Ground-water resources (in Louisiana)

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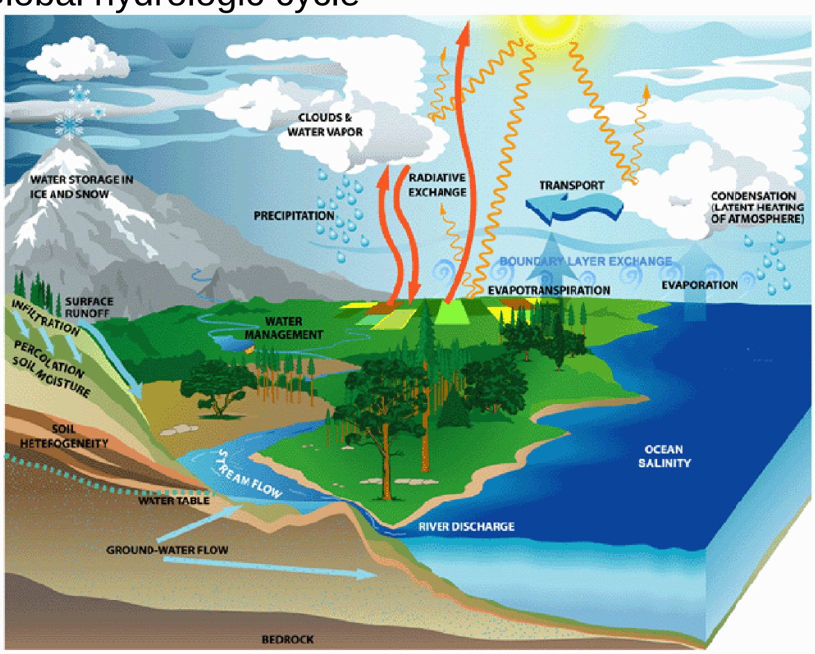
Global hydrologic cycle



Global water budget

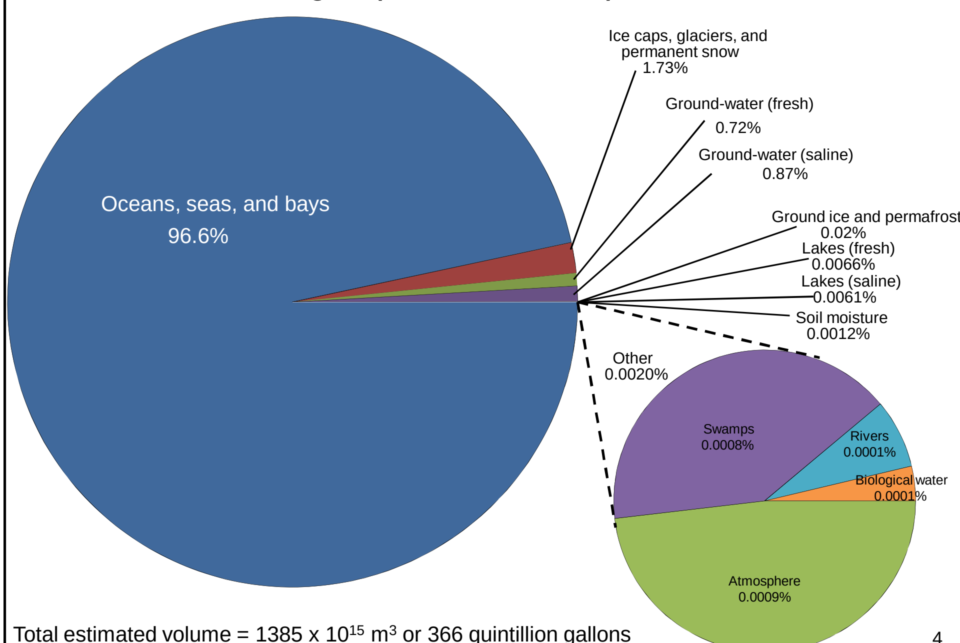
Table 1: Distribution of water on Earth (Gleick, 1996)

	Volume (10^{15} m^3)	Total water (%)	Fresh water (%)
Oceans, seas, & bays	1338	96.6	---
Ice caps, glaciers, & permanent snow	24	1.73	69.7
Ground-water (saline)	12	0.87	---
Ground-water (fresh)	10	0.72	29.0
Ground ice & permafrost	0.300	0.022	0.87
Lakes (fresh)	0.091	0.007	0.26
Lakes (saline)	0.085	0.006	---
Soil moisture	0.016	0.001	0.046
Atmosphere	0.013	0.001	0.038
Swamps	0.011	0.001	0.032
Rivers	0.002	0.000	0.006
Biological water	0.001	0.000	0.003
Total	1385	100	100

Oceans: 97% (1338×10^{15} m^3)
saline; can't use without high cost.
Surface: 0.008%
Rivers, lakes, swamps, etc.
Ground: 0.8%
Not all is suitable for consumption.
Frozen: 1.7%
Good storage, but the caps are melting…
Logistics of retrieval?

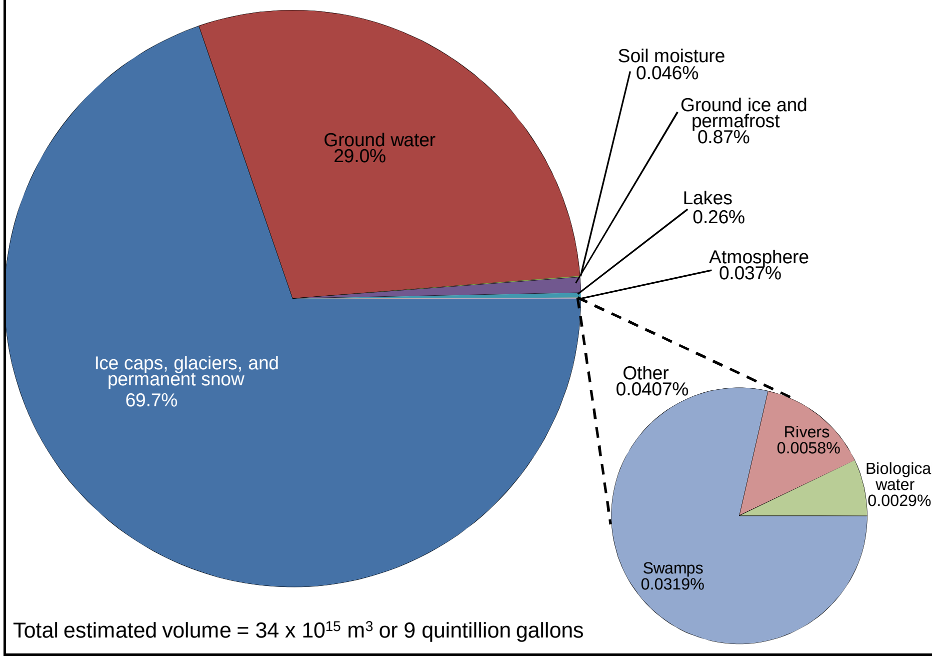
Large variability in fresh water availability due to:
1. latitude and topography
2. weather and climate
3. human influences

Global water budget (saline + fresh)



Total estimated volume = 1385×10^{15} m^3 or 366 quintillion gallons

Global fresh-water budget



Total estimated volume = 34 x 10^{15} m^3 or 9 quintillion gallons

Ground water: Fundamental concepts

Hydrology: The study of the occurrence, distribution, movement, and chemistry of all waters of the earth.

