

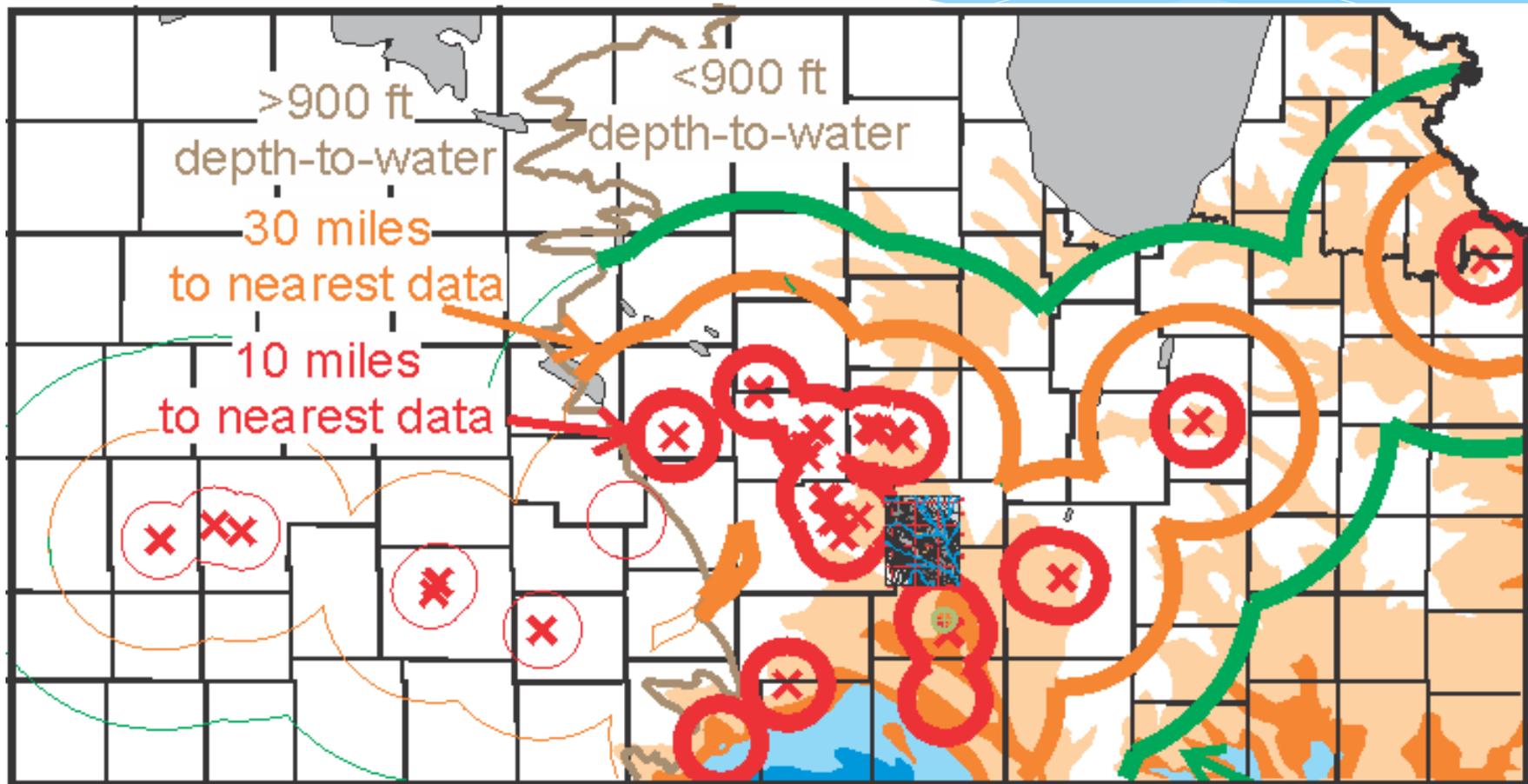
Update on Class-I & Class-II Arbuckle Disposal Volumes and Static Fluid Levels

Kansas Geological Survey

KGS Seismic Consortium
August 9, 2023



Data Proximity and Depth to Fresh-Water Equivalent Static Fluid Level



-  200 ft head above land surface necessary for freshwater to enter Arbuckle by gravity feed (~50,000 ppm TDS minimum necessary for brine to enter Arbuckle by gravity feed from surface)
-  0 ft separation between land surface and hydrostatic level for fresh water (fresh water will not enter Arbuckle by gravity feed)
-  <100 ft separation between land surface and hydrostatic level for fresh water
-  <300 ft separation between land surface and hydrostatic level for fresh water

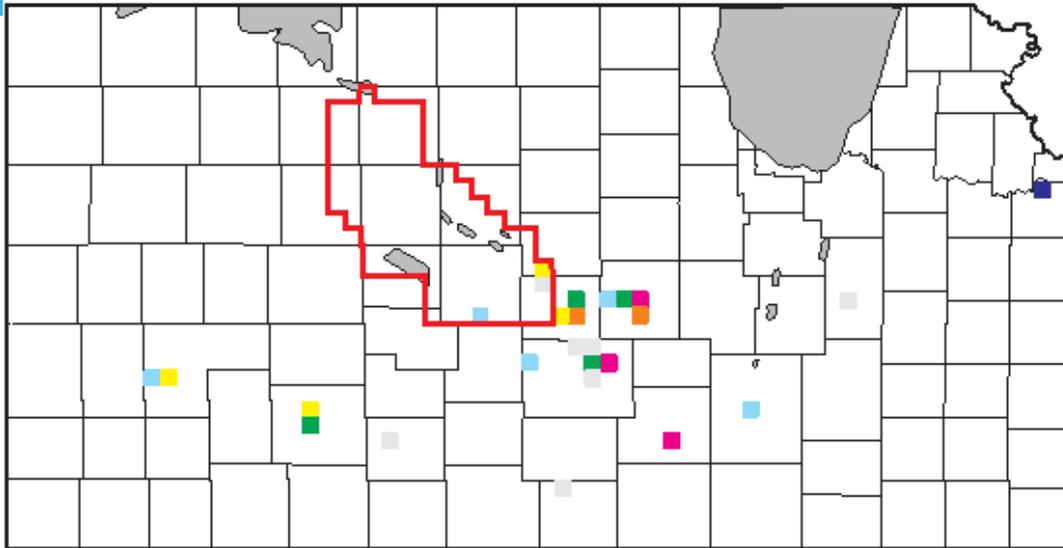
 Class-I disposal well

50 miles
to nearest data

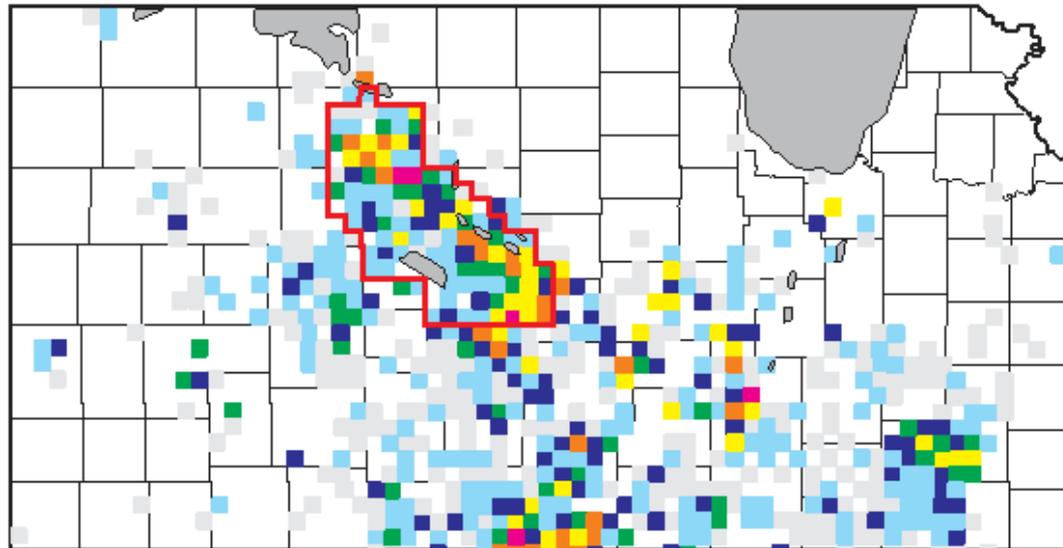
ARBUCKLE DISPOSAL VOLUMES (by township)

RED OUTLINED AREA
is where cycling floods
may distort summation
of disposal volume

