Lower Colorado River Basin Operations and Modeling

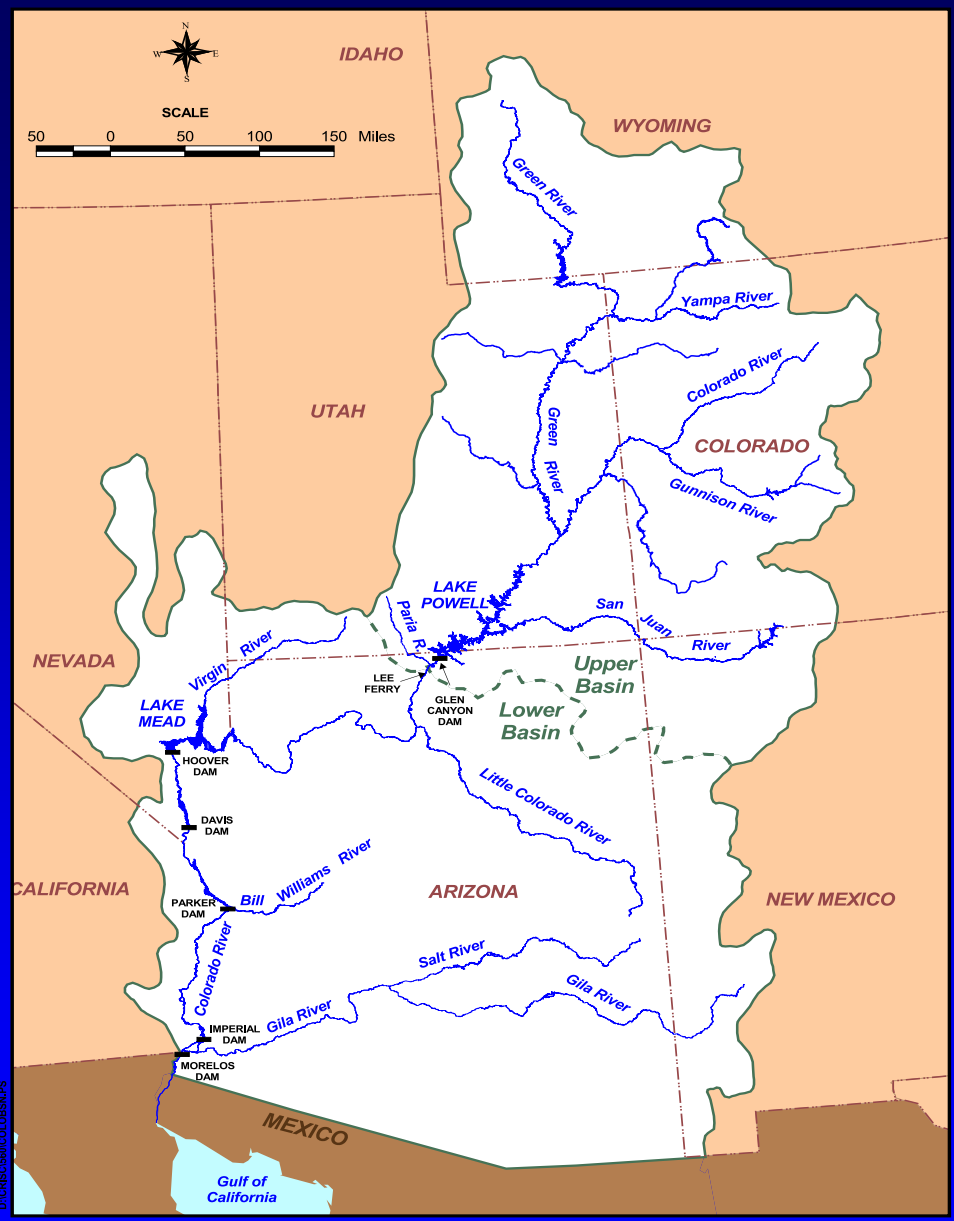
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Lower Colorado River Basin Operations and Modeling

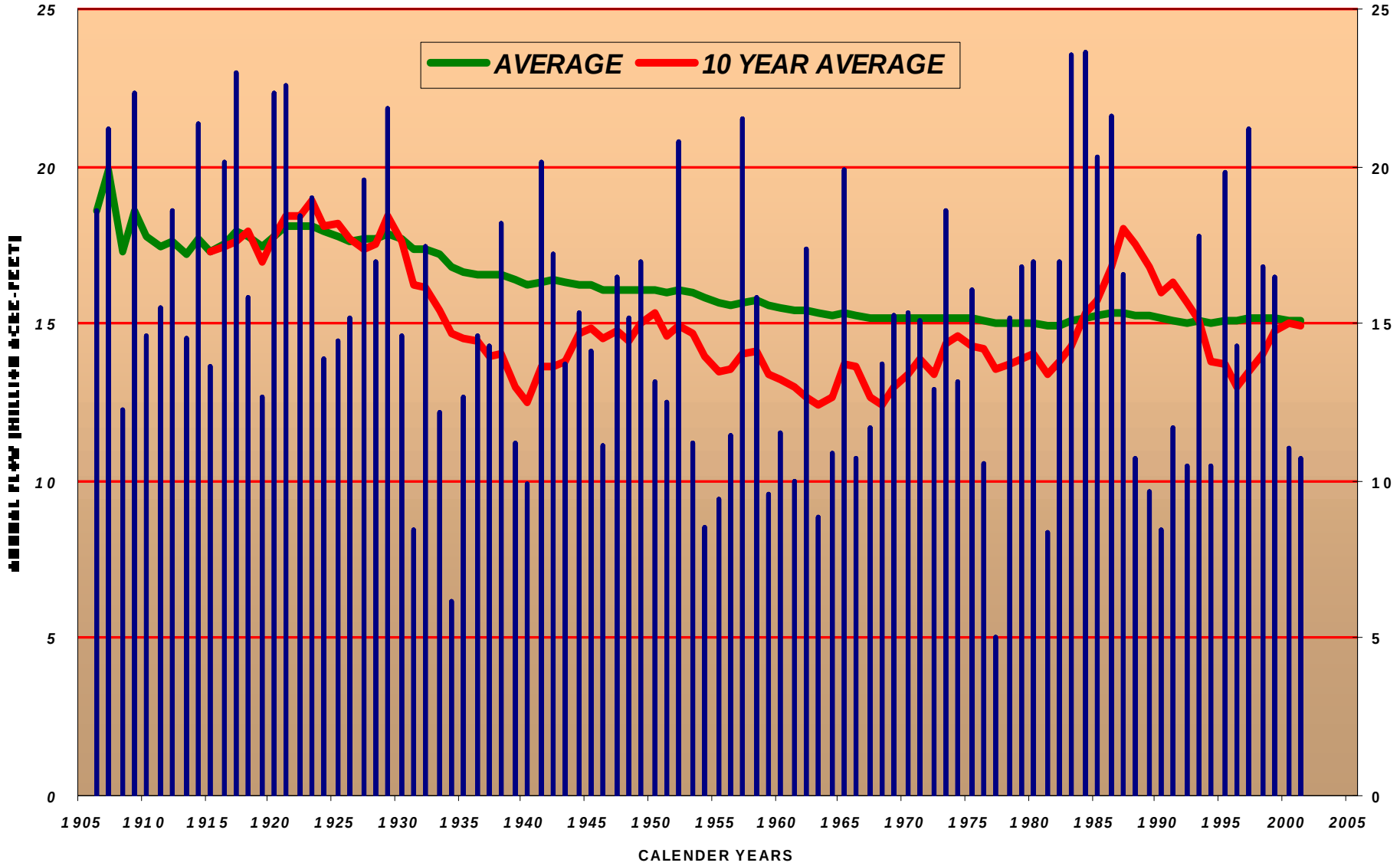
- Colorado River Operations Objectives
- Hierarchy of Operational Decisions
  - Long-term, mid-term, and short-term
  - Operation of the Lower Basin reservoirs
  - "Special" operations
- Current state of the system
- Questions

Colorado River Basin

- 1,450 miles in length
- 15.1 million acre-feet average “natural flow” at Lee Ferry Az
- 16.5 maf allocated per year
- 14.5 maf current use per year
- 60 maf of storage
- Irrigates about 3 million acres
- Serves about 30 million people
- Generation capacity - 4.2 GW
- 2002 generation - 11000 GWH



NATURAL FLOW (AT LEE'S FERRY)
1906-2001



Colorado River Management Objectives

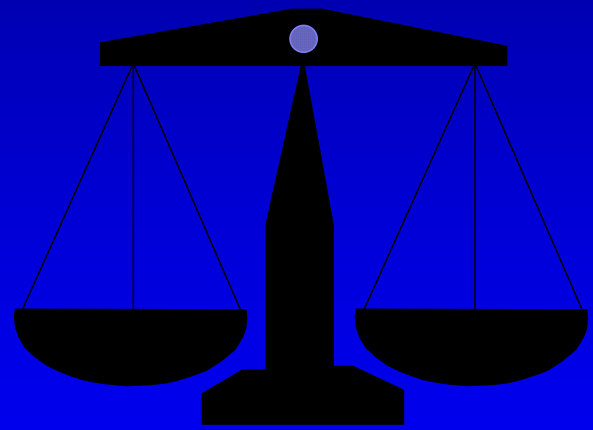
- Provide flood control and river regulation
- Provide water for consumptive use
- Generate hydropower
- Provide recreation
- Enhance and maintain ecosystem habitat
- Recover and protect endangered species

These objective are often in conflict

We seek “equitable” balance of the objectives.

Considerations for Achieving an Equitable Balance in Decision-Making

- Legal and political constraints
- Community involvement and consensus-building
- Sound technical knowledge



“Law of the River”

- Colorado River Compact (1922)
- Boulder Canyon Project Act (1928)
- California Seven-Party Agreement (1932)
- Mexican Water Treaty (1944)
- Upper Colorado River Basin Compact (1948)
- Colorado River Project Storage Act (1956)
- Supreme Court Decree in Arizona vs. California (1964)
- Colorado River Basin Project Act (1968)
- National Environmental Policy Act (1970)
- Long-Range Operating Criteria (1970)
- Endangered Species Act (1973)
- Grand Canyon Protection Act (1992)

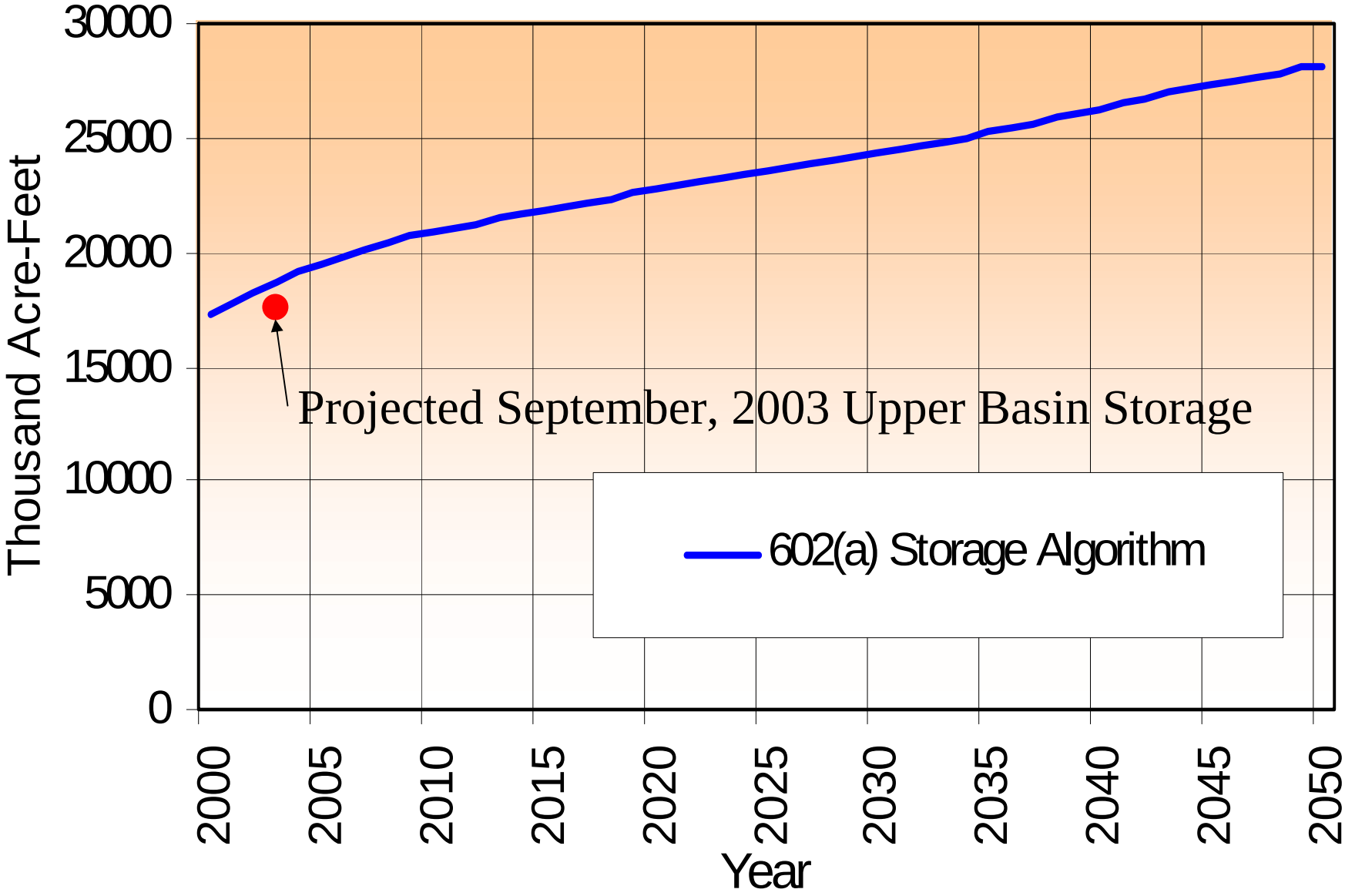
Operation of Lake Powell

- Three modes of operation governing the annual releases from Lake Powell
  - Minimum objective release – 8.23 maf
  - Equalization (if Powell storage > Mead and "sufficient storage" in Upper Basin)
  - Spill avoidance

