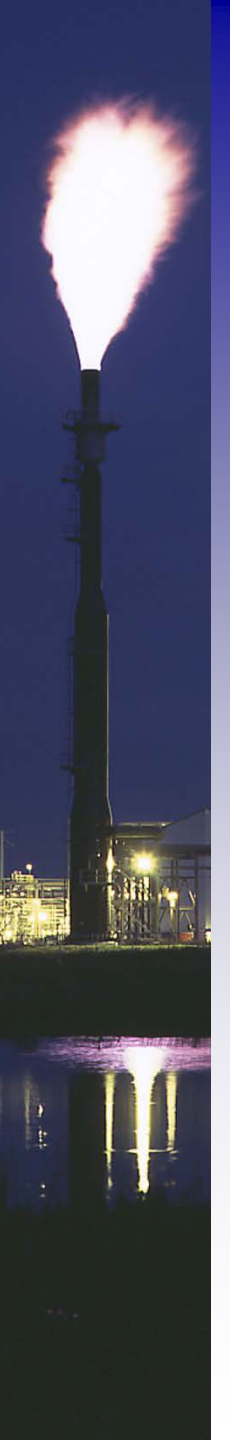


Sources of Data for Quantifying Hydraulic Fracturing Water Use in Texas

Jean-Philippe 'JP' Nicot

Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

EPA Technical Workshop on Water Acquisition Modeling

Arlington, VA – June 5, 2013

The University of Texas at Austin
John A. & Katherine G.
JACKSON SCHOOL OF GEOSCIENCES

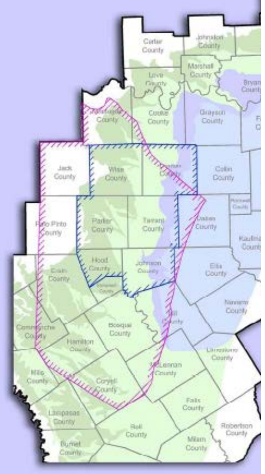
Source of data for publications?

Northern Trinity / Woodbine Aquifer

Groundwater Availability Model

Assessment of Groundwater Use in the Norther
Due To Urban Growth and Barnett Shale Devel

TWDB Contract Number: 0604830613



2007

June 2011

Current and Projected V
Texas Mining and Oil an

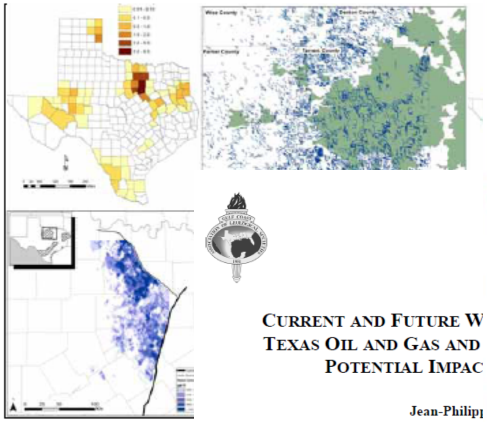
Prepared for
Texas Water Developmer

Bureau of Economic Ge
Scott W. Tinker, Direc
Jackson School of Geosci
The University of Texas at
Austin, Texas 78713-89

2011

September 2012

Oil & Gas Water Use in Tex
Update to the 2011 Mining Water U



CURRENT AND FUTURE W
TEXAS OIL AND GAS AND
POTENTIAL IMPAC

Texa

Jean-Philipp

Bureau of Economic Geology, Jac
University of Texas at Austin, University Stati

ABSTRA

The Texas mining industry, in addition to oil and gas, produ crushed rocks). Operations always involve water, either as an aic current water use in the various sectors of the mining industry a cerned the upstream segment of the oil and gas industry (drilling, hydraulic fracturing, waterfloods), the aggregate industry (washing included but no further processing), the coal industry (pit dewatering and aquifer depressurizing), and other substances mined in a fashion similar to that of aggregates (industrial sand, lime, etc.), as well as through solution mining. Overall, in 2008, the industry used ~160 thousand acre-ft (kAF), including 35 kAF for hydraulic fracturing and ~21 kAF for other purposes in the oil and gas industry. The coal and aggregate industries used 20 kAF and 71 kAF, respectively. Mining of industrial sand dominates the remainder. Approximately three-fourths of the water used is consumed, and approximately two-thirds of the water consumed is groundwater. Projection estimates call for a steady increase in water use in coal and aggregate production and a sharp increase, followed by a slow decrease, in the oil and gas industry. Operators favor surface water when it is plentiful, but groundwater is a more drought-proof source. Because the various segments of the energy industry are spread out across the state, they impact many different aquifers. Mining withdrawals represent only ~1% of total withdrawals at the state level but can be much higher locally and compete with other uses, such as municipal usage or irrigation.

INTRODUCTION

Mineral resources in Texas fall into four categories: (1) hydrocarbons (oil and gas), (2) lignite and coal, (3) crushed rock and sand and gravel (collectively known as aggregates), and (4) other substances. Oil and gas make up most of the dollar value and compose a significant fraction in terms of volume with the aggregate category (Table 1). Oil and gas are produced from almost every county in the state (Fig. 1a), whereas lignite mines are located in a narrow band in the middle of the state (Fig. 1c) and parallel to the coast (Kyle, 2008; Kyle and Clift, 2008). Sand and gravel are exploited mostly along rivers (Fig. 1d). Crushed-stone quarries are present mostly in the footprint of the Edwards Limestone. The objective of a recent study performed for the Texas Water Development Board (TWDB) was to determine county-level historical and projected mining water use in Texas, focusing on fresh water (total dissolved solid content [TDS] < 1000 mg/L). Disregarding oil and gas wells and other oil- and gas-related facilities, the U.S. Census Bureau (2005) listed a total of 11 lignite mines, 100+ crushed stone, and ~200 sand and gravel operations, many of them small, as well as ~70 facilities of a different type, neither lignite nor aggregate, in Texas in 2000. More details about mine count, as well as a more detailed account of water use, can be found in Nicot et al. (2011).

Oil and gas resources are generally sorted into conventional and unconventional categories (Figs. 1a and b). The former represents the archetypal reservoir traps in either sandstones or carbonates and is made up of interconnected pores that allow 'easy' communication with the well bore. The latter is generally characterized by the use of advanced technologies and consists of different types of formation and/or extreme environmental conditions (pressure and temperature). Characteristics of unconventional resources of interest relevant to this study include low permeability and a need to stimulate the reservoir through hydraulic

Manuscript received March 14, 2012; revised manuscript received May 25, 2012; manuscript accepted May 25, 2012.

GCAGS Journal, v. 1 (2012), p. 145–161.

Environmental Science & Technology

Article

pubs.acs.org/est

Water Use for Shale-Gas Production in Texas, U.S.

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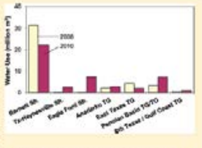
Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, 10100 Burnet Road, Building 130, Austin, Texas 78758, United States

Supporting Information

ABSTRACT: Shale-gas production using hydraulic fracturing of mostly horizontal wells has led to considerable controversy over water-resource and environmental impacts. The study objective was to quantify net water use for shale-gas production using data from Texas, which is the dominant producer of shale gas in the U.S. with a focus on three major plays: the Barnett Shale (~15 000 wells, mid-2011), Texas-Haynesville Shale (390 wells), and Eagle Ford Shale (1040 wells). Past water use was estimated from well-completion data, and future water use was extrapolated from past water use constrained by shale gas resources. Cumulative water use in the Barnett totaled 145 Mm³ (2000–mid-2011). Annual water use represents ~9% of water use in Dallas (population 1.3 million). Water use in younger (2008–mid-2011) plays, although less (6.5 Mm³ Texas-Haynesville, 18 Mm³ Eagle Ford), is increasing rapidly. Water use for shale gas is <1% of statewide water withdrawals; however, local impacts vary with water availability and competing demands. Projections of cumulative net water use during the next 50 years in all shale plays total ~4350 Mm³, peaking at 145 Mm³ in the mid 2020s and decreasing to 23 Mm³ in 2060. Current freshwater use may shift to brackish water to reduce competition with other users.



INTRODUCTION

Natural gas has spurred intense interest in reducing greenhouse gases and enhancing energy security. Natural gas produces emissions that are much lower than those from oil and coal: 30%–40% lower for CO_2, 80% for NO, and ~100% for SO_2, particulates, and mercury.[1] Natural gas is used widely for industrial (31%), electric power (27%), residential (22%), commercial (14%), and other purposes (mean 2000–2010).[2] Production of natural gas from hydrocarbon-rich shales is referred to as shale gas. Shales contain gas in micropores, fractures, and adsorbed onto organic matter. Conventional gas has been produced from permeable geologic formations for decades; however, within the past decade, advances in directional drilling, combined with breakthroughs in fracking in Texas, have allowed large-scale expansion of gas production from low-permeability shale formations at depths of >1 km. Shale gas reservoirs differ from typical oil and gas reservoirs in that the shale serves as the source rock, reservoir, and seal. Although older wells in older plays, such as the Barnett, and exploratory wells in newer plays are vertical (Supporting Information, A), most wells are currently drilled vertically almost to the depth of the shale formation, then deviated to the horizontal and drilled horizontally within the shale. Fracking involves injection of water containing chemical additives and proppant (e.g., sand) under high pressure to fracture the shales.[3] Early expansion of shale-gas production was restricted primarily to the Barnett Shale in Texas, which was the main producer in the 2000s, accounting for 66% of shale-gas production in the U.S. in 2007–2009;[2] however, shale gas is currently produced in 22 of the 50 states, and production increased by an annual average rate of ~50% between 2006 and 2010.[4] Shale-gas production is projected to increase from 23% of U.S. natural gas production in 2009 to 47% by 2035.

