Can Shale Oil and Water Mix?

Perspectives on Water Resources and Oil Shale Development

Robert Vagnetti

U.S. Department of Energy

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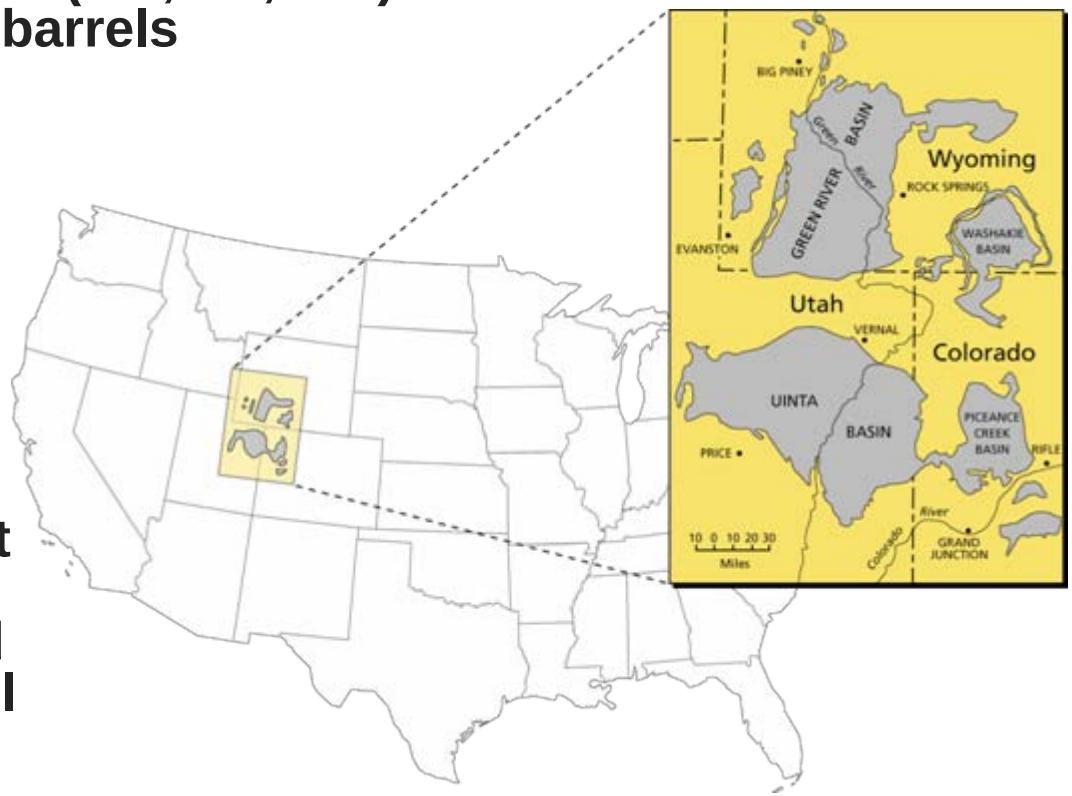
The Energy Challenge

- **U.S. oil demand forecast to grow by 34 percent by 2030 with imports' share of U.S. oil supply increasing to 62 percent** (*EIA AEO 2006*)
- **Rapidly increasing global competition for oil**
- **Conventional petroleum supplies are not meeting increases in world demand**
- **Growing dependence on unstable foreign oil suppliers**
- **Potential disruptions from natural disasters, acts of terrorism, and failures of an aging infrastructure**
- **Price volatility and soft investment confidence**

Western Oil Shale – A Huge Domestic Resource

- Green River Formation (CO, UT, WY) - estimated 1.5 trillion barrels
- Initial development - high-grade oil shale yielding 25 or more gallons per ton; estimated between 400 and 750 billion barrels
- More than 80 percent of the resource of this richness located in a remarkably small area of the Piceance Basin



- Some portions of the Piceance basin have oil shale deposits in excess of 2000 feet thick with the potential to yield over 2.5 million barrels per acre