602(a) Storage

- Storage in Upper Basin necessary to assure deliveries to Lower Basin without impairment to consumptive use in the Upper Basin
- Equalization releases are not required in years when Upper Basin storage is less than 602(a) storage
- LROC defines “factors to be considered” but does not specify exactly how to calculate 602(a) storage

602(a) Storage



Operation of Lake Mead

- Two modes of operation governing the releases from Lake Mead
  - Meet the downstream demands (surplus, normal, or shortage)
  - Flood Control (releases in excess to downstream demands)
- Flood Control operation governed by Corps of Engineers regulations

Operation of Lake Mead
Downstream Requirements

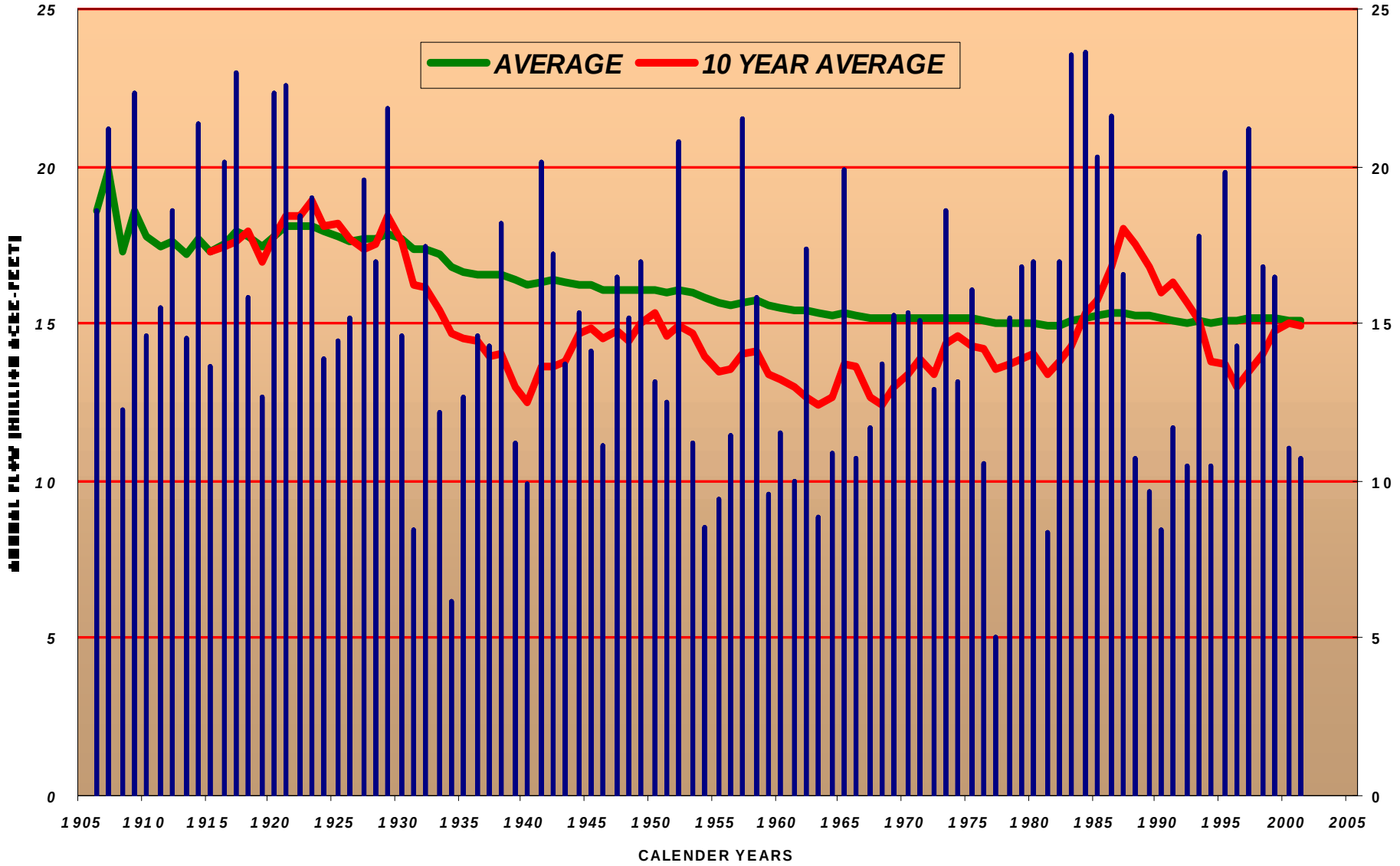
- Downstream demands include:
  - California 4.4 maf
  - Arizona 2.8 maf
  - Nevada 0.3 maf
  - Mexico 1.5 maf
  - Reservoir regulation of Lakes Mohave and Havasu
  - System gains and losses
- Deliveries can be larger or smaller under “surplus” or “shortage” conditions

Spatial Resolution/ Time Horizon	Operational Activity	Decisions
Basin-wide over decades	**Long-term Planning**	**Operating Criteria**
Basin-wide over 1-2 years	Mid-term Operations	Annual Operating Plan
Sub-basin over 4-6 weeks	Short-term Scheduling	Water and Power Schedules
		Unit Commitment Economic Dispatch
Single project over 1-7 days	Real-time Control	Automatic Generation and Control

Long-term Planning

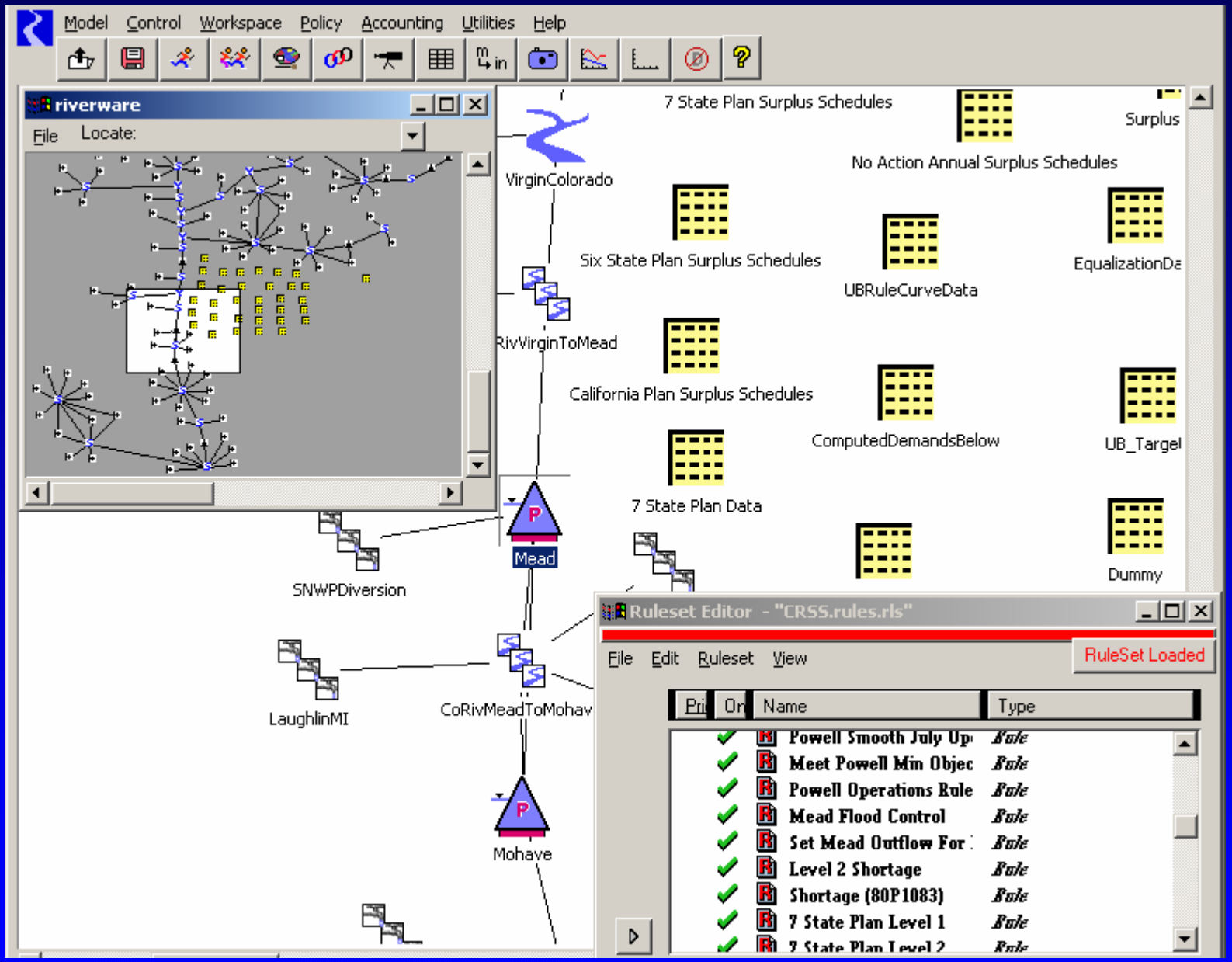
- Primary purpose is to “negotiate” operating criteria
- Uncertainty in:
  - Future water supply
  - Future water demands
- Uncertainty in future water supply overwhelms differences in future demands or in policy

NATURAL FLOW (AT LEE'S FERRY)
1906-2001



Long-Term Planning Model ("CRSS")