CLASS-I WELLS



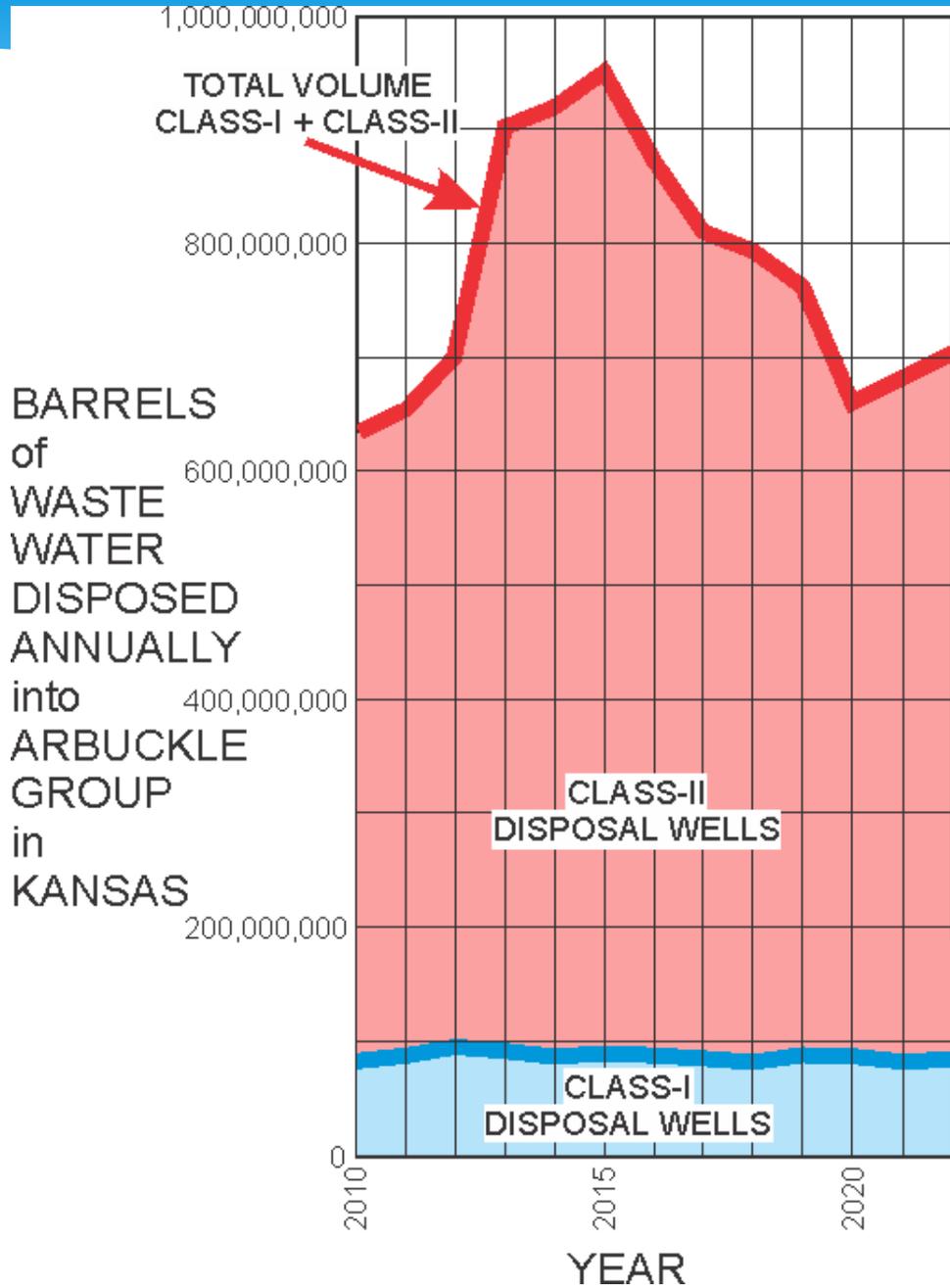
CLASS-II WELLS

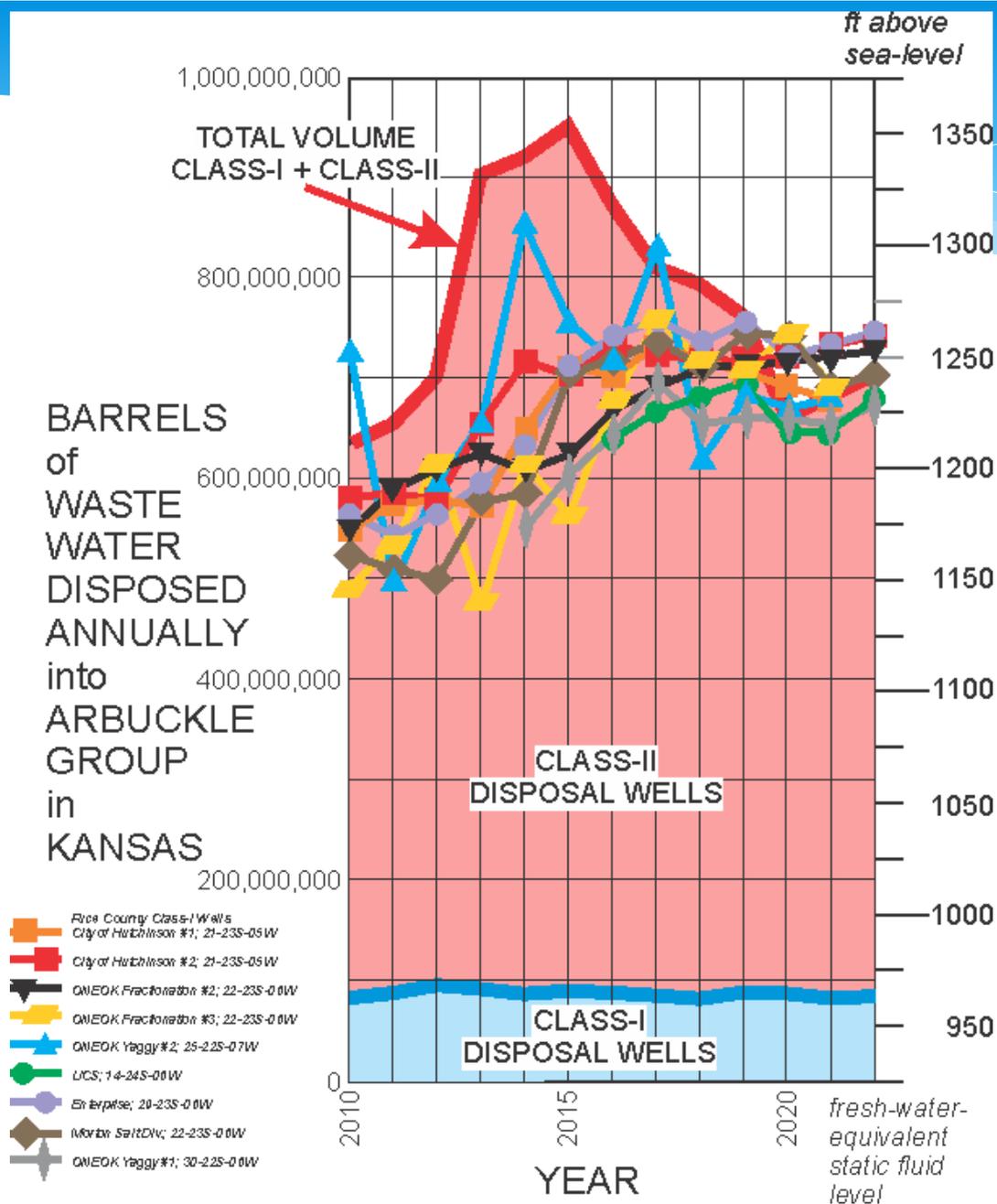


BBL WASTE-WATER DISPOSED INTO ARBUCKLE, 2010-2016

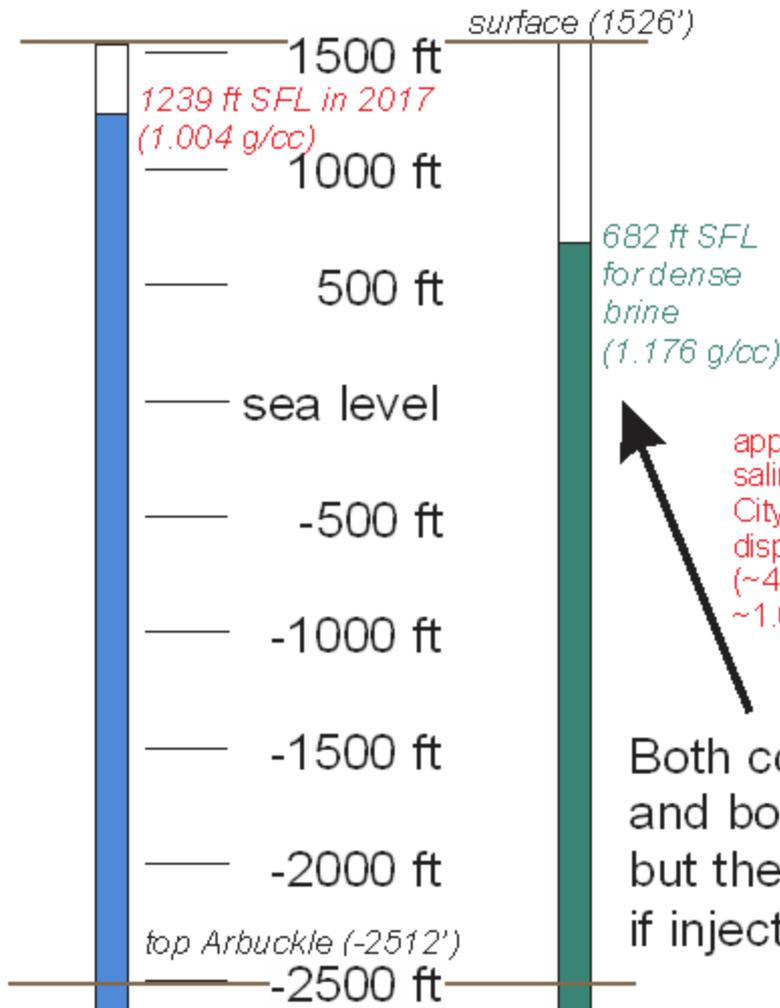
Legend for disposal volumes (BBL):

<1,000,000	1,000,000 to <5,000,000	5,000,000 to <10,000,000	10,000,000 to <20,000,000	20,000,000 to <40,000,000	40,000,000 to <80,000,000	80,000,000 or greater
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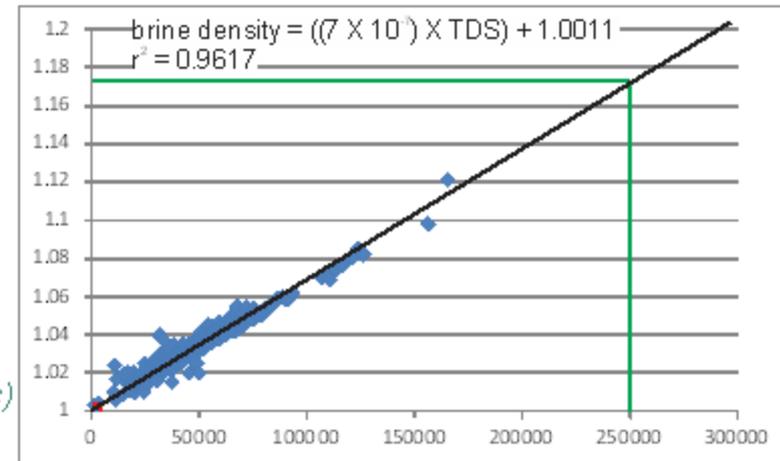




DEPRESSION OF A STATIC FLUID LEVEL as a function of brine density



Salinity vs. Density Kansas Arbuckle Brines



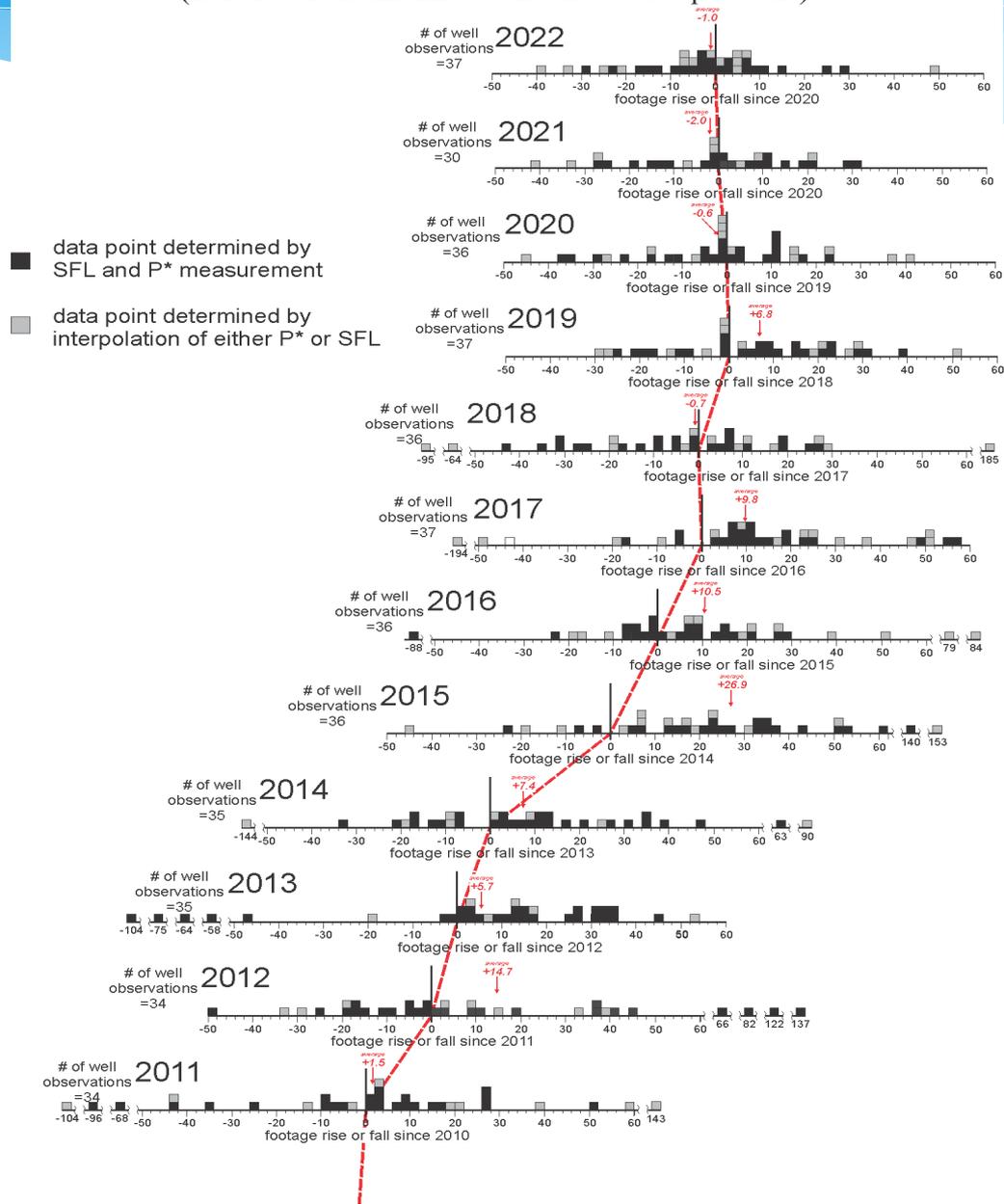
approximate
salinity & density of
City of Hutchinson #1
disposal water
(~4150 ppm TDS;
~1.004 g/cc)

approximate
salinity & density of
basinal brine
(~250,000 ppm TDS;
~1.176 g/cc)