Hydrogeology: The study of the interrelationships of geologic materials and processes with water.

Ground water: Water that fills the empty spaces in soil, sand, or rocks beneath the Earth's surface.

Water table: The top of the water in the soil, sand, or rocks.

Aquifer: A geologic formation, group of formations, or part of a formation through which ground water can easily move.

Confined aquifer: An aquifer bounded above (and below) by a low-permeability geologic unit.

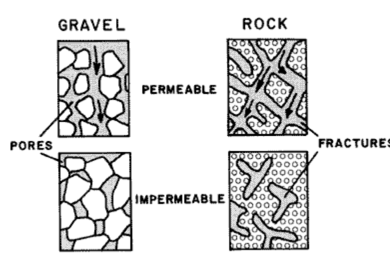
Unconfined aquifer: An aquifer where the water table is the upper boundary.

Porosity: The fraction of subsurface volume that is empty space.

Permeability: A measure of how well the empty spaces are connected.

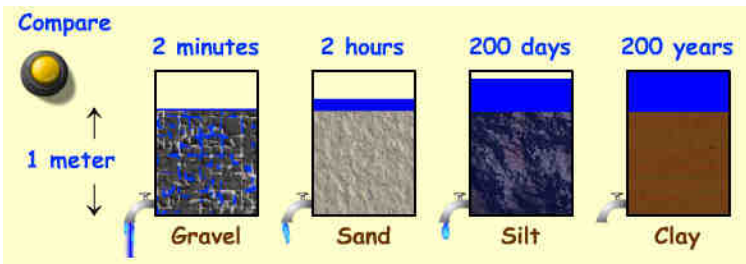
Hydraulic conductivity: Describes how easily water can move through the empty spaces.

Transmissivity: Measure of how much water can be transmitted horizontally .

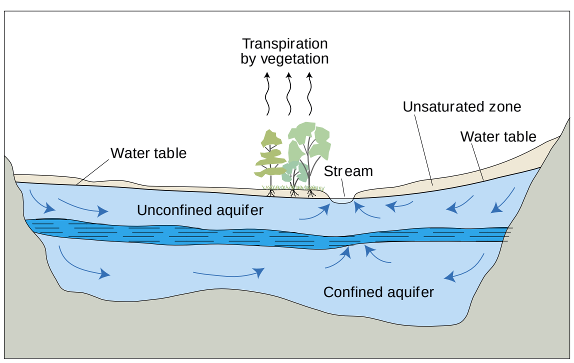


Fundamental concepts: Porosity vs. Permeability

Material	Porosity (%)	Permeability (darcys)	Hydraulic conductivity (ft/day)
Clay	50	0.0001	0.0003
Silt	40	0.01	0.03
Fine Sand	35	0.1	0.3
Sand	30	10	30
Gravel	25	100	300



Fundamental concepts: Illustrated terms



Is there something missing from this picture?

EXPLANATION

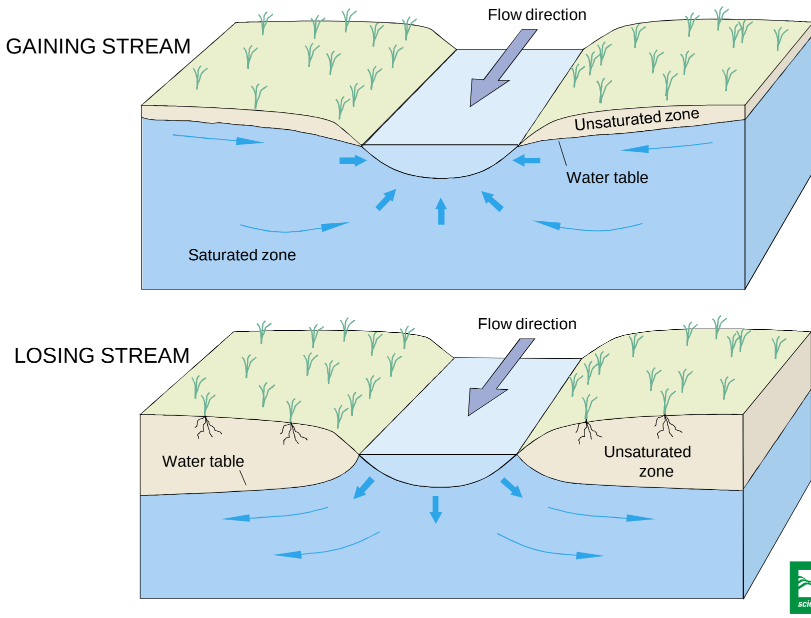
High hydraulic conductivity aquifer

Low hydraulic-conductivity confining unit

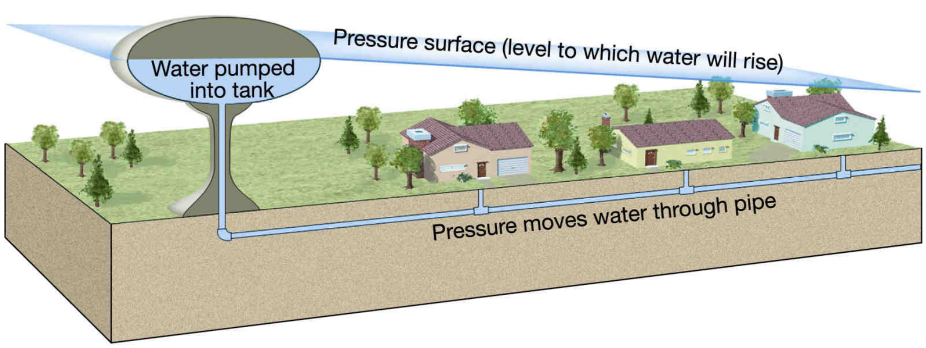
Very low hydraulic-conductivity bedrock

Direction of ground-water flow

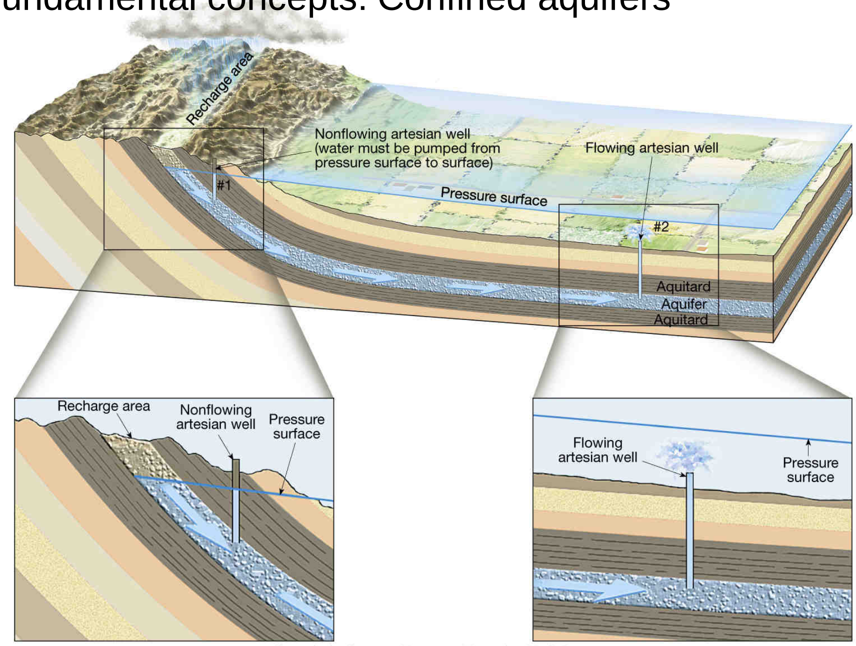
Fundamental concepts: Gaining streams vs. losing streams