- Used to project reservoir operations basin-wide for 50+ years
- "Law of the River" and other operating criteria (i.e., surplus alternatives) are expressed as rules
- Model is used for comparing different policy alternatives
- Uncertainty due to future inflows is quantified using multiple (85) simulations ("traces")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riverware
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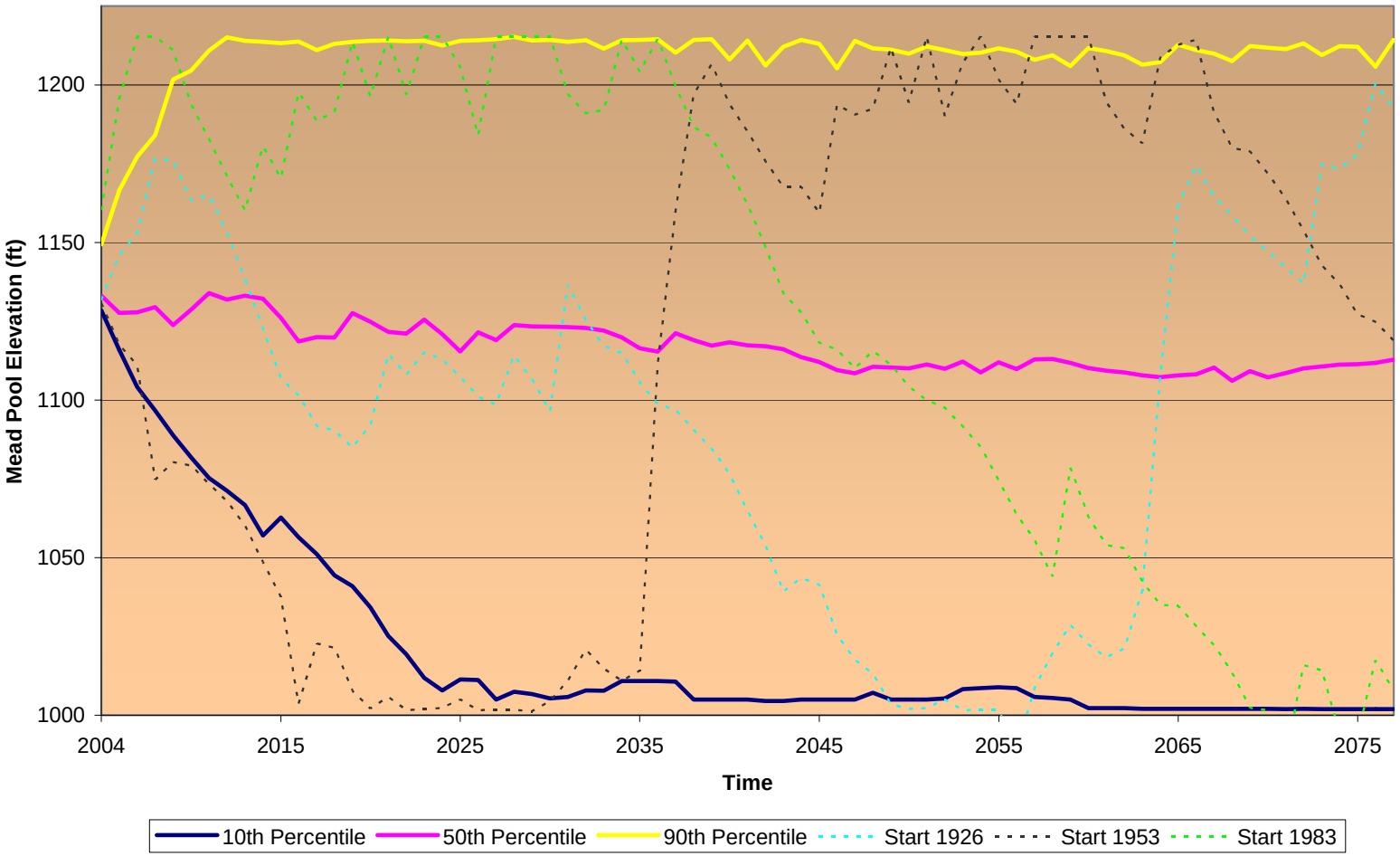
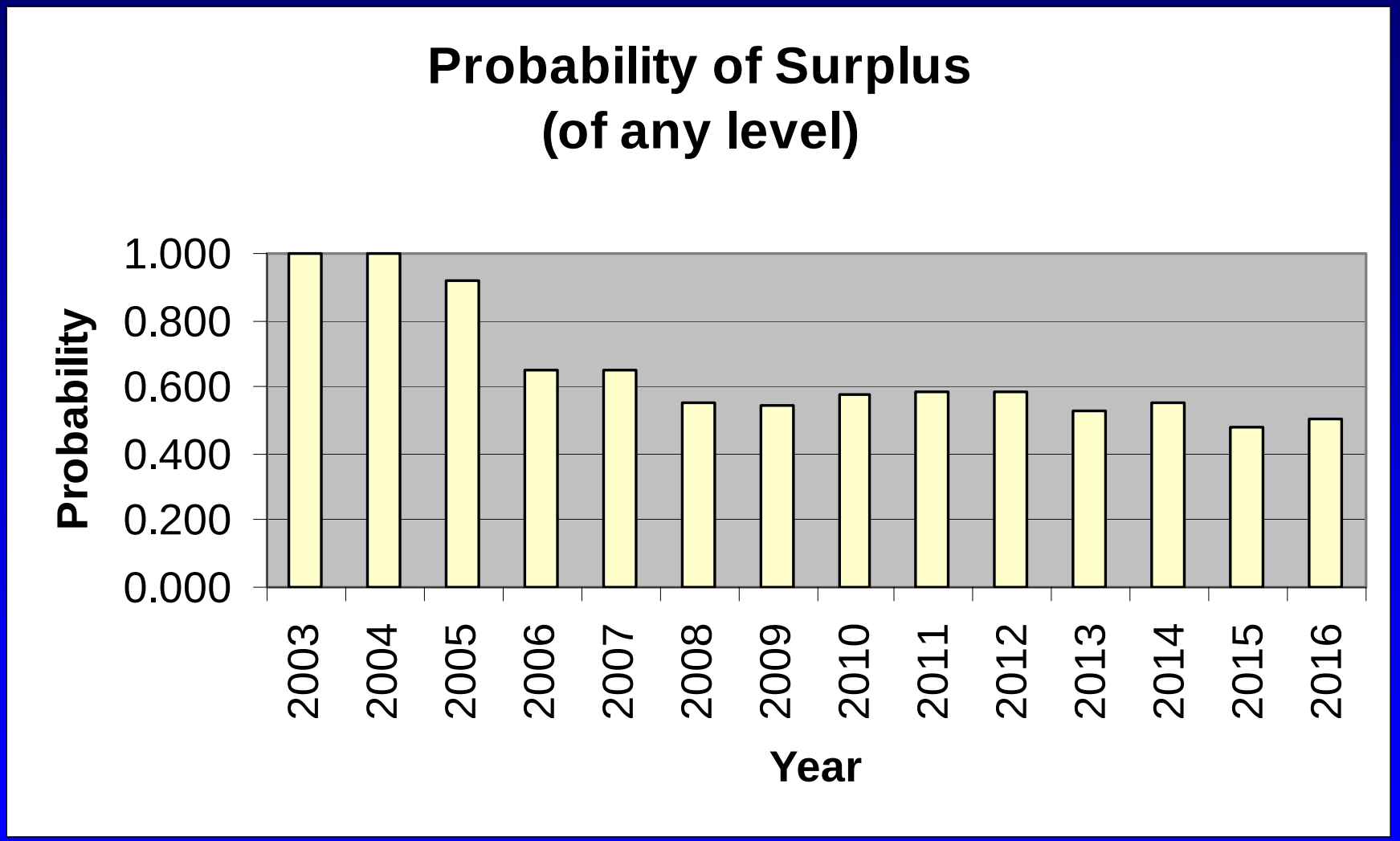
7 State Plan Surplus Schedules
Surplus
No Action Annual Surplus Schedules
VirginColorado
Six State Plan Surplus Schedules
UBRuleCurveData
EqualizationDa
RivVirginToMead
California Plan Surplus Schedules
ComputedDemandsBelow
UB_Targe
7 State Plan Data
Dummy
Mead
SNWPDiversion
LaughlinMI
CoRivMeadToMohav
Mohave
Ruleset Editor - "CRSS.rules.rls"
File Edit Ruleset View
RuleSet Loaded
Name
Type
Powell Smooth July Up
Meet Powell Min Objec
Powell Operations Rule
Mead Flood Control
Set Mead Outflow For
Level 2 Shortage
Shortage (80P1083)
7 State Plan Level 1
7 State Plan Level 2
Rule

Analysis of Model Output

- 85 simulations @monthly time step for each variable of interest (approx. 300 MB file for each alternative analyzed)
- Post-processors filter output data files and produce Excel spreadsheets
- Excel-based analysis tool (GPAT) used to compare alternatives
  - Single trace output
    - e.g., Mead elevation over time for a particular inflow assumption
  - Statistical output (average, std. dev., percentiles, etc.)
    - e.g, 10th percentile Mead elevation at each time (elevation that was not exceeded by 10% of the traces)

Lake Mead Elevation




Probability of Surplus
(of any level)
Probability
1.000
0.800
0.600
0.400
0.200
0.000
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Year

Spatial Resolution/ Time Horizon	Operational Activity	Decisions
Basin-wide over decades	Long-term Planning	Operating Criteria
Basin-wide over 1-2 years	Mid-term Operations	**Annual Operating Plan**
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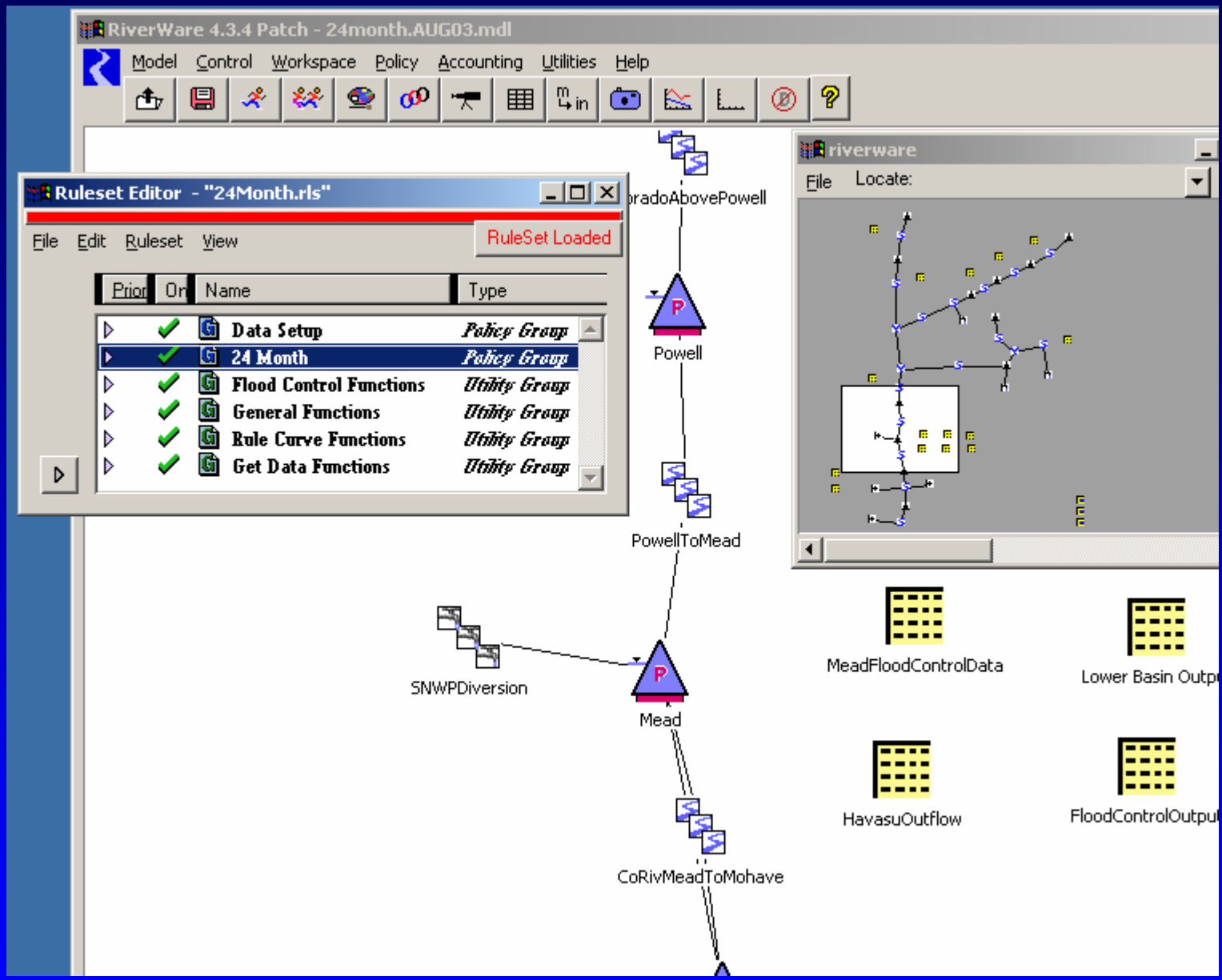
Mid-term Operations

- Development of the Annual Operating Plan (AOP)
- Several determinations are made (based on the most probable inflows)
  - 602(a) storage and release from Glen Canyon dam
  - Normal, Surplus, or Shortage for Lower Division States
  - Delivery to Mexico
  - Availability of unused apportionment – Lower Division
- Plan is updated throughout the year

Mid-term Operations Model ("24 Month Study")