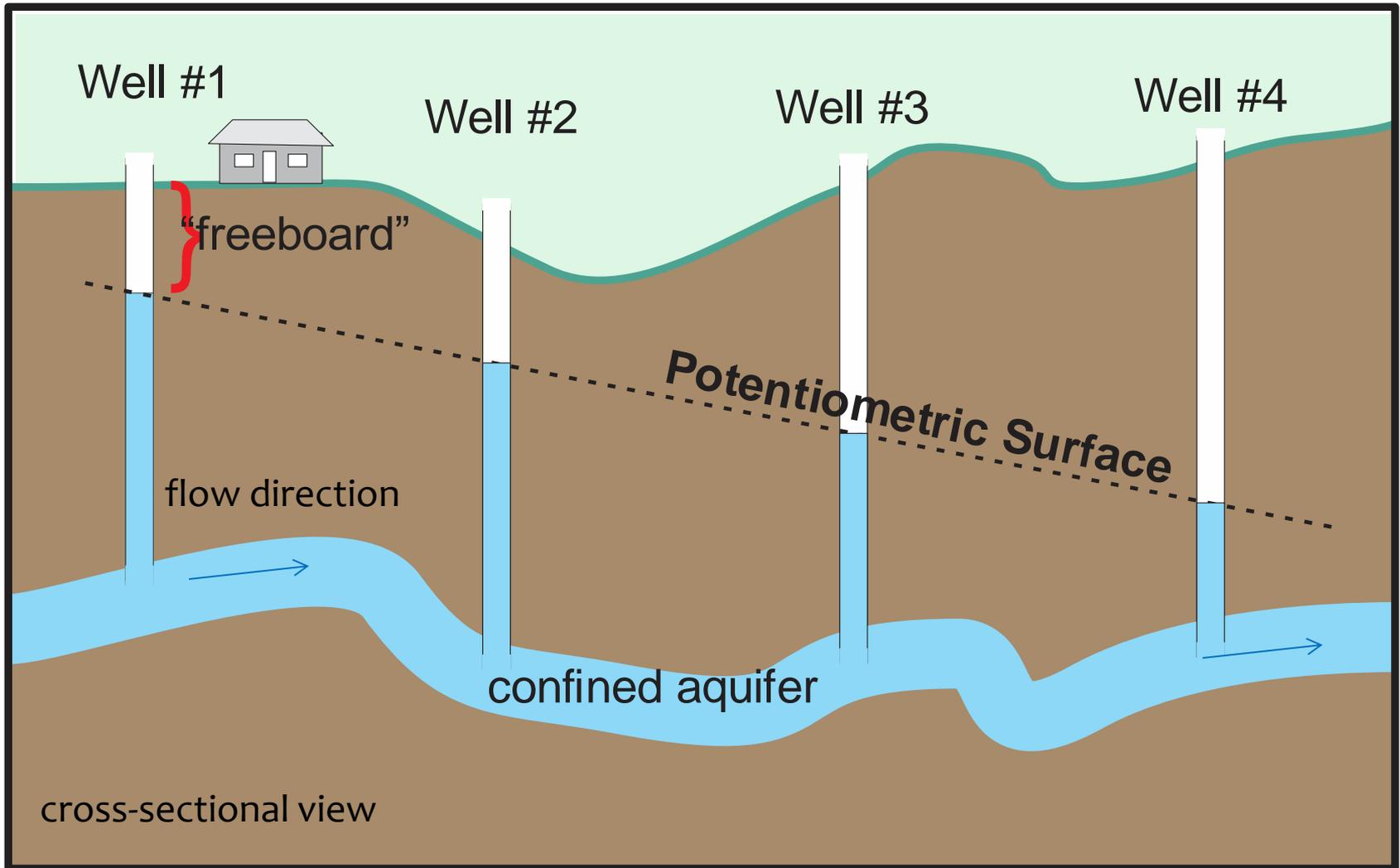
Both columns of water weigh the same,
and bottom-hole P is the same,
but the SFL is depressed 557 ft
if injected water is dense, basinal brine

YEARLY CHANGE in STATIC FLUID LEVELS
of KANSAS CLASS-I WELLS
(fluid levels normalized to fresh-water equivalent)

YEARLY CHANGE
in STATIC FLUID
LEVELS
of KANSAS
CLASS-I WELLS
(fluid levels
normalized to
fresh-water
equivalent)

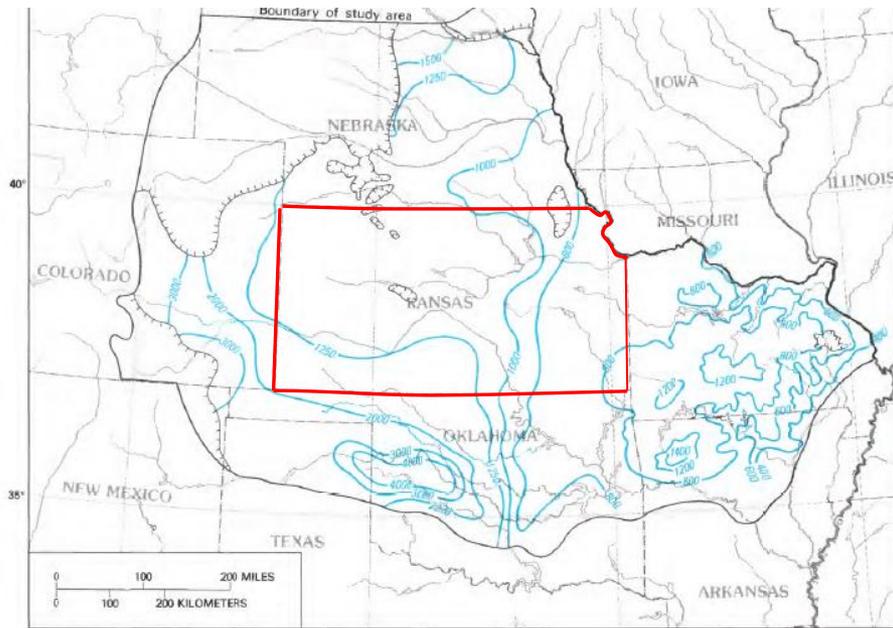


POTENTIOMETRIC SURFACE
HYDROSTATIC SURFACE
PIEZOMETRIC SURFACE
(inference of subsurface flow patterns)



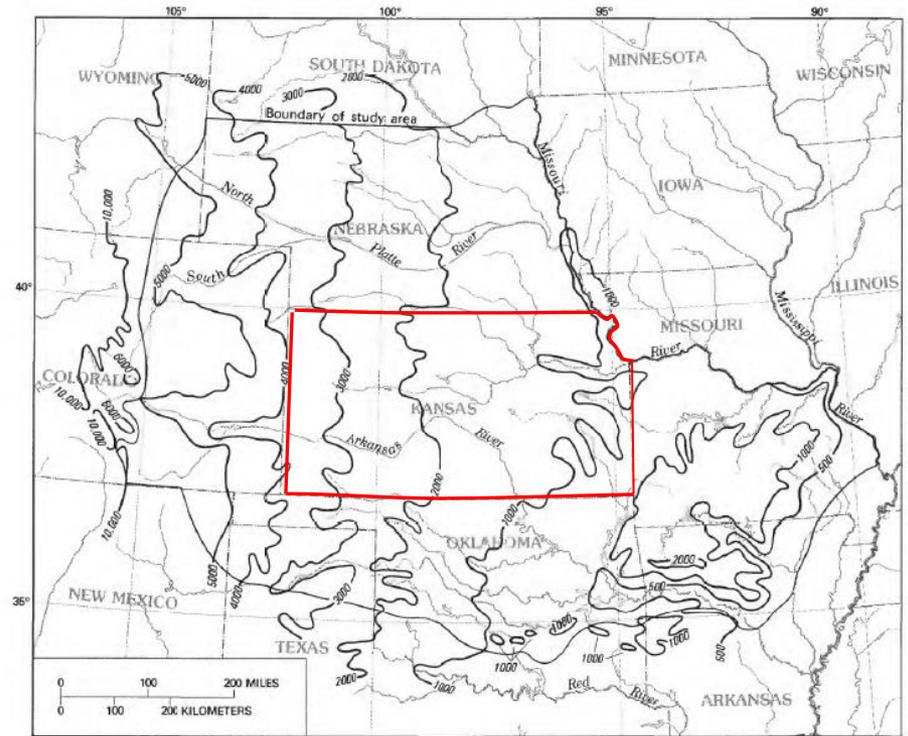
ELEVATION of HYDROSTATIC SURFACE of ARBUCKLE (earlier version)

Elevation of Hydrostatic Surface



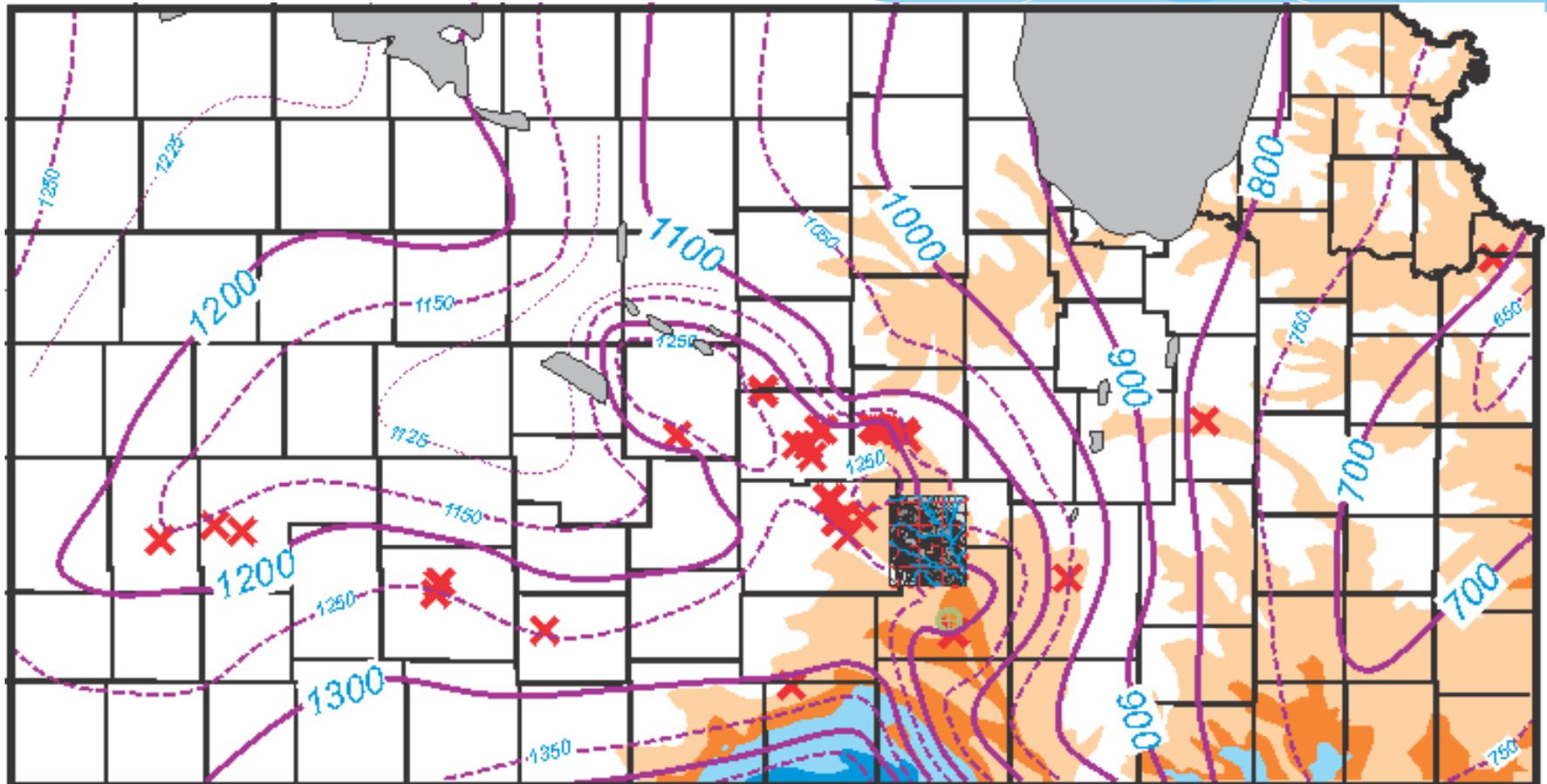
EXPLANATION

- EXTENT OF CAMBRIAN AND ORDOVICIAN ROCKS
- LINE OF EQUIVALENT-FRESHWATER HEAD— Shows approximate altitude of equivalent-freshwater head. Interval, in feet, varies. Datum is sea level



