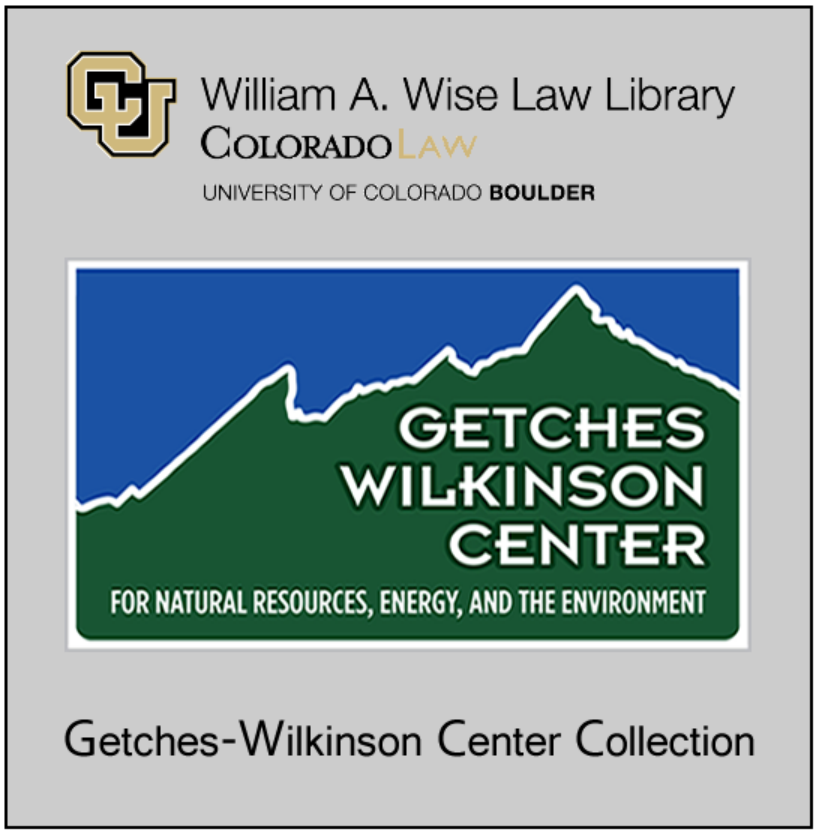
6-16-2004

SLIDES: Ground-Water Resources in the Western United States: Status and Trends

Alan Burns

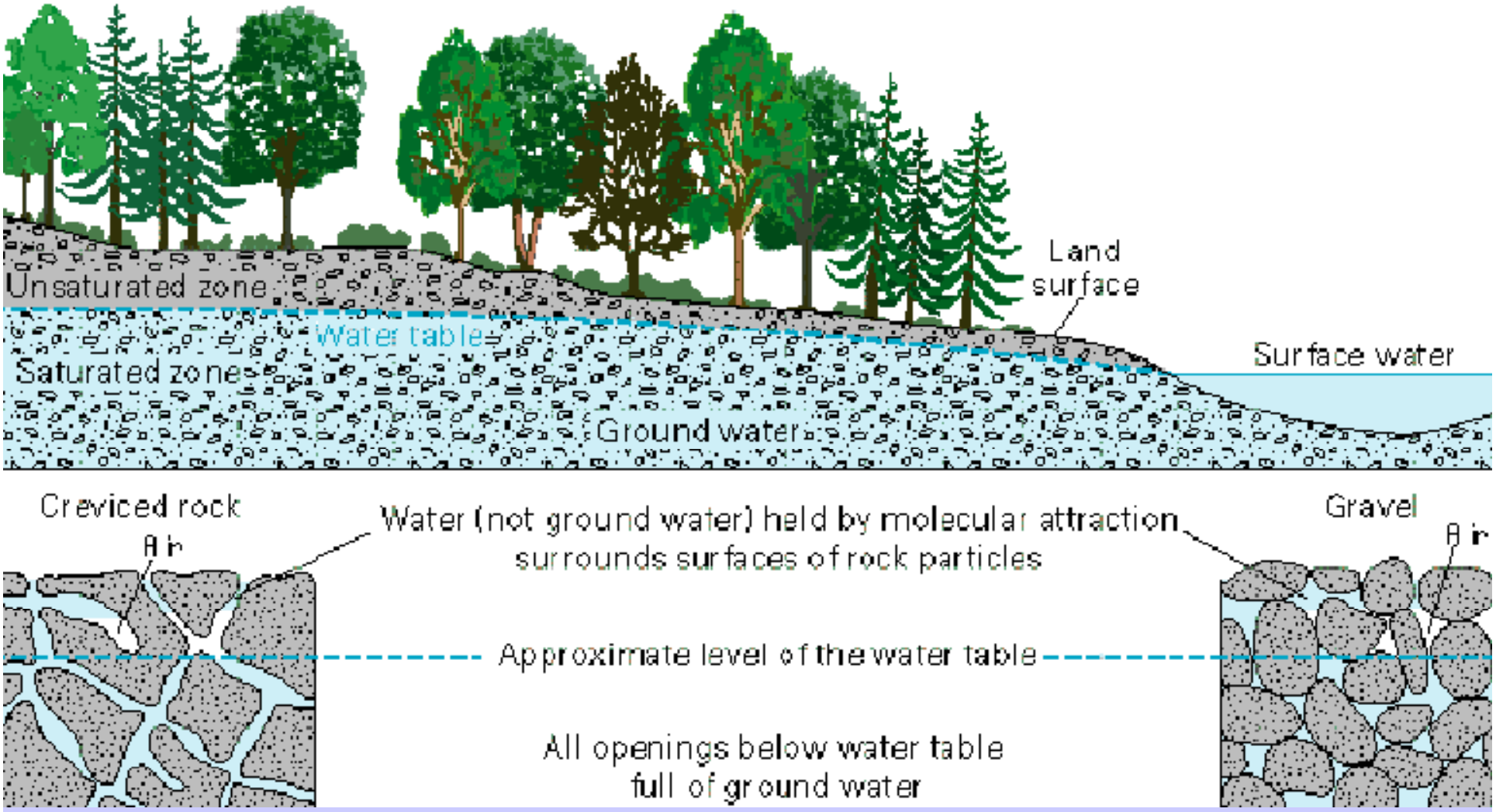


Alan Burns, *Ground-Water Resources in the Western United States: Status and Trends*, *in* GROUNDWATER IN THE WEST (Natural Res. Law Ctr., Univ. of Colo. Sch. of Law, 2004).

Ground-Water Resources in the western United States

Status and trends

USGS


Land
surface
Unsaturated zone
Water table
Saturated zone
Surface water
Ground water
Creviced rock
Air
Water (not ground water) held by molecular attraction
surrounds surfaces of rock particles
Gravel
Air
Approximate level of the water table
All openings below water table
full of ground water

USGS

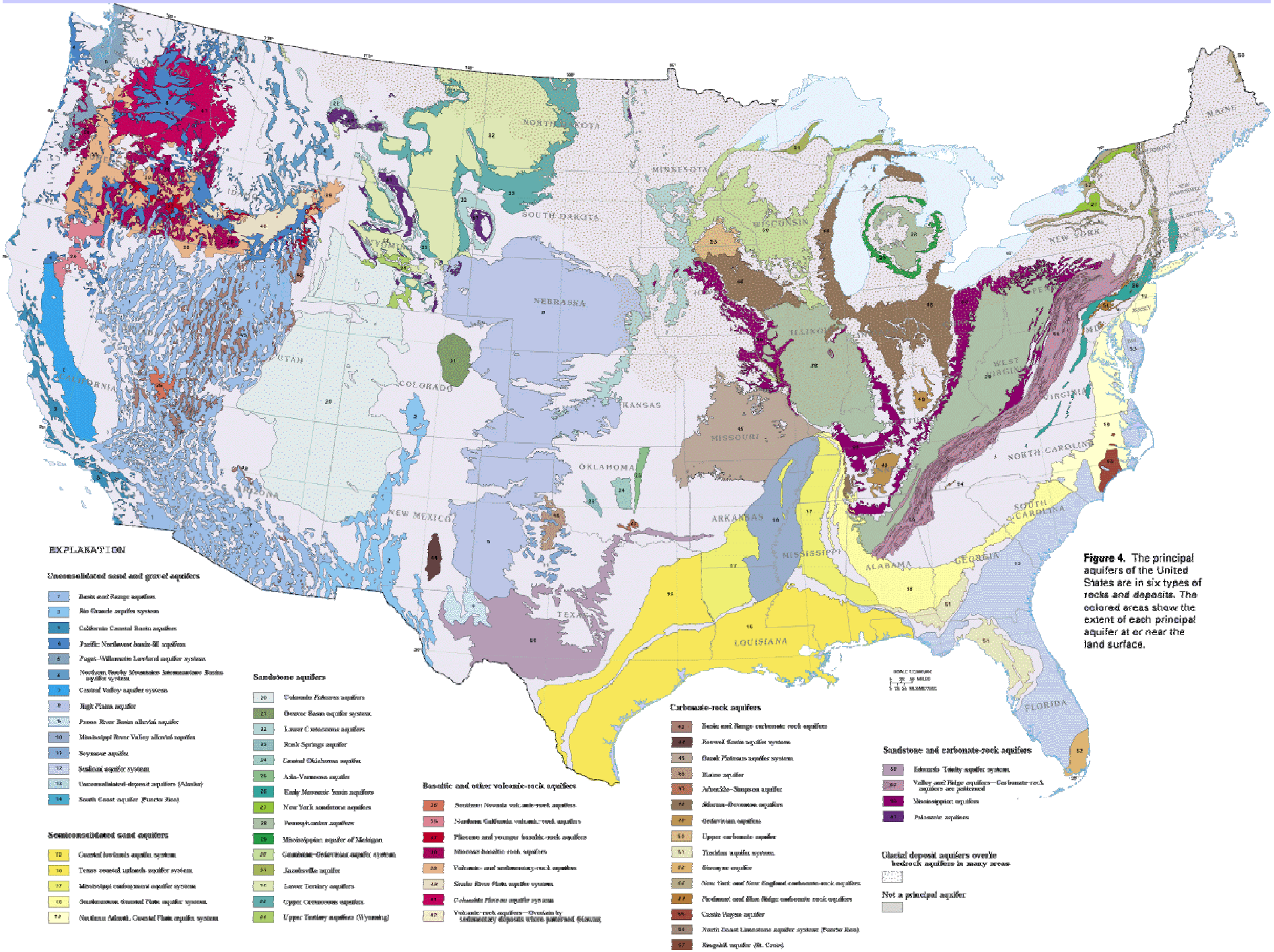
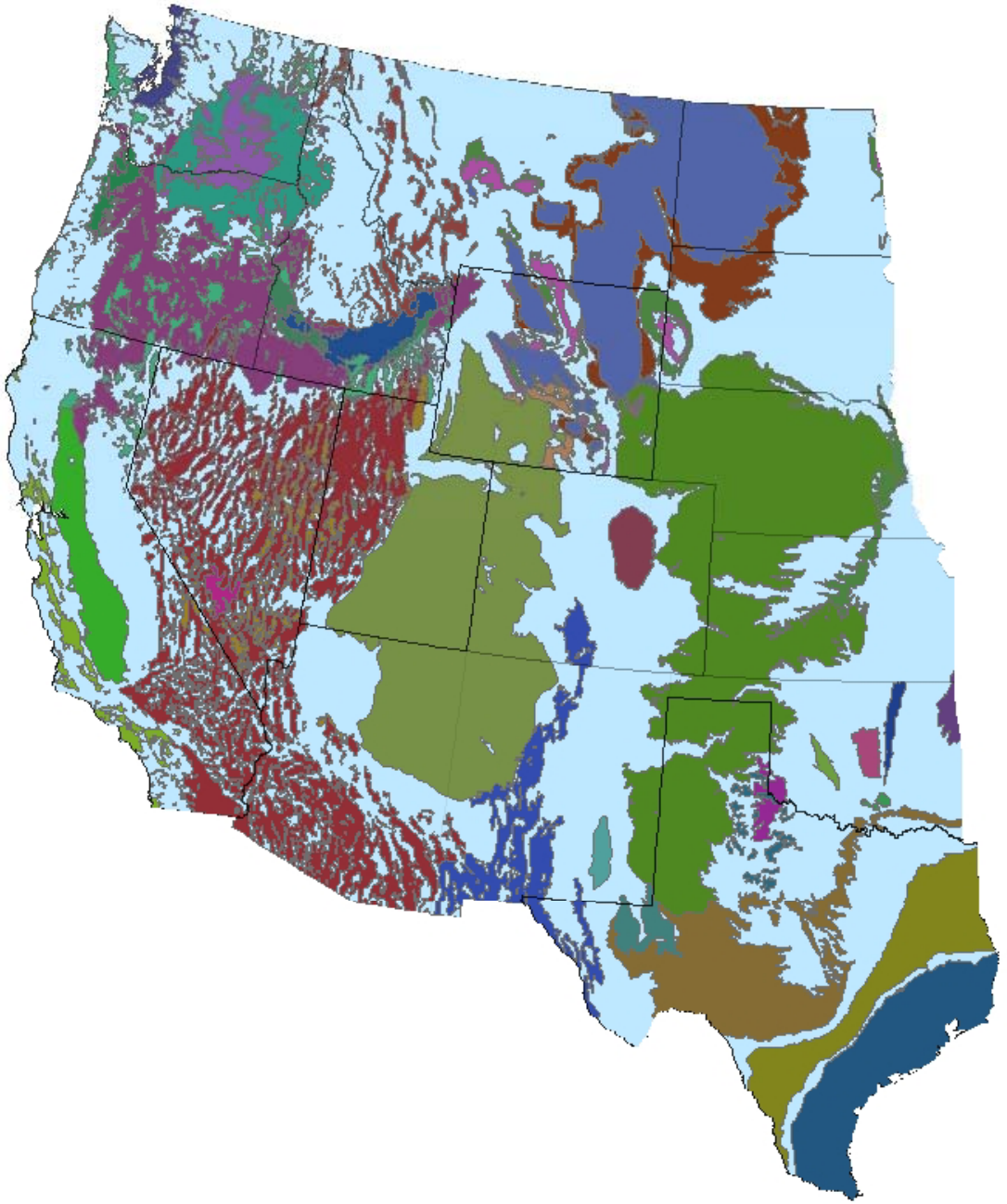
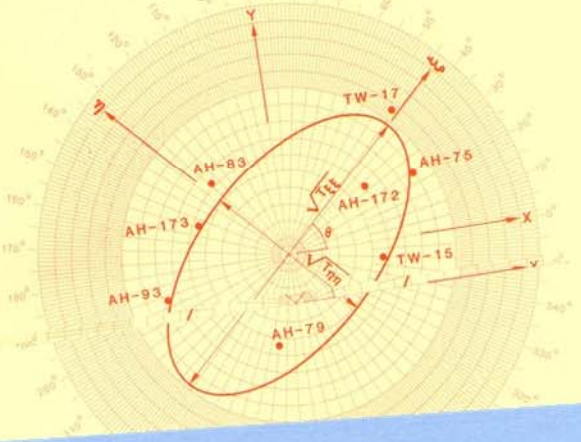


Figure 4. The principal aquifers of the United States are in six types of rocks and deposits. The colored areas show the extent of each principal aquifer at or near the land surface.



USGS

METHODS AND COMPUTER PROGRAM DOCUMENTATION FOR DETERMINING ANISOTROPIC TRANSMISSIVITY TENSOR COMPONENTS OF TWO-DIMENSIONAL GROUND-WATER FLOW



DERIVATION OF EQUATIONS DESCRIBING SOLUTE TRANSPORT IN GROUND WATER

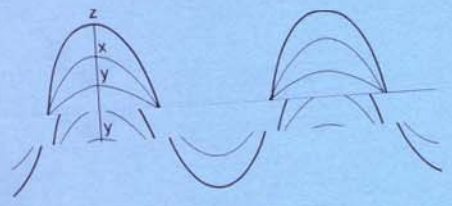
$$+\frac{\xi}{V_0}\sum_{i=1}^{n}\frac{\partial m_i}{\partial t}+W^*_p C^*_p$$

$$q_i=\frac{-k_{ij}}{\mu}\left(\frac{\partial P}{\partial x_j}+\rho g\frac{\partial z^*}{\partial x_j}\right)$$

$$\frac{\partial}{\partial x_j}\left(T_{ij}\frac{\partial h}{\partial x_j}\right)=S\frac{\partial h}{\partial t}+W$$

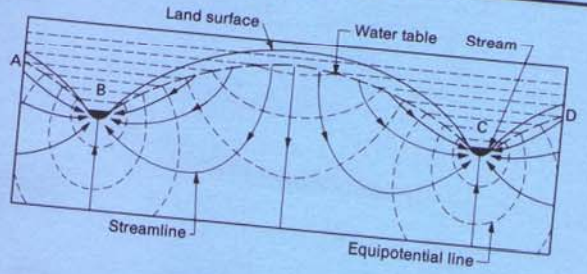
$$\frac{\partial C}{\partial t}=\frac{\partial}{\partial x_i}\left(D_{ij}\frac{\partial C}{\partial x_j}\right)-\frac{\partial}{\partial x_i}\left(v_i C\right)+C'W$$

THE PRINCIPLE OF SUPERPOSITION AND ITS APPLICATION IN GROUND-WATER HYDRAULICS

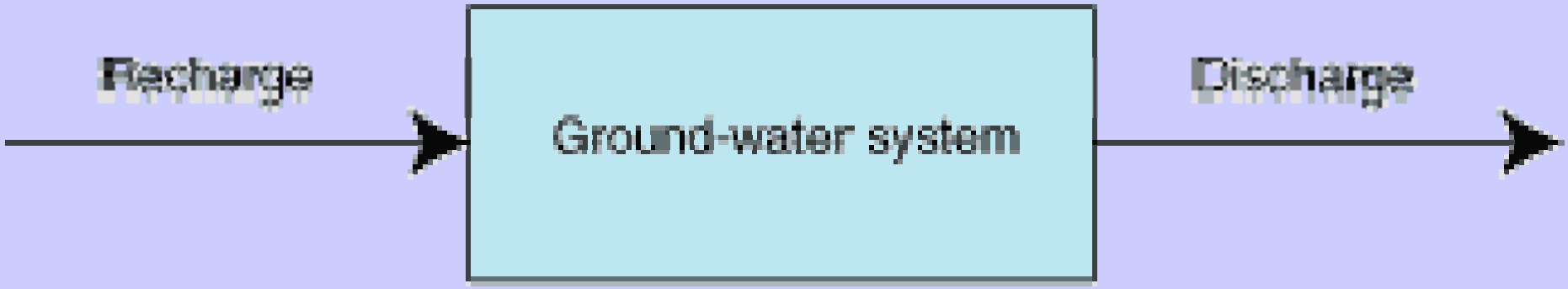


Waves in phase (z = x + y)