- Projects reservoir operations for the next 2 years
- Updated each month to:
  - Reflect changes in hydrology
  - Reflect changes in water demand
- Used to project energy generation for marketing purposes
- Coordination between multiple offices and agencies required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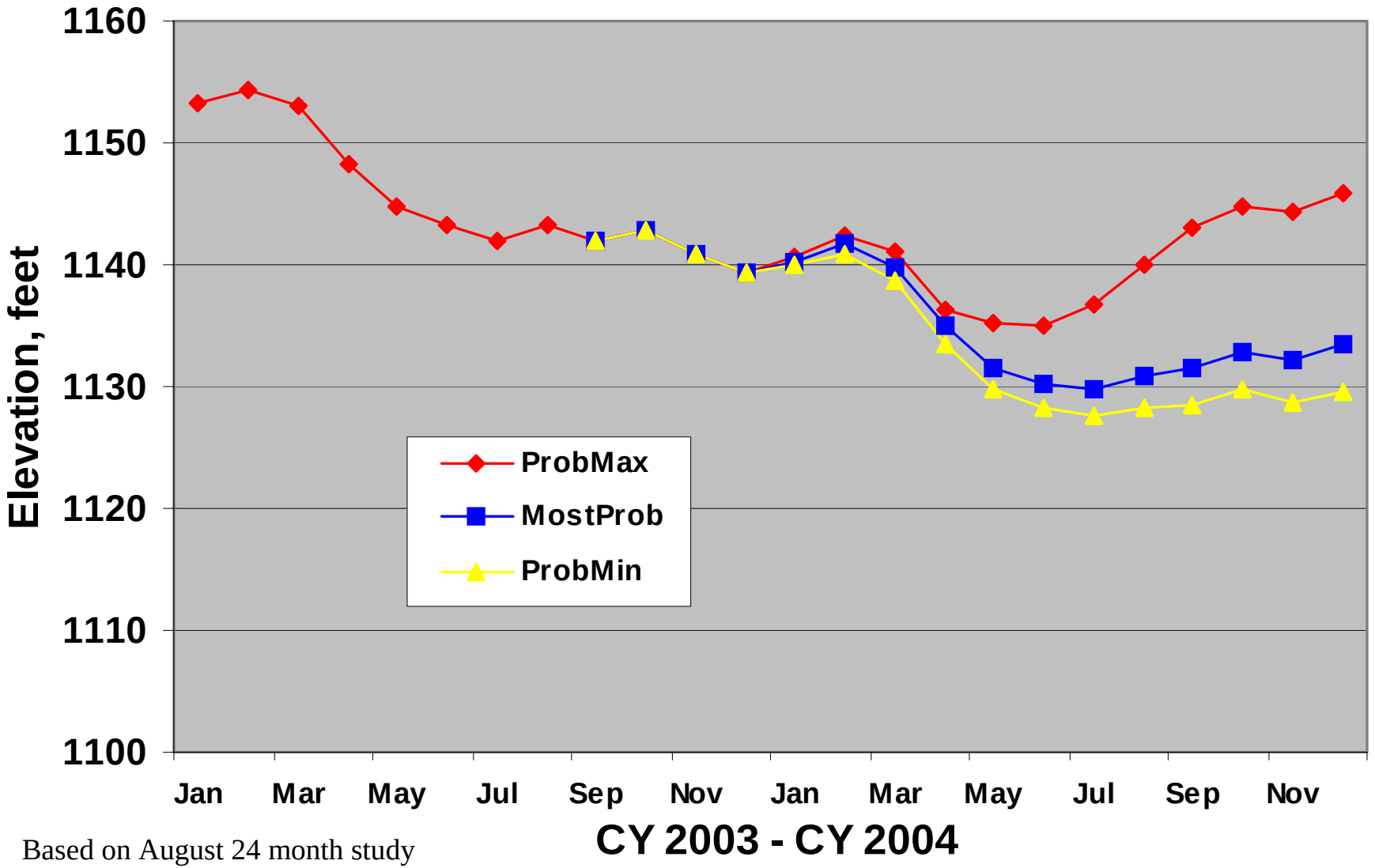
Ruleset Editor - "24Month.rls"
File Edit Ruleset View
RuleSet Loaded
Prior On Name Type
Data Setup Policy Group
24 Month Policy Group
Flood Control Functions Utility Group
General Functions Utility Group
Rule Curve Functions Utility Group
Get Data Functions Utility Group
riverware
File Locate:
radoAbovePowell
Powell
PowellToMead
SNWPDiversion
Mead
CoRivMeadToMohave
MeadFloodControlData
Lower Basin Outp
HavasuOutflow
FloodControlOutpu

Water Supply Forecasting

- Unregulated reservoir inflow
  - April-July
  - Current month
  - Next two months
- Forecast team
  - NWS Colorado Basin River Forecast Center (CBRFC)
  - NRCS Water and Climate Center
  - BOR (CBRFC Liaison at UC Regional Office)
- Forecasts disseminated via e-mail list and published at www.cbrfc.gov

Lake Mead EOM Elevation



Based on August 24 month study

Spatial Resolution/ Time Horizon	Operational Activity	Decisions
Basin-wide over decades	Long-term Planning	Operating Criteria
Basin-wide over 1-2 years	Mid-term Operations	Annual Operating Plan
Sub-basin over 4-6 weeks	**Short-term Scheduling**	**Water and Power Schedules** Unit Commitment Economic Dispatch
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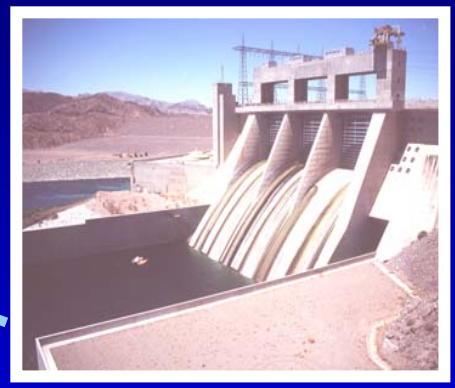
Lower Colorado River Basin Reservoir Operations

Lake Mead

Hoover Dam

Lake Mohave



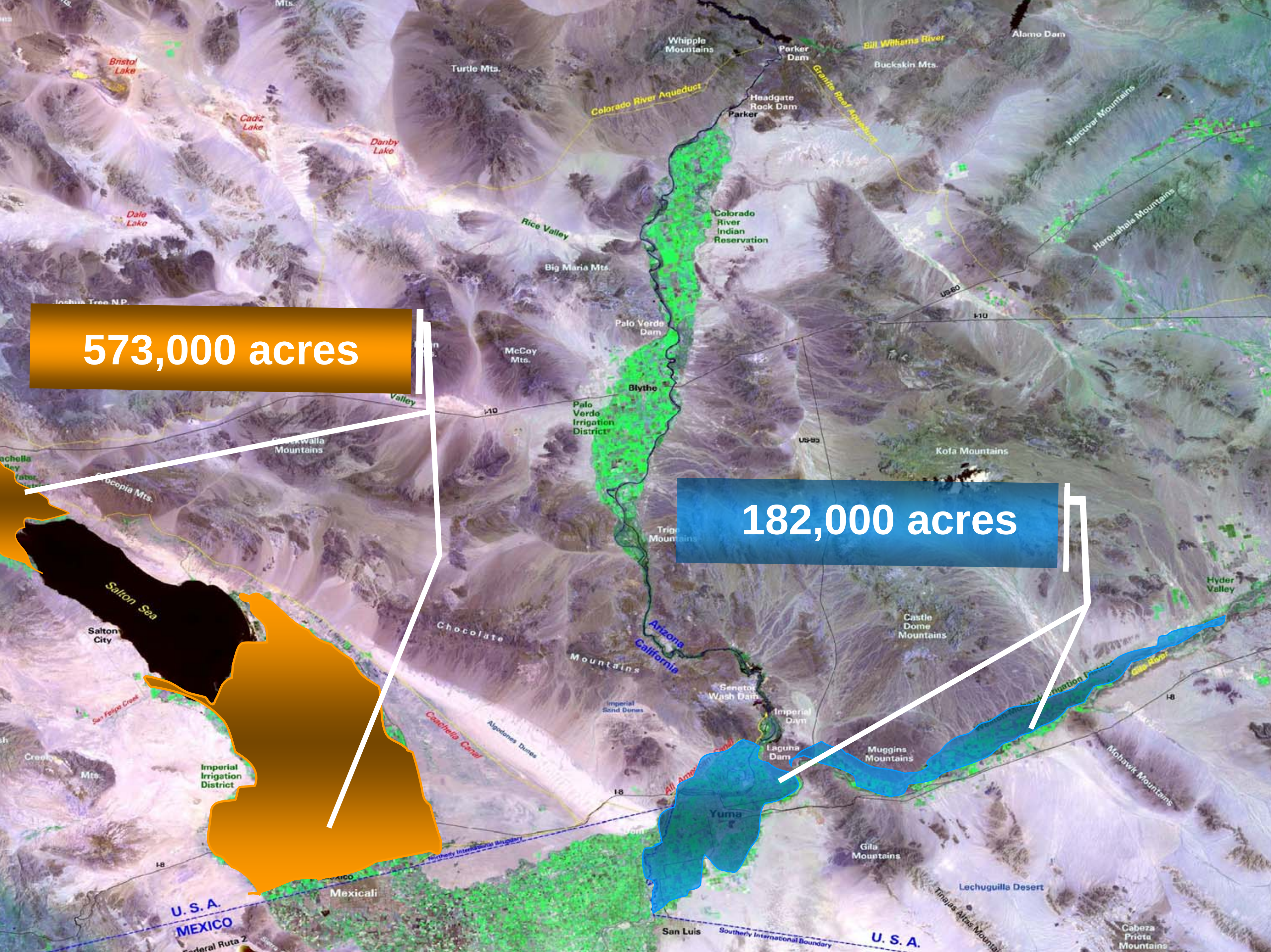
Davis Dam

Lake Havasu

Parker Dam

Yuma

Mexico



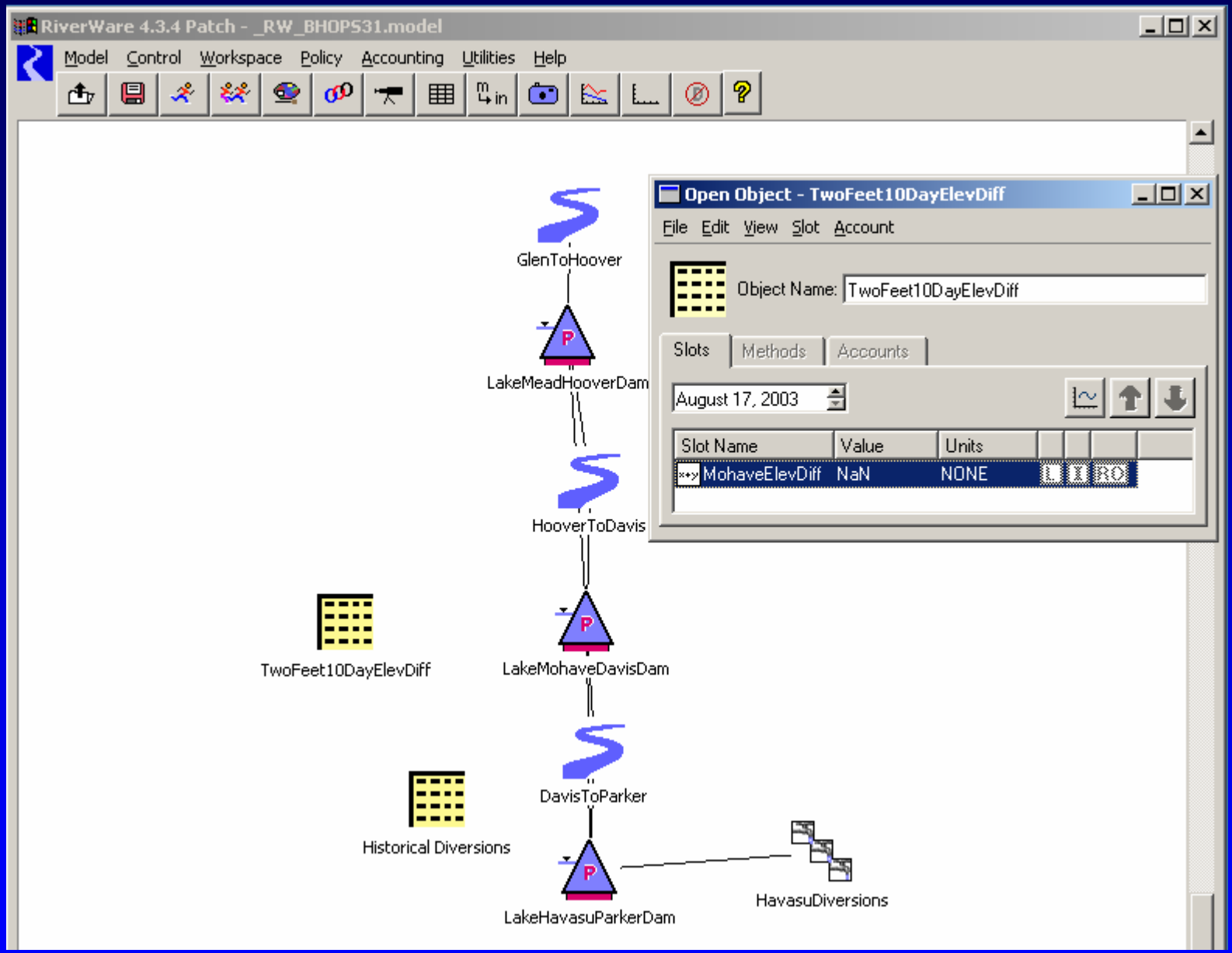
573,000 acres
182,000 acres
Whipple Mountains
Parker Dam
Bill Williams River
Alamo Dam
Buckskin Mts.
Turtle Mts.
Bristol Lake
Cadiz Lake
Danby Lake
Dale Lake
Colorado River Aqueduct
Headgate Rock Dam
Parker
Granite Reef Aqueduct
Harcuvar Mountains
Harquahala Mountains
Colorado River Indian Reservation
Rice Valley
Big Maria Mts.
Joshua Tree N.P.
Palo Verde Dam
McCoy Mts.
Blythe
Palo Verde Irrigation District
I-10
US-60
US-95
Kofa Mountains
Chuckwalla Mountains
Orocopia Mts.
Salton Sea
Salton City
Chocolate Mountains
Arizona
California
Castle Dome Mountains
Hyder Valley
Gila River
Senator Wash Dam
Imperial Dam
Imperial Sand Dunes
Laguna Dam
Muggins Mountains
Coachella Canal
Algodones Dunes
All American Canal
Imperial Irrigation District
I-8
Yuma
Gila Mountains
Mohawk Mountains
Lechuguilla Desert
Mexicali
U. S. A.
MEXICO
San Luis
Southerly International Boundary
Northerly International Boundary
Tinajas Altas Mountains
Cabeza Prieta Mountains