Energy and water production are interdependent. In the shale gas context, there is a strong correlation between water injected and gas production (Supporting Information, B). Most studies of water-resource impacts from shale-gas exploration and production have focused on effects of fracking on water quality;[5] however, some studies also emphasize impacts on water quantity.[6–10] Few published studies quantify water use for shale-gas production and their environmental impact.[11–13] Water use for hydraulically fracturing wells varies with the shale-gas play, the operator, well depth, number of fracking stages, and length of laterals. To date, generally fresh water (total dissolved solids <1000 mg/L) has been used for fracking, sourced from surface water or groundwater, depending on local availability. The commonly used polyacrylamide additives (friction reducers) function best in fresh water.[14]

Impacts of water production for shale-gas development depend on water availability in the region and competing demands for water from other users. Limited water availability in semiarid regions may restrict shale-gas production. Impacts range from declining water levels at the regional[10–12] or local[6]

Received: December 21, 2011
Revised: February 22, 2012
Accepted: March 1, 2012
Published: March 2, 2012

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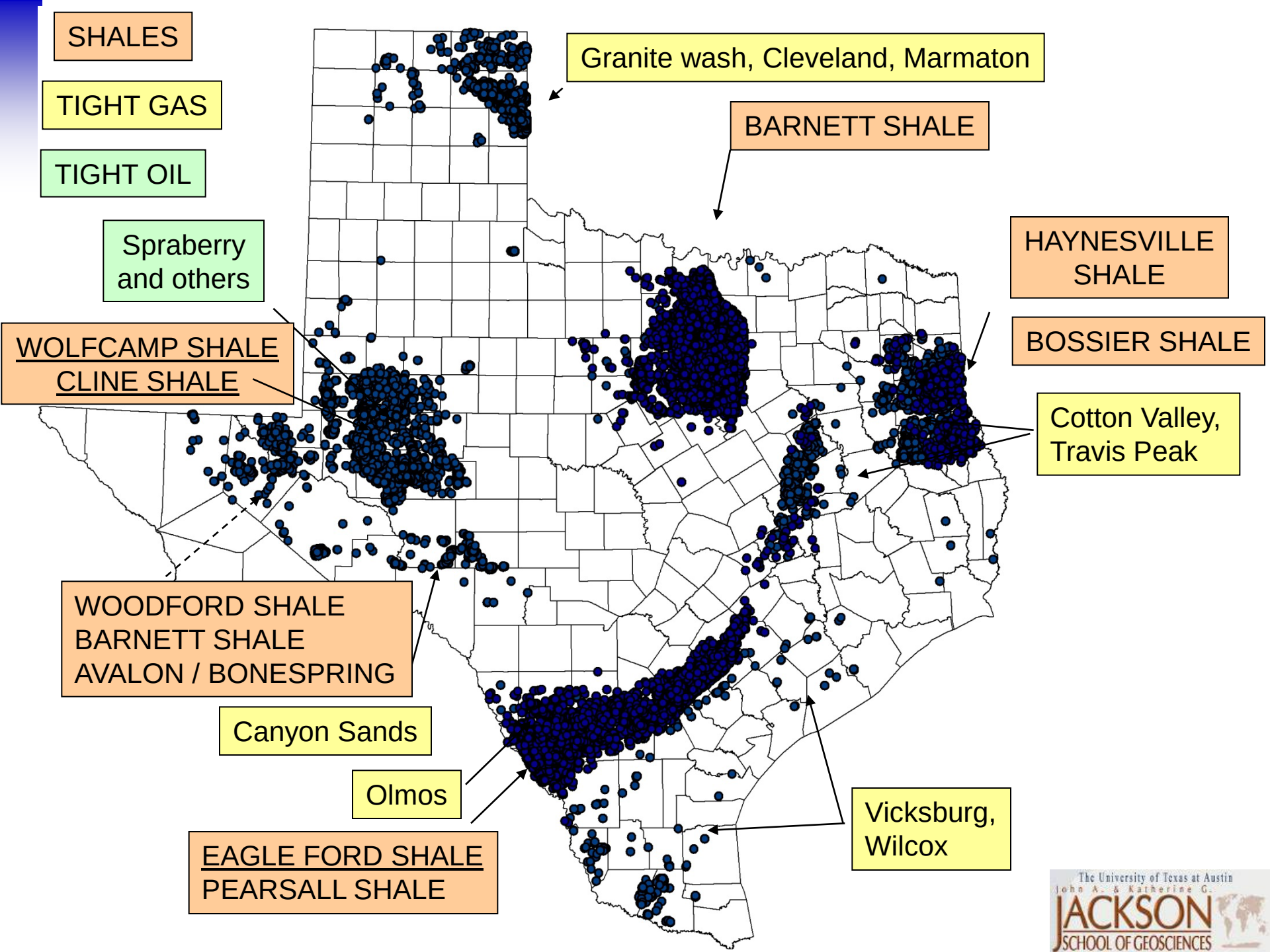
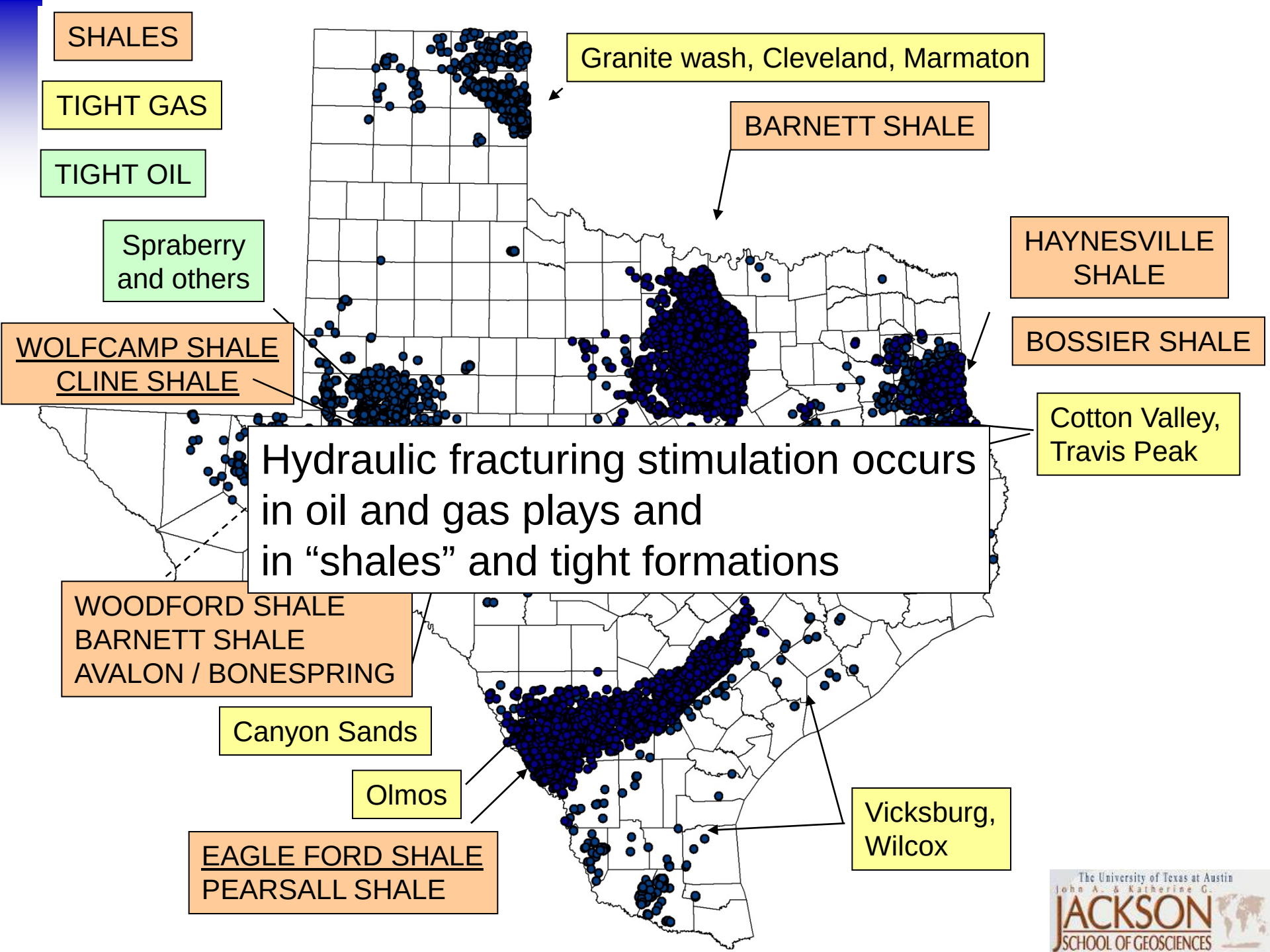



SHALES
TIGHT GAS
TIGHT OIL
Granite wash, Cleveland, Marmaton
BARNETT SHALE
Spraberry and others
HAYNESVILLE SHALE
WOLFCAMP SHALE
CLINE SHALE
BOSSIER SHALE
Cotton Valley, Travis Peak
Hydraulic fracturing stimulation occurs in oil and gas plays and in "shales" and tight formations
WOODFORD SHALE
BARNETT SHALE
AVALON / BONESPRING
Canyon Sands
Olmos
Vicksburg, Wilcox
EAGLE FORD SHALE
PEARSALL SHALE

