

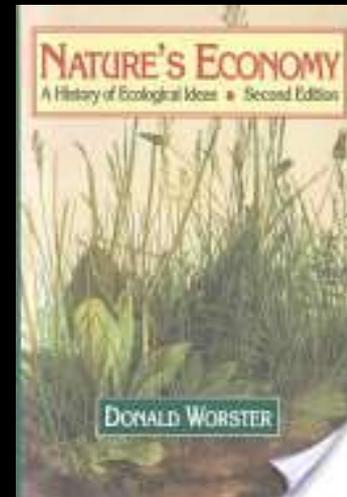
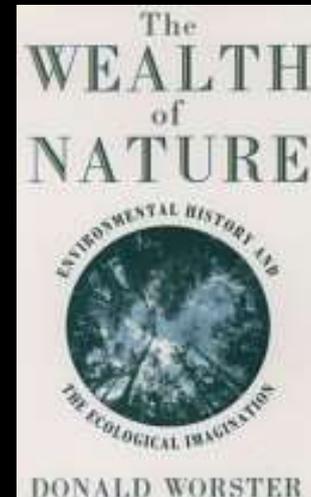
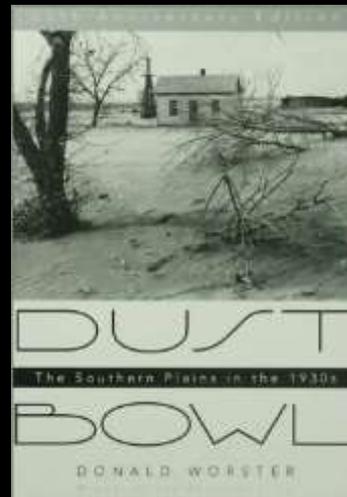
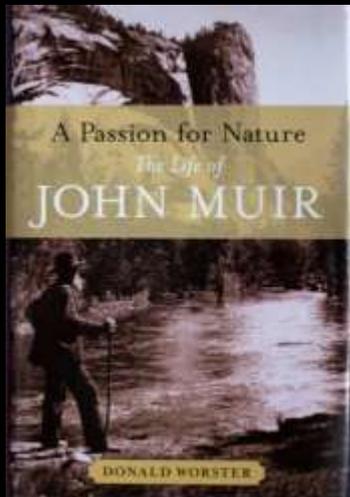
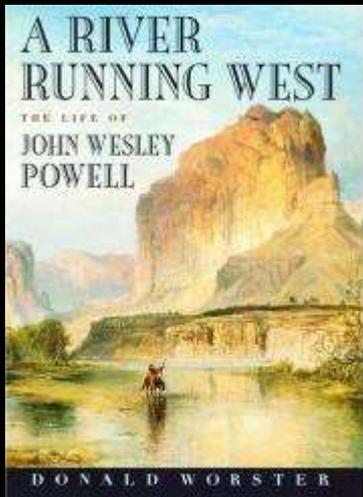
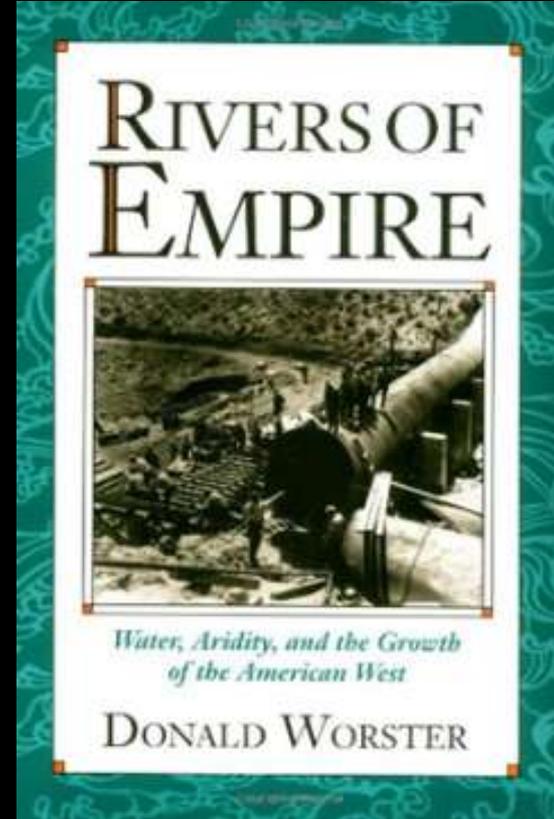


## Rivers of Empire: American Environmental History and Waterways

Kevin M. Anderson, Ph.D.  
Austin Water – Center for Environmental Research



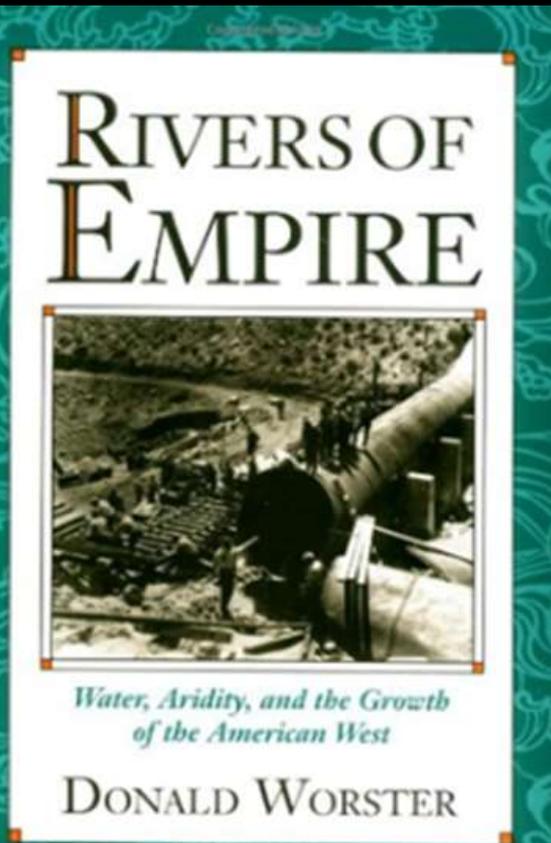
# American Environmental History and Waterways



Donald Worster – *Rivers of Empire: Water, Aridity, and the Growth of the American West* (1985)

The American Hydraulic Empire

Government-sponsored reclamation is a key factor in the development of the West.

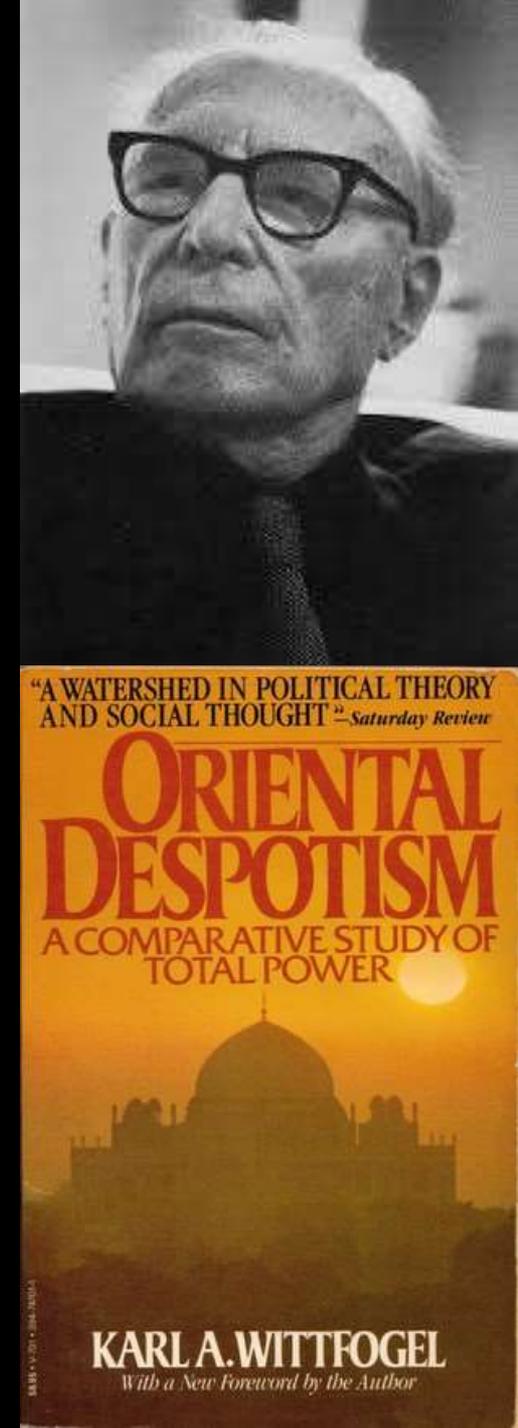


**"The Bureau that Changed the West"**



# Hydraulic Empires and Karl Wittfogel

- The term was coined by the German-American historian Karl Wittfogel (1896–1988), in his book *Oriental Despotism: A Comparative Study of Total Power* (1957).
- A social or government structure which maintains power and control through exclusive control over access to water.
- It arises through the need for flood control and irrigation, which requires central coordination and a specialized bureaucracy.
- Strong Thesis - A developed hydraulic civilization maintains control over its population by means of controlling the supply of water.



# Hydraulic Empire?



# Waterways and Ancient American Empires



# The Cultural Geography of the Americas pre-1492

The American population in 1492 - 54 million  
The population north of Mexico - 8-10 million



The  
Native  
Population  
of the Americas  
in 1492 SECOND EDITION

EDITED BY William M. Denevan

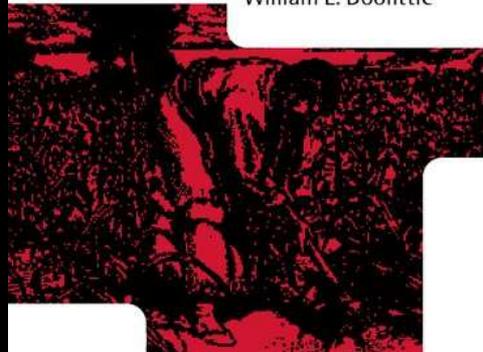


WITH A FOREWORD BY W. George Lovell

OXFORD GEOGRAPHICAL AND ENVIRONMENTAL STUDIES

Cultivated  
Landscapes of  
Native North America

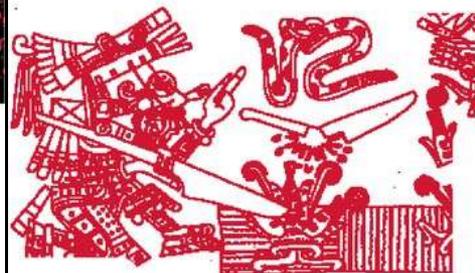
William E. Doolittle



OXFORD GEOGRAPHICAL AND ENVIRONMENTAL STUDIES

Cultivated Landscapes  
of Middle America on the  
Eve of Conquest

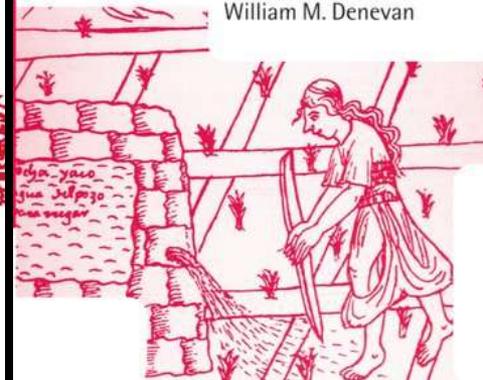
Thomas M. Whitmore  
and B. L. Turner II



OXFORD GEOGRAPHICAL AND ENVIRONMENTAL STUDIES

Cultivated Landscapes  
of Native Amazonia and  
the Andes

William M. Denevan



NATIONAL BESTSELLER

"Marvelous... A sweeping portrait of human life in the Americas before the arrival of Columbus... A remarkably engaging writer."  
—The New York Times Book Review

# 1491

NEW REVELATIONS OF THE AMERICAS BEFORE COLUMBUS



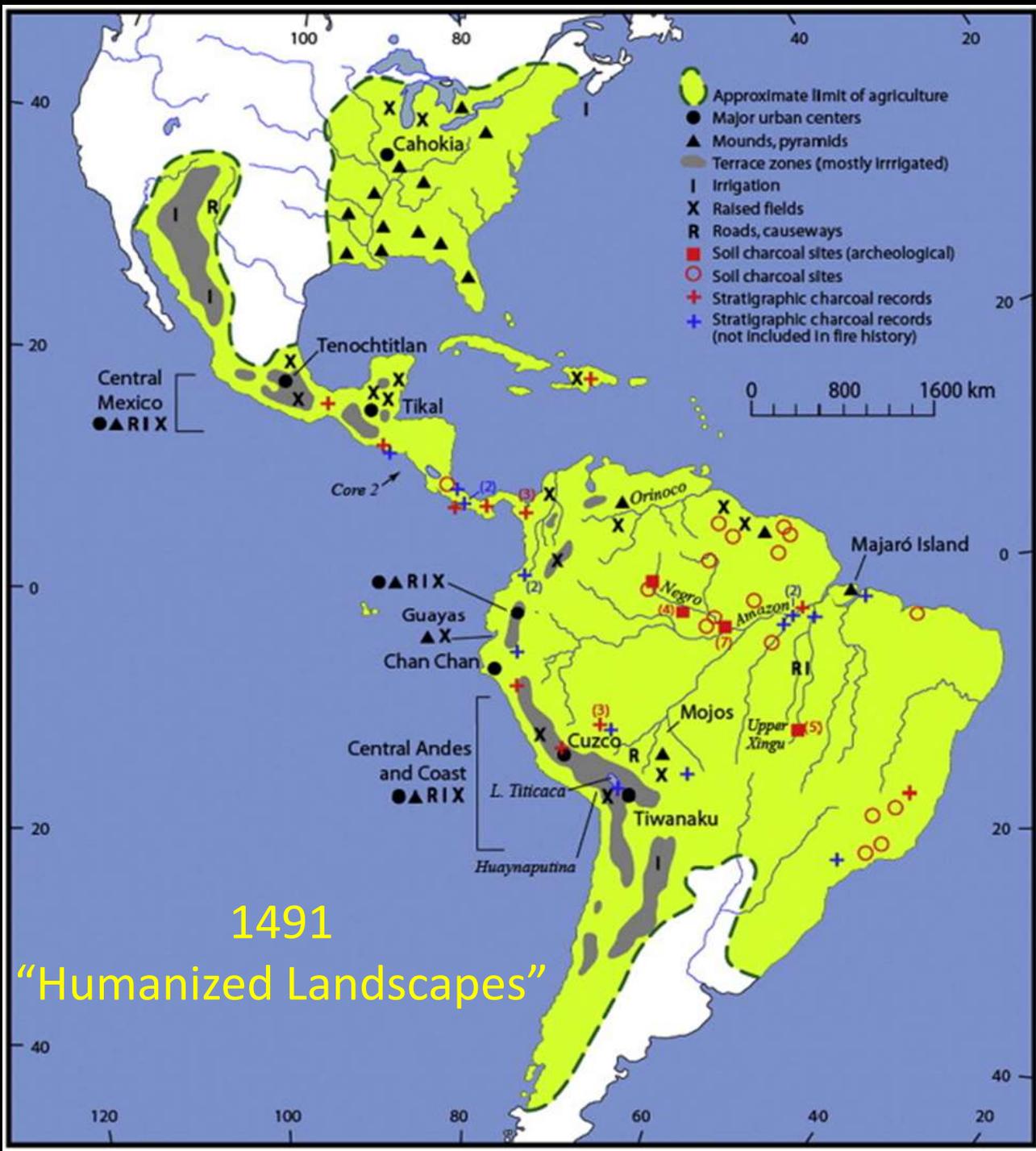
CHARLES C. MANN  
WITH A NEW AFTERWORD

# 1493

UNCOVERING THE NEW WORLD COLUMBUS CREATED



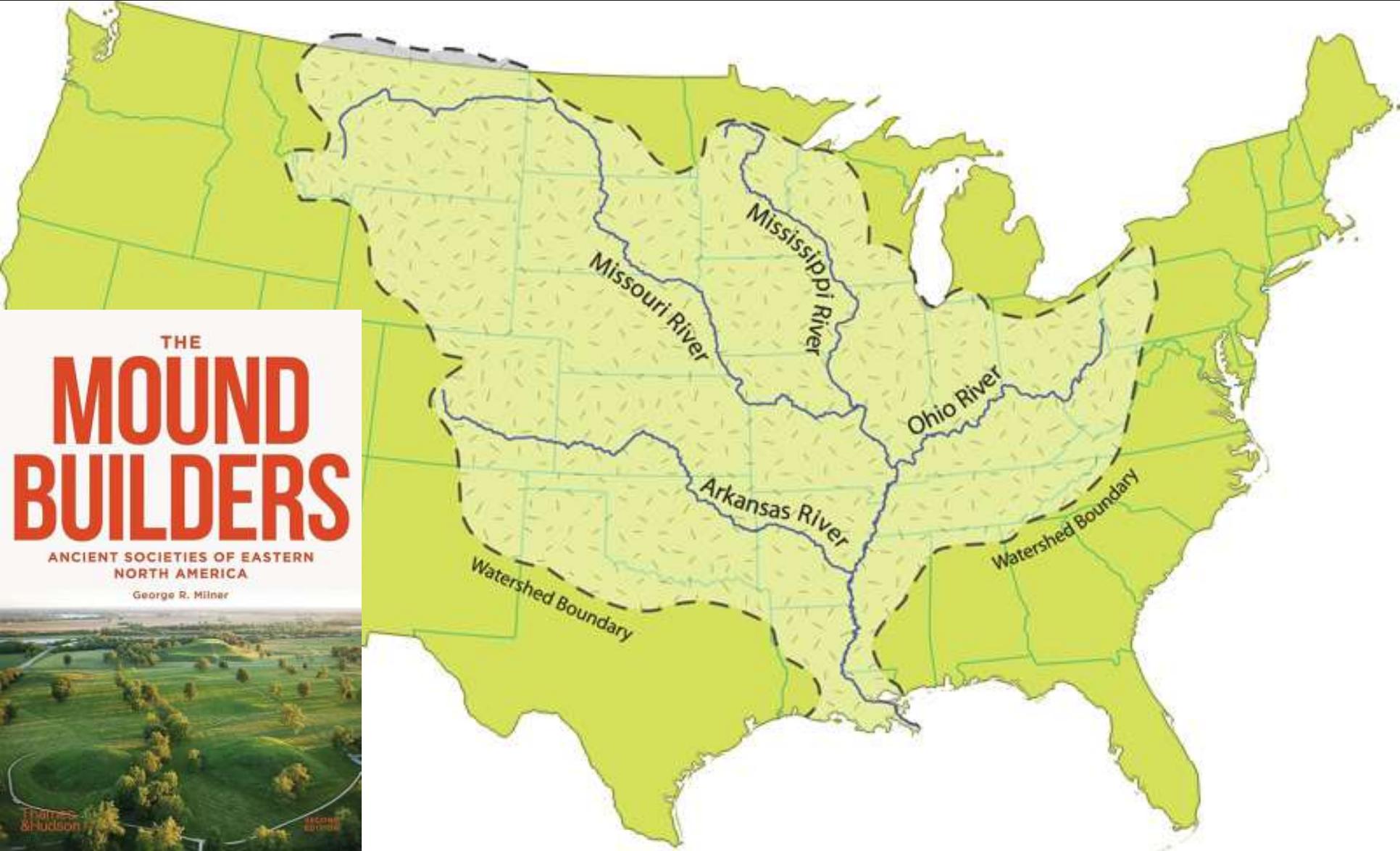
CHARLES C. MANN  
Author of 1491





# American Hydraulic Empire

## The Mississippi Basin and Ancient Cultures

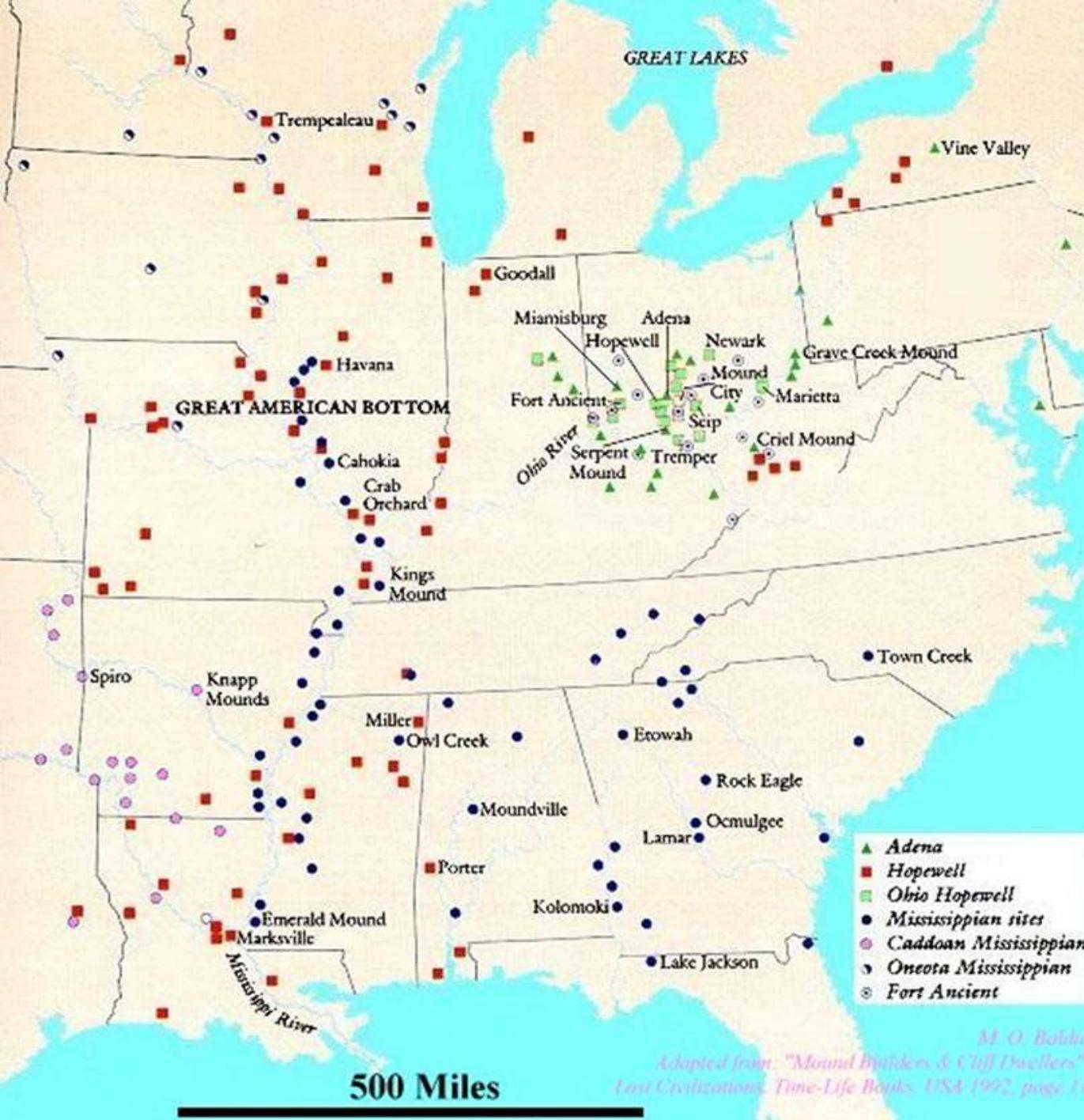


**THE**  
**MOUND**  
**BUILDERS**  
ANCIENT SOCIETIES OF EASTERN  
NORTH AMERICA  
George R. Milner



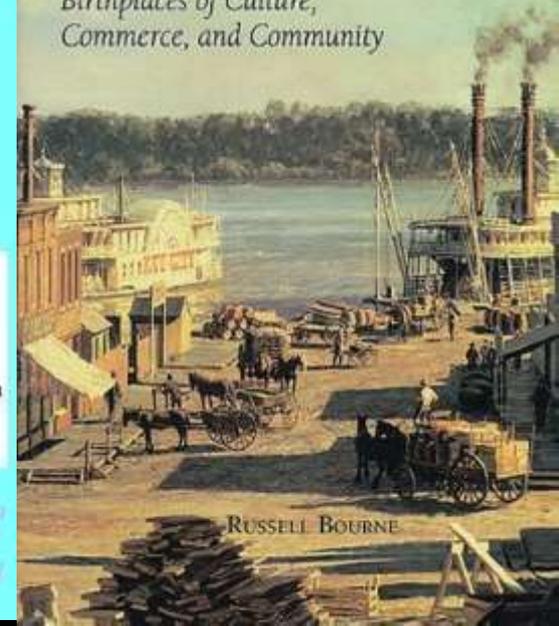
# Mississippian Culture

## The People of the Rivers



# RIVERS OF AMERICA

Birthplaces of Culture, Commerce, and Community



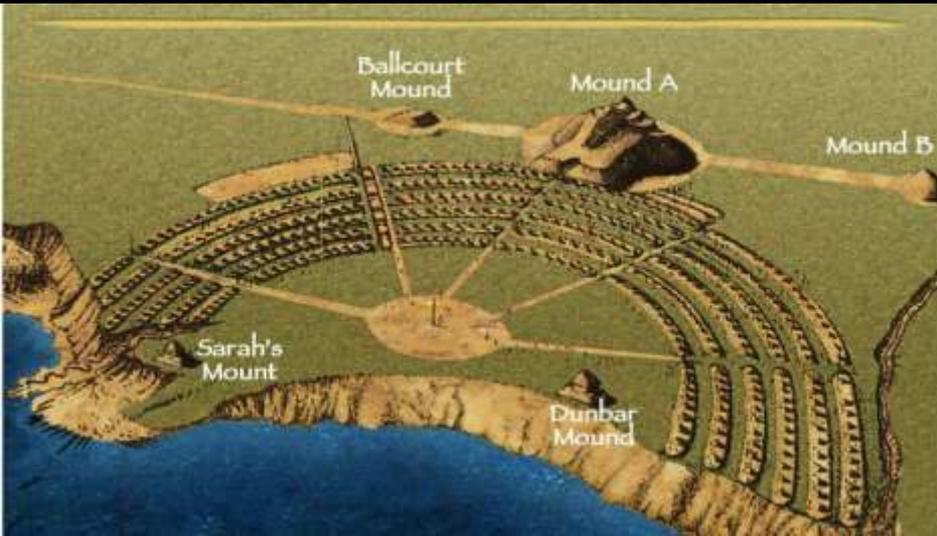
# Watson Brake 4000 BCE

- Watson Brake in northeastern Louisiana is considered the oldest earthwork mound complex in North America.
- A society of hunter-fisher-gatherers
- Indigenous peoples started building earthwork mounds in North America before the pyramids in Egypt or Stonehenge.
- Mound construction took place over six hundred to seven hundred years, from 3500 BCE to sometime after 2800 BCE.
- The site contains eleven earthen mounds connected by ridges.



# Poverty Point 1700 BCE – 1100 BCE

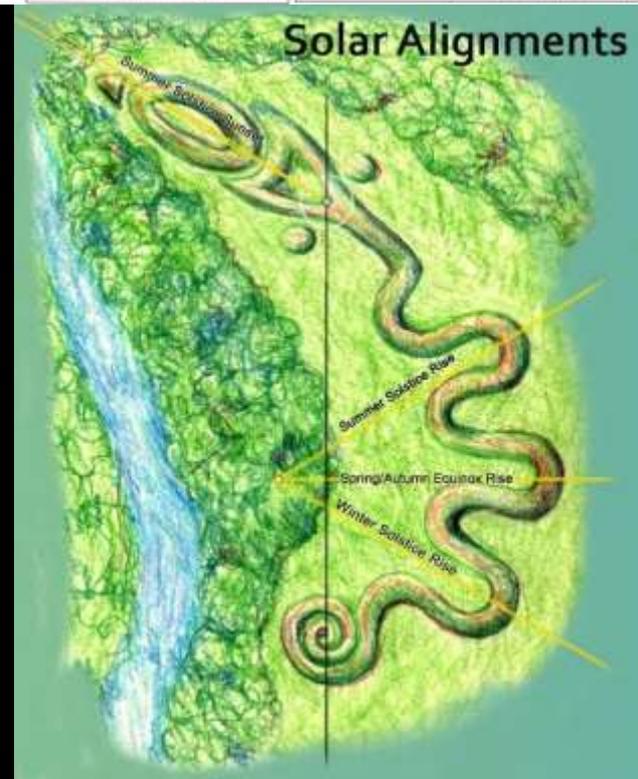
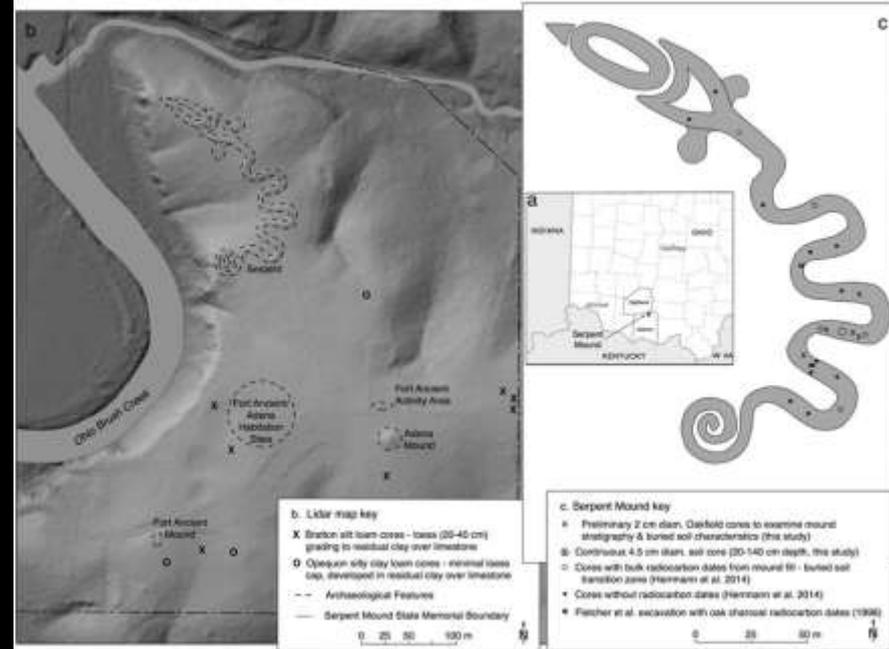
- Located on more than 400 acres, it is a series of earthen mounds and ridges that overlook the Mississippi River flood plain in what is now northeastern Louisiana.
- It was created and used for residential and ceremonial purposes.
- At its peak 3,000 years ago it was part of an enormous trading network that stretched for hundreds of miles across the continent.