Short-term Scheduling

- Schedule releases from Hoover, Davis and Parker Dams
- Ensure that water deliveries ("downstream demands") are met within existing constraints
  - Lake elevation targets
  - Energy targets
  - "Special" operation requests
- Schedules are determined for next 5 days and updated each day (while "looking out" 4-6 weeks)

Short-term Scheduling Model ("BHOPS")

- Projects reservoir operations for lakes Mead, Mohave, and Havasu on a daily basis for 4-6 weeks
- Updated each day to:
  - Reflect changes in water demand
  - Reflect changes in constraints
- Used to set energy generation target for Hoover Dam in the current month and for one month out
- Coordination between multiple offices and agencies required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Model Control Workspace Policy Accounting Utilities Help
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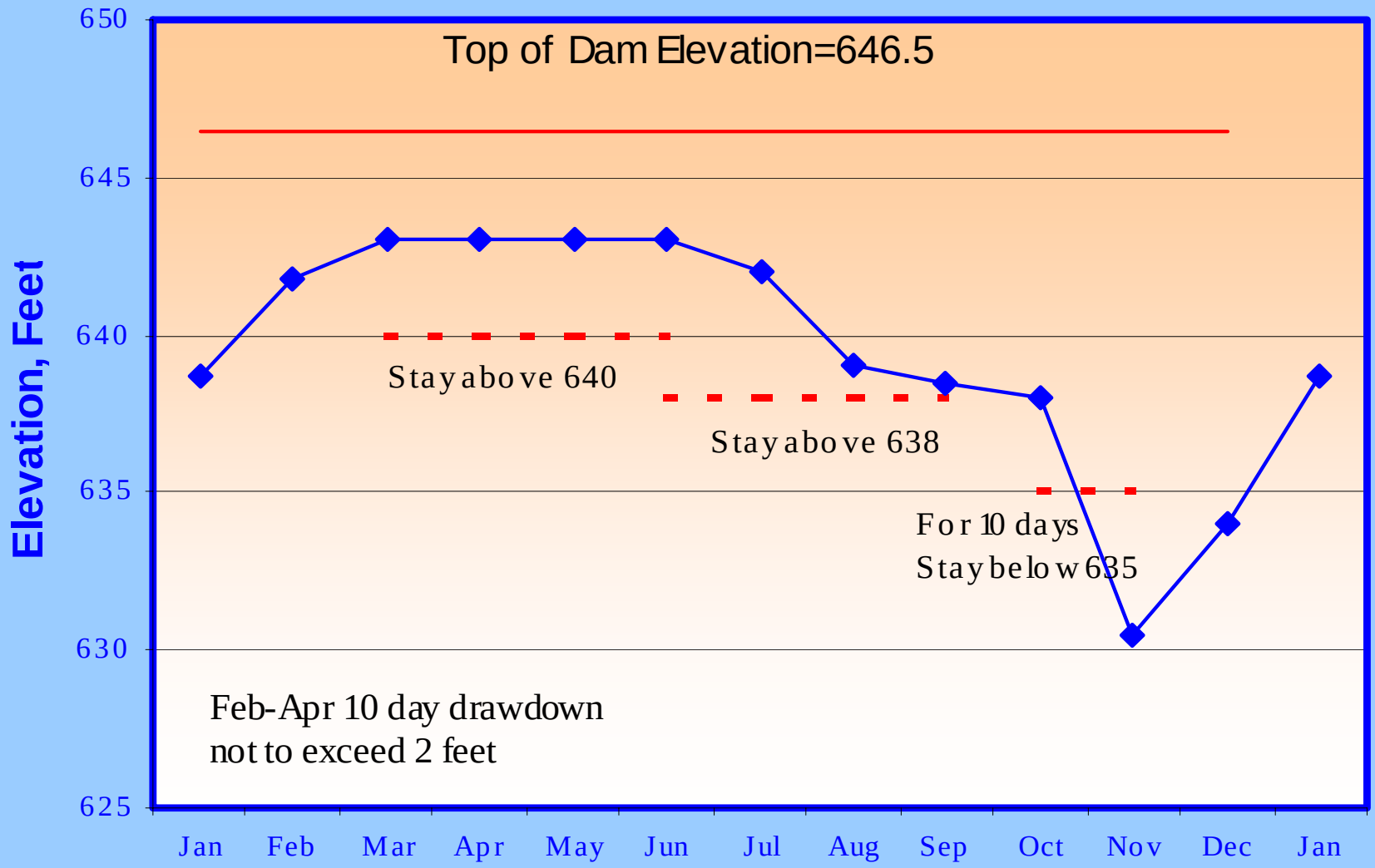
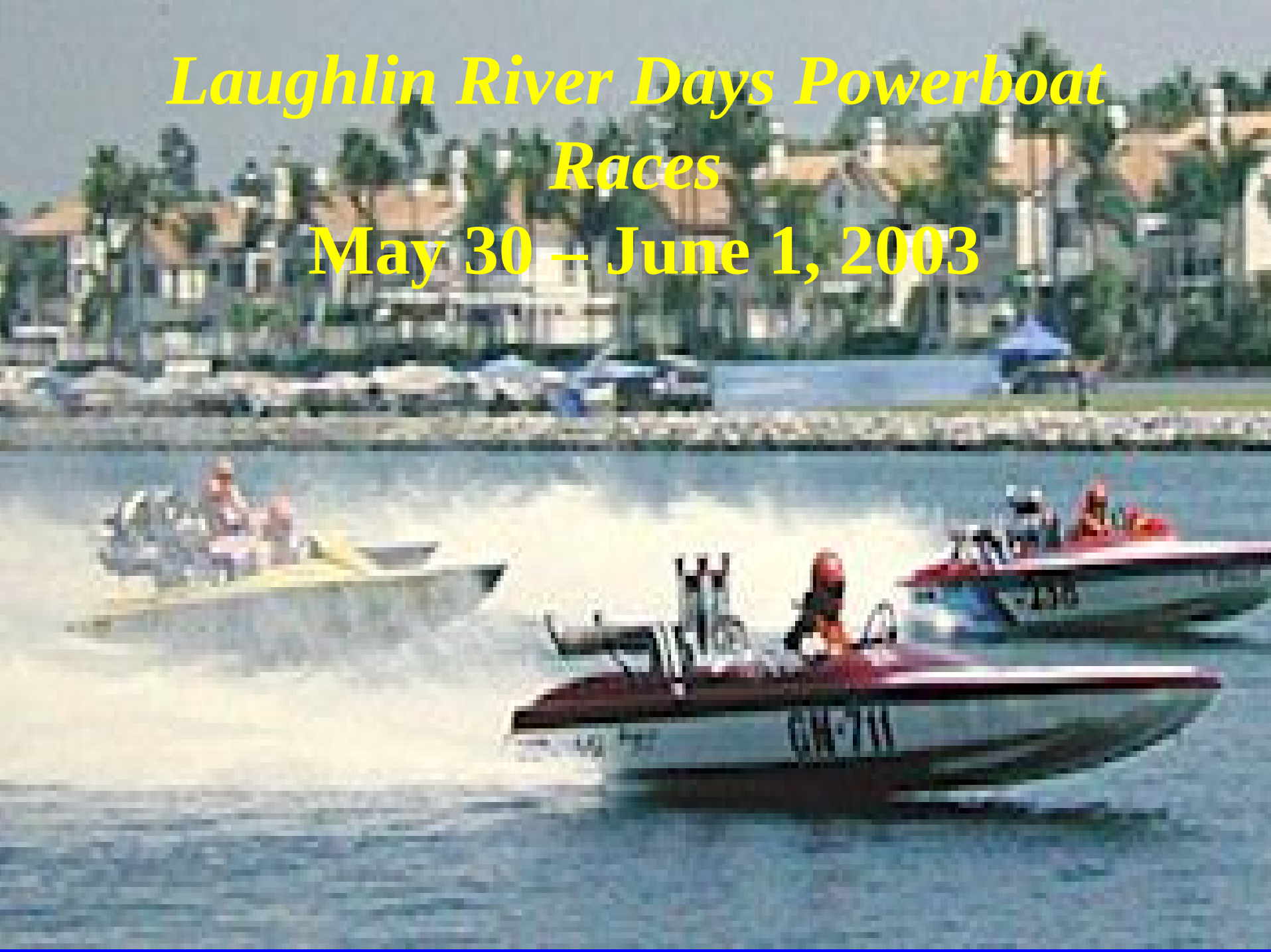
File Edit View Slot Account
Object Name: TwoFeet10DayElevDiff
Slots Methods Accounts
August 17, 2003
Slot Name Value Units
MohaveElevDiff NaN NONE L I RO
GlenToHoover
LakeMeadHooverDam
HooverToDavis
TwoFeet10DayElevDiff
LakeMohaveDavisDam
DavisToParker
Historical Diversions
LakeHavasuParkerDam
HavasuDiversions

