Lower Colorado River Basin Operations and Modeling
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
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 objectives 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

Projected September, 2003 Upper Basin Storage

602(a) Storage Algorithm
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

- **Basin-wide over decades**
  - Long-term Planning
  - Operating Criteria: Annual Operating Plan

- **Basin-wide over 1-2 years**
  - Mid-term Operations
  - Operating Criteria: Water and Power Schedules

- **Sub-basin over 4-6 weeks**
  - Short-term Scheduling
  - Operating Criteria: Unit Commitment Economic Dispatch

- **Single project over 1-7 days**
  - Real-time Control
  - Operating Criteria: 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
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”)

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)
Probability of Surplus
(of any level)

Year

Probability


0.000  0.200  0.400  0.600  0.800  1.000
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
Single project over 1-7 days | Real-time Control | Unit Commitment Economic Dispatch
Automatic Generation and Control
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
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
Based on August 24 month study
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
Lake Mohave Operational Constraints

Top of Dam Elevation = 646.5

- Stay above 640
- Stay above 638 for 10 days
- Stay below 635

Feb-Apr 10 day drawdown not to exceed 2 feet

End of Month Target Elevation
Laughlin River Days Powerboat Races
May 30 – June 1, 2003
Lake Havasu Operational Constraints

End of Month Target Elevation

Top of Dam Elev = 450.5 Ft.

Unofficially conceded to marinas 445.8 ft

MWD pumping contract 440 ft
La Paz County Sheriff Department –
Boat Launch Facility
## Current Basin Reservoir Conditions
(as of February 11, 2004)

<table>
<thead>
<tr>
<th>Current Storage</th>
<th>Percent Full</th>
<th>1000 Ac-Ft</th>
<th>Elev. (Ft)</th>
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<tbody>
<tr>
<td>Lake Powell</td>
<td>44%</td>
<td>10,821</td>
<td>3590.00</td>
</tr>
<tr>
<td>Lake Mead</td>
<td>60%</td>
<td>15,437</td>
<td>1140.42</td>
</tr>
<tr>
<td>Total System Storage</td>
<td>55% *</td>
<td>32,400</td>
<td>NA</td>
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</table>

* Total system storage was 36,246 kaf or 61% this time last year
Lake Mead End of Month Elevations

Spillway Crest 1221 Ft.

Jan 1937 - Aug 2003
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

<table>
<thead>
<tr>
<th>Years</th>
<th>Duration</th>
<th>Average Flow</th>
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</thead>
<tbody>
<tr>
<td>1953-1964</td>
<td>12 years</td>
<td>11.6 maf</td>
</tr>
<tr>
<td>1953-1977</td>
<td>25 years</td>
<td>12.7 maf</td>
</tr>
<tr>
<td>1579-1595</td>
<td>17 years</td>
<td>10.5 maf</td>
</tr>
<tr>
<td>1988-1992</td>
<td>5 years</td>
<td>10.5 maf</td>
</tr>
<tr>
<td>2000-2003*</td>
<td>4 years</td>
<td>10.7 maf</td>
</tr>
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</table>

* Estimated
Hite Bay looking upstream
Full Pool Elevation
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?
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.
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?

- Evap, Precip
- Inflow
- Outflow
- Seepage
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

www.insanityplanet.com
Lower Basin States Use of Colorado River Water

Year

Use, acre-feet


Nevada
Arizona
California

- Nevada
- Arizona
- California
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

- **Spillway Elevation**: 1221 FT
- **Minimum Elevation for Power Generation**: 1083 FT
- **Minimum Nevada Pumping Elevation**: 1000 FT

- **Average Flood Release Trigger**: 1145 FT
- **“70R” Average Trigger Elevations**: 1125 FT
- **Average Flood Release Trigger**: 1145 FT

- **Full Domestic Surplus**
- **Partial Domestic Surplus**: Elevation 1145
- **Normal Deliveries**: Elevation 1125

Year:
- 2000
- 2005
- 2010
- 2015
- 2020
- 2025
- 2030
- 2035
- 2040
- 2045
- 2050
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