# Serpent Mound

300 BCE? 1000 AD?

- Located in southern Ohio
- The largest serpent effigy in the world



# American Hydraulic Empire

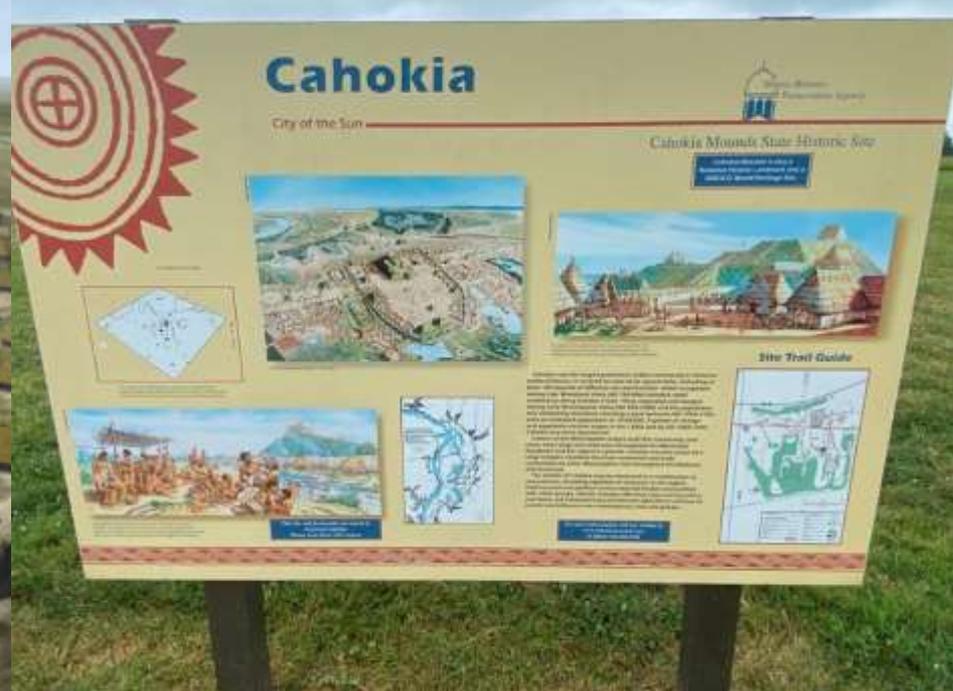
The Mississippian Culture reached its climax about 1200 AD  
An Agricultural Society



**Native American  
Three Sisters Garden**

Grow a living history garden: gorgeous multicolored Indian Corn.





1000 AD -1300 AD

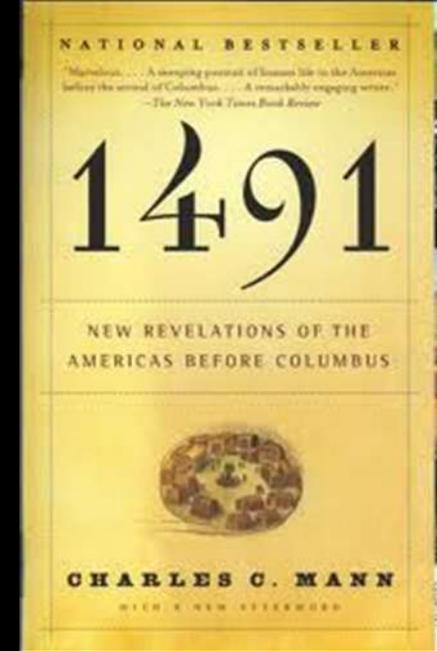
## Cahokia – The Center of the Mississippian Culture

- Located near present day St. Louis, Cahokia was the great city of the Mississippian Culture where groupings of pyramids and burial mounds cover five square miles.
- Cahokia's population at its peak in the 1200s, and its ancient population would not be surpassed by any city in the United States until about the year 1800.
- In 1200, its population was about 15,000, comparable to that of London or Paris during the same period.

# Cahokia 1100 AD

“Anyone who traveled up the Mississippi in 1100 AD would have seen it looming in the distance: a four-level earthen mound bigger than the Great Pyramid of Giza...

Cahokia was a busy port...Covering five square miles and housing at least fifteen thousand people. Cahokia was the biggest concentration of people north of the Rio Grande until the eighteenth century.” Mann, *1491*



# Monks Mound

The largest prehistoric earthwork in the Americas

Chickasaw National Monument  
Cahokia Mounds State Historic Site

**Monks Mound** is the largest prehistoric earthenwork in the Americas. Its base covers more than 14 acres, and it rises to a height of 100 feet or more. It is situated on a hillside overlooking the Mississippi River, and it is one of the largest earthen mounds in the Cahokia area. It was built by the Mississippian culture, and it is one of the largest earthen mounds in the Cahokia area. It was built by the Mississippian culture, and it is one of the largest earthen mounds in the Cahokia area.

**Site Trail Guide**

**Mound Parks**

1) South Group  
2) North Group  
3) East Group  
4) West Group

**Monks Mound**

1) South Group  
2) North Group  
3) East Group  
4) West Group

**Monks Mound**

1) South Group  
2) North Group  
3) East Group  
4) West Group

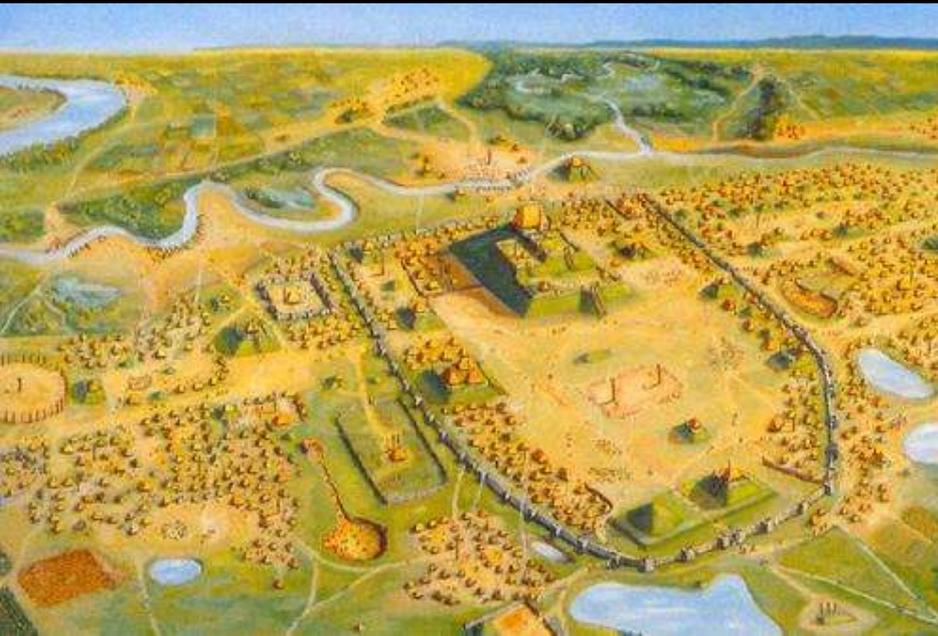
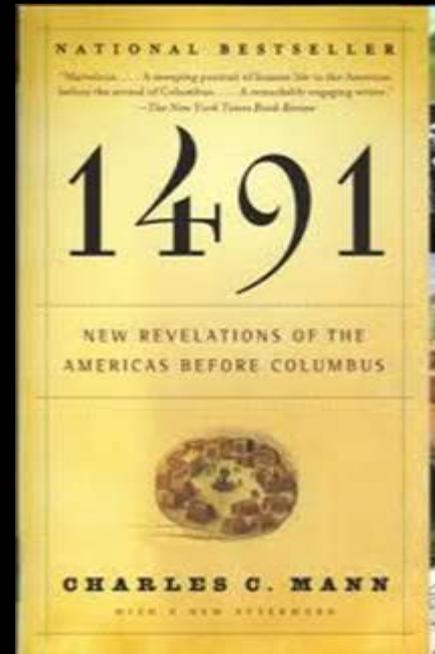


# Decline and Disappearance 1300 AD

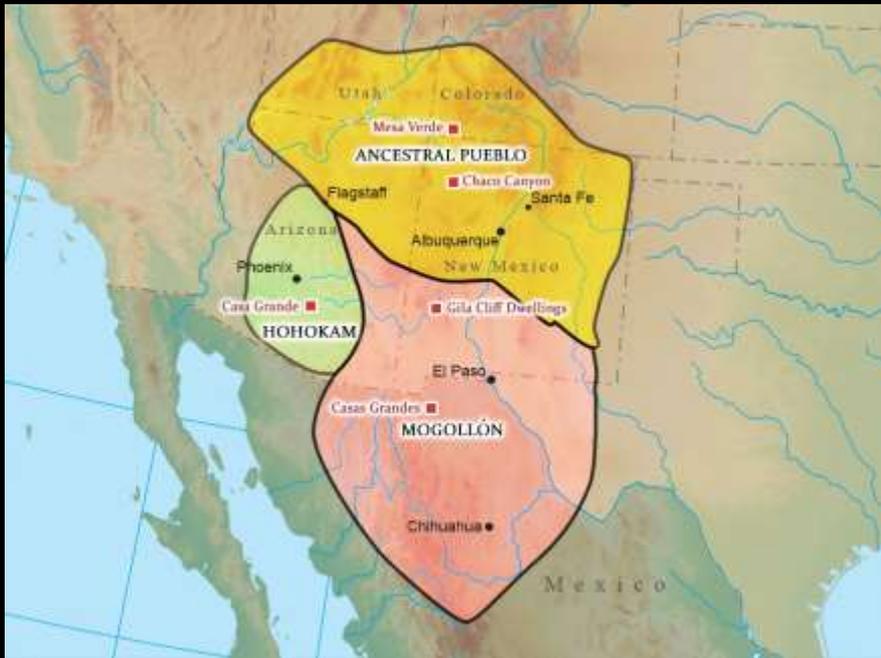
Cahokia began to decline after 1300 AD. It was abandoned more than a century before Europeans arrived in North America.

“To obtain fuel and construction material and to grow food, they cleared trees and vegetation from the bluffs to the east and planted every inch of arable land. Because the city’s numbers kept increasing, the forest could not return. Instead people kept moving further out to get timber, which then had to be carried considerable distances...Meanwhile...the city began to outstrip its water supply...”

Mann, *1491*



# Western Humanized Landscapes – Southwest Irrigation Cultures





OXFORD GEOGRAPHICAL AND ENVIRONMENTAL STUDIES



# Cultivated Landscapes of Native North America

William E. Doolittle



# CANAL IRRIGATION IN PREHISTORIC MEXICO

## The Sequence of Technological Change



William E. Doolittle

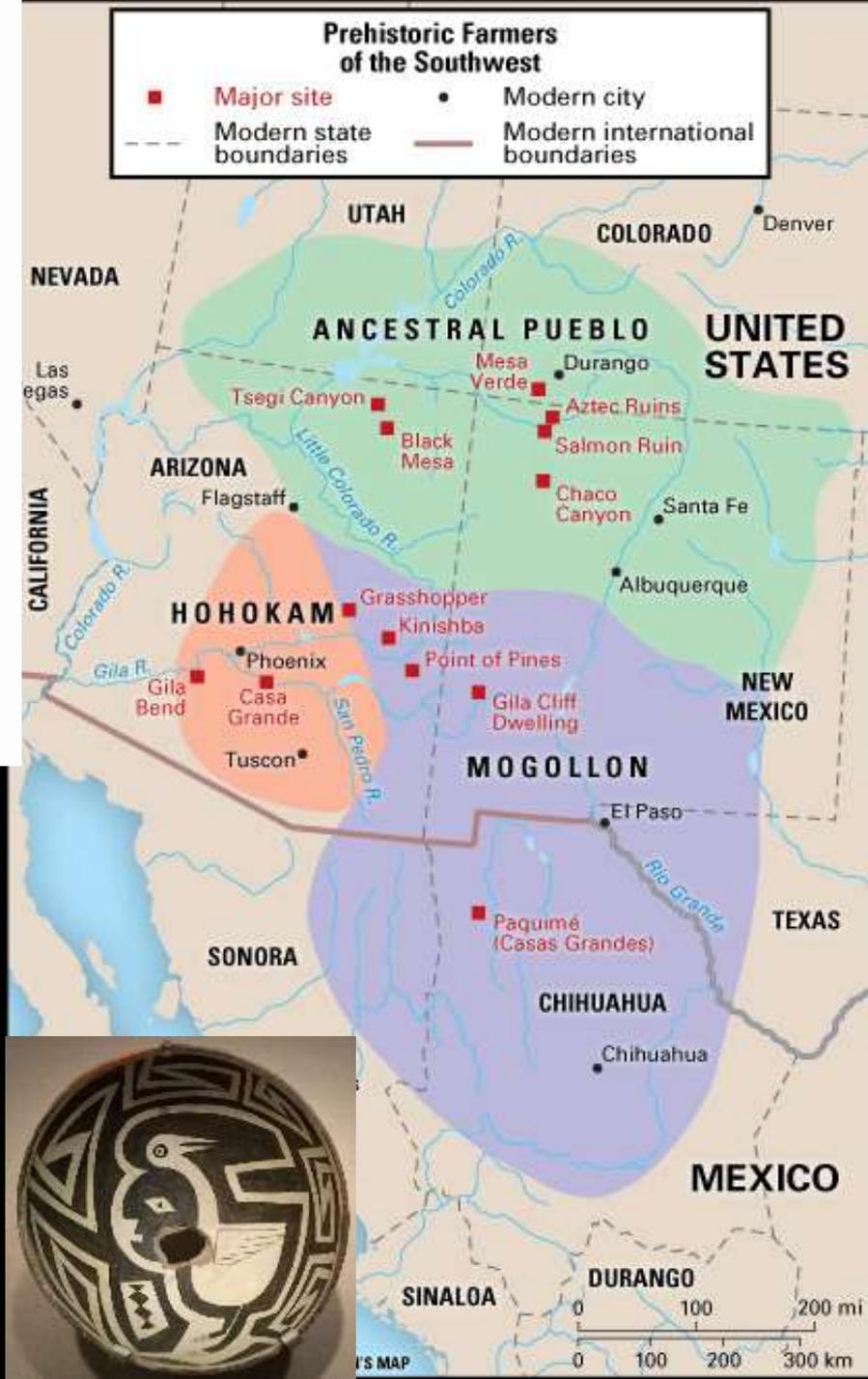
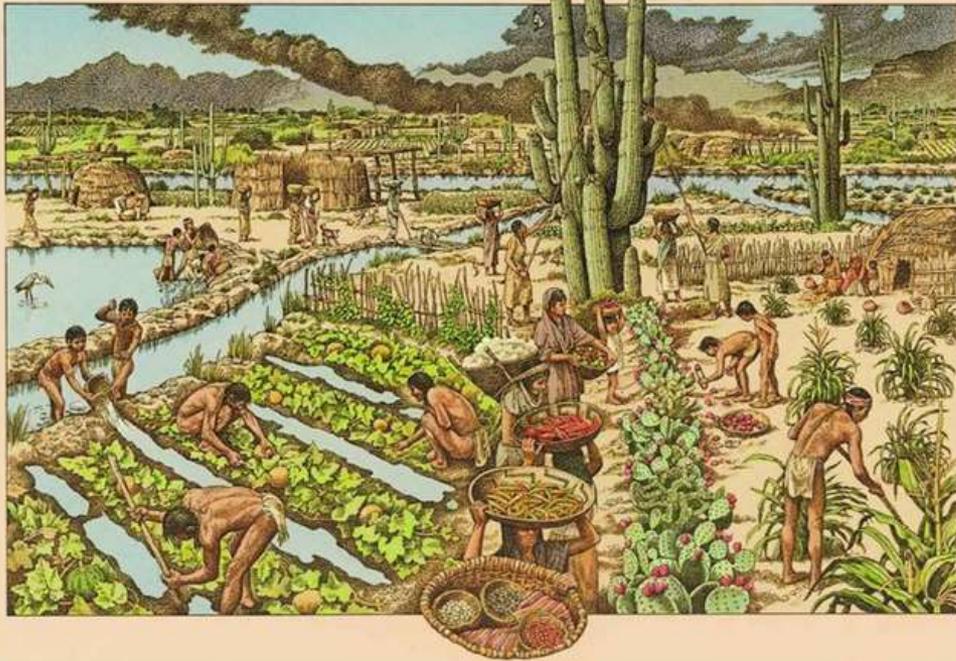
ANTHROPOLOGICAL PAPERS OF  
THE UNIVERSITY OF ARIZONA  
NUMBER 70

## The Safford Valley Grids Prehistoric Cultivation in the Southern Arizona Desert



William E. Doolittle and James A. Neely  
Editors

THE UNIVERSITY OF ARIZONA PRESS  
TUCSON  
2004



## The Hohokam Canal Masters of the American Southwest

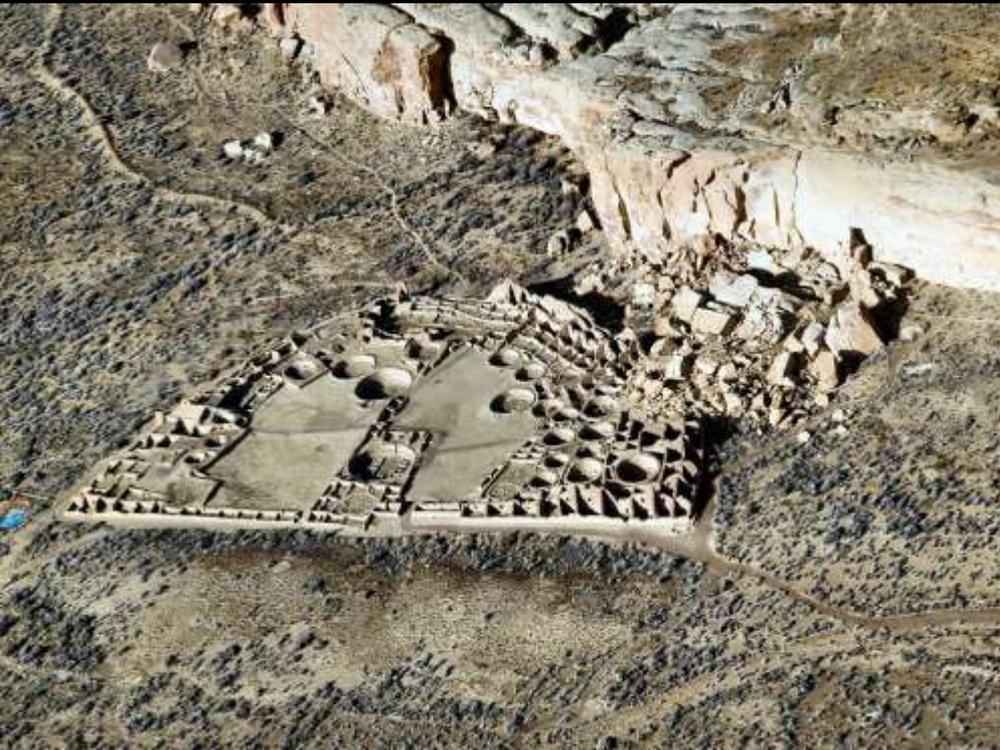
- Extensive irrigation canals along the Salt and Gila rivers.
- The largest and most complex irrigation systems of any culture in the New World north of Peru.

Mogollon-Mimbres pot, c. 1000 BCE



# Water, the Anasazi, and Chaco Canyon 850 AD – 1300 AD

- Around 600 AD, the Anasazi of Chaco Canyon and other settlements abandoned hunting and gathering in favor of cultivating crops such as maize (corn).
- The Anasazi culture of the southwestern United States reached its zenith between 1050 and 1125 AD before experiencing a dramatic collapse.
- Disappear 1200-1300 AD - Why would the Anasazi leave pueblos it had taken them decades to construct?
- In the period between AD 1125 and 1180, very little rain fell in the region.



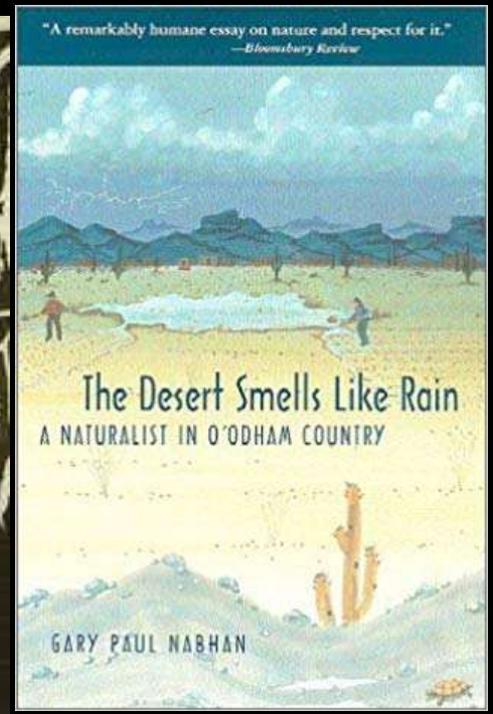
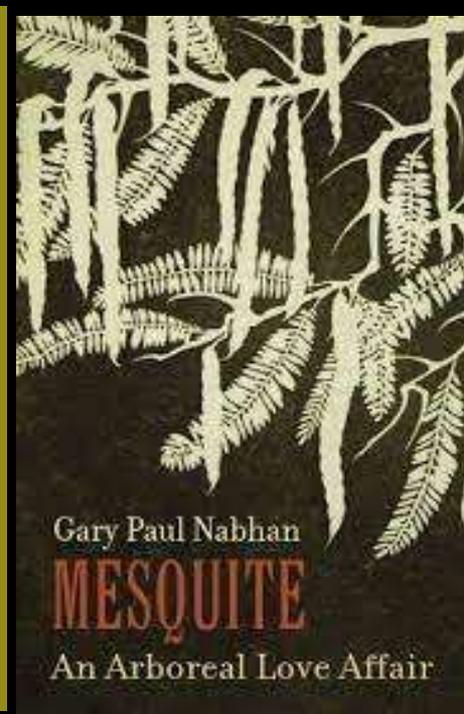
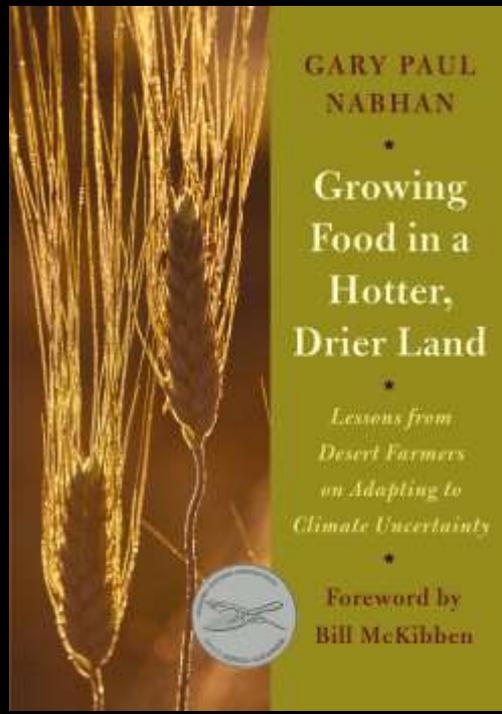
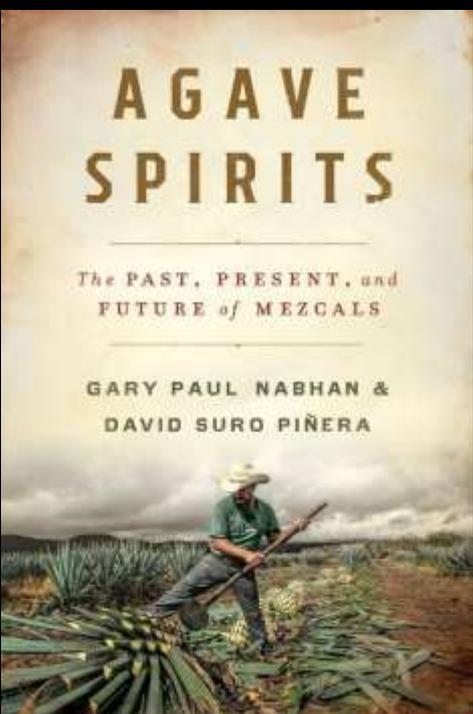
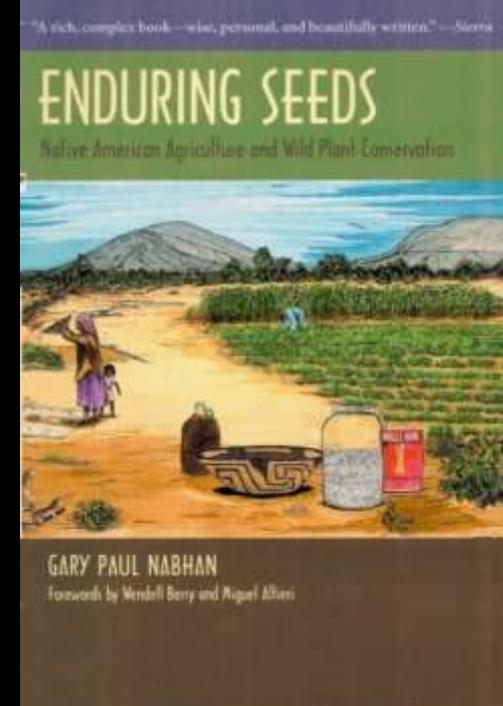
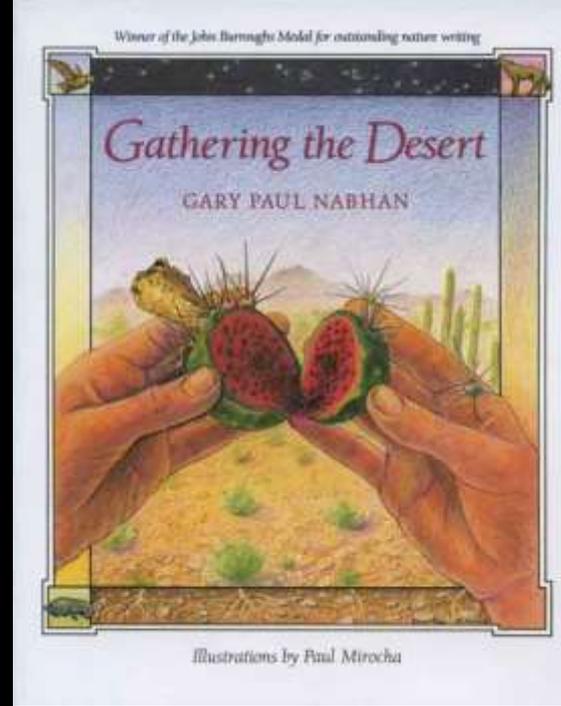
## Pueblo Bonito - built 850 AD to 1150 AD

- Pack rat middens reveal that 800 AD, Chaco Canyon area was ponderosa pine forest.
- Forest clearing for fuel and building.
- This tree removal, combined with a period of drought, led the water table in the valley to drop severely, making the land infertile.