Lake Mohave Operational Constraints

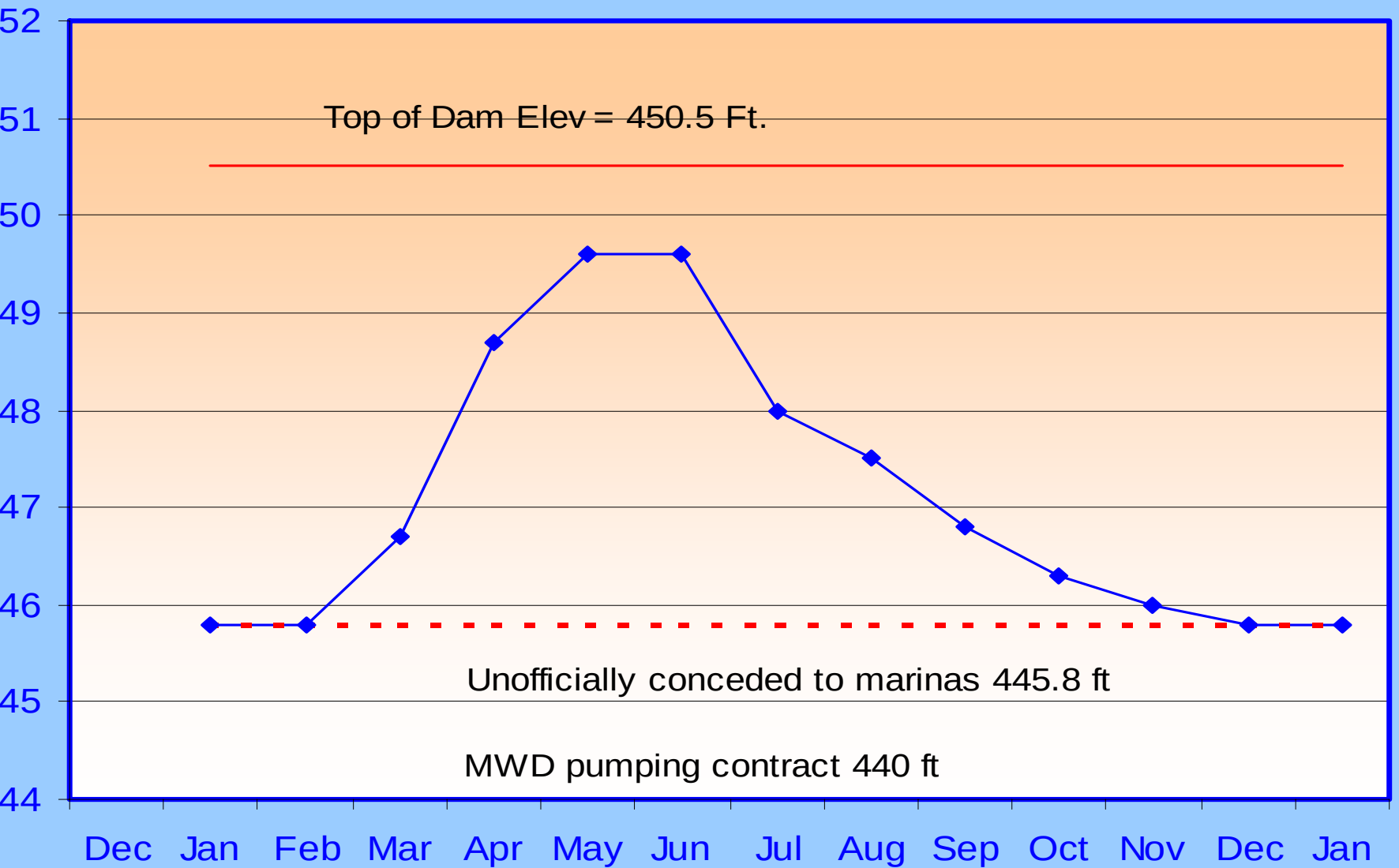


End of Month Target Elevation


YUMA COVE at LAKE MOHAVE


Laughlin River Days Powerboat Races
May 30 – June 1, 2003

Lake Havasu Operational Constraints



End of Month Target Elevation


2003 Nationals – Lake Havasu


La Paz County Sheriff Department –
Boat Launch Facility

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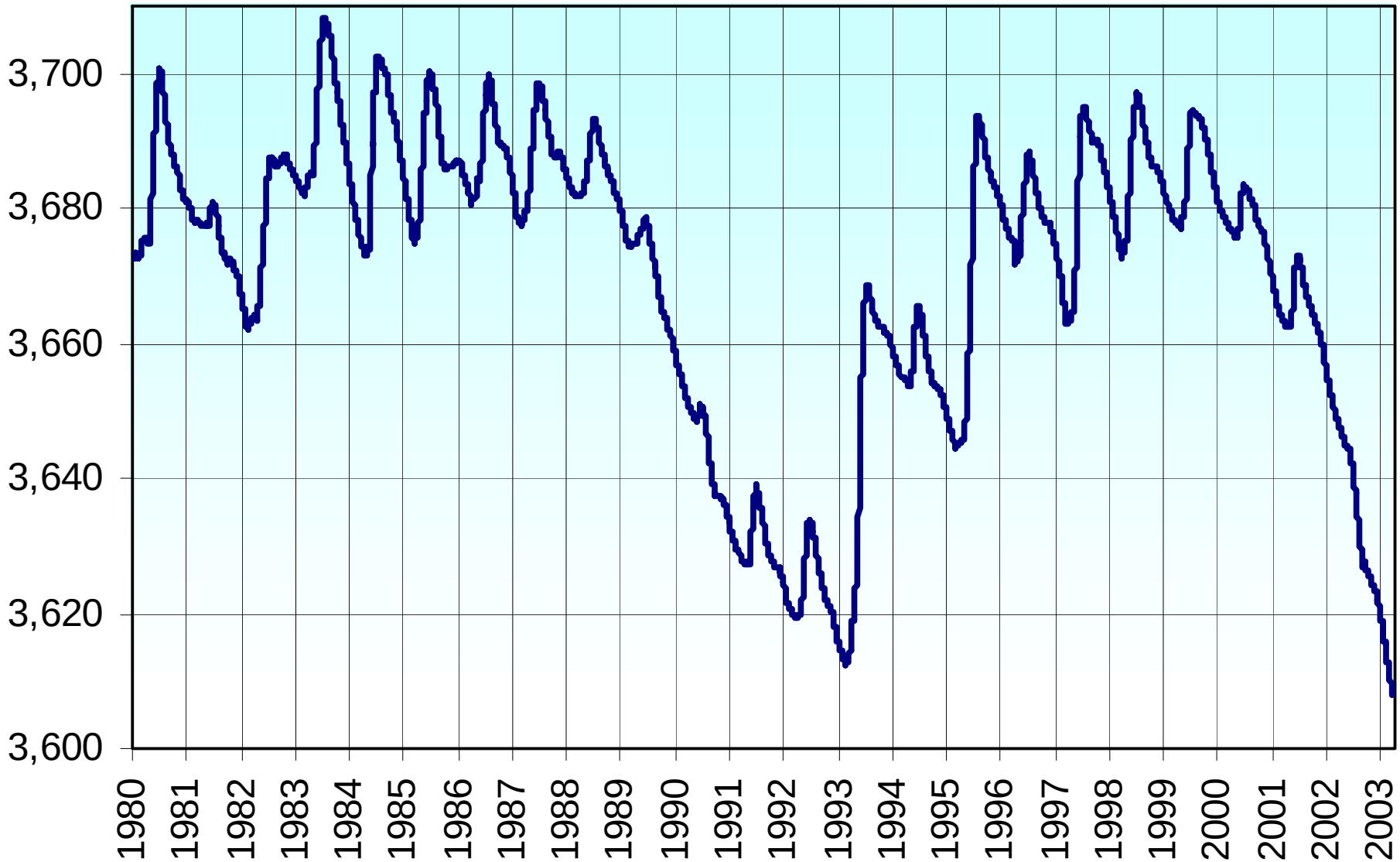
Current Basin Reservoir Conditions
(as of February 11, 2004)

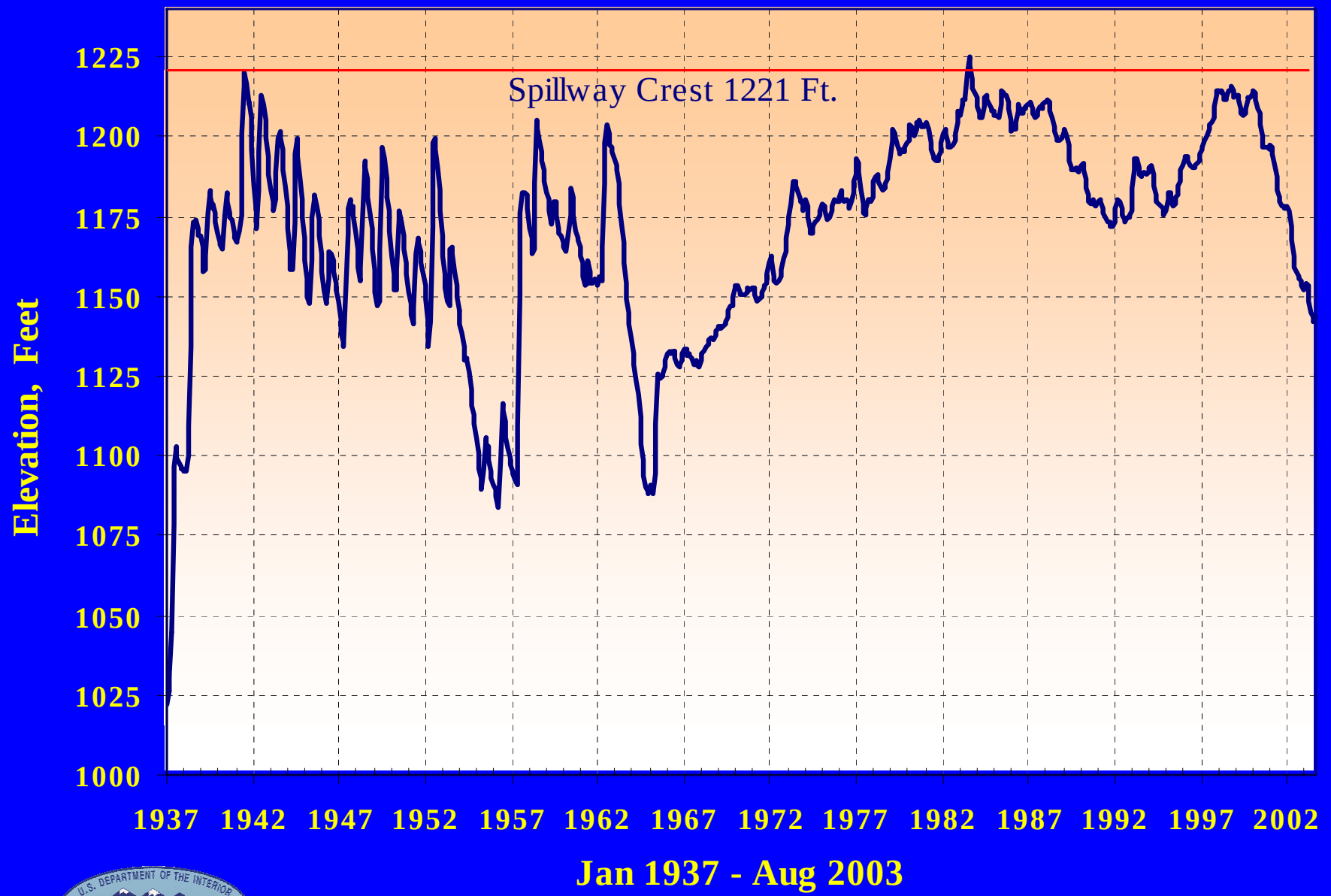
Current Storage	Percent Full	1000 Ac-Ft	Elev. (Ft)
Lake Powell	44%	10,821	**3590.00**
Lake Mead	60%	15,437	**1140.42**
Total System Storage	55% *	32,400	NA

* Total system storage was 36,246 kaf or 61% this time last year

Lake Powell Water Surface Elevations
1980 through Present



Lake Mead End of Month Elevations



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Four Years of Drought

Lake Powell Unregulated Inflow 2000-2003

- WY 2000 — 62 percent of average
- WY 2001 — 59 percent of average
- WY 2002 — 25 percent of average
- WY 2003 — 53 percent of average

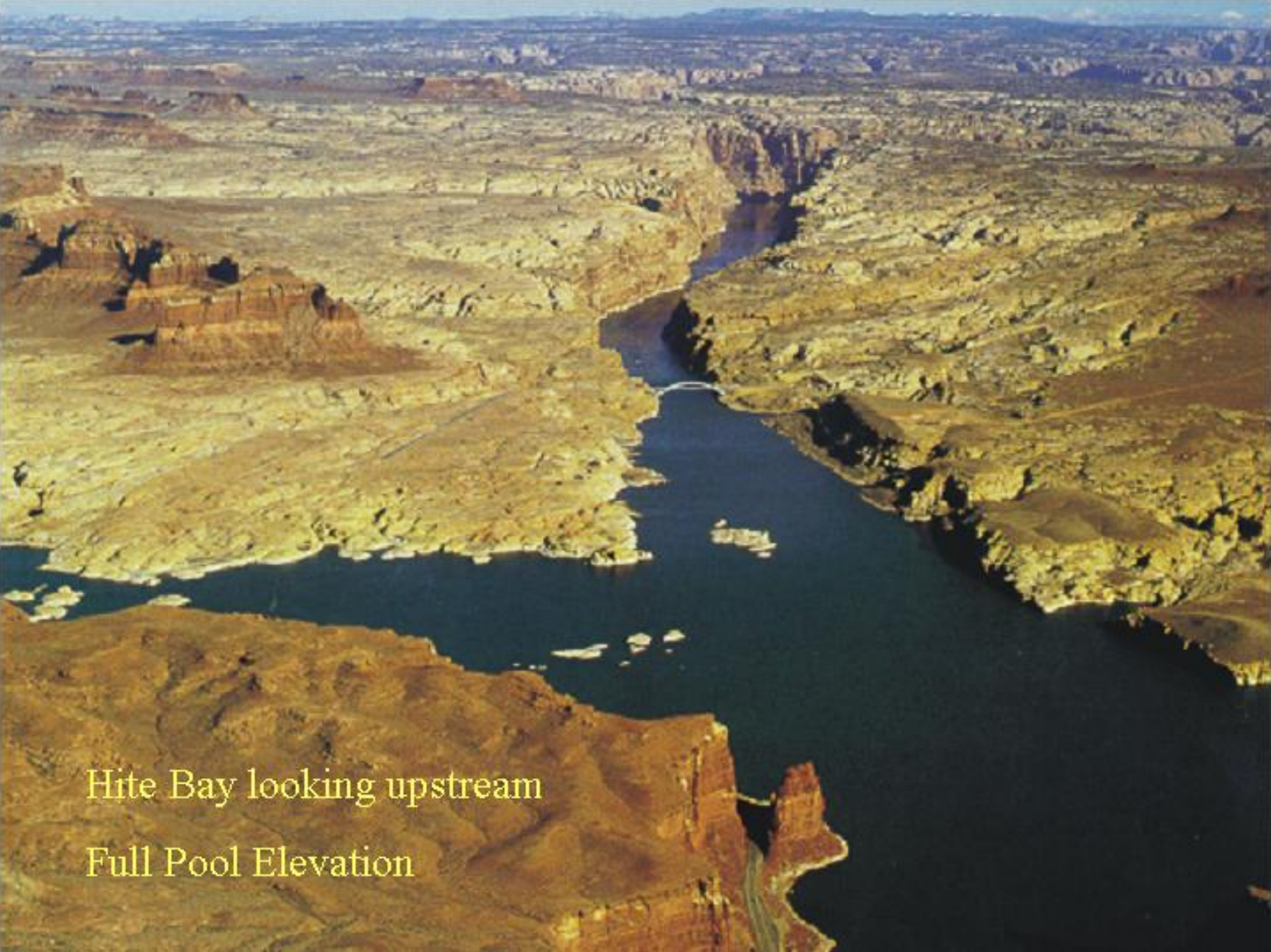
Colorado River

Critical Periods (Periods with Low Flows)

