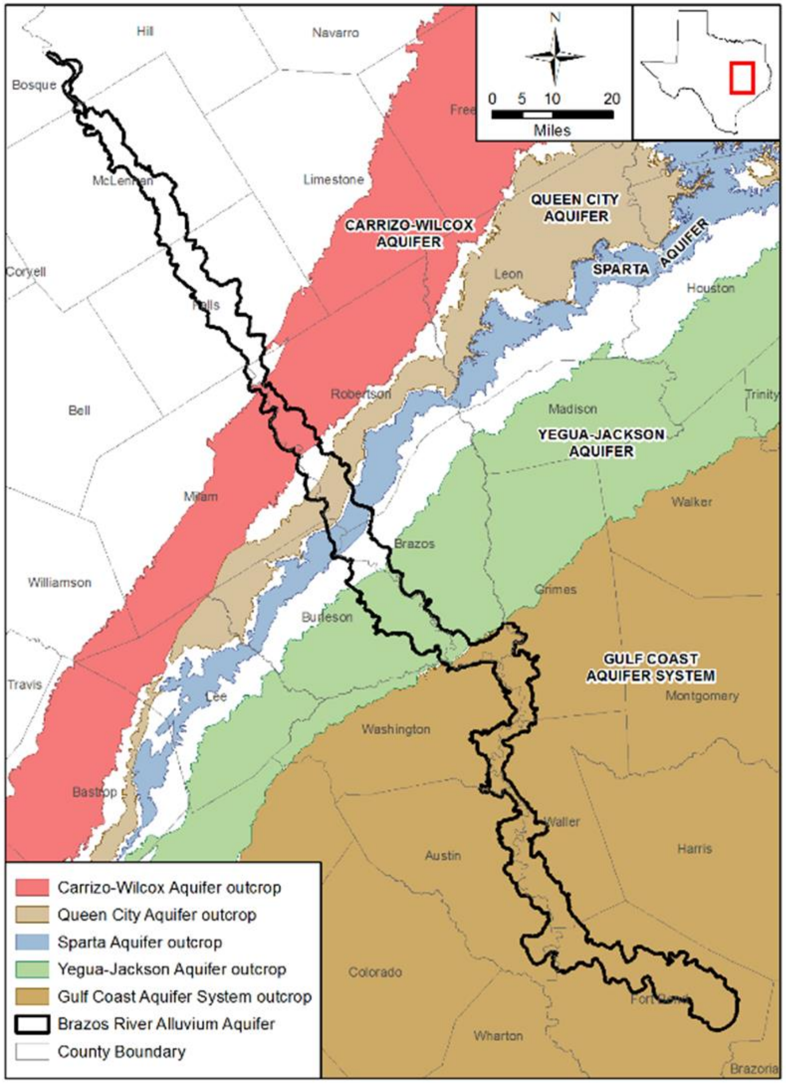


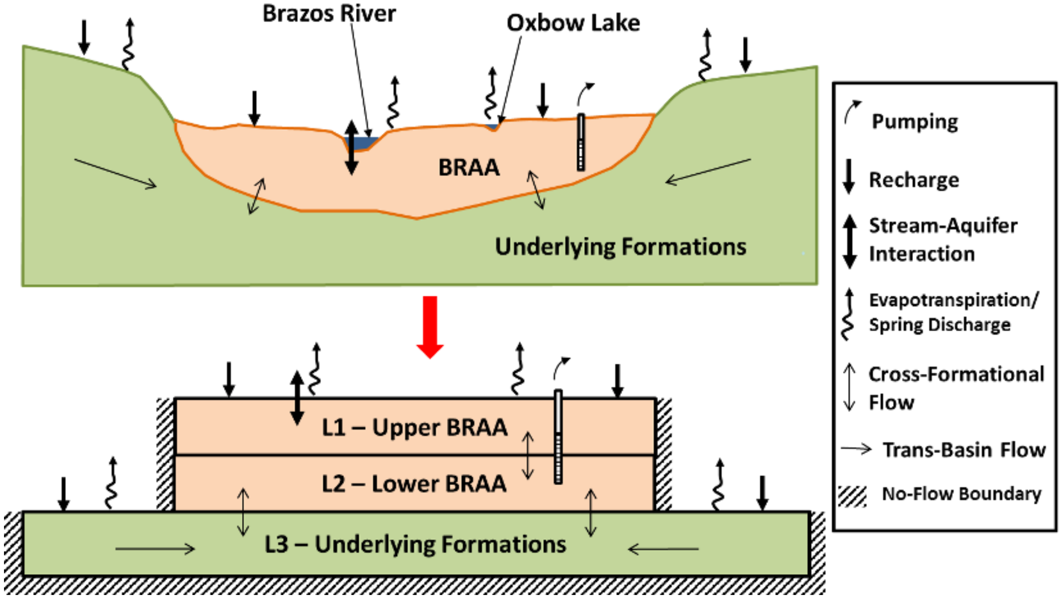
GW-SW Interaction

Flow from Aquifer to Stream is Negative
Flow From Stream to Aquifer is Positive

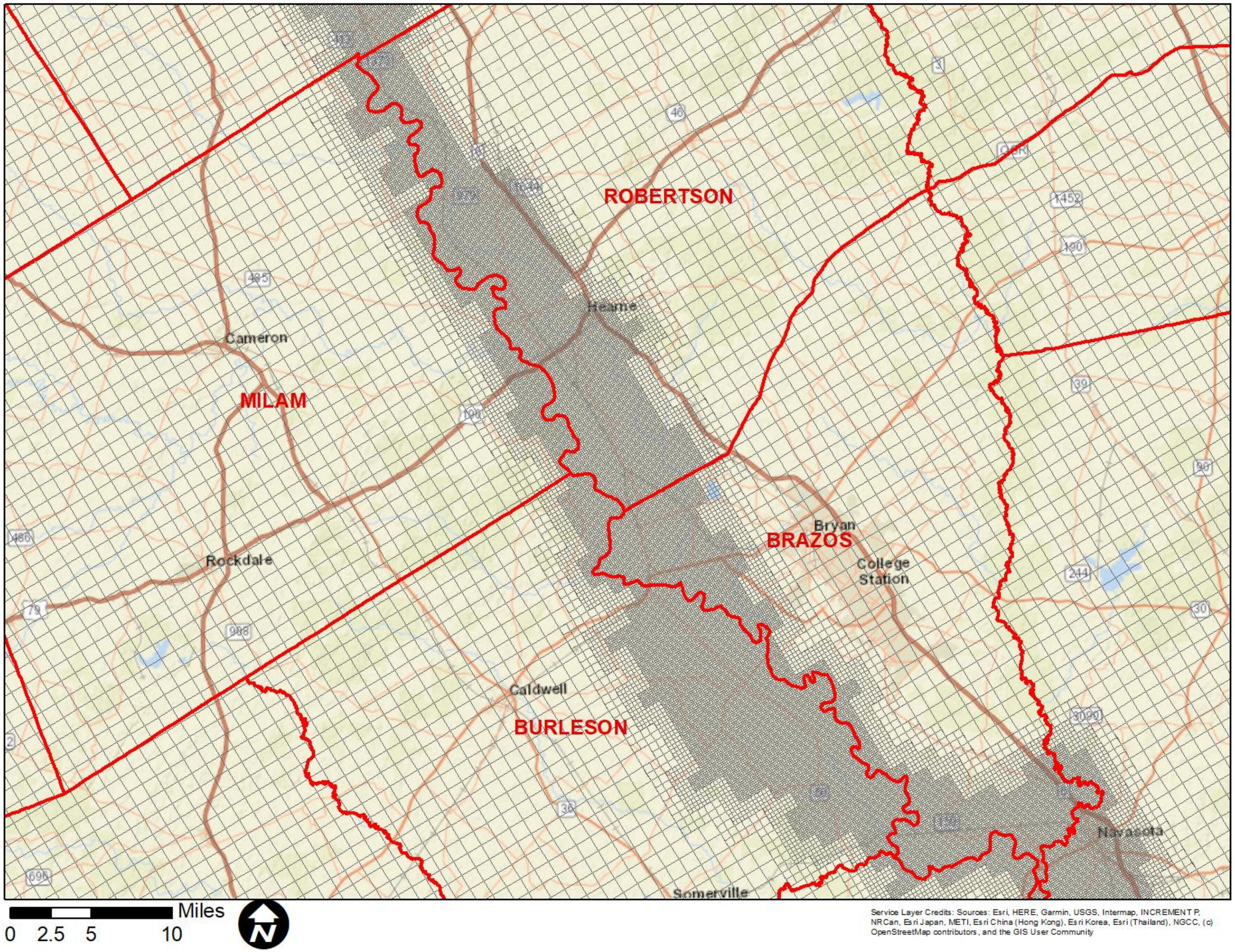
Positive Net Flow Stream Flow = Losing Stream
Negative Net Flow Stream Flow = Gaining Stream