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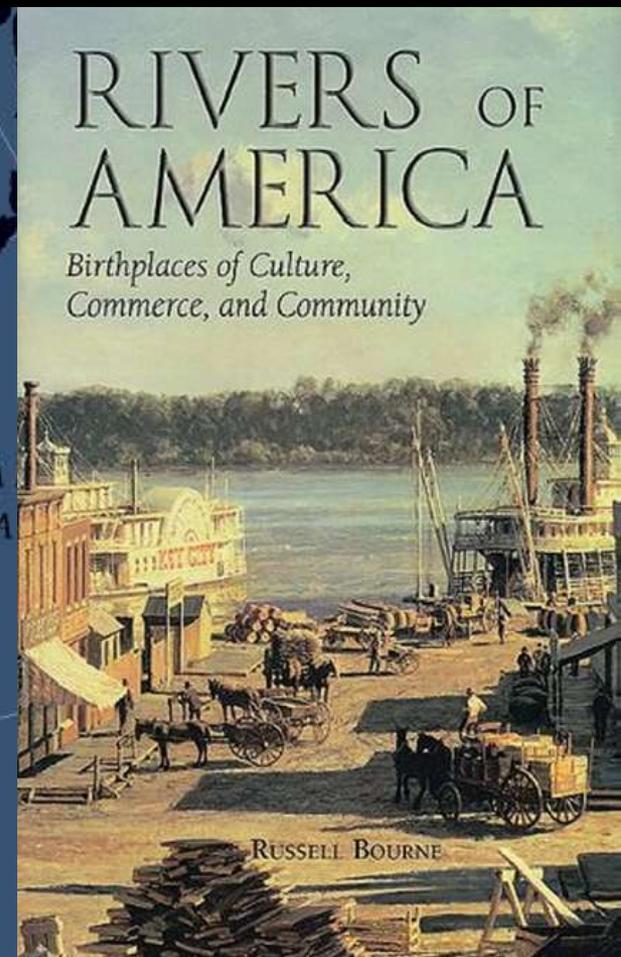
**GARY PAUL NABHAN**





# West by Water

## Boats, Culture, Commerce, and American Hydraulic Empires

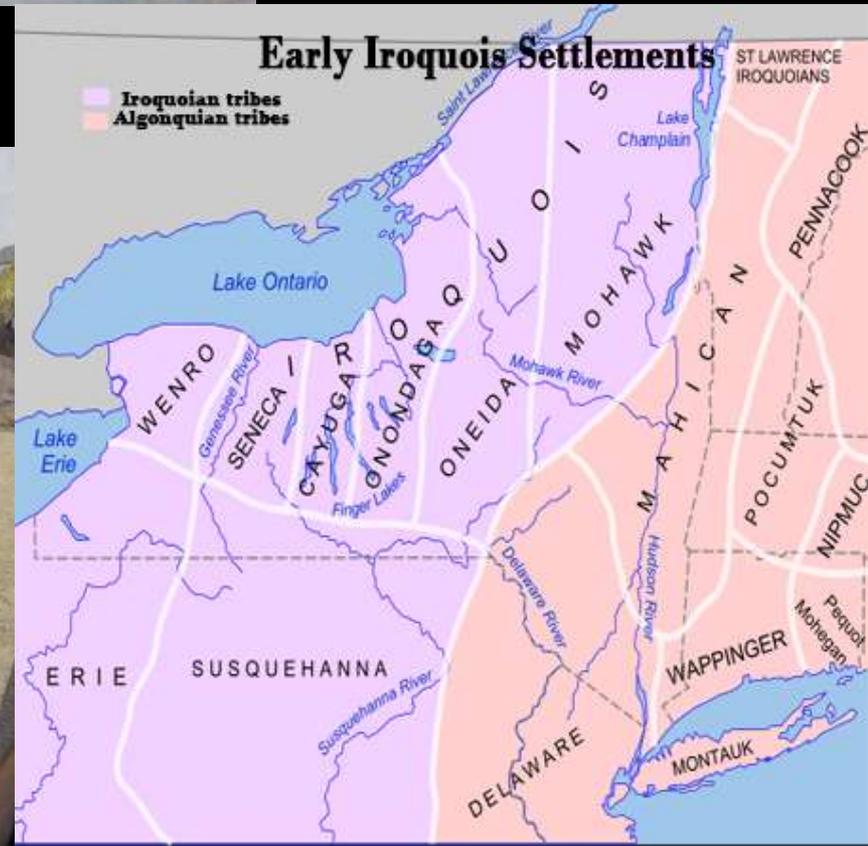


# Native American Hydraulic Empire

Boats and Waterways

The Dugout

The Canoe



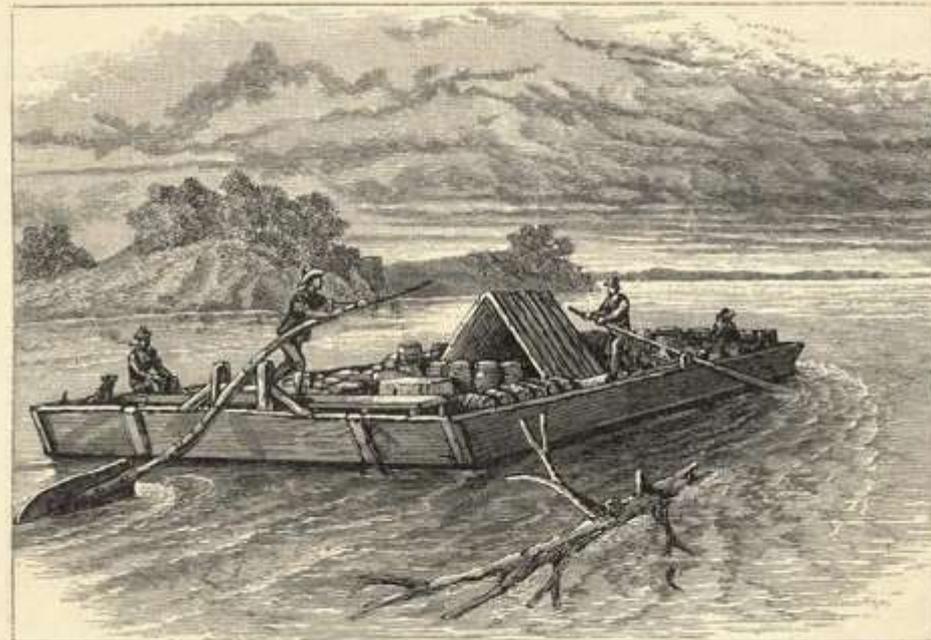
# The Empire of the Beaver - Fur Trade, the Canoe and Waterways 1700s

- France
- Great Britain
- Territories ceded by France to Great Britain by the Treaty of Utrecht in 1713
- Spain
- Cities
- Forts



# American River Boats open the West - The Flatboat

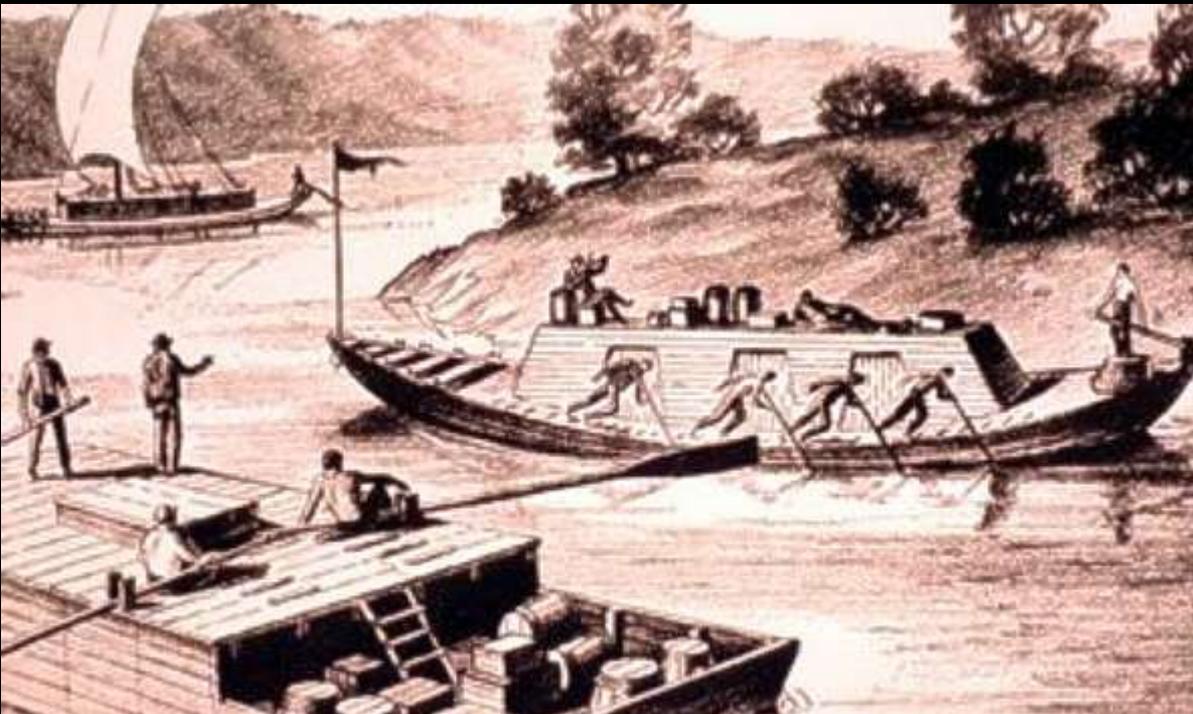
- In 1781, Pennsylvania farmer Jacob Yoder built the first flatboat near Pittsburgh on the Monongahela River.
- The flatboat was designated as "the boat that never came back." It was broken up at the end of its journey and the lumber used for building houses, furniture, etc.
- The crew walked or rode a horse back upriver for the next trip.
- In 1785, 1000 boats go down the Ohio River. By 1800, 300,000 Americans live west of the Alleghenies.



Flat-boat going down the Missis'sippi.

# American River Boats Open the West - The Keelboat

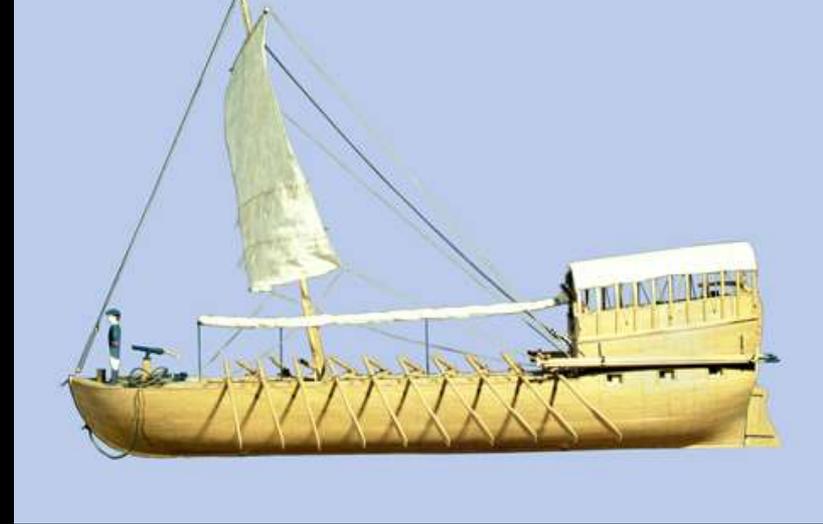
- Keelboats got their name from the keel, a four-inch square timber that extended along the bottom of the vessel from bow to stern.
- The keel stabilized a heavy boat in dangerous river currents.
- Most keelboats were from 45 to 75 feet long and 7 to 9 feet wide.
- Boatmen could power them by poling, rowing, sailing, or hauling them by rope from the shore, known as cordelling.
- Keelboats could be poled back upstream with cargoes going both ways



# Rivers and Exploration – Lewis and Clark

The Lewis and Clark Expedition (1804–1806), was the first transcontinental expedition to the Pacific coast undertaken by the United States - the Missouri River and down the Columbia River.

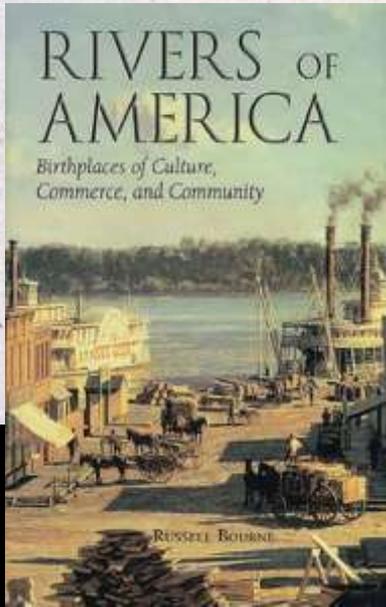
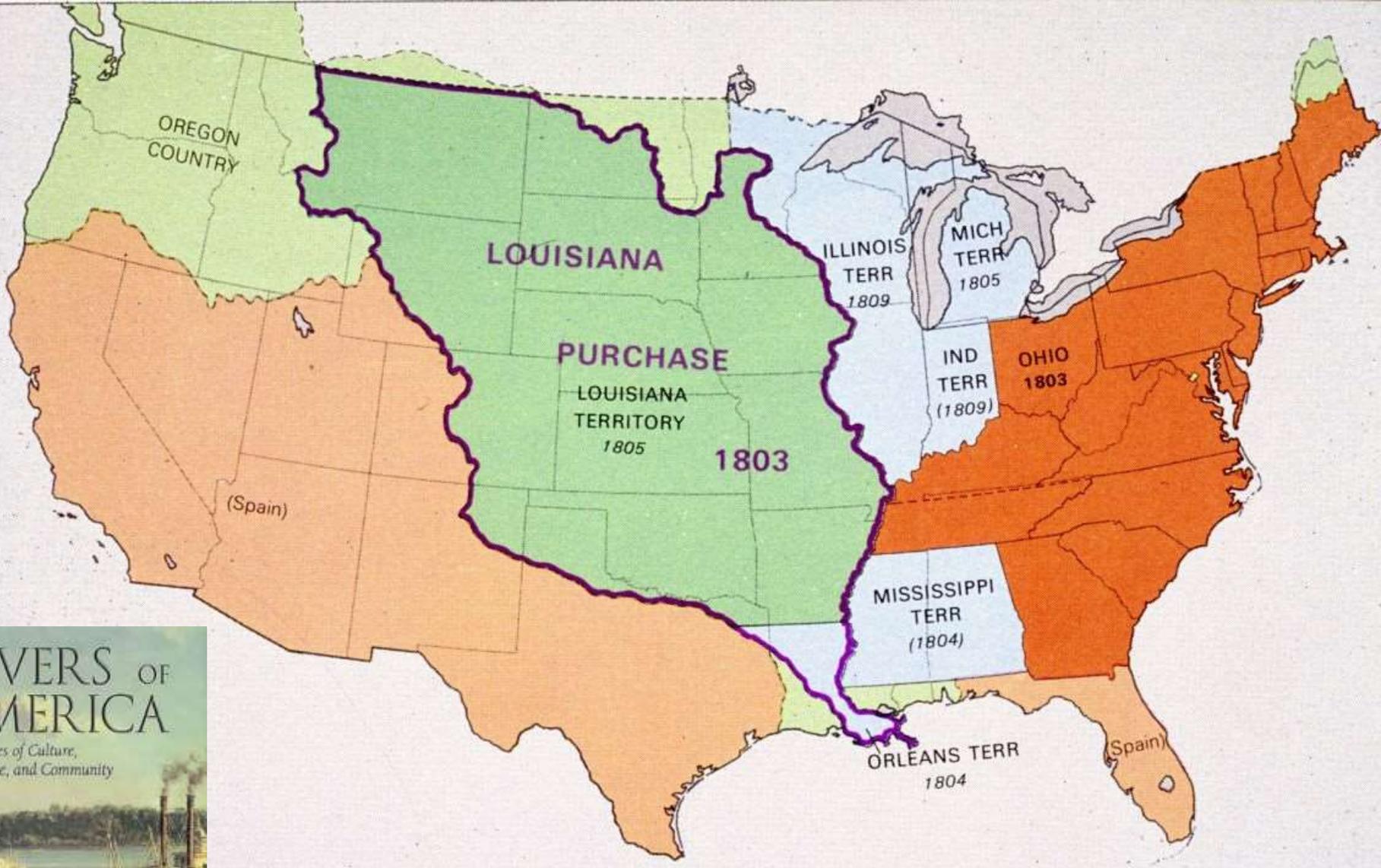
Commissioned by President Thomas Jefferson, it was led by Meriwether Lewis and William Clark (and Sacagawea!)



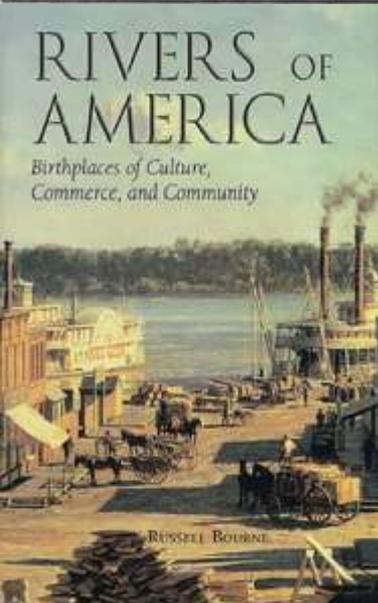
Lewis and Clark Expedition (1804-1806)

## COMPLETE JOURNALS OF LEWIS AND CLARK 1804-1806





Jefferson offers Napoleon \$2 million for New Orleans. Napoleon offers all of the French territory for \$15 million.

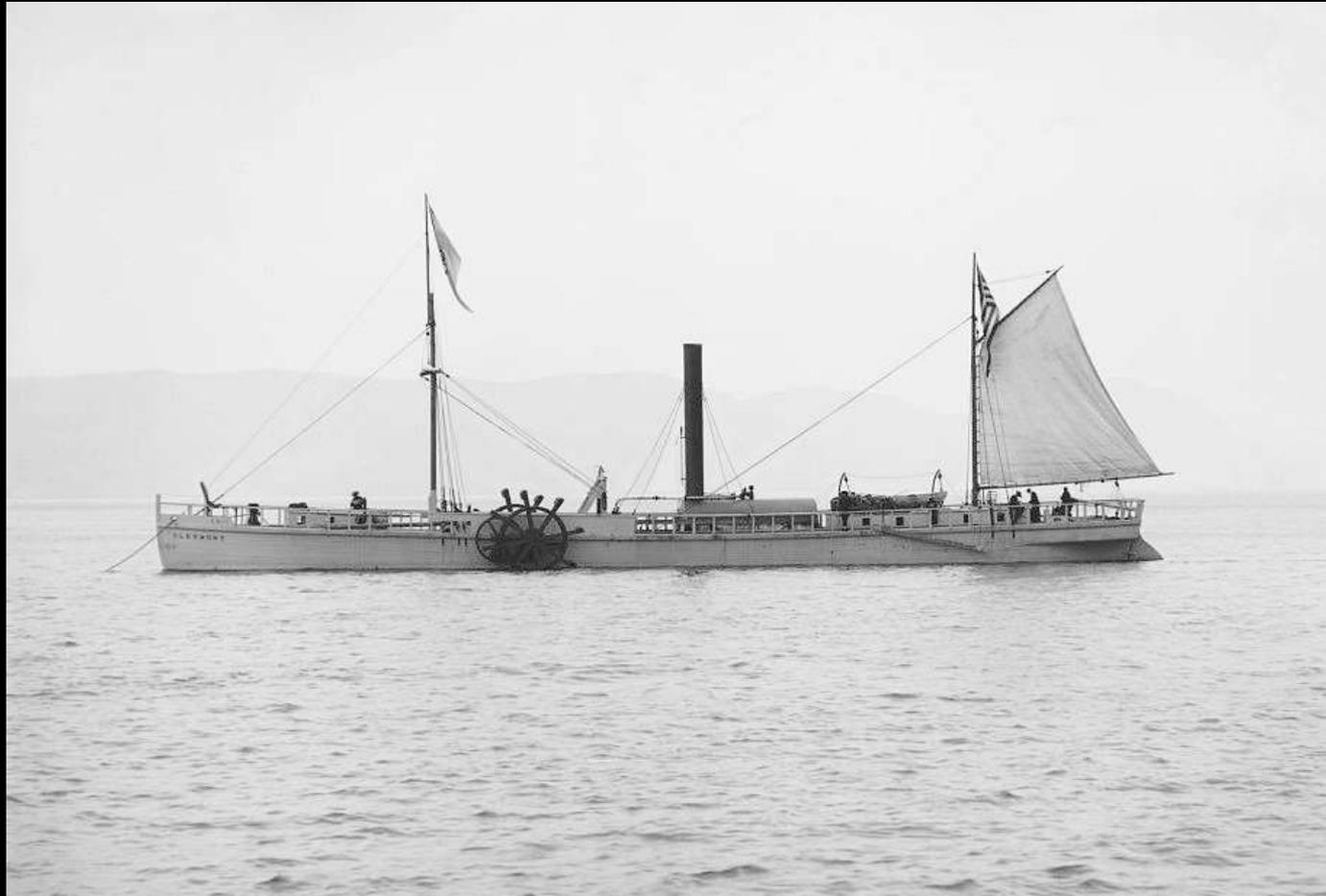


A continental  
river connected nation

“Jefferson’s...riverborne  
revolution could now be played  
out on the magnificently broad  
canvas of an entire continent”

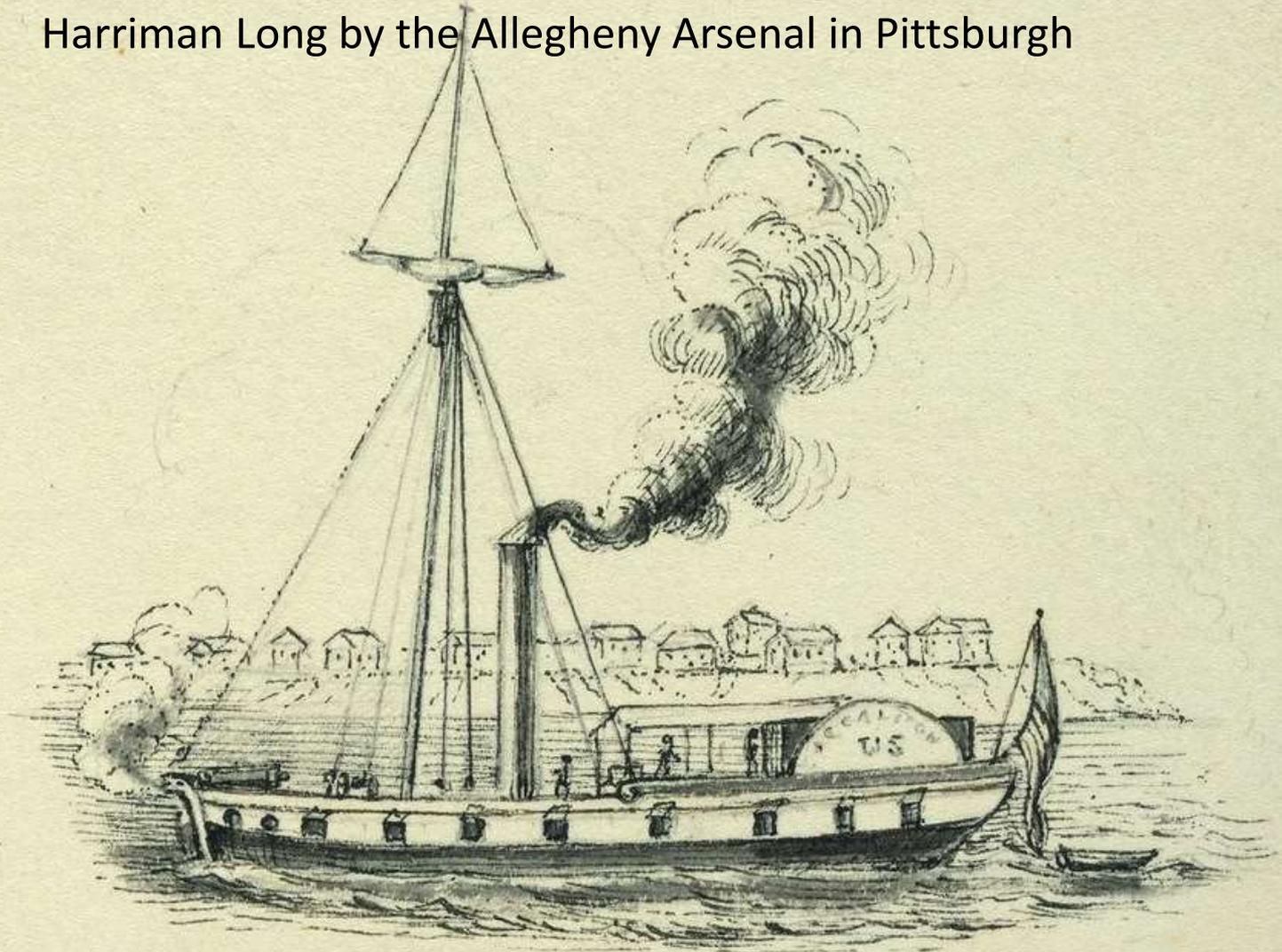
## The Steamboat - Robert Fulton (1765–1815)

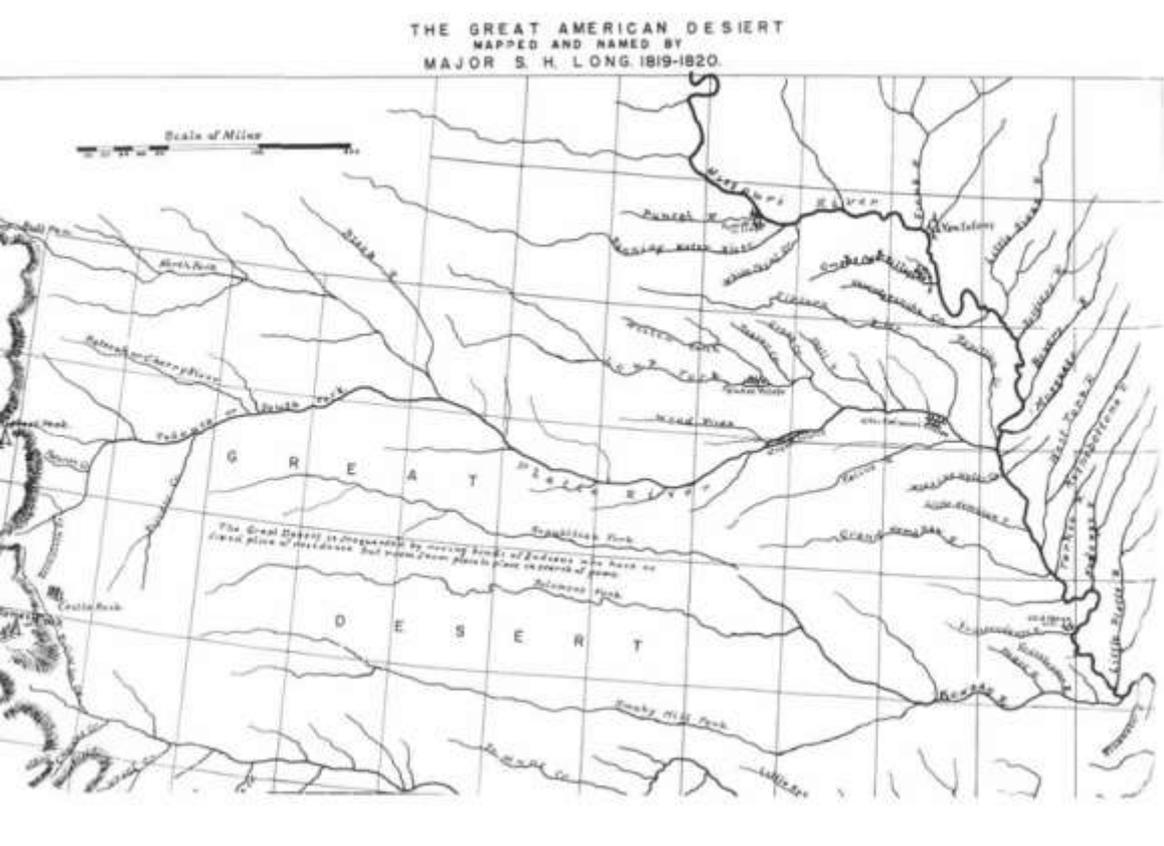
- The North River Steamboat, colloquially known as the Clermont, is widely regarded as the world's first vessel to demonstrate the viability of using steam propulsion for commercial water transportation.
- Built in 1807, it operated on the Hudson River – at that time often known as the North River – between New York City and Albany.