Average Natural Flow 15.0 maf

Years	Duration	Average Flow
• 1953-1964	12 years	11.6 maf
• 1953-1977	25 years	12.7 maf
• 1579-1595	17 years	10.5 maf
• 1988-1992	5 years	10.5 maf
• 2000-2003*	4 years	10.7 maf

*** Estimated**


Hite Bay looking upstream
Full Pool Elevation

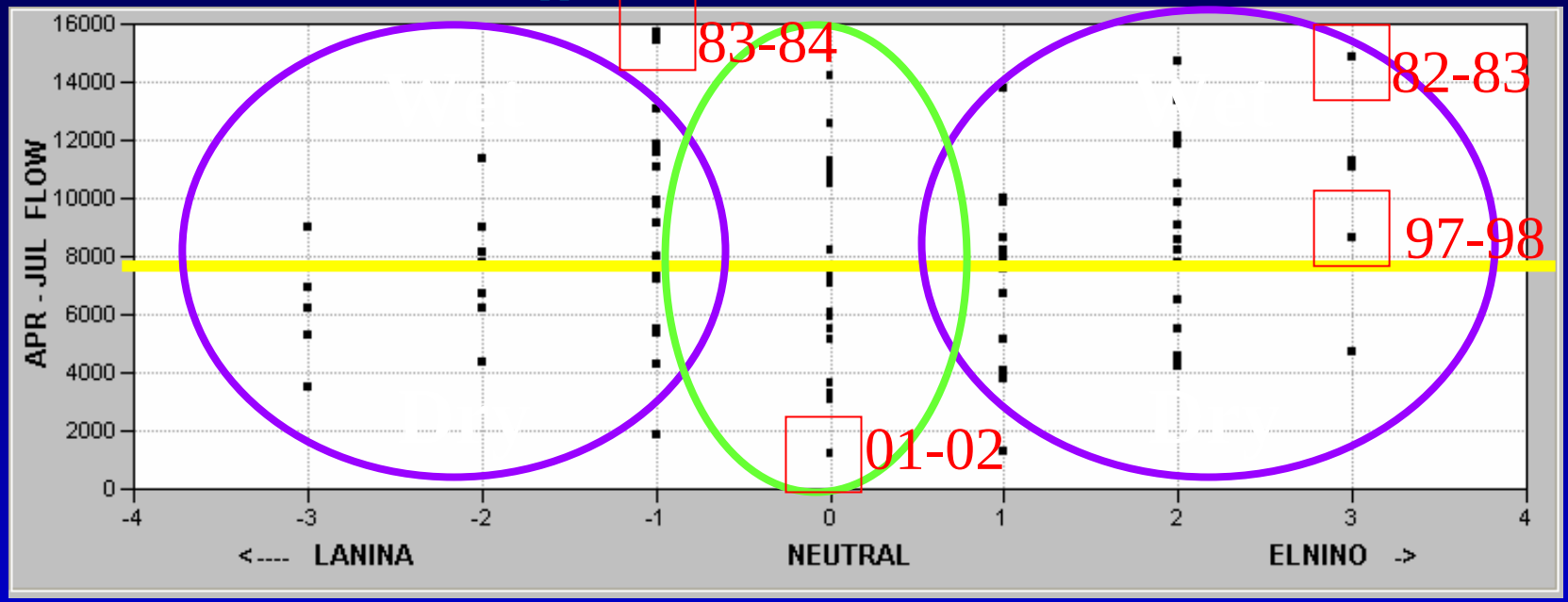

Lake Powell
03/09/2003

To Refill Colorado River Reservoirs

- More challenging than the 88-92 Drought
- Lake Powell water storage similar to 1993
  - March 1993 – 53 percent of capacity
  - April 2003 – 50 percent of capacity
- Lake Mead much lower today than 1993
  - April 1993 – 85 percent of capacity
  - April 2003 – 63 percent of capacity
- Basin Demands are higher than 10 years ago
- Will likely take a number of years

What is the prognosis over the next 1-2 years?

Upper Colorado – Lake Powell Inflow



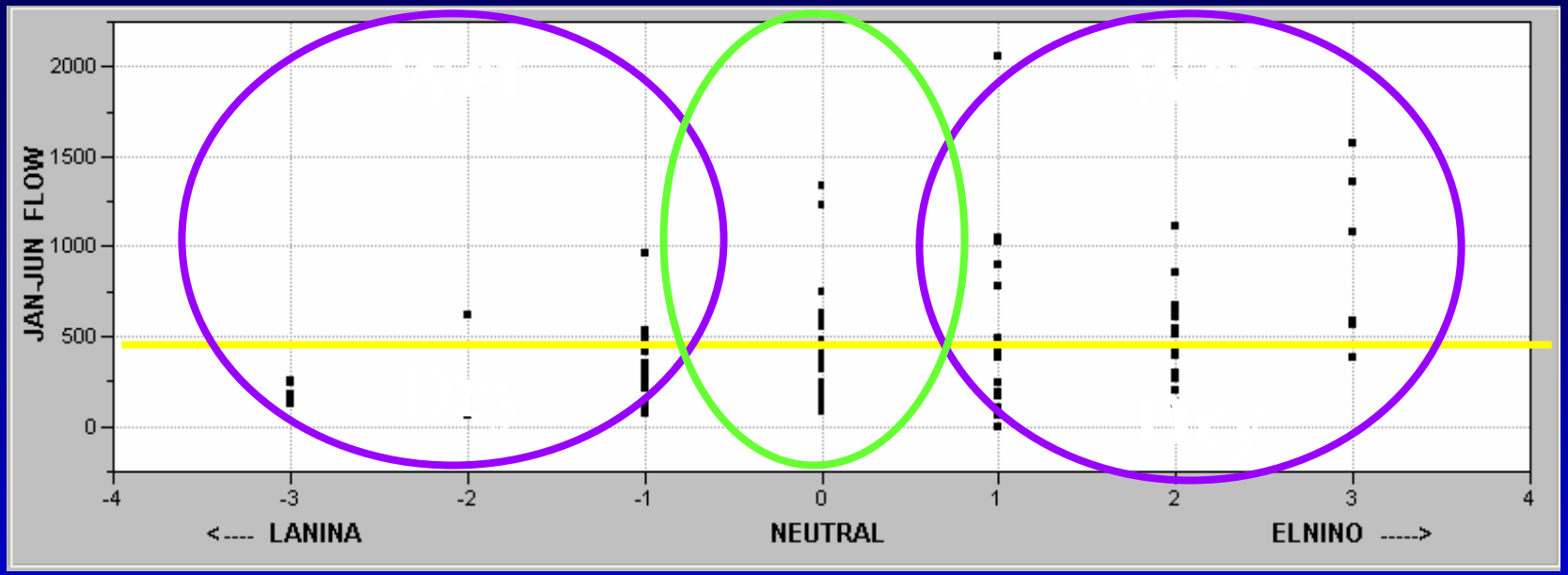
Each dot on the graph represents a runoff year.

When you hear 'ElNino' do not always assume high runoff in the Upper Colorado Basin Above Lake Powell. But…

Extremely strong ElNino's are usually wetter and Extremely strong LaNina's are usually dryer.

Information provided by CBRFC, Salt Lake City, UT.

Lower Colorado – Salt River Inflow



Each dot on the graph represents a runoff year.

When you hear ‘ElNino’ it is **usually** wetter in the Lower Colorado Basin.

When you hear ‘LaNina’ it is **almost always** dry In the Lower Colorado Basin.

Information provided by CBRFC, Salt Lake City, UT.

Current Inflow and Forecast (as of February 17, 2004)

- Current basin snowpack is 93% of average
- Water year-to-date precipitation is 88% of average
- From the Colorado Basin River Forecast Center (CBRFC):
  - Observed unregulated inflow into Lake Powell for January, 2004 was 75% of average (3.9 million acre-feet)
  - April through July unregulated inflow into Lake Powell is projected to be 76% of average (6.0 million acre-feet)
- For the Gila River Basin:
  - Current snowpack is 69% of average; precipitation to date is 75% of average

What is the prognosis over the long-run?

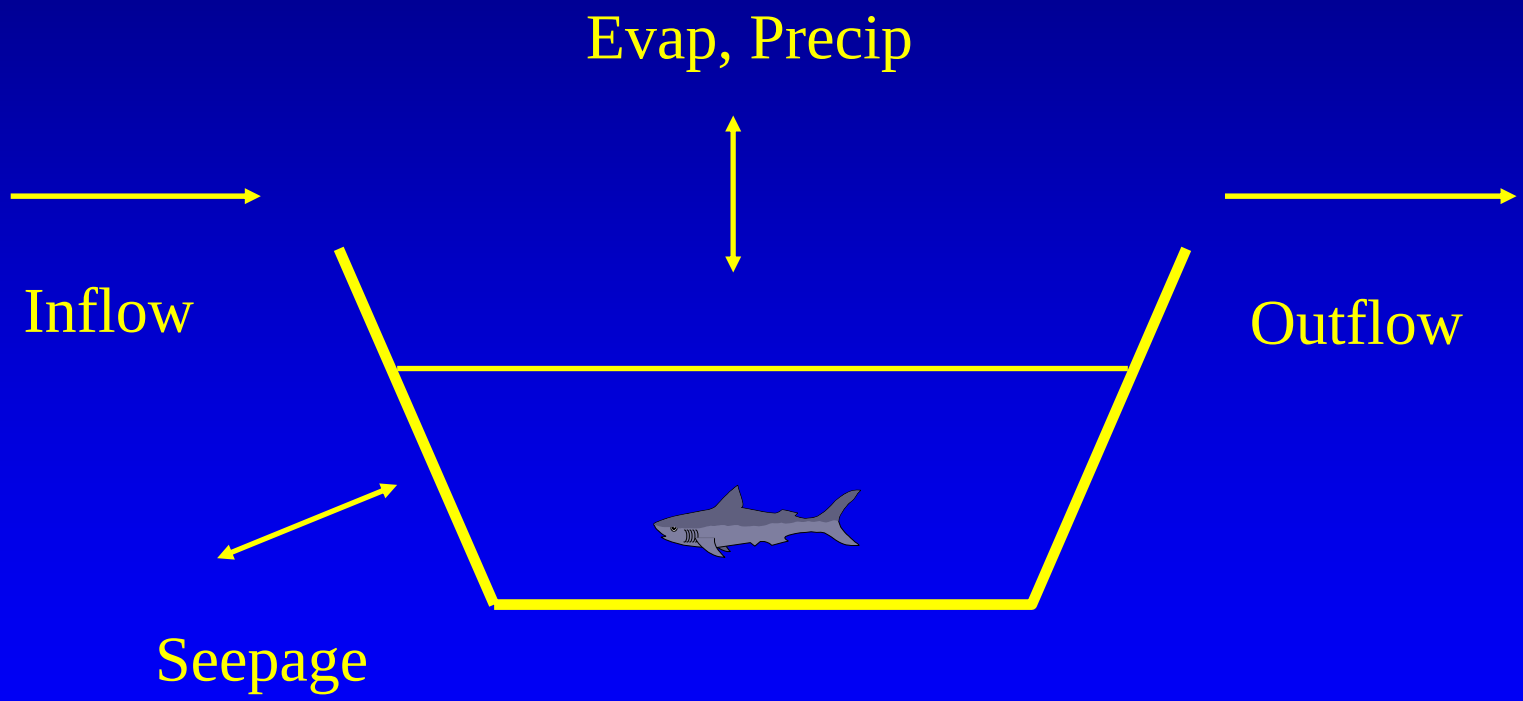
What is the Probability of refilling Colorado River reservoirs (with storage > 90 percent of capacity) by the year 2010?

15 – 20 percent

Some Current Issues in the Lower Basin

- Decreasing Lake Mead levels
- Surplus guidelines
- Shortage guidelines

What affects the elevation of a reservoir?