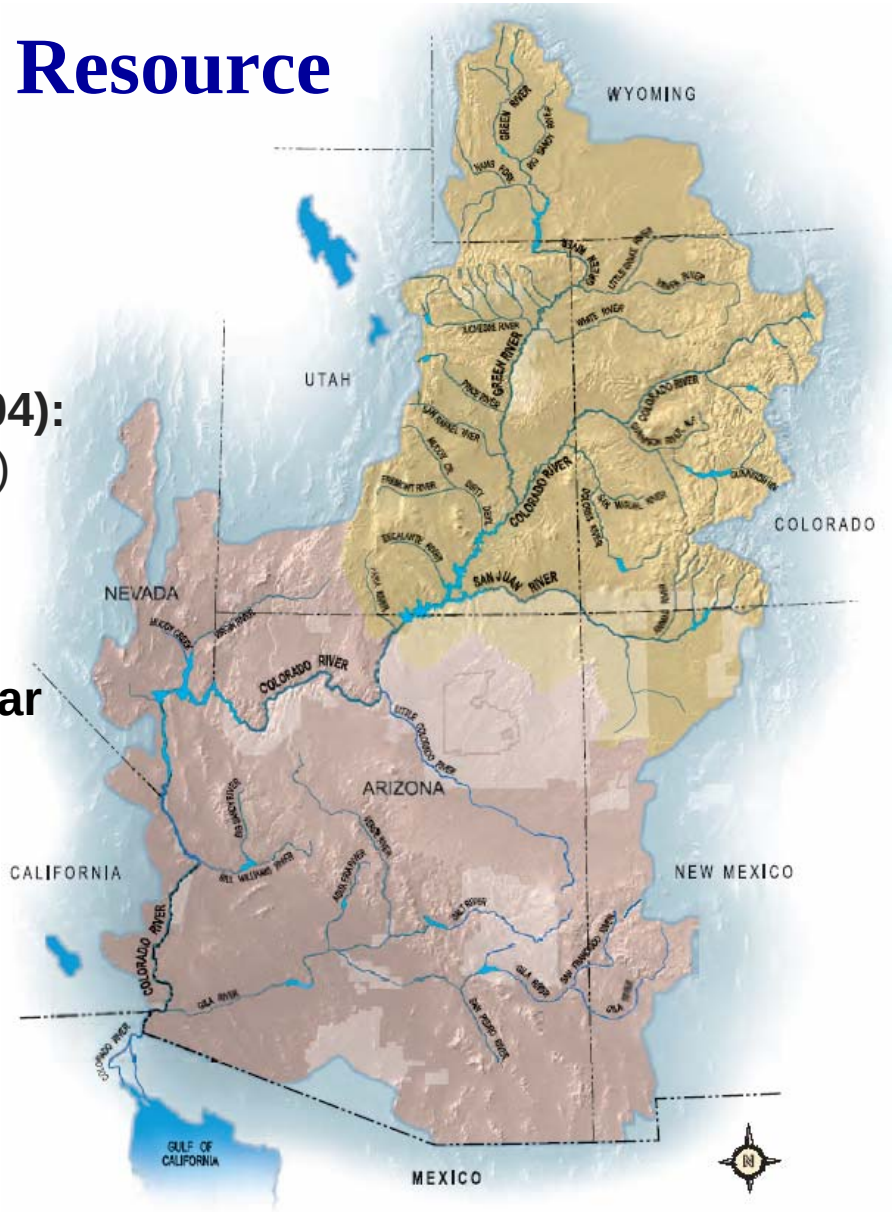
Water Quality and Quantity is a Key Concern

“Questions about the amount of water that oil shale and tar sands development technologies would require and how the technologies would impact surface and groundwater were the most frequently stated concerns in the public comments.”

Summary of Public Scoping Comments for the Oil Shale and Tar Sands Resources Leasing Programmatic Environmental Impact Statement, BLM March 2006.
http://ostseis.anl.gov/documents/docs/OSTS_PEIS_Scoping_Summary_Report060310.pdf

The Water Resource

- **The Upper Colorado River Basin – 110,000 square mile drainage area**
- **Annual flows vary greatly (1896-2004):**
  - Minimum 5.6 million acre-feet (maf)
  - Average 14.8 maf
  - Maximum 24.5 maf
- **Average Flow 2000-2004; 10 maf/year**
- **Substantial groundwater resources**
  - near-surface alluvial aquifers
  - deeply buried bedrock aquifers, moderately poor quality
  - limited hydrological data available



Management of the Colorado River Resources are Highly Regulated

- **The Colorado River is one of the world's most controlled and regulated rivers**
- **Colorado River Compact of 1922 – divides water 50:50 between Upper and Lower Basins**
- **Mexican Water Treaty of 1944 – annual delivery of 1.5 maf split evenly between Upper and Lower Basins**
- **Upper Colorado River Basin Compact of 1948 – sets allocations between Upper Basin States**

Law of the River

- **Colorado River Compact of 1922 – divided water 50:50 between Upper and Lower Basins**
- Boulder Canyon Project Act of 1928 – provided for the construction of the Hoover Dam and the All-American Canal
- California Limitation Act of 1929 – required California to reduce annual consumption to 4.4 maf plus not more than half the surplus water provided to the Lower Basin
- **Mexican Water Treaty of 1944 – guaranteed annual delivery of 1.5 maf to Mexico**
- **Upper Colorado River Basin Compact of 1948 – allocations between Upper Basin States**
- Colorado River Storage Project Act of 1956 – provided for new storage reservoirs to assist the Upper Basin states in meeting their obligation to the Lower Basin
- U.S. Supreme Court Decree 1964; *Arizona v. California* – allocations between Lower Basin States
- Colorado River Basin Project Act of 1968 – coordinated long-range reservoir operations
- Colorado River Basin Salinity Control Act of 1974 (as amended) - authorized the construction, operation, and maintenance of facilities to control the salinity of water delivered to Mexico.