CONCEPTUAL MODEL FOR THE BRAZOS RIVER ALLUVIAL AQUIFER (BRAA) GAM



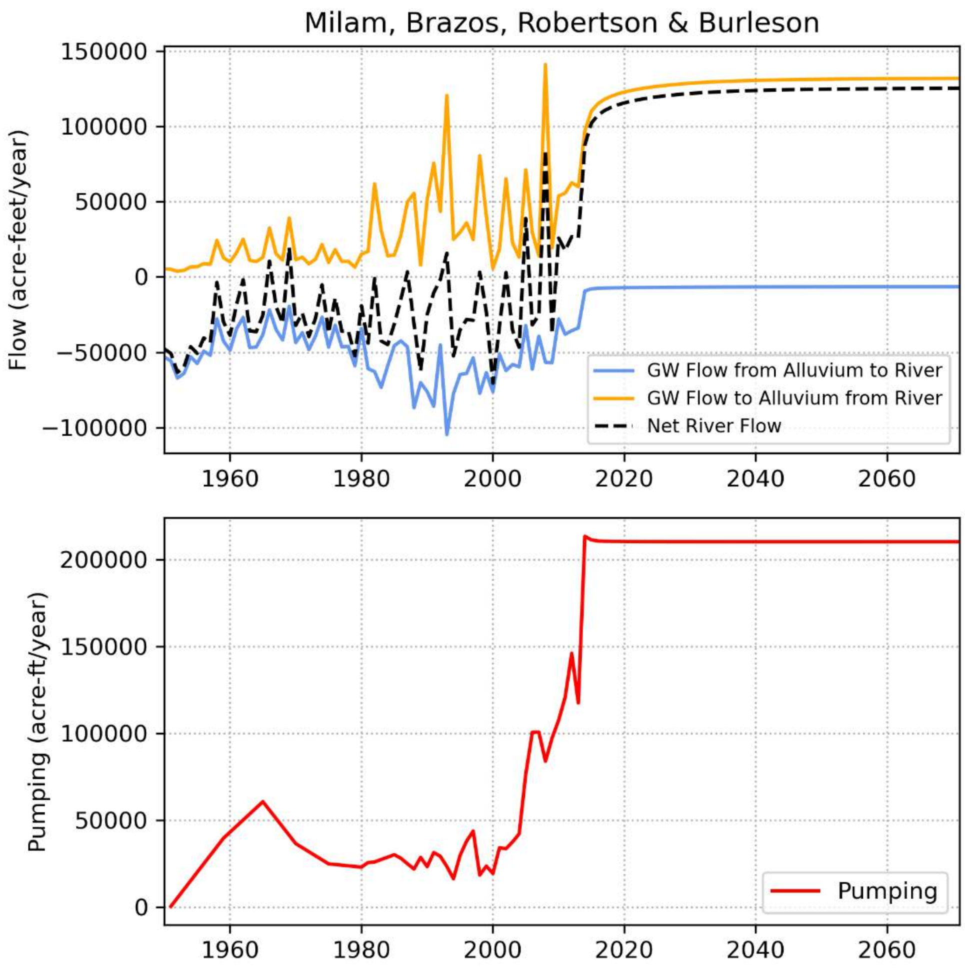


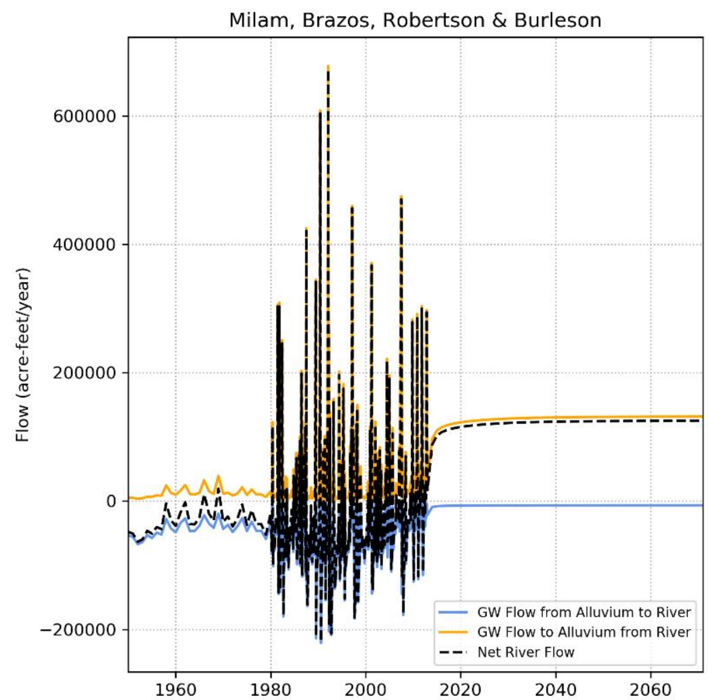
MODEL GRID FOR THE BRAA



BRAA GAM SIMULATED WATER BALANCE: GMA 12

Year	Net GW Flow (acft/yr)
2010	4,399
2070	125,111
Differerence	120,712

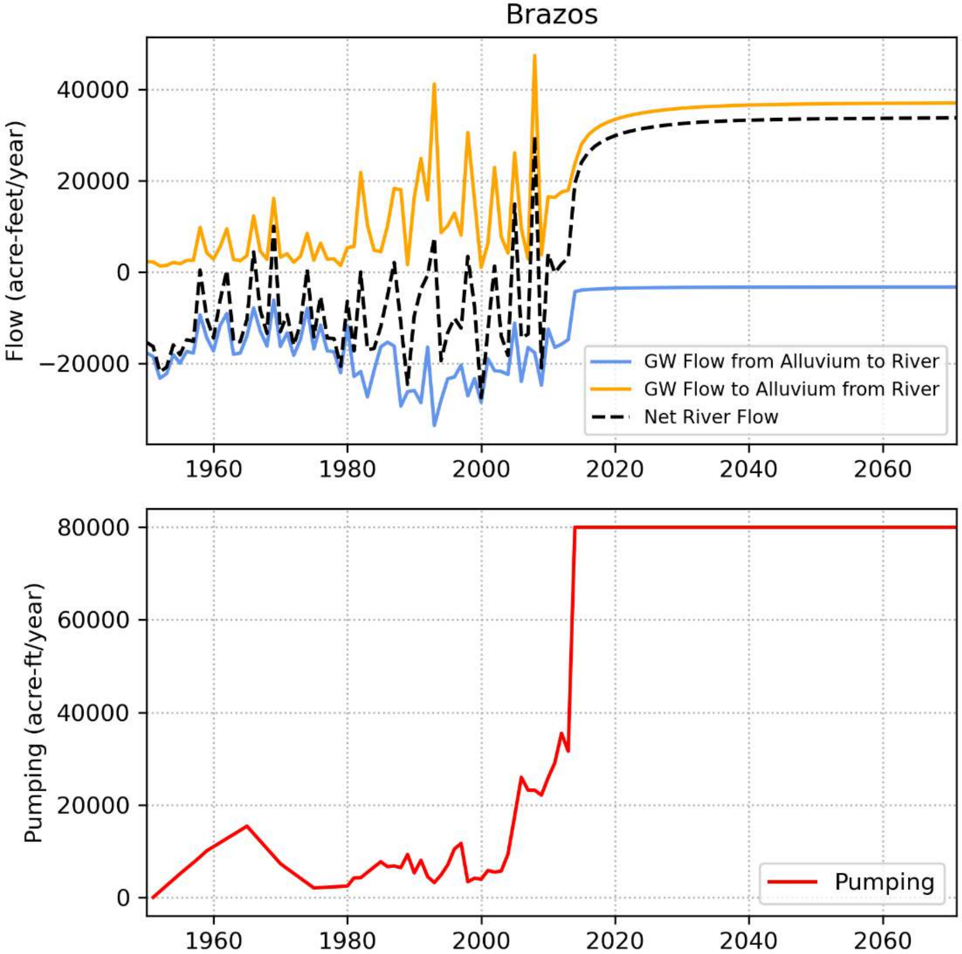


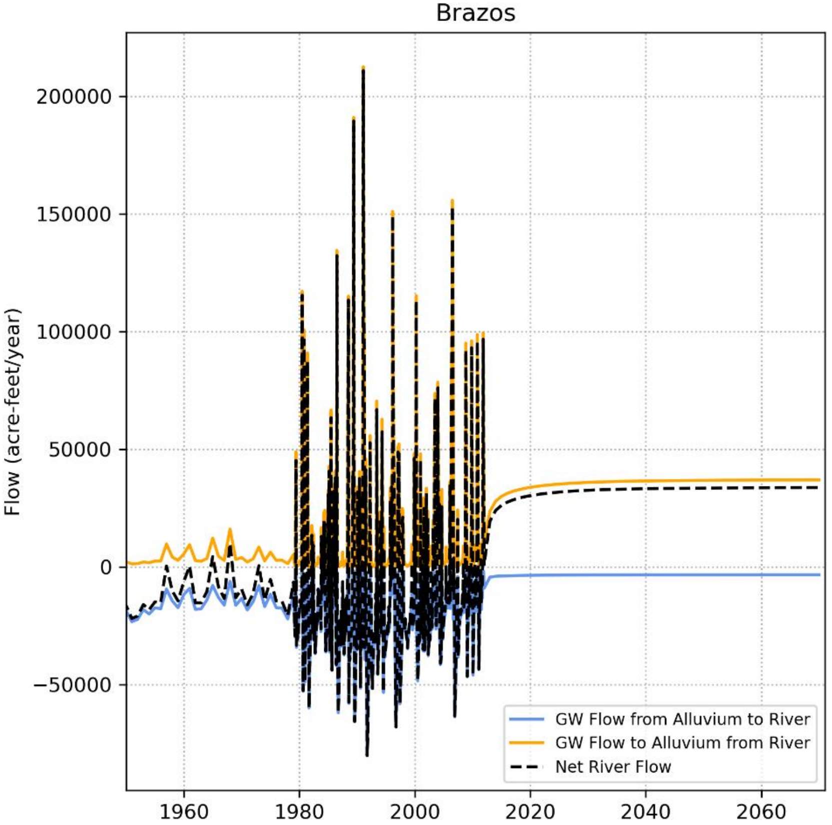


Note: over 200,000 AFY pumping continuously from 2010 to 2070