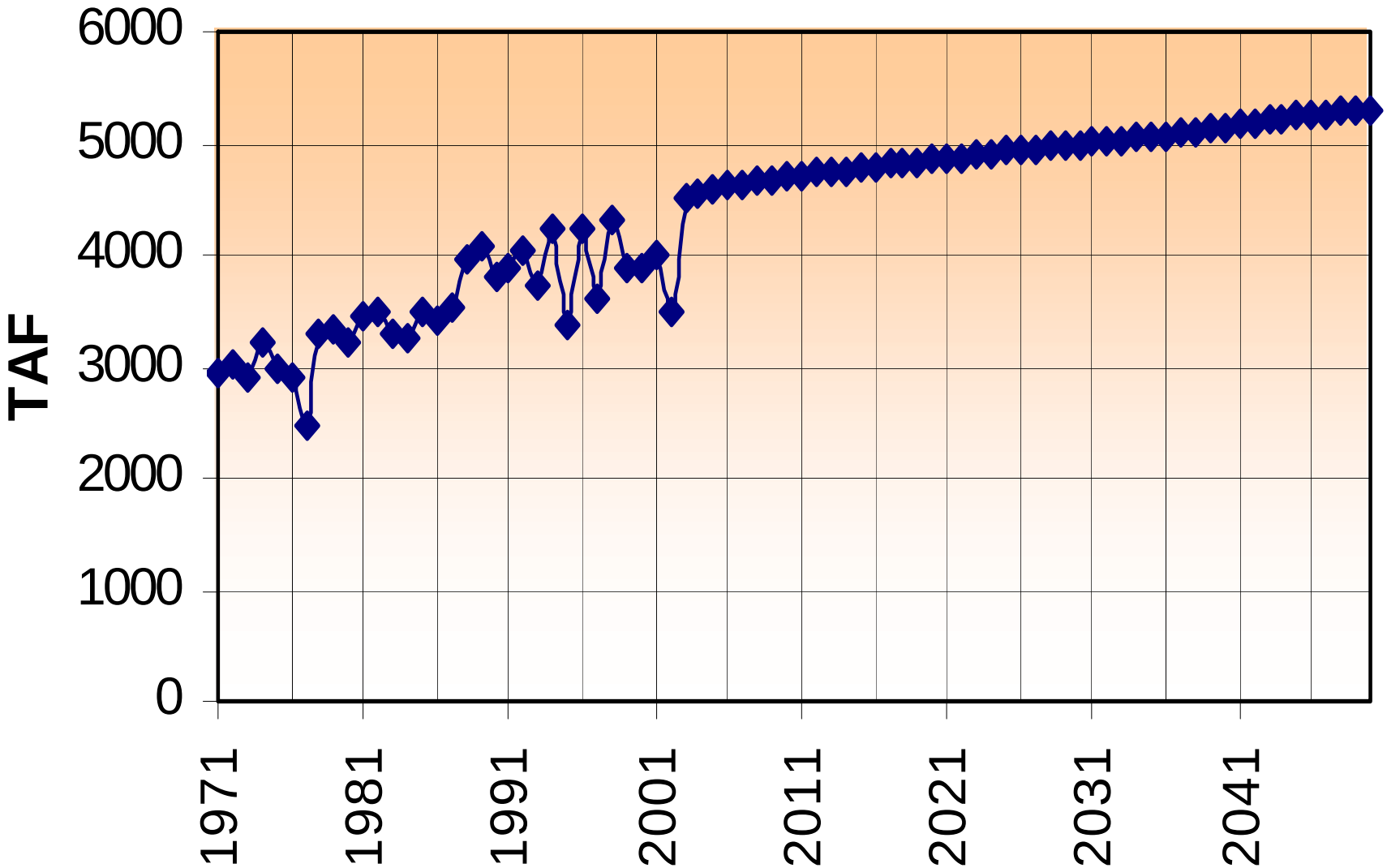
Why is Lake Mead Going Down?

- Inflow = 9.0 maf
  - release from Powell + side inflows
- Outflow = - 9.7 maf
  - LB and Mexico apportionments
    + downstream regulation and losses
- Mead evaporation loss = - 0.7 maf
- Balance = - 1.40 maf
  (about 12 – 13 feet)

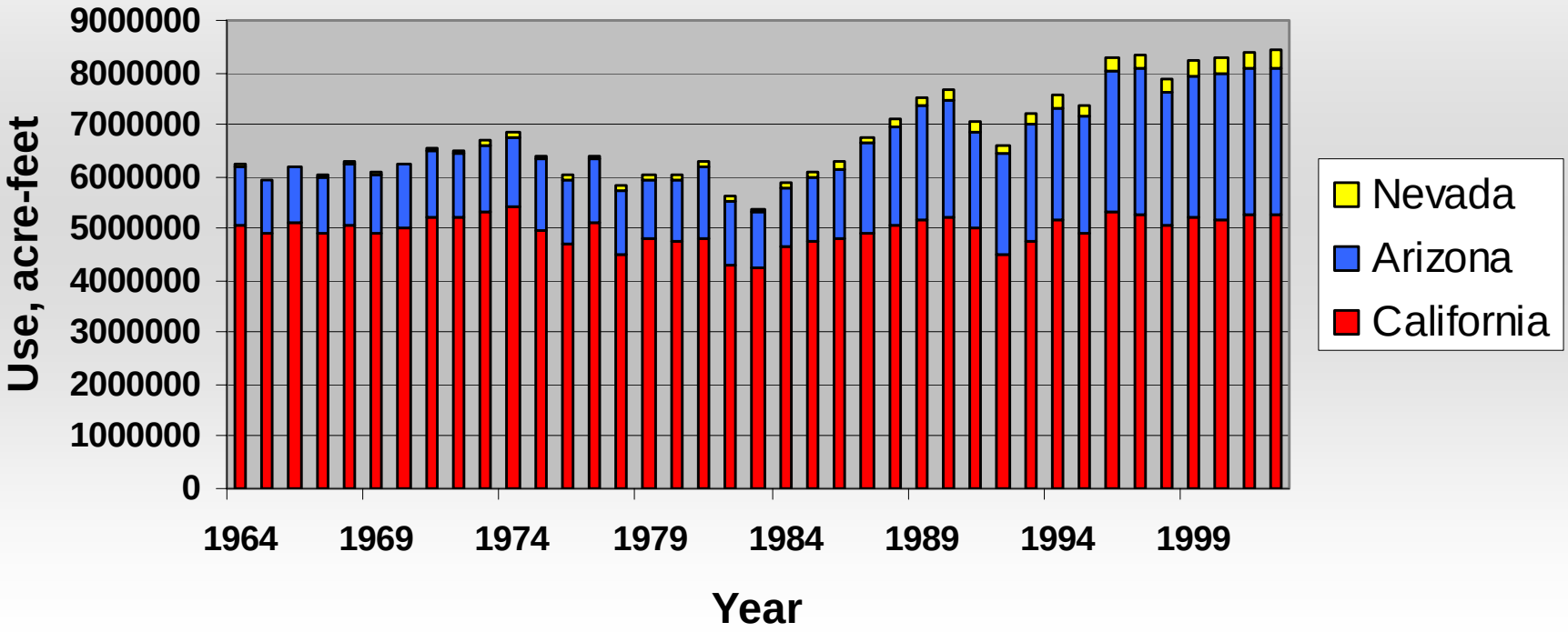
When All Else Fails

Upper Basin Depletions 1971-2050

No Reservoir Evaporation



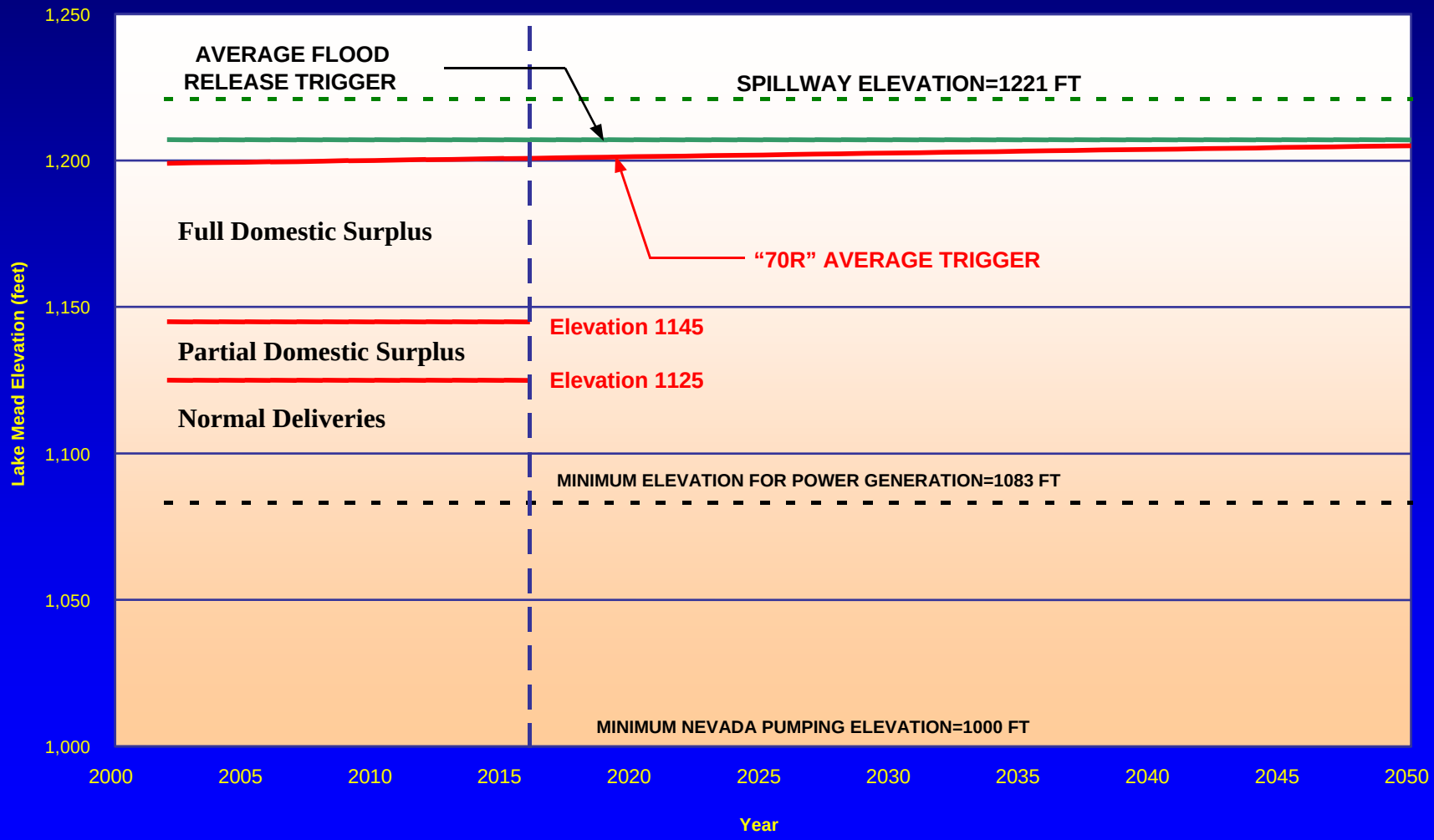
Lower Basin States Use of Colorado River Water



Interim Surplus Guidelines
Highlights

- Defines levels in Lake Mead to determine amount of surplus water available
- Guidelines are in effect through 2016
- Domestic surplus levels can be suspended due to:
  - failure to execute the Quantification Settlement Agreement (QSA)
- Colorado River Water Delivery Agreement ("new QSA")

Interim Surplus Guidelines
Lake Mead Surplus Trigger Elevations



Water Delivery Agreement
(Signed on October 16, 2003)

- California agrees to specific steps to reduce its use of Colorado River water through transfers from agricultural to urban use, canal linings, and other conservation measure
- Quantifies entitlements for Imperial Irrigation District and Coachella Valley Water District
- Re-instates Interim Surplus Guideline levels
- Provides framework for Salton Sea mitigation and restoration

Shortage in the Lower Basin

- Shortage as defined (by the Decree):
  - "if insufficient mainstream water is available for release … to satisfy annual consumptive use of 7.5 maf …, then the Secretary of the Interior … may apportion the amount remaining available … consistent with the Boulder Canyon Project Act … and with other applicable federal statutes"
- Long Range Operating Criteria lists some "relevant factors" to consider including: Mexico Treaty obligations, reasonable use requirements in the Lower Basin; actual and forecast storage in Mead, estimate of net inflow to Mead, historic streamflows, etc.
- There are no shortage guidelines in effect today
- Certain modeling assumptions have been made for future, long-term simulation of the river basin


For further information:
http://www.usbr.gov/lc/region