DEFINITION OF BOUNDARY AND INITIAL CONDITIONS IN THE ANALYSIS OF SATURATED GROUND-WATER FLOW SYSTEMS — AN INTRODUCTION

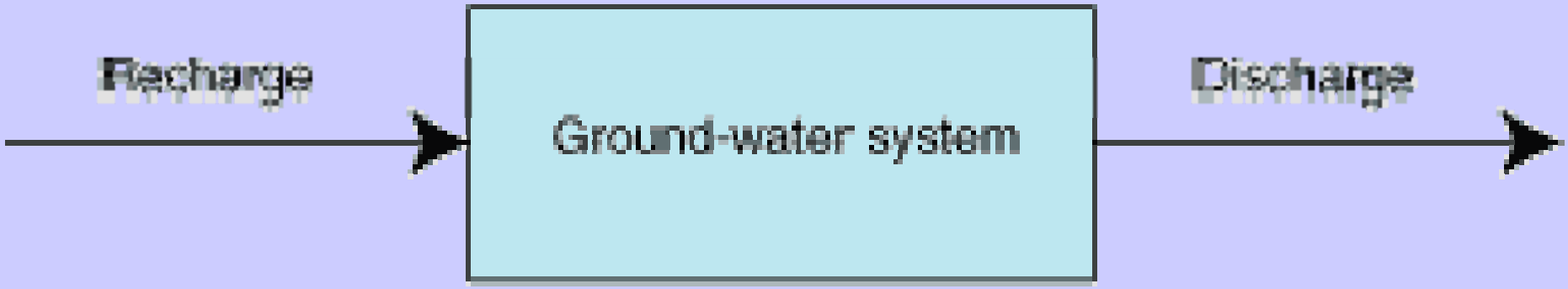


$$I - O = \Delta S$$



USGS

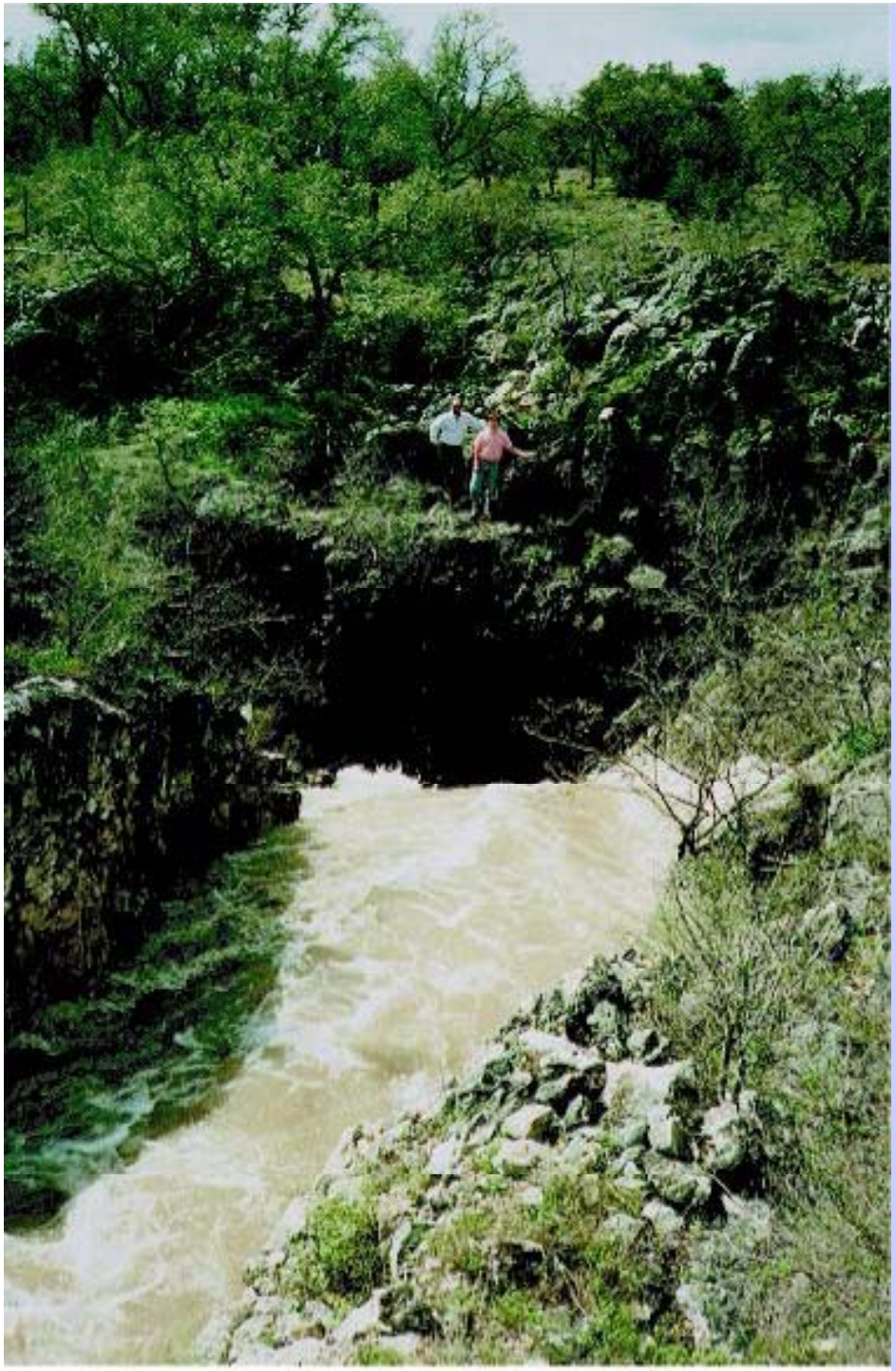
$$I - O = \Delta S$$

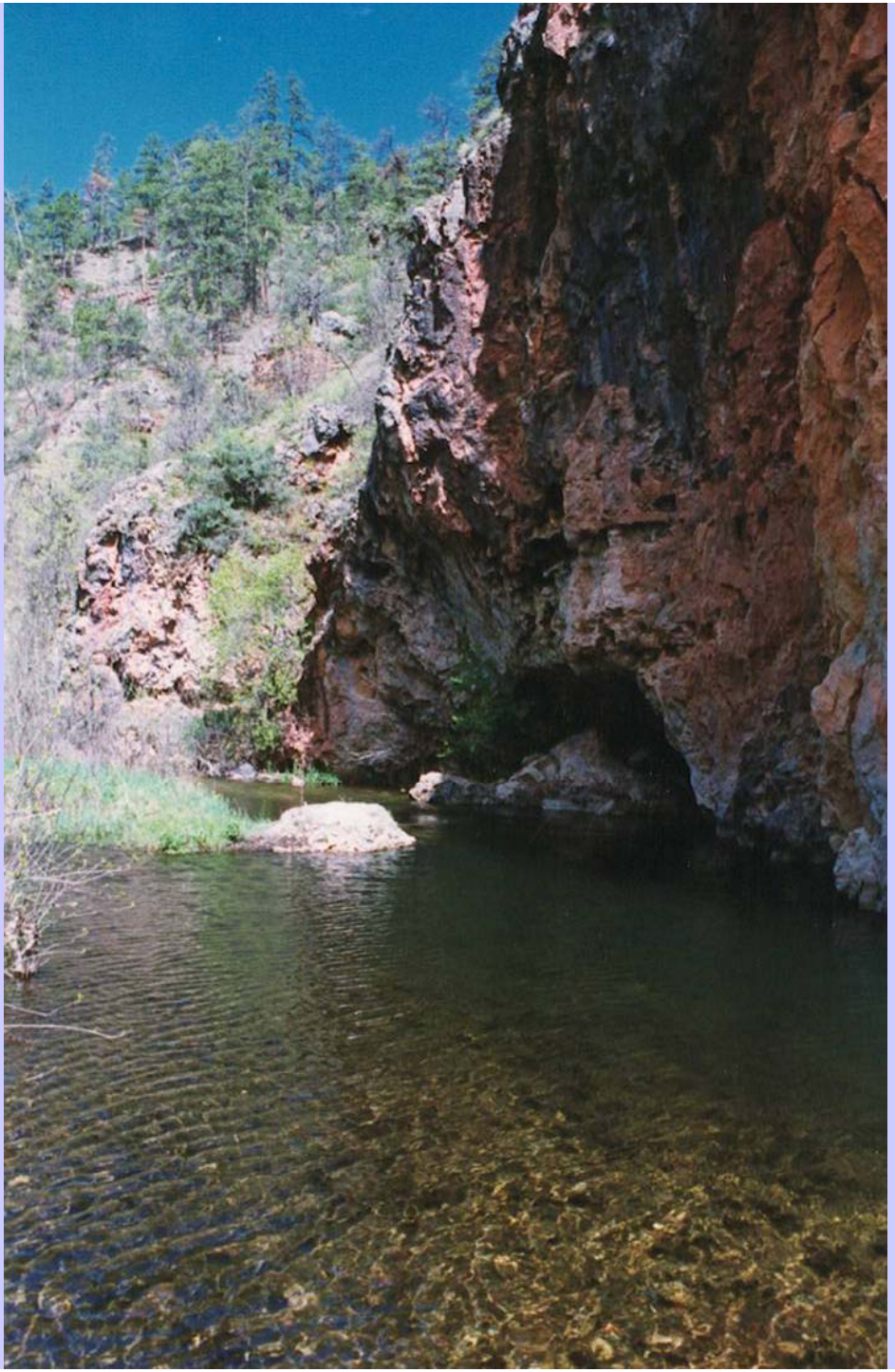


$$I = O$$

USGS

USGS





USGS

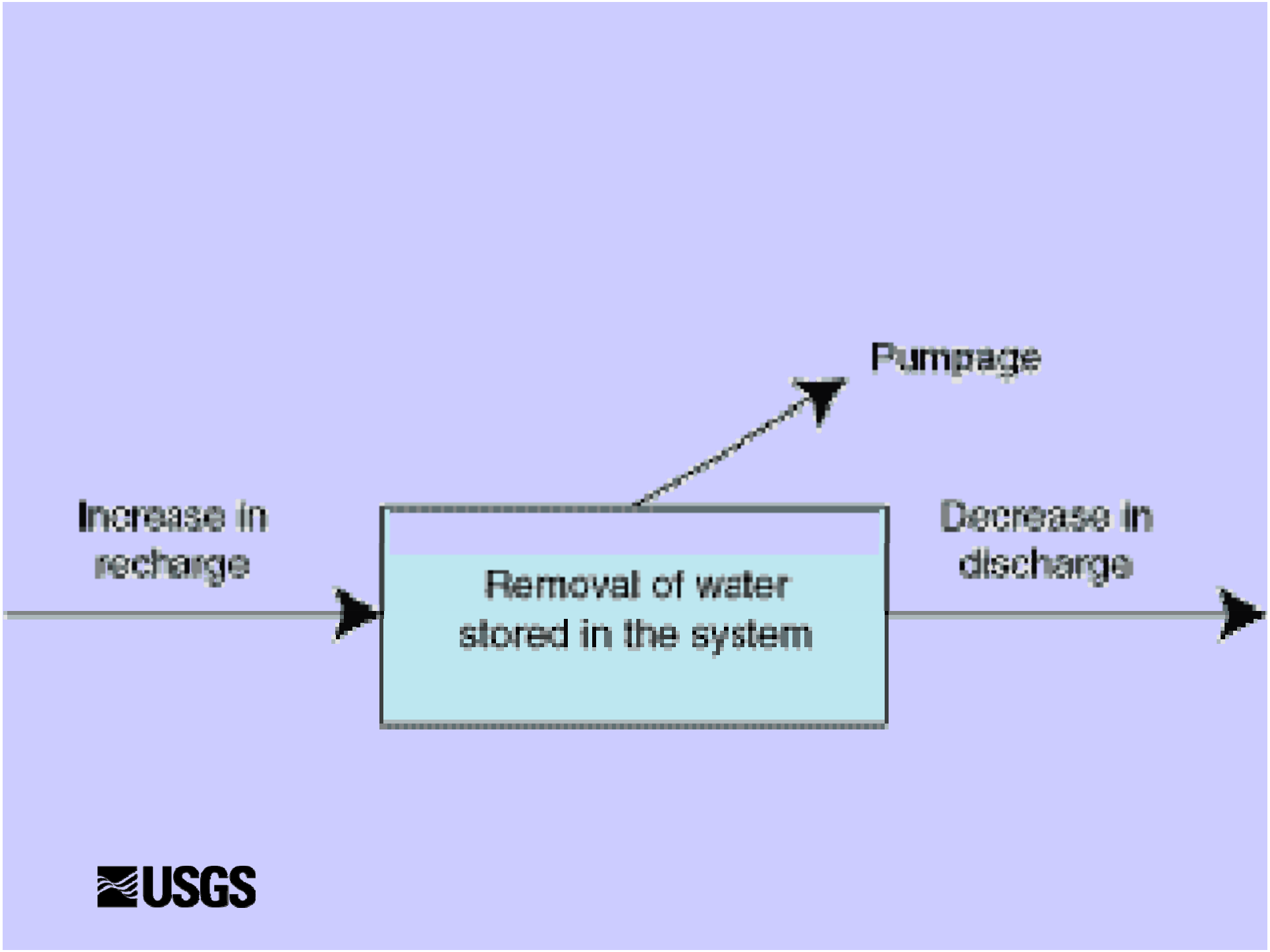
USGS

USGS

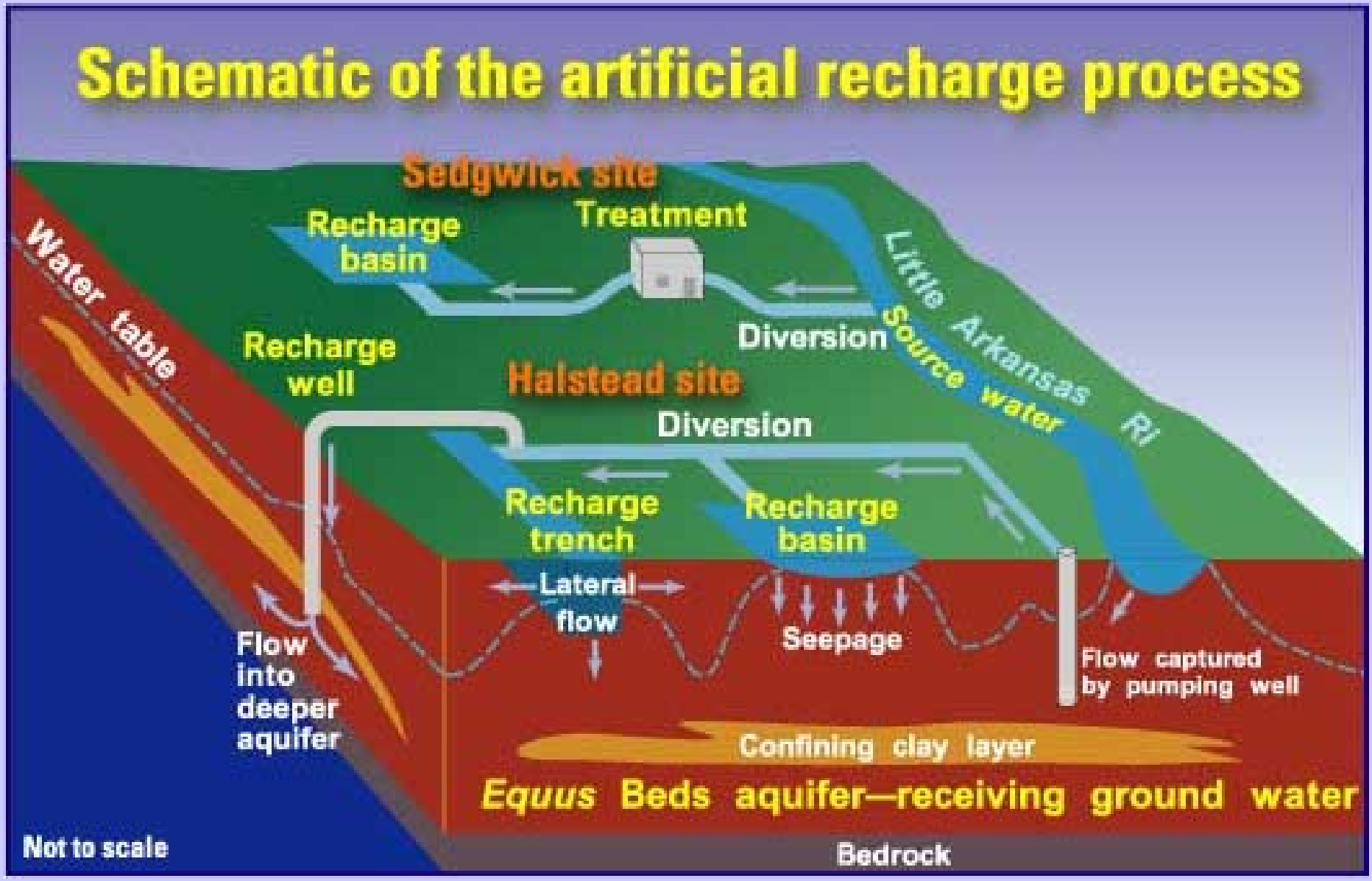
USGS

USGS

USGS

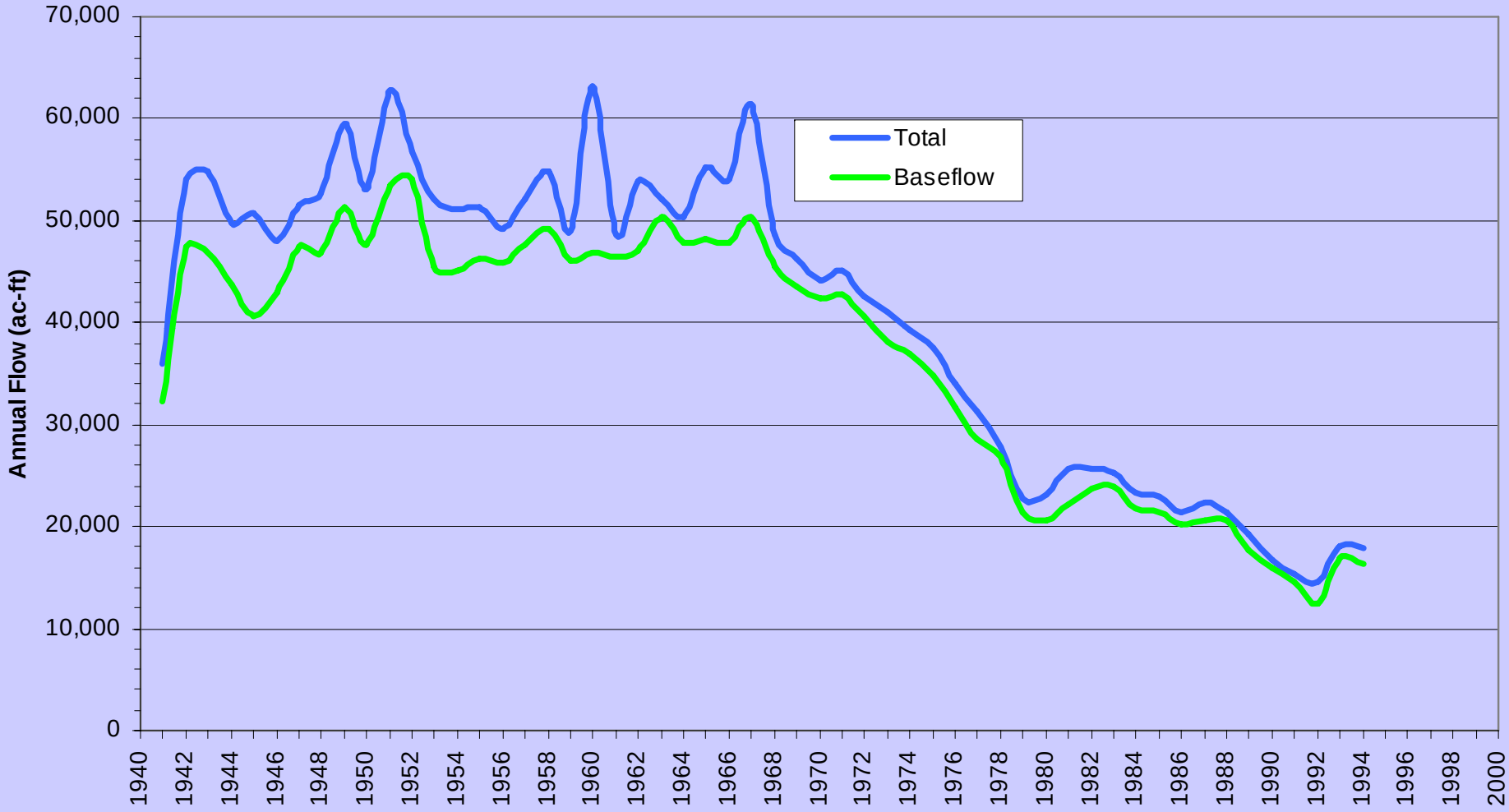

Pumpage
Increase in recharge
Removal of water stored in the system
Decrease in discharge

USGS


Schematic of the artificial recharge process
Sedgwick site
Treatment
Recharge basin
Water table
Little Arkansas R
Source water
Diversion
Recharge well
Halstead site
Diversion
Recharge trench
Recharge basin
Lateral flow
Seepage
Flow into deeper aquifer
Flow captured by pumping well
Confining clay layer
Equus Beds aquifer—receiving ground water
Not to scale
Bedrock

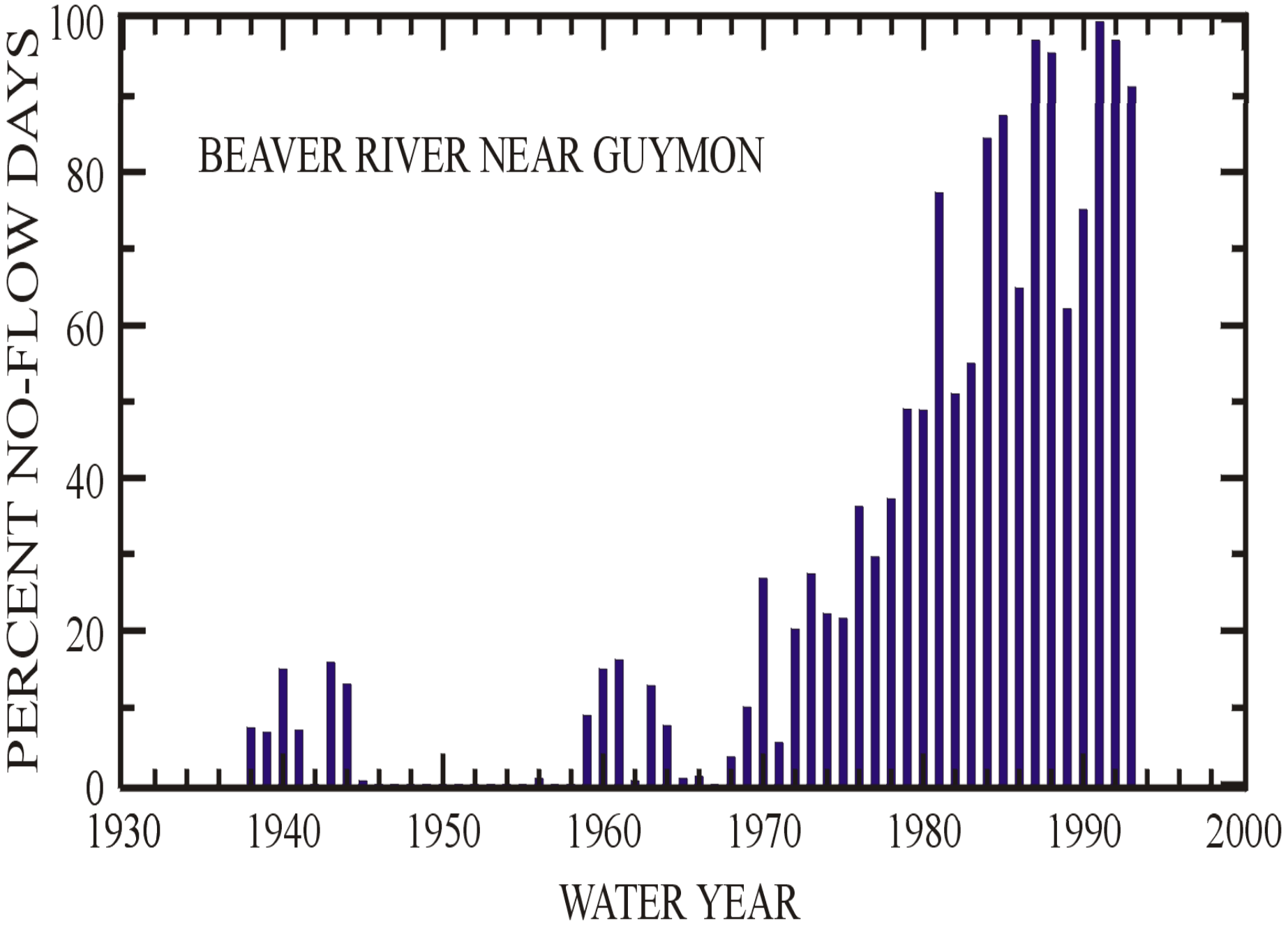
USGS

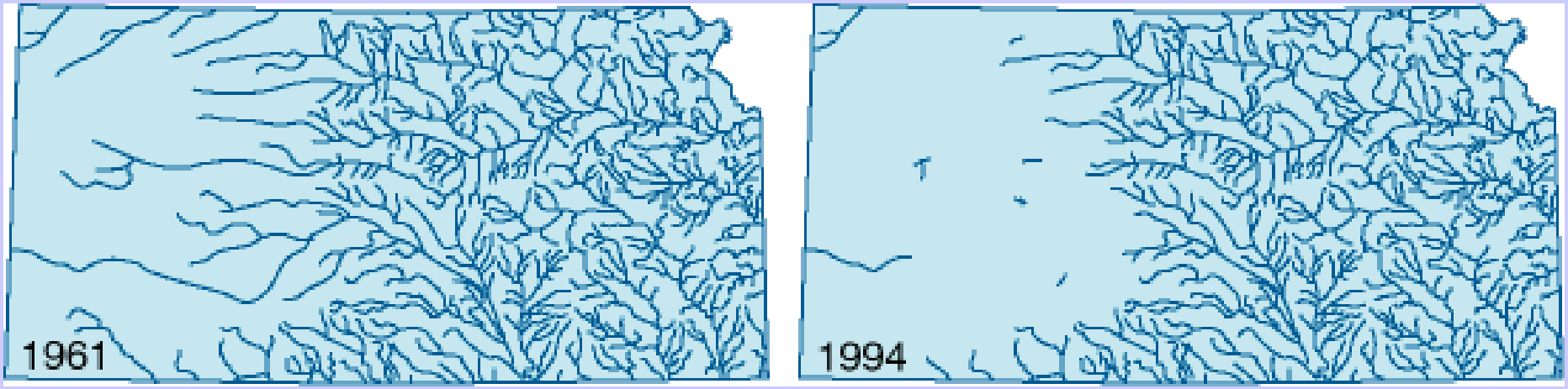
Estimated Baseflow - Frenchman Creek near Imperial, Ne (6831500)



(values in ac-ft)	Avg 1950-	Avg 1986-	Differenc
	53,390	18,552	-34,838
	47,952	17,278	-30,674

USGS


BEAVER RIVER NEAR GUYMON
PERCENT NO-FLOW DAYS
0
20
40
60
80
100
1930
1940
1950
1960
1970
1980
1990
2000
WATER YEAR



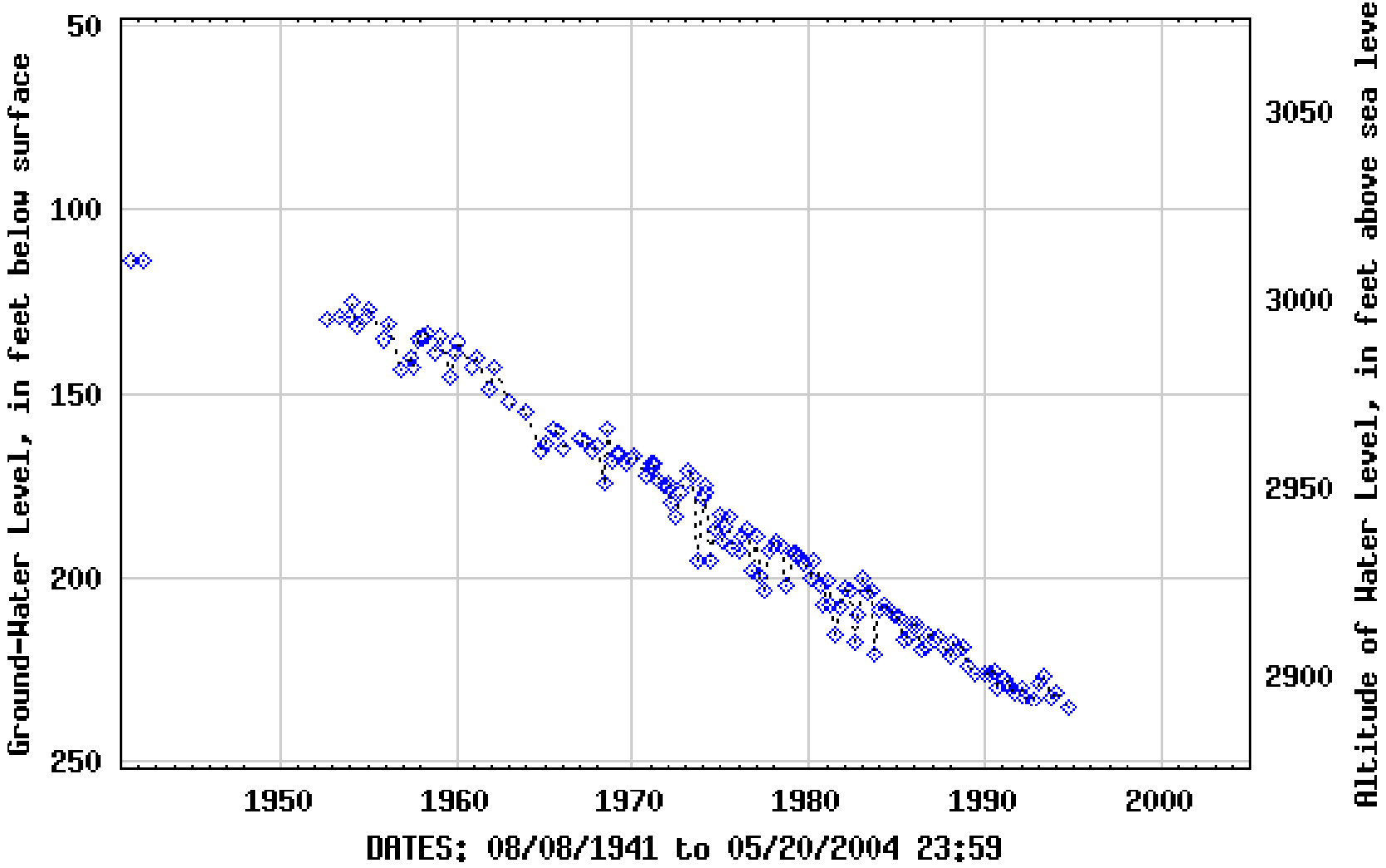
Map of perennial stream reaches in Kansas