BRAA GAM SIMULATED WATER BALANCE: BRAZOS

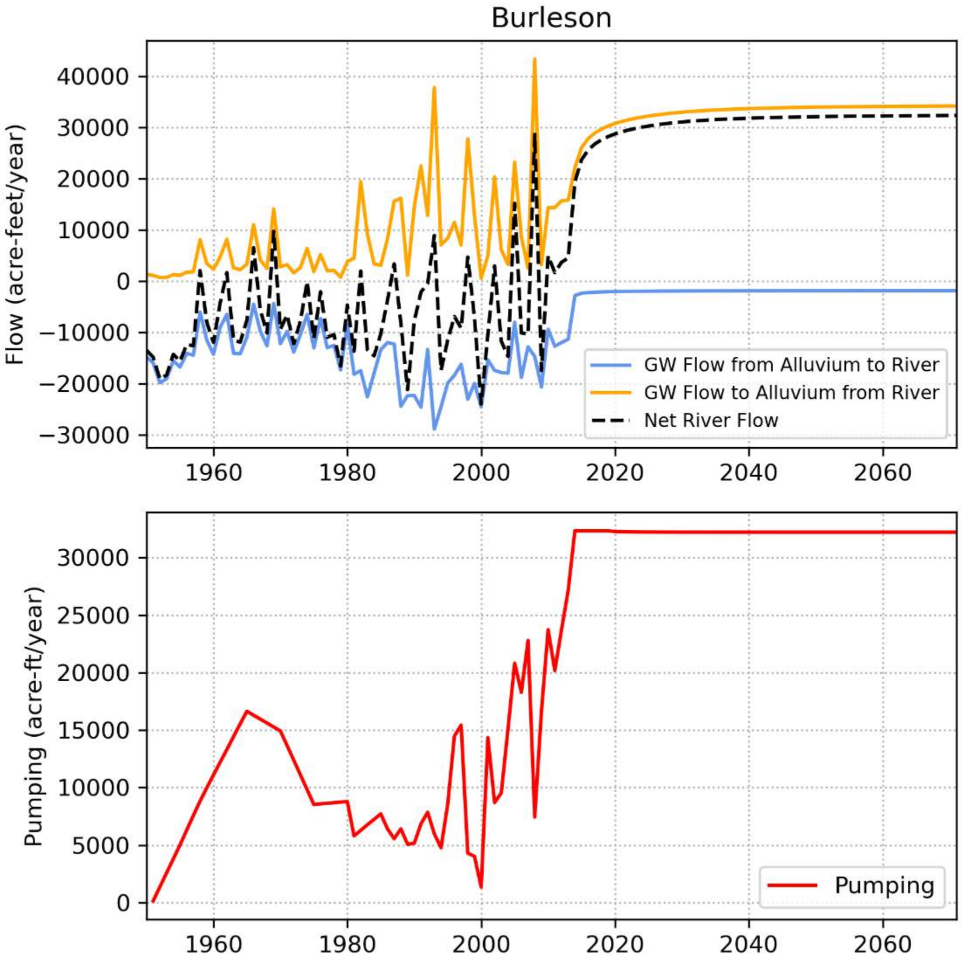
Year	Net GW Flow (acft/yr)
2010	-3,247
2070	33,728
Differerence	36,975

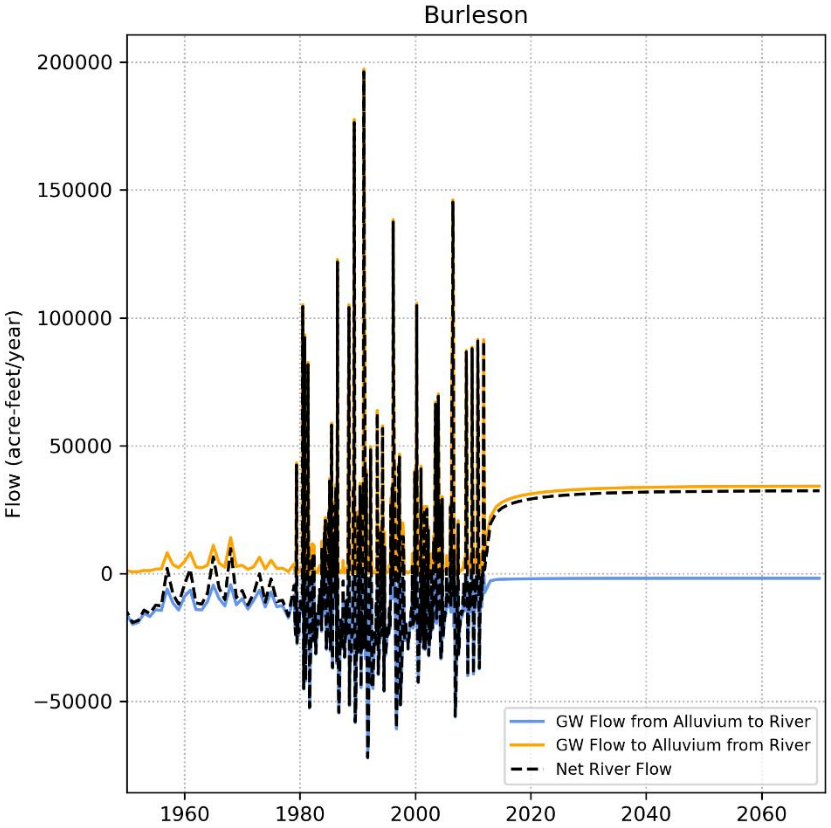




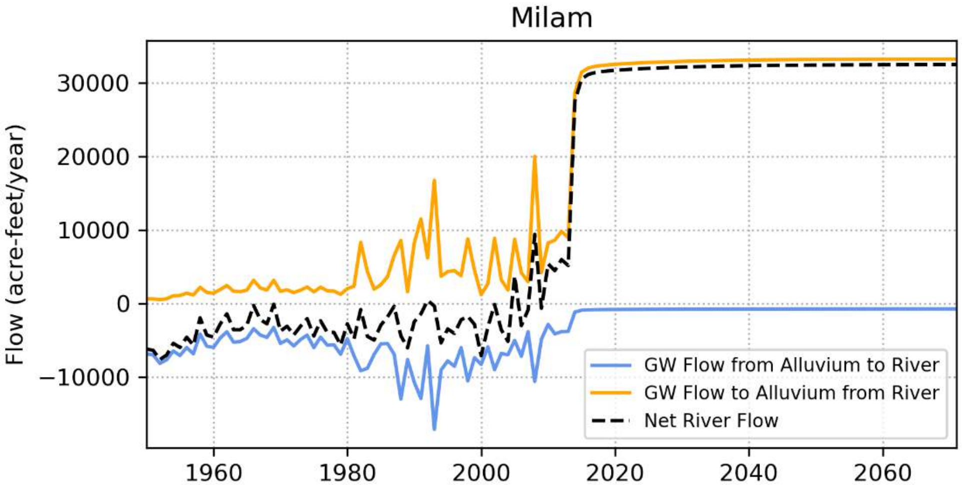
BRAA GAM SIMULATED WATER BALANCE: BURLESON

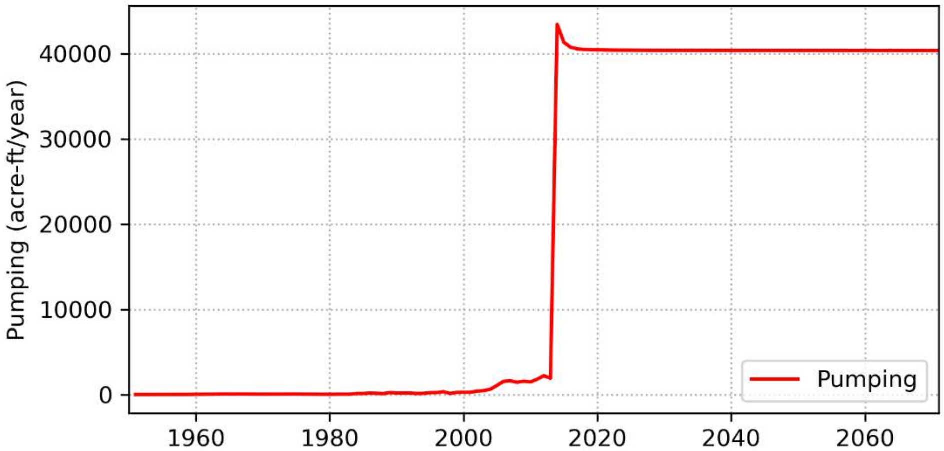
Year	Net GW Flow (acft/yr)
2010	-2,267
2070	32,355
Differerence	34,622