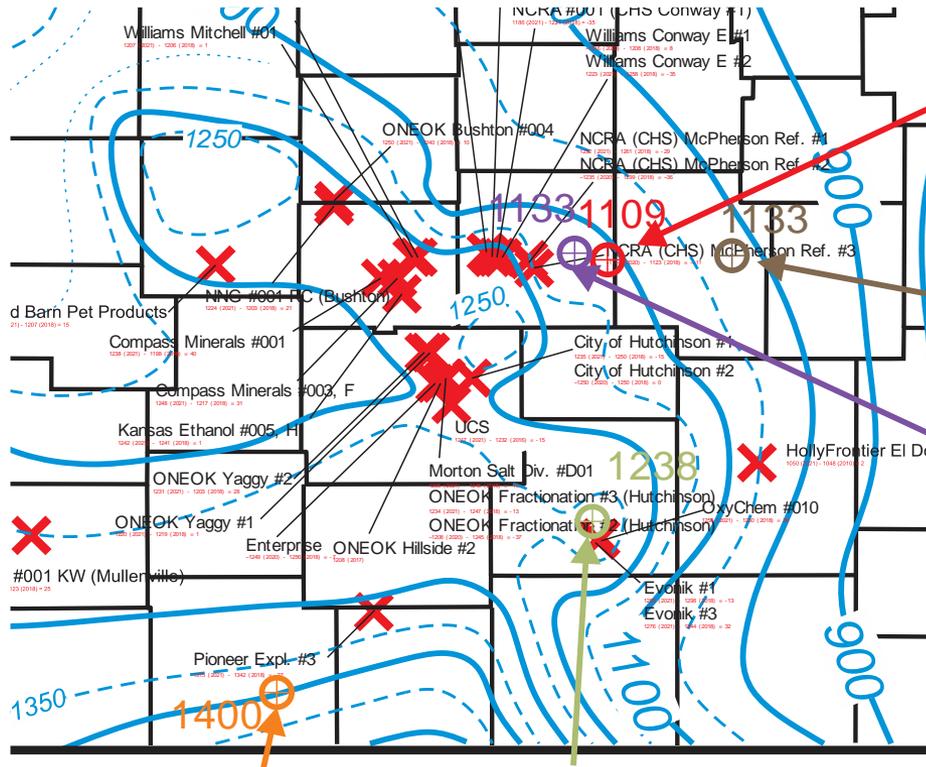
Elevation of Land Surface

FRESH-WATER EQUIVALENT PIEZOMETRIC SURFACE (contoured)



- 200 ft head above land surface necessary for freshwater to enter Arbuckle by gravity feed (~50,000 ppm TDS minimum necessary for brine to enter Arbuckle by gravity feed from surface)
- 0 ft separation between land surface and hydrostatic level for fresh water (fresh water will not enter Arbuckle by gravity feed)
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- <300 ft separation between land surface and hydrostatic level for fresh water
- Class-I disposal well

ADDITIONAL DATA for FRESH-WATER EQUIVALENT STATIC FLUID LEVEL Using FIVE CLASS-II WELLS



Te-Pe Oil #1 Canton
~5 ft upward correction
to previous contouring

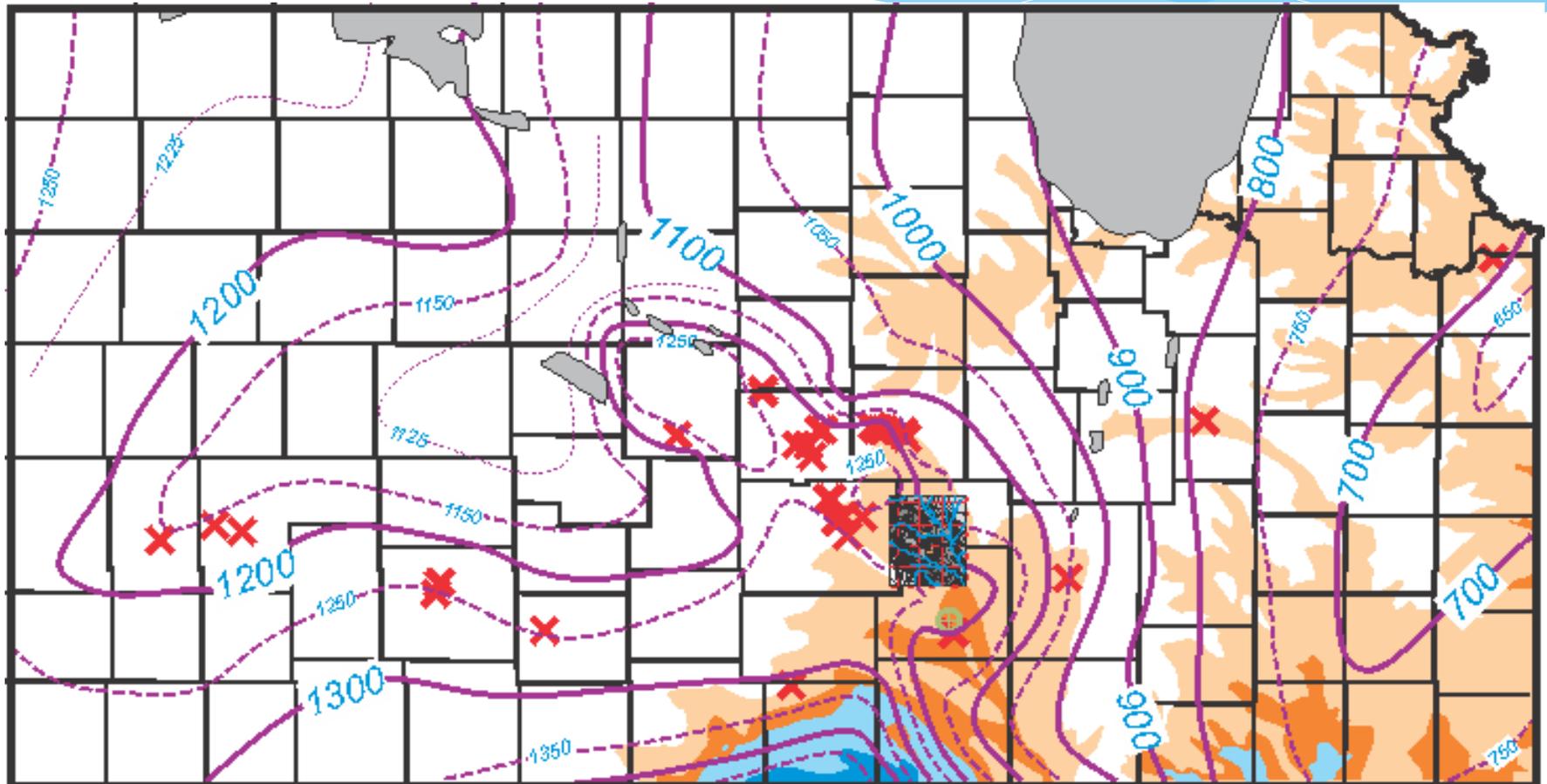
Te-Pe Oil #3 Koehn SWD #'
~115 ft upward correction
to previous contouring

KGS #2 Koehn
~10 ft upward correction
to previous contouring

KCC Harbaugh SWD #1
no correction necessary
to previous contouring

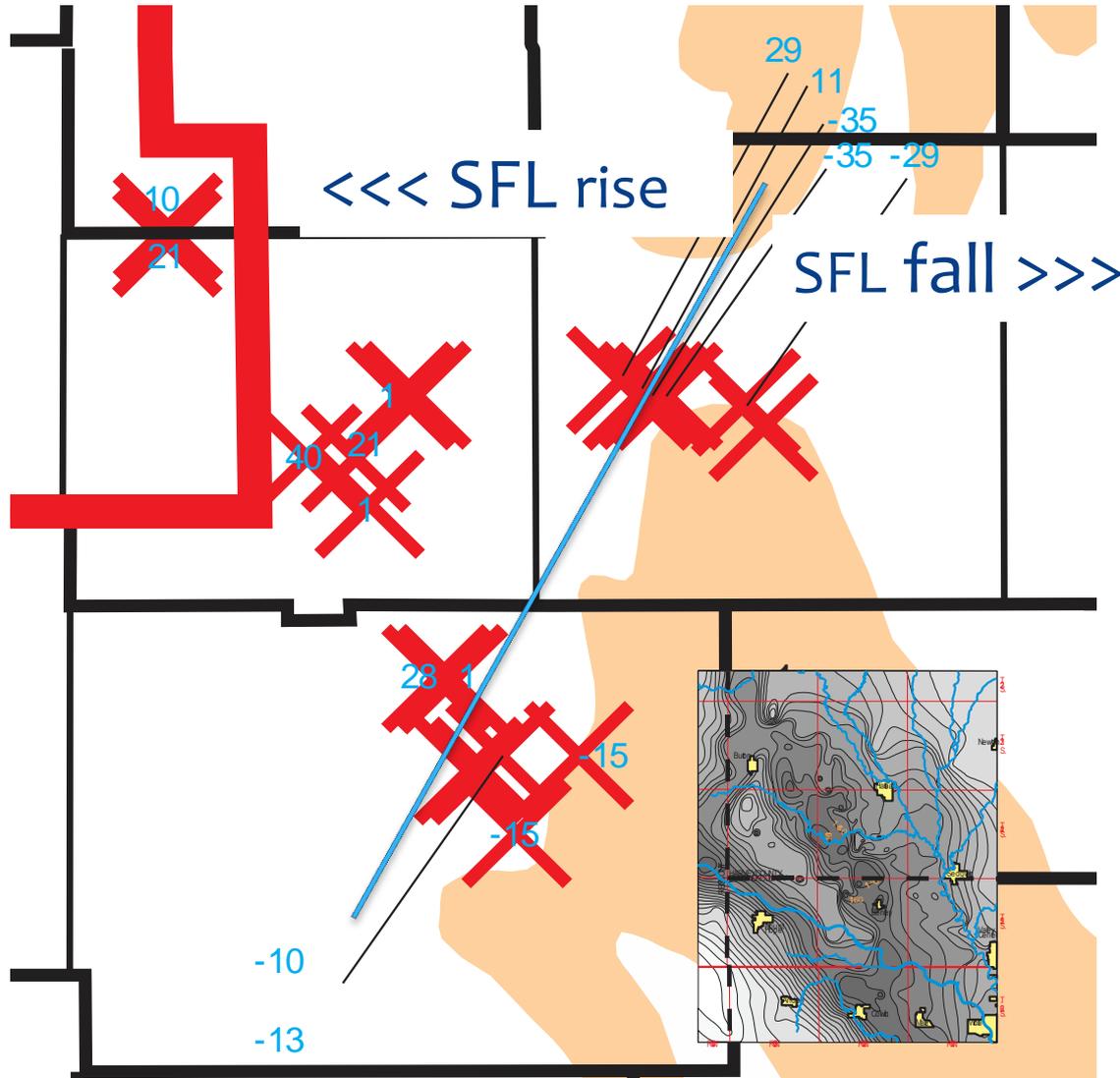
KCC Lampe #1
~20 ft downward correction.
possibly represents stable
SFL whereas Evonik &
OxyChem SFLs may have
near-well interference

FRESH-WATER EQUIVALENT PIEZOMETRIC SURFACE (contoured)