USGS

USGS

USGS

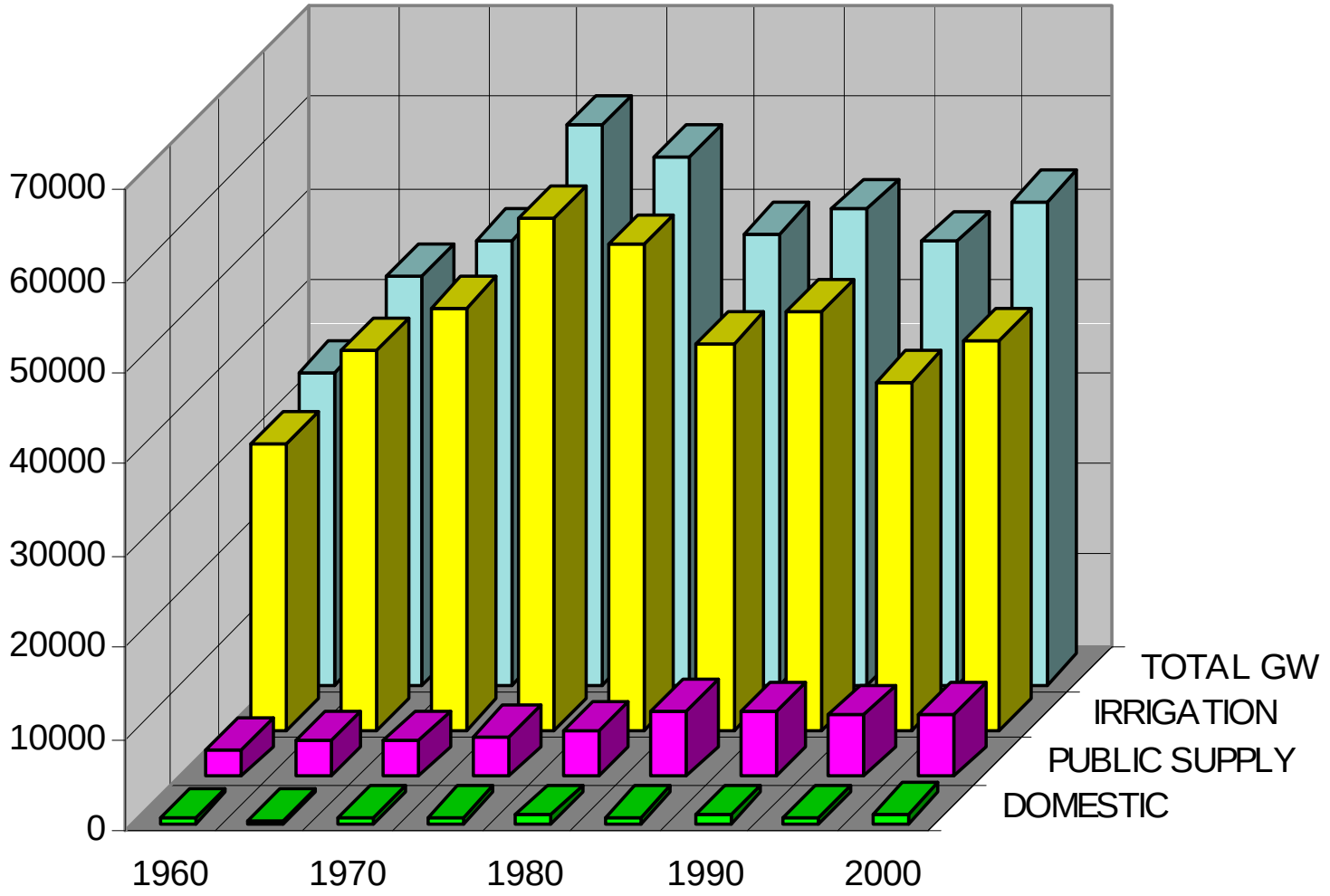
USGS 372515101235101 30S 37W 20CBC 01



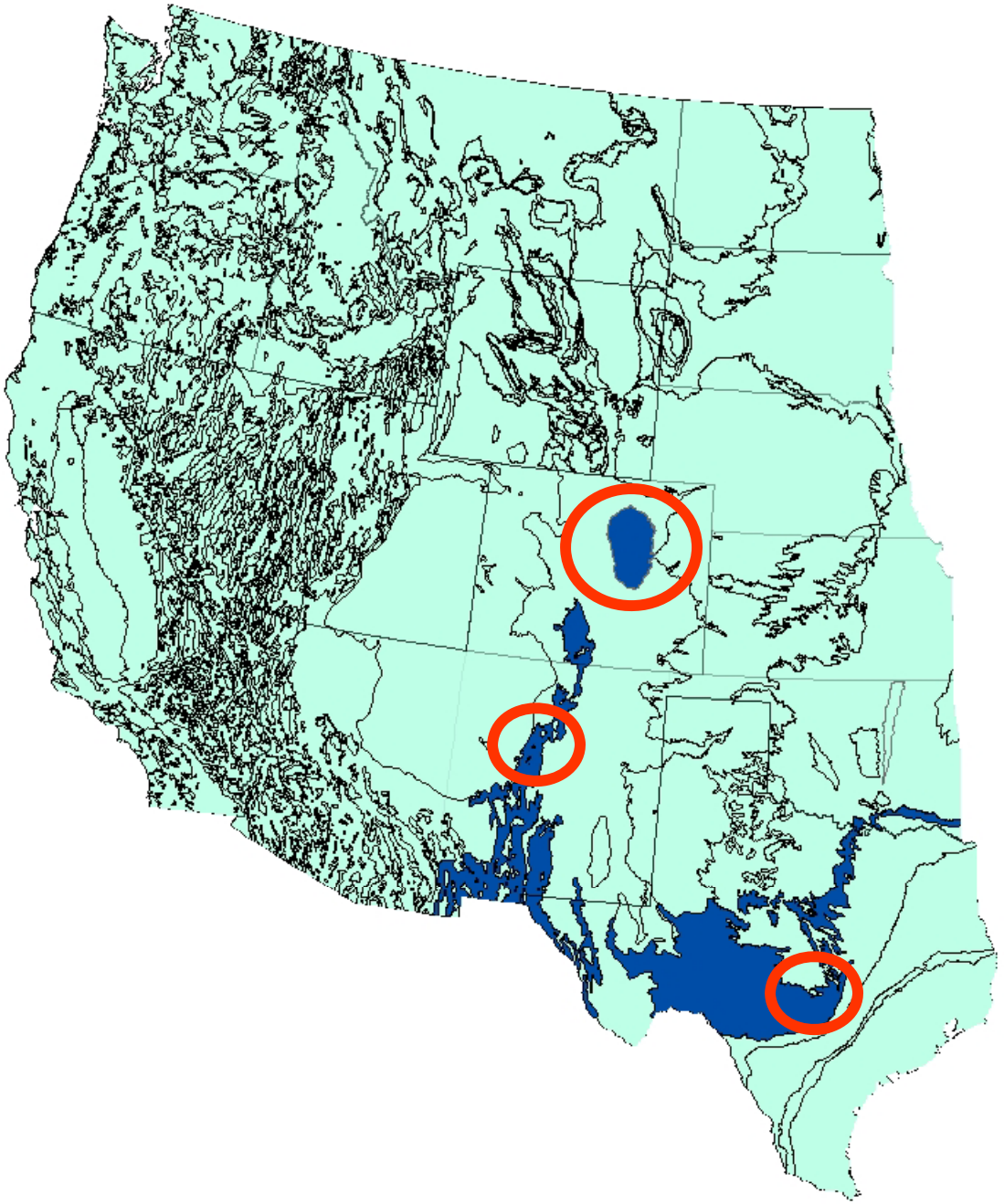
DATES: 08/08/1941 to 05/20/2004 23:59

Provisional Data Subject to Revision

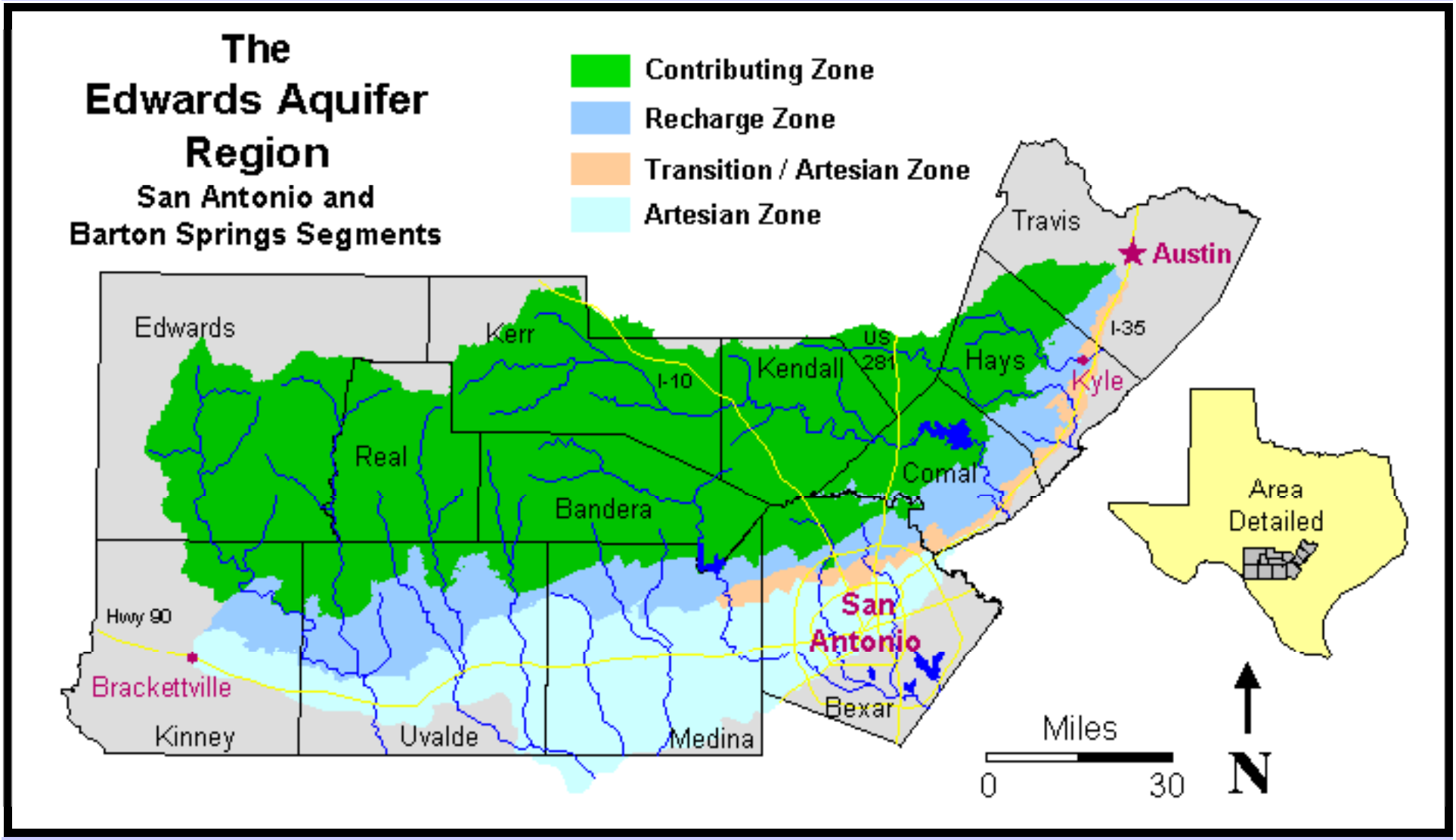
GROUND-WATER USE (MGD) IN THE 17 WESTERN STATES



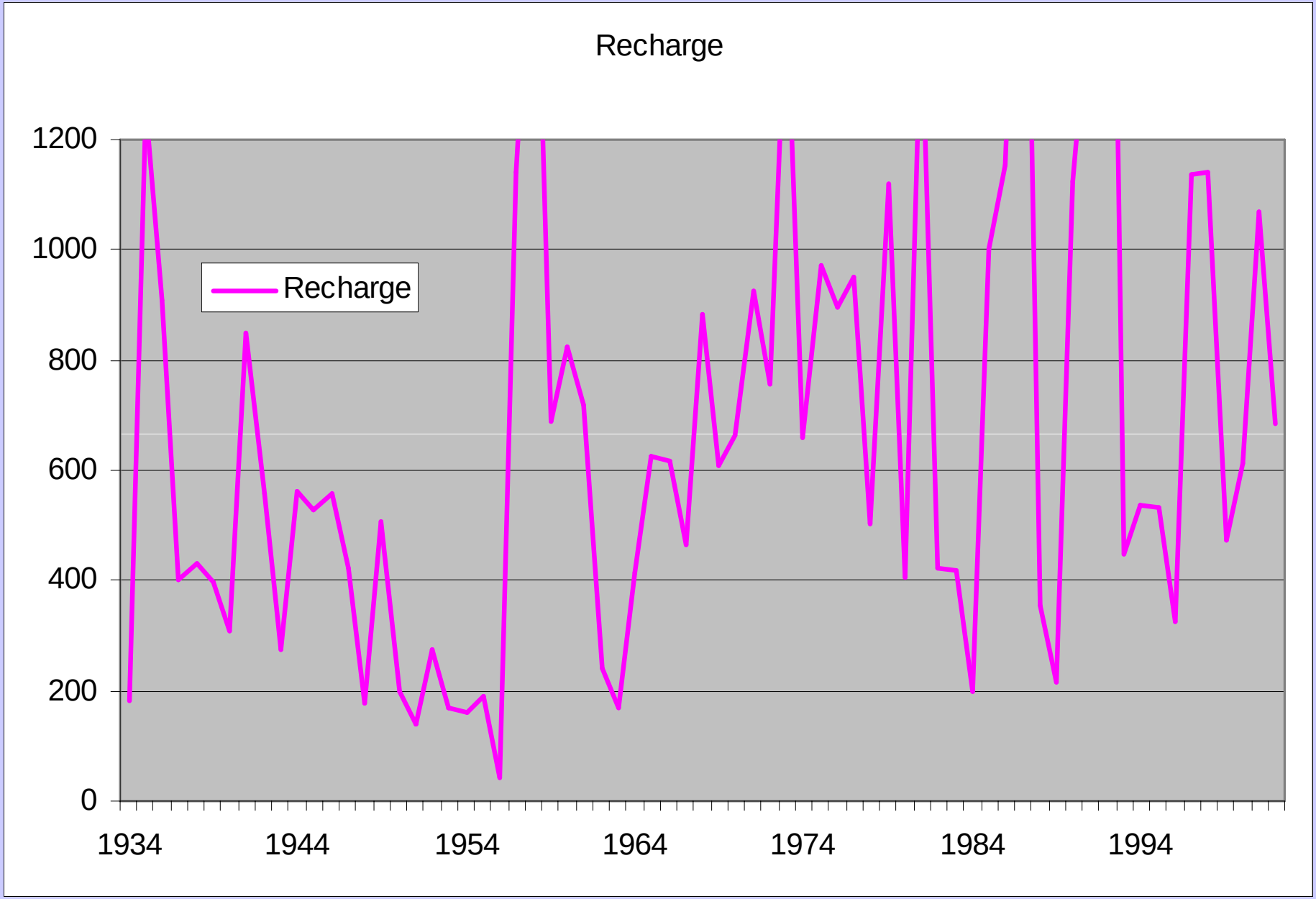
USGS



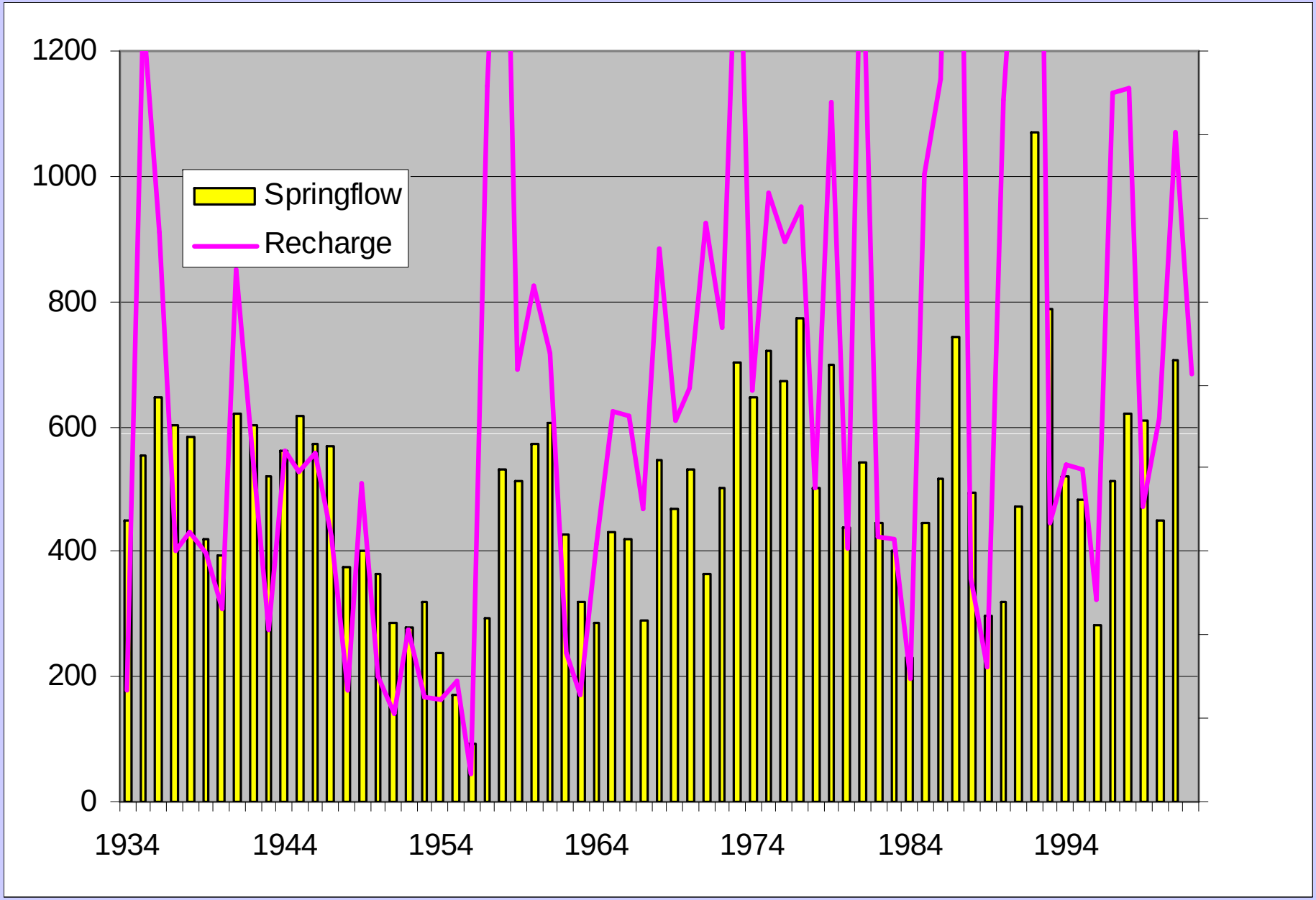
USGS


The
Edwards Aquifer
Region
San Antonio and
Barton Springs Segments
Contributing Zone
Recharge Zone
Transition / Artesian Zone
Artesian Zone
Travis
Austin
Edwards
Kerr
I-10
Kendall
US
281
Hays
I-35
Kyle
Real
Bandera
Comal
Area
Detailed
Hwy 90
San
Antonio
Brackettville
Kinney
Uvalde
Medina
Bexar
Miles
0
30
N

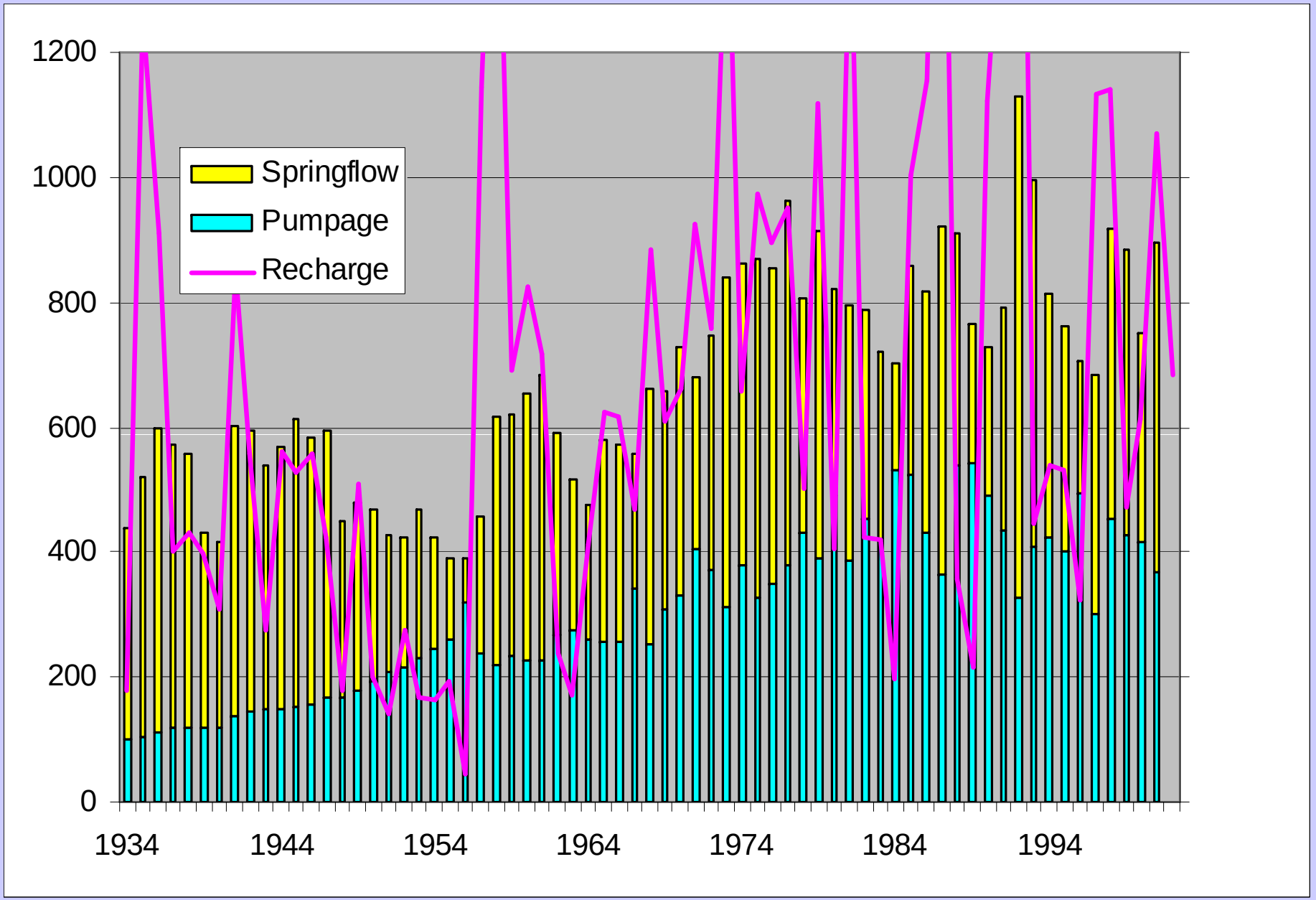
USGS


Recharge
1200
1000
800
600
400
200
0
Recharge
1934
1944
1954
1964
1974
1984
1994

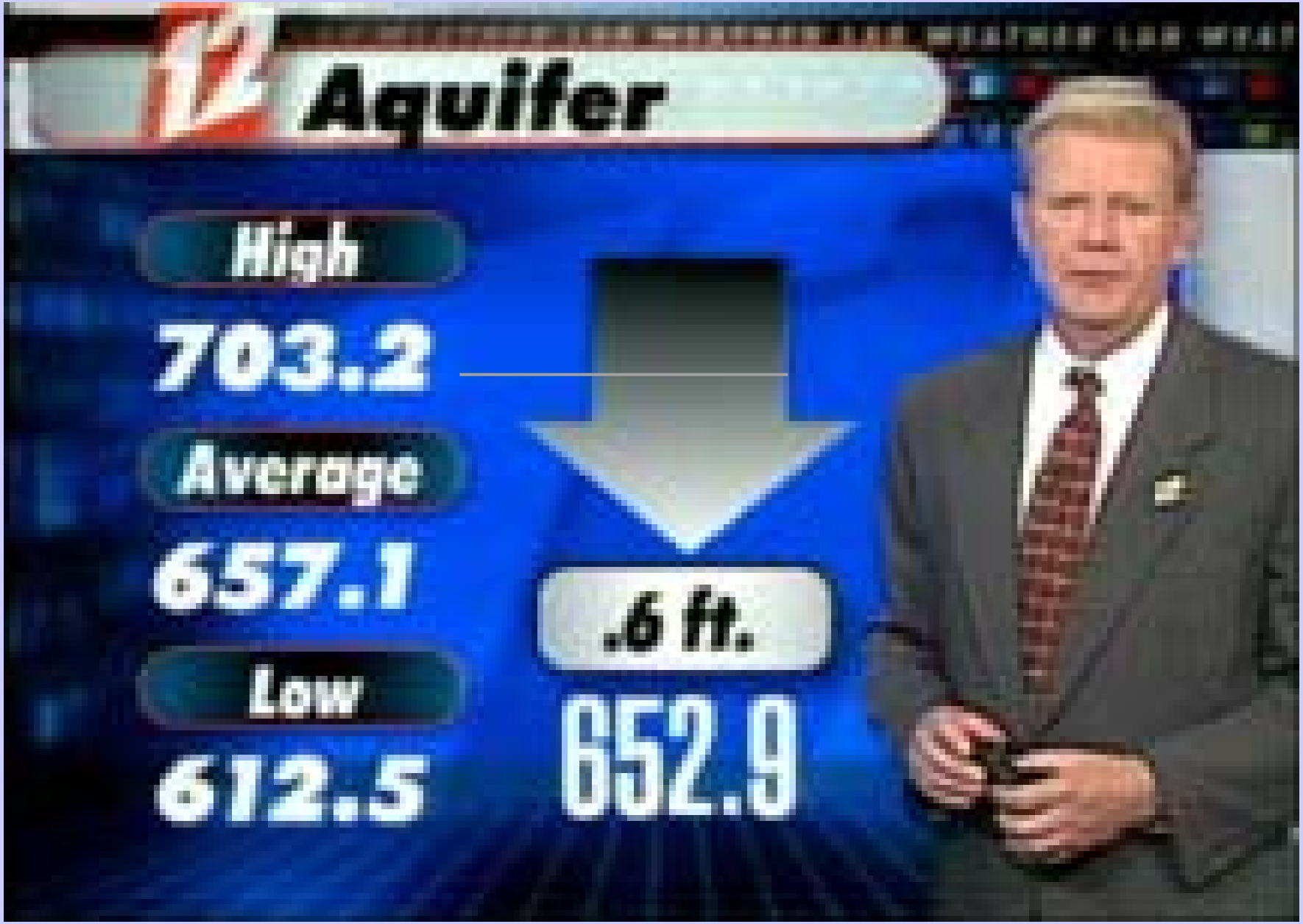
USGS


1200
1000
800
600
400
200
0
Springflow
Recharge
1934
1944
1954
1964
1974
1984
1994