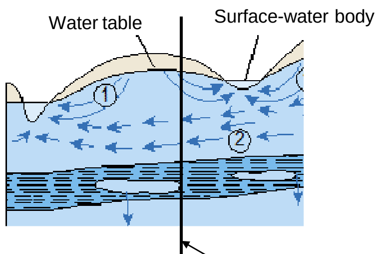
Fundamental concepts: Potentiometric (pressure) surface



Fundamental concepts: Confined aquifers

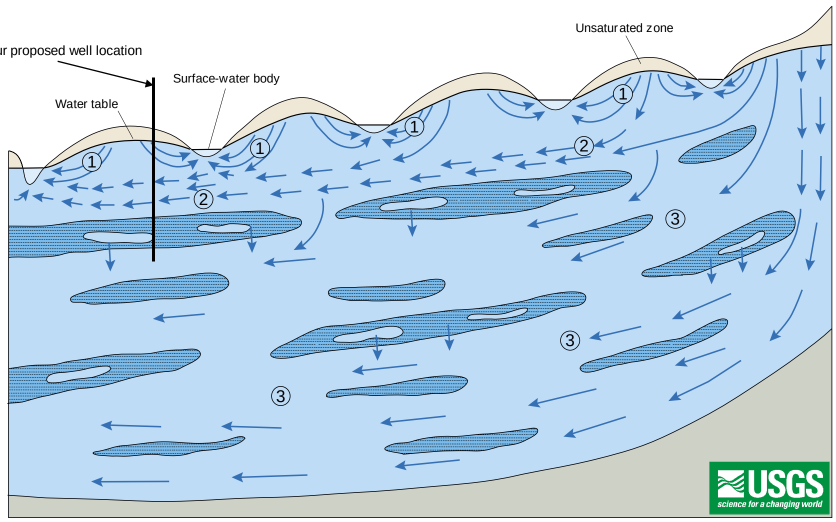


How confined is confined?



Good well location?
Looks like it may be.
There is a relatively thick confining unit...
No readily identifiable sources of contamination...
So, what's the catch?
Well, what exactly does "local" mean?
Zoom out to the next level...

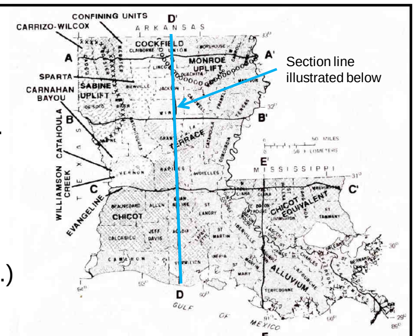
Still confined?



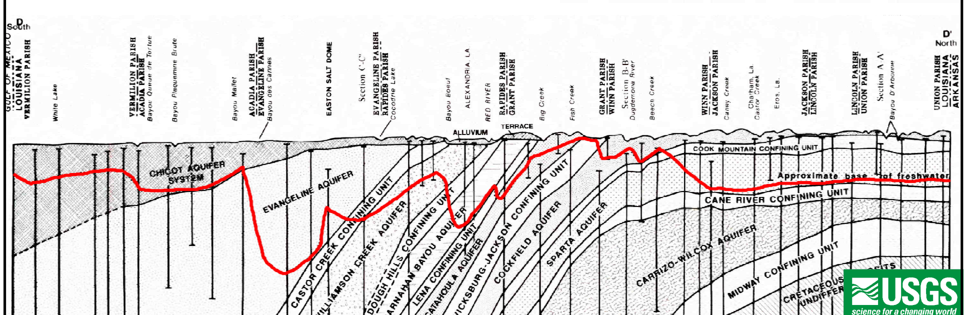
What happened to your “confined” aquifer? Most aquifer systems may contain many “locally” confined aquifers, but few (if any) are regionally confined.

The ground beneath your feet…

- May be quite old to us, but is young geologically.
- Is not necessarily flat or horizontal, even if the surface looks like it.
- Was generally deposited in a marine or coastal environment (shallow seas, deltas, beaches, etc.)
- The red line indicates the approximate base of freshwater along the section line.