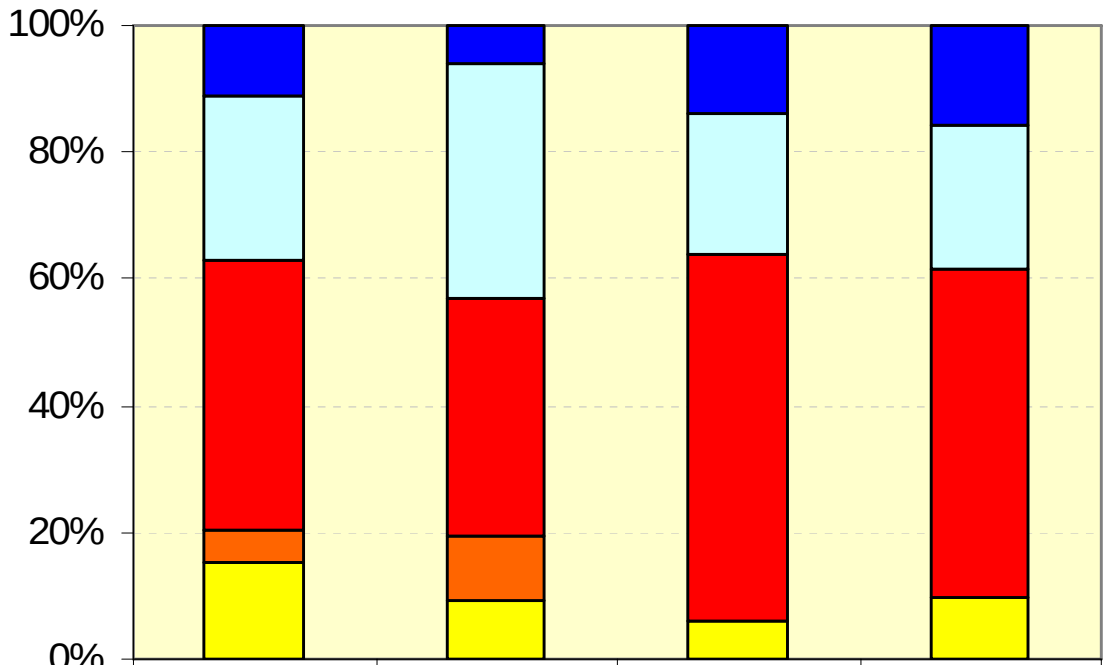
www.usbr.gov/lc/region/g1000/lawofrvr.html

Oil Shale Development - Water Requirements (1980)

	Direct Above-ground Retort (AGR)	Indirect AGR	MIS & AGR	Modified In-situ (MIS)
acre-feet/year	5,350-6,400	9,900-11,800	5,650-5,800	4,900
barrel of water per barrel of shale oil	2.3-2.7	4.2-5.0	2.4-2.5	2.1

Source: Information adapted from the Office of Technology Assessment; An Assessment of Oil Shale Technologies, June 1980; based on 50,000 bpd plant.

Oil Shale Development - How Water is Used



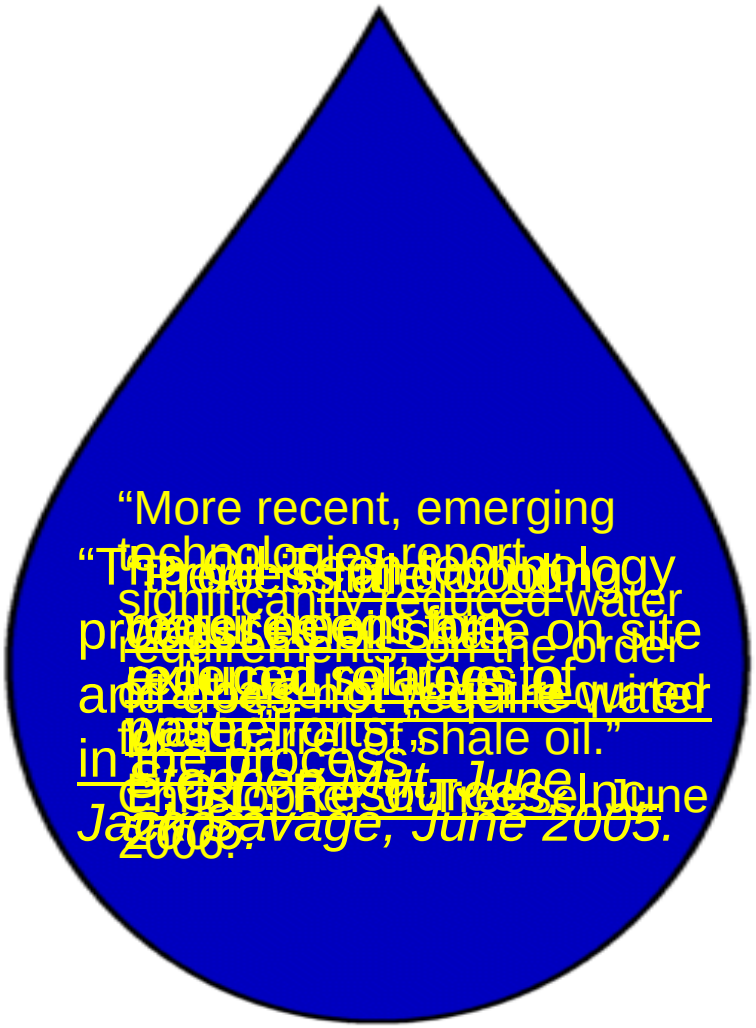
	Direct AGR	Indirect AGR	MIS/AGR	MIS
Municipal	11.06%	5.99%	13.89%	15.94%
Disposal & Reclamation	25.93%	36.87%	22.40%	22.68%
Retort & Upgrading	42.65%	37.89%	57.92%	51.45%
Power Generation	5.19%	9.89%	0.00%	0.00%
Mining & Ore Handling	15.17%	9.36%	5.79%	9.93%