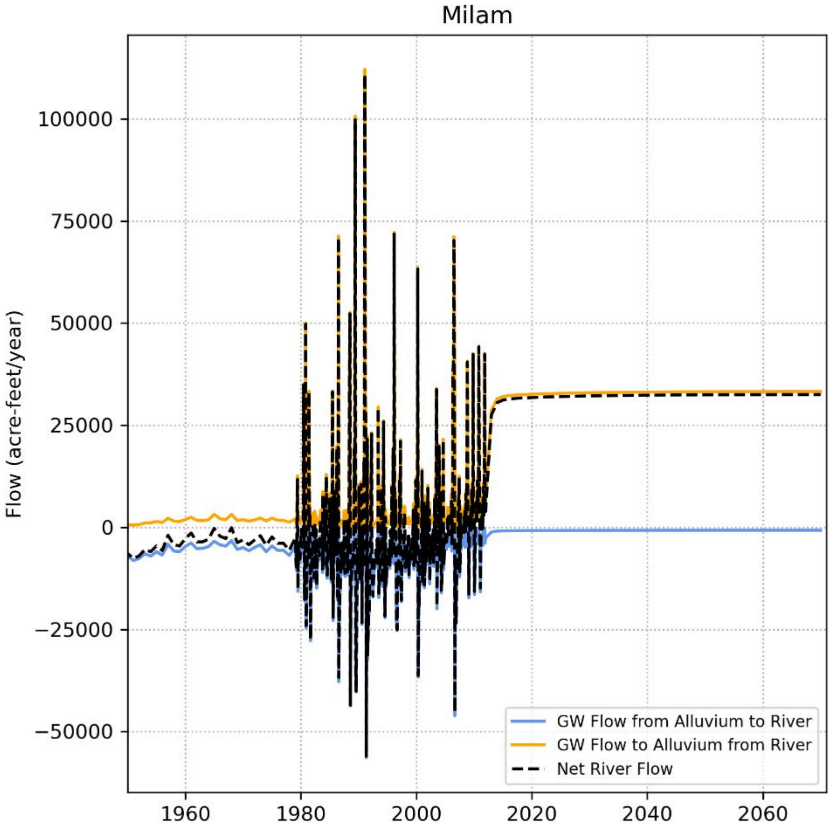


BRAA GAM SIMULATED WATER BALANCE: MILAM



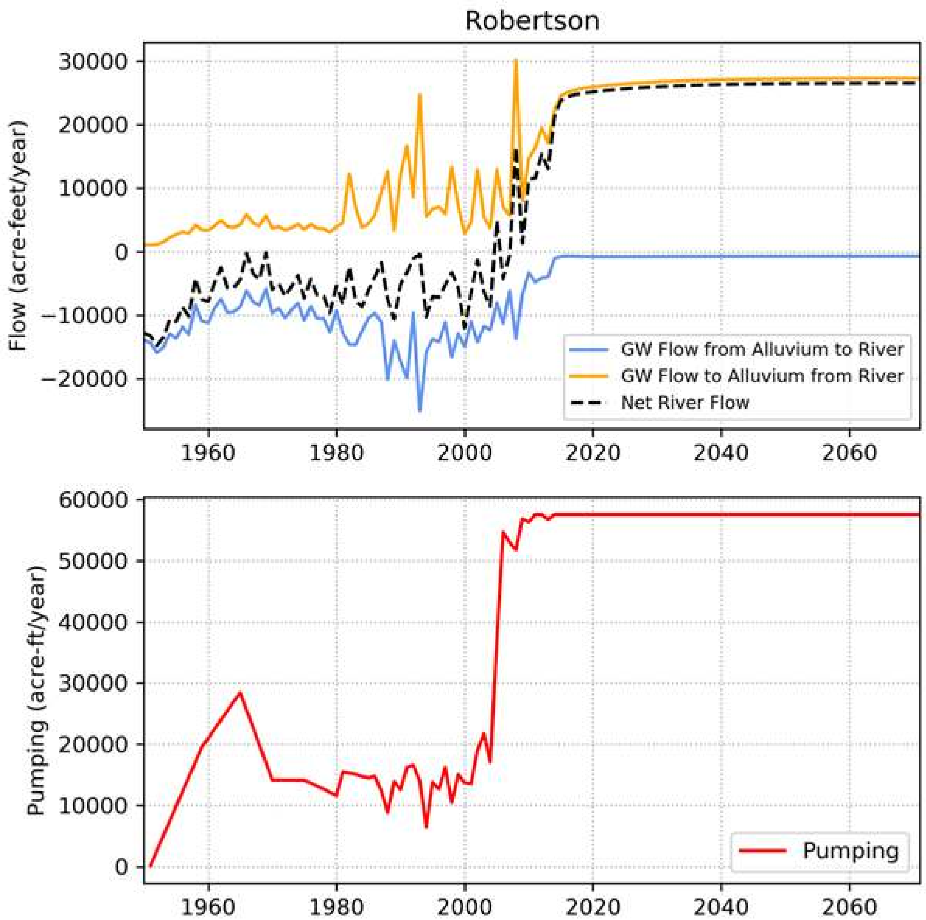


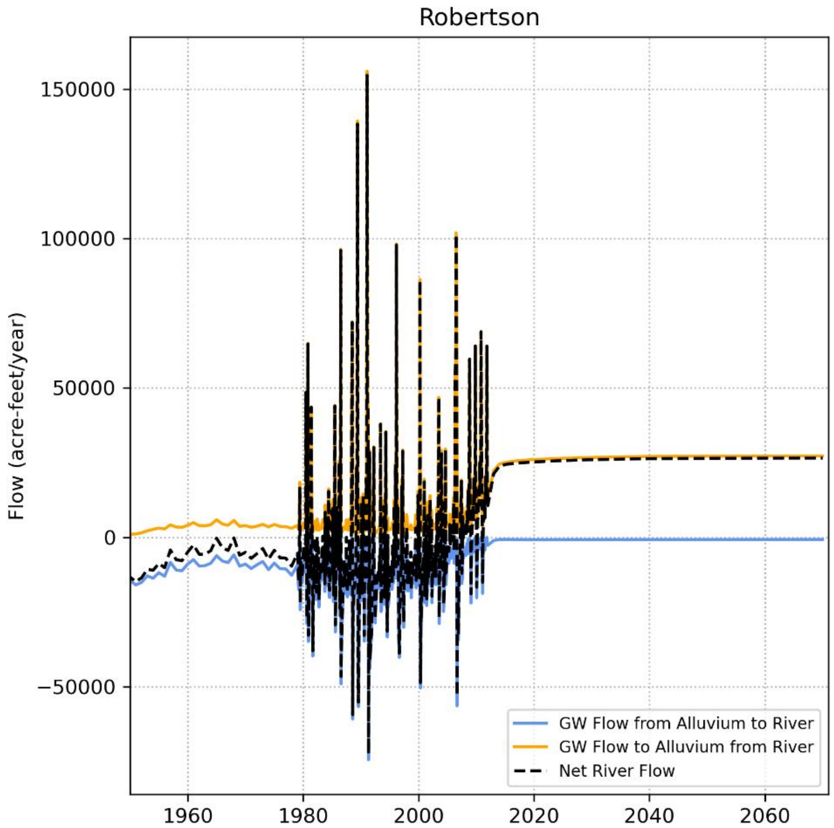
Year	Net GW Flow (acft/yr)
2010	2,429
2070	32,494
Differerence	30,065



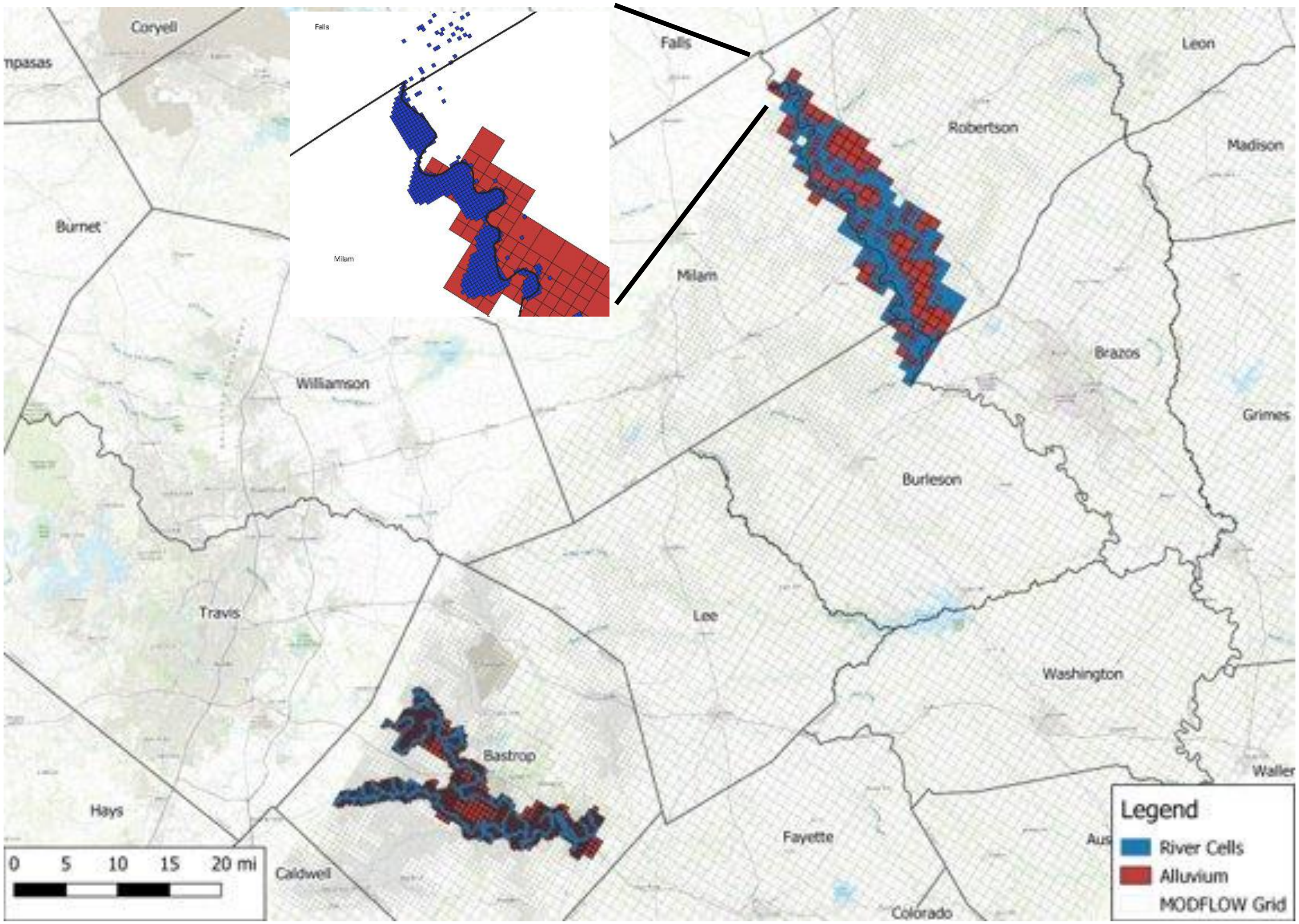
BRAA GAM SIMULATED WATER BALANCE: ROBERTSON