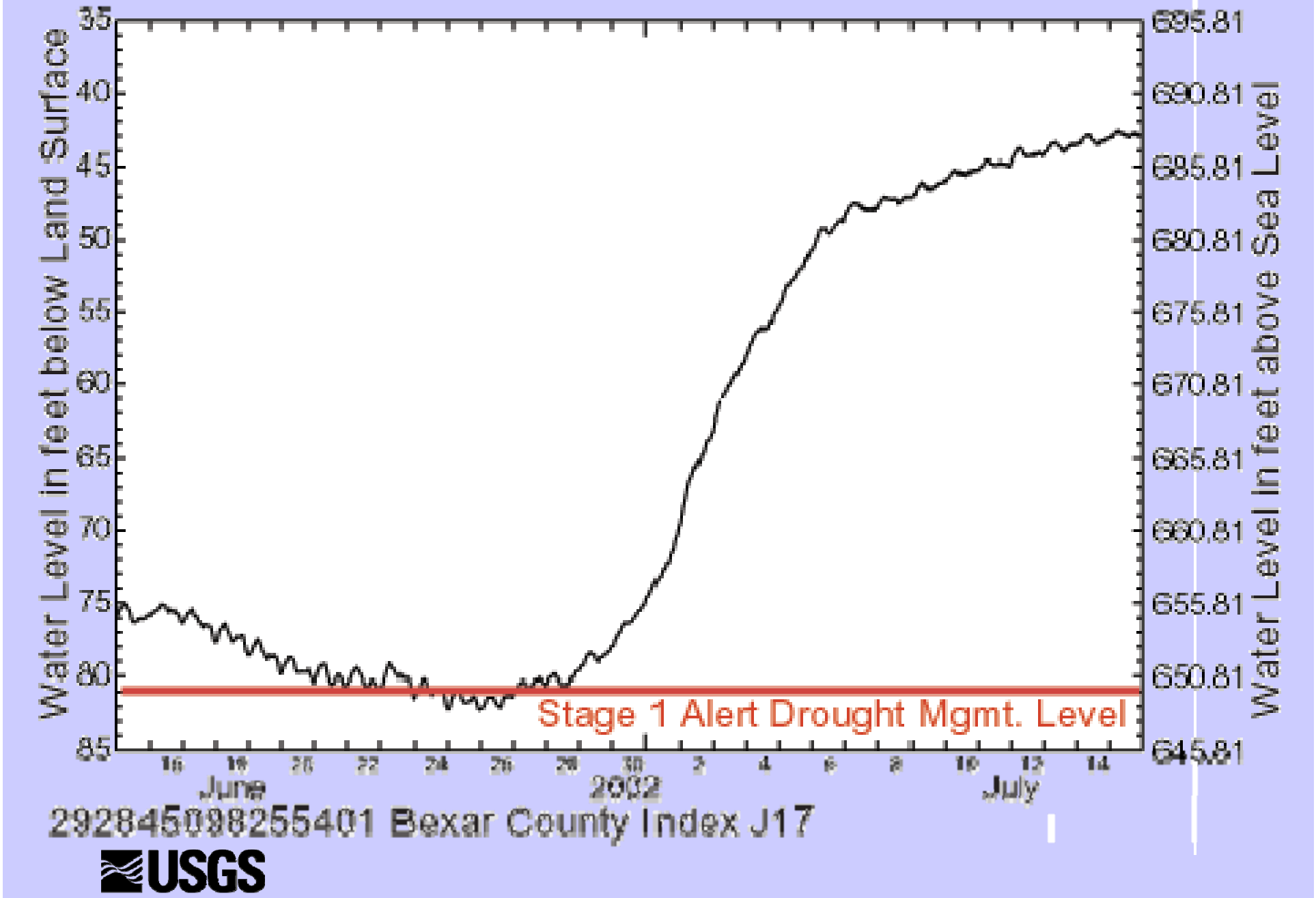
USGS

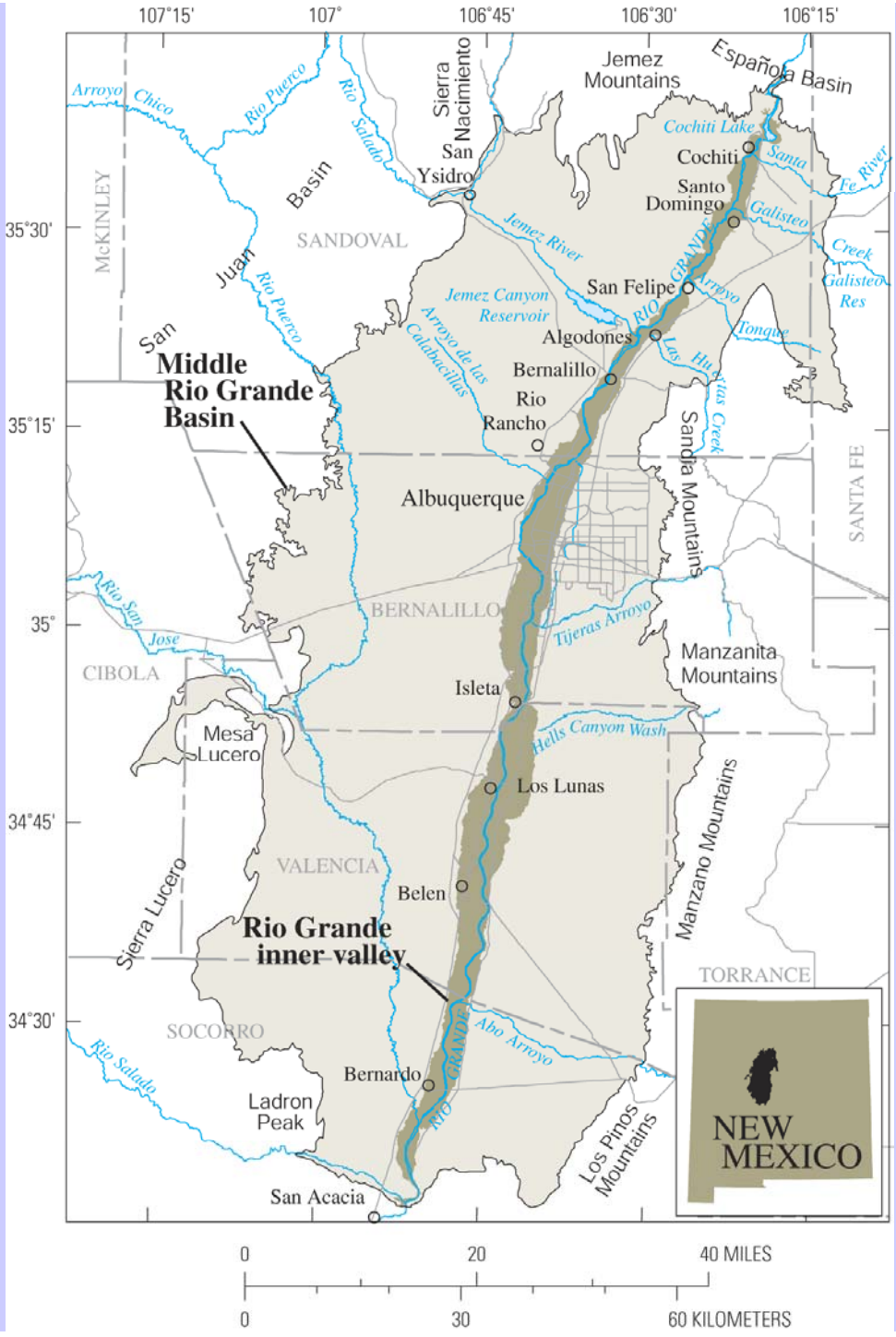

1200
1000
800
600
400
200
0
Springflow
Pumpage
Recharge
1934
1944
1954
1964
1974
1984
1994

USGS



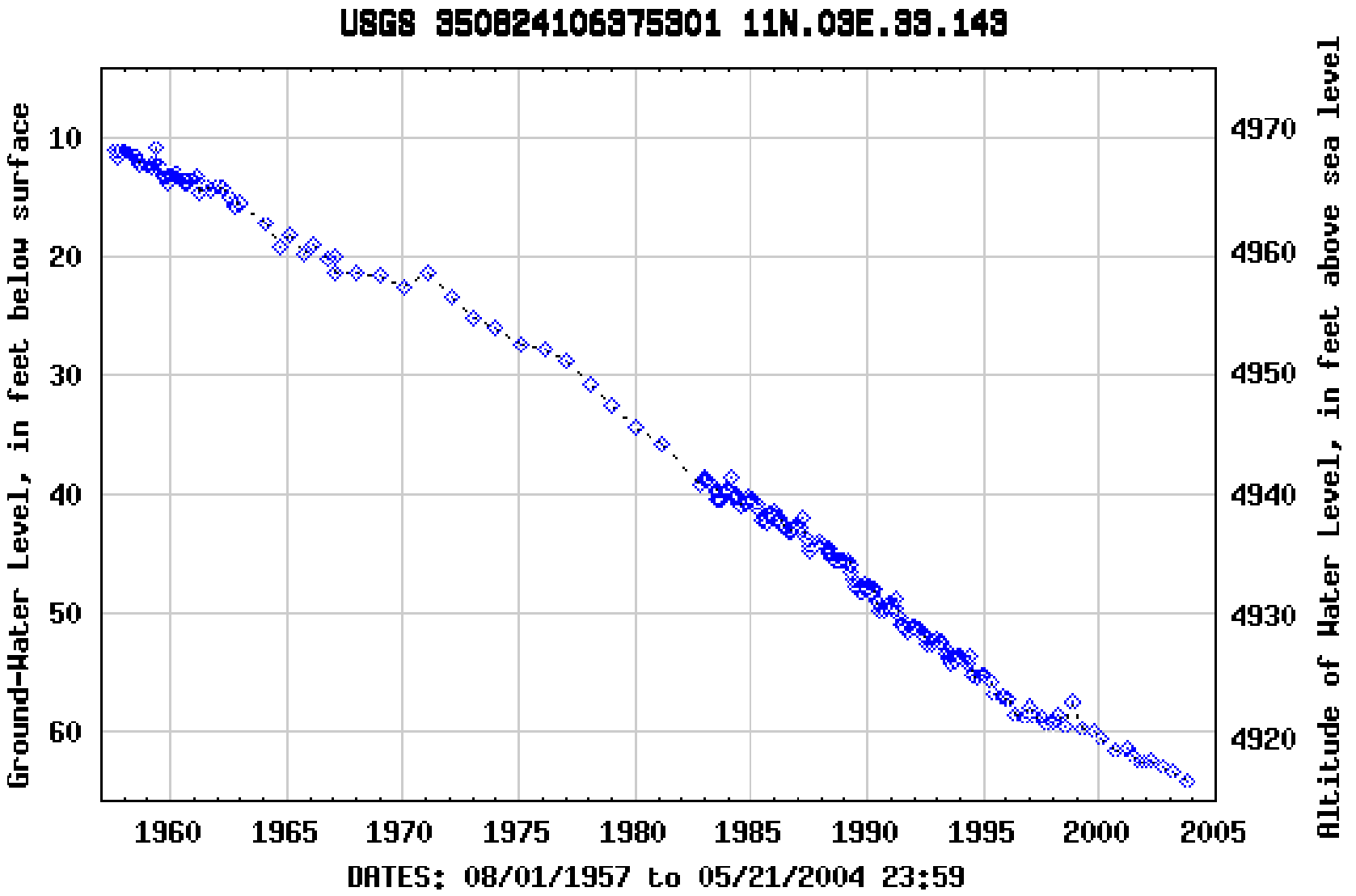
USGS


Water Level in feet below Land Surface
35
40
45
50
55
60
65
70
75
80
85
Water Level in feet above Sea Level
695.81
690.81
685.81
680.81
675.81
670.81
665.81
660.81
655.81
650.81
645.81
Stage 1 Alert Drought Mgmt. Level
June
2002
July
292845098255401 Bexar County Index J17
USGS


107°15'
107°
106°45'
106°30'
106°15'
35°30'
35°15'
35°
34°45'
34°30'
Middle Rio Grande Basin
Rio Grande inner valley
Jemez Mountains
Sierra Nacimiento
Española Basin
Cochiti Lake
Cochiti
Santo Domingo
San Ysidro
San Felipe
Algodones
Bernalillo
Rio Rancho
Albuquerque
Sandia Mountains
Manzanita Mountains
Manzano Mountains
Los Pinos Mountains
Isleta
Los Lunas
Belen
Bernardo
San Acacia
Mesa Lucero
Sierra Lucero
Ladron Peak
SANDOVAL
BERNALILLO
VALENCIA
SOCORRO
TORRANCE
SANTA FE
CIBOLA
MCKINLEY
San Juan Basin
Jemez River
Jemez Canyon Reservoir
Arroyo de las Calabacillas
Tijeras Arroyo
Hells Canyon Wash
Abo Arroyo
Galisteo Creek
Galisteo Res
Tonque Arroyo
Los Huertas Creek
Santa Fe River
Arroyo Chico
Rio Puerco
Rio Salado
Rio San Jose
RIO GRANDE
NEW MEXICO
0 20 40 MILES
0 30 60 KILOMETERS

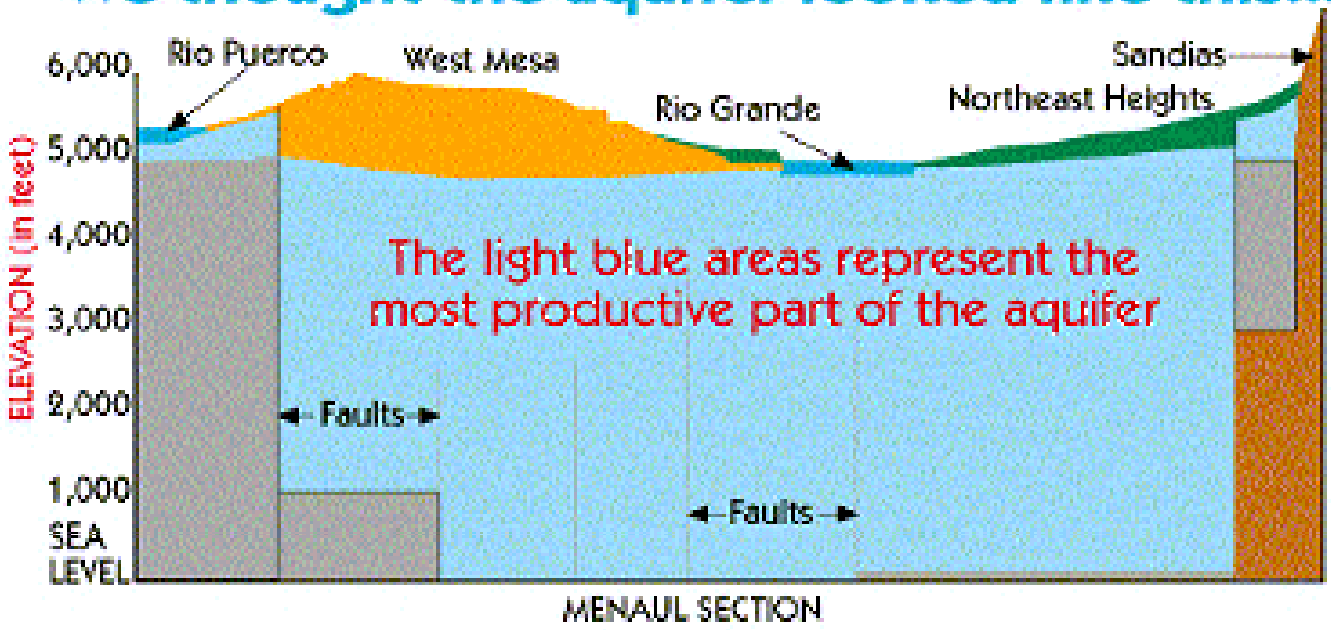
USGS

USGS

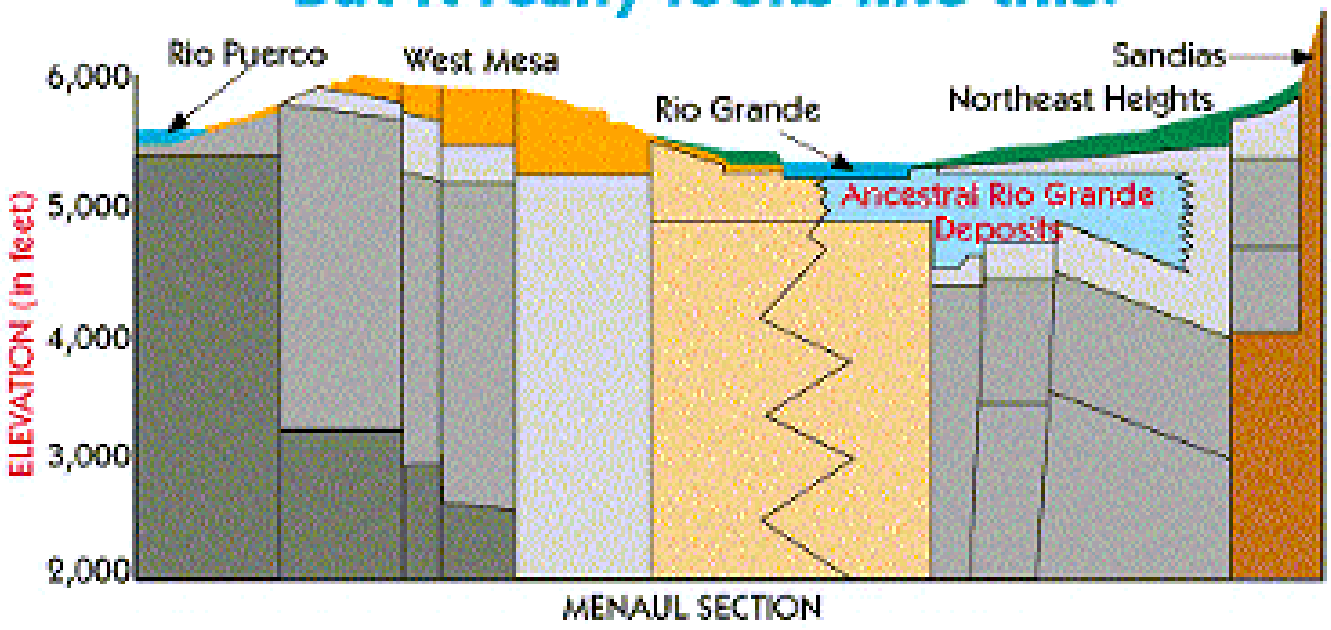


Provisional Data Subject to Revision

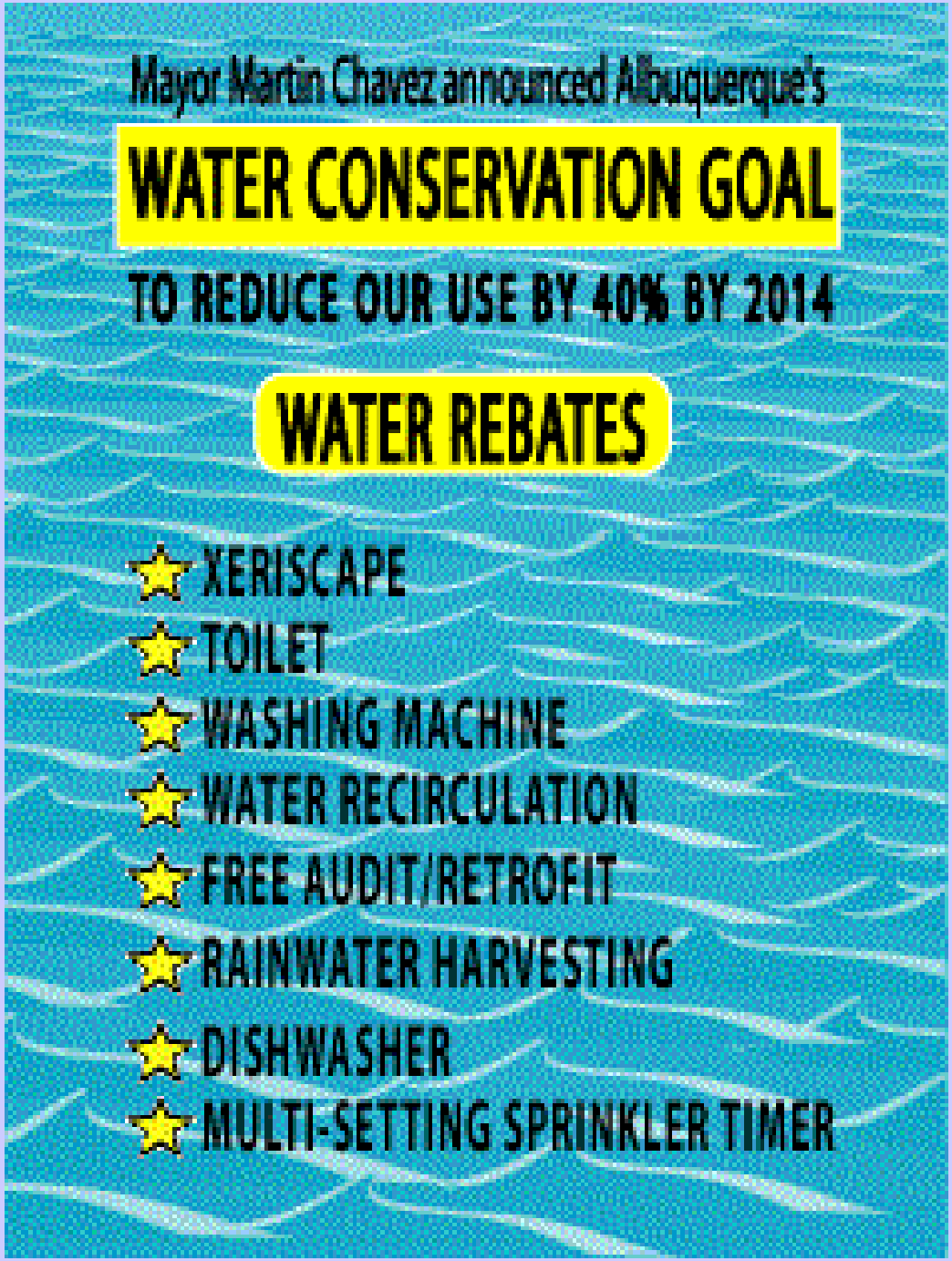
We thought the aquifer looked like this...



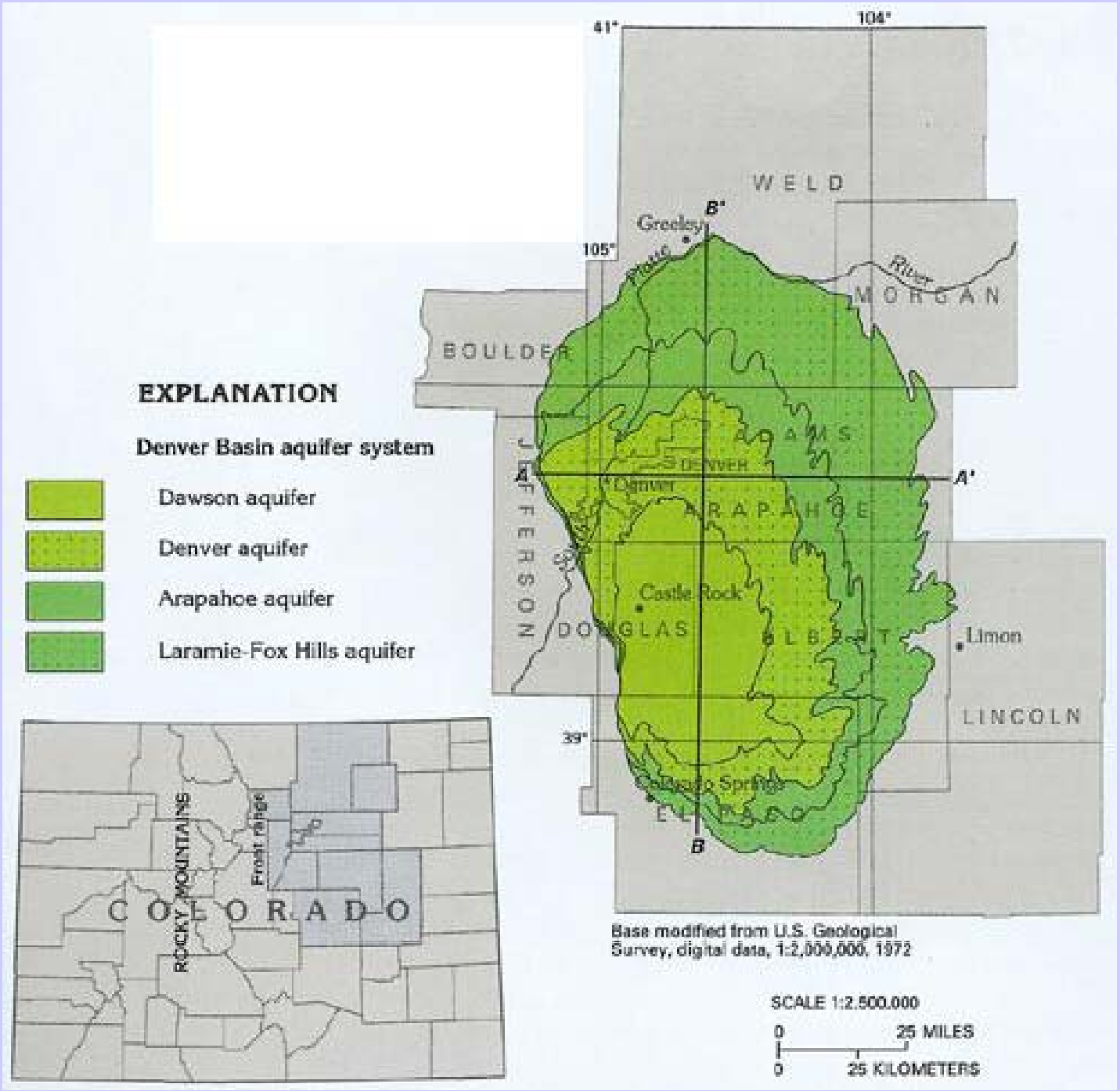
But it really looks like this:



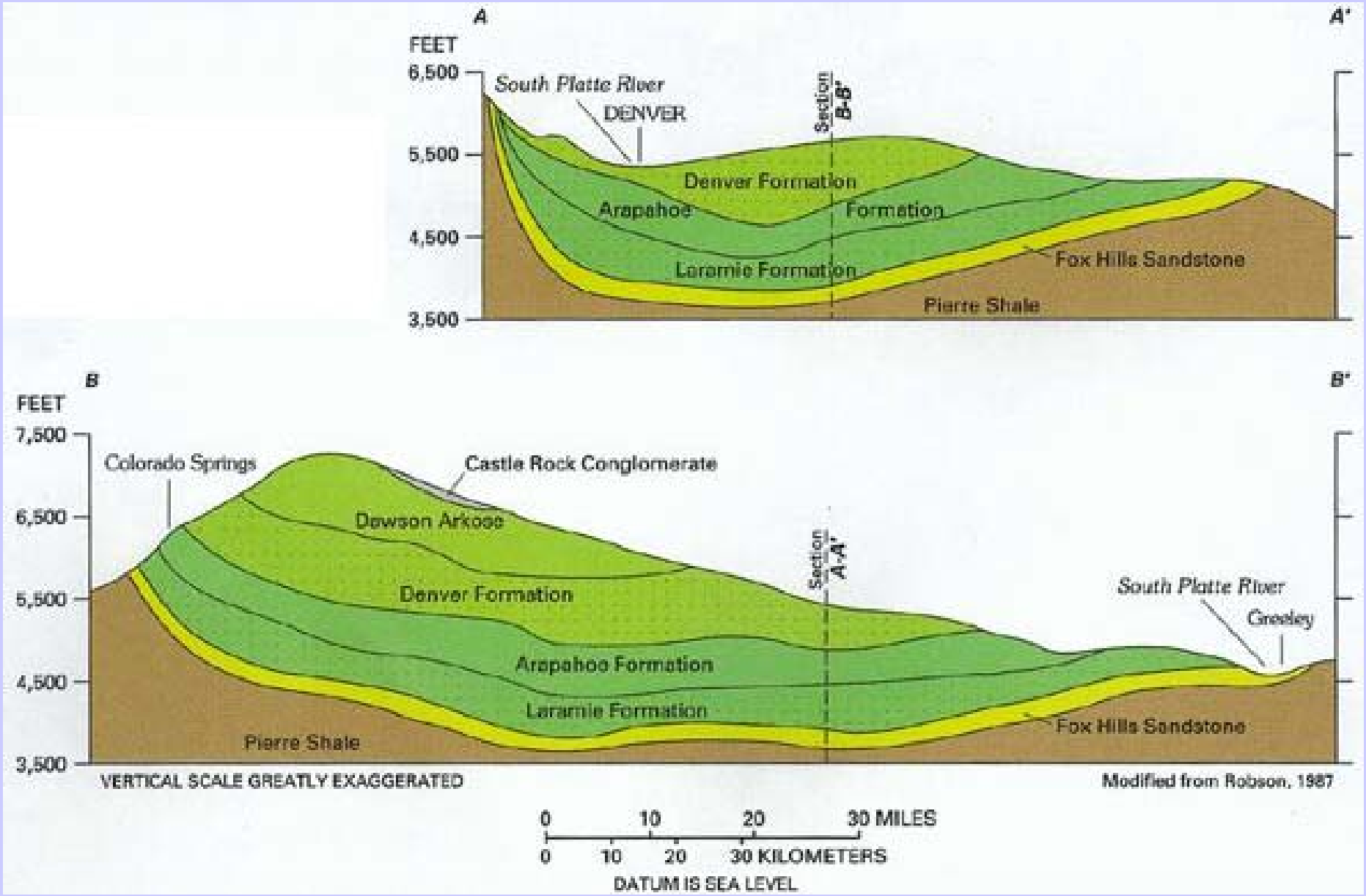
USGS


Mayor Martin Chavez announced Albuquerque's
WATER CONSERVATION GOAL
TO REDUCE OUR USE BY 40% BY 2014
WATER REBATES
XERISCAPE
TOILET
WASHING MACHINE
WATER RECIRCULATION
FREE AUDIT/RETROFIT
RAINWATER HARVESTING
DISHWASHER
MULTI-SETTING SPRINKLER TIMER

USGS

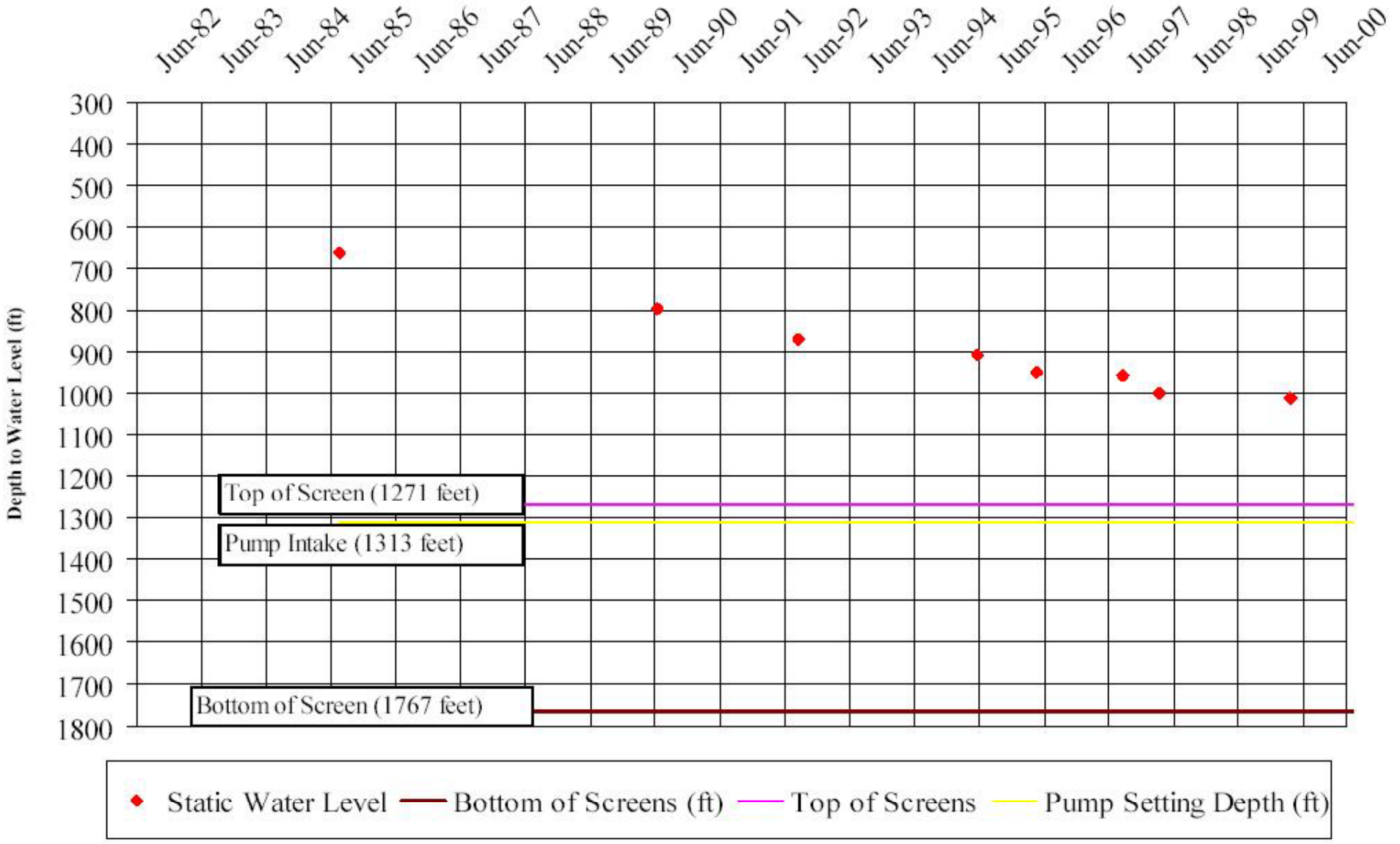

41°
104°
105°
39°
WELD
MORGAN
BOULDER
ADAMS
JEFFERSON
ARAPAHOE
DOUGLAS
ELBERT
LINCOLN
Greeley
Denver
Castle Rock
Limon
Colorado Springs
Platte River
B'
A
A'
B
EXPLANATION
Denver Basin aquifer system
Dawson aquifer
Denver aquifer
Arapahoe aquifer
Laramie-Fox Hills aquifer
COLORADO
ROCKY MOUNTAINS
Front range
Base modified from U.S. Geological Survey, digital data, 1:2,000,000, 1972
SCALE 1:2,500,000
0
25 MILES
0
25 KILOMETERS

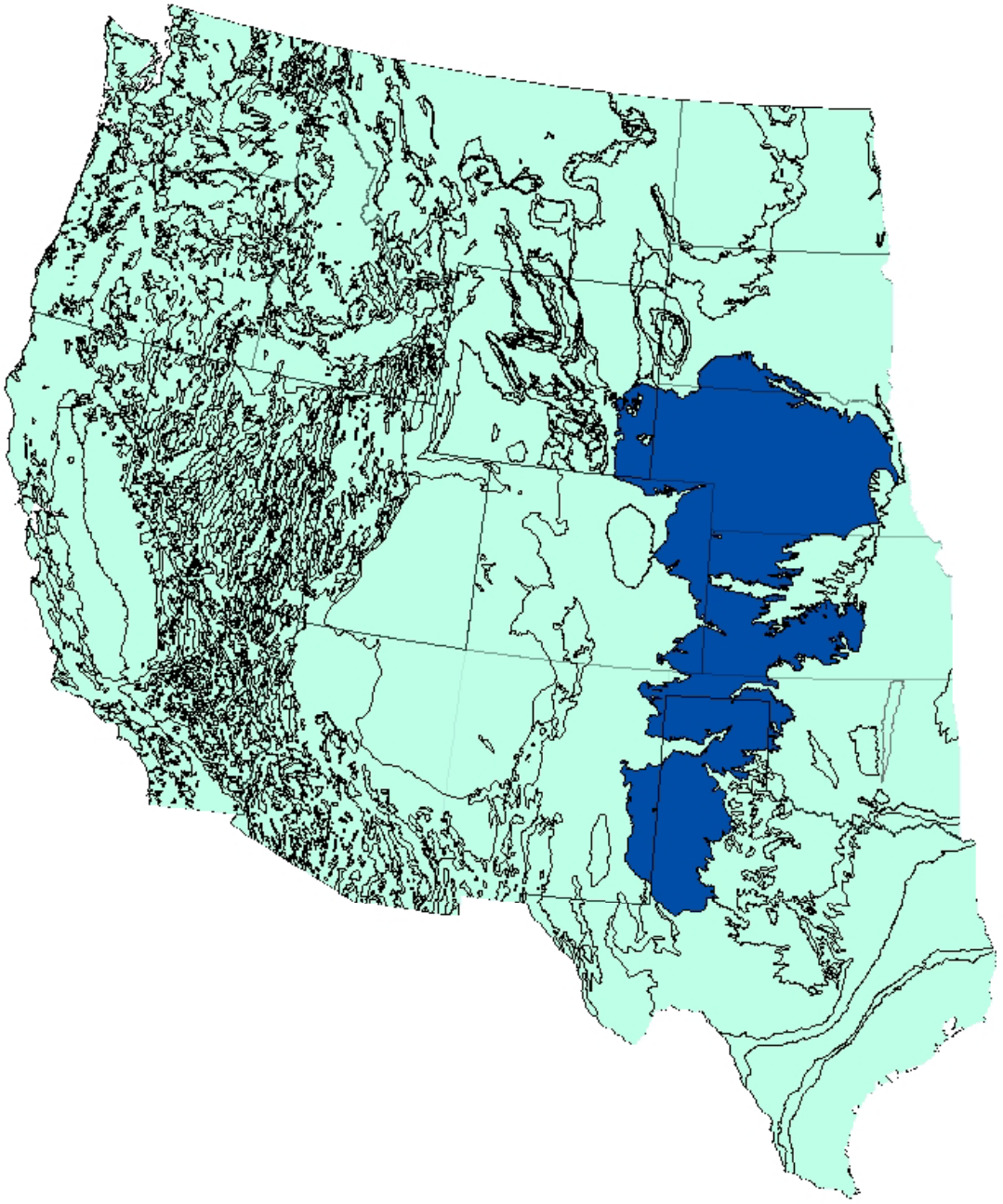
USGS


A
A'
FEET
6,500
5,500
4,500
3,500
South Platte River
DENVER
Section B-B'
Denver Formation
Arapahoe Formation
Laramie Formation
Fox Hills Sandstone
Pierre Shale
B
B'
FEET
7,500
6,500
5,500
4,500
3,500
Colorado Springs
Castle Rock Conglomerate
Dawson Arkose
Denver Formation
Arapahoe Formation
Laramie Formation
Pierre Shale
Section A-A'
South Platte River
Greeley
Fox Hills Sandstone
VERTICAL SCALE GREATLY EXAGGERATED
Modified from Robson, 1987
0 10 20 30 MILES
0 10 20 30 KILOMETERS
DATUM IS SEA LEVEL

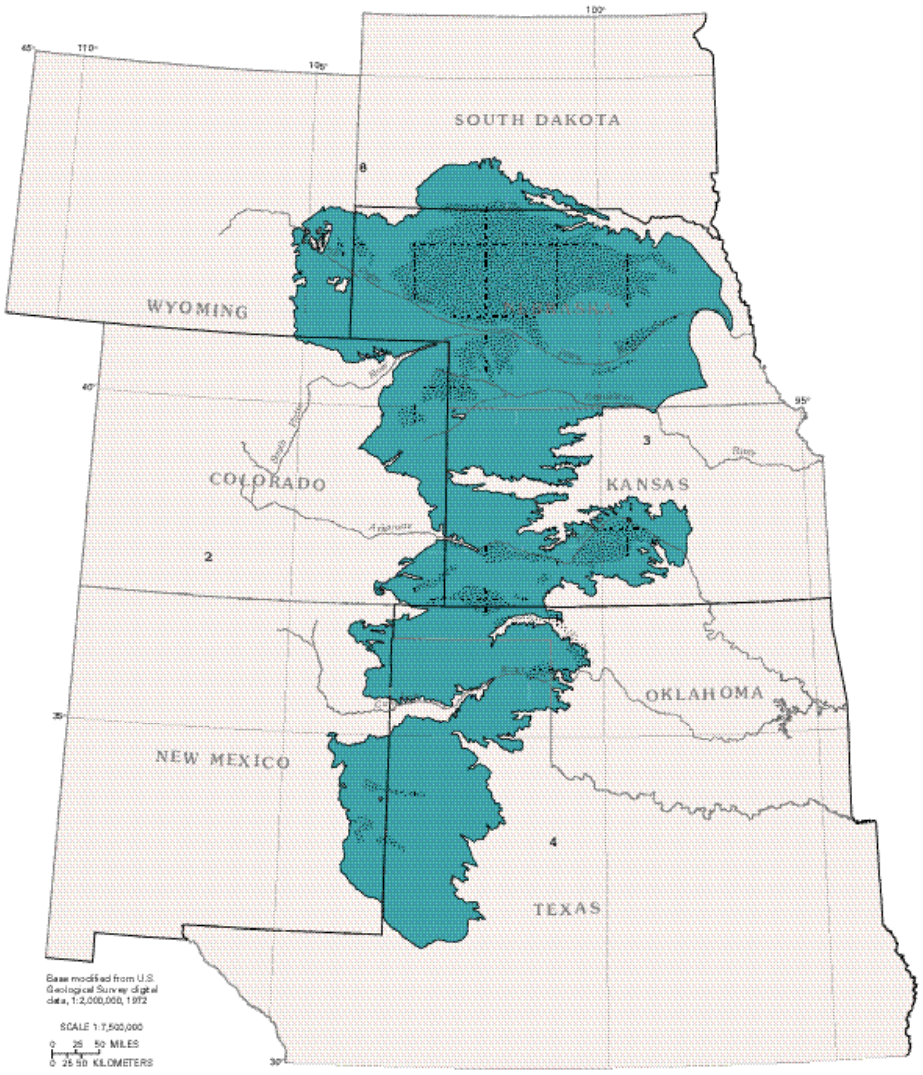
USGS

Arapahoe Aquifer Well - Permit No. 29073-F - Castle Rock





USGS



Modified from:

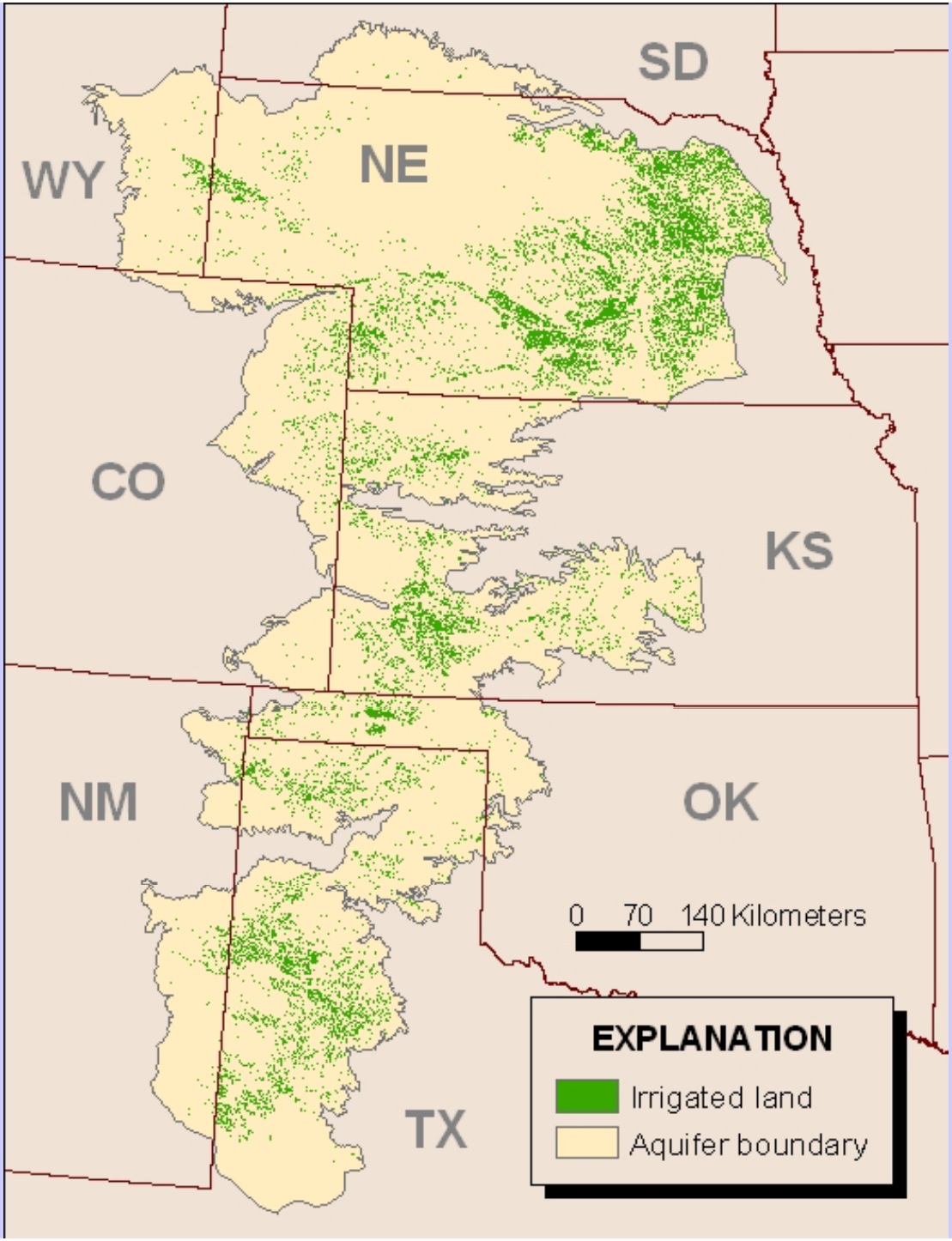
Gutentag, E.D., Heimes, F.J., Kroethe, N.C., Luckey, R.R., and Weeks, J.B., 1984, Geohydrology of the High Plains aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Professional Paper 1400–B, 63 p.

Weeks, J.B., Gutentag, E.D., Heimes, F.J., and Luckey, R.R., 1988, Summary of the High Plains regional aquifer-system analysis in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Professional Paper 1400–A, 30 p.

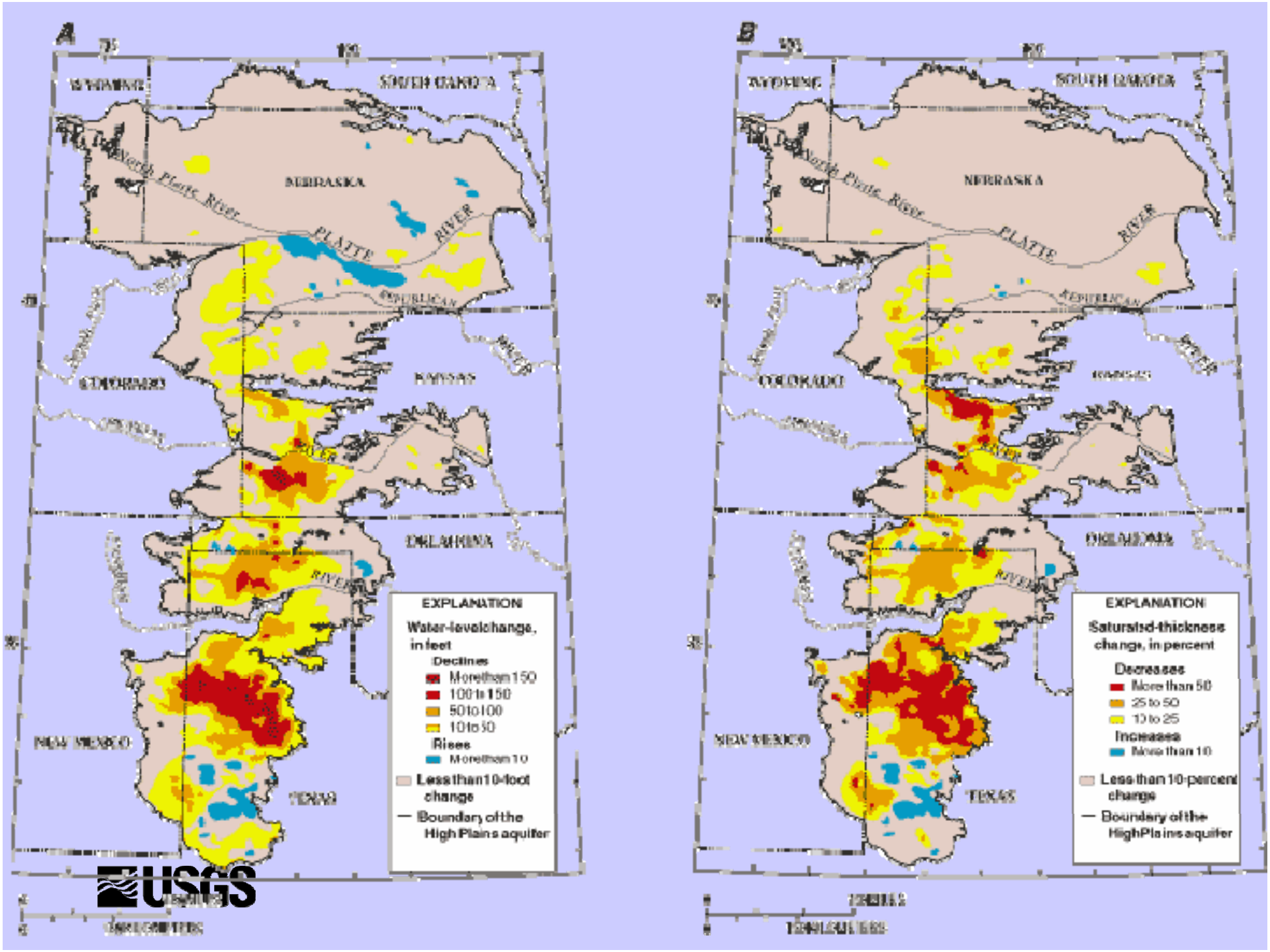
EXPLANATION

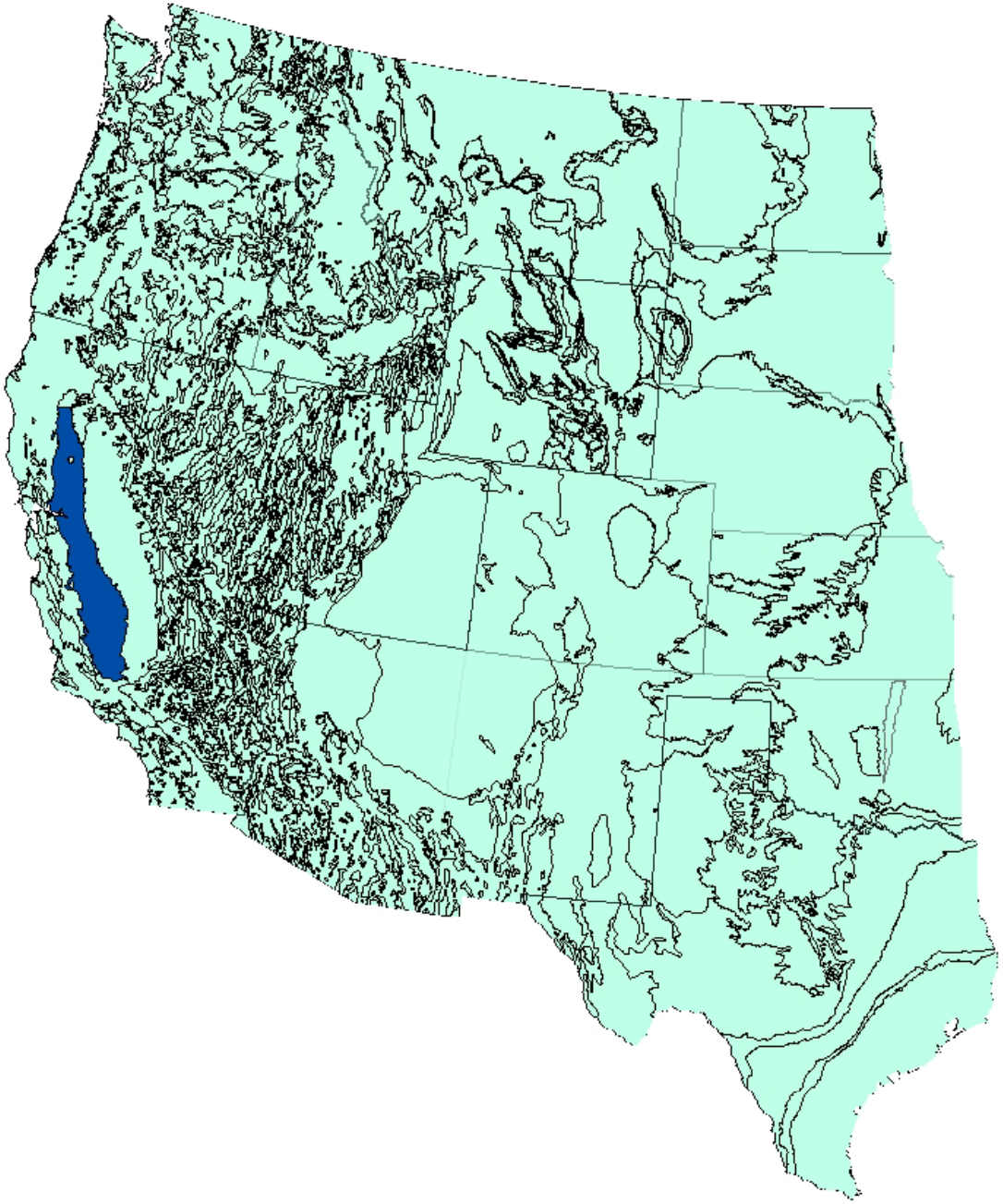
- High Plains aquifer
- Dune sand
- 3 — Atlas segment boundary and number

