Glen Canyon Dam Temperature Control Device

Engineering
Economics
Environment
Science

Dennis Kubly, BR and Barry Gold, GCMRC
What do we Desire?

• To provide environmental conditions suitable for successful reproduction and recruitment of humpback chub in the Colorado River

• To do no harm to other important resources in the system
Elements of the Reasonable and Prudent Alternative

- Develop a program of experimental flows
- Implement a selective withdrawal program and determine feasibility
- Establish a second spawning aggregation of humpback chub below Glen Canyon Dam
- Determine responses of endangered fish to temperatures and flows
- Develop actions to help ensure continued existence of razorback sucker
- Develop a management plan for the Little Colorado River basin
Other Threats to Endangered Fish in Grand Canyon

- Existing exotic fish, parasites, and disease organisms
- New invading exotic fish, parasites, and disease organisms
- Surface water and groundwater diversions and depletions
- Catastrophic events such as toxic spills
Pre- and Post-Dam Water Temperature

Time (days)

Temperature (°C)

Pre-Dam

Post-Dam

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec
Thermal Profiles in Lake Powell
Conditions below Glen Canyon Dam with Controls

- Temperature Preferred by Humpback Chub
- River Temperature Increases With Temperature Controls
Uncontrolled Overdraw-Fixed Inlet

Overview

Operating Range/Minimum Reservoir Elevation: 30’/3670’
Controlled Overdraw Overview

Operating Range/Minimum Reservoir Elevation: 100’/3600’
The Shasta Temperature Control Device (TCD) allows water at selected temperatures to go through powerplant.

Reaching for Shasta’s cold water:
The gated temperature control device will allow operators to draw from the surface during the winter when that water is suitably cool, and from the bottom in the summer when the surface is warm. A portion of the device will reach deep into the ancient river channel (see right) to reach the oldest water.

Numbers of returning salmon:
Estimates of the number of winter-run chinook salmon returning to spawm below Keswick Dam. During construction of Shasta Dam, runs were estimated at 40,000 or 100,000 fish.

Drought Years:
- 1967: 8,000
- 1968: 1,397
- 1969: 1,397
- 1970: 1,397
- 1971: 1,397
- 1972: 1,397
- 1973: 1,397
- 1974: 1,397
- 1975: 1,397
- 1976: 1,397
- 1977: 1,397
- 1978: 1,397
- 1979: 1,397
- 1980: 1,397
- 1981: 1,397
- 1982: 1,397
- 1983: 1,397
- 1984: 1,397
- 1985: 1,397
- 1986: 1,397
- 1987: 1,397
- 1988: 1,397
- 1989: 1,397
- 1990: 1,397
- 1991: 1,397
- 1992: 1,397
- 1993: 1,397
- 1994: 1,397
- 1995: 1,397
- 1996: 1,397
- 1997: 1,397
- 1998: 1,397
- 1999: 1,397
- 2000: 1,397
- 2001: 1,397
- 2002: 1,397
- 2003: 1,397
- 2004: 1,397
- 2005: 1,397
- 2006: 1,397
- 2007: 1,397
- 2008: 1,397
- 2009: 1,397
- 2010: 1,397
- 2011: 1,397
- 2012: 1,397
- 2013: 1,397
- 2014: 1,397
- 2015: 1,397
- 2016: 1,397
- 2017: 1,397
- 2018: 1,397
- 2019: 1,397
- 2020: 1,397
- 2021: 1,397
- 2022: 1,397
- 2023: 1,397
- 2024: 1,397
- 2025: 1,397
- 2026: 1,397
- 2027: 1,397
- 2028: 1,397
- 2029: 1,397
- 2030: 1,397
- 2031: 1,397
- 2032: 1,397
- 2033: 1,397
- 2034: 1,397
- 2035: 1,397
- 2036: 1,397
- 2037: 1,397
- 2038: 1,397
- 2039: 1,397
- 2040: 1,397
- 2041: 1,397
- 2042: 1,397
- 2043: 1,397
- 2044: 1,397
- 2045: 1,397
- 2046: 1,397
- 2047: 1,397
- 2048: 1,397
- 2049: 1,397
- 2050: 1,397
Figure 1. Schematic of Surface Water Pump Concept
Figure 3. General Arrangement of Surface Water Pumps at Douglas Dam
Alternative 4: Release Temperature
Modify Intakes

The graph shows the release temperature over time from January 1, 1992, to December 31, 1995. The x-axis represents the dates, while the y-axis represents the release temperature in Celsius. The graph includes data for 2 of 8 structures, 3 of 8 structures, 4 of 8 structures, and 8 structures, each represented by different colored lines.
## Alternative Temperature Control Device Options & Estimated Costs

<table>
<thead>
<tr>
<th>Design option</th>
<th>Operating range (Min. op. W.S.***</th>
<th>Construction cost</th>
<th>Add’l design time*</th>
<th>Construction time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option 1 - Fixed inlet design</strong></td>
<td>30 feet (El.3670)</td>
<td>$13.5 M</td>
<td>2 months</td>
<td>24 months</td>
</tr>
<tr>
<td><strong>Option 2- Controlled overdraw</strong></td>
<td>80 feet (El. 3600)</td>
<td>$43.0 M (6/8 = $32 M)</td>
<td>15 months</td>
<td>33-35 months</td>
</tr>
<tr>
<td><strong>Option 3 – External frame</strong></td>
<td>100 feet (El. 3580)</td>
<td>$65.0 M (6/8 = $49 M)</td>
<td>18 months</td>
<td>24 months</td>
</tr>
<tr>
<td><strong>Option 4 - Surface water pumps</strong></td>
<td>150 feet</td>
<td>$9.9 M</td>
<td>10 months</td>
<td>12 Months</td>
</tr>
</tbody>
</table>
## Operation and Maintenance Costs for Temperature Controls