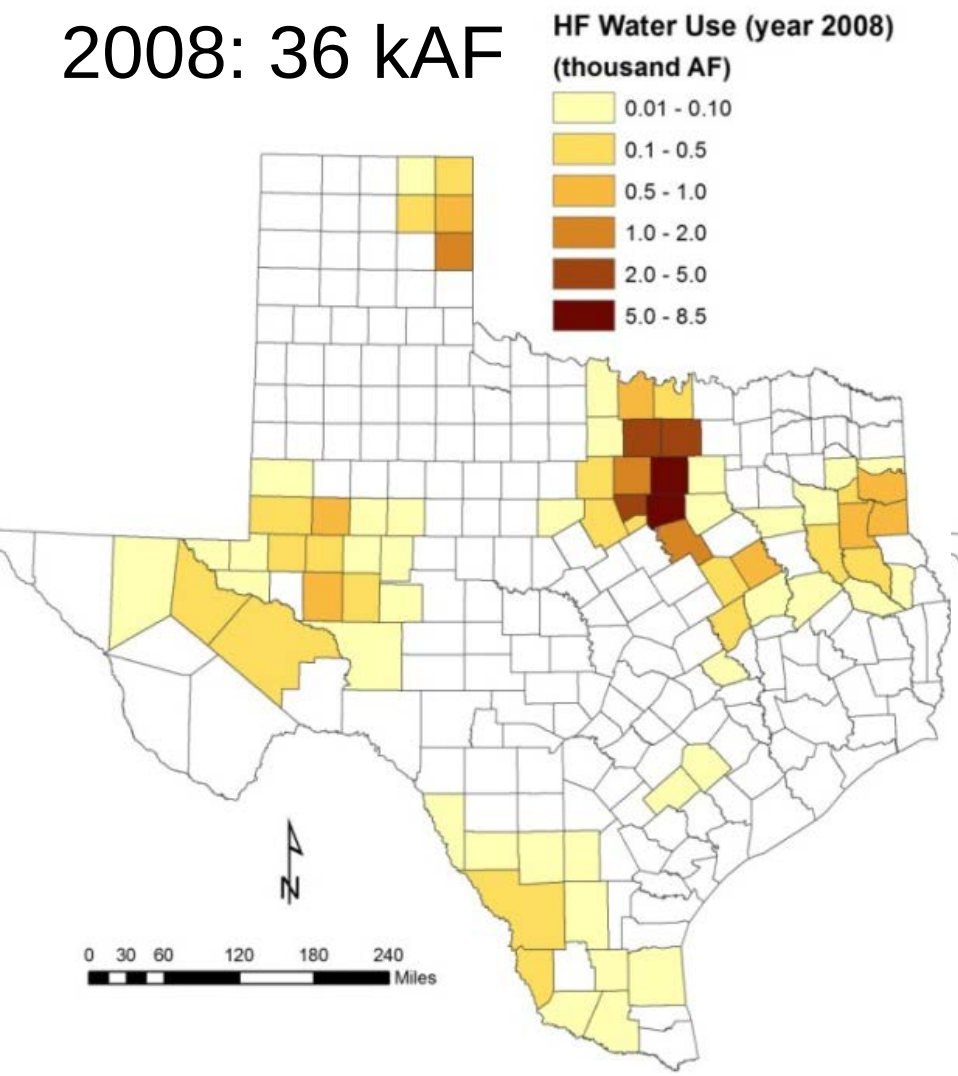
Final Result: Hydraulic Fracturing Water Use

1 AF = 325,851 gallons

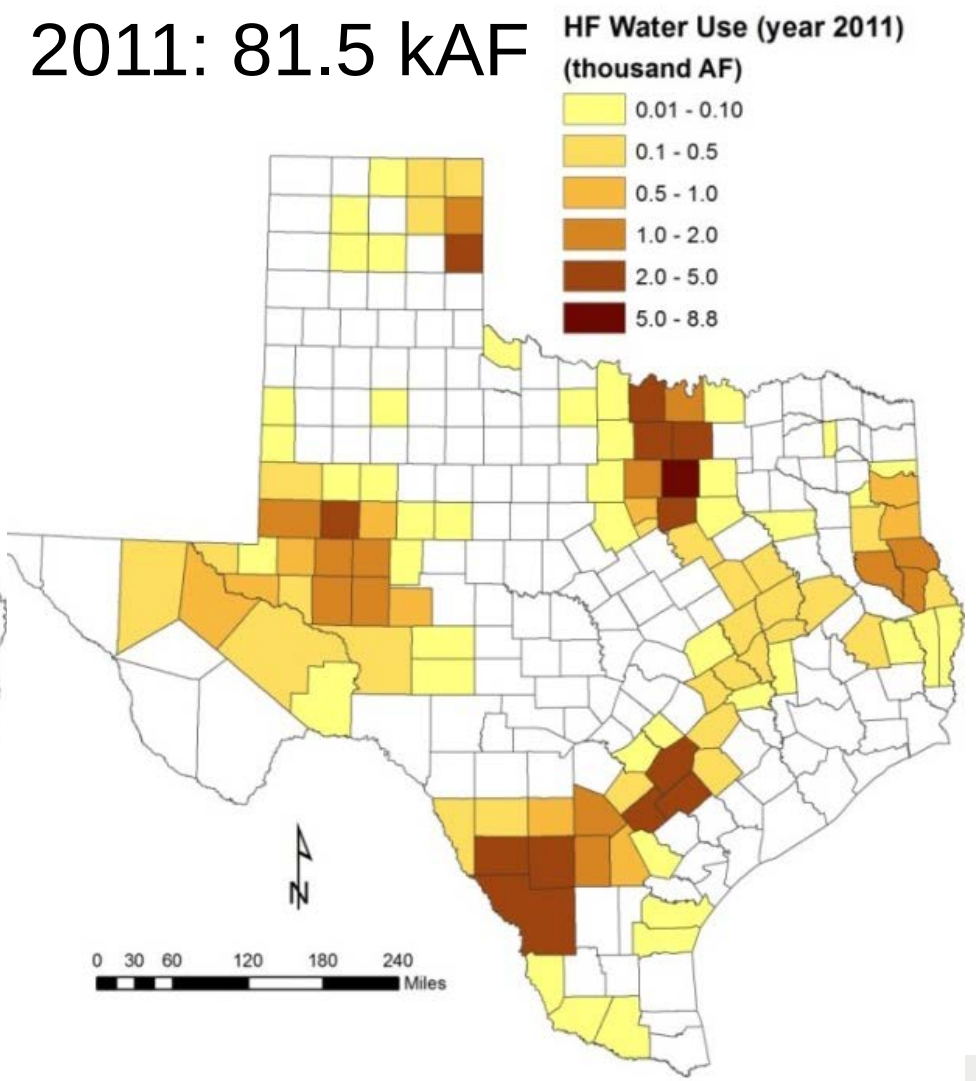
1 AF = 2-3 households/yr

1kAF = 1.23 10^6 m^3

2008: 36 kAF



2011: 81.5 kAF



Source of raw data: IHS Enerdeq database; in Nicot et al. 2012 report

Final Result: Hydraulic Fracturing Water Use

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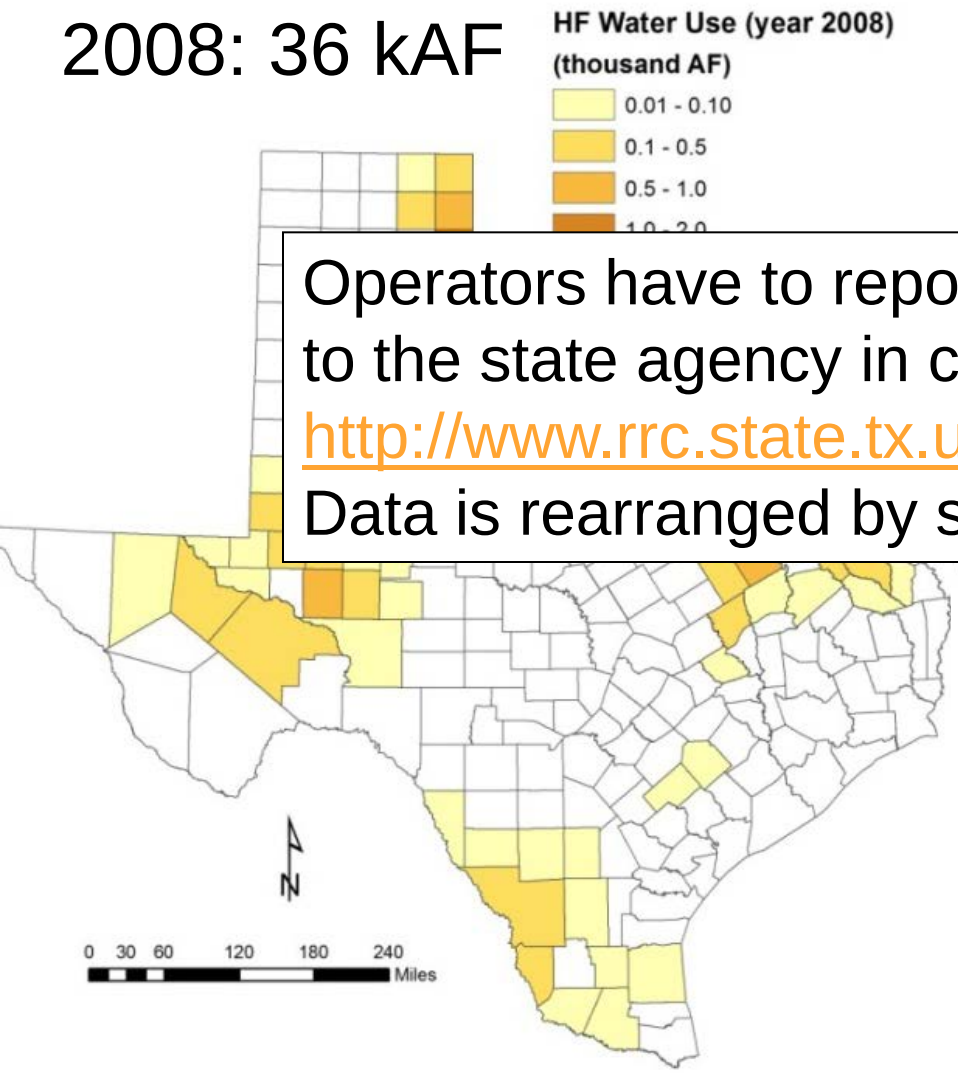