INDEX MAP SHOWING GEOHYDROLOGIC SECTIONS, GENERALIZED GEOHYDROLOGIC UNITS, MONROE UPLIFT, AND SABINE UPLIFT, LOUISIANA



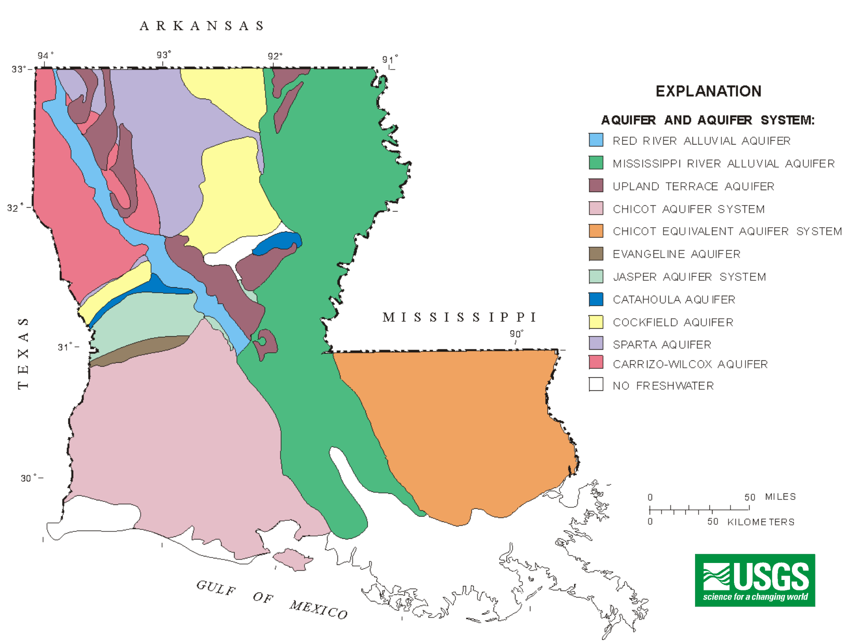
Millions of years ago

GEOHYDROLOGIC UNITS OF LOUISIANA

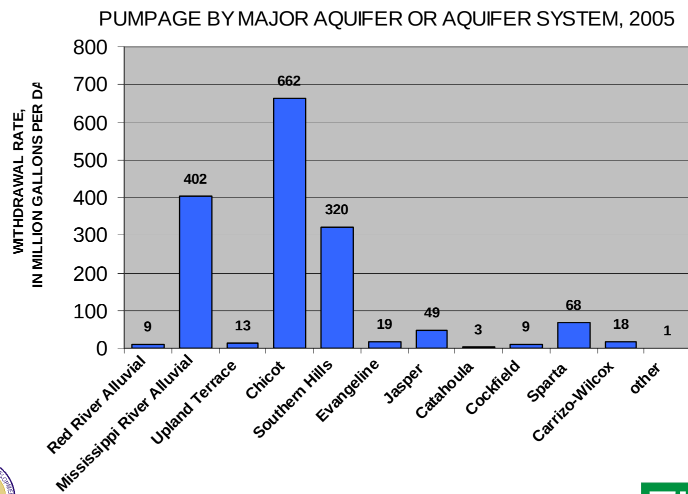
System	Series	Stratigraphic Unit		Hydrogeologic Unit: Northern Louisiana — aquifer or confining unit	Central Louisiana — aquifer system or confining unit		Southwestern Louisiana — aquifer or confining unit: Lake Charles area	Southwestern Louisiana — aquifer or confining unit: rice growing area	Southeastern Louisiana — aquifer system or confining unit [1]	Southeastern Louisiana — aquifer or confining unit [2]: Baton Rouge area	St. Tammany, Tangipahoa, and Washington Parishes	New Orleans area and lower Mississippi River Parishes [3]
Quaternary	Pleistocene (0.01)	Red River alluvial deposits Mississippi River alluvial deposits Northern Louisiana terrace deposits Unnamed Pleistocene deposits		Red River alluvial aquifer or surficial confining unit Mississippi River alluvial aquifer or surficial confining unit Upland terrace aquifer or surficial confining unit	Alluvial aquifer, undifferentiated or surfical confining unit Prairie aquifer Montgomery aquifer Williana-Bentley aquifer	Chicot aquifer system or surficial confining unit	"200-foot" sand "500-foot" sand "700-foot" sand	Upper sand unit Lower sand unit	Chicot equivalent aquifer system or surficial confining unit	Mississippi River alluvial aquifer or surficial confining unit Shallow sand "400-foot" sand "600-foot" sand	Upland terrace aquifer Upper Pontchatoula aquifer	Gramercy aquifer Norco aquifer Gonzales-New Orleans aquifer "1,200-foot" sand
Tertiary	Pliocene (2)	Fleming Formation	Blounts Creek Member	units absent	Evangeline aquifer or surficial confining unit				Evangeline equivalent aquifer system or surficial confining unit	"800-foot" sand "1,000-foot" sand "1,200-foot" sand "1,500-foot" sand "1,700-foot" sand	Lower Pontchatoula aquifer Big Branch aquifer Kentwood aquifer Abita aquifer Covington aquifer Slidell aquifer	
	? (5) Miocene		Castor Creek Member		Castor Creek confining unit				unnamed confining unit	"2,000-foot" sand "2,400-foot" sand "2,800-foot" sand	Tchefuncte aquifer Hammond aquifer Amite aquifer Ramsay aquifer Franklinton aquifer	
			Williamson Creek Member Dough Hills Member Carnahan Bayou Member		Jasper aquifer system or surficial confining unit	Williamson Creek aquifer Dough Hills confining unit Carnahan Bayou aquifer			Jasper equivalent aquifer or surficial confining unit			
			Lena Member		Lena confining unit				unnamed confining unit			
	Oligocene (23)	Catahoula Formation			Catahoula aquifer				Catahoula equivalent aquifer system or surficial confining unit			
	(34)	Vicksburg Group, undifferentiated		Vicksburg-Jackson confining unit	no freshwater occurs in deeper units							
	Eocene	Jackson Group, undifferentiated										
		Claiborne Group	Cockfield Formation	Cockfield aquifer or surficial confining unit								
			Cook Mountain Formation	Cook Mountain aquifer or confining unit								
			Sparta sand	Sparta aquifer or surficial confining unit								
			Cane River Formation	Cane River aquifer or confing unit								
			Carrizo sand ?	Carrizo-Wilcox aquifer or surficial confining unit Wilcox aquifer								
	Paleocene (59)	Wilcox Group, undifferentiated										
		Midway Group, undifferentiated		Midway confining unit								

[1] The interval containing the four aquifer systems is refered to as the Southern Hills aquifer system.
[2] Clay units separating aquifers in southeastern Louisiana are discontinuous, unnamed, and not listed herein.
[3] The interval containing the four aquifers is refered to as the New Orleans aquifer system.

Surface extents of Louisiana aquifers



Louisiana aquifers – withdrawal rates



Aquifer characteristics – Sparta aquifer

Sparta Aquifer

The Sparta aquifer is a very important source of ground water for the people of northern Louisiana, particularly north-central Louisiana (fig. 11). The Sparta aquifer also provides water for southern Arkansas. Large quantities of water from this aquifer are pumped for drinking-water and industrial purposes.

Facts

Sediments

- Very fine to medium sand
- Interbedded with thin layers of clay and lignite

Thickness

- 50 to 700 feet, increases toward south and southeast

Recharge

- From rainfall on outcrop area and water moving downward through terrace deposits in Bossier, Webster, and Bienville Parishes
- Leakage from overlying Cockfield and underlying Carrizo-Wilcox aquifers

Wells[1]

- Approximately ~~1,300~~ 5200
- Depth--200 to 900 feet

[1] Excludes domestic wells.

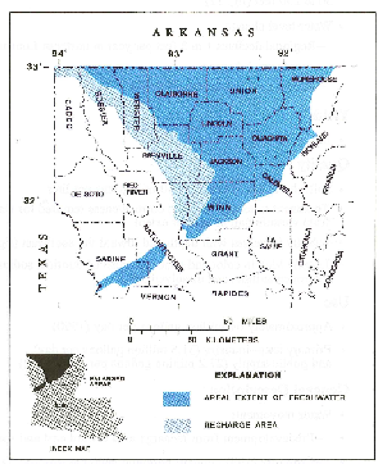
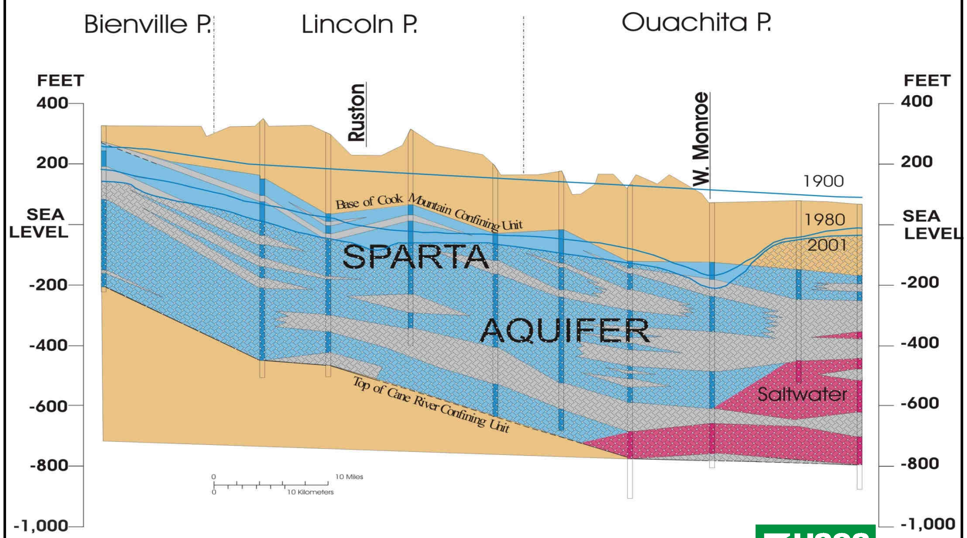


Figure 11. Recharge area and areas where Sparta aquifer contains freshwater.