Year	Net GW Flow (acft/yr)
2010	7,484
2070	26,534
Differerence	19,050





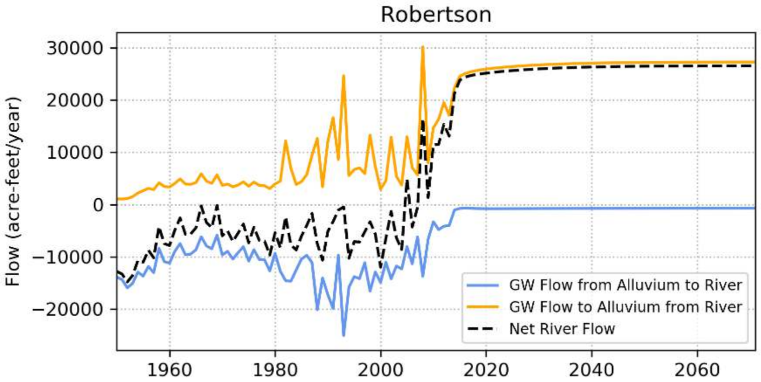
LOCATION OF ALLUVIUM IN SPARTA/QUEEN CITY/CARRIZO WILCOX GAM

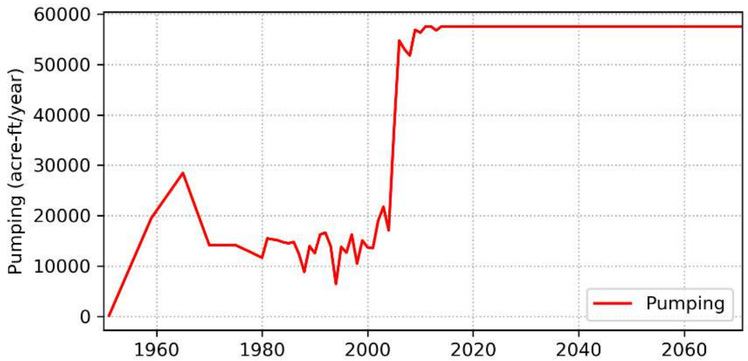


COMPARISON OF GAM SIMULATIONS FOR ROBERTSON COUNTY

BRAA GAM

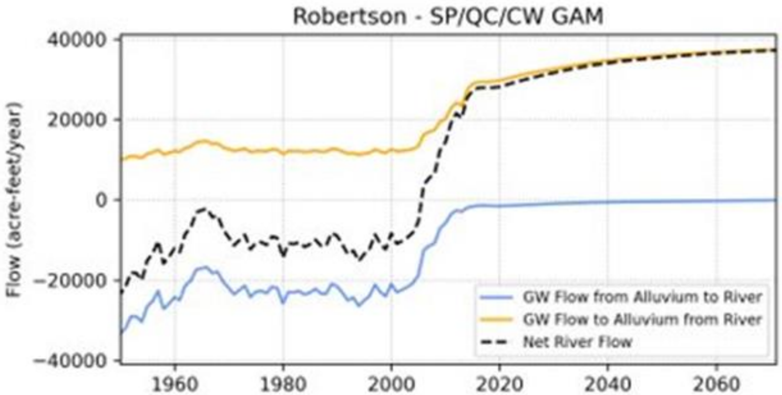
Year	Net GW Flow (acft/yr)
2010	7,484
2070	26,534
Differerence	19,050

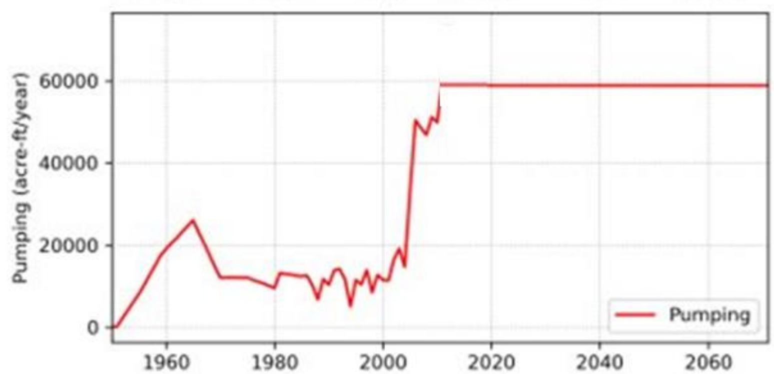




SP/QC/CW GAM

Year	Net GW Flow (acft/yr)
2010	14,285
2070	37,198
Differerence	22,913



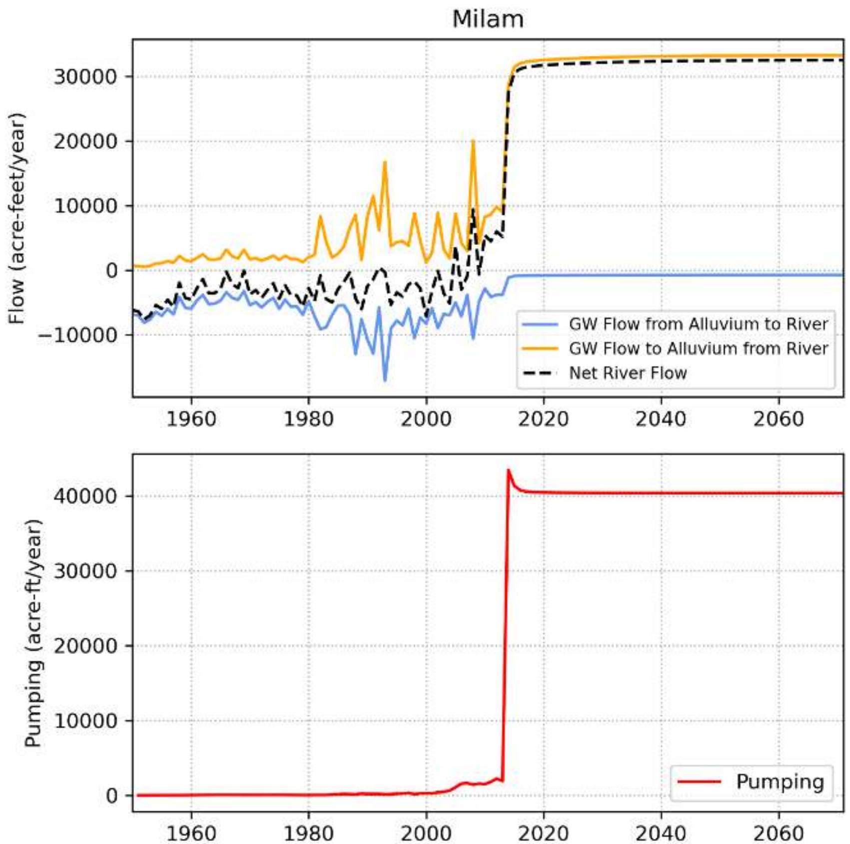


Note: pumping is from alluvium

COMPARISON OF GAM SIMULATIONS FOR MILAM COUNTY

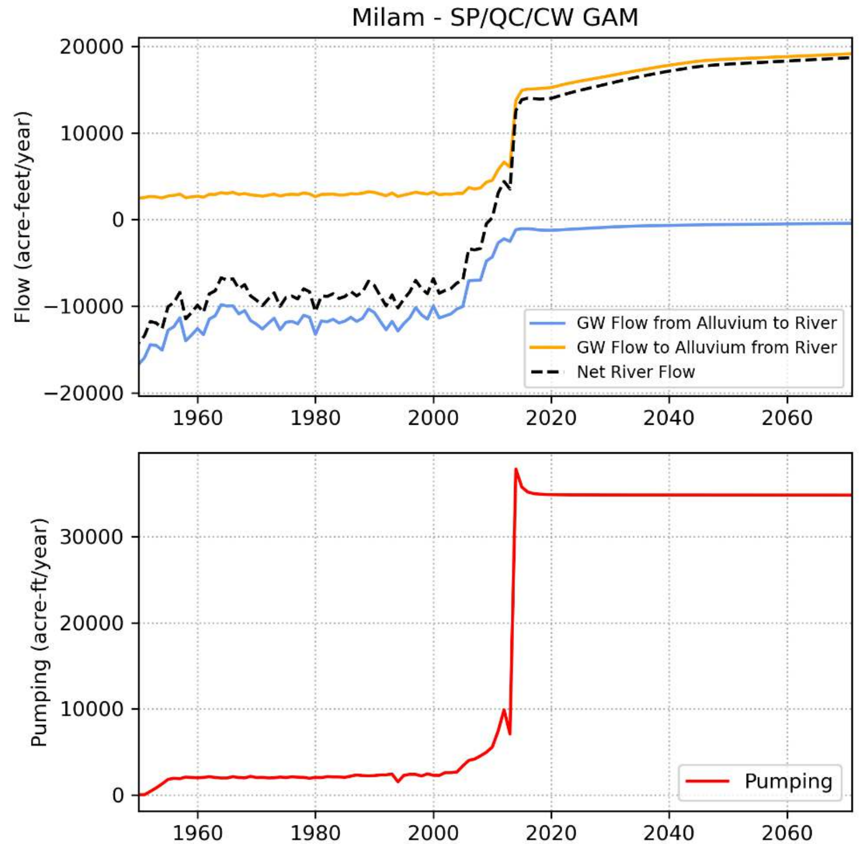
BRAA GAM

Year	Net GW Flow (acft/yr)
2010	2,429
2070	32,494
Differerence	30,065



SP/QC/CW GAM

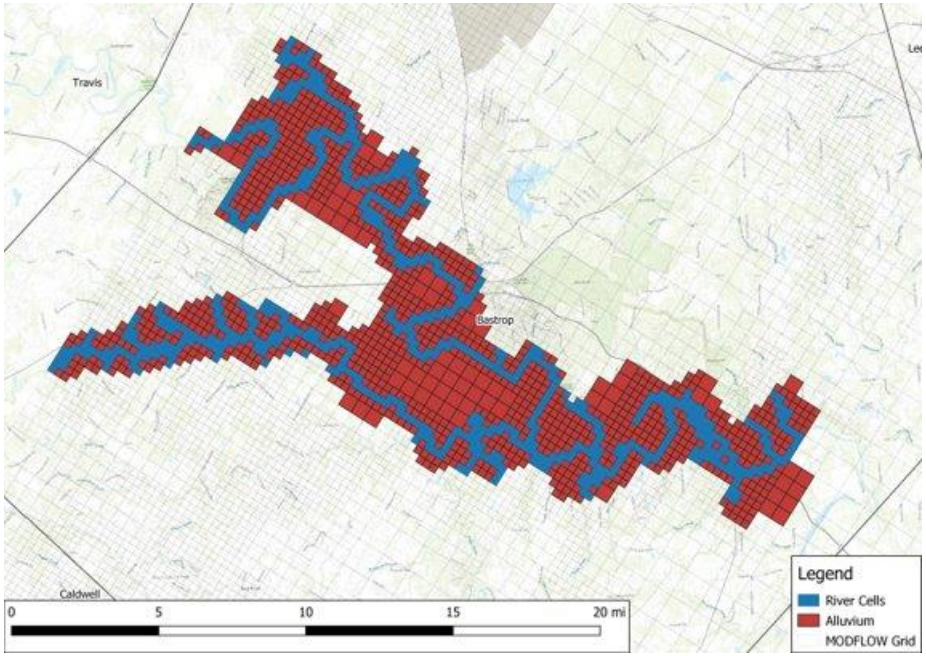
Year	Net GW Flow (acft/yr)
2010	199
2070	18,702
Differerence	18,503