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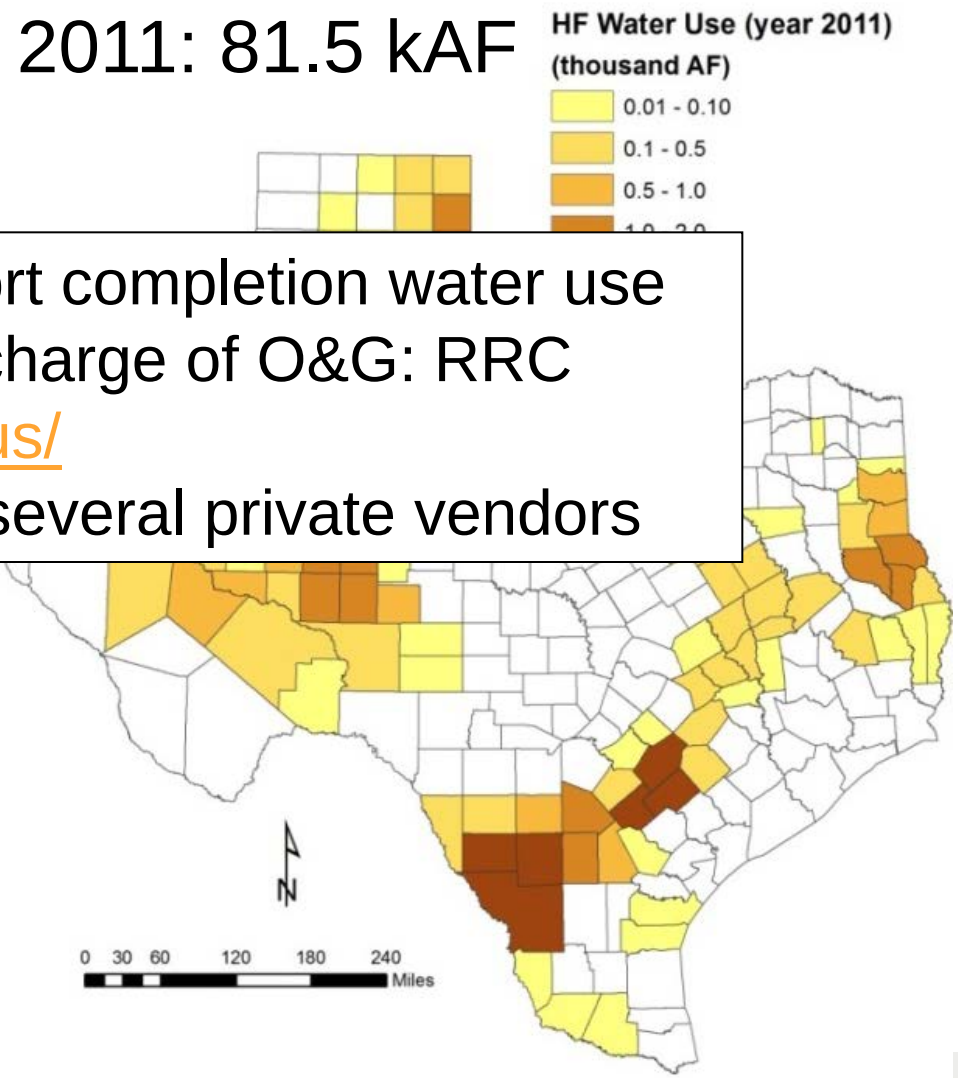
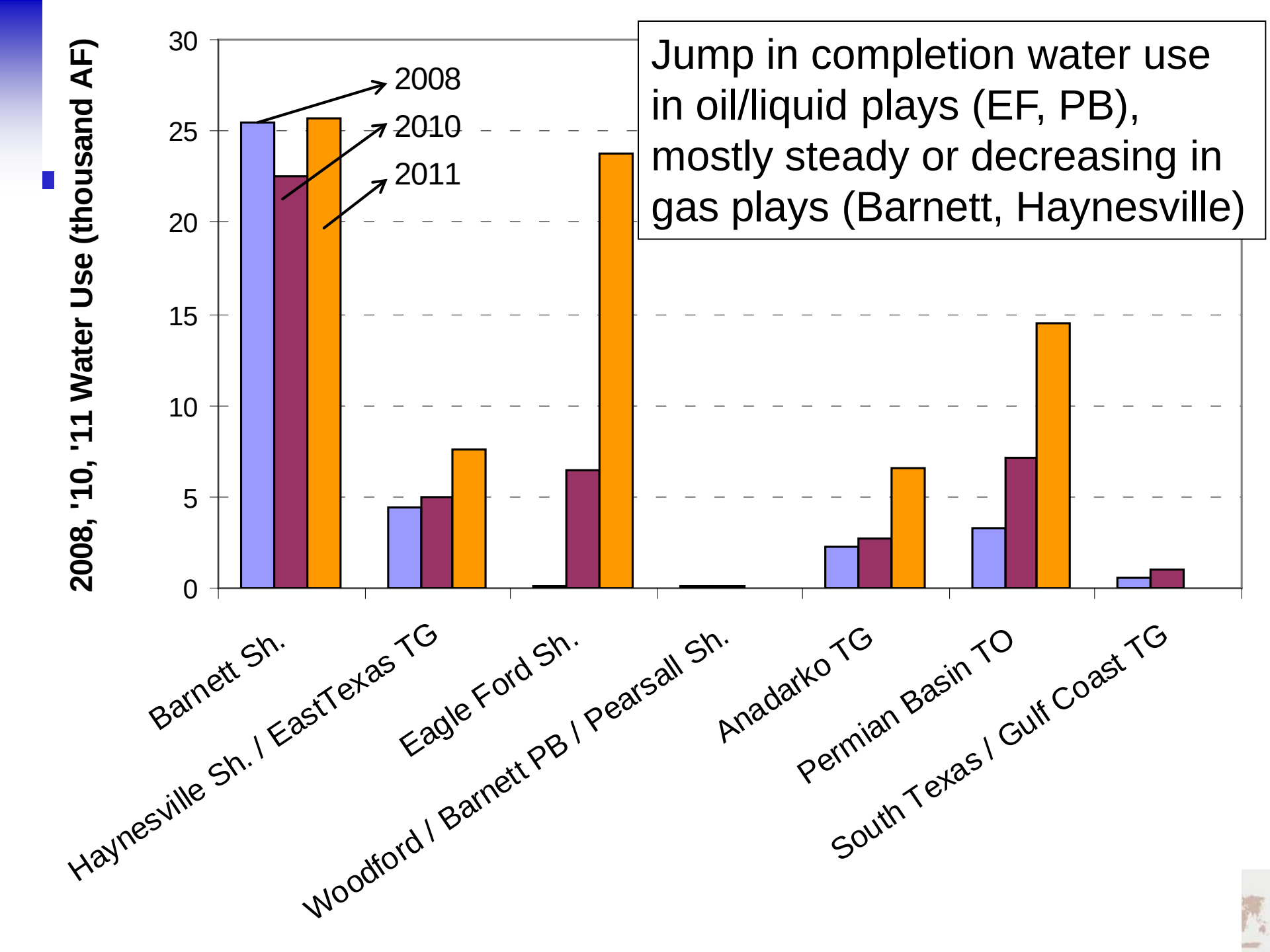


Operators have to report completion water use to the state agency in charge of O&G: RRC
http://www.rrc.state.tx.us/
Data is rearranged by several private vendors

Source of raw data: IHS Enerdeq database; in Nicot et al. 2012 report


Jump in completion water use in oil/liquid plays (EF, PB), mostly steady or decreasing in gas plays (Barnett, Haynesville)
2008, '10, '11 Water Use (thousand AF)
30
25
20
15
10
5
0
2008
2010
2011
Barnett Sh.
Haynesville Sh. / EastTexas TG
Eagle Ford Sh.
Woodford / Barnett PB / Pearsall Sh.
Anadarko TG
Permian Basin TO
South Texas / Gulf Coast TG

Example 2 of RRC data

40. ACID, SHOT, FRACTURE, CEMENT SQUEEZE, ETC.

Depth Interval	Amount and Kind of Material Used
7120' – 9128'	60,391 bbl. Slickwater and 8000 sx sand

41. FORMATION RECORD (LIST DEPTHS OF PRINCIPAL GEOLOGICAL MARKERS AND FORMATION TOPS)

Formations	Depth	Formations	Depth
Upper Barnett	6552'		
Lower Barnett	6611'		
Ellenburger	6720'		

REMARKS

Well shut in waiting on pipeline connection.

JUL 29 2008

VALID PERMIT

- Year 2006
- 60,391bbl = ~2.5 Mgal for ~2000ft; 1250gal/ft OK
- 8000sx = ~2,900,000#; loading of 1.15lb/gal OK

Example 2 of RRC data

38. TUBING RECORD			39. Producing Interval (this completion) Indicate depth of perforation or open hole	
Size	Depth Set	Packer Set		
2 3/8"	5188'		From 5781' md	To 7217' md
			From	To
			From	To
			From	To

40. ACID, SHOT, FRACTURE, CEMENT SQEEZE, ETC.	
Depth Interval	Amount and Kind of Material Used
5781' - 6043'	12643 bbls SW w/110006#'s 30/70 + 24772#'s 20/40 WSD
6335' - 6615'	13842 bbls SW w/119050#'s 30/70 + 30404#'s 20/40 WSD
6924' - 7217'	13992 bbls SW w/119050#'s 30/70 + 30404#'s 20/40 WSD

41. FORMATION RECORD (LIST DEPTHS OF PRINCIPAL GEOLOGICAL MARKERS AND FORMATION TOPS)			
Formations	Depth	Formations	Depth
Lower Atoka	4999'		
Marble Falls	5469'		
Lower Barnett	5884'		

REMARKS Amended Test Information

- Year 2006
- 40,477bbl = ~1.7 Mgal for 835 (1436) ft; 2000 (1200) gal/ft
- 433,689#; loading of 0.26 lb/gal

Oil & Gas Well Data
Data Sets

The following data sets are available either on CD or by FTP. Pricing does not include the cost of CDs and postage. **Please note that some data is provided in the original EBCDIC format. Conversion of data and choice of conversion tools is the responsibility of the user.** Refer to the General Ordering page for further details.