## Steamboat Exploration

The paddle steamer Western Engineer was the first steamboat on the Missouri River. It was purpose built after a design by Major Stephen Harriman Long by the Allegheny Arsenal in Pittsburgh



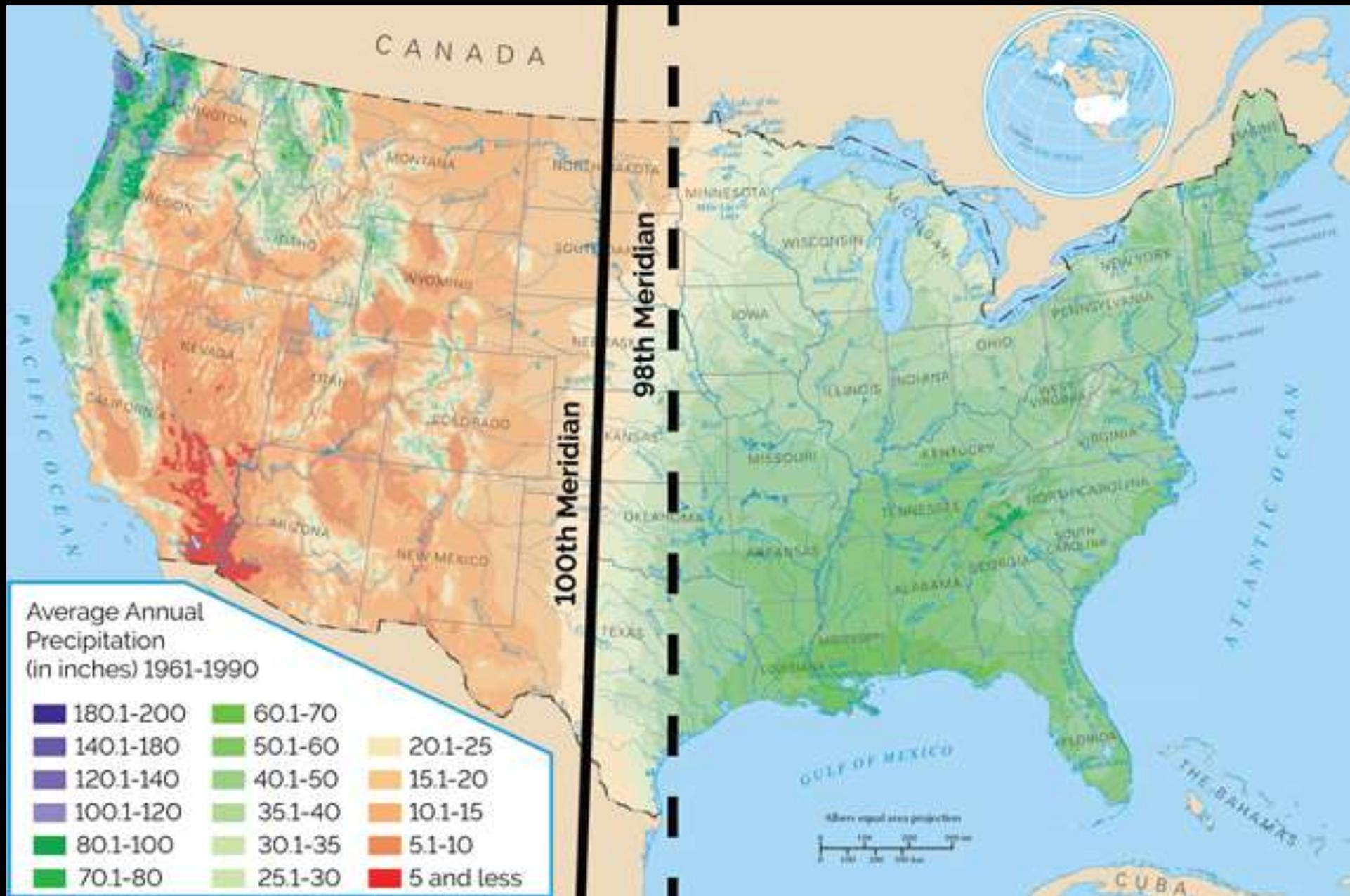


## The 1819-20 Long Survey and the Great American Desert

In his report of the 1820 expedition, Major Stephen Harriman Long wrote that the Plains from Nebraska to Oklahoma were "unfit for cultivation and of course uninhabitable by a people depending upon agriculture."

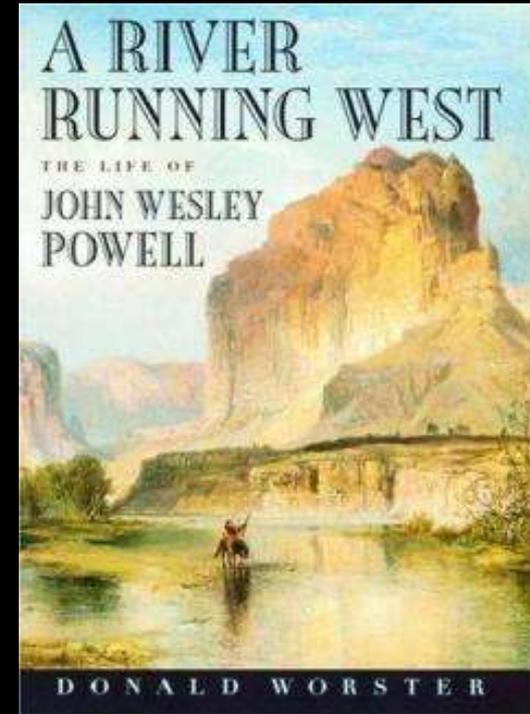
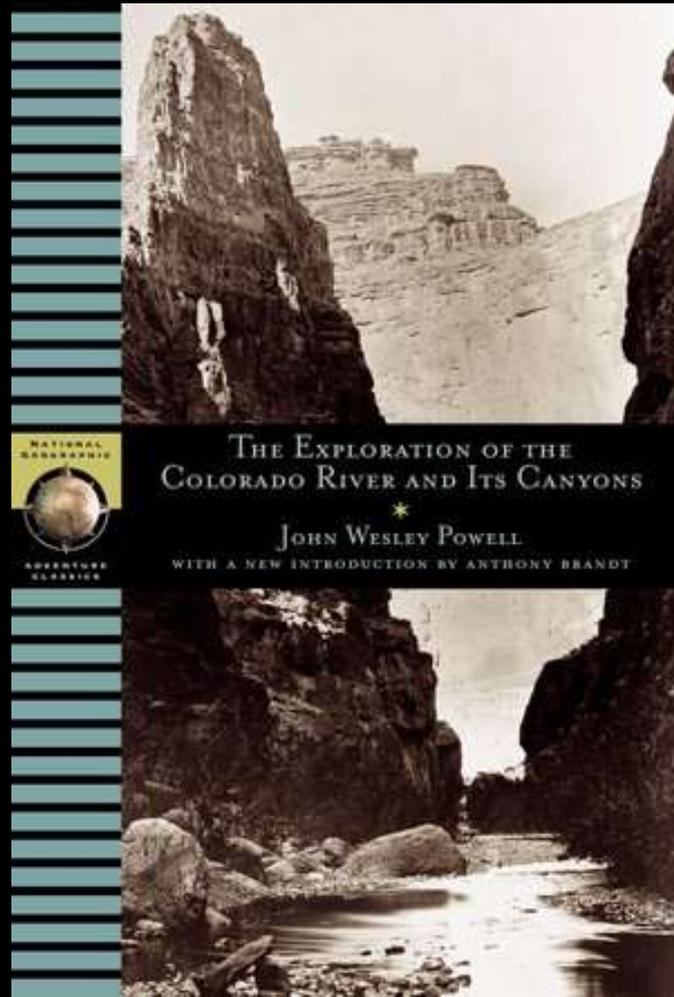
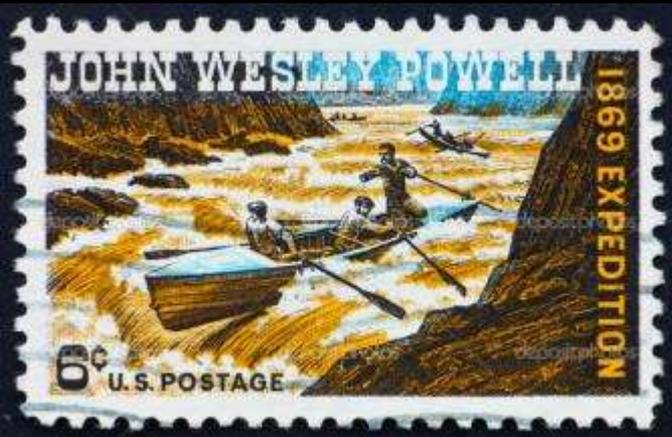
On the map he made of his explorations, he called the area a "Great Desert." He argued that the eastern wooded portion of the country should be filled up before the republic attempted any settlement westward.

# The West and Water – Exploration, Settlement, and Hydraulic Empire

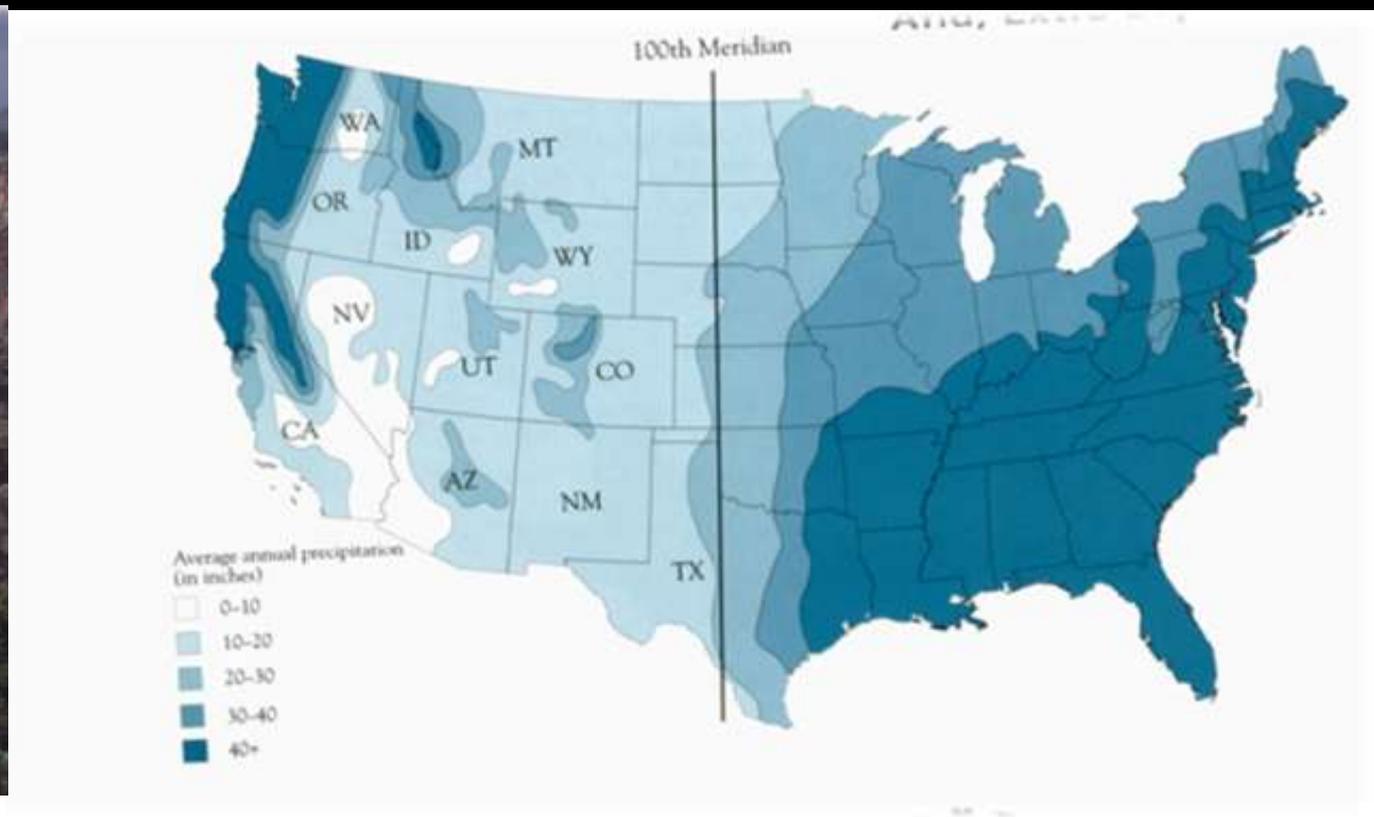
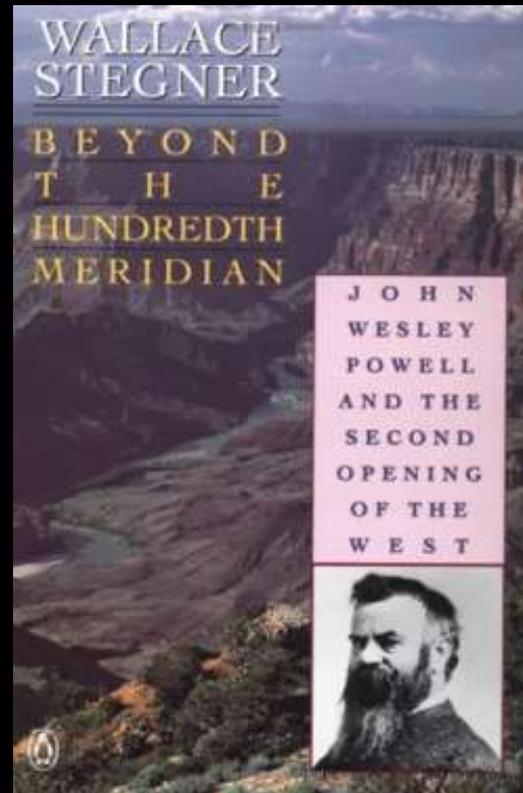


# John Wesley Powell and the Colorado River 1869-72

The Powell Geographic Expedition in 1869 was the first-ever thorough investigation of the Green and Colorado rivers, including the first known passage through the Grand Canyon.



# Beyond the 100<sup>th</sup> Meridian and The Great American Desert



## *Report on the Lands of the Arid Regions of the United States 1878*

Arid West was not suitable for agricultural development, except for 2% of the lands near water sources.

Irrigation systems and state boundaries based on watershed areas to avoid “squabbles”.

For the remaining lands, he proposed conservation and low-density, open grazing.

Walter Prescott Webb 1888-1963

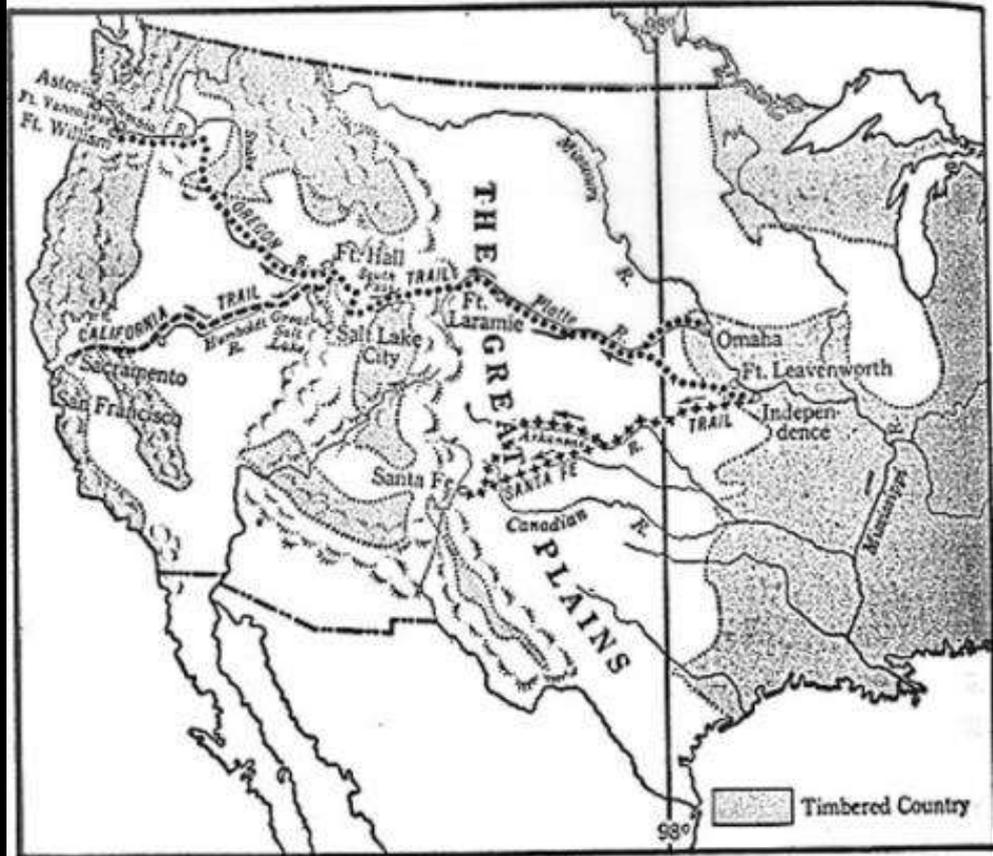
The Great Plains stand as a distinct environmental entity radically different from the wet timbered areas of the East.

Three characteristics differentiated the Plains from the East:

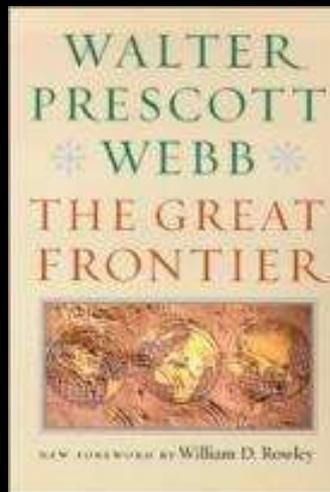
1. their flat geography,
2. the scarcity of timber,
3. their semi-arid climate.

Webb argued that between the 98th meridian and the western slope of the Rocky Mountain system from Canada to Mexico the two most important elements of life in the eastern United States - abundant rainfall or available water and large stands of timber - were missing.

This environment was absolutely foreign to the Eastern citizen of the United States, who found the Plains impossible to cope with for a long period of time.

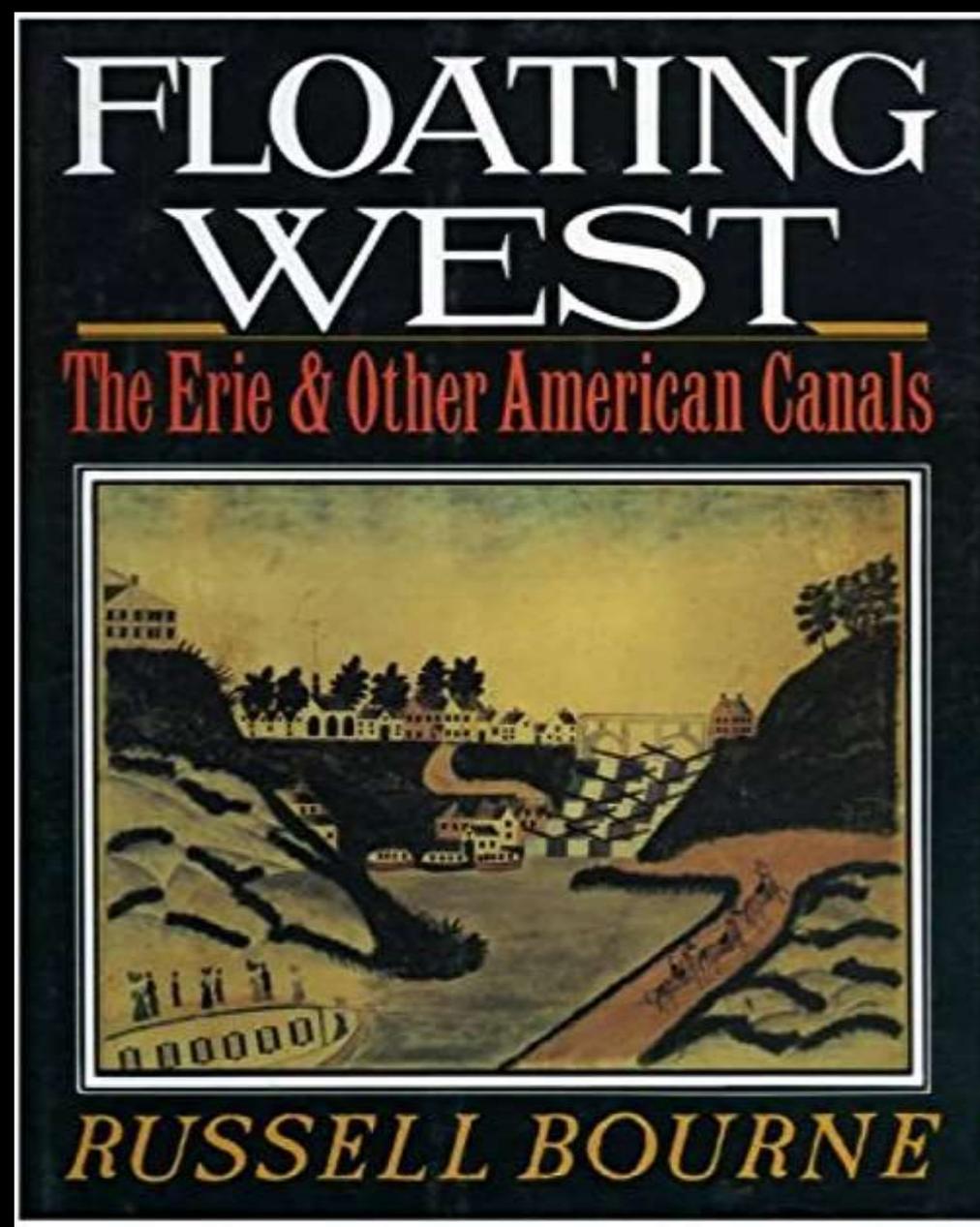
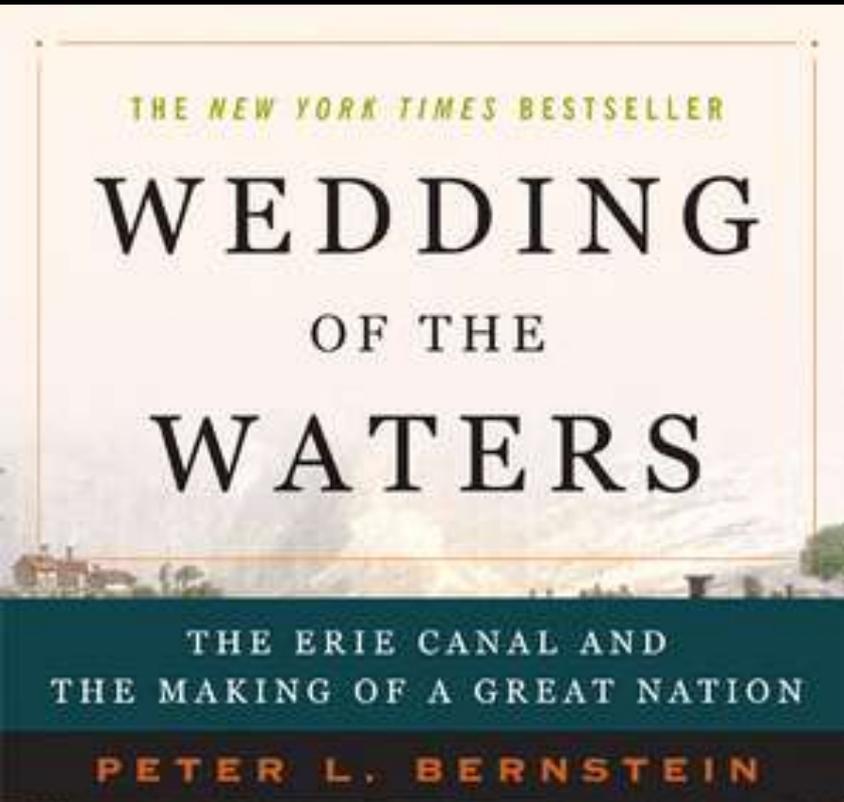


The trans-Plains trails, usually called transcontinental





## Linking the Rivers - American Canals



# The Fall Line and River Transport

The Atlantic fall line was generally the head of navigation on Eastern rivers due to their rapids or waterfalls, and the necessary portage around them.

Numerous cities initially formed along the fall line because of the availability of water power to operate mills which concentrated mercantile traffic and labor.

Great Falls Park,  
Potomac River, Virginia



Figure 1. Location of the Atlantic Coastal Plain Province.

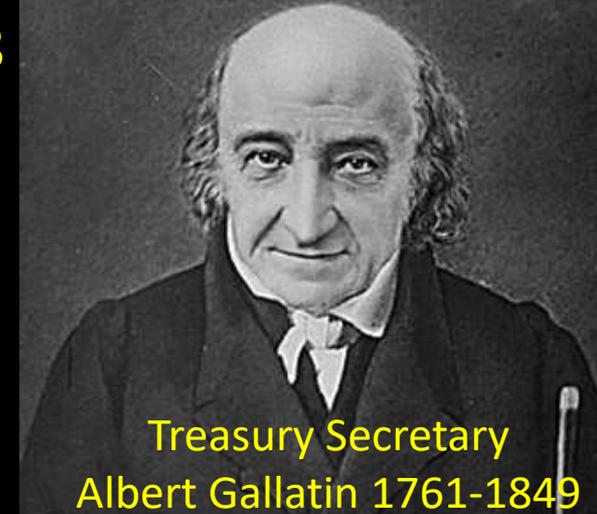


# Report on Roads, Canals, Harbors, and Rivers 1808

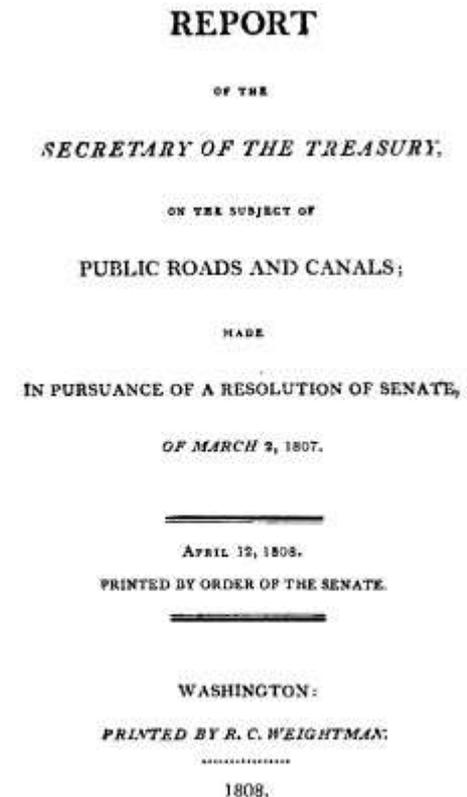
In 1807 the U.S. Senate passed a resolution calling upon the treasury department to compile a report proposing ways that the federal government could address the transportation problems in the nation.

- Noted the significance of the fall line as an obstacle to improved national communication and commerce between the Atlantic cities and the western river systems
- Some of the projects Gallatin proposed were:
  - ❖ A series of canals parallel to the Atlantic coast from New York City to South Carolina (Intercoastal Waterway)
  - ❖ A major turnpike from Maine to Georgia (I-95)
  - ❖ Improvements to make rivers passable to major river navigation (Army Corps of Engineers)
  - ❖ A National Road from Washington to St. Louis (1810)
  - ❖ A series of inland canals heading to Ohio
  - ❖ A canal crossing New York state

The entire projected expense for all the construction work proposed by Gallatin was \$20 million, an astronomical sum at the time.