Source: Information adapted from the Office of Technology Assessment; An Assessment of Oil Shale Technologies, June 1980; based on 50,000 BPD plant.

Key Findings of the 1980 OTA Study

- **Available surface water could support a 2,000,000 bpd industry through 2000, if:**
  - additional reservoirs and pipelines were built
  - demand for other uses did not increase faster than the State's medium growth rate projections
  - the mix of technologies was similar to active and proposed projects
  - average flows (virgin) of the Colorado River did not decrease below the 1930-1974 average of 13.8 maf per year
- **In the longer term the OTA study found that surface water may not be adequate to sustain growth**

Data for Emerging Technologies is Limited



Confirmation of Water Requirements Requires RD&D

"Water requirements can vary by an order of magnitude for differing technologies and resources. Requirements will not be reliably known without the benefit of operating experience -- achieved through design, development and operation of pilot and demonstration projects at a commercially-representative scale."

Development of America's Strategic Unconventional Fuels Resources, Initial Report to the President and the Congress of the United States, Task Force on Strategic Unconventional Fuels, September 2006.

Upper Basin Water Availability and Use Absent an Oil Shale Industry

	Colorado	Utah	Wyoming
Water Allocation	3.467	1.541	0.938
	2000		
Water Use[1]	2.686	0.953	0.570
Surplus	0.781	0.588	0.368
	2010 Forecast		
Water Use[1]	2.870	1.095	0.590
Surplus	0.597	0.446	0.348
	2030 Forecast		
Water Use[1]	2.970	1.190	0.644
Surplus	0.497	0.351	0.294