2-Year Inactive Wells

3-Year Inactive Wells

Final Oil and Gas Annuals

Gas Allowable by Gatherer

Gas Allowable by Operator

Gas Master

Gas Proration Schedule

Gas Purchaser Stripout

Gas Well Status (Monthly G-10)

Historical Ledger

Oil Allowable by Gatherer

Oil Allowable by Operator

Oil Detail Well

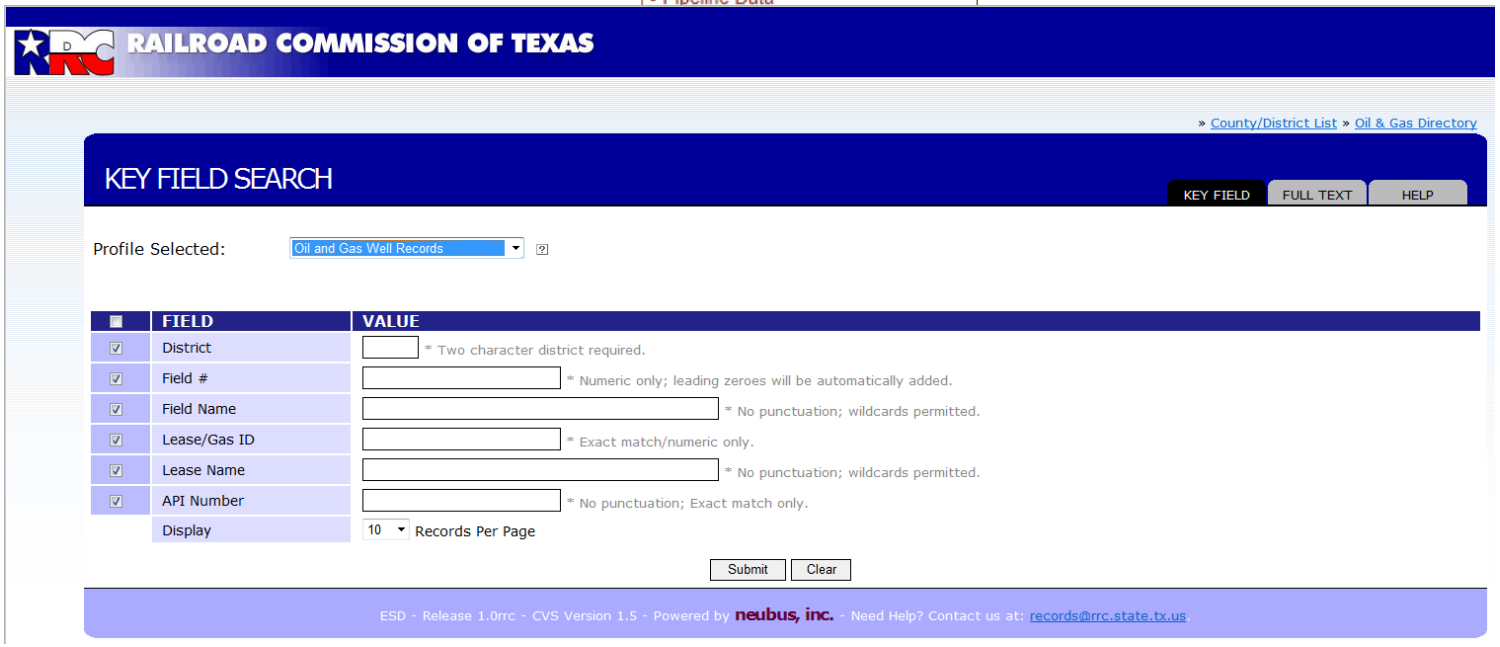
Oil Master

Oil Proration Schedule

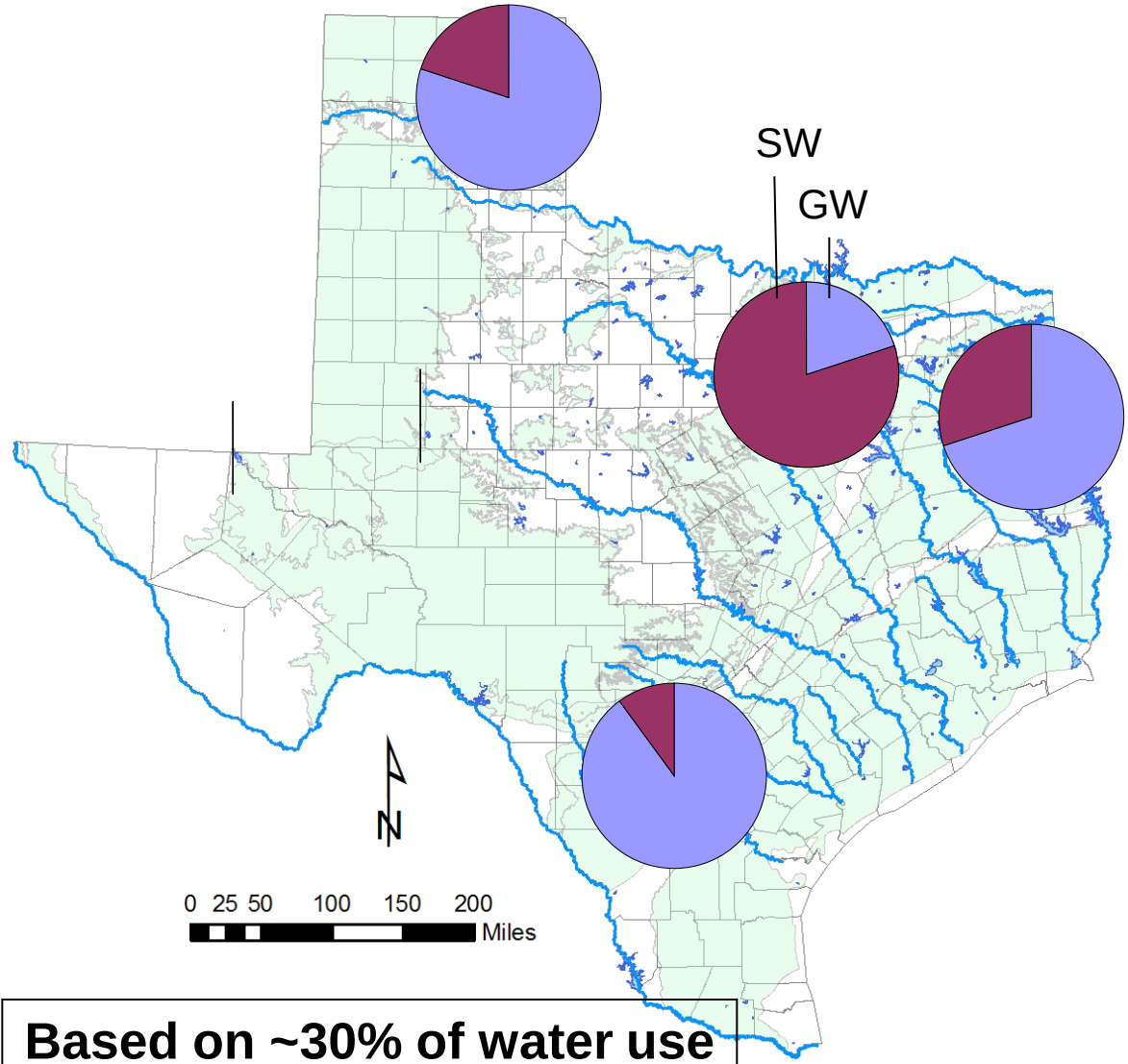
Oil Well Status (Monthly W-10)

RRC Data Sets Information

- General Ordering
- Computer Generated Listings
- Digital Map Data
- Drilling Permit Data
- Oil & Gas Field Data
- Oil & Gas Production Data
- Oil & Gas Regulatory Data
- Oil & Gas Well Data
- Pipeline Data