USGS

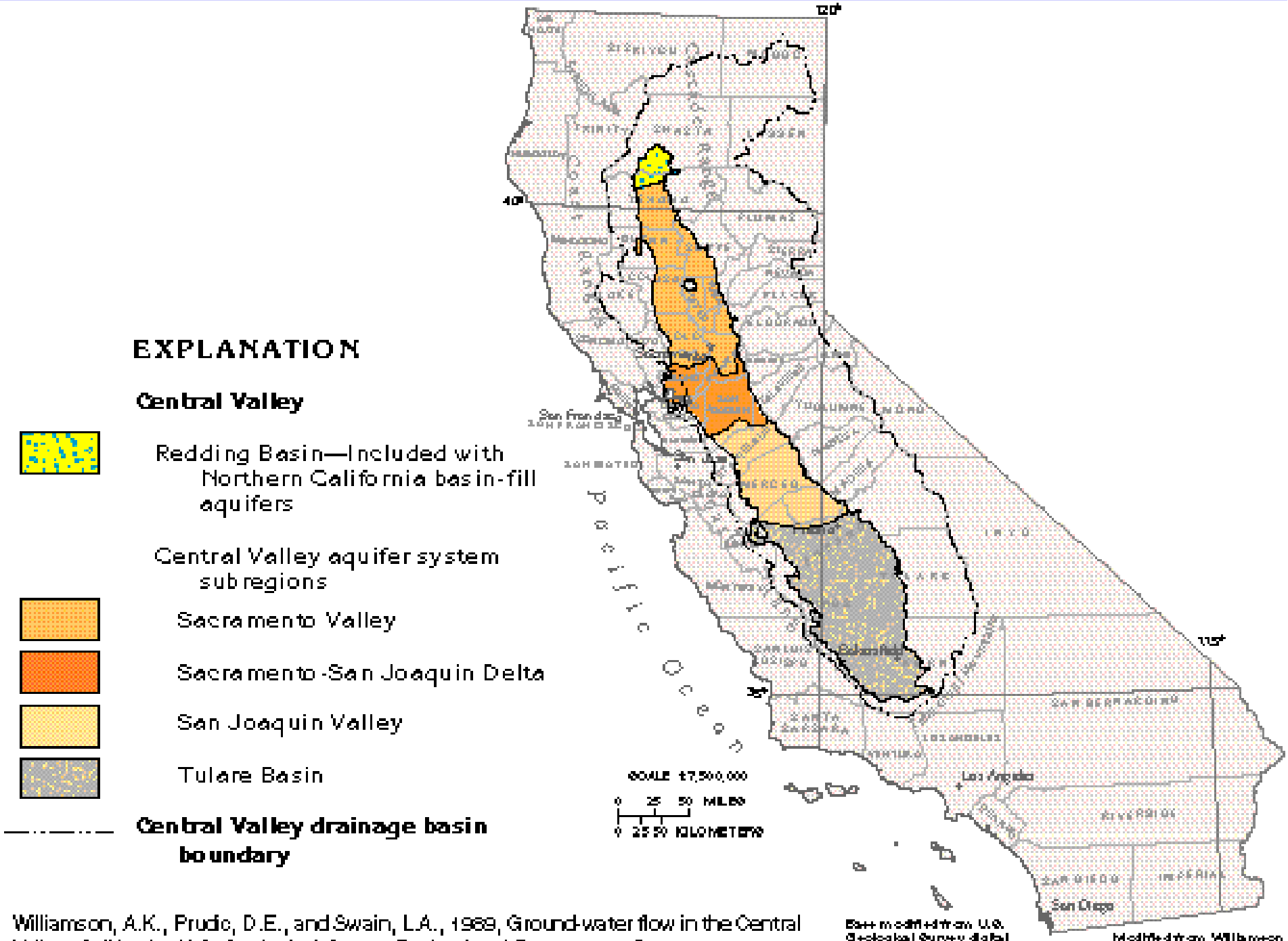

SD
WY
NE
CO
KS
NM
OK
TX
0 70 140 Kilometers
EXPLANATION
Irrigated land
Aquifer boundary

USGS


A
B
NEBRASKA
SOUTH DAKOTA
WYOMING
COLORADO
KANSAS
OKLAHOMA
NEW MEXICO
TEXAS
North Platte River
PLATTE
RIVER
REPUBLICAN
RIVER
CANADIAN
RIVER
EXPLANATION
Water-level change, in feet
Declines
More than 150
100 to 150
50 to 100
10 to 50
Rises
More than 10
Less than 10-foot change
Boundary of the High Plains aquifer
Saturated-thickness change, in percent
Decreases
More than 50
25 to 50
10 to 25
Increases
More than 10
Less than 10-percent change
Boundary of the High Plains aquifer
USGS

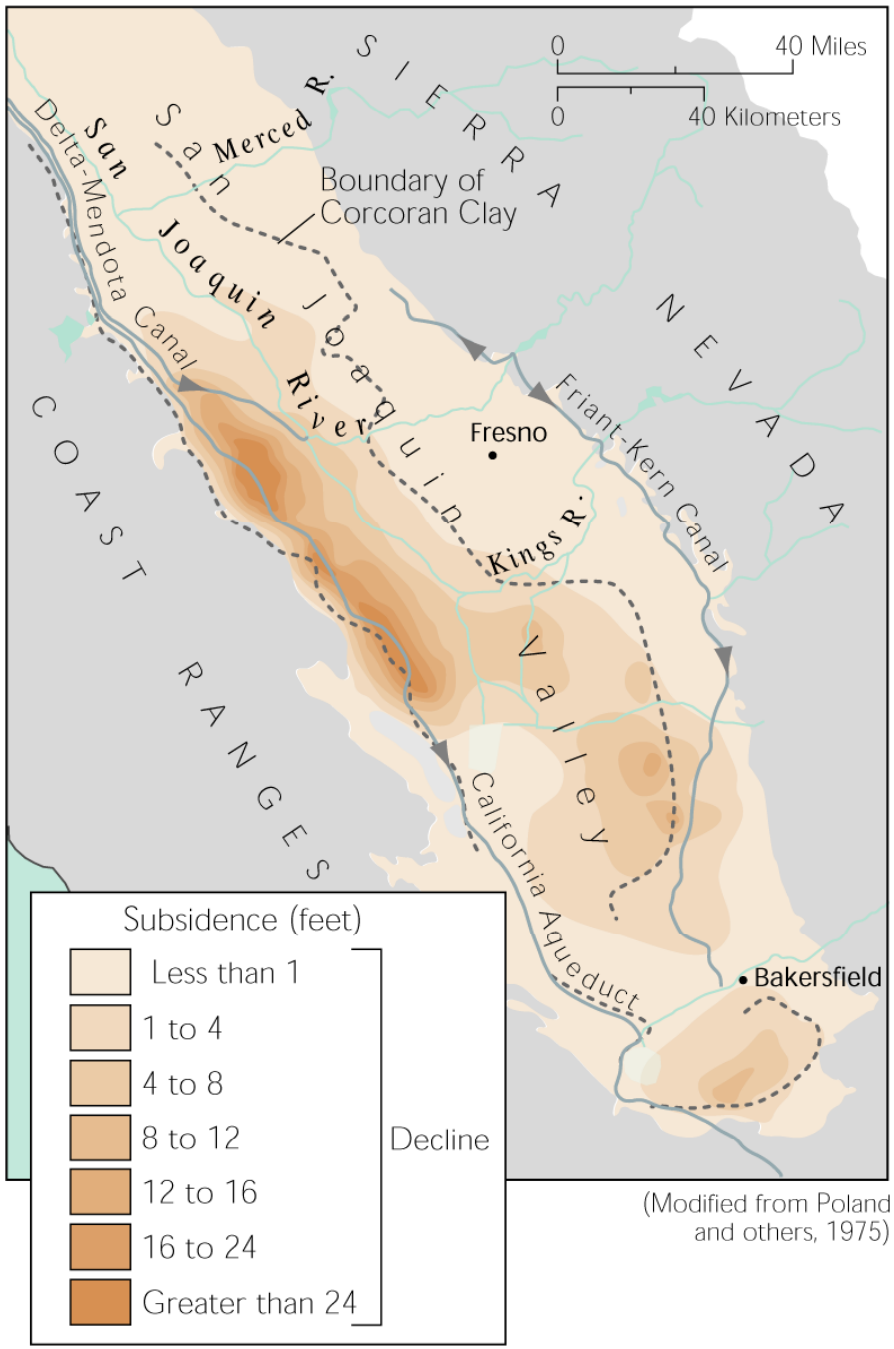


USGS

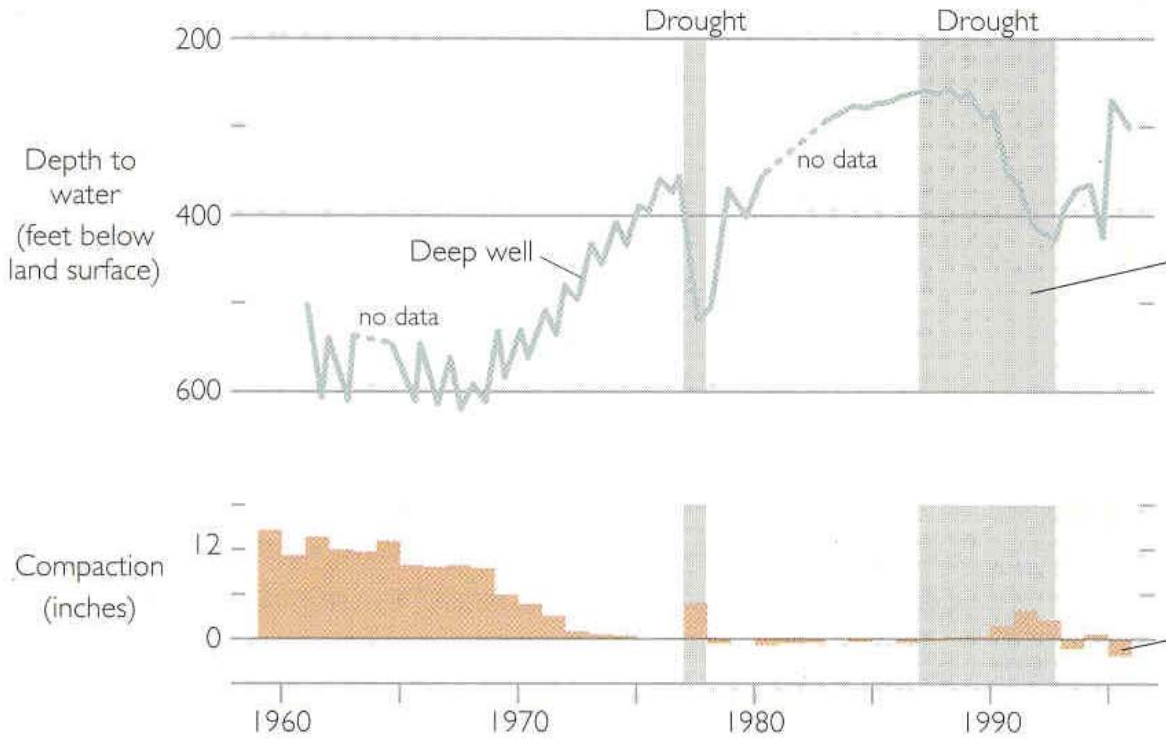


Williamson, A.K., Prudic, D.E., and Swain, L.A., 1989, Ground-water flow in the Central Valley, California: U.S. Geological Survey Professional Paper 1401–D, 127 p.

Land subsidence from 1926 to 1970



(Modified from Poland and others, 1975)

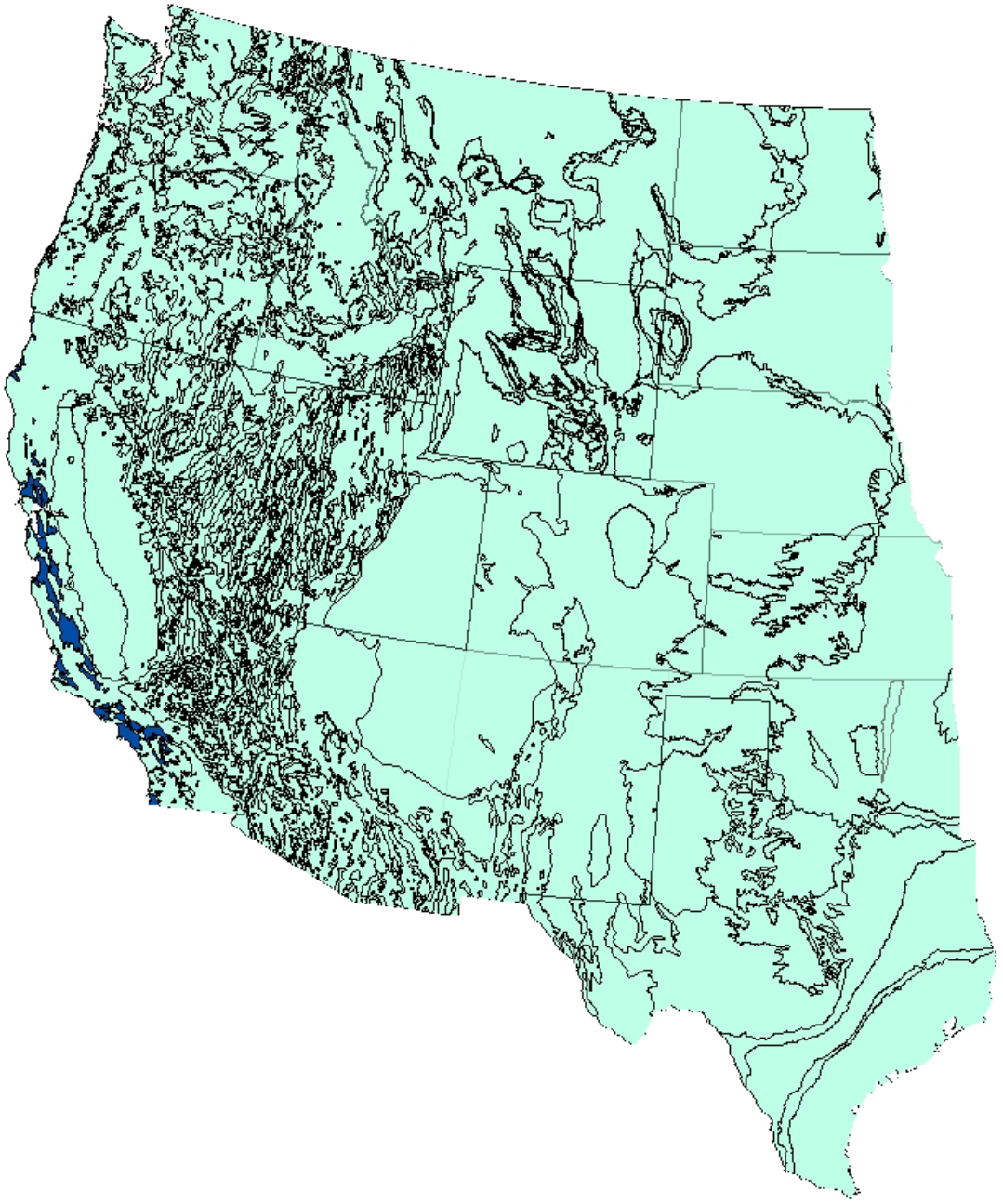


During the droughts of 1976–77 and 1987–91, deliveries of imported water to the west side of the San Joaquin Valley were cut back. More ground water was pumped to meet the demand, resulting in a drop in the water table and consequent compaction.

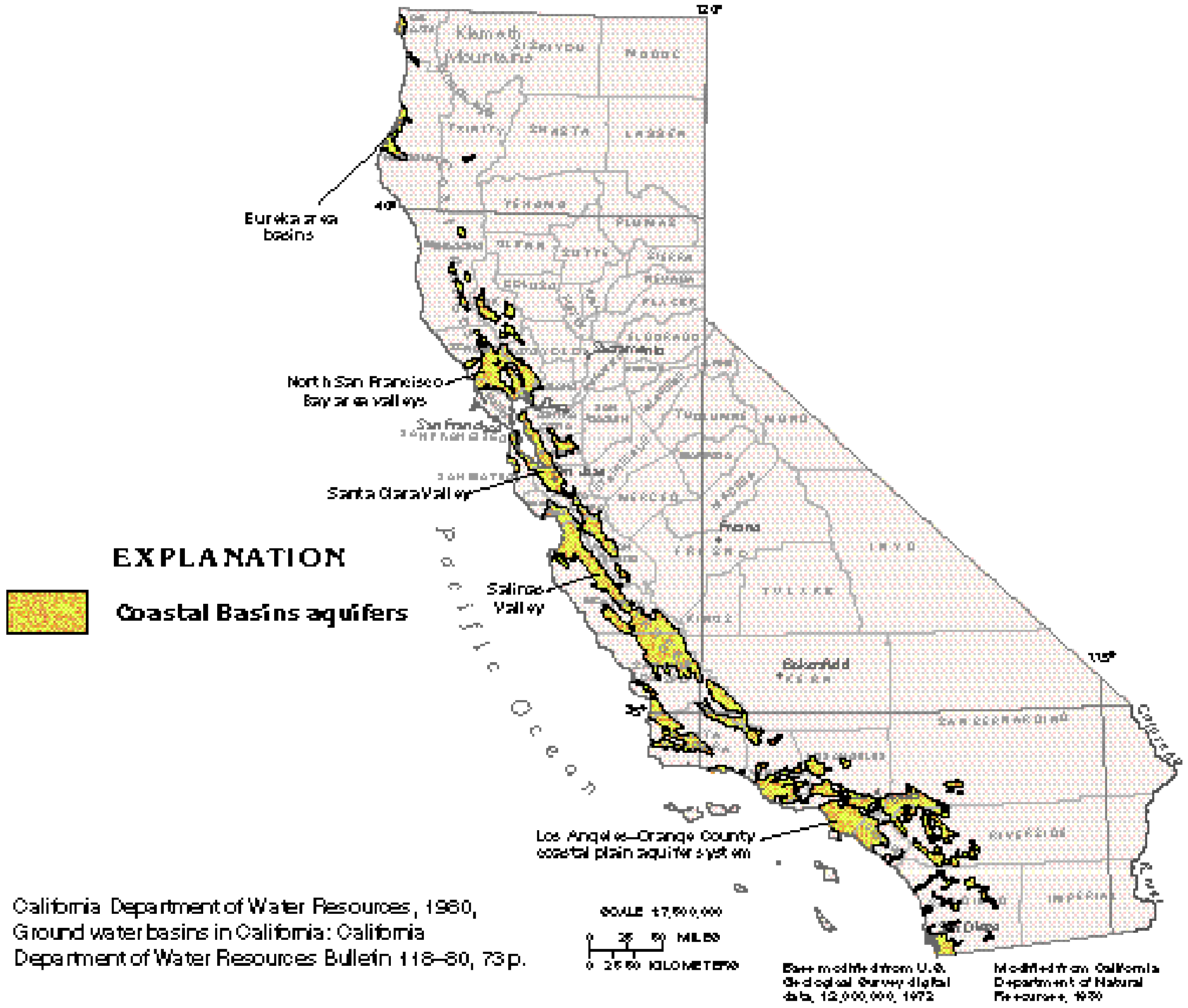
Some elastic expansion of the aquifer system has occured, but the compacted materials can never return to their pre-compacted thickness.

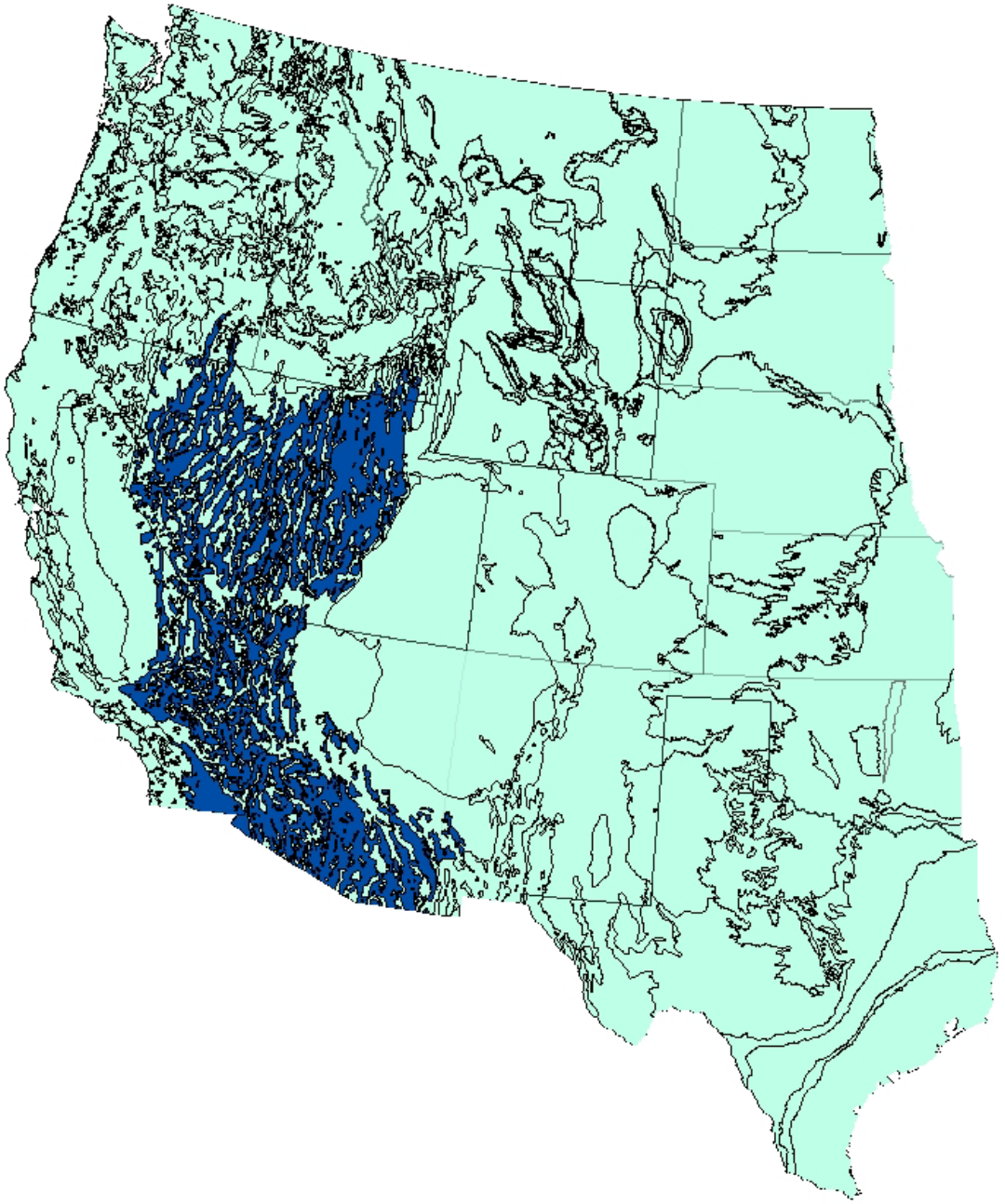
(Modified from Swanson, 1998)