Treasury Secretary  
Albert Gallatin 1761-1849



# Canals and the Hydraulic Empire

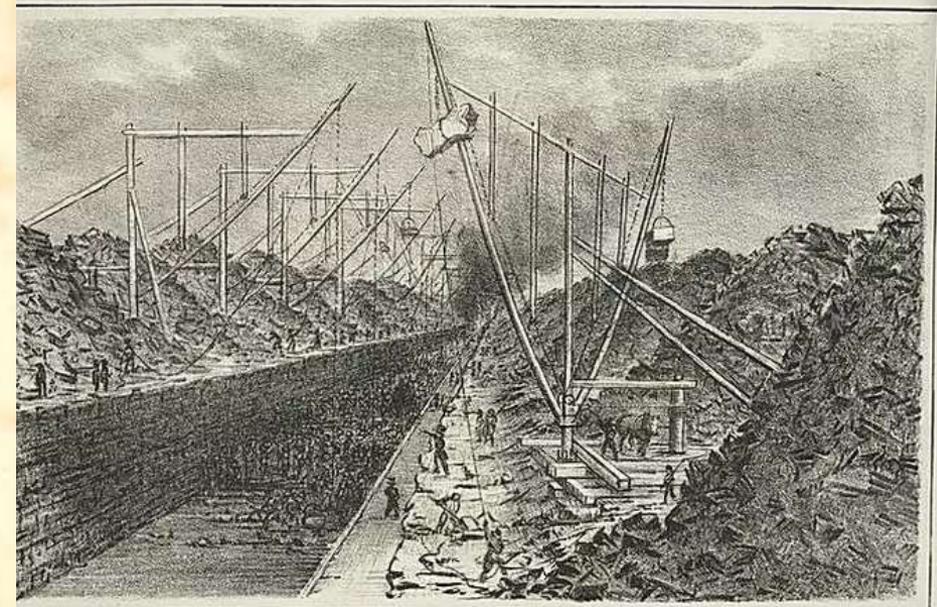
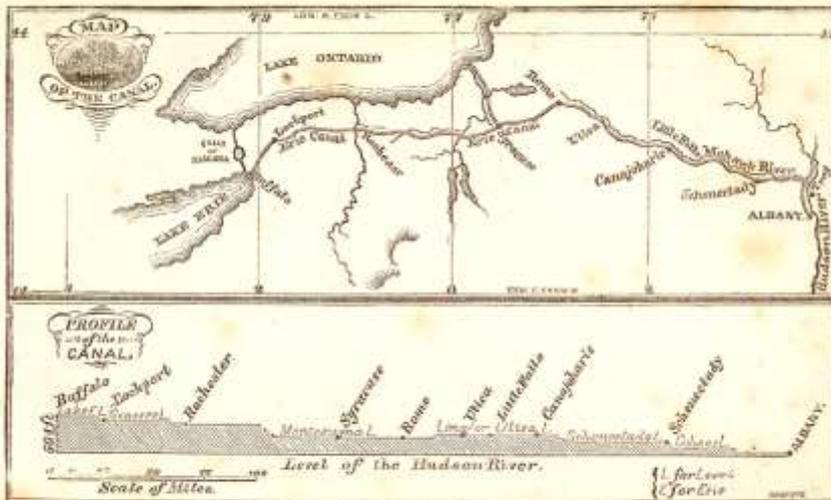
## The Erie Canal

First proposed in 1807, the plans for building the canal were delayed by the War of 1812. But construction finally began on July 4, 1817. DeWitt Clinton had just been elected governor of New York, and his determination to build the canal became legendary, and it was derided as "Clinton's Big Ditch" or "Clinton's Folly." Cost to build \$8 million

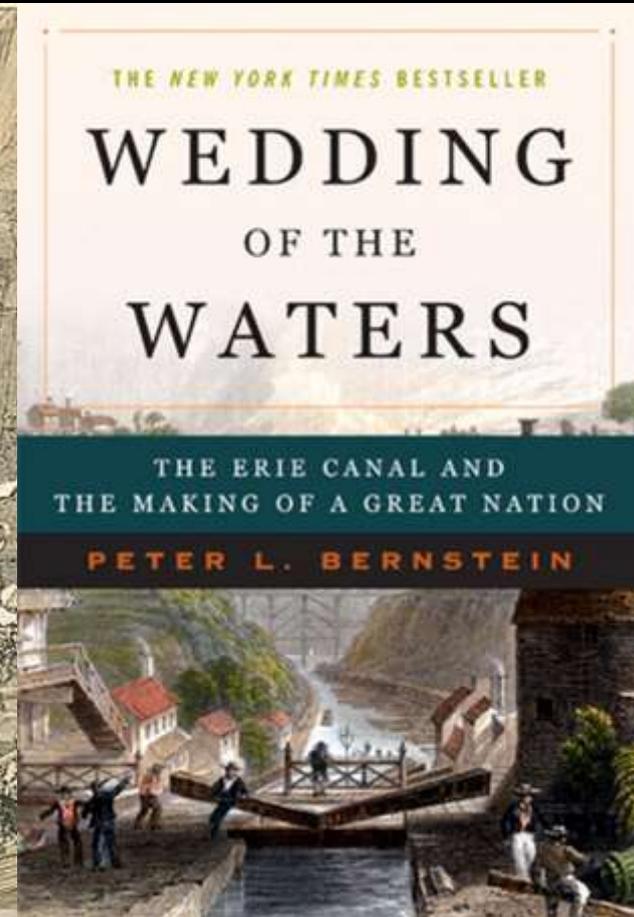
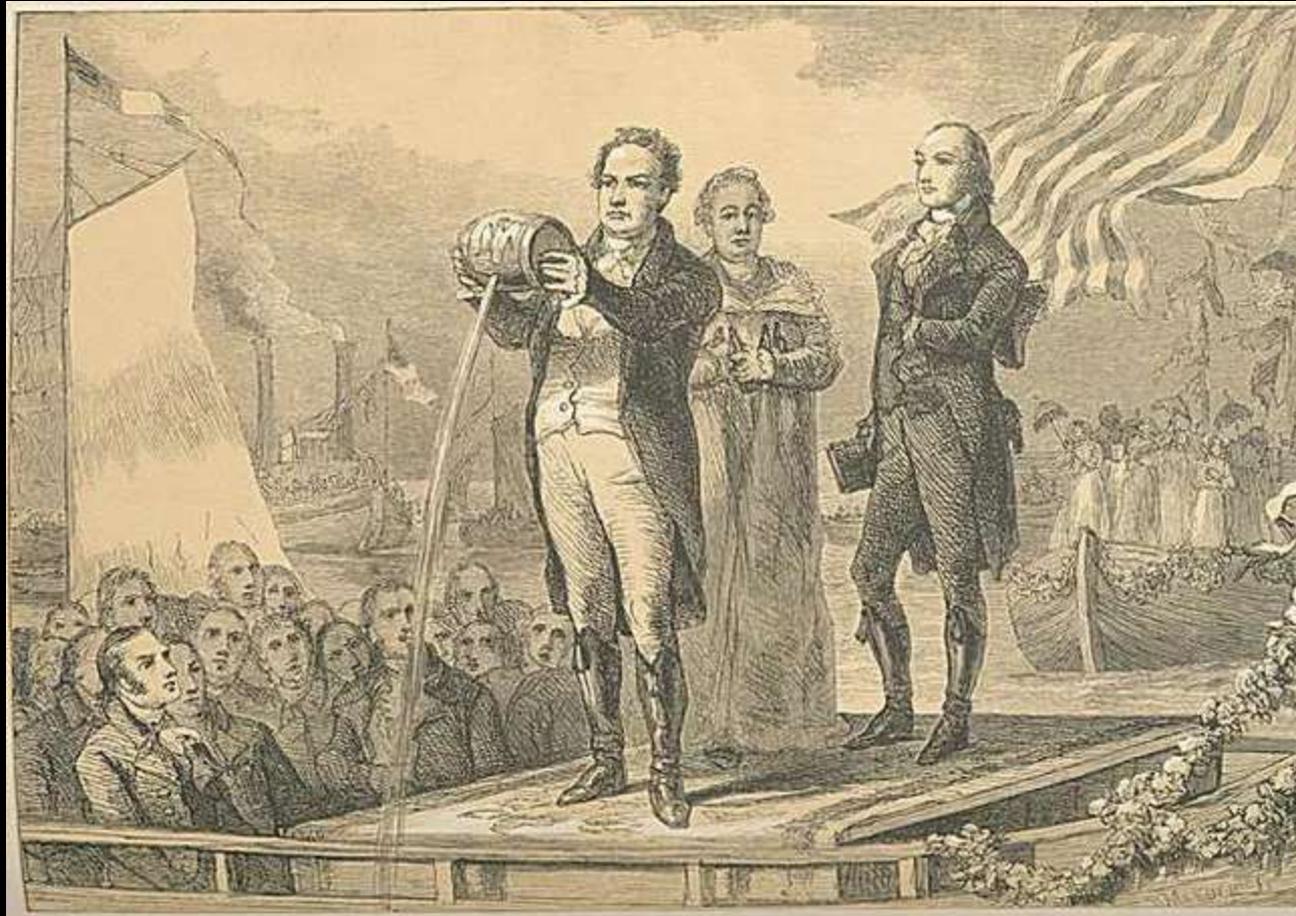
Under construction from 1817 to 1825.



DE WITT CLINTON ESQ'



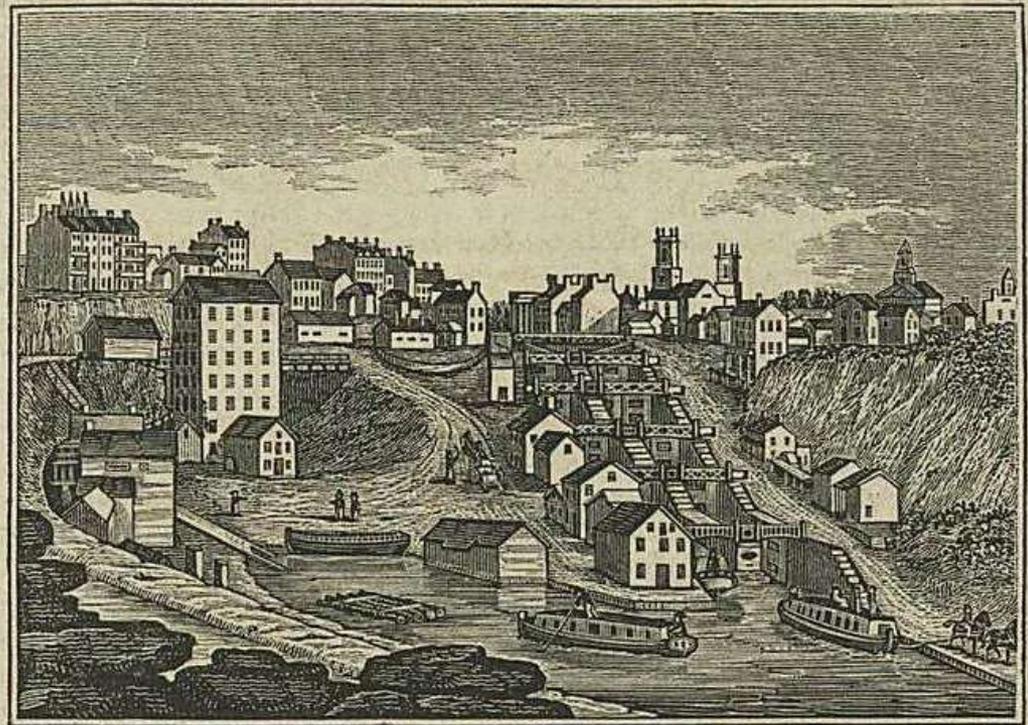
The Erie Canal officially opened on October 26, 1825.



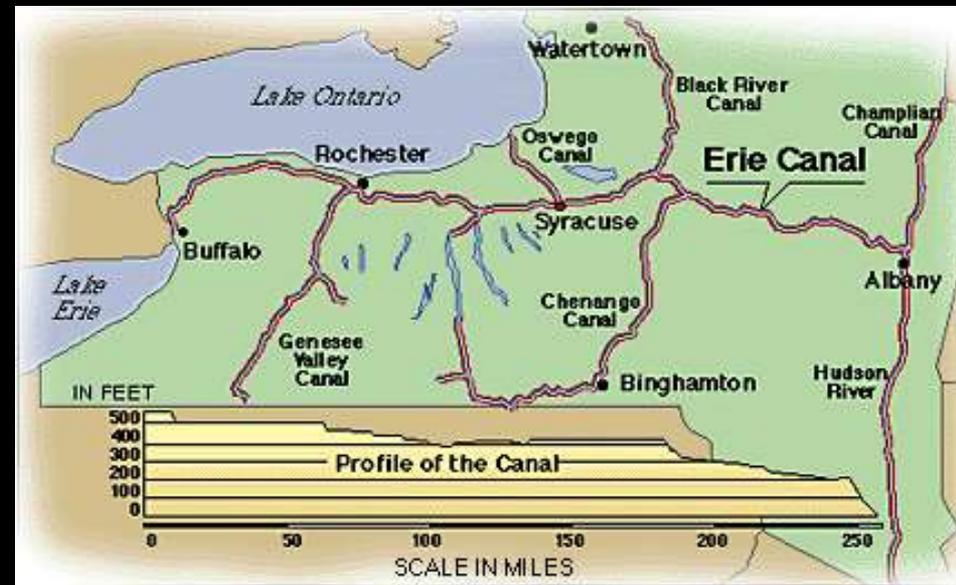
# The Hydraulic Empire

## The Erie Canal

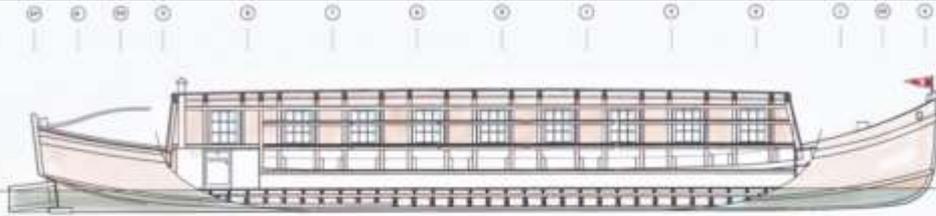
The Erie Canal originally ran about 363 miles from Albany, New York, on the Hudson River to Buffalo, New York, at Lake Erie, completing a navigable water route from New York City and the Atlantic Ocean to the Great Lakes.



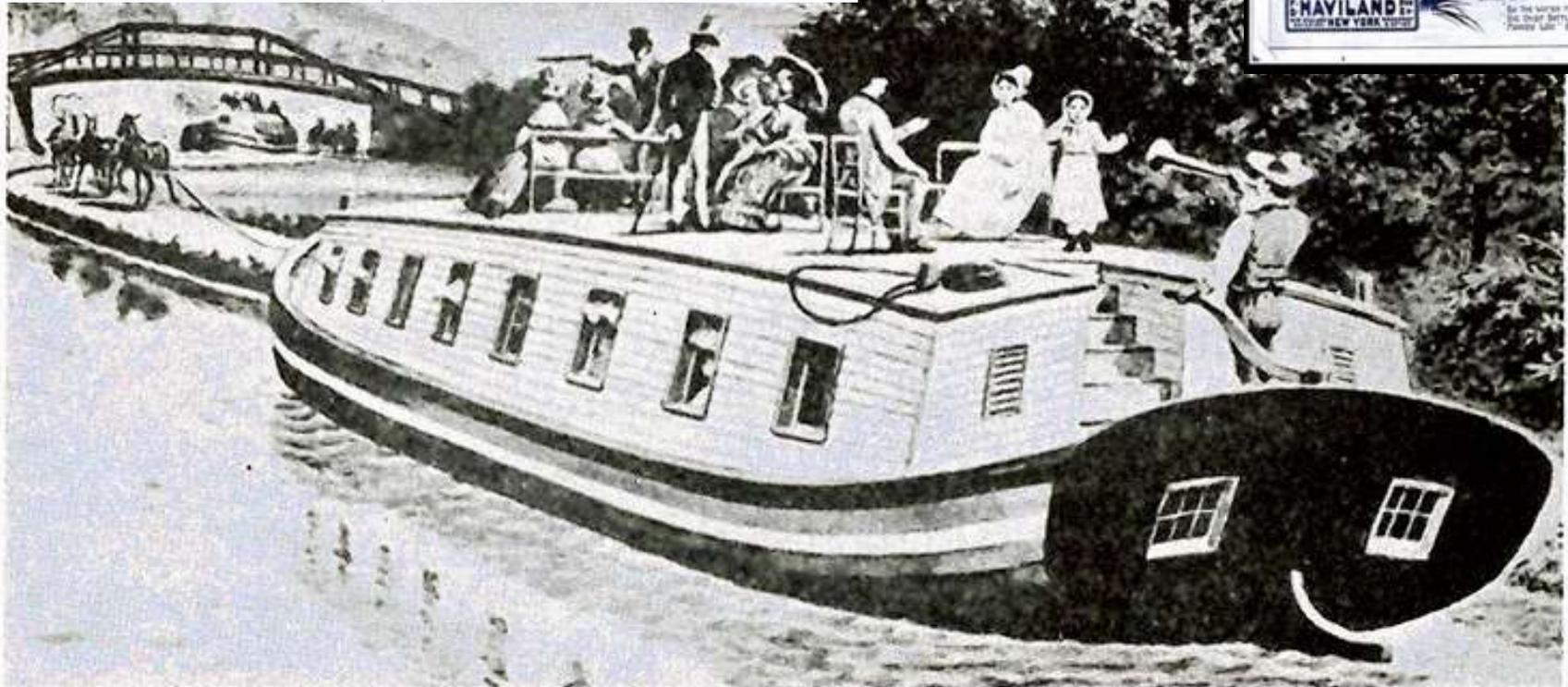
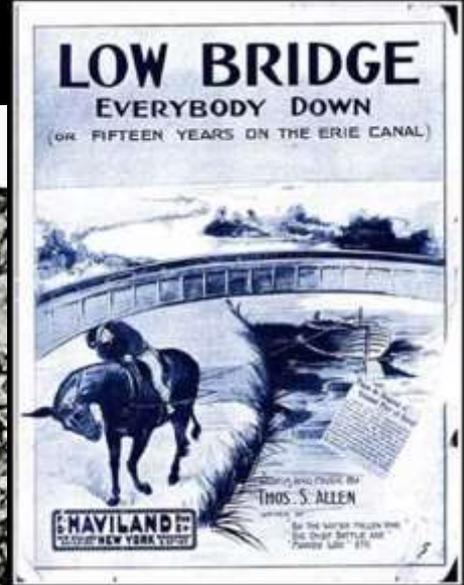
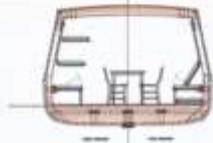
*Northeastern view of the locks at Lockport.*



# Canal Packet Boats



GOV. DEWITT CLINTON'S 1825 PACKET BOAT



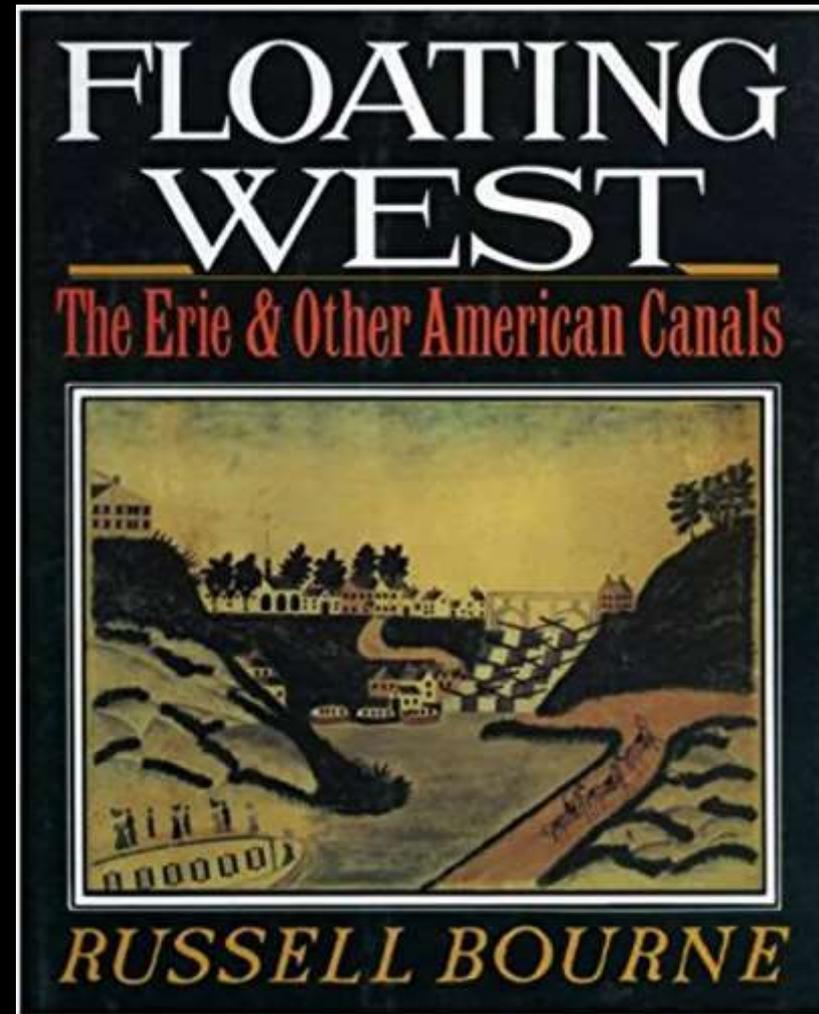
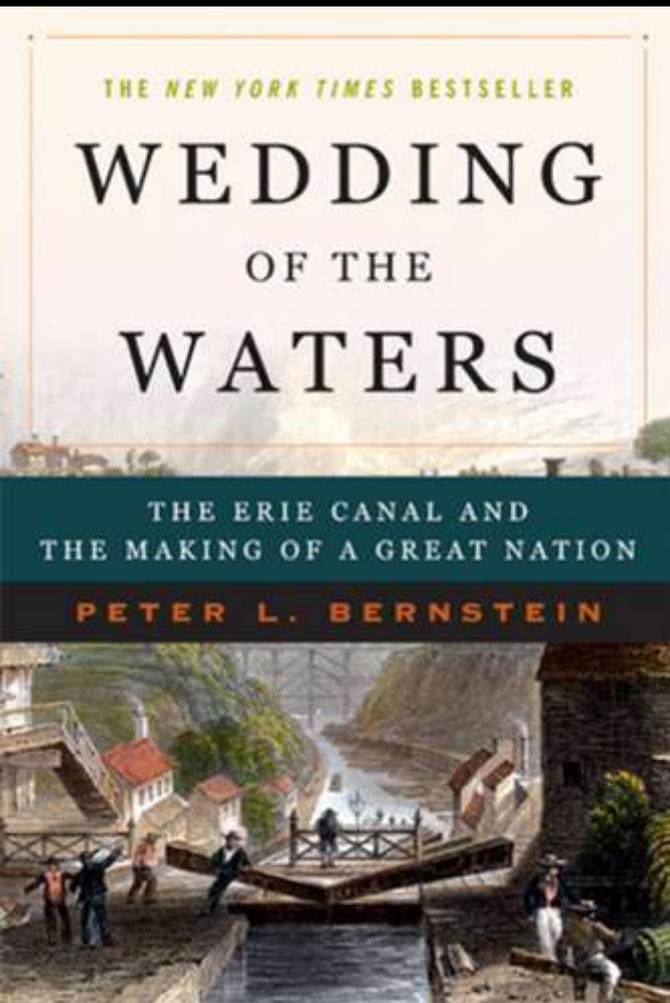
*Erie Canal Packet Boat, 1840 Era.*

1810 – 30 days by horse carriage Albany to Buffalo  
50 tons of freight – 6 days (passenger boats 4-5 days)

# The Hydraulic Empire and the Empire State

The Erie canal helped New York City eclipse Philadelphia as the largest city and port on the Eastern Seaboard and made New York State the “Empire State”.

Cost drops from \$100 a ton to \$5 ton  
By 1837 \$8 million debt paid off



# Ohio Canals – Linking East to West

Construction of the canal began on July 4, 1825 with a ground breaking at Licking Summit near Newark, Ohio. The Cleveland to Akron connection was completed by 1827 and the connection all the way to Portsmouth completed by 1832.

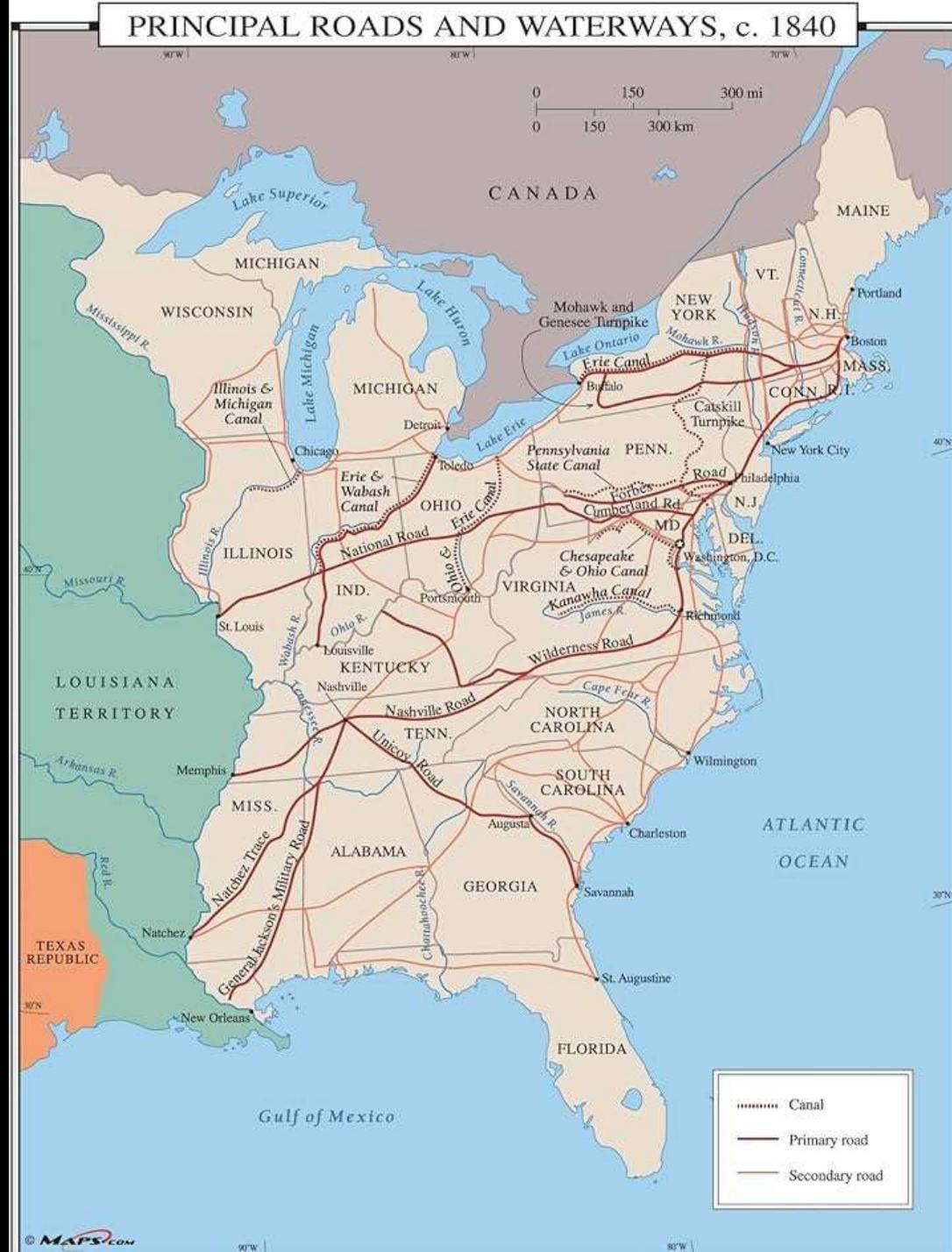
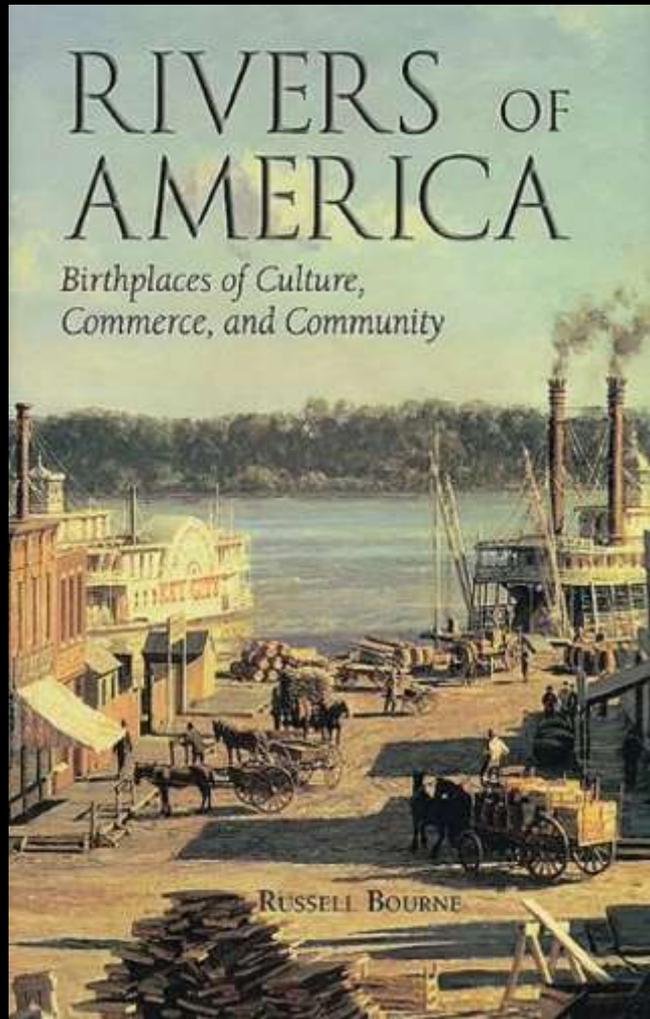
The entire canal system was 308 miles long with 146 lift locks and a rise of 1,206 feet.