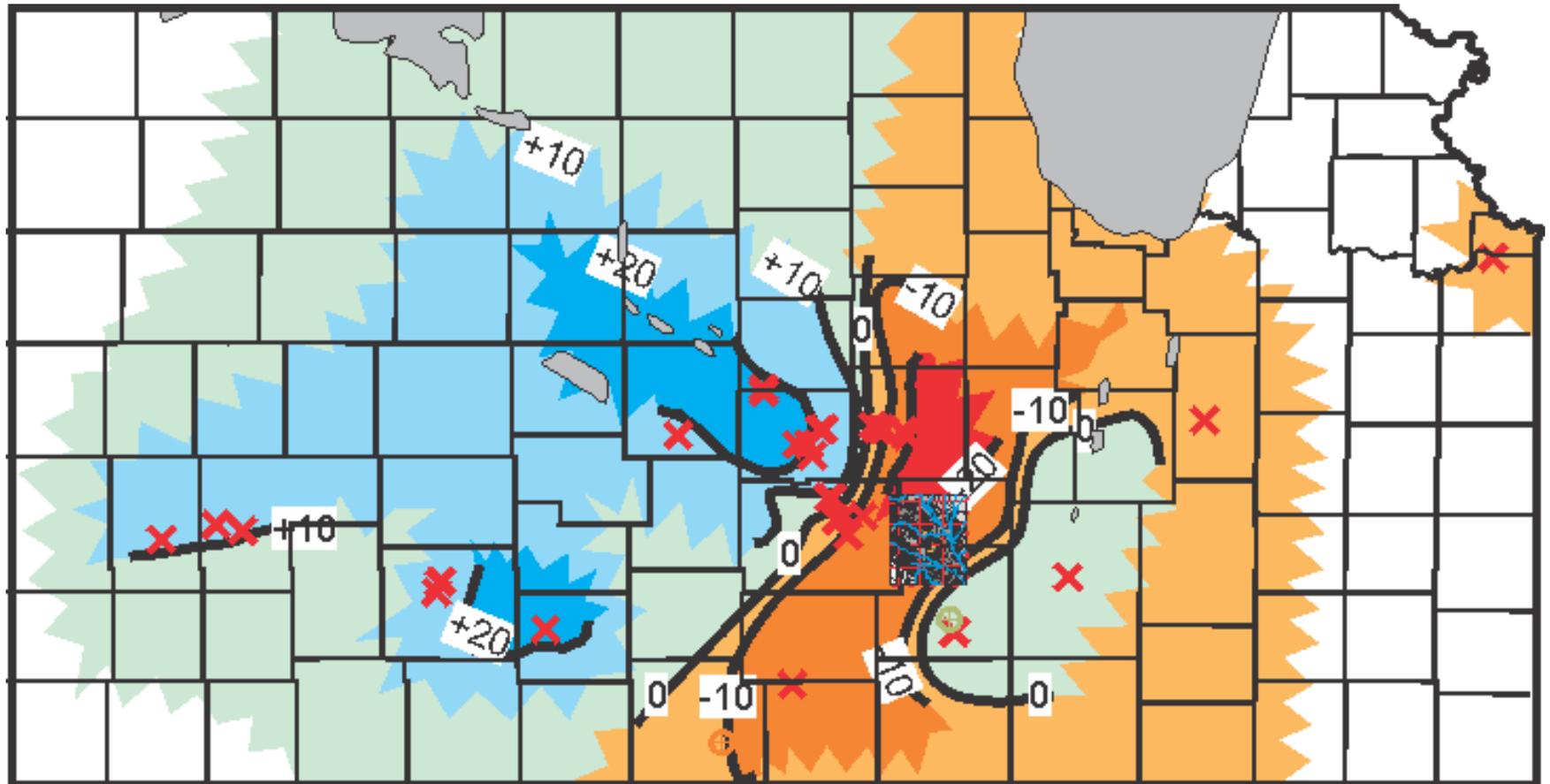
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2018-2021 SFL ELEVATION CHANGE



no apparent
geologic
reason for
rise-fall
boundary
for the fresh-
water
equivalent
static fluid level

Fresh-Water Equivalent Static Fluid Level Change between 2018-2021

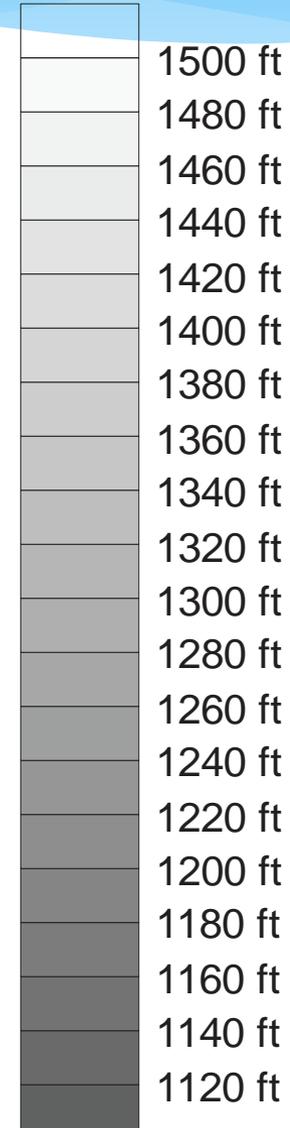
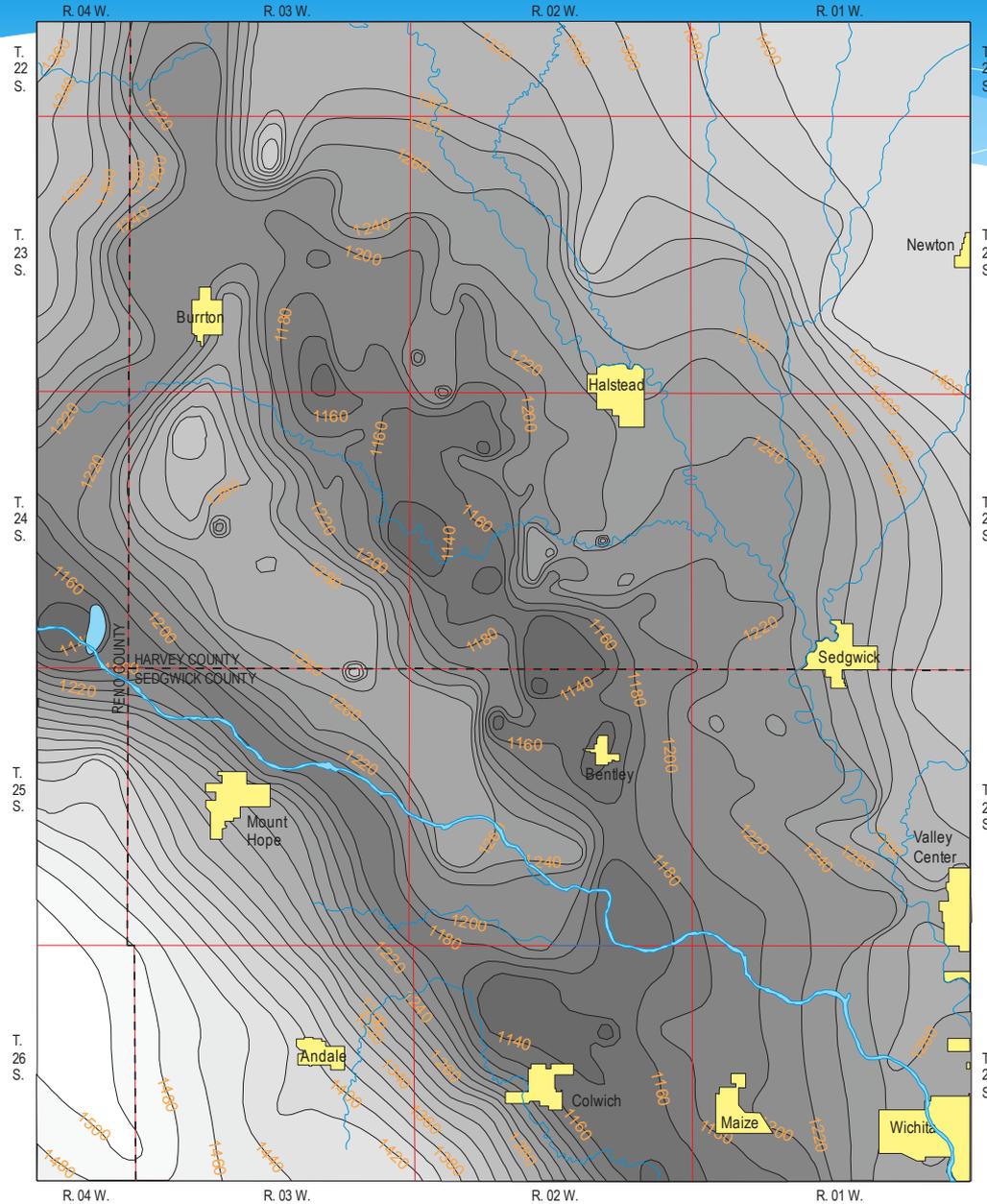


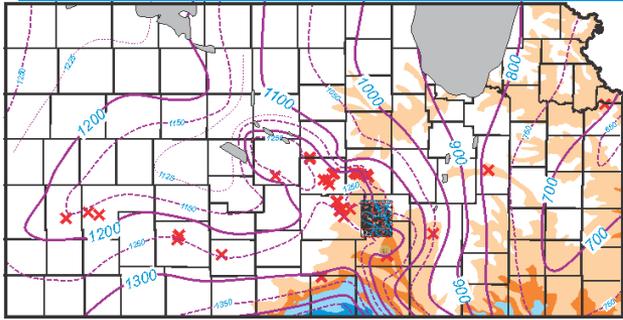
✗ Class-I disposal well

How Close is the Arbuckle Static Fluid Level to the Base of the Equus Beds?

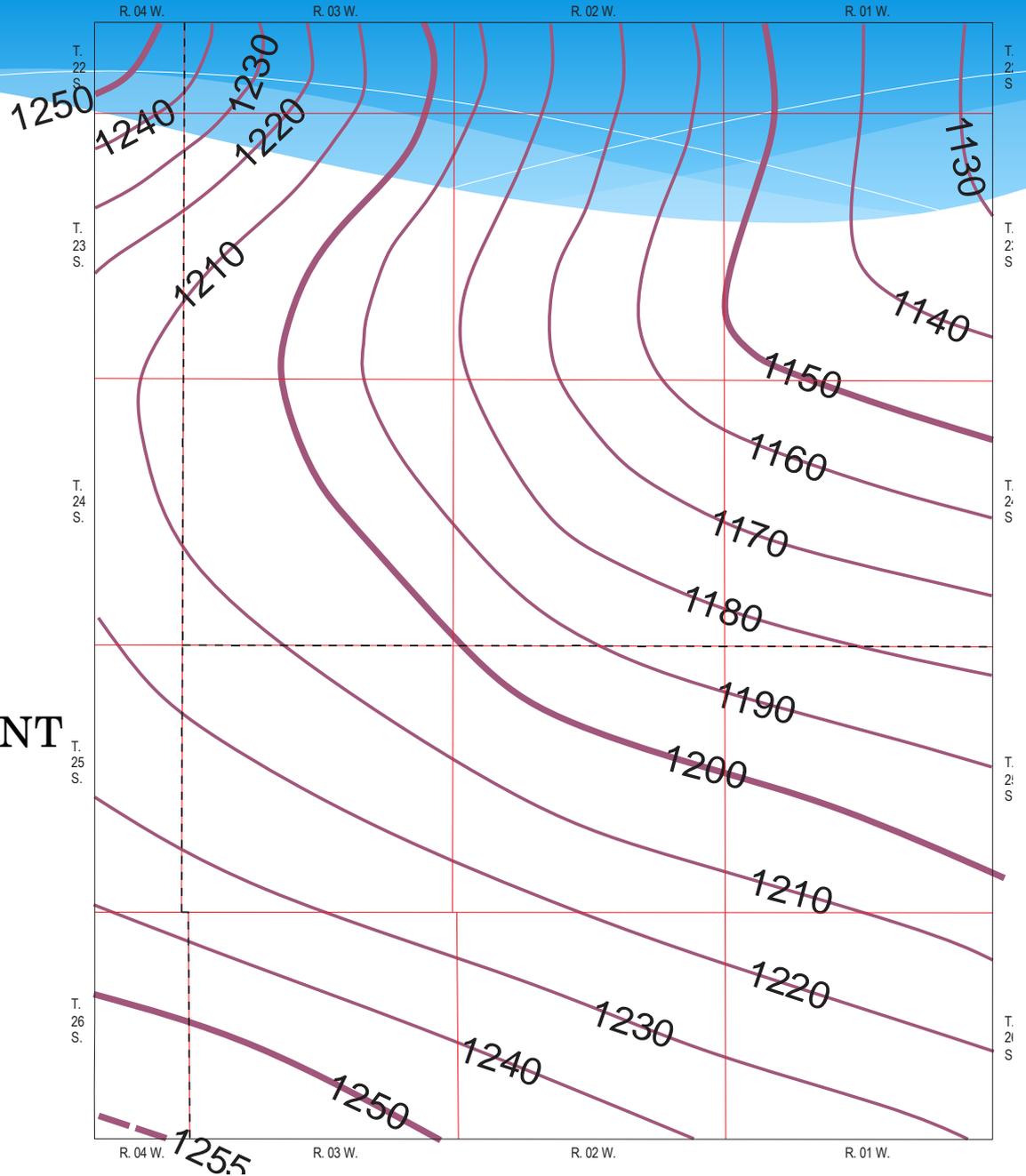


ELEVATION of BASE of "EQUUS BEDS" (feet above Sea Level (C.I. = 20 ft; from Ziegler et al (2010))