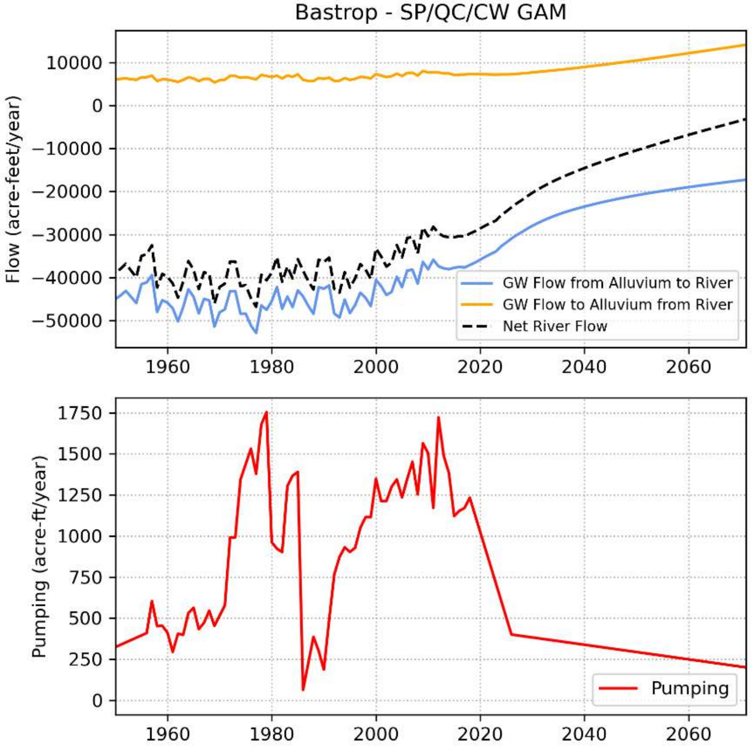


Note: pumping is from alluvium

SP/QC/CW GAM SIMULATED WATER BALANCE: IN BASTROP

Year	Net GW Flow (acft/yr)
2010	-30,413
2070	-3,167
Differerence	27,246





Note: pumping is from alluvium

SUMMARY OF SW-GW EXCHANGE SIMULATED FROM 2010-2070 FOR STREAM-ALLUVIUM INTERACTIONS

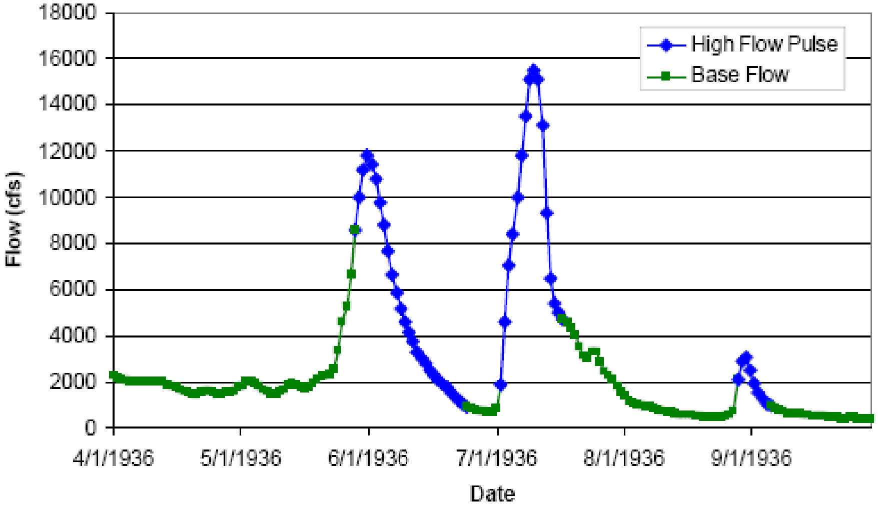
- GAMs have been developed to include shallow flow system that include alluvium for Colorado Rivers and Brazos Rivers
- GAMs have not yet been updated to accurately simulate the important transient and dynamic nature of GW-SW exchange
- Insufficient field data exists to accurately provide a framework for interpreting GAM results and assessing importance of bank storage
- GAMs results indicate that large increases in pumping will reduce the amount of groundwater that flows from the alluvium to the rivers

TCEQ INSTREAM FLOW PROGRAM MONITORS RIVER FLOW CONDITIONS

- Perform statistical analysis of flow data to identify one of five river flow regimes per day using a computer program
  - Indicators of Hydrological Alterations (IHA)
  - Hydrology-based Environmental Flow Regime (HEFR)

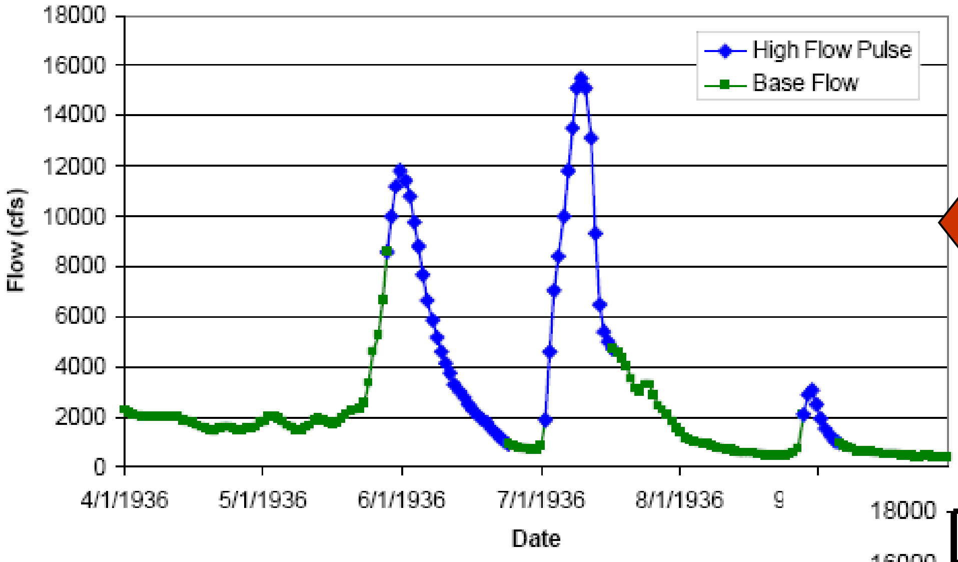
- Source of river water is not a factor in determining flow regimes

- Groundwater could be an important component of subsistence and critical flow regimes in some basins



Regime	Hydrologic Condition
Overbank Flows	NA
High-Pulse Flows	Wet
	Average
	Dry
Base Flows	Wet
	Average
	Dry
Subsistence Flows	Subsistence
Critical Flows	Critical

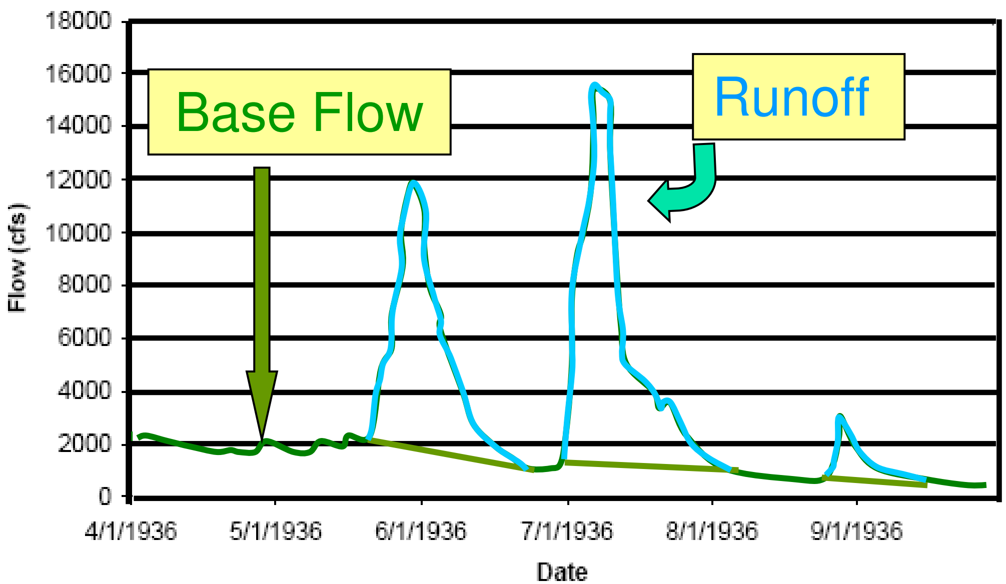
TCEQ InSTREAM PROGRAM ANALYSIS OF HYDROGRAPHS MEASURED AT RIVER GAUGES



TCEQ hydrograph separation segregates hydrograph into different flow regimes – one for each day