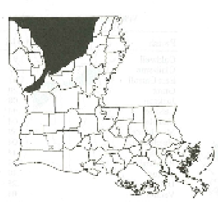
Aquifer characteristics – Sparta aquifer



Sparta aquifer in Ruston and W. Monroe area

Water use – Sparta aquifer

SPARTA AQUIFER

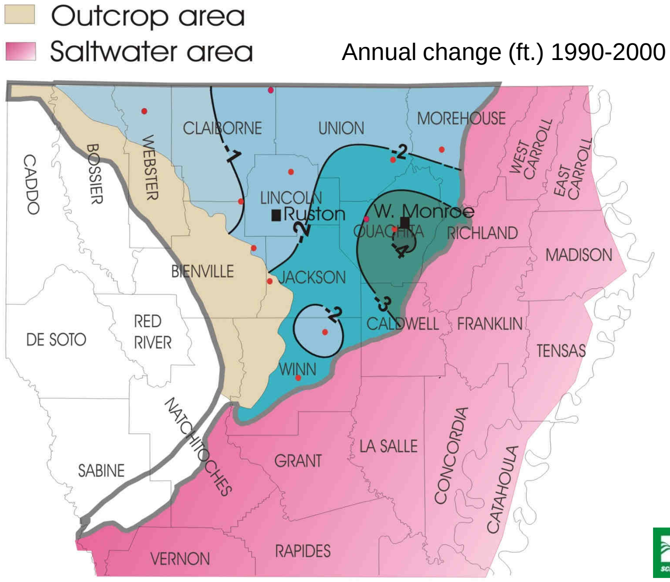


Withdrawals by Parish

Parish	Mgal/d
Bienville	12.09
Bossier	.19
Caddo	.04
Caldwell	.05
Claiborne	2.53
Jackson	1.95
LaSalle	.20
Lincoln	7.76
Morehouse	4.44
Natchitoches	.50
Ouachita	22.32
Sabine	.17
Union	5.29
Webster	7.44
Winn	5.08

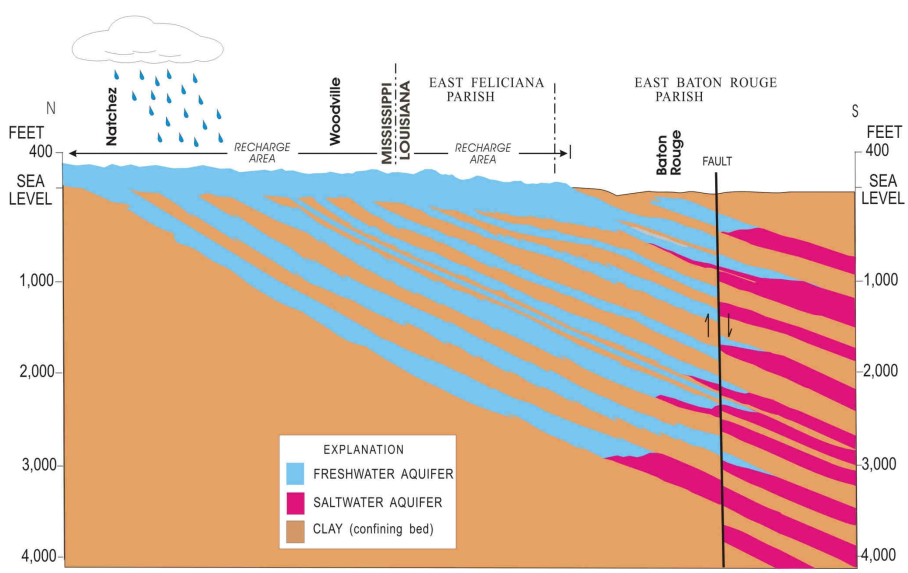
Withdrawals, in million gallons per day (Mgal/d)	
Public supply	35.70
Industry	30.01
Power generation	.00
Rural domestic	1.44
Livestock	.15
Rice irrigation	.18
General irrigation	.30
Aquaculture	.19
TOTAL	67.98

Water level trends – Sparta aquifer



Based on data from the USGS/DOTD water-level network.

Aquifer characteristics – Southern Hills aquifer system

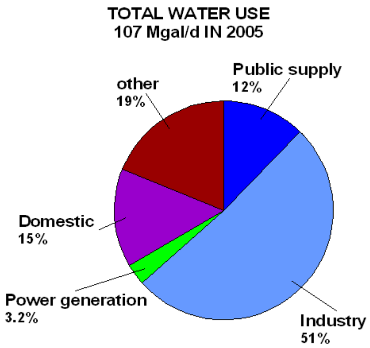


Water use – Southern Hills aquifer system

CHICOT EQUIVALENT

AQUIFER SYSTEM

(SOUTHEASTERN LOUISIANA)



Withdrawals by Parish

Parish	Mgal/d
Ascension	10.65
Assumption	4.19
East Baton Rouge	25.28
East Feliciana	.21
Iberville	1.60
Jefferson	2.74
Livingston	3.31
Orleans	5.04
Plaquemines	.04
Pointe Coupee	1.87
St. Bernard	.03
St. Charles	4.89
St. Helena	.83
St. James	19.30
St. John the Baptist	9.63
St. Tammany	5.99
Tangipahoa	4.22
Washington	7.18
West Baton Rouge	.01
West Feliciana	.02

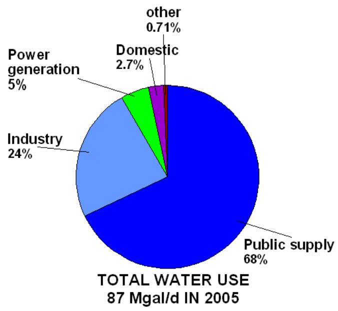
Withdrawals, in million gallons per day (Mgal/d)	
Public supply	13.18
Industry	54.68
Power generation	3.41
Rural domestic	15.61
Livestock	.47
Rice irrigation	.00
General irrigation	1.37
Aquaculture	18.32
TOTAL	107.03

Water use – Southern Hills aquifer system

EVANGELINE EQUIVALENT

AQUIFER SYSTEM

(SOUTHEASTERN LOUISIANA)



Withdrawals by Parish

Parish	Mgal/d
East Baton Rouge	52.27
East Feliciana	0.37
Livingston	4.79
Pointe Coupee	3.17
St. John the Baptist	3.68
St. Tammany	12.32
Tangipahoa	2.64
Washington	0.25
West Baton Rouge	6.85
West Feliciana	0.76

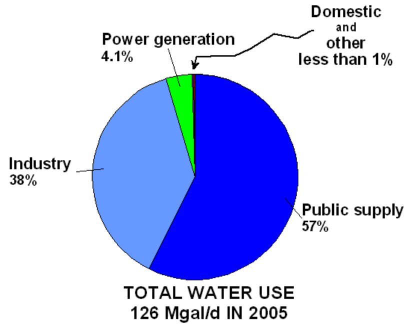
Withdrawals, in million gallons per day (Mgal/d)	
Public supply	59.21
Industry	20.56
Power generation	4.34
Rural domestic	2.36
Livestock	.33
Rice irrigation	.07
General irrigation	.15
Aquaculture	.07
TOTAL	87.09

Water use – Southern Hills aquifer system

JASPER EQUIVALENT

AQUIFER SYSTEM

(SOUTHEASTERN LOUISIANA)