GW/SW split: little known



2006 survey in Barnett:
~60% groundwater

2012 Barnett:
~20% groundwater

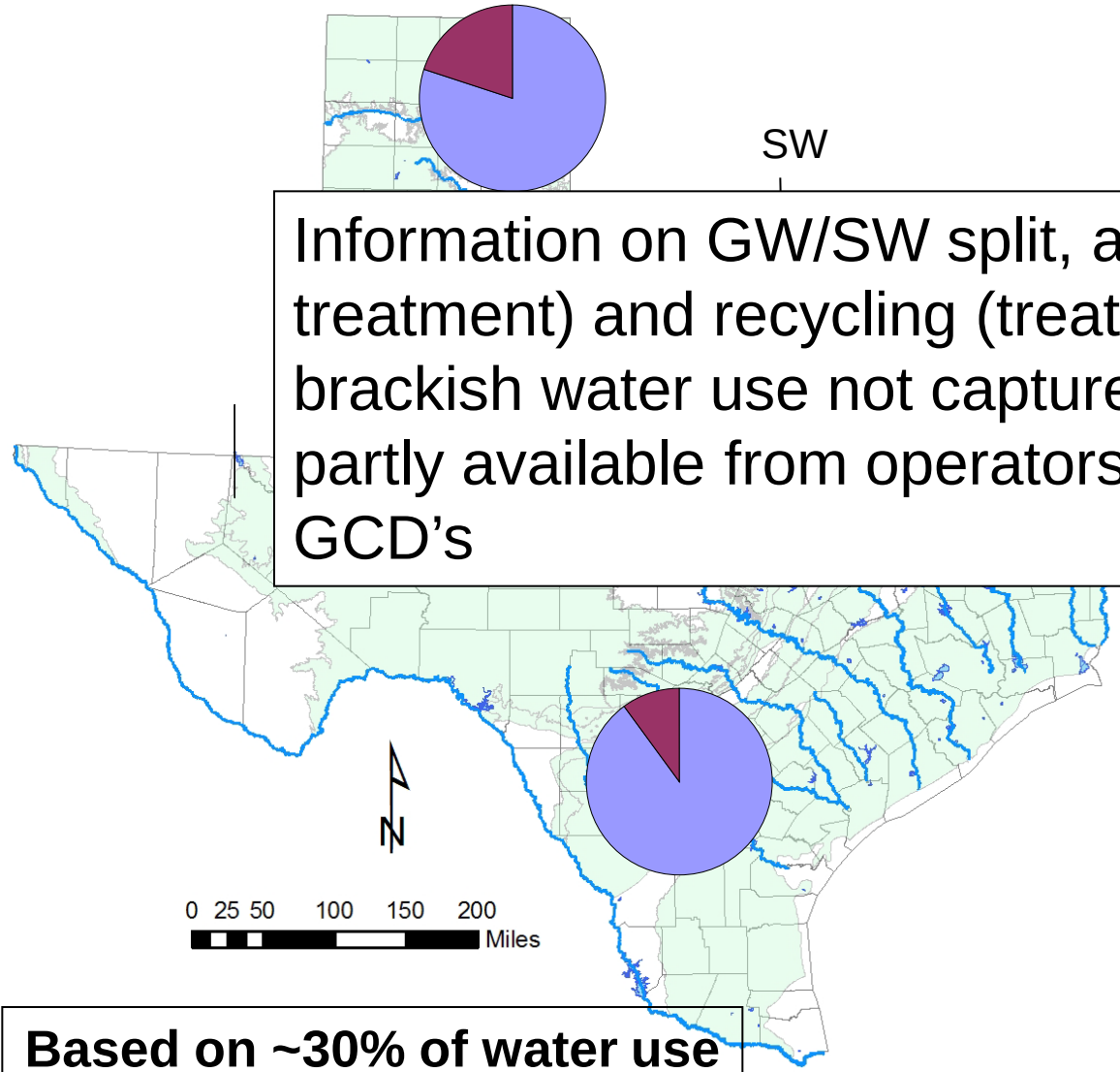
2012 Haynesville-ETx:
~70% groundwater

2012 Eagle Ford:
~90% groundwater

2012 Permian B.:
~100% groundwater

Based on ~30% of water use

GW/SW split: little known



2006 survey in Barnett:
~60% groundwater

Information on GW/SW split, amount of reuse (no treatment) and recycling (treatment), and of brackish water use not captured in state database, partly available from operators, water providers, GCD's

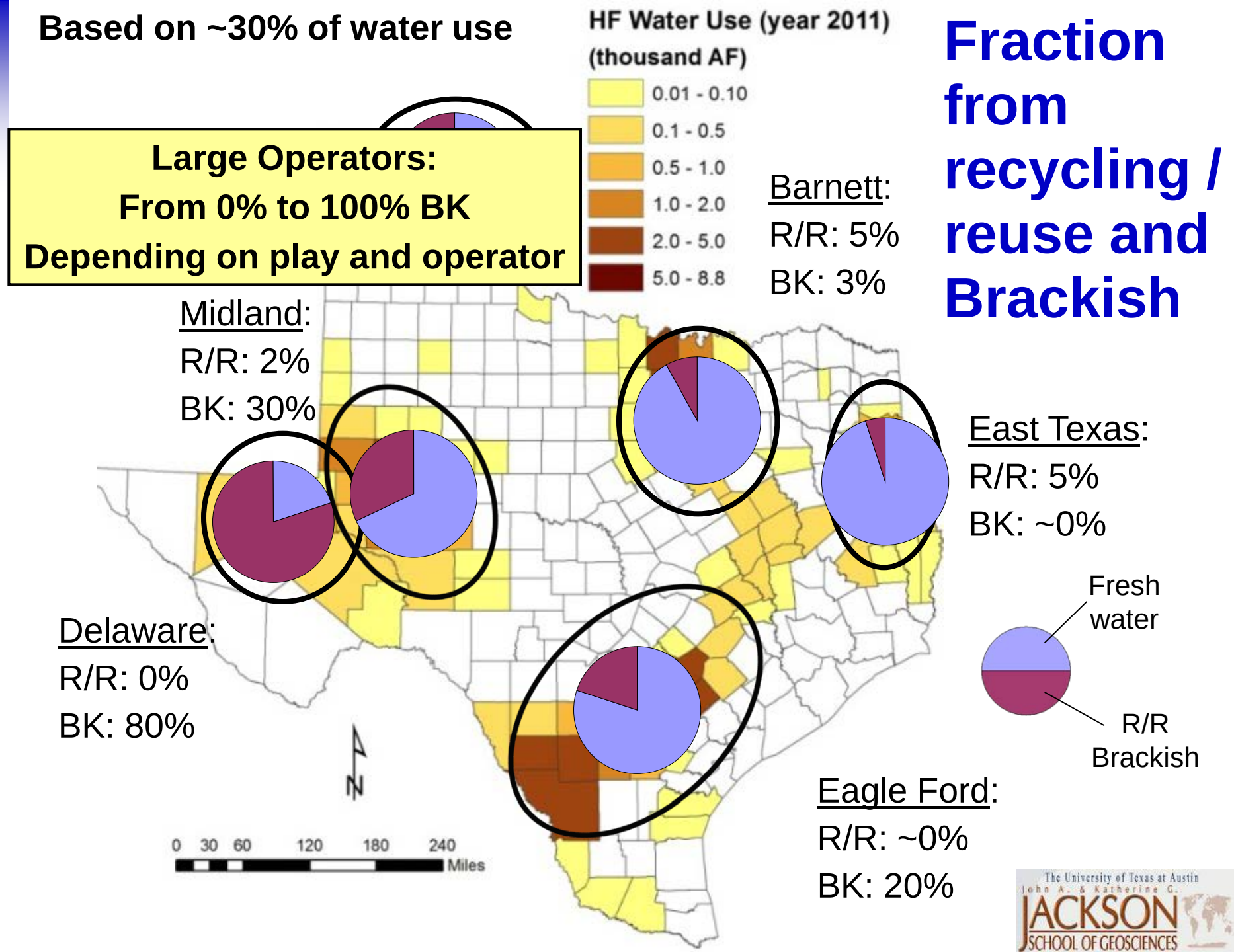
ETx:

2012 Eagle Ford:
~90% groundwater

2012 Permian B.:
~100% groundwater

Based on ~30% of water use

Based on ~30% of water use



Large Operators:
From 0% to 100% BK
Depending on play and operator

Fraction from recycling / reuse and Brackish

Barnett:
R/R: 5%
BK: 3%

Midland:
R/R: 2%
BK: 30%

East Texas:
R/R: 5%
BK: ~0%

Delaware:
R/R: 0%
BK: 80%

Eagle Ford:
R/R: ~0%
BK: 20%

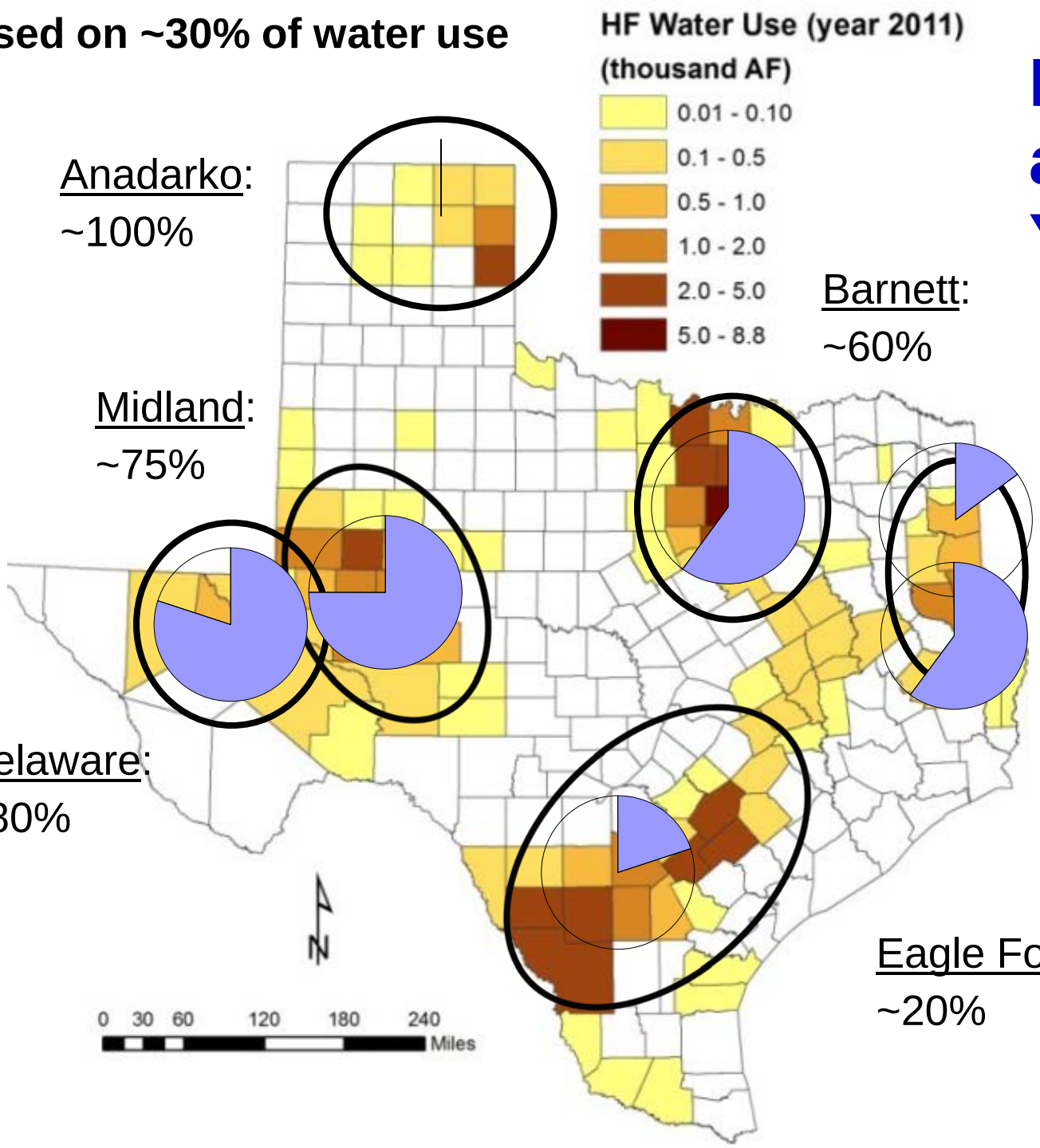
Fresh water

R/R Brackish

The University of Texas at Austin
John A. & Katherine G. Jackson School of Geosciences