“Improvements to make rivers passable to major river navigation”  
(Army Corps of Engineers)

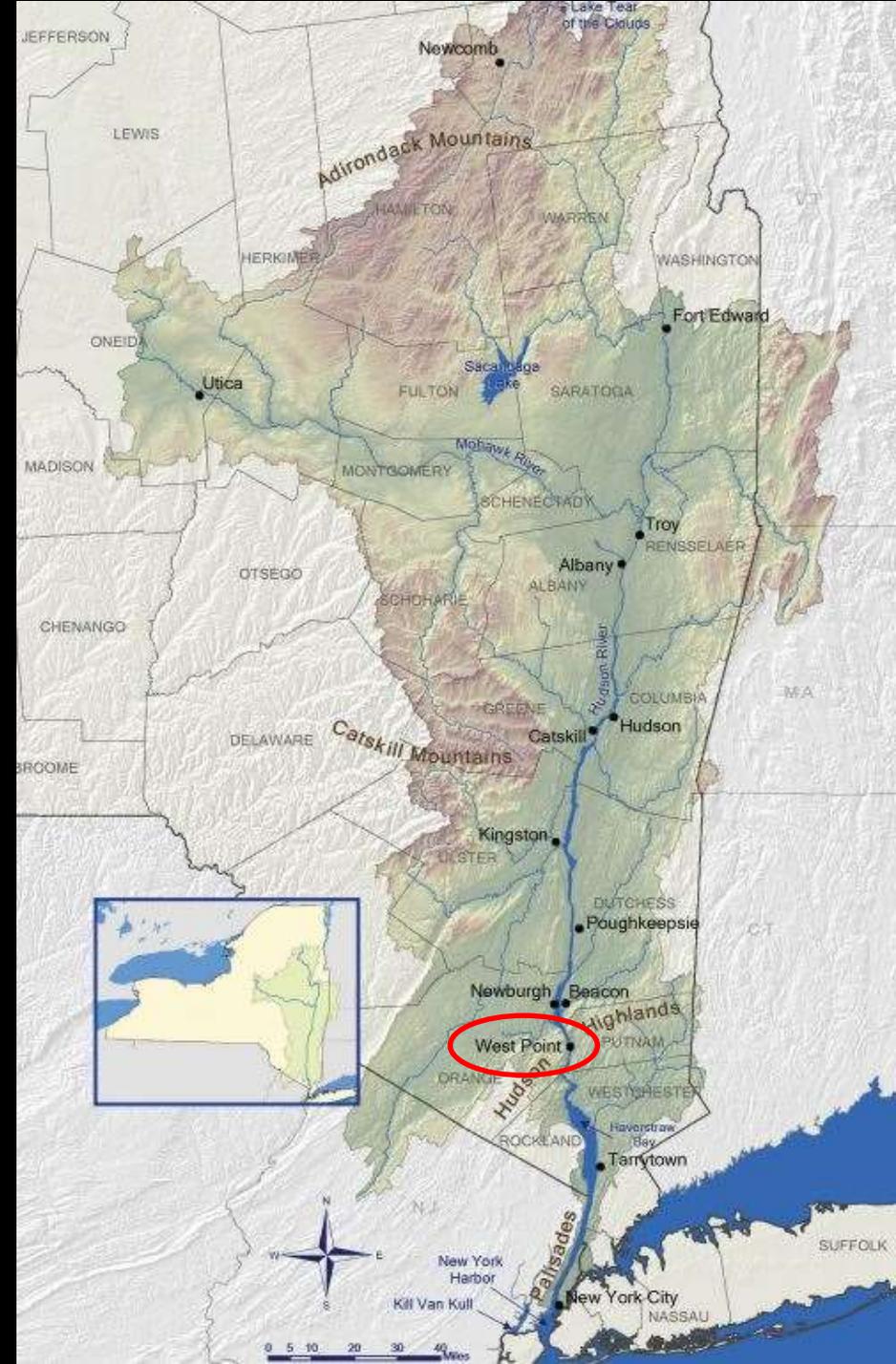
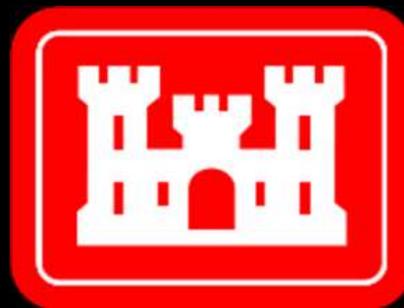


# The Hydraulic Empire Army Corps of Engineers

“Need for flood control and irrigation”

“Central coordination and a specialized  
bureaucracy”

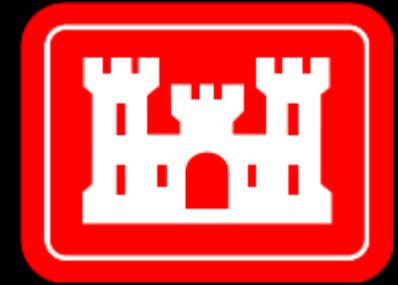
- The Corps of Engineers, founded 1802 by President Thomas Jefferson
- to "organize and establish a Corps of Engineers ... shall be stationed at West Point in the State of New York and shall constitute a military academy."
- During the first half of the 19th century, West Point was the major engineering school in the country.



# Army Corps of Engineers and the Hydraulic Empire

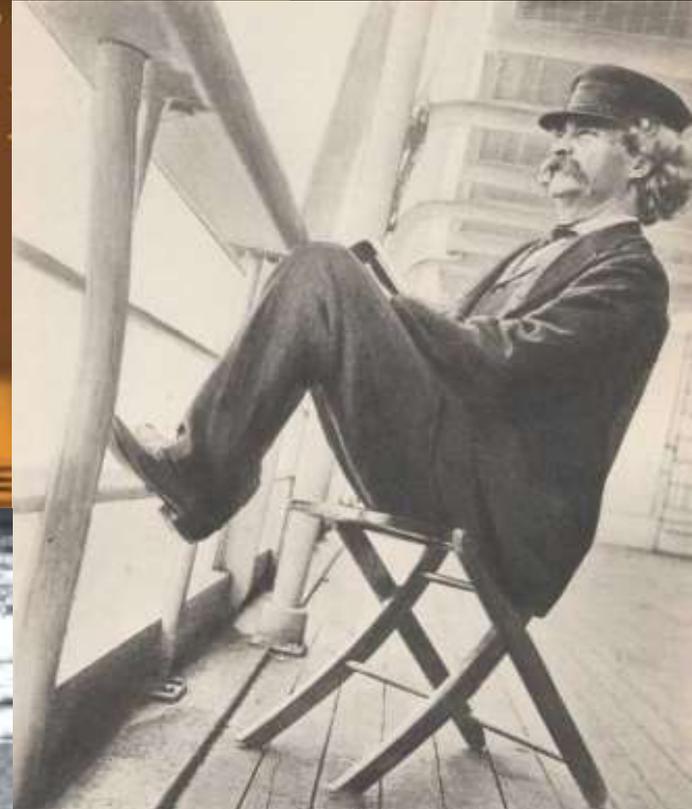
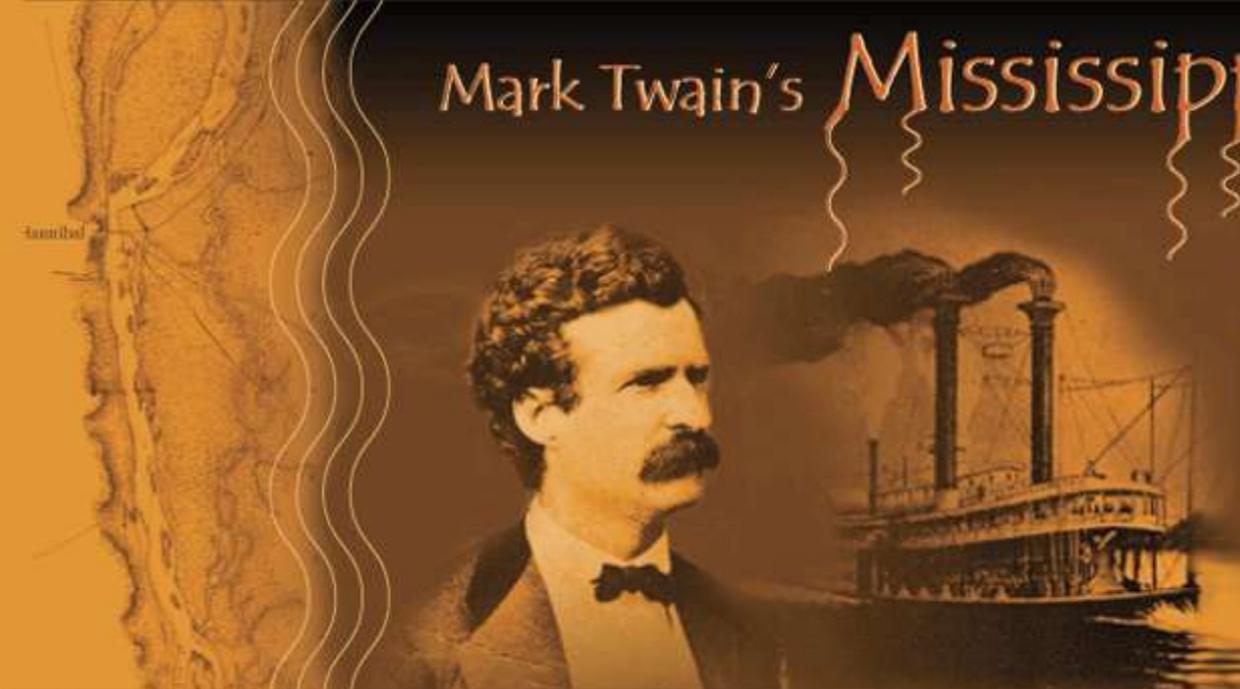
In 1824, Congress passed an "*Act to Improve the Navigation of the Ohio and Mississippi Rivers*" and "to remove sand bars on the Ohio and planers, sawyers, and snags on the Mississippi" for which the corps was the responsible agency.

## US Army Corps Divisions



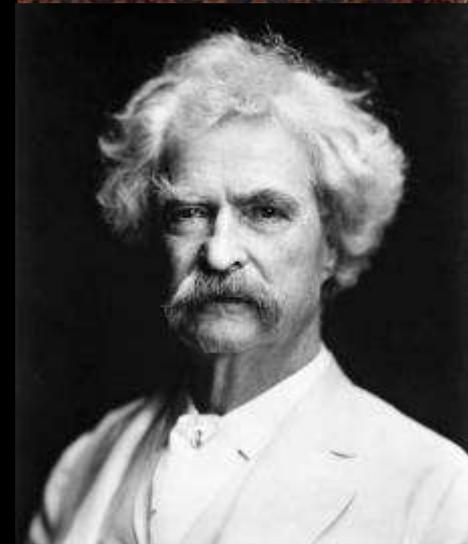
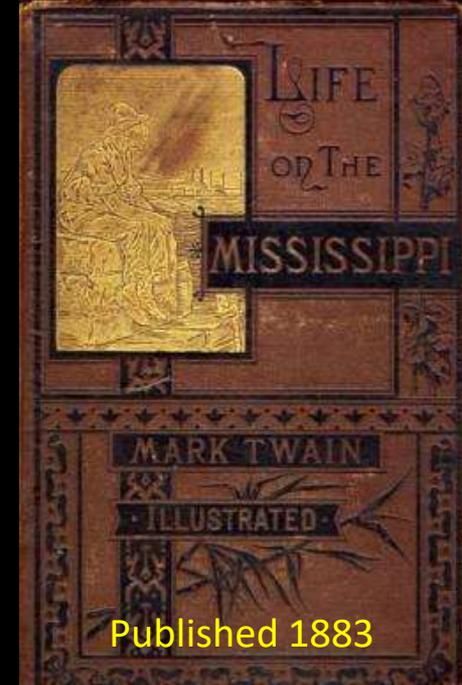
# Mark Twain's *Mississippi*

Mark Twain  
1835 - 1910



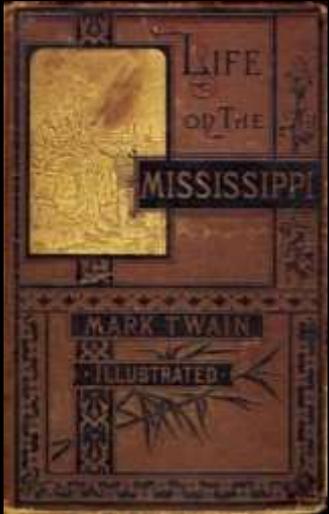
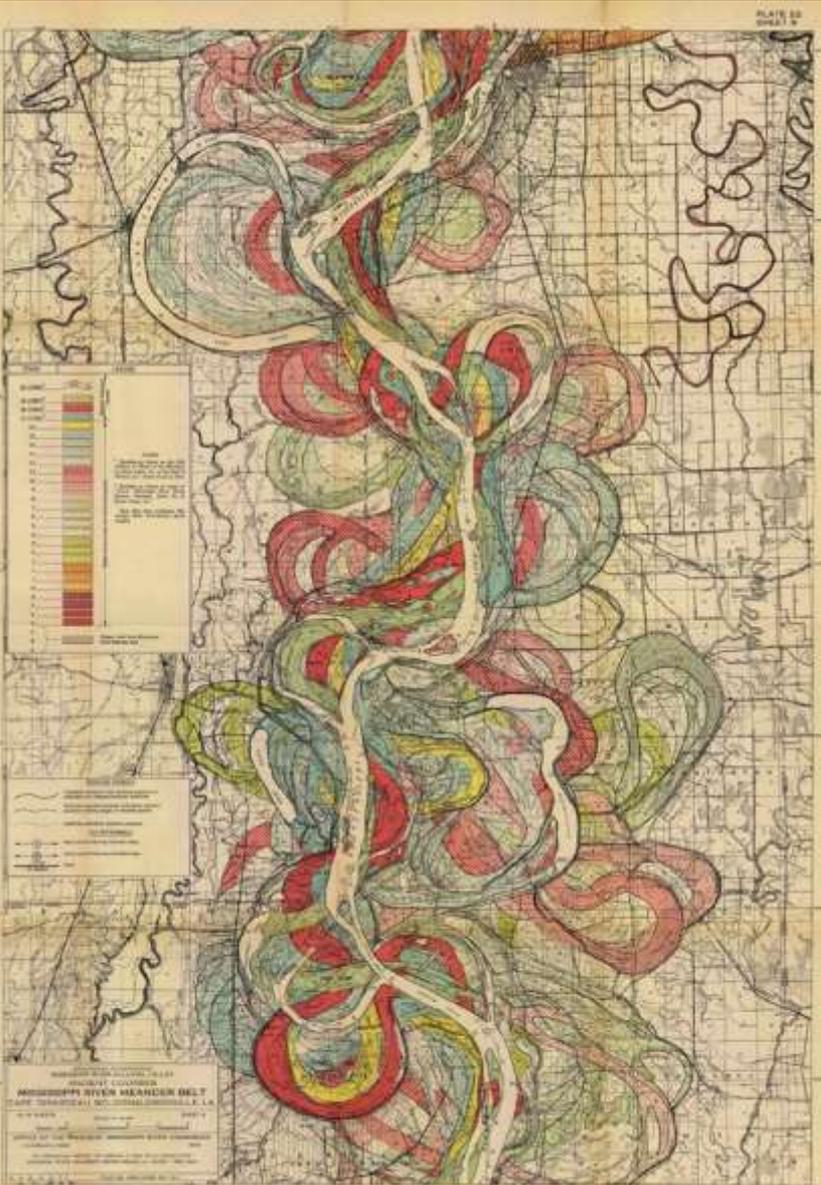
# The Mississippi Basin - The Body of the Nation

*Life on the Mississippi* is a memoir of his days as a steamboat pilot on the Mississippi River before the American Civil War, and also a travel book, recounting his trip along the Mississippi many years after the War. And, finally, a promotional book declaring the Mississippi River as America's most important river.

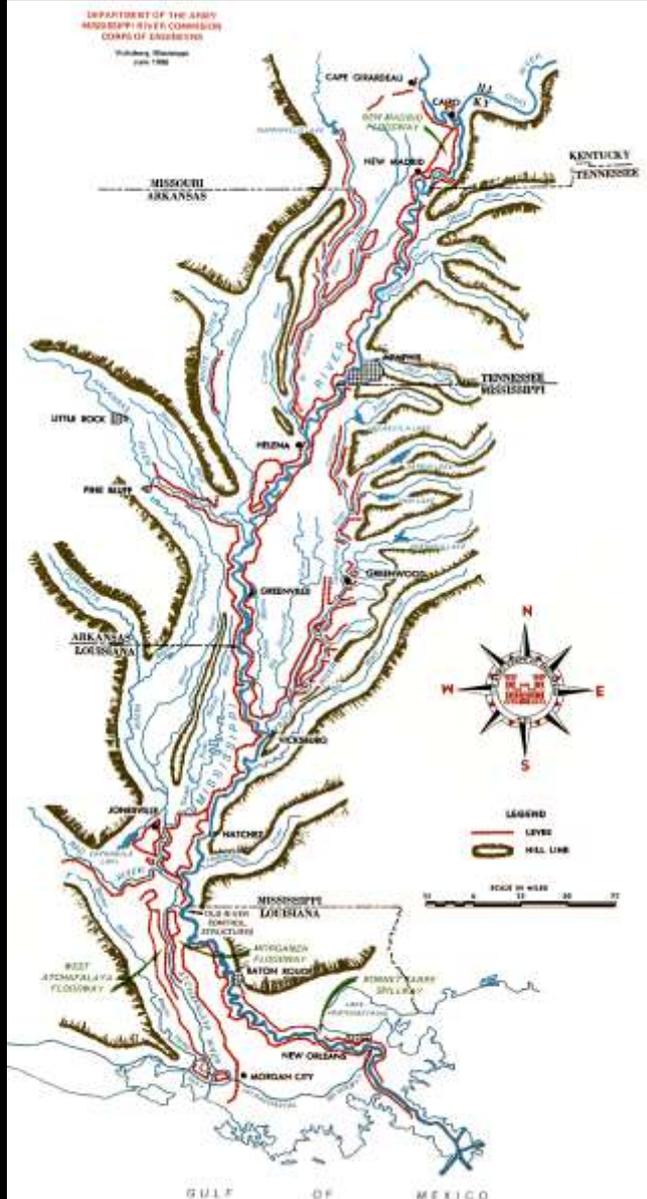


“BUT the basin of the Mississippi is the BODY OF THE NATION. All the other parts are but members, important in themselves, yet more important in their relations to this.”

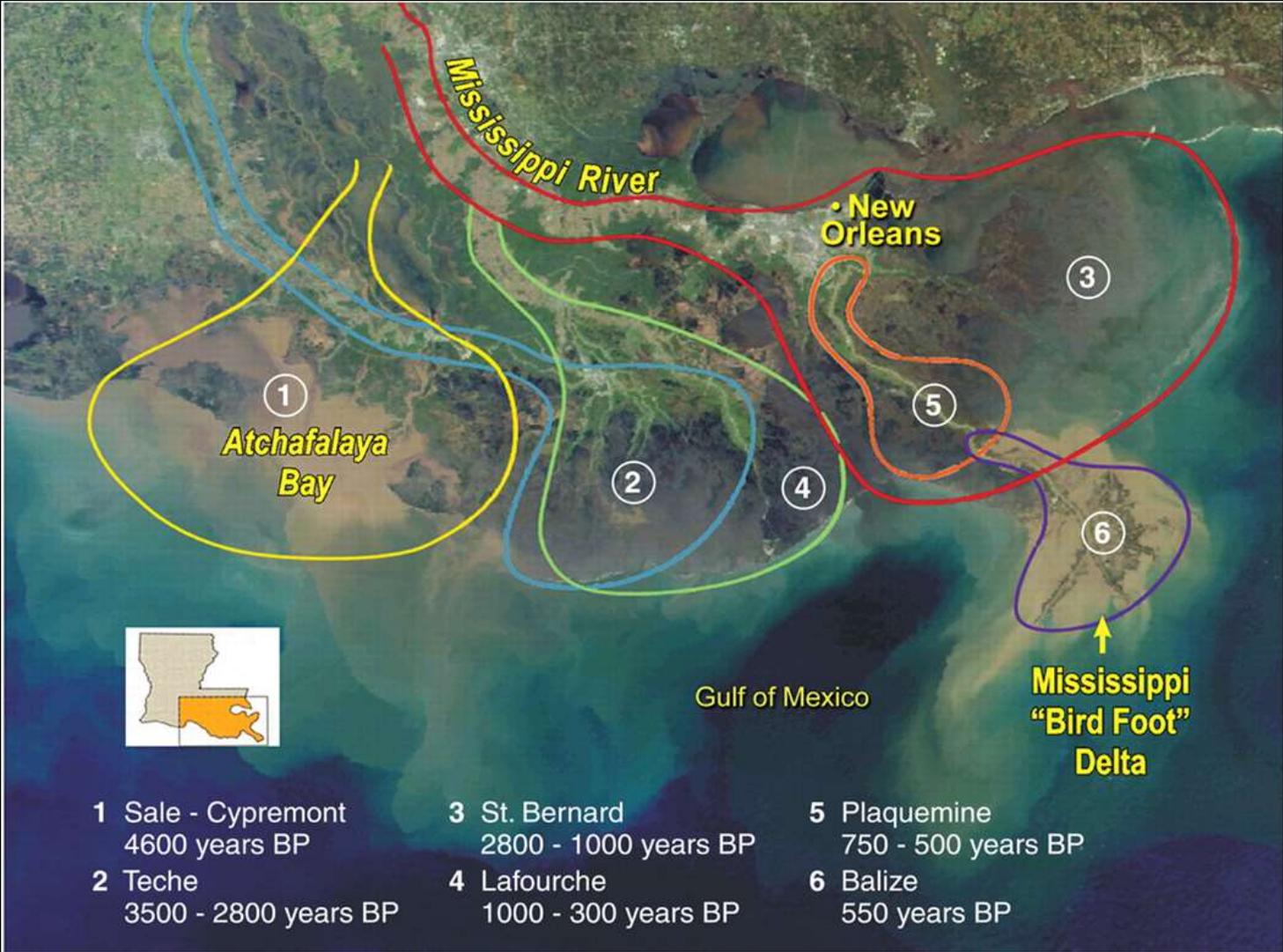
Mark Twain – “One who knows the Mississippi will promptly aver – not aloud, but to himself – that ten thousand River Commissions cannot tame that lawless stream, cannot curve it, or confine it, cannot say to it, Go here, or Go there, and make it obey.”



Between 1932 and 1955 – Mississippi shortened by 150 miles



**Avulsion - the rapid abandonment of a river channel and the formation of a new river channel**



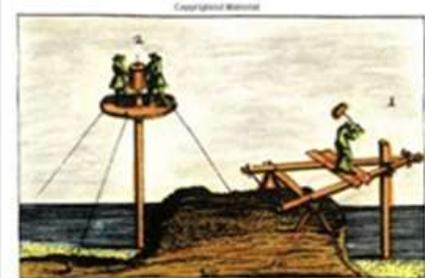
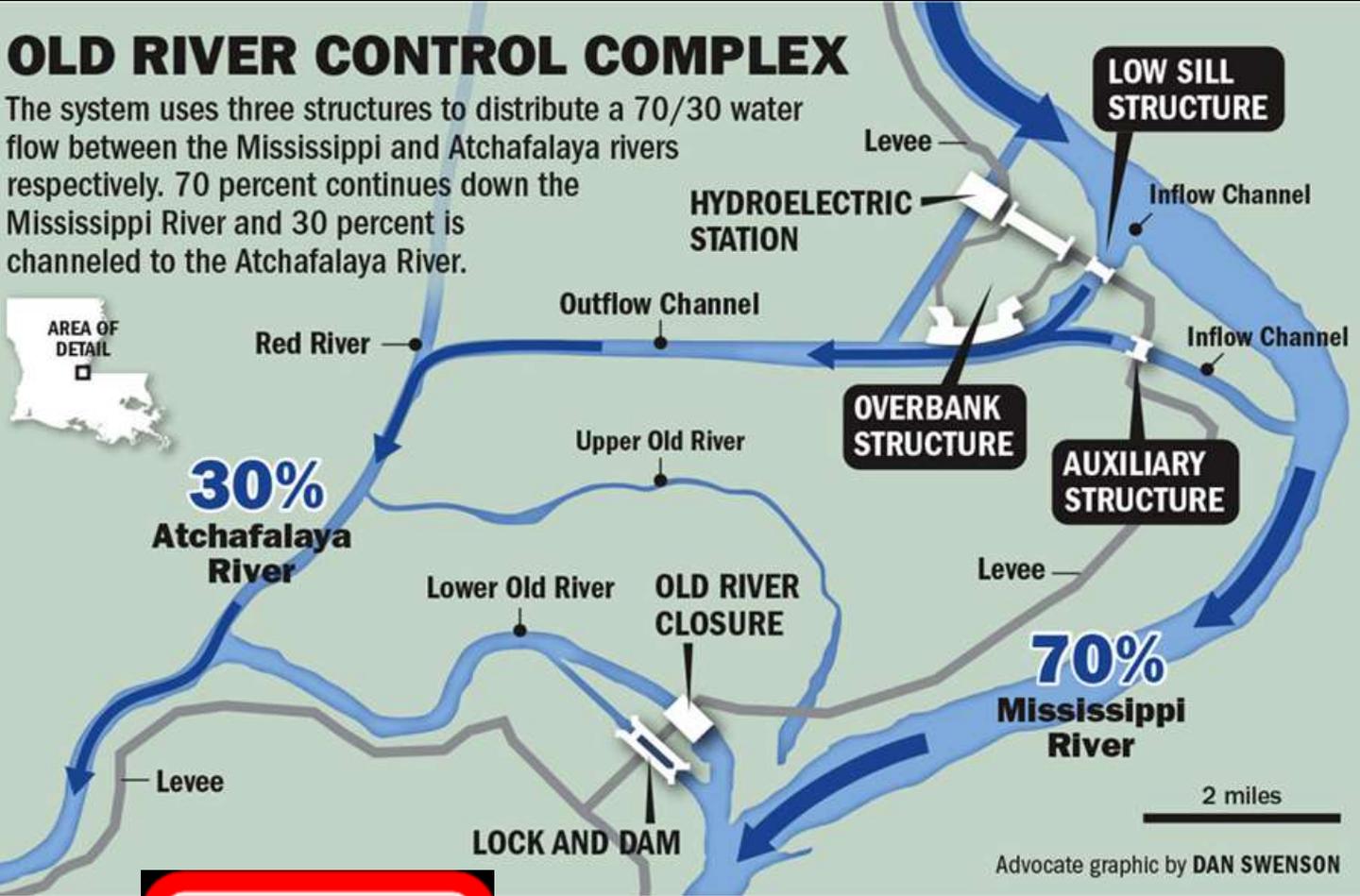
Location of Mississippi River channels discharging water into the Gulf of Mexico over the past 5000 years. Notice the location changes from time to time, keeping all areas of the delta supplied with sediments that balance the natural sinking of the delta. Today, two-thirds of the flow are through the Bird Foot Delta (6) and one third through the Atchafalaya

# America's Achilles' Heel

## Mississippi River's Old River Control Structure

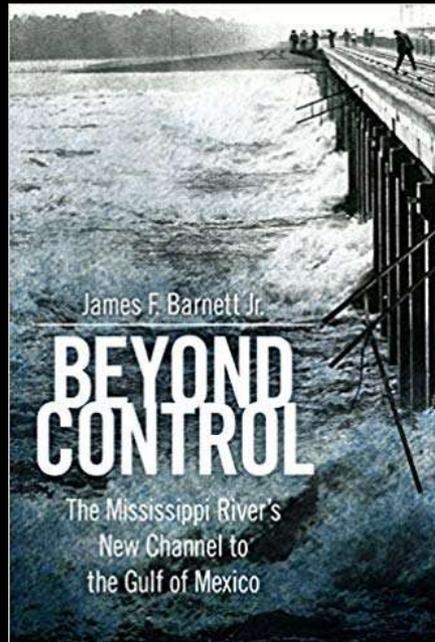
### OLD RIVER CONTROL COMPLEX

The system uses three structures to distribute a 70/30 water flow between the Mississippi and Atchafalaya rivers respectively. 70 percent continues down the Mississippi River and 30 percent is channeled to the Atchafalaya River.