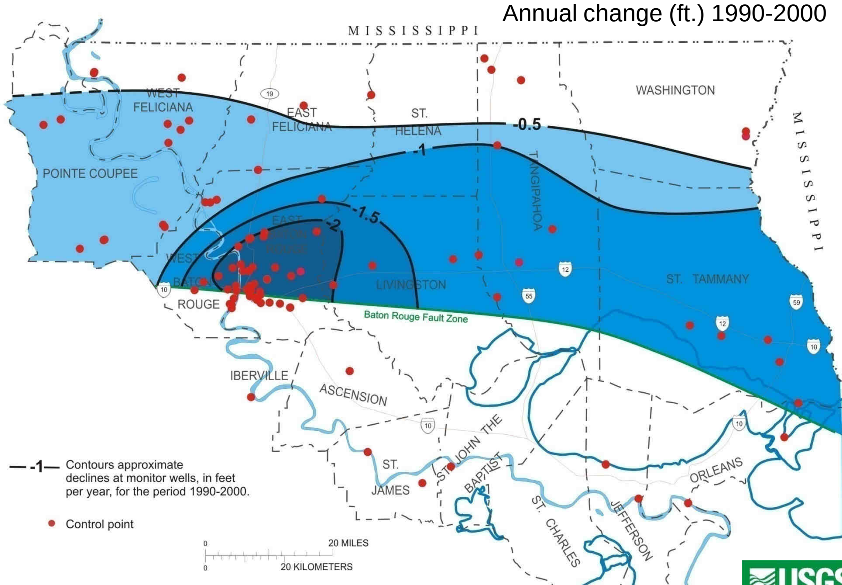
Withdrawals by Parish

Parish	Mgal/d
East Baton Rouge	68.24
East Feliciana	2.68
Iberville	1.25
Livingston	5.76
Pointe Coupee	4.57
St. Helena	.47
St. Tammany	4.39
Tangipahoa	12.21
Washington	21.53
West Baton Rouge	.01
West Feliciana	5.17

Withdrawals, in million gallons per day (Mgal/d)	
Public supply	72.57
Industry	47.93
Power generation	5.20
Rural domestic	.31
Livestock	.12
Rice irrigation	.00
General irrigation	.03
Aquaculture	.14
TOTAL	126.29

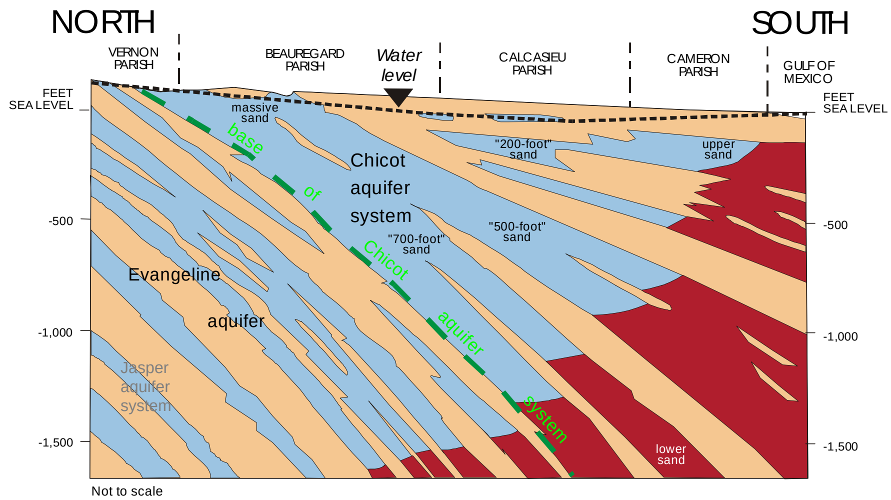
Water-level trends – Southern Hills system

Annual change (ft.) 1990-2000



Based on data from USGS/DOTD water-level network.

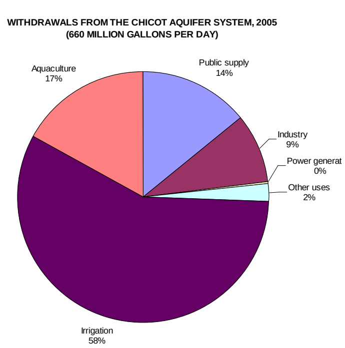
Aquifer characteristics – Chicot aquifer



Water use – Chicot aquifer

CHICOT

AQUIFER SYSTEM

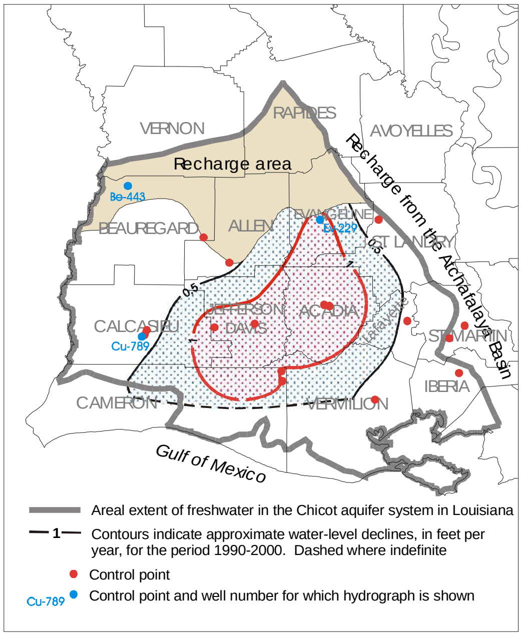


Withdrawals by Parish

Parish	Mgal/d
Acadia	168.47
Allen	23.23
Beauregard	12.35
Calcasieu	89.04
Cameron	6.02
Evangeline	68.62
Iberia	17.11
Jefferson Davis	151.78
Lafayette	43.13
Rapides	.76
St. Landry	31.63
St. Martin	5.91
St. Mary	2.79
Vermillion	40.38
Vernon	.42

Withdrawals, in million gallons per day (Mgal/d)	
Public supply	93.49
Industry	58.43
Power generation	3.09
Rural domestic	12.63
Livestock	1.18
Rice irrigation	377.22
General irrigation	2.79
Aquaculture	112.81
TOTAL	661.64

Water-level trends – Chicot aquifer



Annual change (ft.) 1990-2000

Not nearly as grim as previous examples, however:

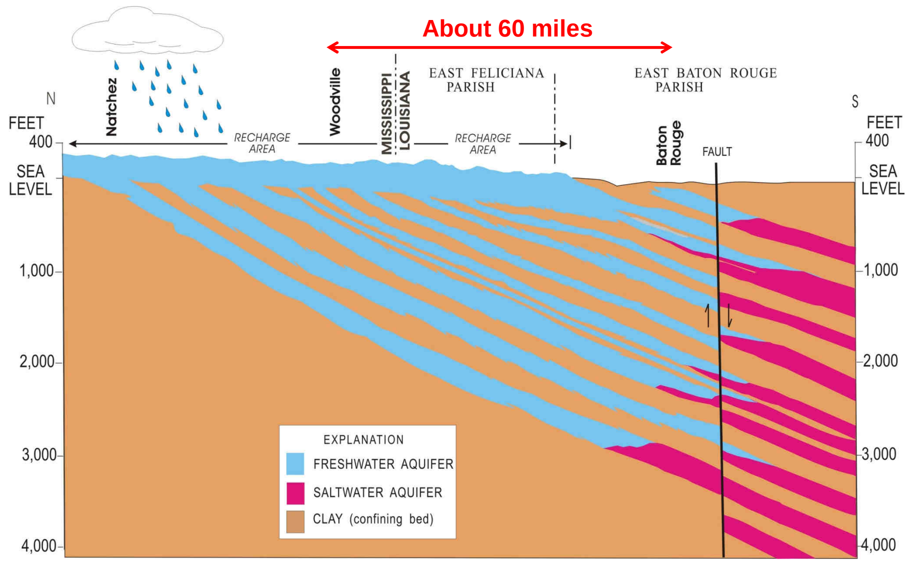
1. This area is heavily affected by chemical industry. Potential for pollution is very high.