Based on ~30% of water use

Flowback at end of Year1



Anadarko:
~100%

Barnett:
~60%

Midland:
~75%

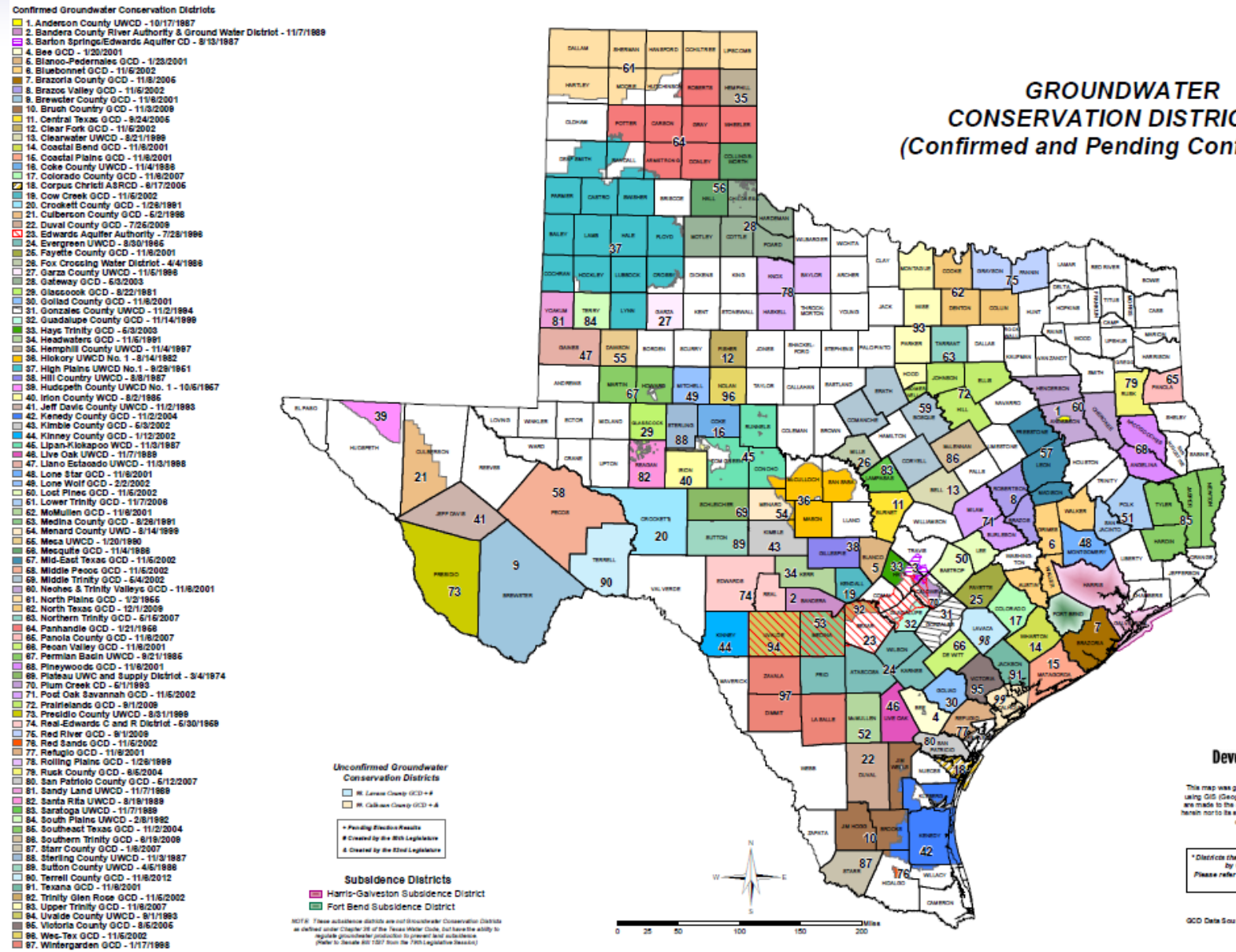
Haynesville:
~15%

Cotton Valley:
~60%

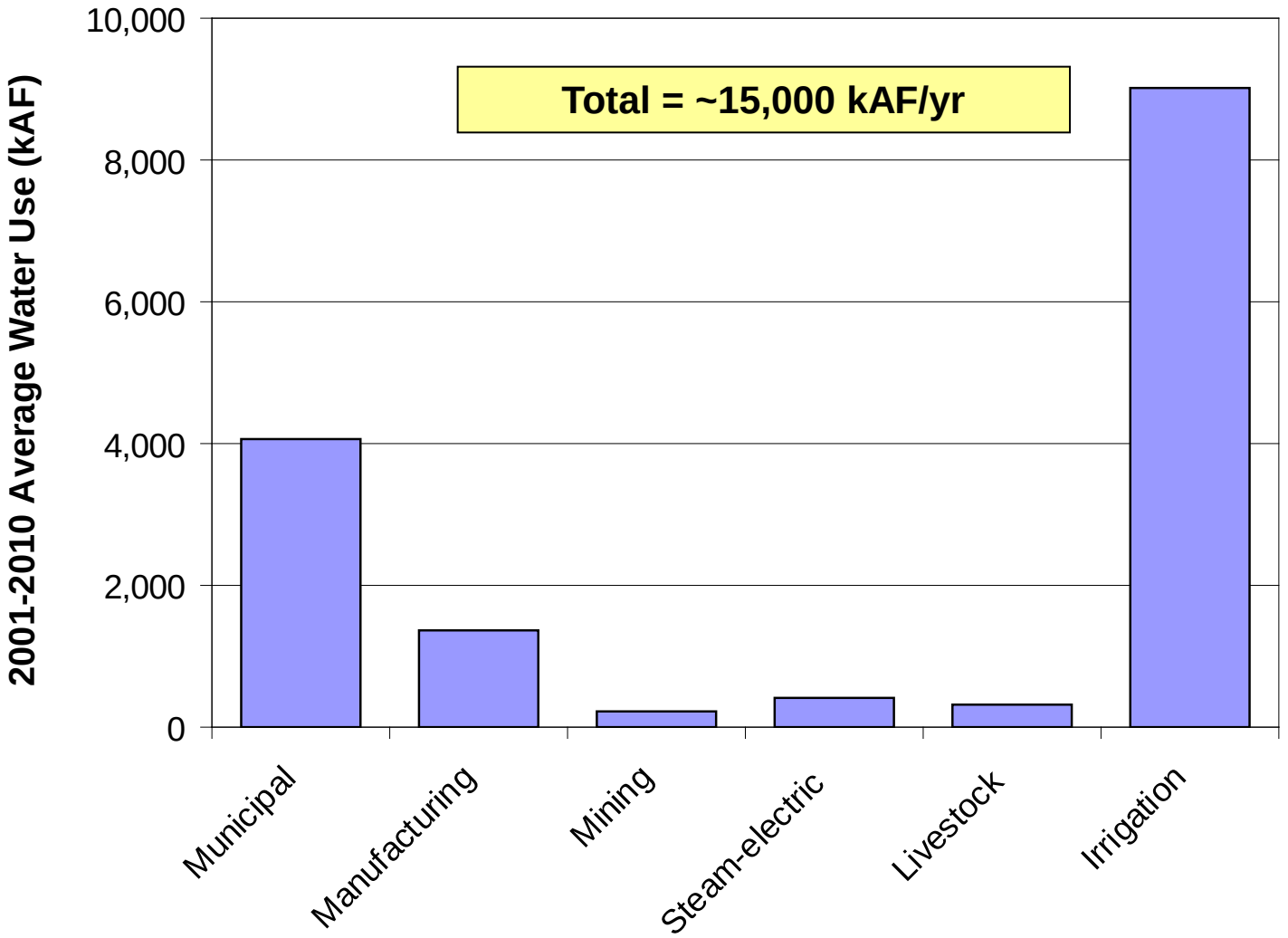
Delaware:
~80%

Eagle Ford:
~20%

Groundwater Conservation Districts (GCD's)



Texas water use



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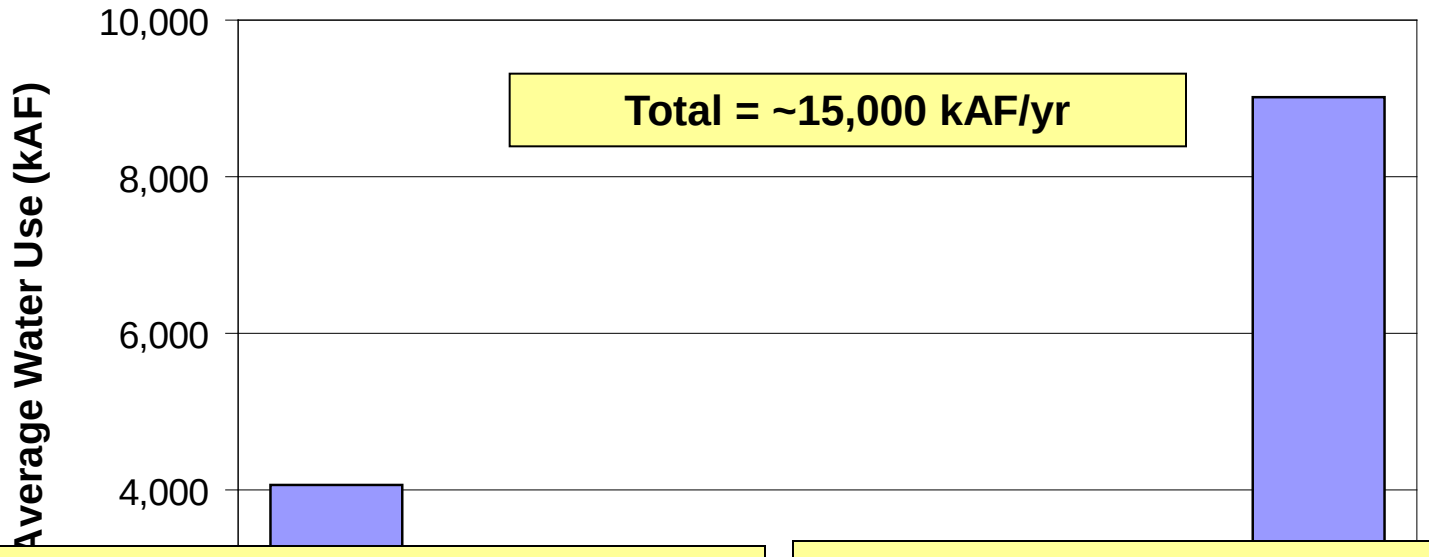