JOHN McPHEE

The Control of Nature

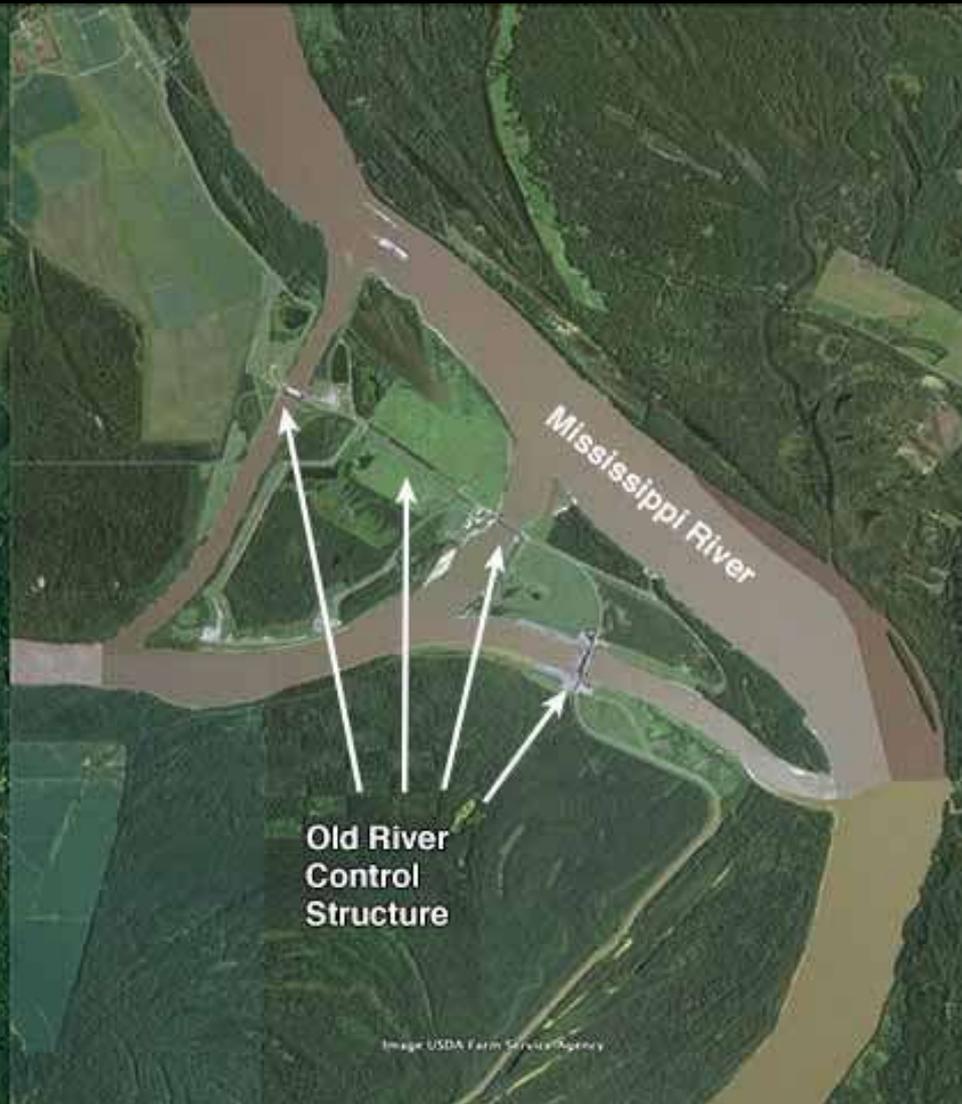
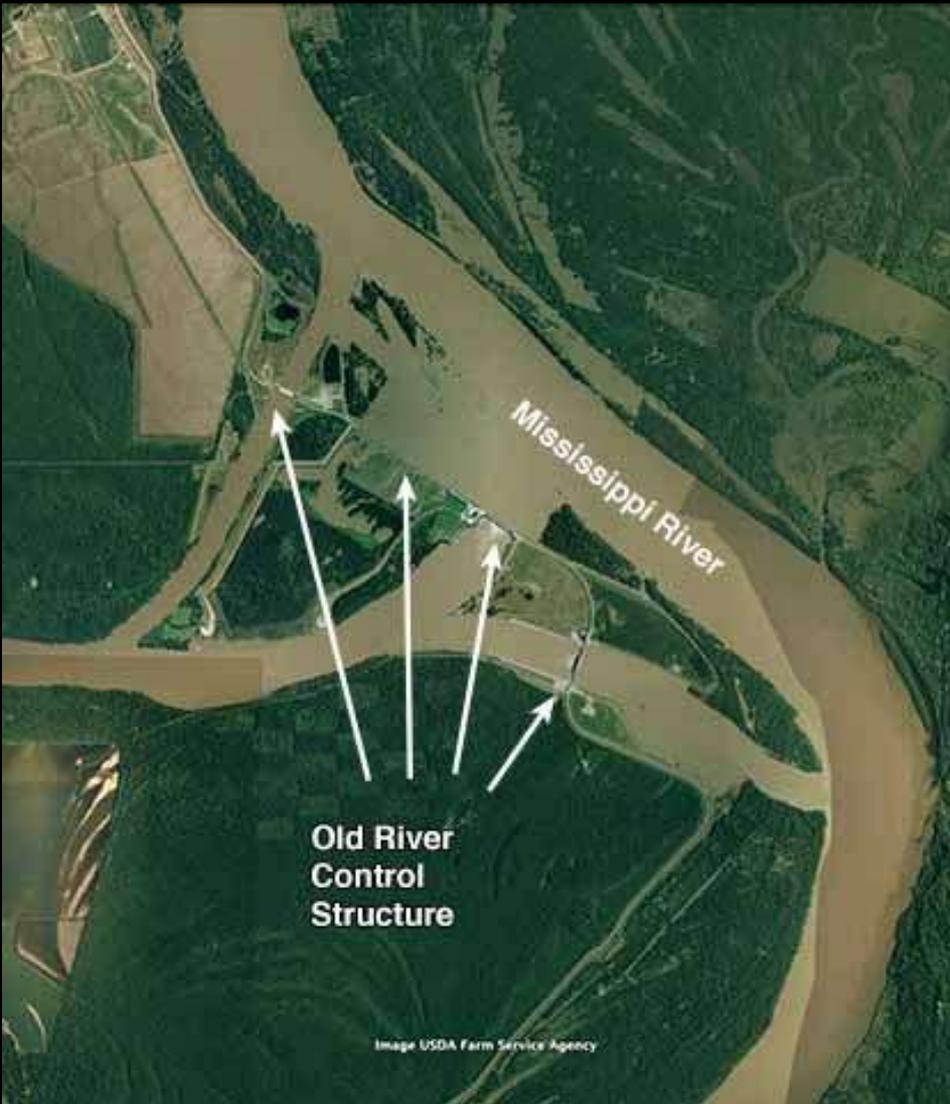


Advocate graphic by DAN SWENSON

# The Mississippi River's Old River Control Structure

2009 Flood

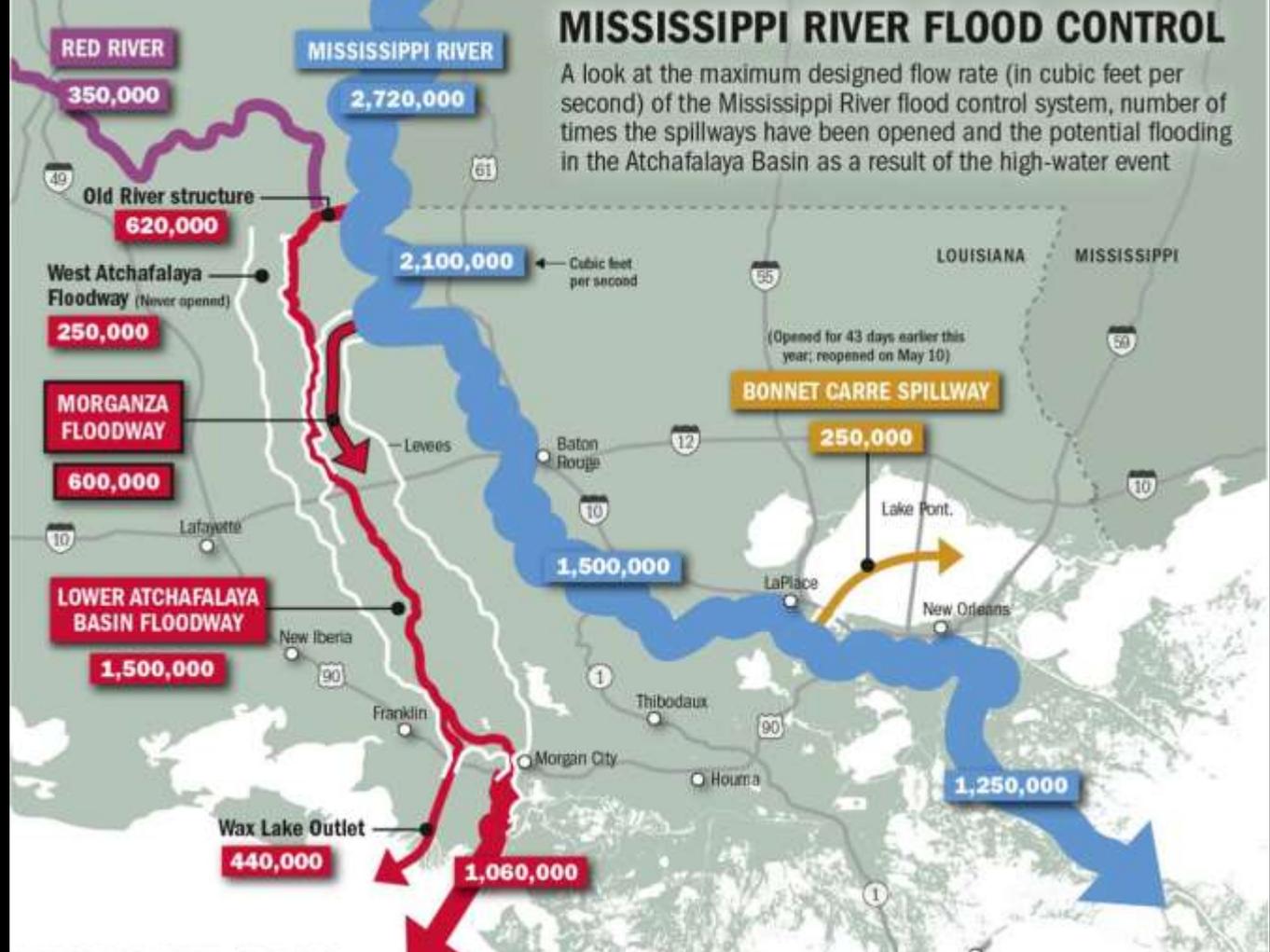
Normal flow



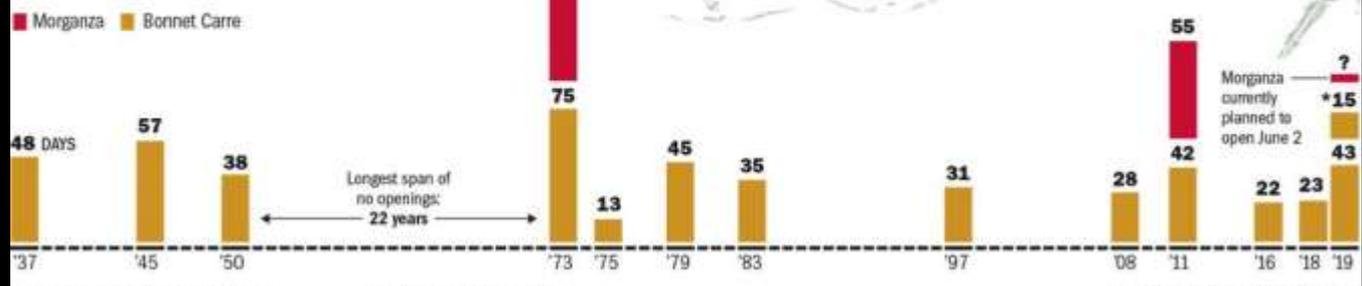
# 2019 Flood

## MISSISSIPPI RIVER FLOOD CONTROL

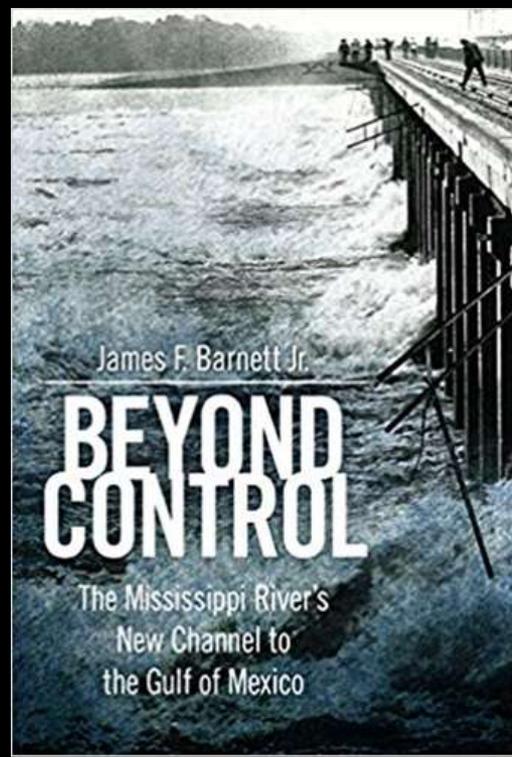
A look at the maximum designed flow rate (in cubic feet per second) of the Mississippi River flood control system, number of times the spillways have been opened and the potential flooding in the Atchafalaya Basin as a result of the high-water event



### YEARS, NUMBER OF DAYS SPILLWAYS OPENED



\*Second opening; currently remains open. Source: Army Corps of Engineers. Advocate graphic by DAN SWENSON





## Different Waterways East and West

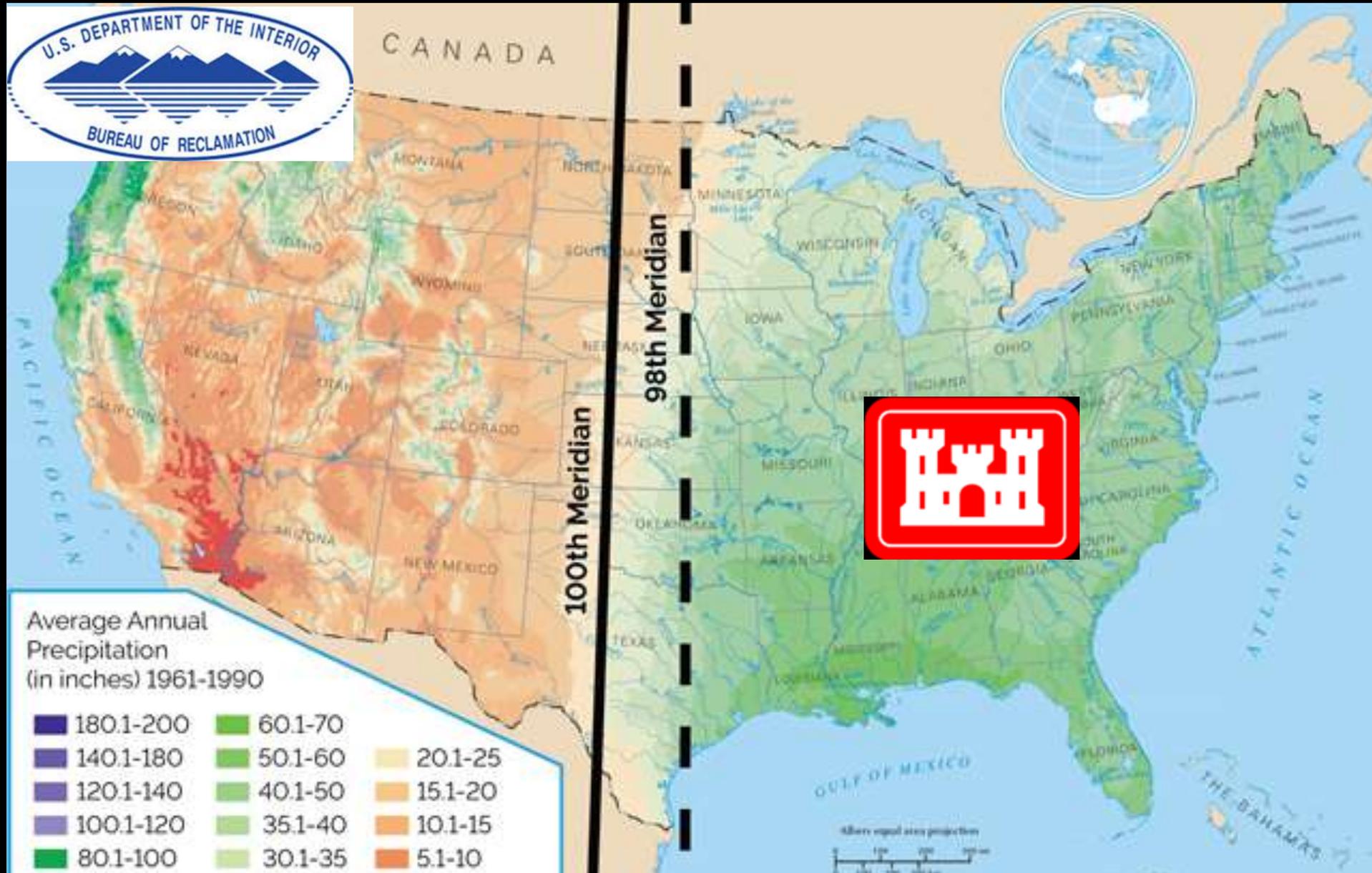


**RECLAMATION**  
*Managing Water in the West*



# The West and Water – Irrigation, Power, and the Hydraulic Empire

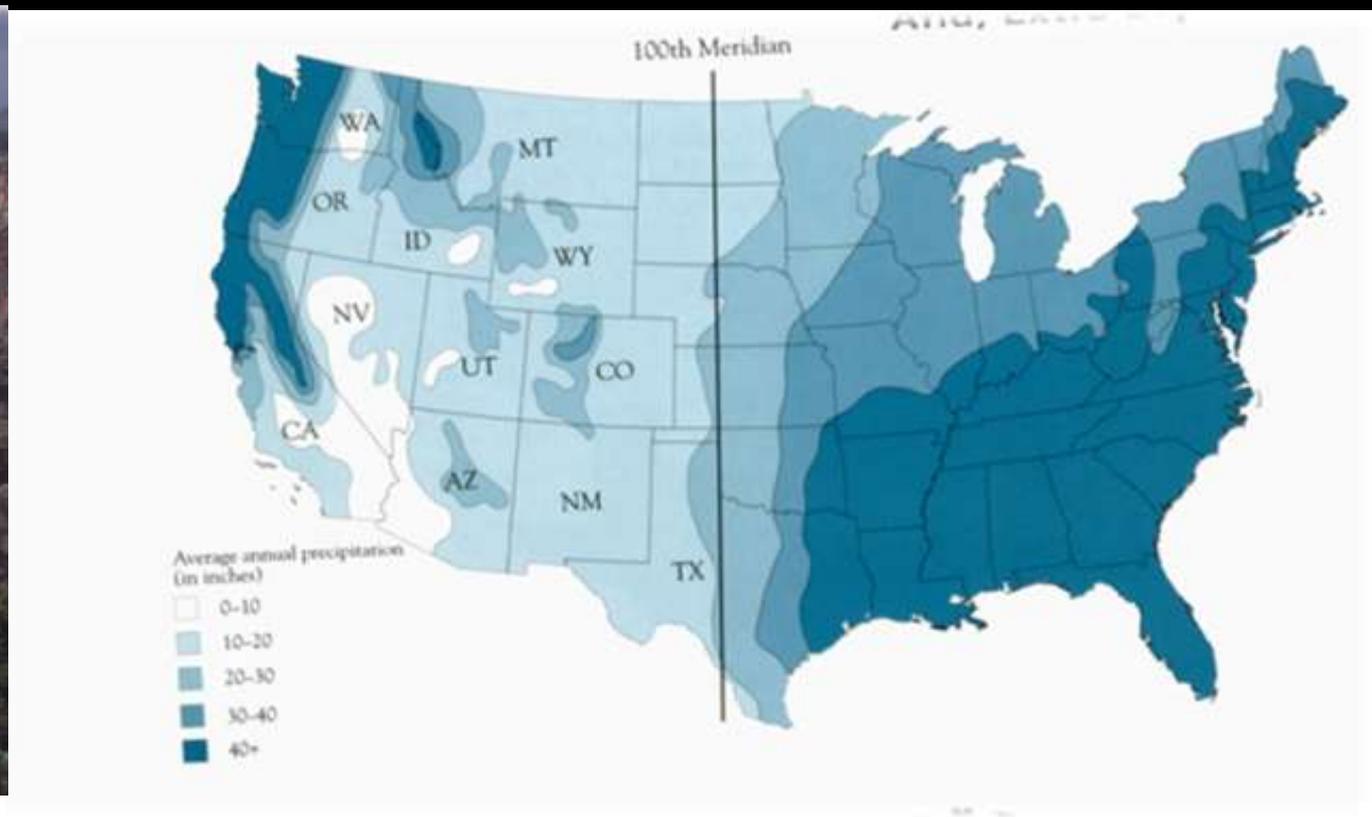
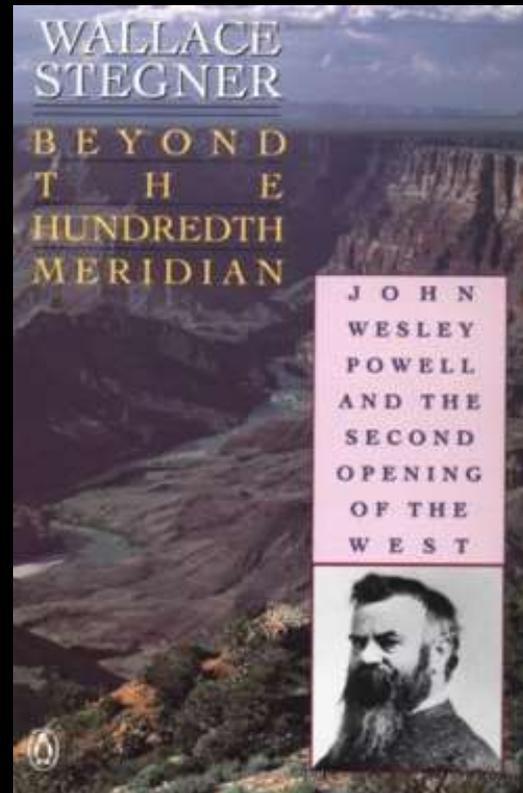
## The Age of Reclamation – Managing Water in the West



Average Annual  
Precipitation  
(in inches) 1961-1990

180.1-200	60.1-70	
140.1-180	50.1-60	20.1-25
120.1-140	40.1-50	15.1-20
100.1-120	35.1-40	10.1-15
80.1-100	30.1-35	5.1-10

# Beyond the 100<sup>th</sup> Meridian and The Great American Desert



## *Report on the Lands of the Arid Regions of the United States 1878*

Arid West was not suitable for agricultural development, except for 2% of the lands near water sources.

Irrigation systems and state boundaries based on watershed areas to avoid “squabbles”.

For the remaining lands, he proposed conservation and low-density, open grazing.

# Railroad Empire to Hydraulic Empire - "Rain follows the plow"

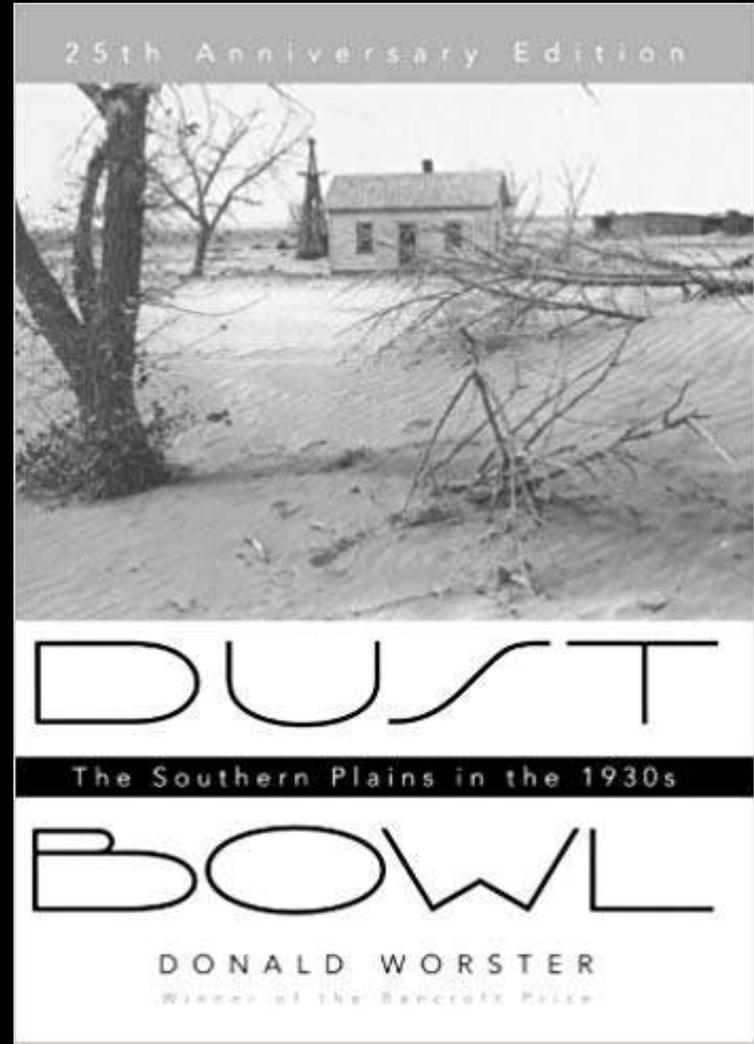
Railroad companies owned vast tracts of lands granted in return for building the lines, did not agree with Powell's opinion.

They insisted that agricultural development of land causes arid lands to generate higher amounts of rain - agriculture "is the instrument which separates civilization from savagery; and converts a desert into a farm or garden. ... To be more concise, Rain follows the plow."





At an 1883 irrigation conference, Powell would remark: "Gentlemen, you are piling up a heritage of conflict and litigation over water rights, for there is not sufficient water to supply the land."



# Hydraulic Empire – The Bureau of Reclamation

- Established in 1902, the United States Bureau of Reclamation is a federal agency under the U.S. Department of the Interior
- Oversees water resource management, specifically as it applies to the oversight and operation of the diversion, delivery, and storage projects throughout the western United States - irrigation, water supply, and hydroelectric power
- The largest wholesaler of water in the country and providing one in five Western farmers with irrigation water for 10 million acres of farmland.
- The largest producer of hydroelectric power in the western United States

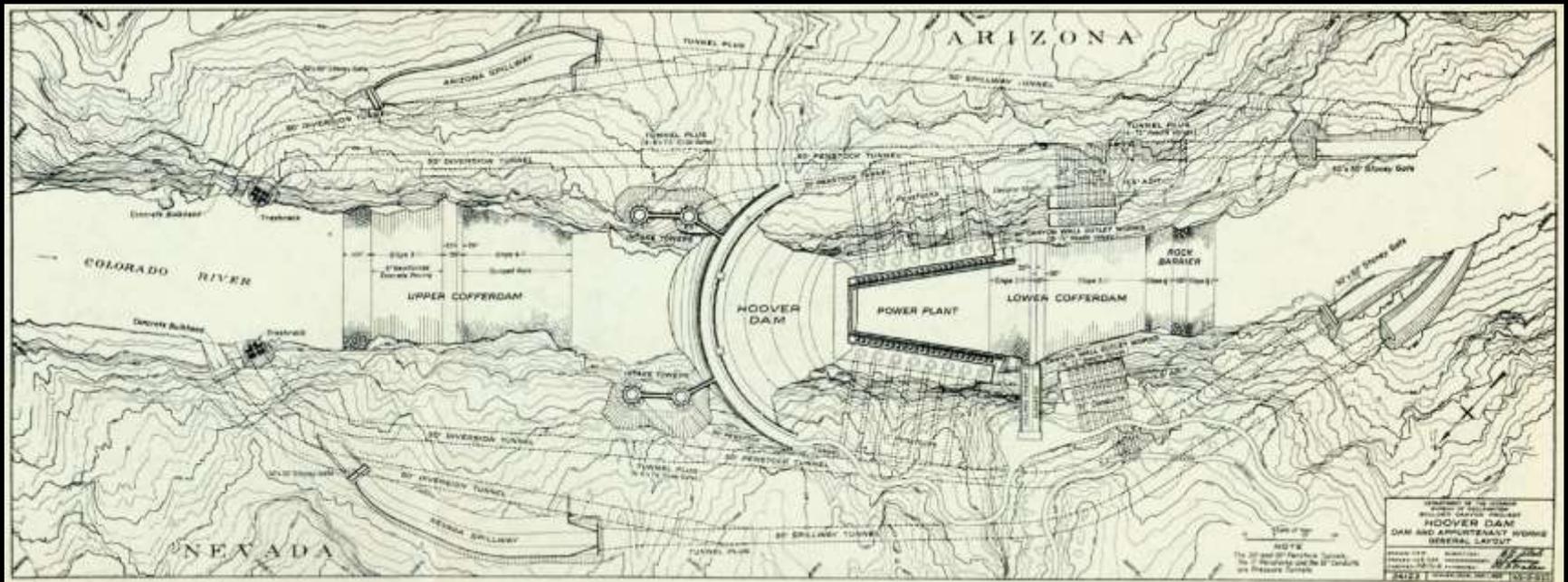
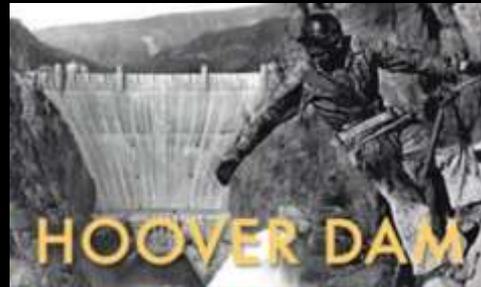
**RECLAMATION**  
*Managing Water in the West*



# The Age of Dam Building – The Colorado River and Hoover Dam

Constructed between 1931 and 1936

Storage 30 Million Acre Feet – 2 entire years of river flow

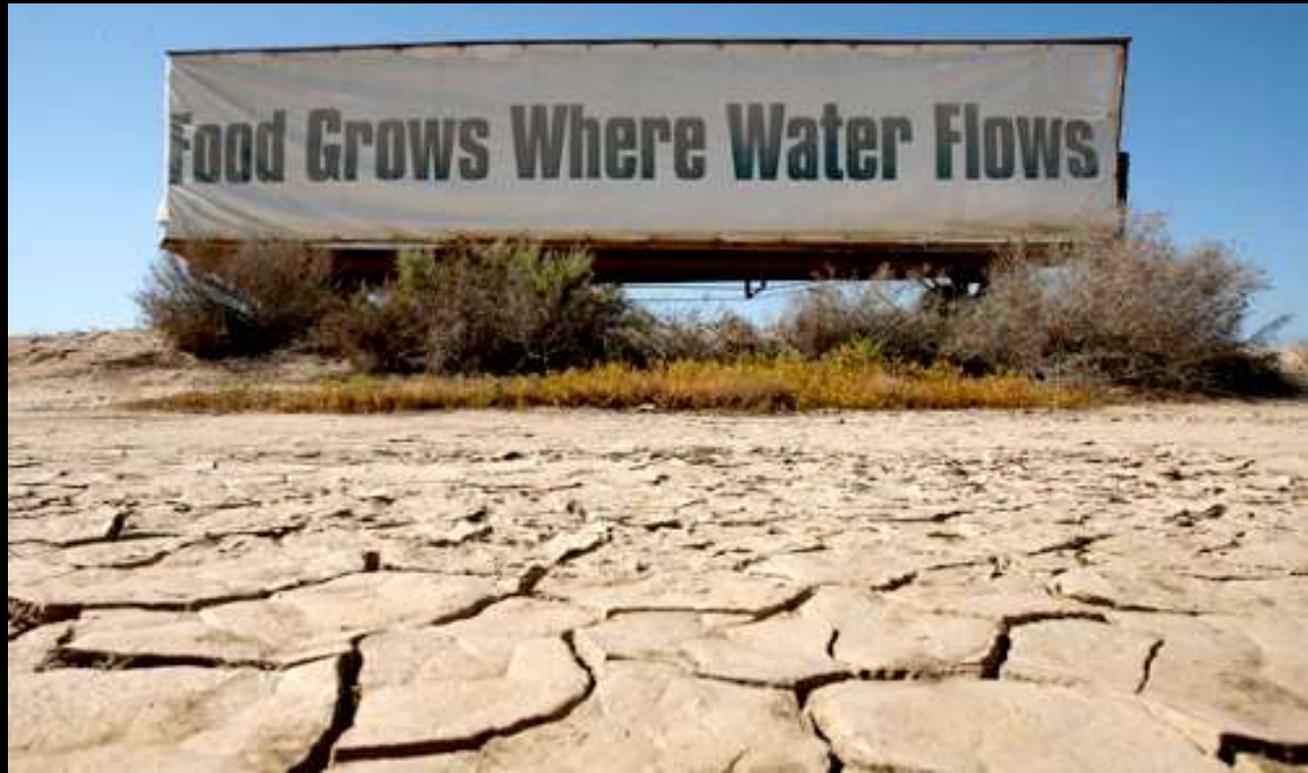
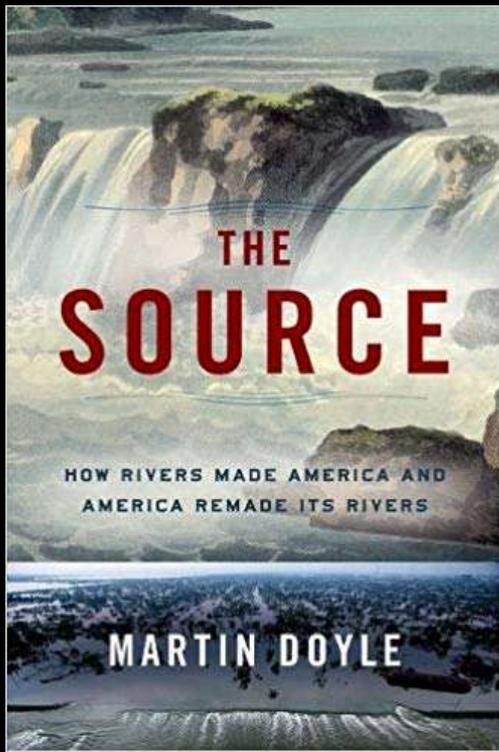


# RECLAMATION

*Managing Water in the West*

“By stabilizing flows and rerouting rivers into canals, Reclamation made possible a new hydrologic norm...with mega-dams capable of storing more than an entire year’s runoff and carefully sequenced networks of dams peppering the upstream river network, rivers became steady, regulated, hydraulic machines...

the desert Southwest became hydrologically interconnected. Simple rivers flowed downhill to the ocean. But once Reclamation had done its work, rivers of the desert Southwest no longer depend on gravity.”