2. Chicot is a Sole Source Aquifer, i.e. it's the only source of drinking water in the area.

Aquifer usage concerns and considerations

- Contamination from above
  - Infiltration of runoff or surface water. GWUDI?
  - Downward migration through leaky confining beds
  - Direct flow via improper well installations
- Contamination from below
  - Saltwater encroachment
  - Upward migration through leaky confining beds from pressurized formations.
- Contamination from "the side"
  - Gravitational flow along confining beds.
  - Changes in ground-water flow direction due to…
- Excessive pumping
  - Discharge > Recharge…Is ground water a renewable resource?

Is ground water a renewable resource?



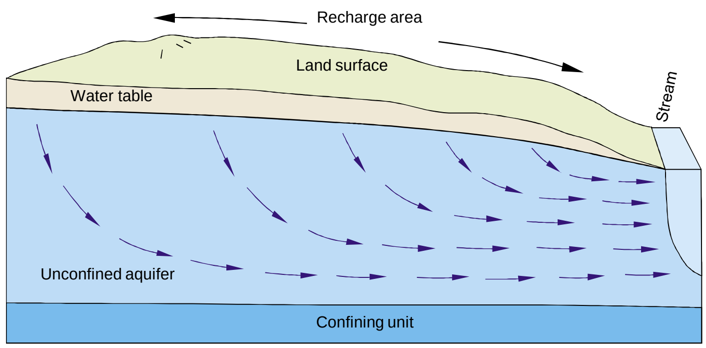
USGS science for a changing world

How long does it take for the water to get to me?

K (gal/day/ft^2)	10^6	10^5	10,000	1,000	100	10	1	0.1	0.01	0.001	0.0001	10^{-5}	10^{-6}
K (ft/day)*	10^5	10,000	1,000	100	10	1	0.1	0.01	0.001	0.0001	10^{-5}	10^{-6}	10^{-7}
v_x (ft/day)**	4545	455	45	5	0.5	0.05	0.005	0.0005	$5x10^{-5}$	$5x10^{-6}$	$5x10^{-7}$	$5x10^{-8}$	$5x10^{-9}$
v_x (mi/yr)**	314	31	3	0.3	0.03	0.003	0.0003	$3x10^{-5}$	$3x10^{-6}$	$3x10^{-7}$	$3x10^{-8}$	$3x10^{-9}$	$3x10^{-10}$
Transmissivity	Proportional to saturated thickness of aquifer: T = K · b												
Relative permeability	Pervious				Semi-pervious				Impervious				
Aquifer	Good					Poor				None			
Unconsolidated sand & gravel	Well-sorted gravel (25-50%)		Well-sorted sand or sand & gravel (20-35%)			Very fine sand, silt, loess, loam (35-50%)							
Unconsolidated clays & organics					Peat		Layered clay (33-60%)			Fat / unweathered clay (33-60%)			
Consolidated rocks	Highly fractured rocks (30-60%)				Oil reservoir rocks			Sandstone (3-30%)		Limestone, dolomite (1-30%)		Granite (1-2%)	

*This is more educationally expressed as ft^3/ft^2/day.
**Assumptions: dh/dl = 0.01, n_e = 0.22.

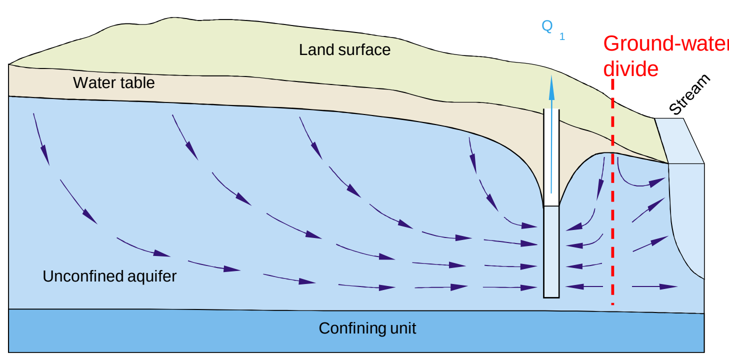
Excessive pumping affects ground-water flow



A "hydraulically healthy" ground-water system

- Ground-water flows towards stream ("gaining stream").
- No contaminant recharge into the aquifer from surface water.

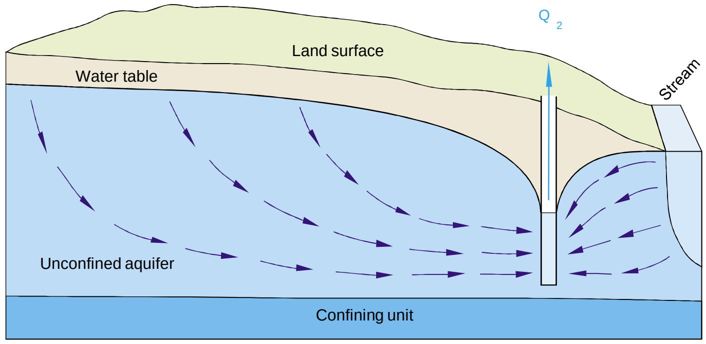
Excessive pumping affects ground-water flow



Well installed, no excessive pumping

- Ground-water still flows towards stream ("gaining stream"), although greatly reduced; ground-water divide.
- No contaminant recharge into the aquifer from surface water.

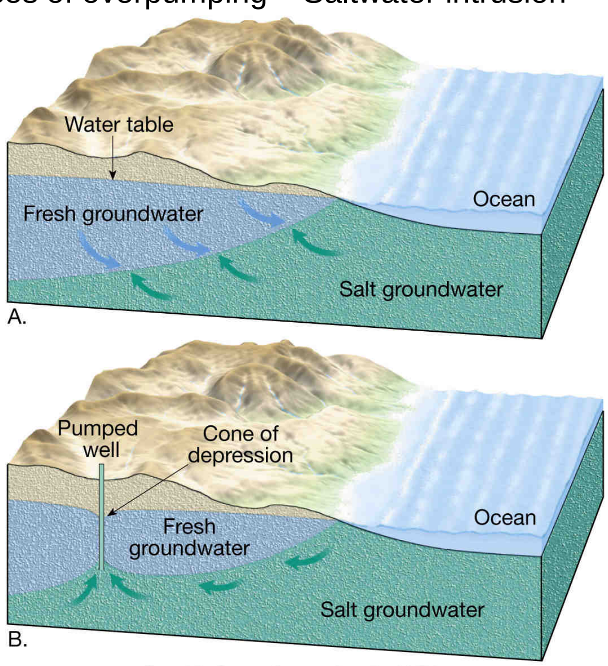
Excessive pumping affects ground-water flow



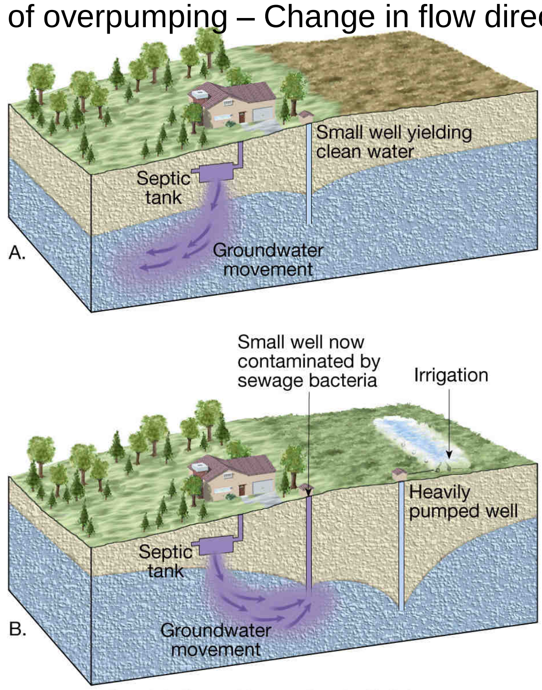
Trouble! Excessive pumping!