[1] Includes evaporative losses

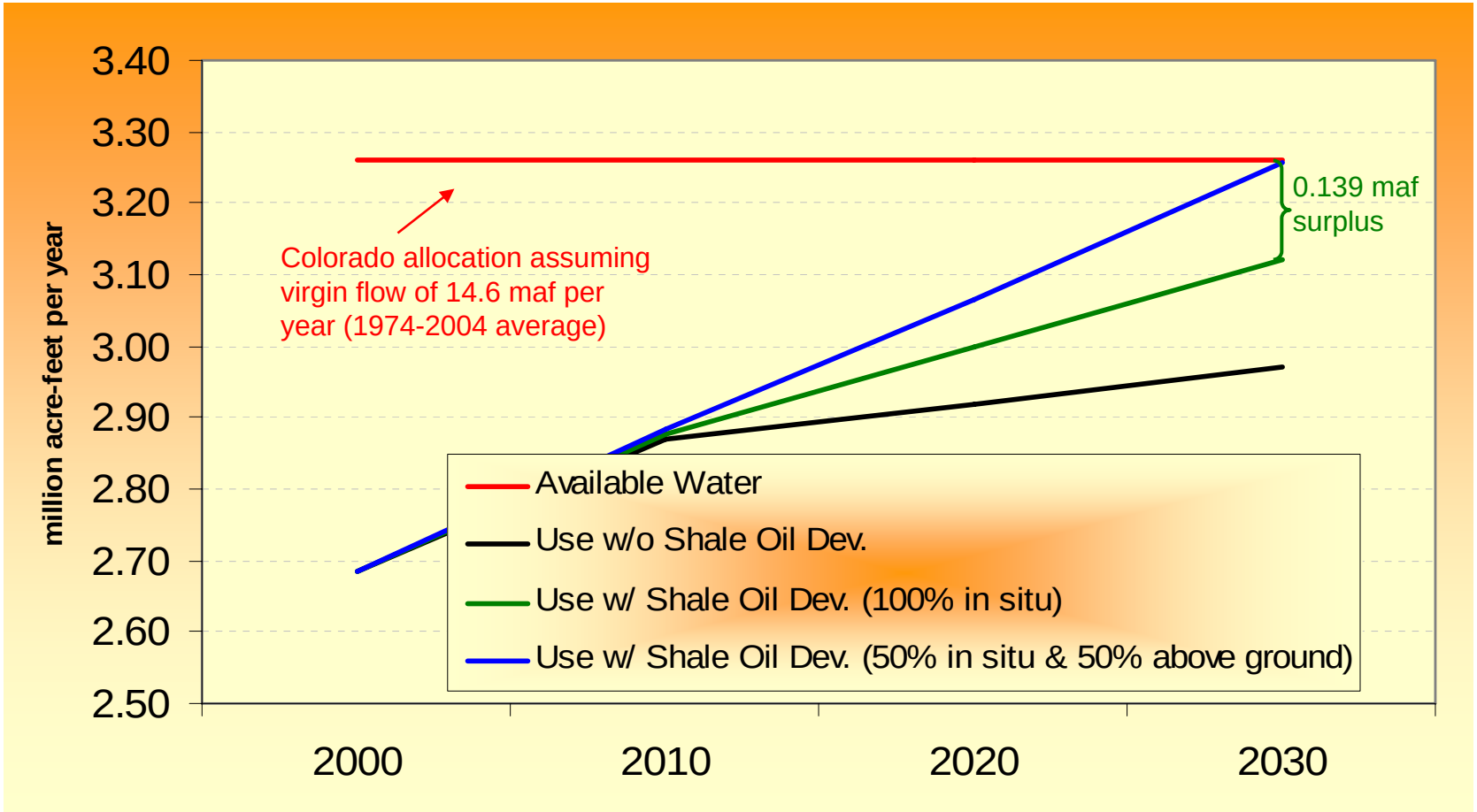
Virgin Flow: 15.000 maf
LB Allocation: 7.500 maf
UB to Mexico: 0.750 maf
UB to AZ: 0.050 maf

Available to CO, UT, WY & NM: 6.700 maf

LB allocated accordingly:
CO = 51.75% = 3.467 maf
UT = 23.00% = 1.541 maf
WY = 14.00% = 0.938 maf
NM = 11.25% = 0.754 maf

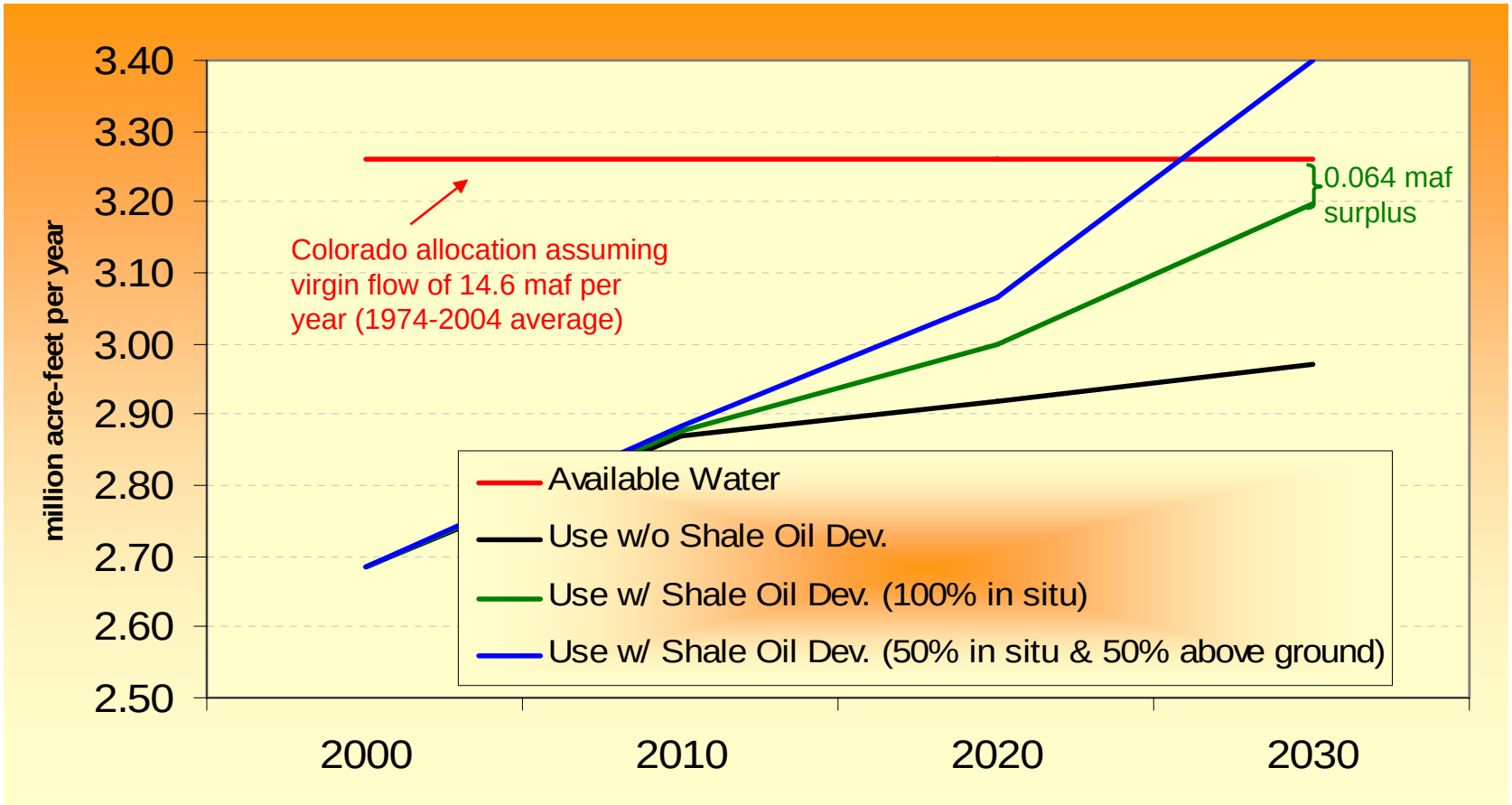
Source: Don Ostler, Upper Colorado River Commission, *Do the Upper Basin States Have Enough Water to Grow?*, Hard Times on the Colorado River: Drought, Growth, and the Future of the Compact Conference, June 8-10, 2005.