USGS

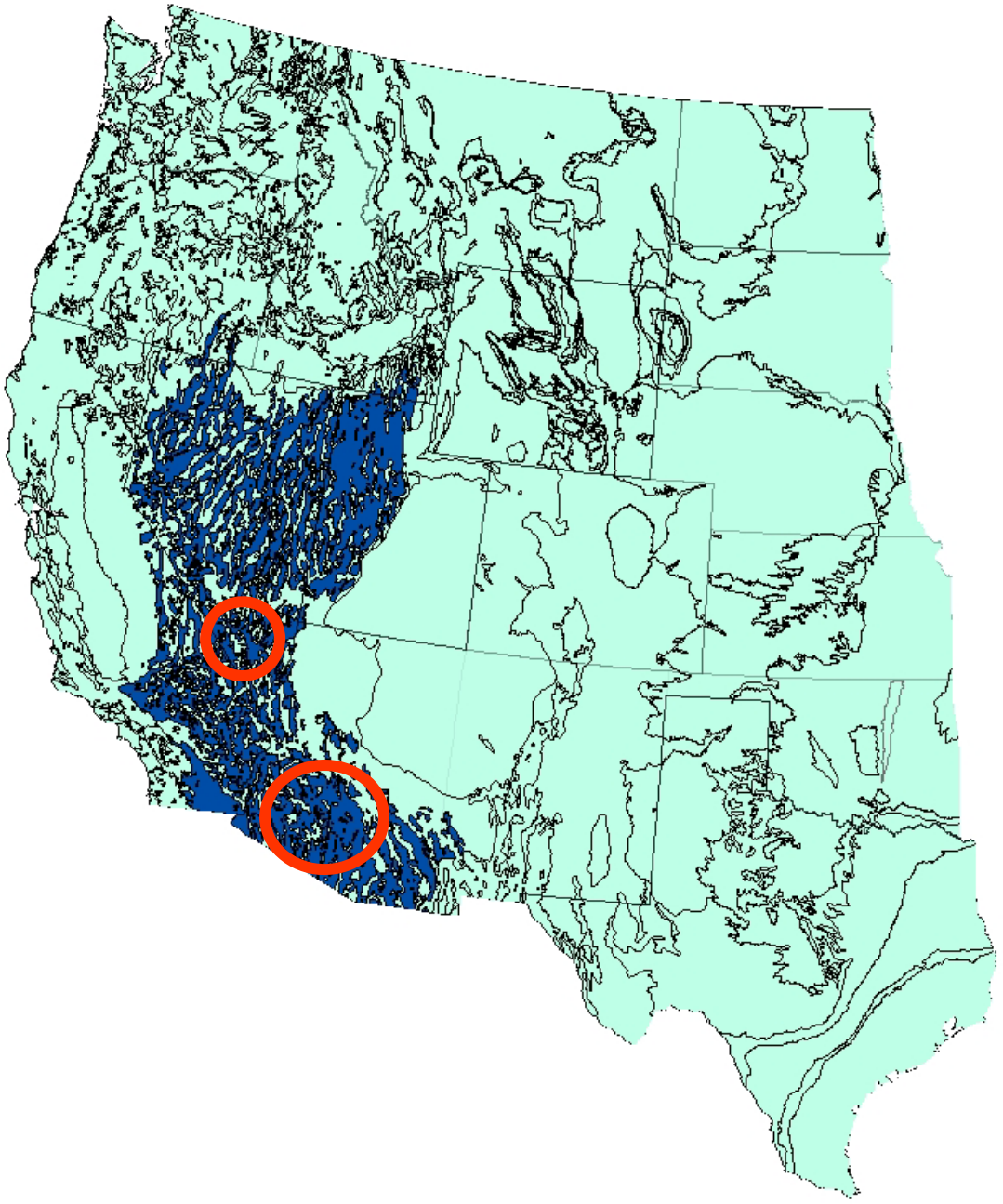


USGS

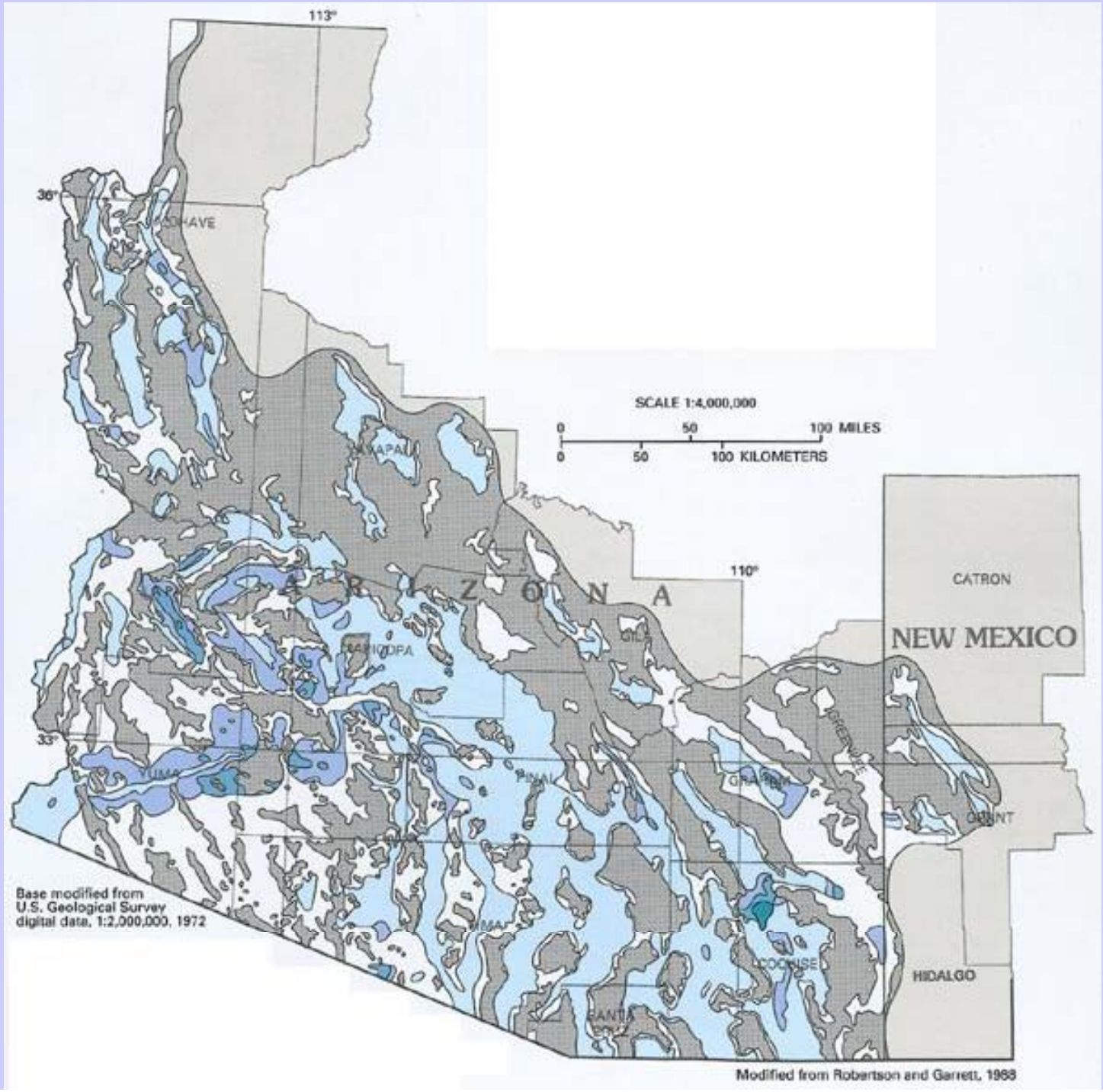

Eureka area basins
North San Francisco Bay area valleys
Santa Clara Valley
Salinas Valley
Los Angeles–Orange County coastal plain aquifer system
EXPLANATION
Coastal Basins aquifers
California Department of Water Resources, 1960, Ground water basins in California: California Department of Water Resources Bulletin 118–80, 73 p.



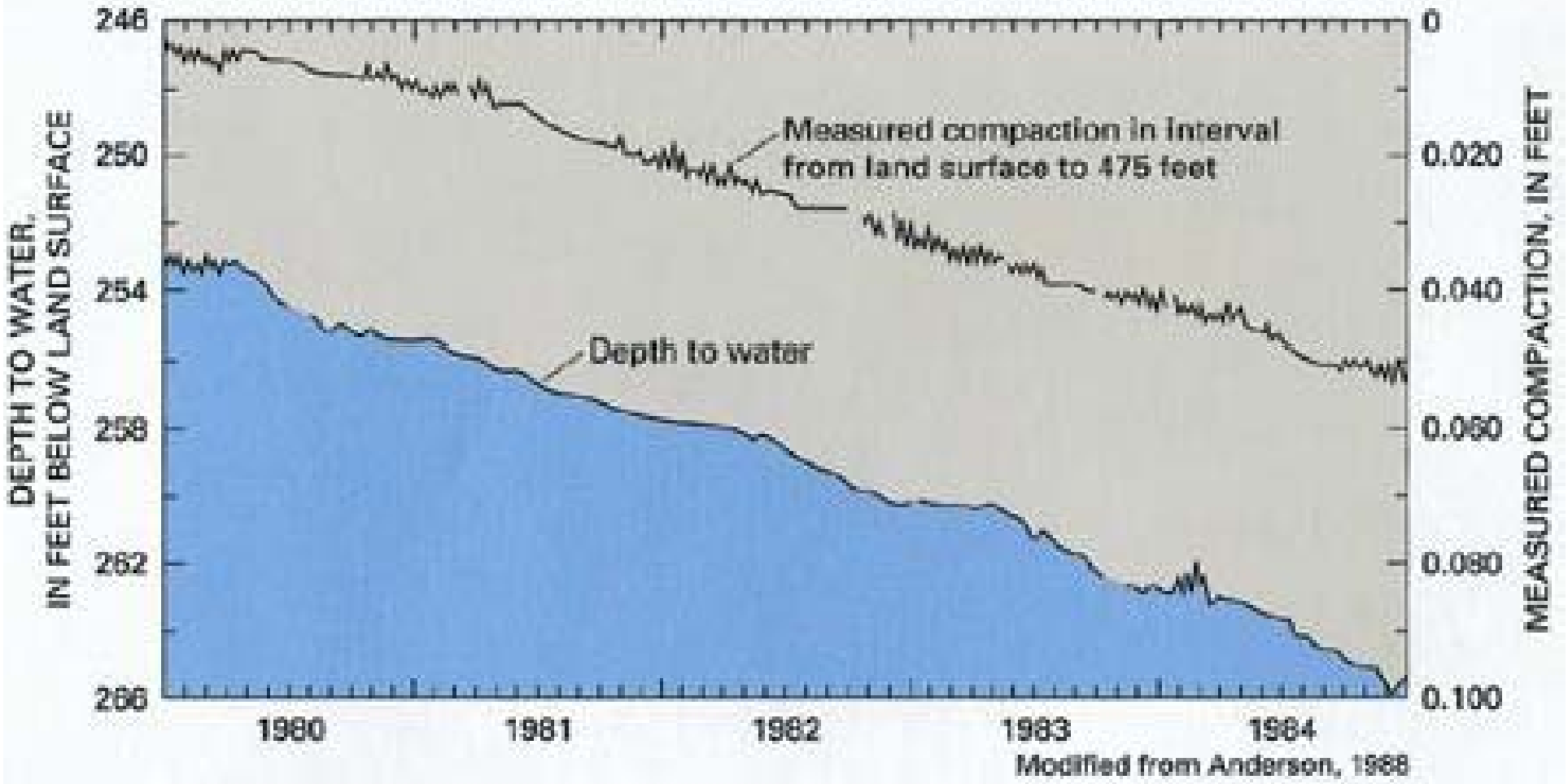
USGS

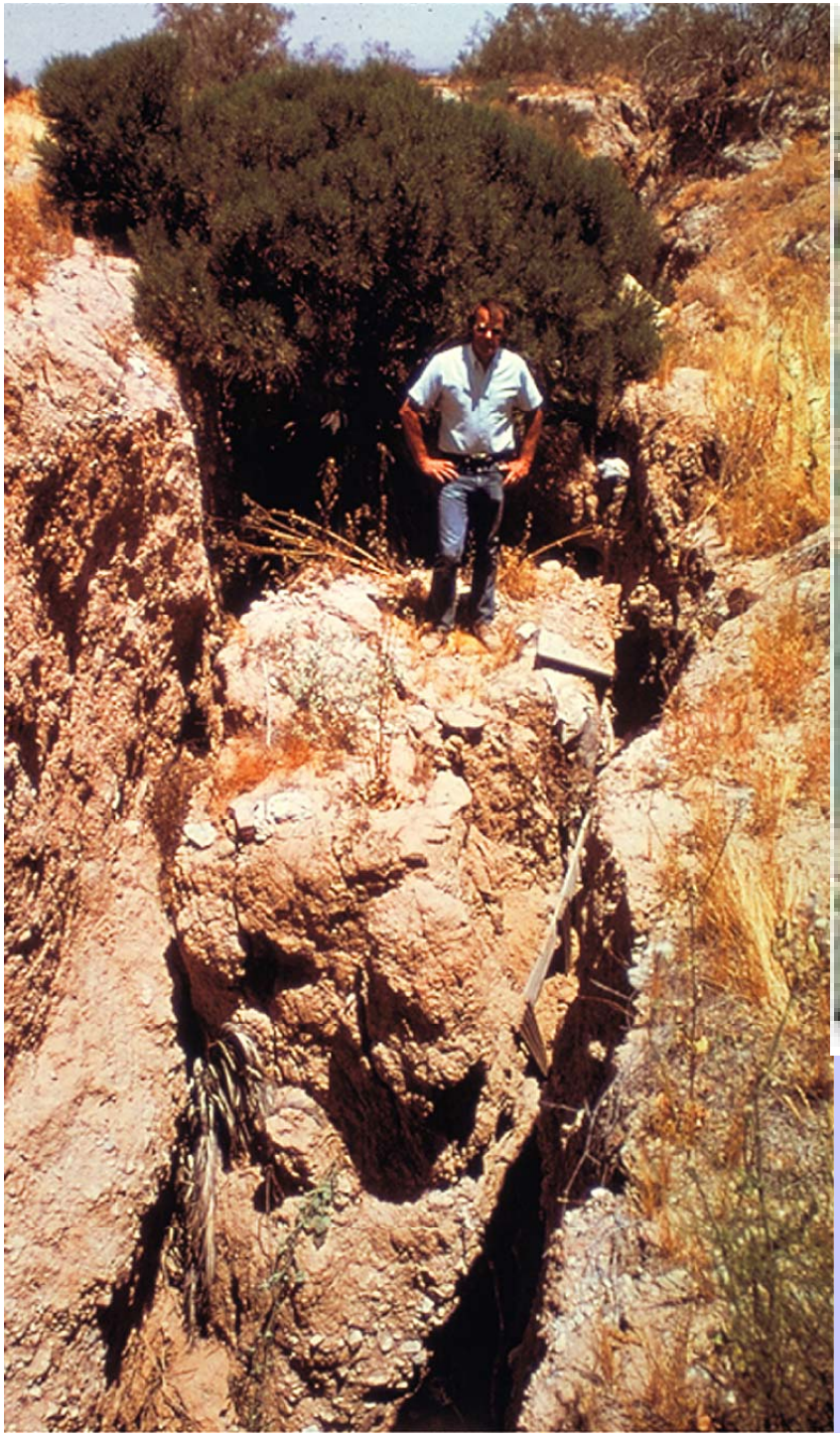


USGS


113°
36°
MOHAVE
COCONINO
SCALE 1:4,000,000
0 50 100 MILES
0 50 100 KILOMETERS
110°
A R I Z O N A
CATRON
NEW MEXICO
GILA
MARICOPA
YUMA
PIMA
GRAHAM
GREENLEE
GRANT
COCHISE
HIDALGO
SANTA CRUZ
Base modified from
U.S. Geological Survey
digital data, 1:2,000,000, 1972
Modified from Robertson and Garrett, 1983

USGS

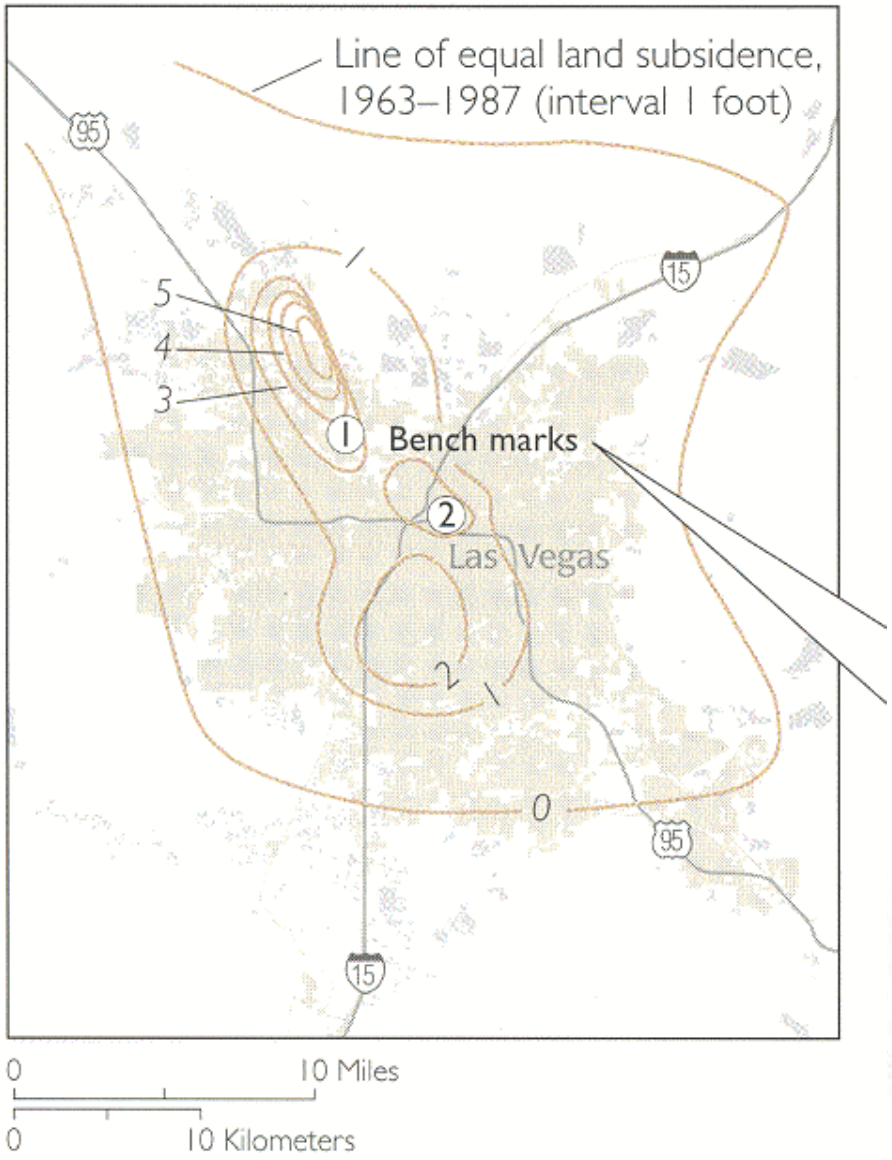

DEPTH TO WATER, IN FEET BELOW LAND SURFACE
246
250
254
258
262
266
MEASURED COMPACTION, IN FEET
0
0.020
0.040
0.060
0.080
0.100
Measured compaction in interval from land surface to 475 feet
Depth to water
1980
1981
1982
1983
1984
Modified from Anderson, 1988