2008 Mining consumption:

Oil and Gas = ~60 kAF (~36 kAF HF)
(HF, drilling, waterflooding)

Coal/Lignite = ~20 kAF

Aggregates = ~70 kAF

Others= ~10 kAF

Total= ~160 kAF

2011 Mining consumption:

Oil and Gas = ~120 kAF water use
(HF, drilling, waterflooding)

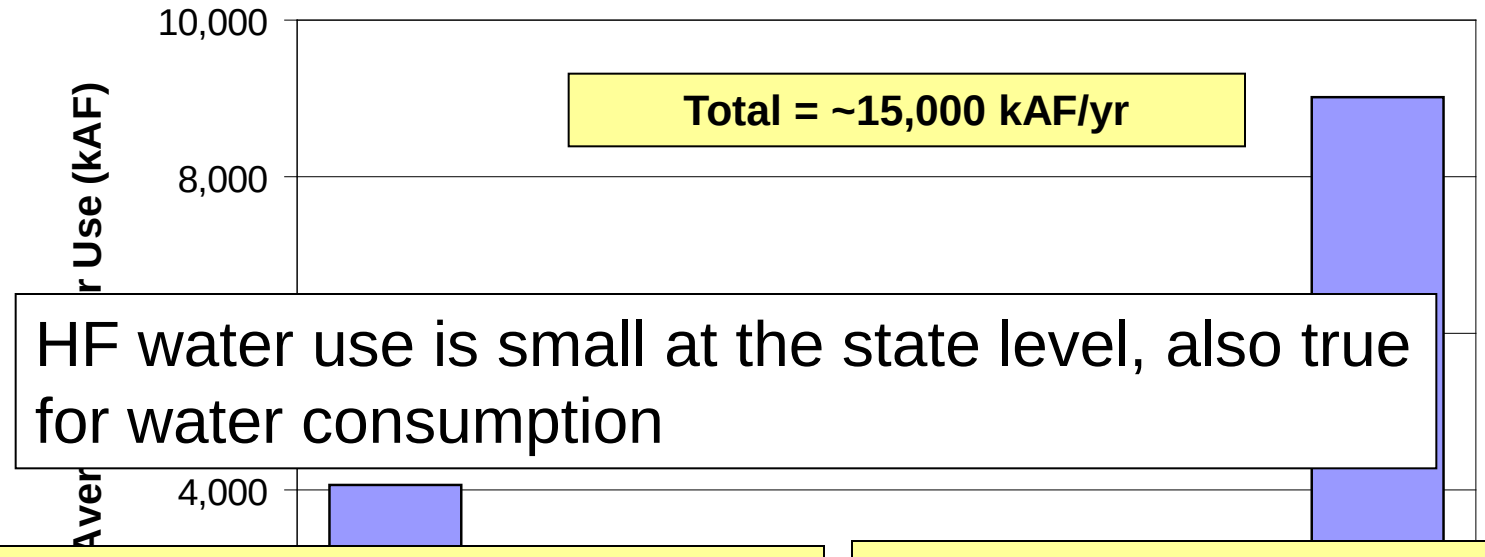
HF = ~81.5 kAF water use

HF = ~65 kAF water consumption

All others = ~100kAF

Total consumption = ~190 kAF

Texas water use



HF water use is small at the state level, also true for water consumption

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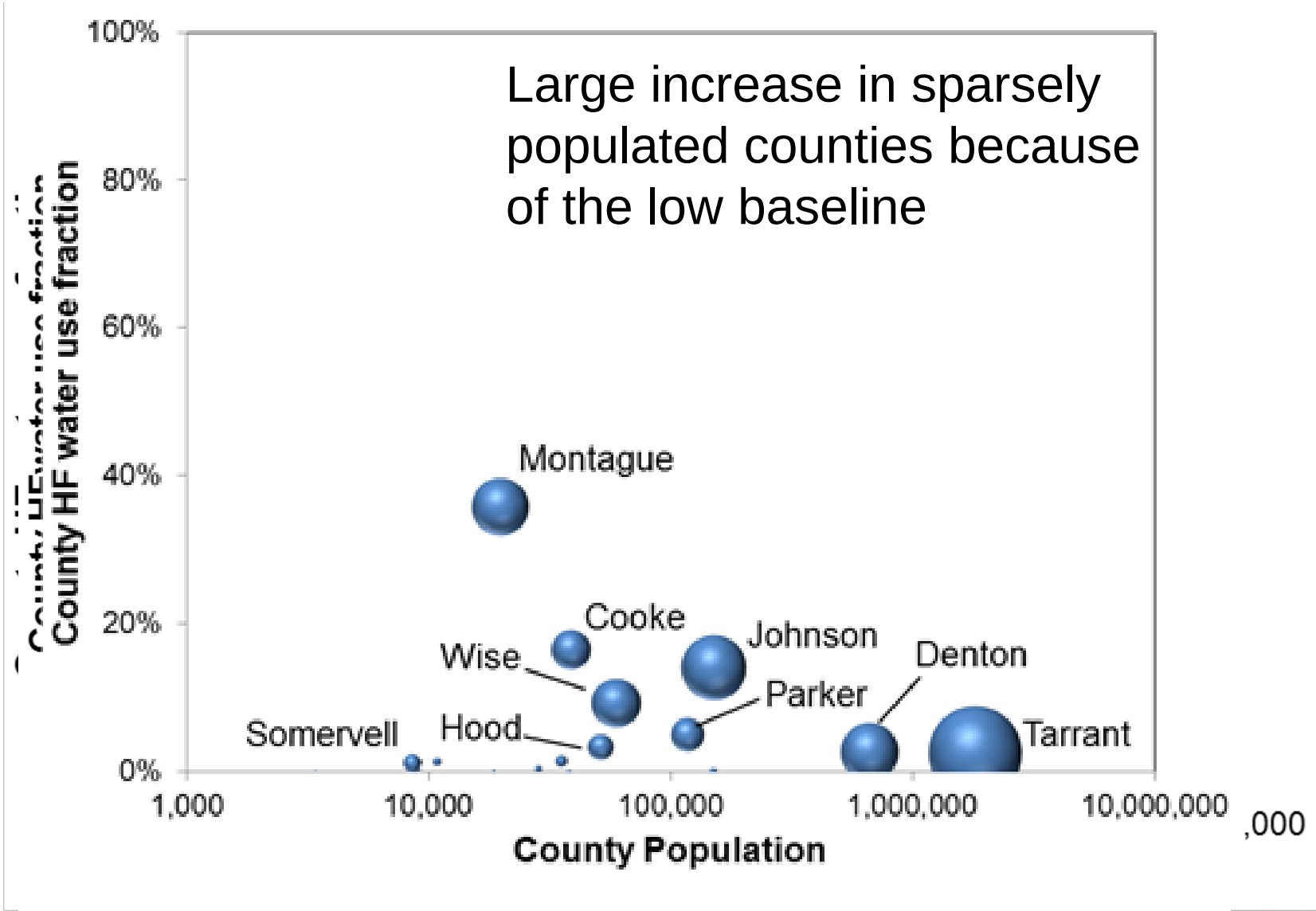
Baseline water use



Texas Water Development Board

Sustainable and affordable water for Texas.

Geology

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State Water Plan | Regional Water Planning | Planning Data | Water Use Survey | Water Bank & Trust | Maps & GIS Data | Planning Staff

Historical Water Use Estimates

Each year the Texas Water Development Board conducts an annual survey of ground and surface water use by municipal and industrial entities within the state of Texas. The information obtained is then utilized by the Texas Water Development Board for Water Resources Planning. The hitstorical water use estimates are subject to revision as additional data and corrections are made available to the TWDB.

Please read Frequently Asked Questions for more information on water use survey estimates and GPCDs and how they are derived.

For more information, please contact Water Use Survey Team.

Water Use Summary Estimates

- 2010 Water Use Summary Estimates
- 2009 Water Use Summary Estimates
- 2008 Water Use Summary Estimates
- 2007 Water Use Summary Estimates
- 2006 Water Use Summary Estimates
- 2005 Water Use Summary Estimates
- Historical Water Use Summary Information Database

Water Planning

- State Water Plan
- Regional Water Planning
- Planning Data
- Water Use Survey
  - Online Water Use Survey
  - Printable Water Use Survey
  - Historical Water Use Estimates
  - Historical Groundwater Pumpage
  - Frequently Asked Questions
- Water Bank and Trust
- Maps & GIS Data
- Useful links and Resources
- Water Planning Staff

Flood Mitigation Planning

TNRIS

QUESTIONS?

San Antonio

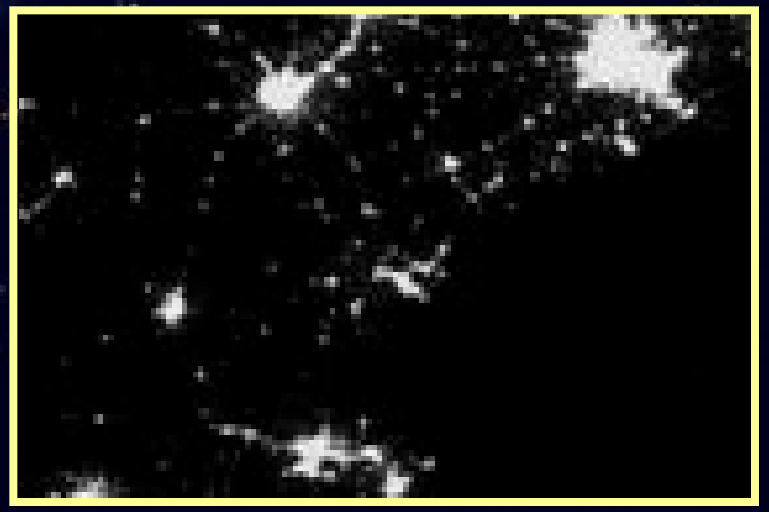
Eagle Pass+

Houston

C.C.

Laredo+

The Valley



Credit: ***NASA - NOAA***