Technology Mix Affects Water Use



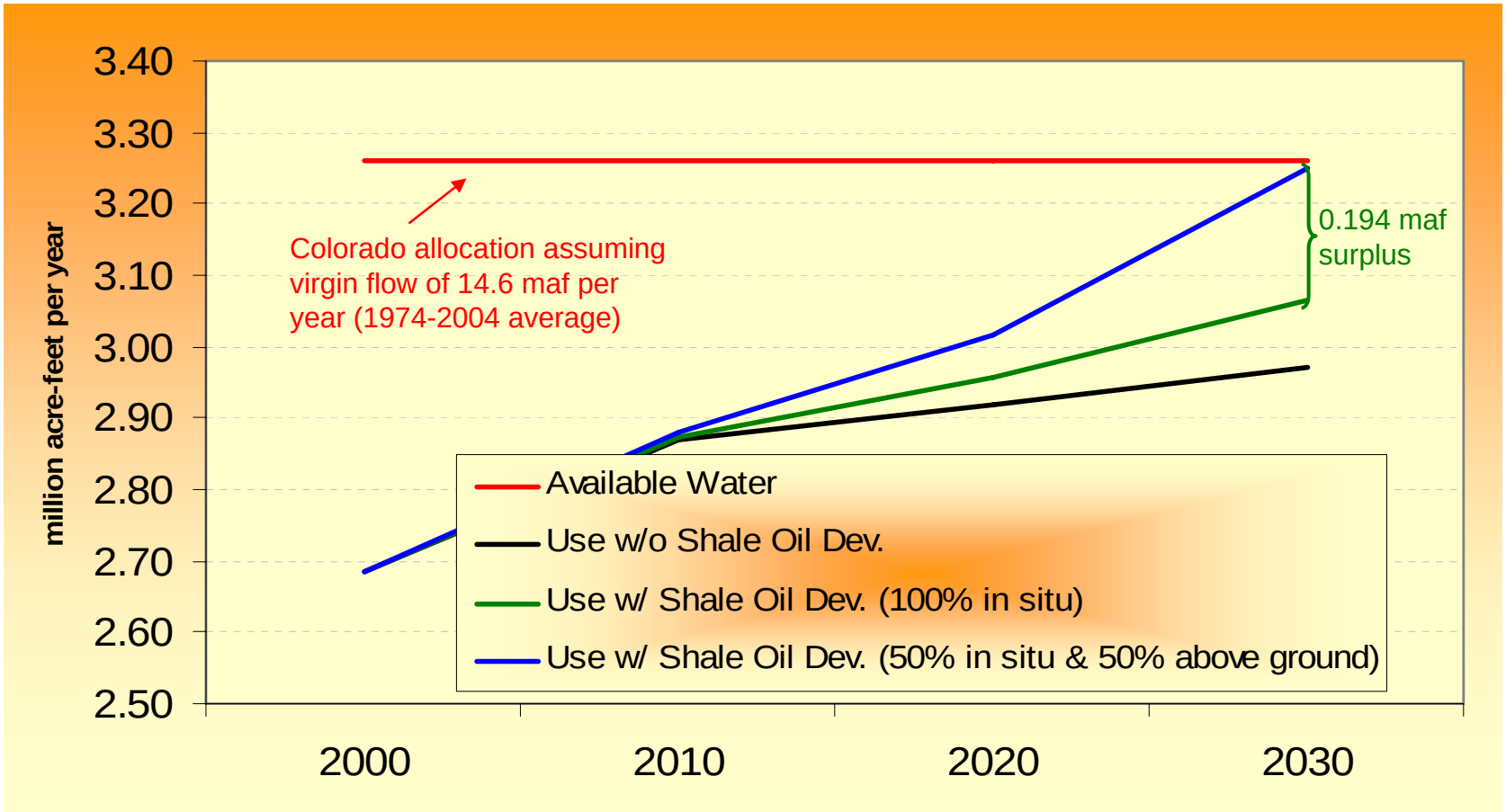
100,000 bpd **1,000,000 bpd** **2,000,000 bpd**