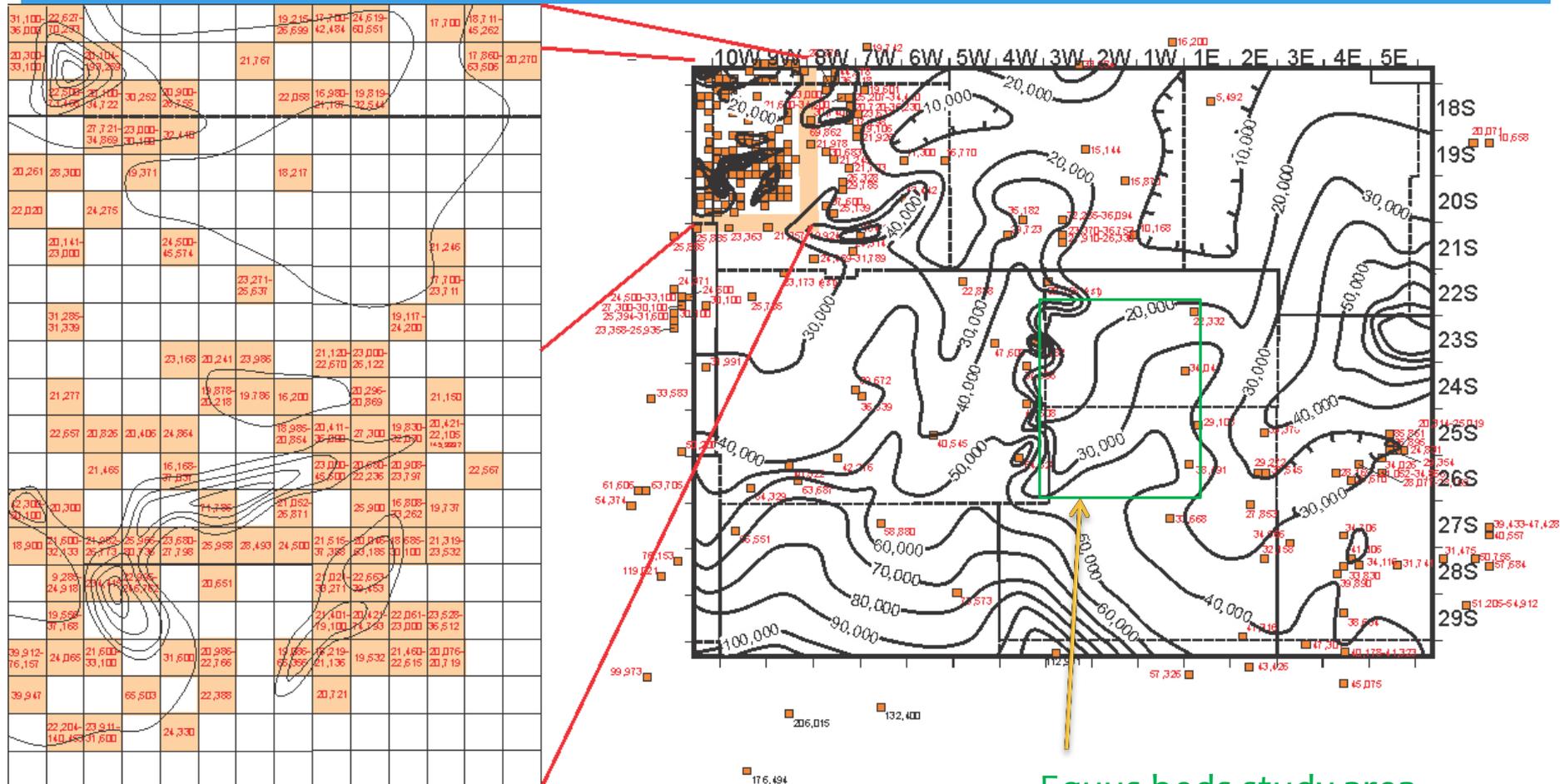




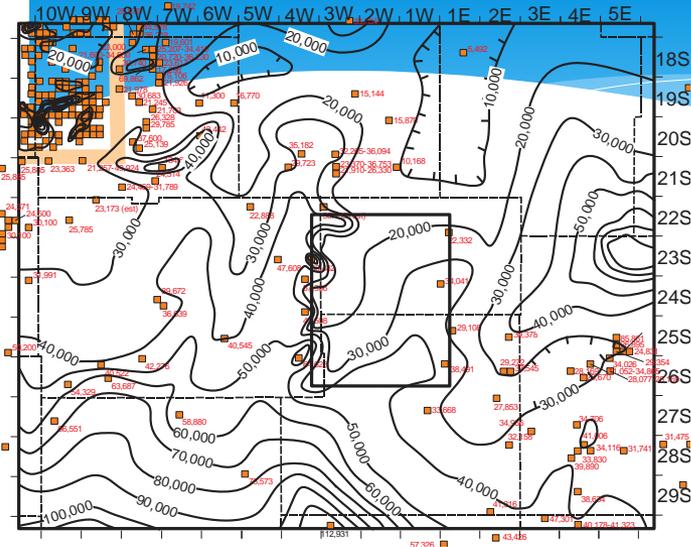
ELEVATION of FRESH-WATER EQUIVALENT STATIC FLUID LEVEL



REGIONAL SALINITY (total dissolved solids; ppm) of ARBUCKLE in CENTRAL KANSAS from Kansas Brine Database

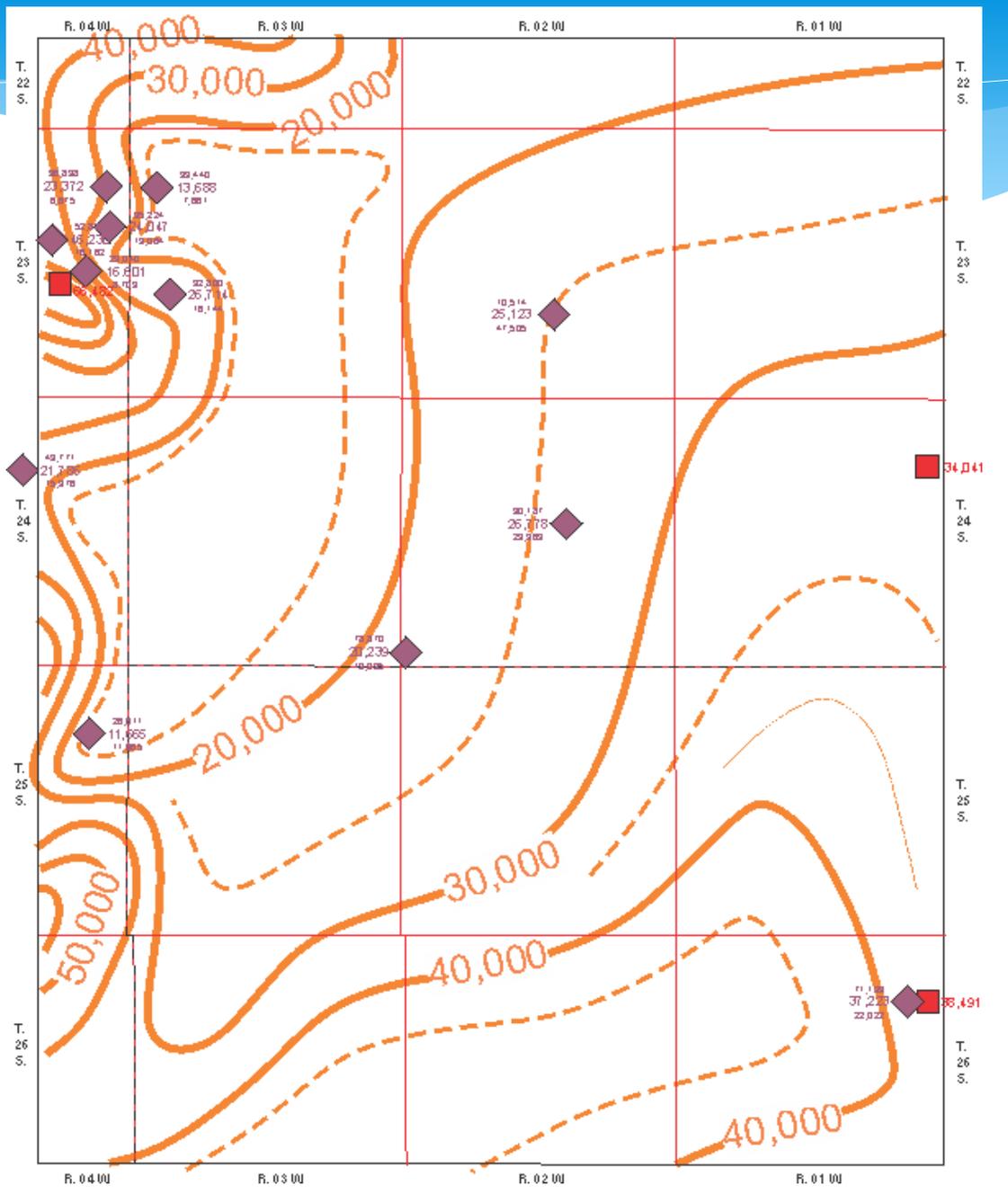


Equus beds study area



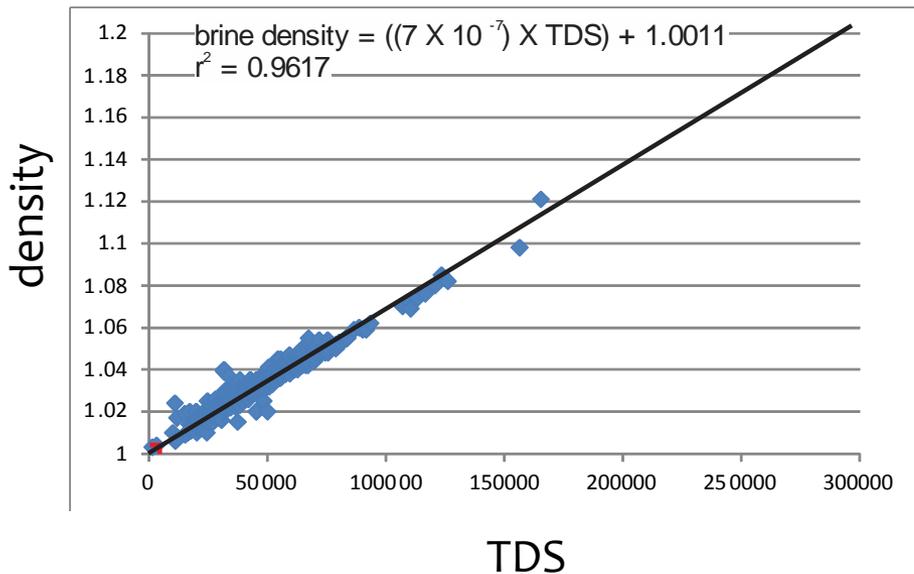
TOTAL DISSOLVED SOLIDS
 from
 Kansas Brine Database
 supplemented by
 well-log analysis