Does not attempt to segregate groundwater discharge

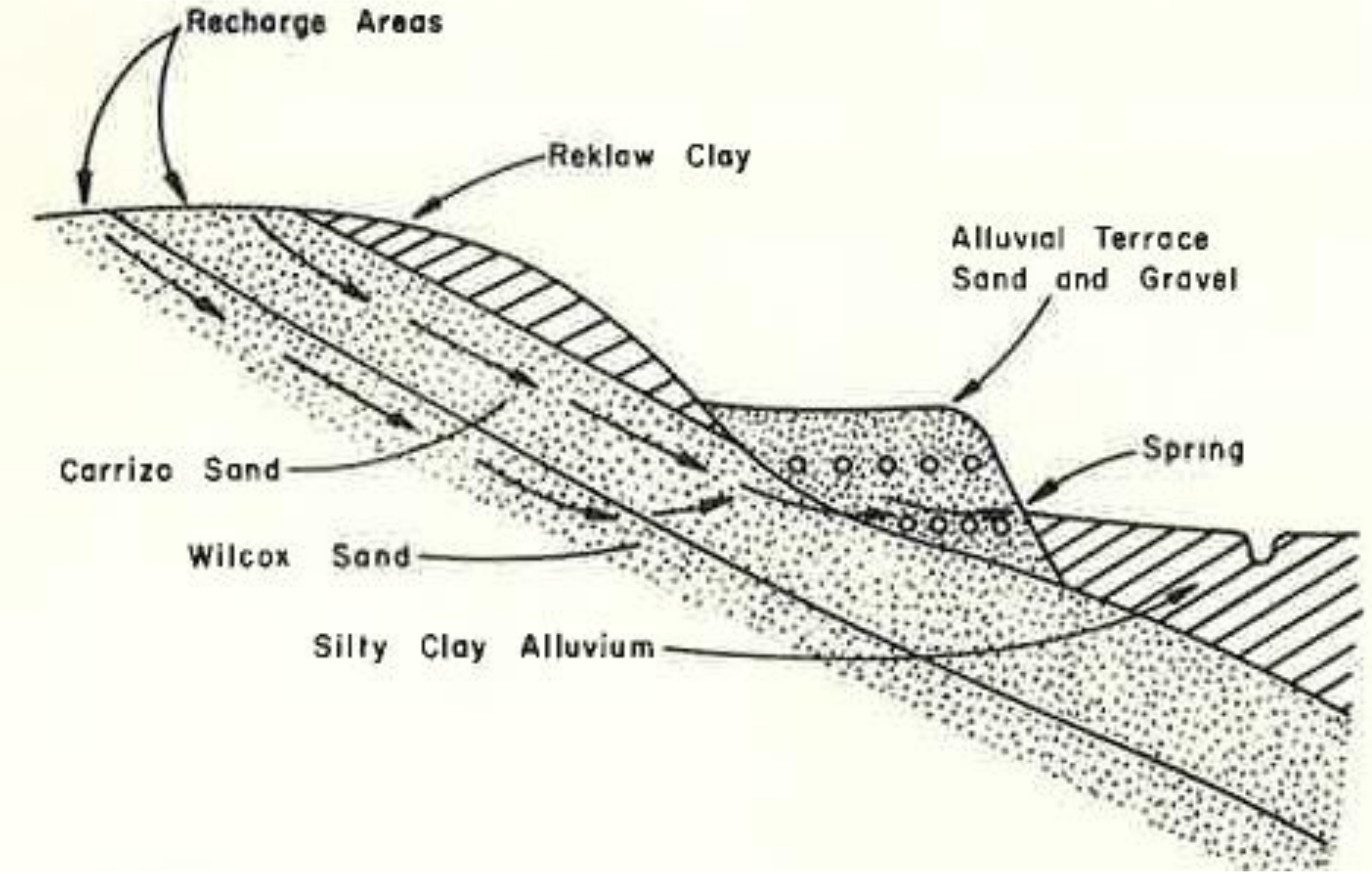
Groundwater hydrograph Separation segregates hydrograph into groundwater discharge and runoff



REQUIREMENTS FOR A SPRING TO OCCUR IN THE GEOLOGICAL FORMATIONS IN GMA 12

- Aquifer to deliver water to a spring
- Sufficiently large recharge area
- Sufficient hydraulic pressure gradient between recharge and discharge area to cause flow
- Water table intersected by ground surface

EXAMPLE SCENARIO FOR SPRINGS OR SEEP IN GMA 12

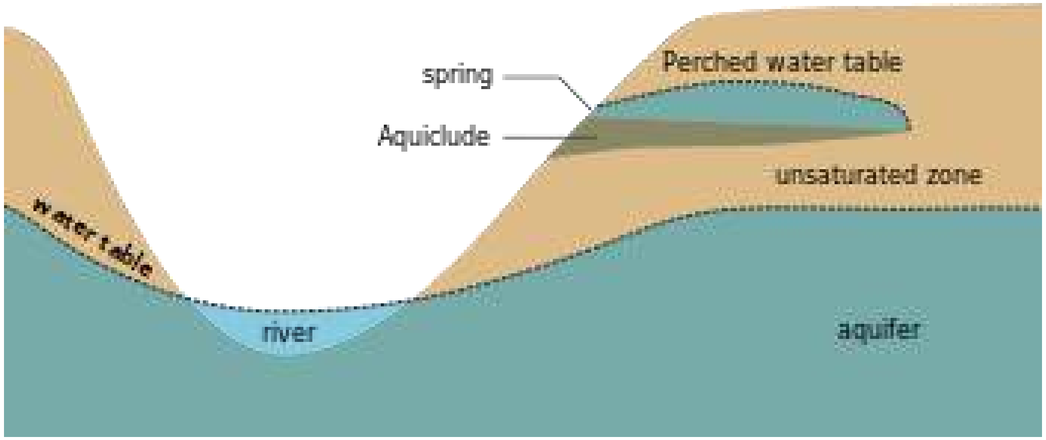


Schematic of a spring in Carrizo-Wilcox sand and terrace sand and gravel (1981, Brune)

SPRINGS OR SEEP ASSOCIATED WITH A PERCHED WATER TABLE

A perched water table is a water-bearing unit that occurs above the regional water table, in the unsaturated zone where there is an impermeable layer of sediment (aquiclude) above the main water table/aquifer.

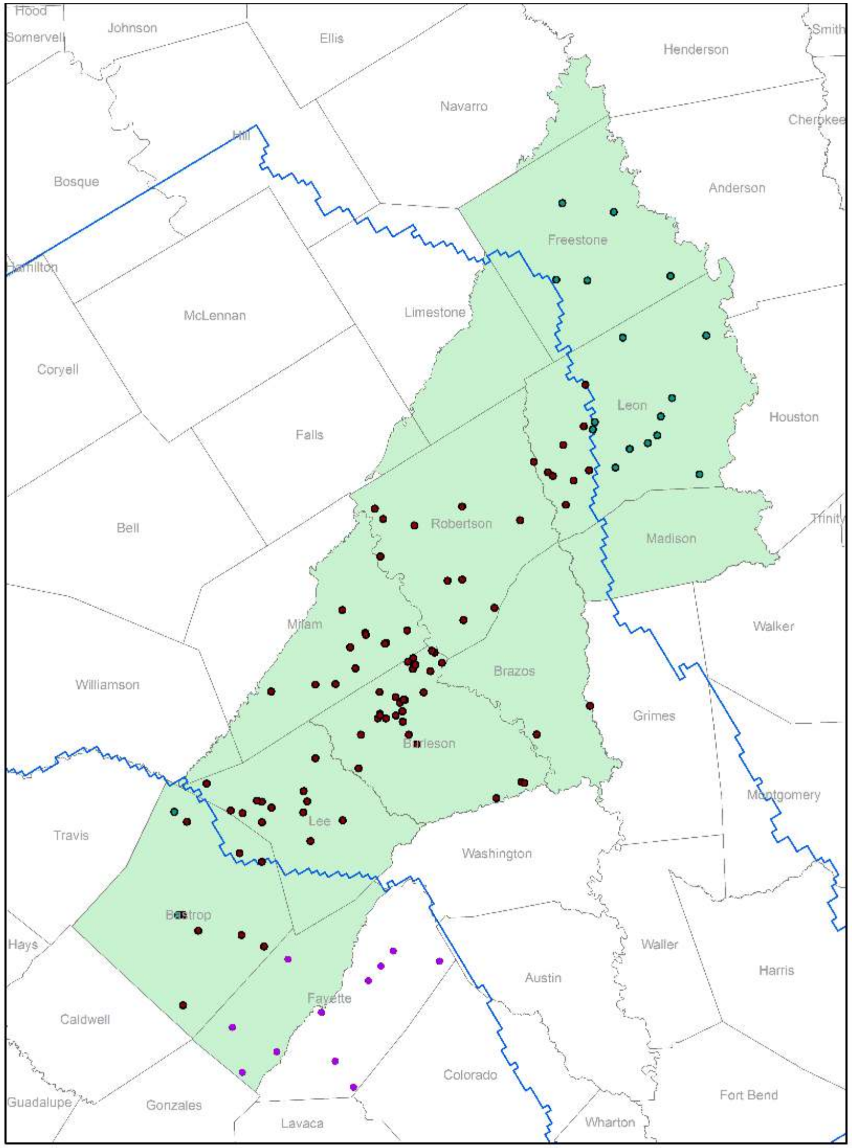
If a perched aquifer's flow intersects the Earth's dry surface, at a valley wall for example, the water is discharged as a spring