- Ground-water flows away from stream ("losing stream").
- Contaminant recharge into the aquifer from surface water very likely.
- GUI!

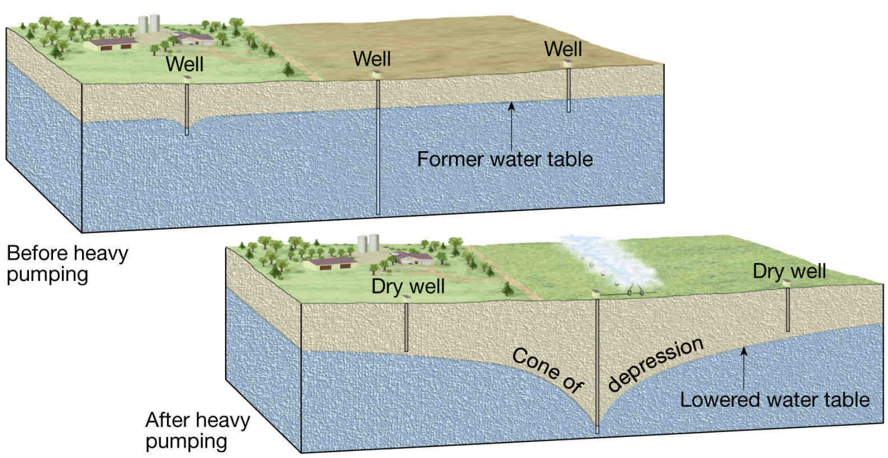
Consequences of overpumping – Saltwater intrusion



Consequences of overpumping – Change in flow direction



Consequences of overpumping – other wells go dry



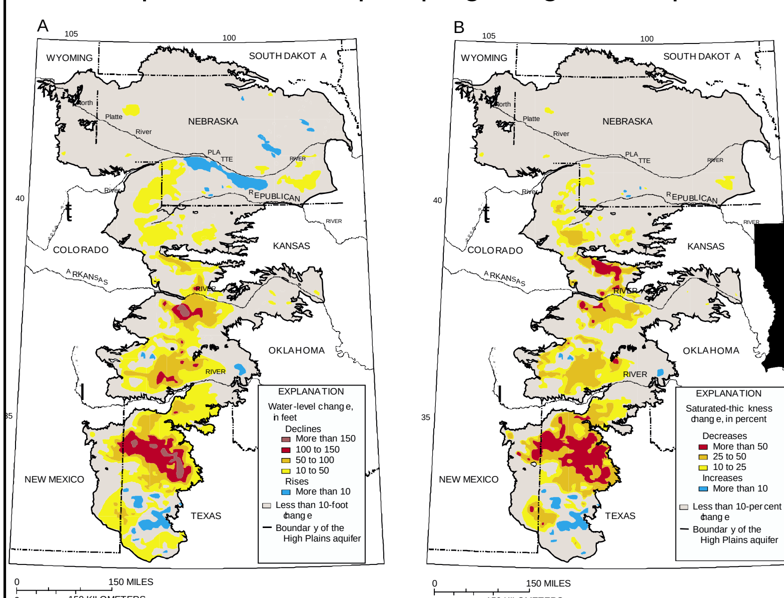
Consequences of overpumping – where's my lake?

Dock on Crooked Lake in central Florida in the 1970s.

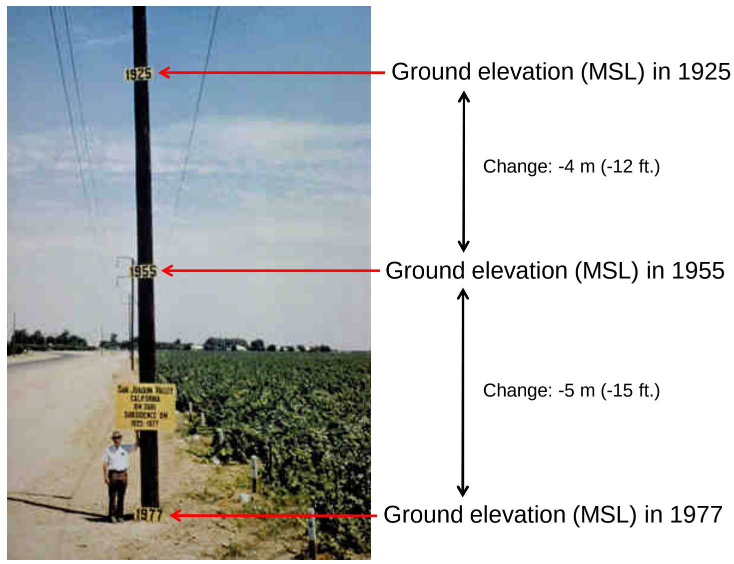
The same dock in 1990.

As a result of very low topographic relief, high rainfall, and a karst terrain, the Florida landscape is characterized by numerous lakes and wetland areas. The underlying Floridian aquifer is one of the most extensive and productive aquifers in the world. Over the past two decades, lake levels declined and wetlands dried out in highly developed west-central Florida as a result of both extensive pumping and low precipitation during these years. Differentiating between the effects of the drought and pumping has been difficult. Photographs courtesy of Florida Water Resources Journal, August 1990 issue.

Consequences of overpumping – Ogallala aquifer example



Consequences of overpumping – Land subsidence



Consequences of excessive pumping

- Wetlands, swamps, and marshes dry up. Permanently destroyed? No fish! No ducks! No deer? Oh My!
- Waterlevels down – recreational uses reduced. “I used to have water-front property...” → property values in the tank.
- Aquifer compaction → permanent reduction of storage
- Land subsidence – matters to people near open water, e.g. coastal Louisiana.
- Salt water intrusion – destroys drinking water sources; desalinization may be expensive.
- Accelerated contamination
- Higher water costs → alternate source (surface?), more treatment
- Local/regional economy – no water, no people, no business, no $$$
- Quality of life – what will you drink, bathe, and play in?

QUIZ!

1. What combination of porosity and permeability makes the best aquifer? _____
   ____
2. In Louisiana, what is the most common material in a confining bed? ________
3. Does an artesian well always flow to the ground surface? Please explain. ___
   ____
4. What happens to the water table when discharge exceeds recharge? ______
   ____
5. Please explain what is meant by “potentiometric surface”. _______________
   ____
6. Name three problems associated with excessive pumping. _______________
   ____
7. Approximately what percentage of all water on Earth is fresh? ___________
8. In what form is most of the fresh water on Earth stored? _______________
9. Name the three most productive aquifers in Louisiana. _________________
   ____

When water chokes you, what are you to drink to wash it down?

--Aristotle (384 BC – 322 BC), *Nicomachean Ethics*