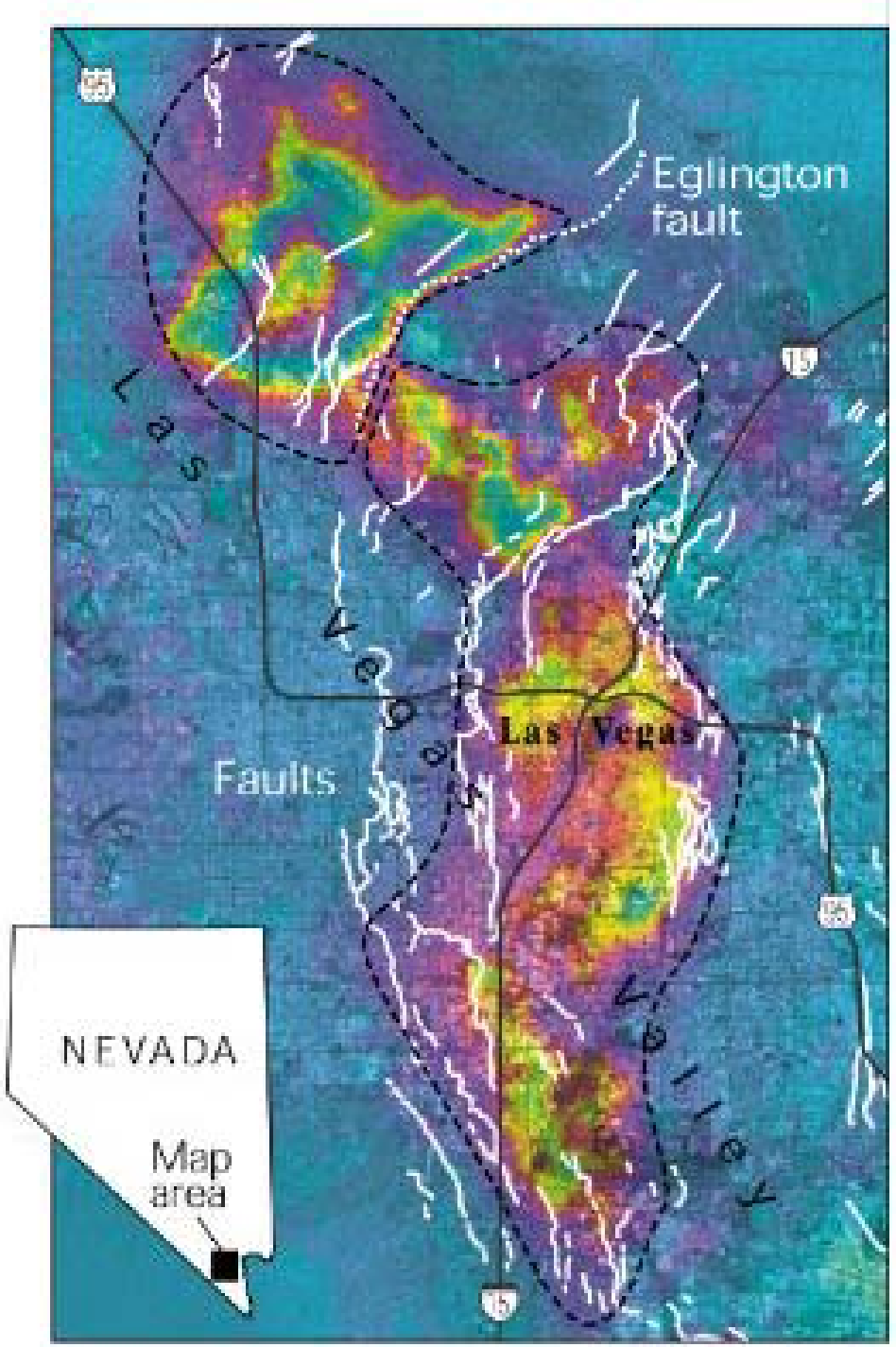


USGS

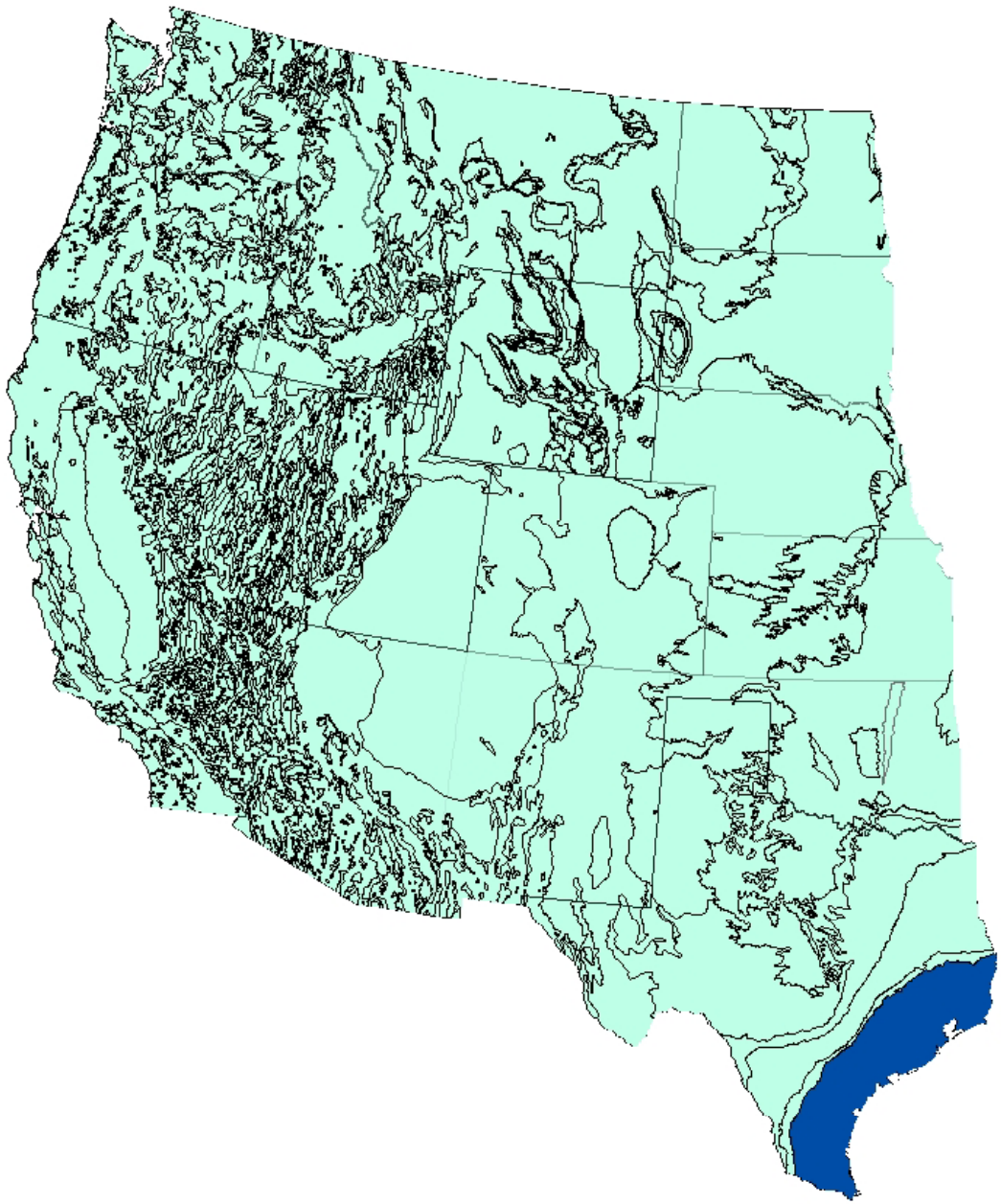
USGS

USGS

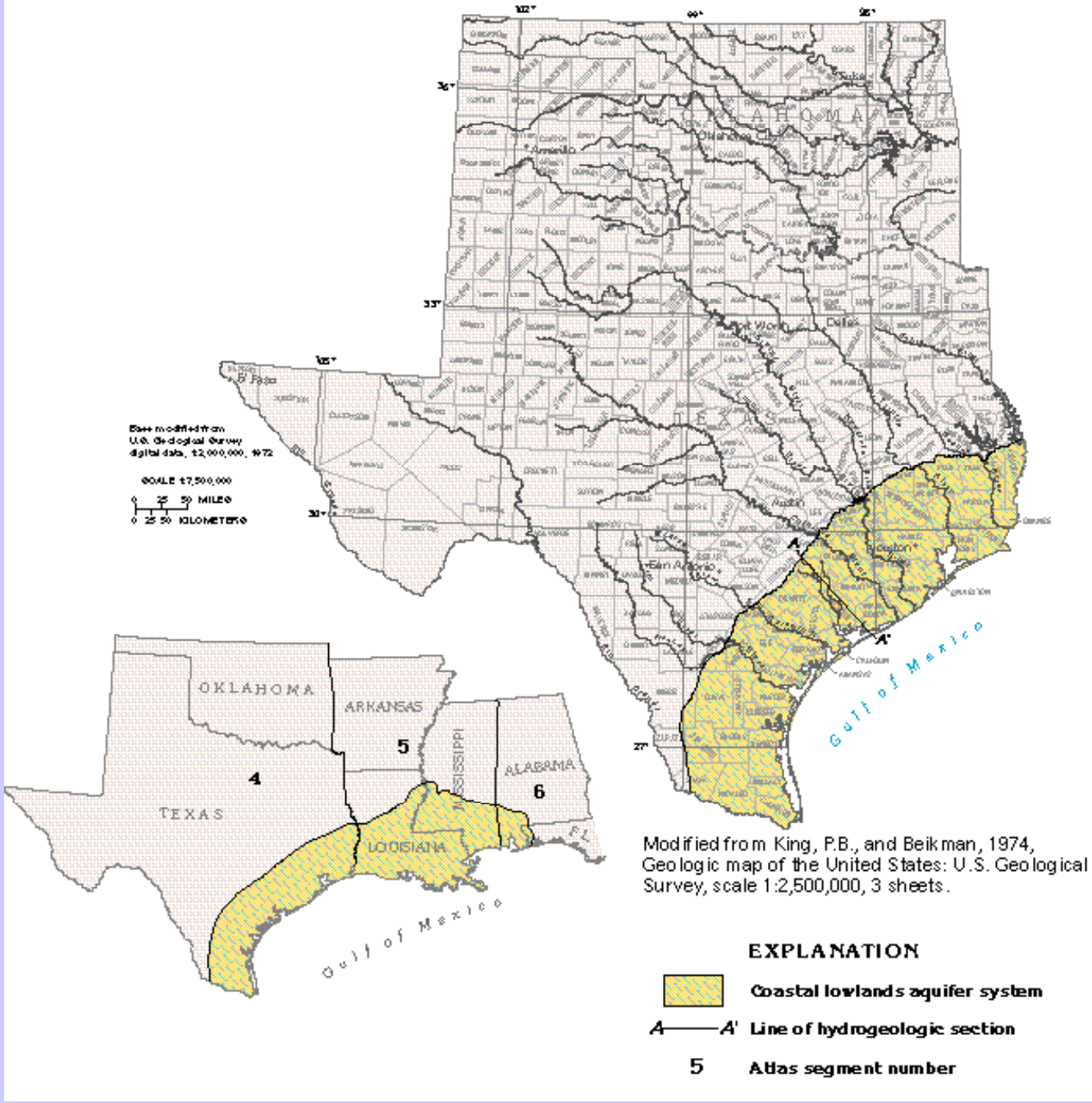

Line of equal land subsidence, 1963–1987 (interval 1 foot)
95
15
5
4
3
1
Bench marks
2
Las Vegas
2
0
95
15
0
10 Miles
0
10 Kilometers


Eglington fault
Las Vegas Valley
Las Vegas
Faults
NEVADA
Map area
95
15

USGS

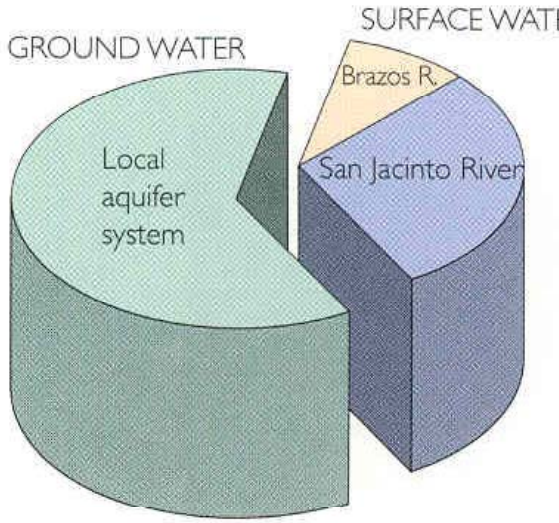


USGS


OKLAHOMA
ARKANSAS
LOUISIANA
TEXAS
MISSISSIPPI
ALABAMA
4
5
6
Gulf of Mexico
Gulf of Mexico
Base modified from
U.S. Geological Survey
digital data, 1:2,000,000, 1972
SCALE 1:7,500,000
0 25 50 MILES
0 25 50 KILOMETERS
Modified from King, P.B., and Beikman, 1974,
Geologic map of the United States: U.S. Geological
Survey, scale 1:2,500,000, 3 sheets.
EXPLANATION
Coastal lowlands aquifer system
A——A' Line of hydrogeologic section
5 Atlas segment number

USGS

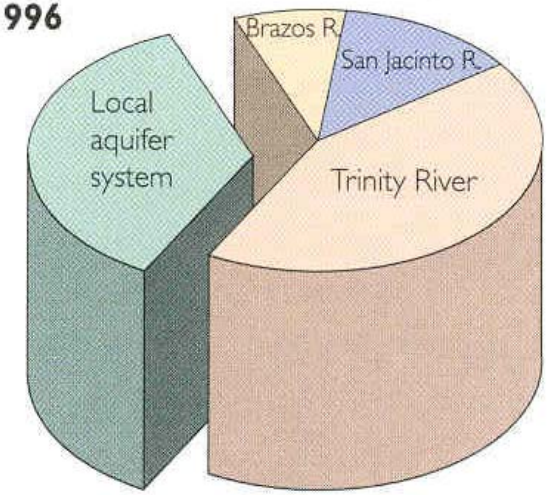
1976



TOTAL WATER USE

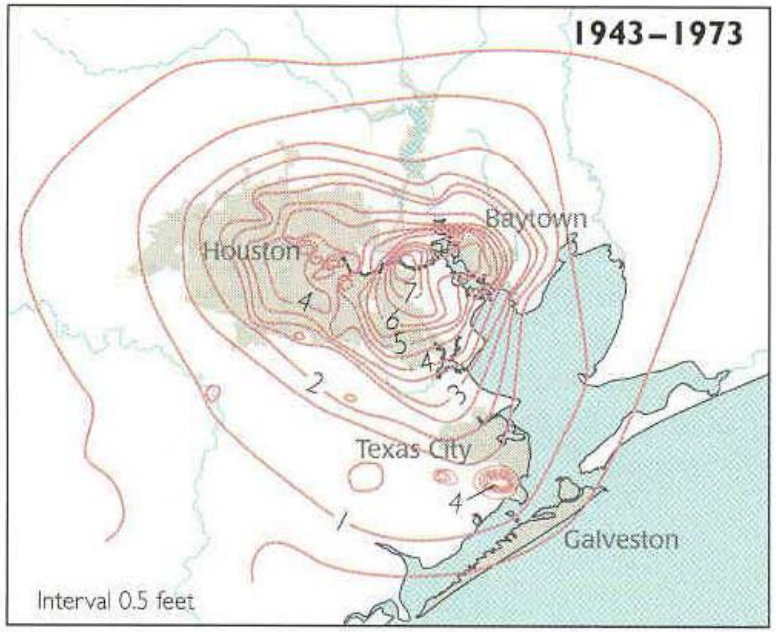
0.826 million acre-feet

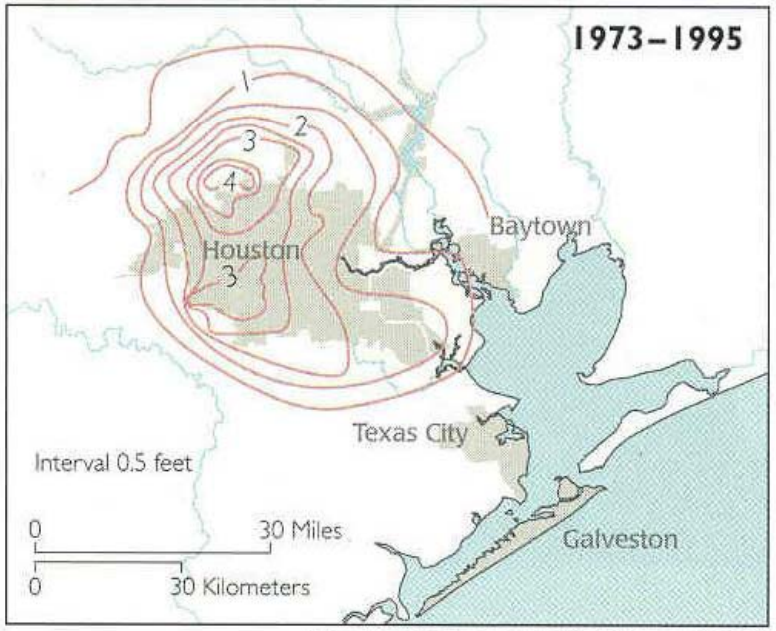
1996



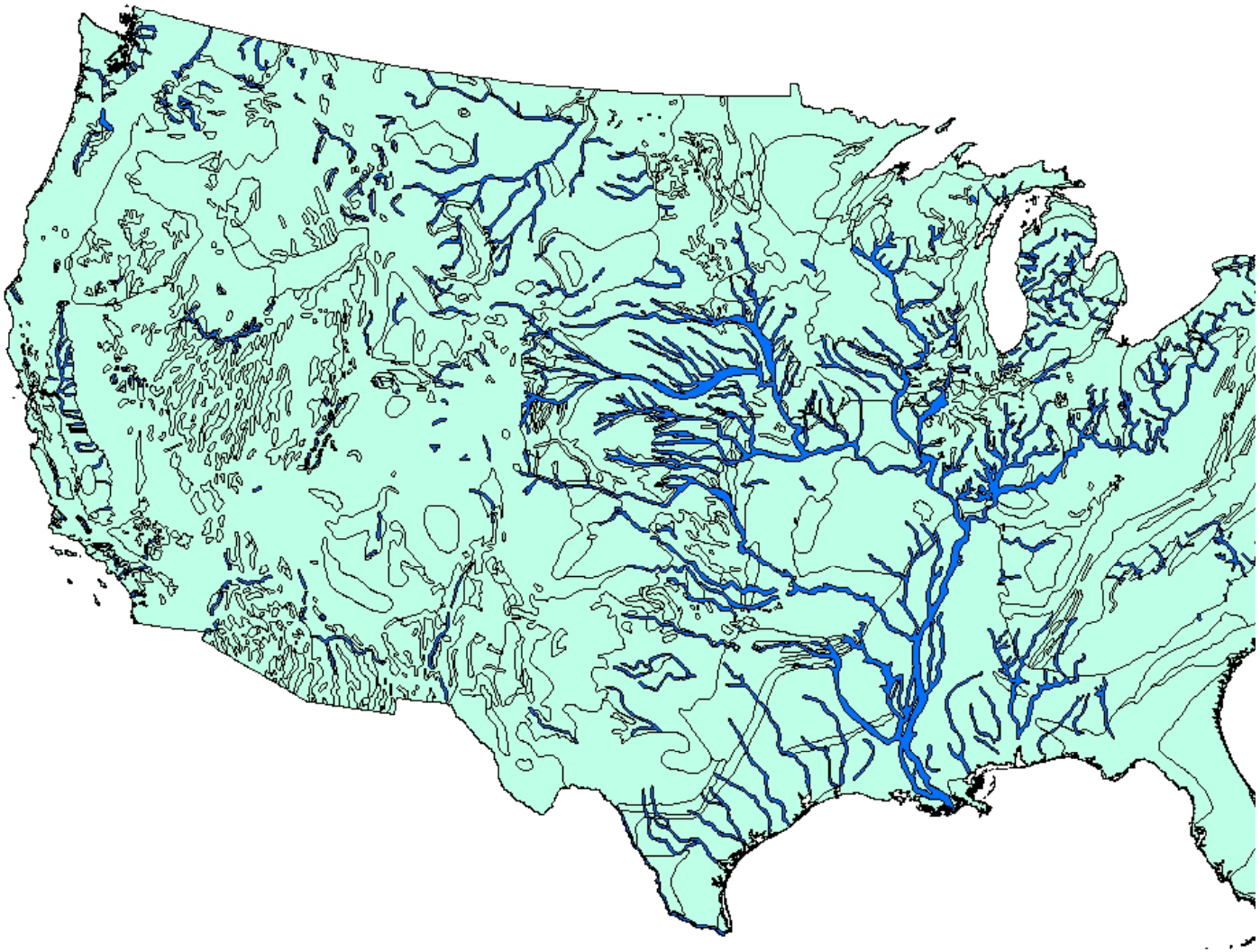
1.016 million acre-feet

As a percentage of the total, ground-water use has dropped significantly, but total water use is rising.

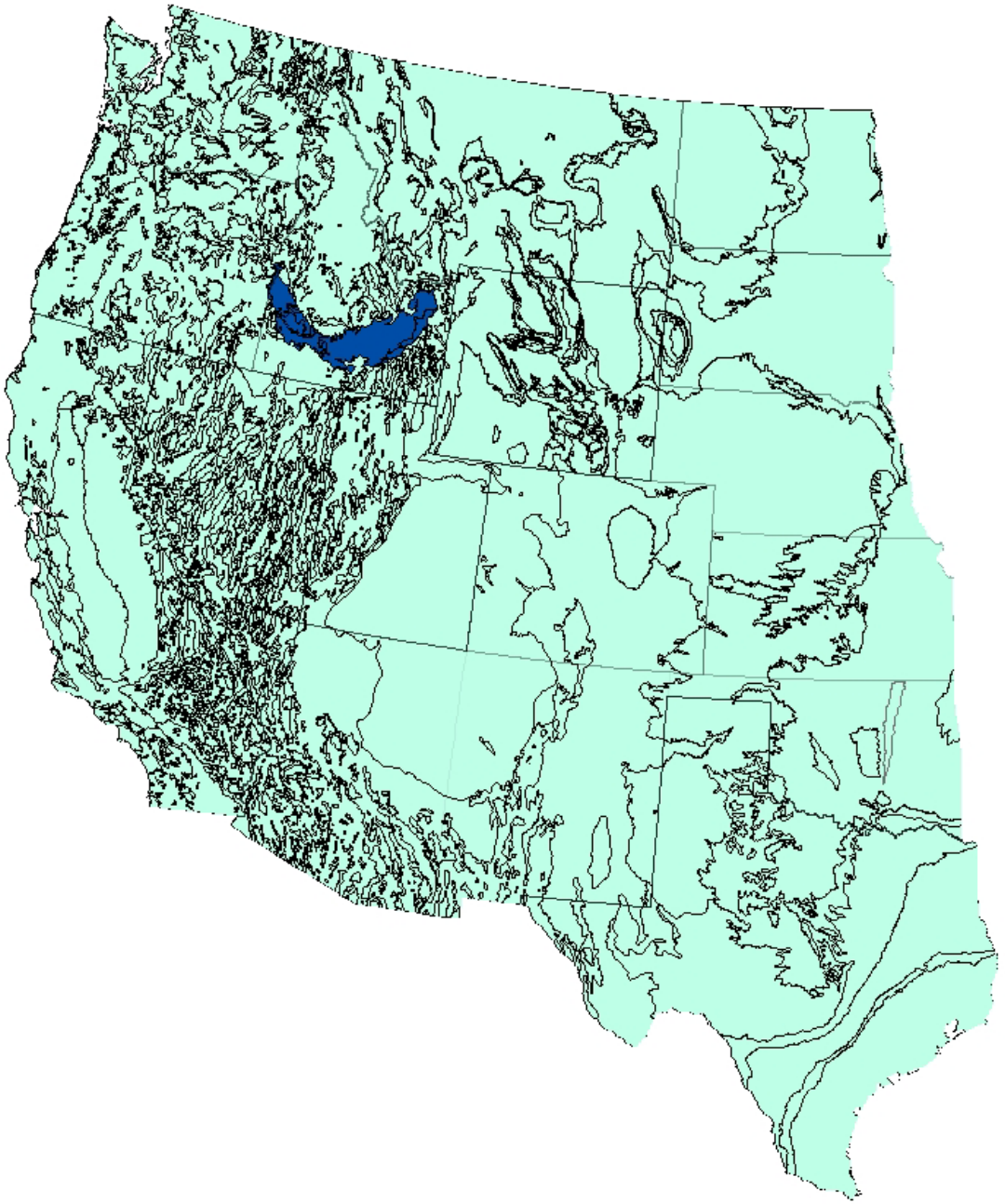




(Harris-Galveston Coastal Subsidence District)



USGS



USGS

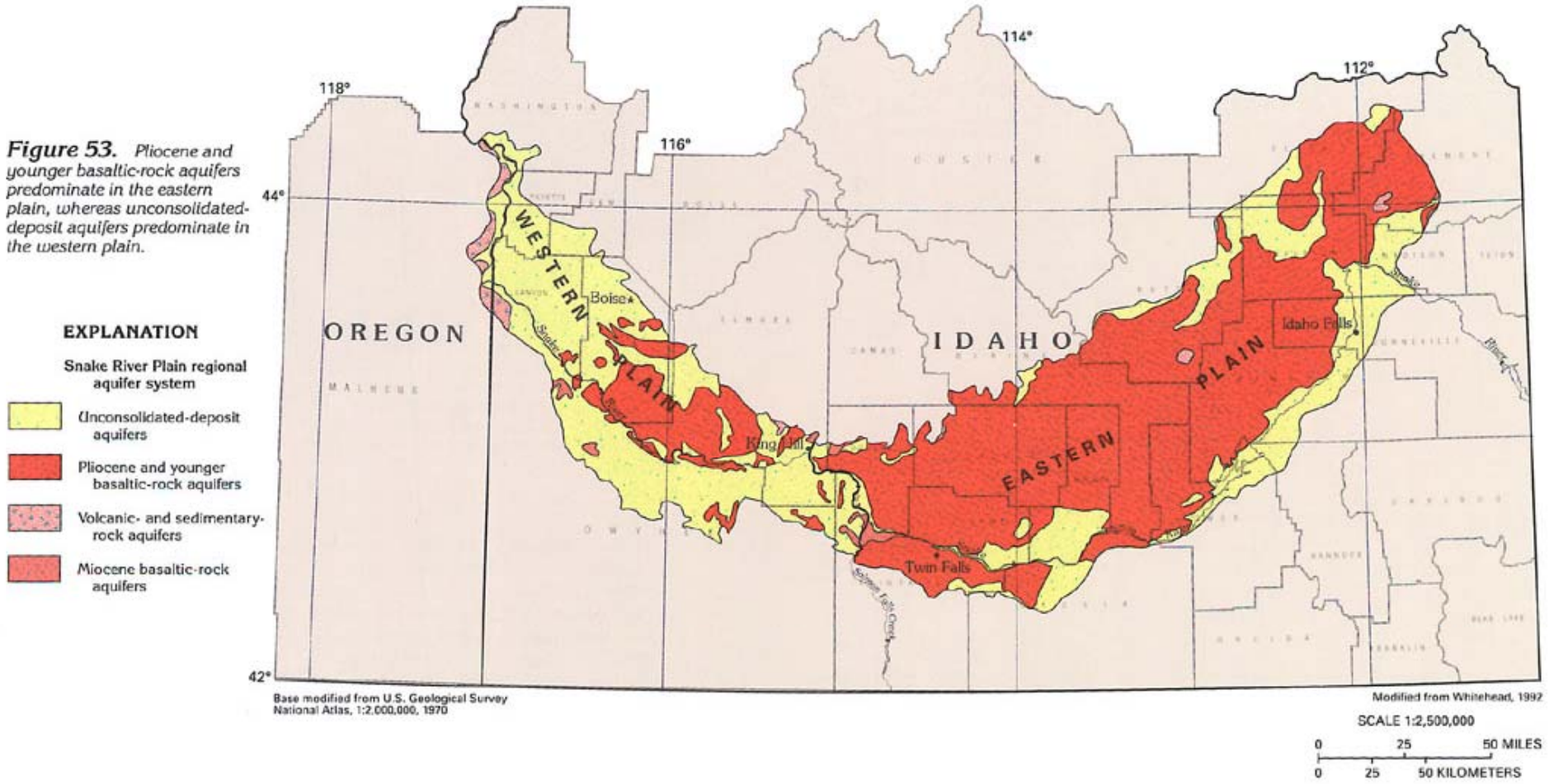
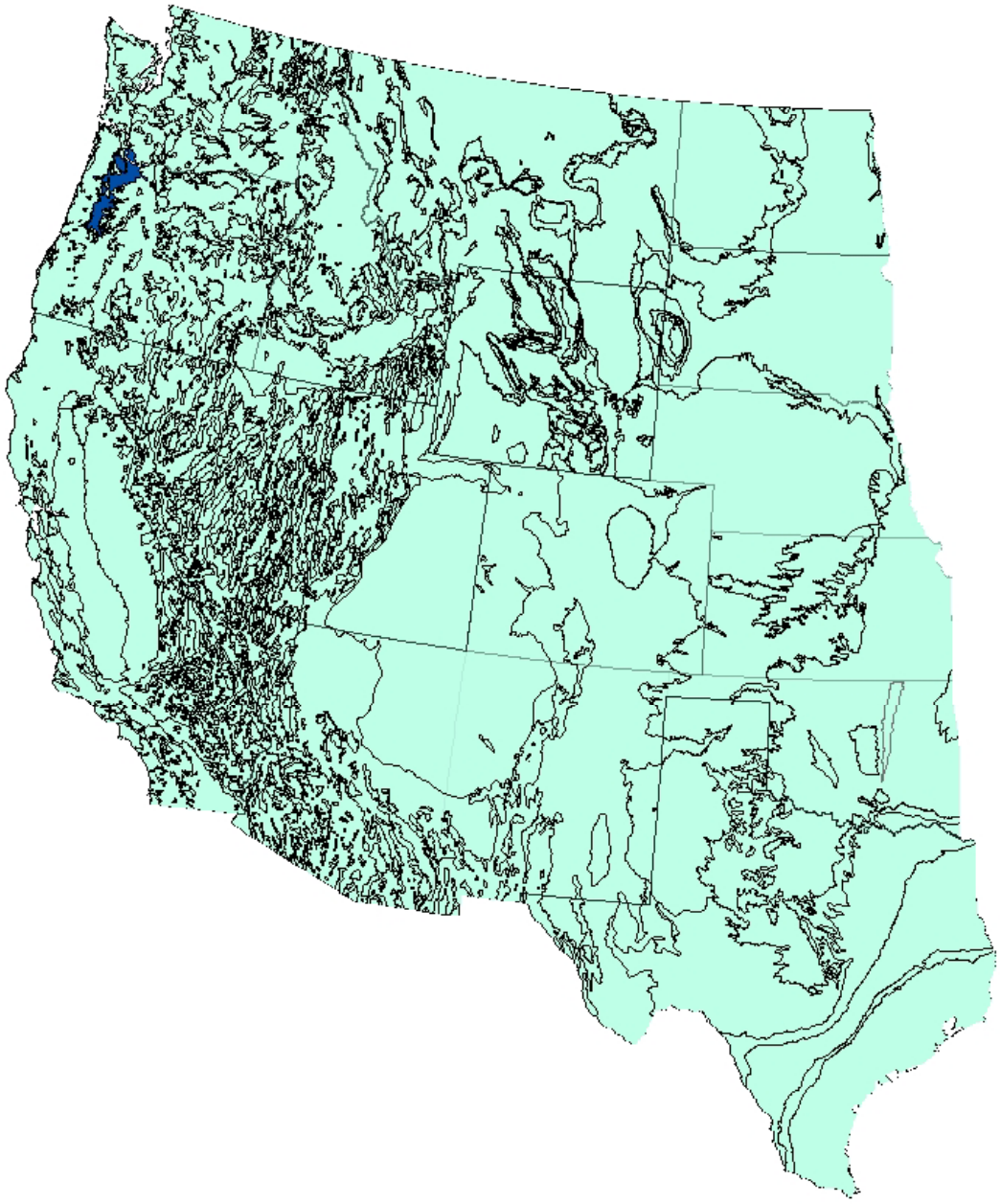


Figure 53. *Pliocene and younger basaltic-rock aquifers predominate in the eastern plain, whereas unconsolidated-deposit aquifers predominate in the western plain.*

USGS



USGS

Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from Weeks and Sun, 1987

Ground Water Atlas of the United States

The series consists of 13 chapters which describe the ground-water resources of regional areas that collectively cover the 50 States, Puerto Rico, and the U.S. Virgin Islands

Area described in each chapter:

Each of the 13 chapters is published as a Hydrologic Investigations Atlas (HA).

For chapter author, table of contents and book availability:

USGS