As Industry Expands, the Importance of the Technology Mix Increases



100,000 bpd **1,000,000 bpd** **3,000,000 bpd**

Advanced Cooling Technology for Thermoelectric Power Can Help to Reduce Water Requirements



100,000 bpd **1,000,000 bpd** **3,000,000 bpd**

Analysis Results

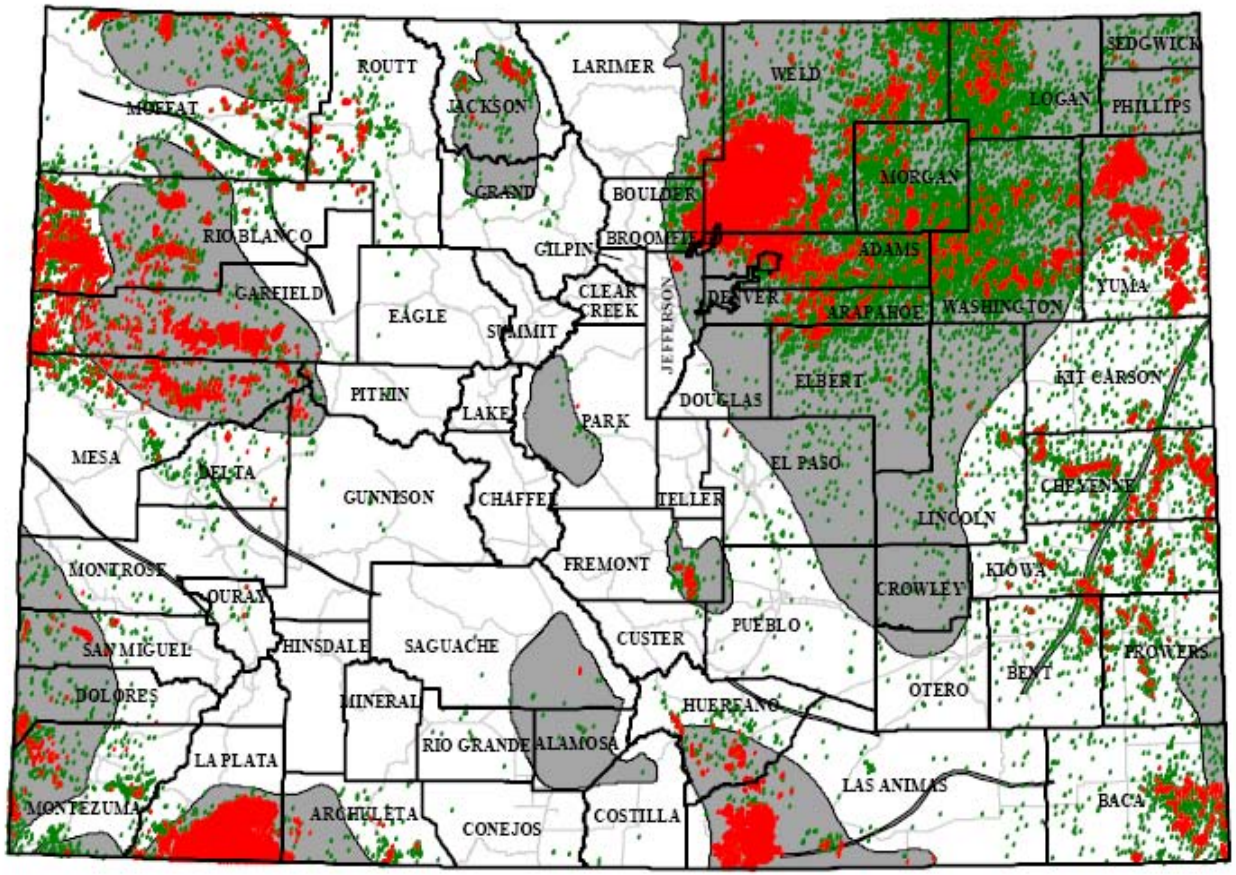
	Above-ground Retort	In-situ
acre-feet/year (closed-loop cooling)	21,400	7,900
barrel of water per barrel of shale oil (closed-loop cooling)	4.6	1.7
acre-feet/year (dry cooling)	15,800	3,500
barrel of water per barrel of shale oil (dry cooling)	3.4	0.8