- Brine sample
- ◆ Well-log analysis



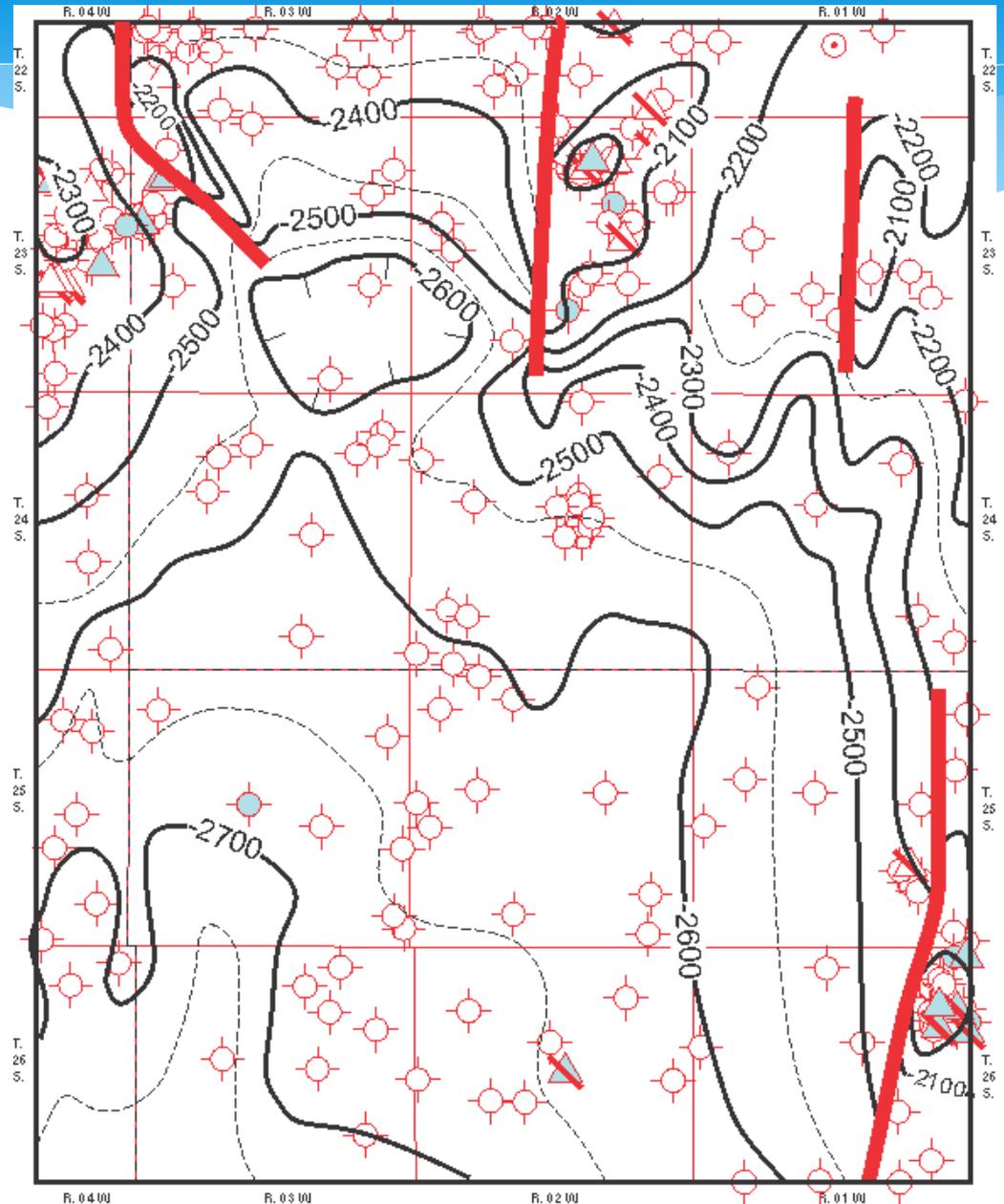
DENSITY of SUBSURFACE BRINE in ARBUCKLE correlates to TOTAL DISSOLVED SOLIDS

Salinity vs. Density Kansas Arbuckle Brines



Total Dissolved Solids (TDS, parts per million)	Density (grams/cubic centimeter)
110,000	1.078
100,000	1.071
90,000	1.064
80,000	1.057
70,000	1.050
60,000	1.043
50,000	1.036
40,000	1.029
30,000	1.022
20,000	1.015
10,000	1.008
5,000	1.004
0	1.000

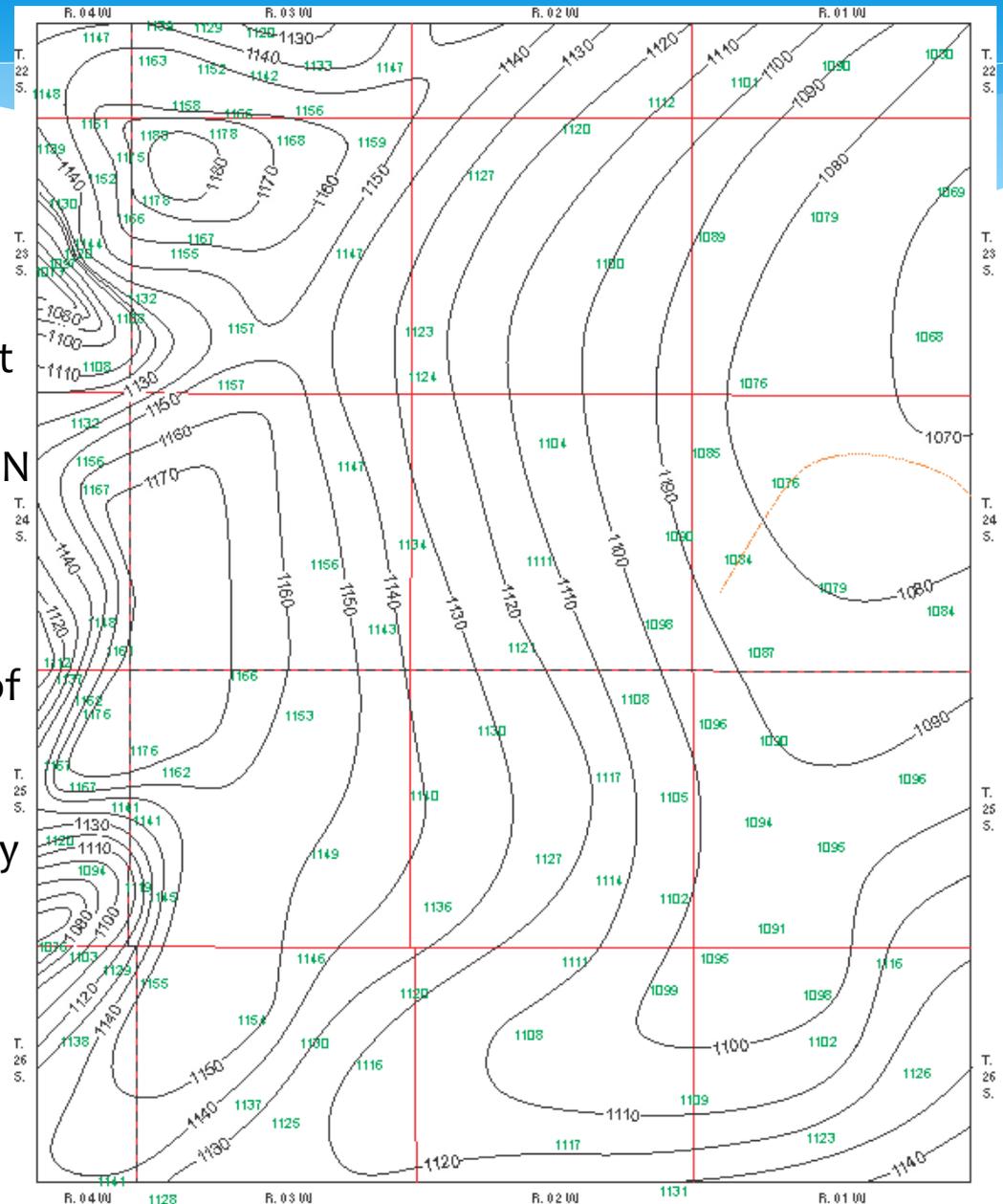
STRUCTURE MAP
of the top of the Arbuckle
from well-log picks



ELEVATION of ARBUCKLE STATIC FLUID LEVEL (taking into account salinity of the formation brine)

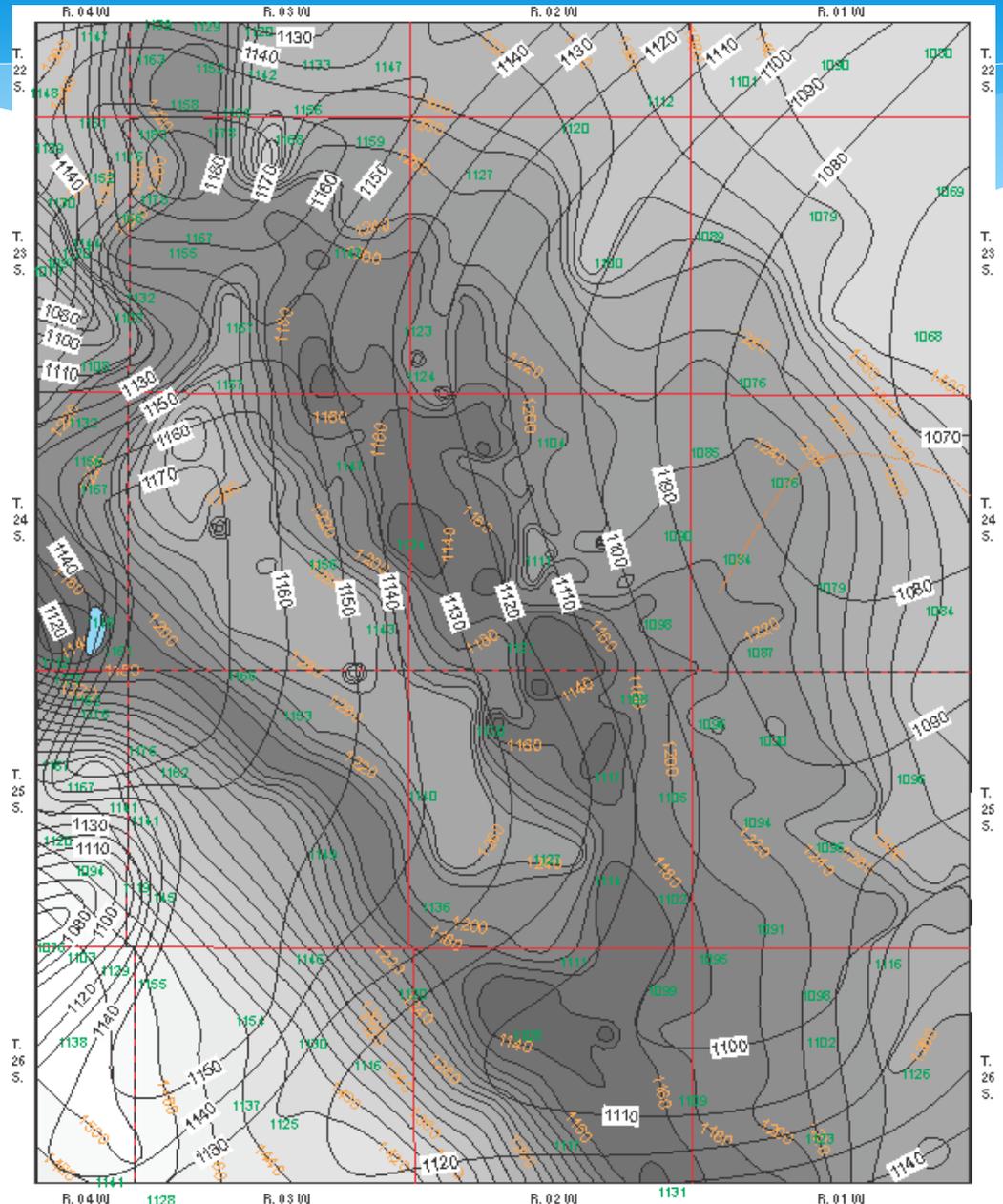
1. elevation of fresh-water equivalent SFL – elevation of top of Arbuckle yields THICKNESS of WATER COLUMN
2. PRESSURE at top of ARBUCKLE can be determined by THICKNESS of WATER COLUMN using the density of fresh water (i.e., 1.0 grams/cc)
3. thickness of saline water necessary to produce the PRESSURE at top of ARBUCKLE can be determined from the TDS-density relationship for ARBUCKLE brines

VOILA! A STATIC FLUID LEVEL MAP



THE FOOTAGE SEPARATION
between
the **BASE of the EQUUS BEDS**
and the underlying(?)
STATIC FLUID LEVEL
for the **ARBUCKLE**
is determined by subtracting
the elevation data on these
two superimposed maps