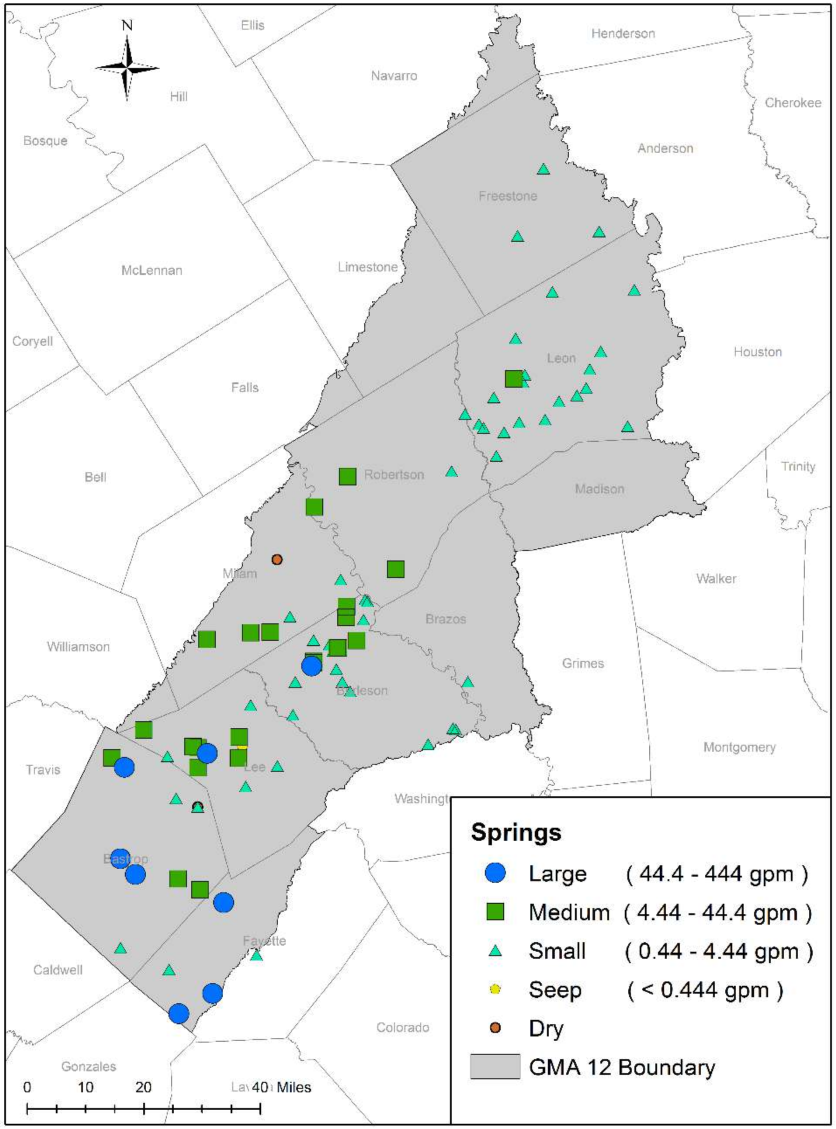
Schematic of a spring connected to a perched water table (2015,https://en.wikipedia.org/wiki/Water_table)

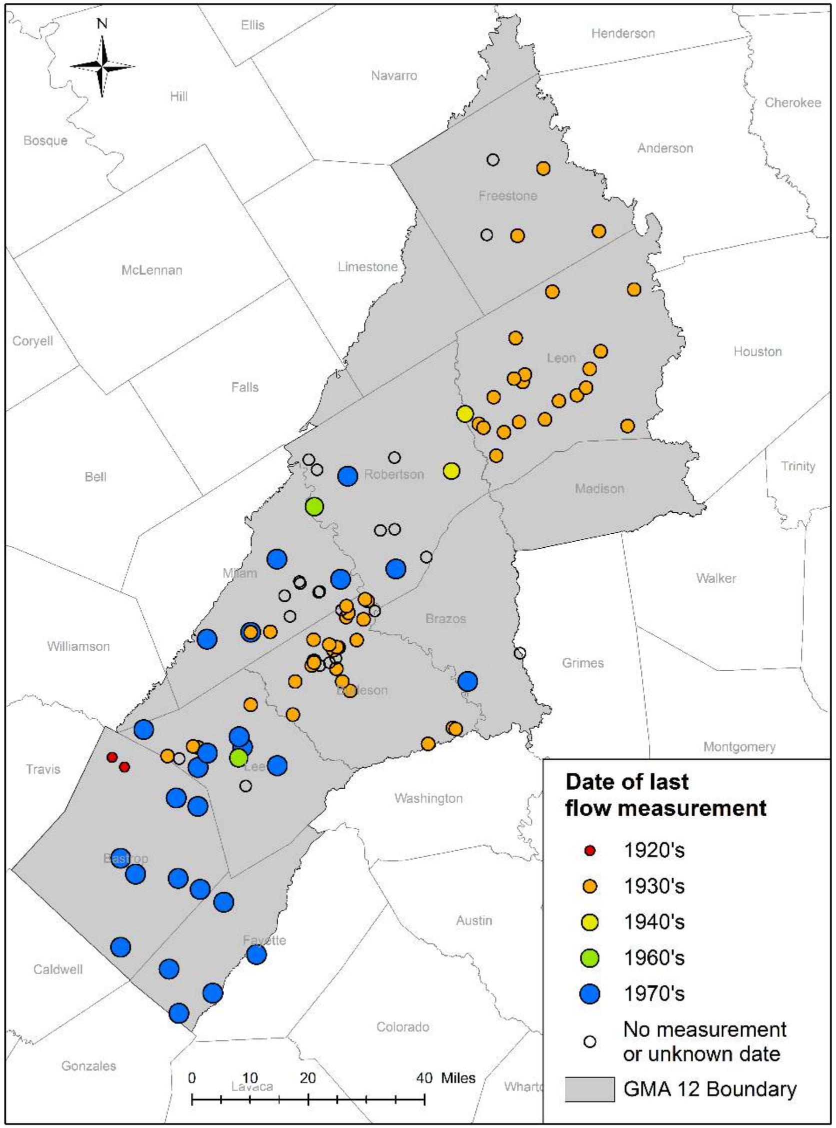
IDENTIFIED SPRING IN GMA 12

- Sources
  - Springs of Texas, Volume 1 (2002, Brune)
  - Database of historically documented springs and spring flow measurements in Texas(2003, Heitmuller and Reece)
  - No springs identified in GMA 12 that are tied to endangered species
  - TWDB Groundwater Database (March, 2014)



IDENTIFIED SPRINGs IN GMA 12 (CONT.)





SUMMARY OF KEY ENVIRONMENTAL ISSUES

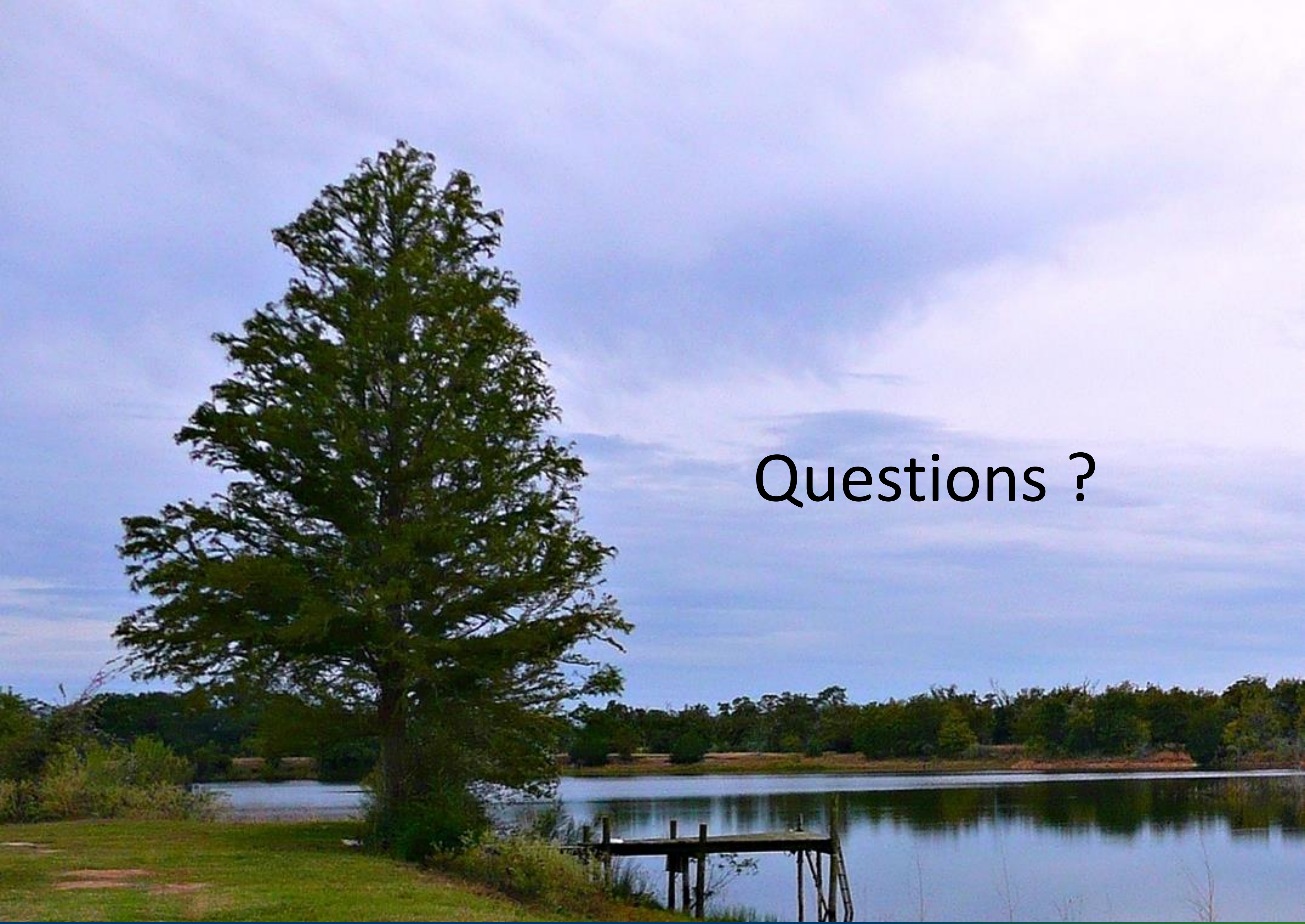
- Spring flow and SW-GW interaction are two potential environmental issues of interest in GMA 12
- Springs are typically controlled by localized site-specific topographic, hydrologic, and geological conditions
- SW-GW interactions largely controlled by local hydraulic gradients over time scales of hours to days and in the immediately vicinity of stream/aquifer contact
- Collection of representative data on SW-GW interaction and spring flow is time consuming, relatively expensive, and difficult to perform. Very limited data exists in GMA 12.

MEASURED SPRING FLOW: SUMMARY POINTS

- Extremely limited spring flow data collected since 1970s
- GMA 12 GAMs are not suitable for quantitative analysis for specific springs or for GW-SW exchange
- TCEQ Environmental Instream Flow program established to protect the health of the Colorado and Brazos Rivers

SUMMARY OF KEY ENVIRONMENTAL ISSUES

- River authorities are currently managing in-stream flows in Colorado and Brazos rivers
- The evaluation river gage hydrographs by the TCEQ Instream Flow program does not quantify GW flow
- Groundwater flow into streams can be an important contributor for helping river authorities maintain critical or subsistence flows



Questions ?