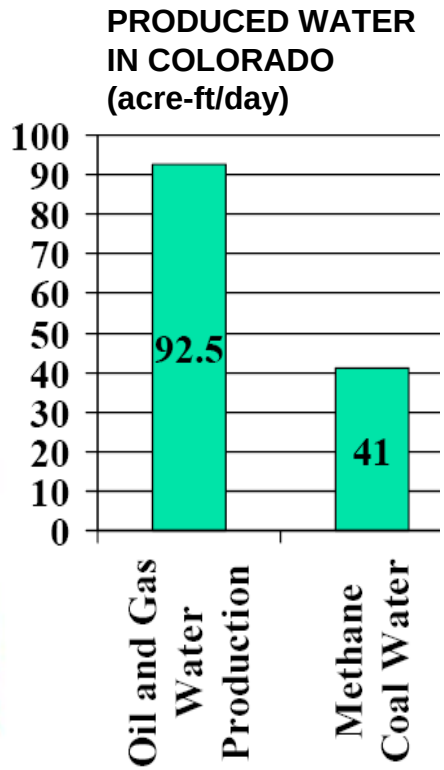
Based on 100,000 BPD plant gross water use

Recycle and Reuse of Process Produced Water is Essential

- In 1980, OTA estimated that water produced during operations could satisfy from 25 to 40 percent of the processing needs
- Some areas of the Piceance Basin have been estimated to produce as much as 16,000 acre-feet per year during dewatering operations; enough to satisfy all processing needs for a 200,000 bpd facility
- BLM's Environmental Assessment of the Oil Shale Exploration Company's RD&D project indicates as much as 12 bbl of retort and connate water could be generated per barrel of shale oil

Oil and Gas Produced Water Offer Another Potential Source of Water





Source: Dick Wolfe, Colorado Division of Water Resources, *Use of Produced Water from Oil and Gas Wells in Colorado*, February 28, 2006, map originally sourced to Colorado Oil and Gas Conservation Commission.

Critical Needs

- **Assessment of long-term water requirements**
  - Oil Shale & Competing Uses
  - Withdrawals versus Consumptive Use
- **Updated and improved water resource data**
  - Surface & Ground Water
    - Sub-basin analysis (e.g., White River)
    - Seasonal variations
    - Climate change impacts
  - Produced Water (oil, gas, CBM)
  - Other Potential Reuse Water (industrial, municipal, etc.)
- **Identification of infrastructure requirements and other opportunities to increase water availability and reduce water consumption**

Summary

- **Shale oil holds huge potential to mitigate many of the Nation's energy challenges**
- **Regarding oil shale development, water quality and quantity are a key public concern**
- **The Colorado River Basin's water resources are highly regulated and in great demand**
- **Advanced technologies can reduce water demands but further RD&D is necessary to confirm industry requirements**
- **Optimizing the recycle and reuse of process produced water is critical to industry growth**
- **Opportunities may exist for beneficial reuse of waters produced from other industries**

Questions?

For more Information:

National Energy Technology Laboratory
www.netl.doe.gov

RAND Corporation
Oil Shale Development in the United States - Prospects and Policy Issues
www.rand.org/pubs/monographs/MG414

Analysis Assumptions

- **14.6 maf annual virgin flow of Colorado River (1974-2004 average)**
  - All commitments to Lower Basin and Mexico met
- **Mining (incl. reclamation) 0.85 barrels of water per barrel of shale oil**
  - Kennecott's Bingham Canyon mine water consumption 2004 and assumes oil shale richness of 28 gallons per ton oil shale
- **Above ground retorting feed makeup water 4.1 million barrels (OSEC EA)**
- **In-situ processing 48 acre-feet per year (Shell Oil EA)**
- **In-situ reclamation 25 acre-feet per year (Shell Oil EA)**
- **Upgrading 0.4 barrels of water per barrel of shale oil (OTA, 1980) applied to shale oil from surface retorting only**
- **Municipal water use; 75 gallons per person per day**
  - Direct and indirect employment 125,000 @ 1,000,000 bpd, 175@ 2,000,000 bpd and 250,000 @ 3,000,000 bpd (RAND 2005)
- **Power, closed loop**
  - Natural gas combined cycle 180 gallons per million kilowatt-hour (NETL)
  - Coal steam 400 gallons per million kilowatt-hour (NETL)
- ***Processing and mine dewatering produced waters are not considered***