>>>>>>>>>>

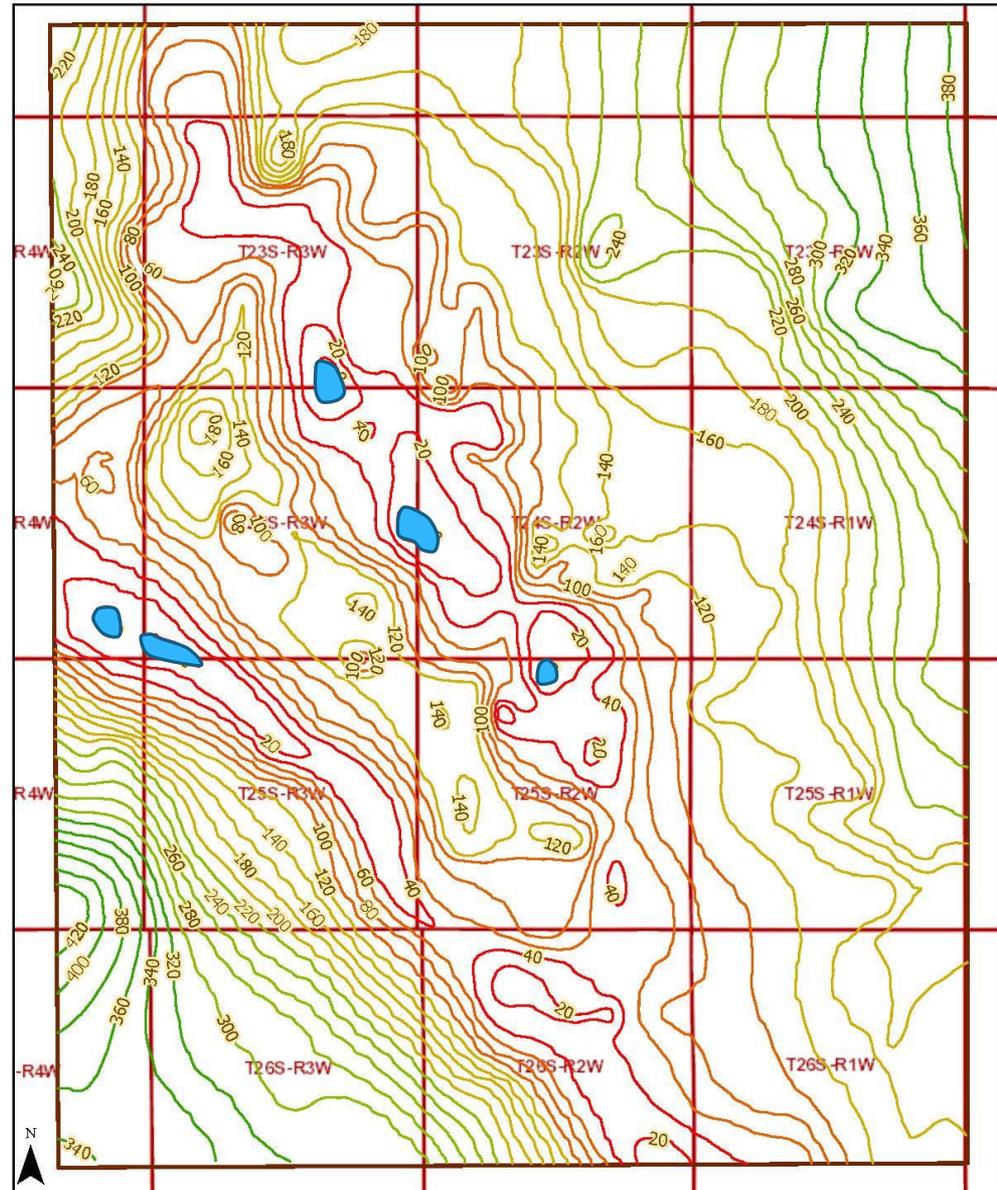


Elevation Difference in Feet Between Equus Beds and Arbuckle SFL

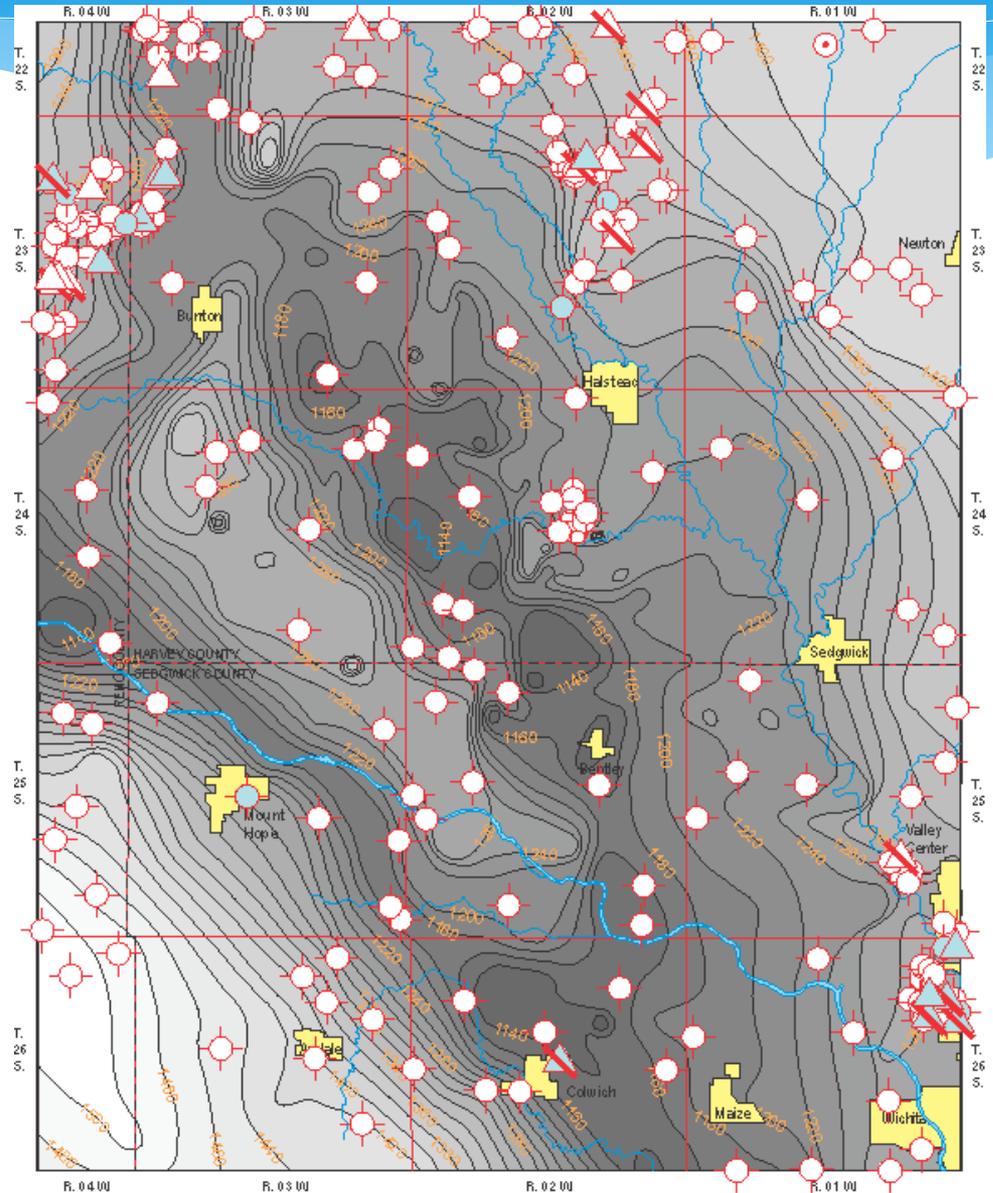
By the Kansas Geological Survey, April 2023

ELEVATION DIFFERENCE
(in feet)
BETWEEN the BASE of the
EQUUS BEDS and the
ARBUCKLE
STATIC FLUID LEVEL

“0 difference” in blue areas



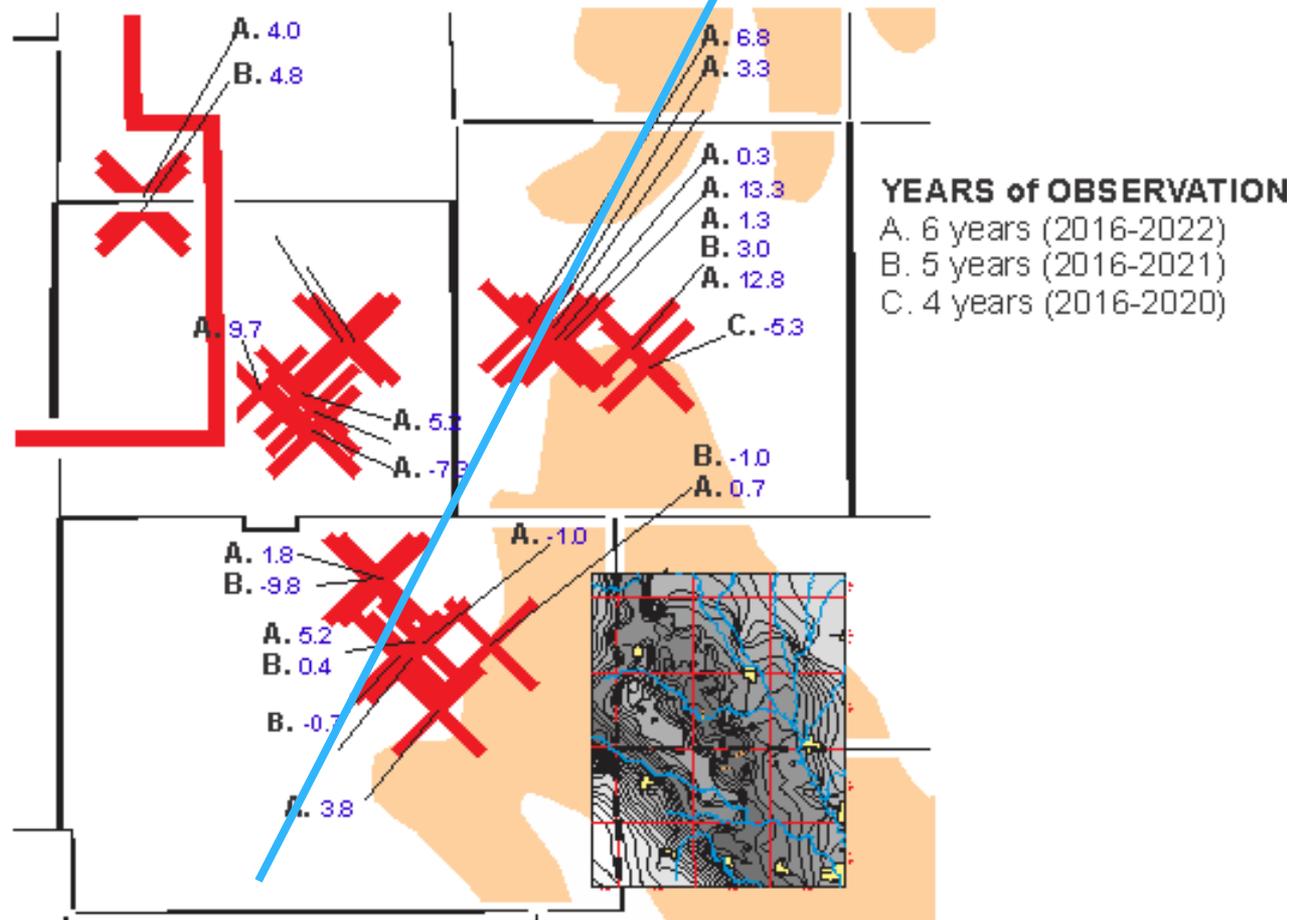
BASE of EQUUS BEDS
with
WELLS PENETRATING
the
ARBUCKLE
superimposed



Fresh-Water Equivalent SFL ELEVATION CHANGE

average yearly change, five-years minimum

2016-2022 rise/fall boundary



Major Points

- Measuring selected Class-II wells supplements understanding of Arbuckle SFLs & P*
- 2022 disposal volume in Kansas modestly increased from 2021
- Arbuckle SFLs overall in Kansas are remaining steady
- Boundary between 2018-2021 SFL rise-and-fall in central Kansas mostly persists into 2022
- Arbuckle SFL is close to base of Equus beds NW of Wichita
- Arbuckle SFL in central Kansas rising slowly? (~0-2 ft/year?)
- Monitoring well NW of Wichita will yield more accurate data on SFL position and movement relative to Equus beds
- Additional wells measured will improve spatial density of data and will allow better understanding for undrilled areas