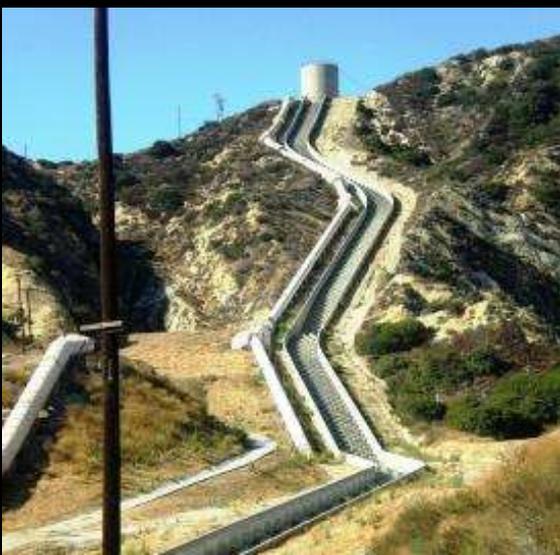
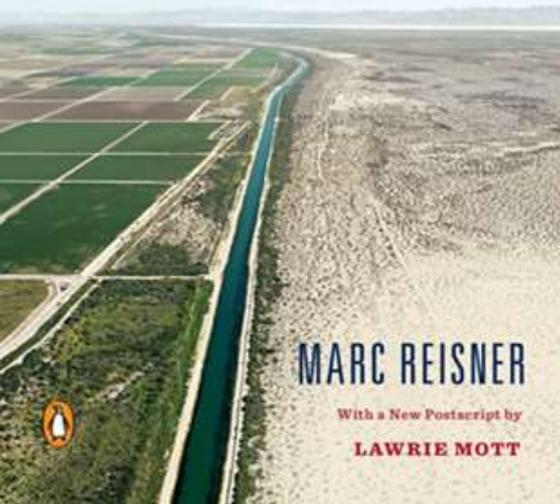
"The definitive work on the West's water crisis." —Newsweek

# CADILLAC DESERT

THE AMERICAN WEST and its  
DISAPPEARING WATER

MARC REISNER

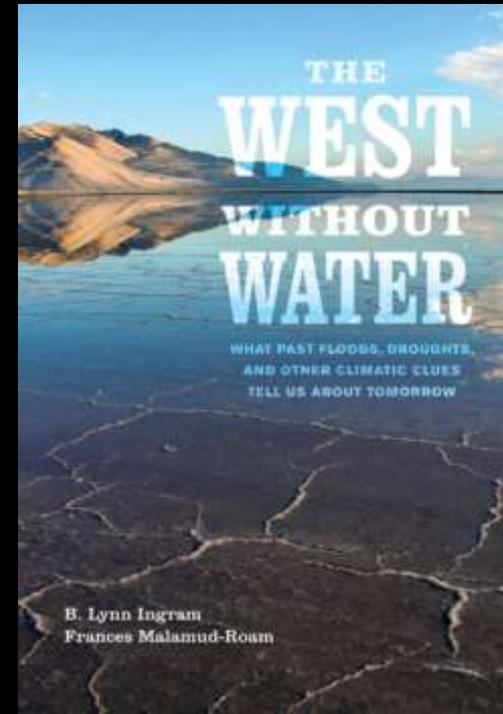
With a New Postscript by  
LAWRIE MOTT



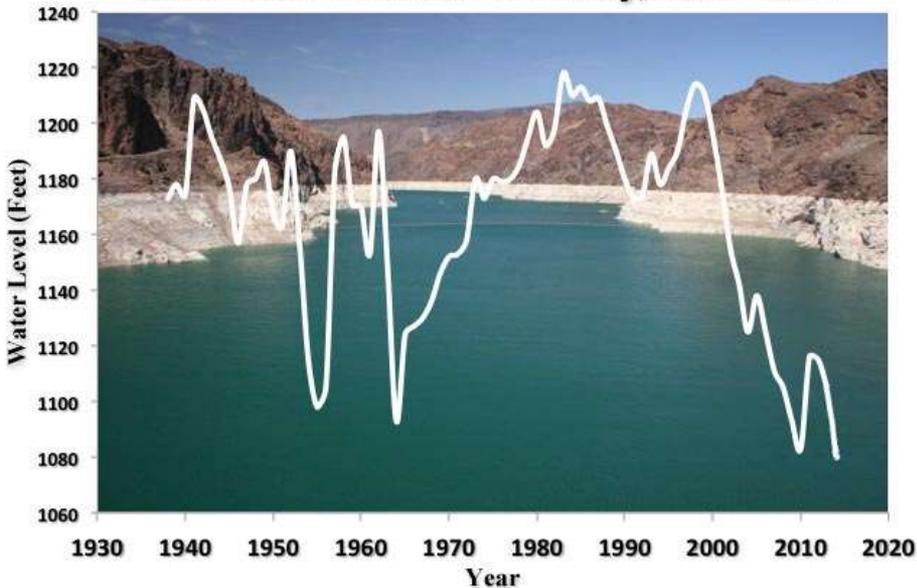
"Gentlemen, you are piling up a heritage of conflict and litigation over water rights, for there is not sufficient water to supply the land."

# Limits of Hydraulic Empire

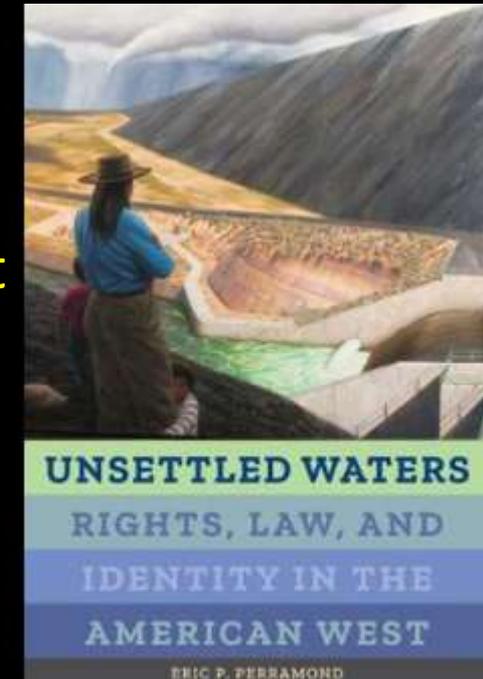
Hoover Dam - Lake Mead 2011



Lake Mead Water Level in July, 1938 - 2014



Heritage of Conflict



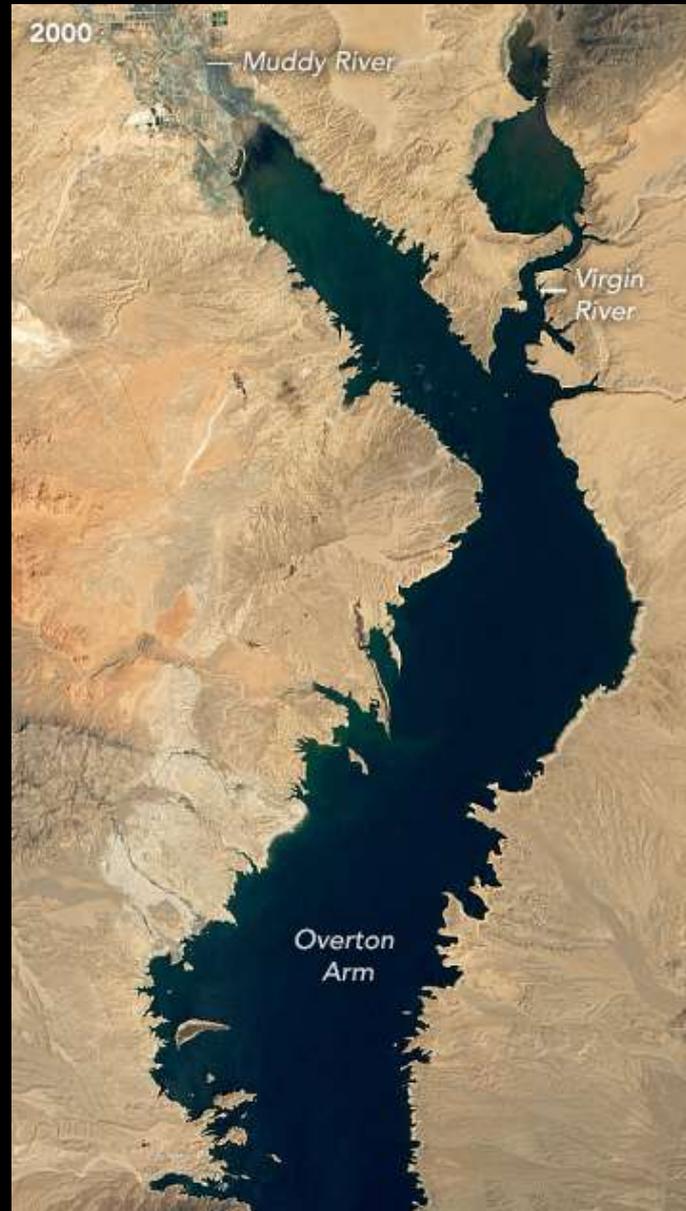
# Limits of Hydraulic Empire

## Droughts, Urbanization, Agricultural Use of Water

Lake Mead 2021

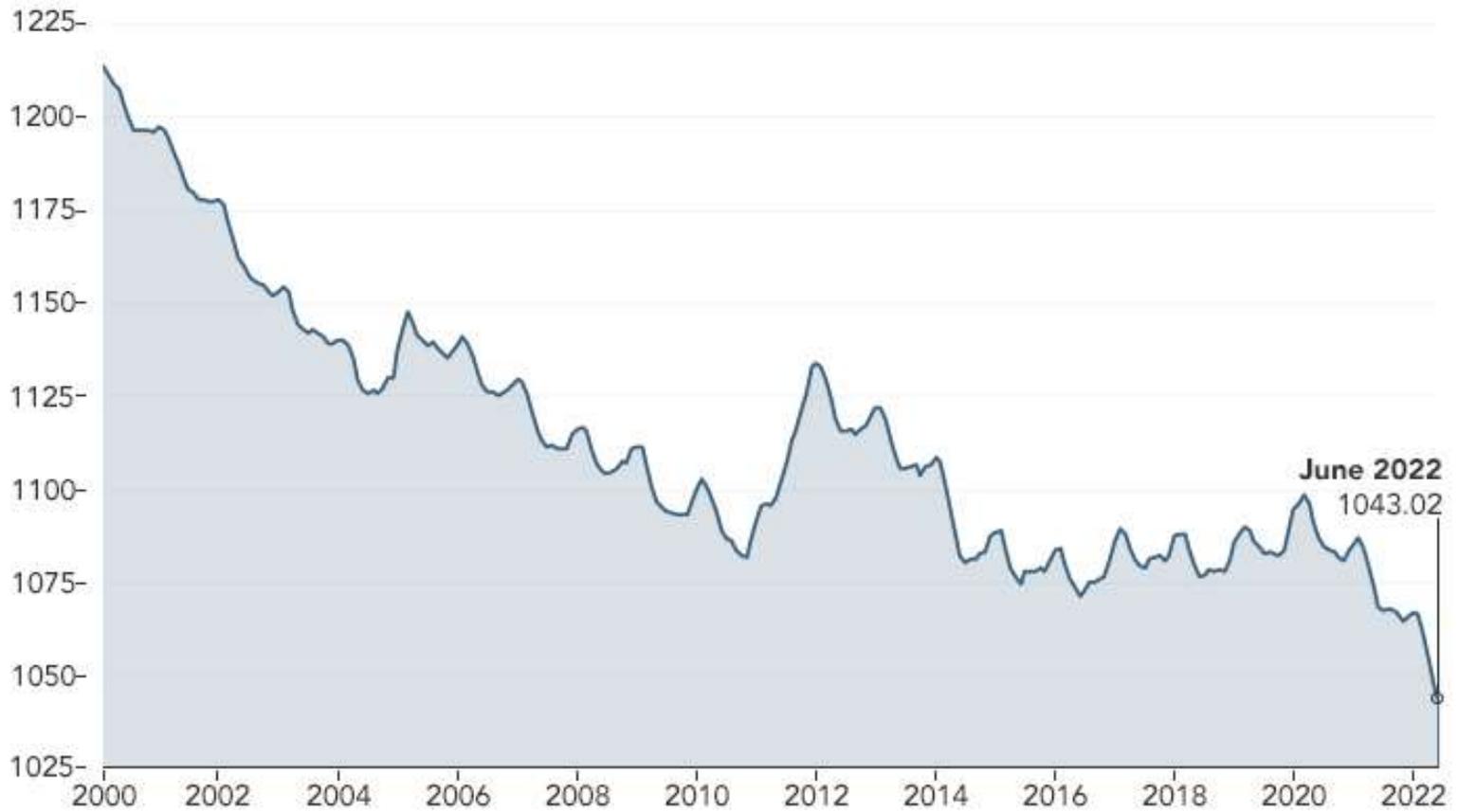
Continuing a 22-year downward trend, water levels in Lake Mead stand at their lowest since April 1937, when the reservoir was still being filled for the first time.

As of July 18, 2022, Lake Mead was filled to just 27 percent of capacity.





Lake Mead Monthly Elevation at Hoover Dam (ft)





BUREAU OF  
RECLAMATION

# Climate Change

## Water Reliability in the West - 2021 SECURE Water Act Report

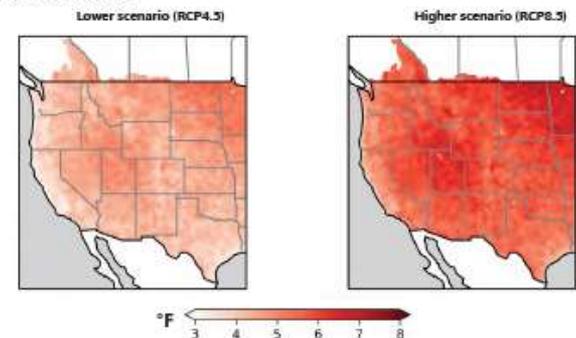


U.S. Department of the Interior

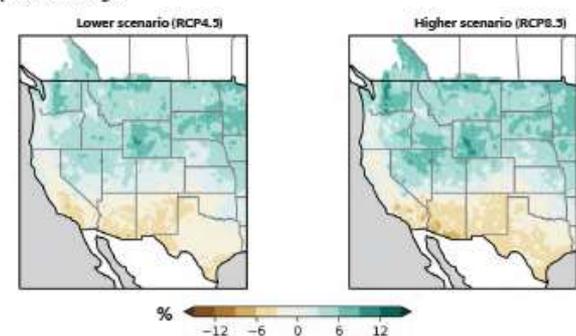
January 2021

- A temperature increase of 5–7 degrees Fahrenheit (°F) during the 21st century;
- Basins throughout the West are projected to experience increasing temperatures, snowpack declines, and earlier seasonal peak runoff.
- The magnitude of impacts becomes greater with time

### Temperature Increases

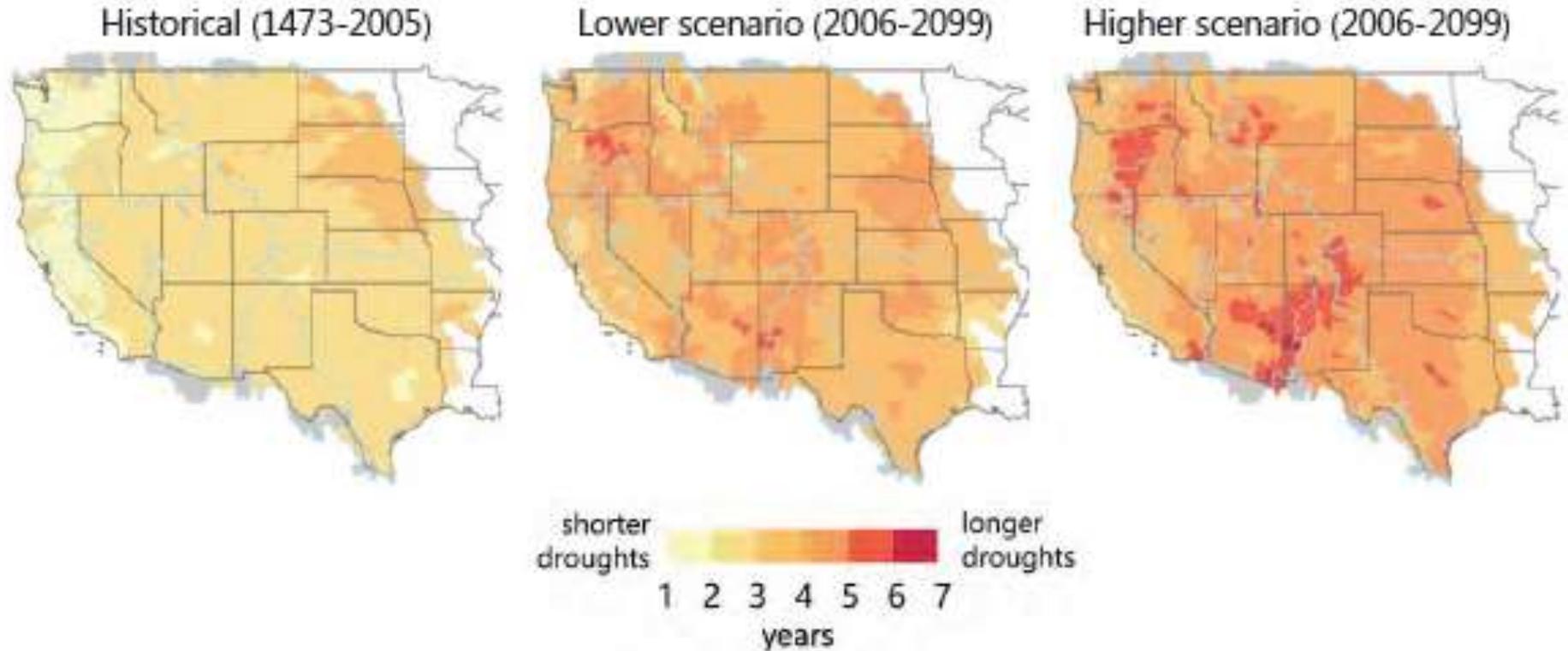


### Precipitation Changes



Maps show average annual temperature increases and average percent changes in precipitation across a lower scenario (RCP4.5) and a higher scenario (RCP8.5) for the period 2040–2099 relative to 1970–1999 using the

## Average Drought Duration Projected to Increase



Droughts, defined as PDSI values less than or equal to zero, historically last an average of 1 to 4 years (yellow and light orange). In the future, these conditions are projected to last longer (orange and red) under both the lower and higher scenarios.

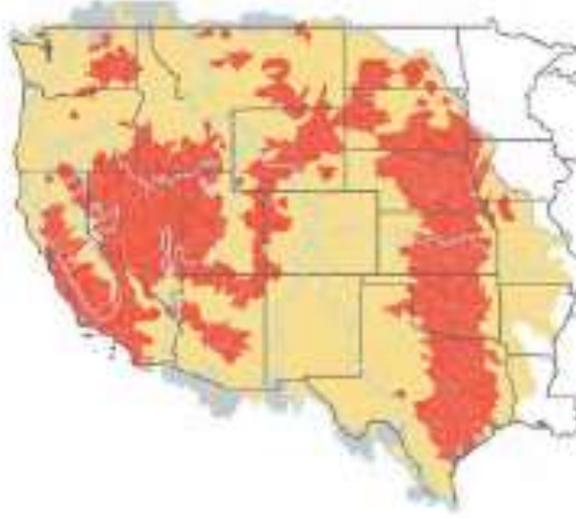
Limits of Hydraulic Empire - Climate Change

## Average Drought Severity Projected to Increase

Historical (1473-2005)



Lower scenario (2006-2099)



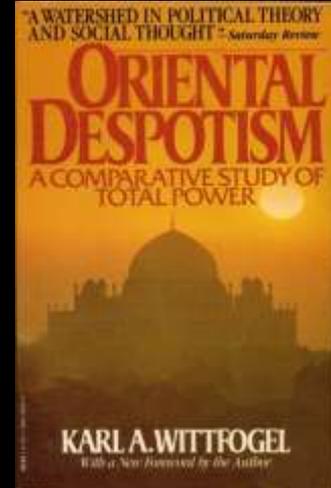
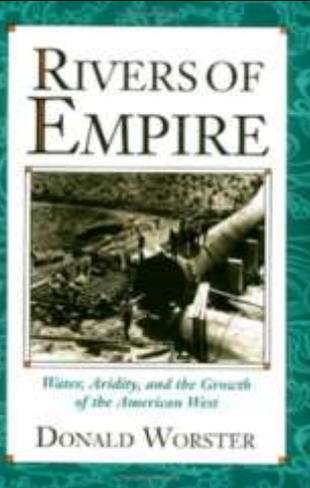
Higher scenario (2006-2099)



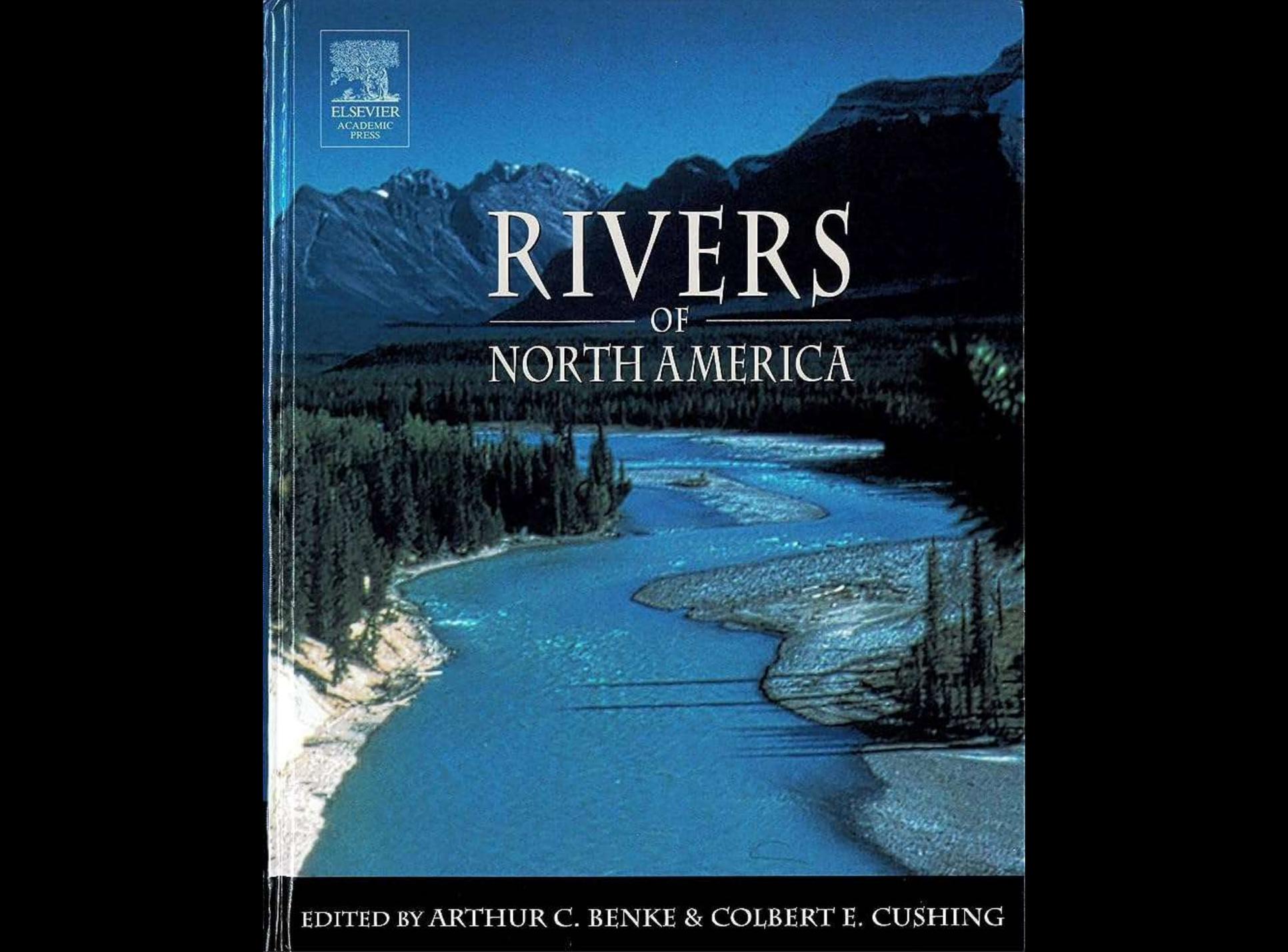
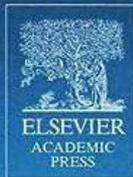
Historically, drought severity, including the paleo and observed historical period, is between PDSI values of -1 and -2. In the future, droughts are projected to become more severe (darker orange) in portions of the West under both the lower and higher scenarios.

Limits of Hydraulic Empire - Climate Change

# Hydraulic Empire?



- A social or government structure which maintains power and control through exclusive control over access to water.
- It arises through the need for flood control and irrigation, which requires central coordination and a specialized bureaucracy.
- Strong Thesis - A developed hydraulic civilization maintains control over its population by means of controlling the supply of water.

The background of the cover is a high-angle, aerial photograph of a wide river. The river is a vibrant blue color, likely due to glacial silt. It winds through a valley with steep, rocky slopes. The banks are lined with dense evergreen forests. In the distance, a range of rugged mountains with snow-capped peaks is visible under a clear sky. The overall scene is a classic representation of a North American mountain river landscape.

# RIVERS OF NORTH AMERICA

EDITED BY ARTHUR C. BENKE & COLBERT E. CUSHING