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Monitoring</th>
<th>O&amp;M</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>$200,000</td>
<td>$100,000</td>
<td>$302,000</td>
</tr>
<tr>
<td>2001</td>
<td>$1,100,000</td>
<td>$100,000</td>
<td>$1,202,001</td>
</tr>
<tr>
<td>2002</td>
<td>$1,600,000</td>
<td>$100,000</td>
<td>$1,702,002</td>
</tr>
<tr>
<td>2003</td>
<td>$1,600,000</td>
<td>$100,000</td>
<td>$1,702,003</td>
</tr>
<tr>
<td>2004</td>
<td>$1,300,000</td>
<td>$100,000</td>
<td>$1,402,004</td>
</tr>
<tr>
<td>2005</td>
<td>$550,000</td>
<td>$100,000</td>
<td>$652,005</td>
</tr>
</tbody>
</table>
Optimal Hourly Release and Generation

Peakshaving Model

Hydrology Data
- release volume
- reservoir elevation

Constraints
- max/min flow
- ramp rates
- max daily change

TCD Head Loss

Hourly Load

Optimal Hourly Release and Generation

Evaluation

Variable Costs
- hydroplant
- spot price

Avoided Cost (economic value)

What Do We Know?

- Cold water temperatures restrict successful reproduction of humpback chub
- Cold water temperatures cause mortality of young humpback chub by thermal shock
- In the post-dam period, some non-native fish have been reduced, others have increased
- Primary productivity has increased dramatically in the tailwater
What Could go Wrong?

• We may entrain undesirable fish from higher levels in the reservoir and deliver them to the tailwater. Some will survive.
Fish of Lake Powell

Striped bass  Threadfin shad

Largemouth bass  Walleye

Carp  Red shiner  Crappie
What Could go Wrong?

• Benthic algae and invertebrates that form the fish food base are adapted to constant, cold water temperatures. They may not be able to withstand cycling between warm and cold temperatures.
Aquatic Vegetation Colorado River

Cocconeis

Diatoma

Cladophora glomerata

Potamogeton

Oscillatoria
Figure 14. Longitudinal sediment concentration and biomass of *Cladophora* and macroinvertebrates in the Colorado River from Glen Canyon Dam to Diamond Creek (Source: Carothers and Brown 1991).
What Could go Wrong?

• Cold water temperatures suppress important diseases, parasites, competitors, and predators of the native fish

• Therefore, warming the water could result in negative impacts to native fish, including the endangered humpback chub
Life Cycle of Whirling Disease

Whirling Disease poses a serious threat to New Mexico’s trout population. To prevent the spread of this disease it is helpful to understand its life cycle.

1. Microscopic spores are found on the river bottom.
2. Bottom-dwelling tubifex worms eat the spores.
3. Inside the tubifex worm, the spore changes form and becomes a Trachnemysis (TAM).
4. The TAMs are released from the tubifex worm into the water.
5. Trout become infected when the TAMs enter the skin of the fish and release even smaller parasites that multiply and move to the fish’s nerves.
6. After travelling up the nerves to the head and spinal cord, the parasites attack cartilage, cause inflammation, and then develop into mature spores.
7. After several weeks, infected fish may exhibit a “whirling” behavior, include deformities, and death.
8. When the infected fish dies and decomposes or is eaten by a predator, the spores in its body are released into the water and the cycle starts over.
Intermediate Host & Infective Stage
Whirling Disease

*Tubifex*

*Myxobolus*
‘tam’ stage
## Number of Parasites Infecting Each Fish Species

| Parasite Species | Host Species | BHS | FMS | HBC | SPD | CCF | CRP | FHM | PKF | RBT |
|------------------|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Myxosporea       |              |     |     |     |     |     |     |     |     |     |     |
| *Henneguya sp.*  |              |     |     | X   |     |     |     |     |     |     |     |
| Cestoda          |              | X   | X   | X   | X   | X   | X   |     |     |     |     |
| *Bothriocephalus acheilognathi* |                  |     |     |     |     |     |     |     |     |     |     |
| *Corallobothrium fimbriatum* |              |     |     | X   |     |     |     |     |     |     |     |
| *Megathylocoides giganteum* |              |     |     |     | X   |     |     |     |     |     |     |
| Trematoda        |              | X   | X   | X   | X   | X   | X   |     |     |     |     |
| *Ornithodiplostomum sp.* |            |     |     |     |     |     |     |     |     |     |     |
| Nematoda         |              |     |     |     |     | X   | X   |     |     |     |     |
| *Rhabdochona sp.* |              |     |     |     |     |     | X   | X   |     |     |     |
| *Truttaedacnitis truttae* |              |     |     |     |     |     |     |     |     |     | X   |
| *Eustrongylides sp.* |              |     |     |     |     |     |     |     |     |     | X   |
| *Contracaecum sp.* |              |     |     |     |     |     |     |     |     |     | X   |
| Hirudinea        |              |     |     |     |     |     |     |     |     |     | X   |
| *Myzobdella lugubris* |              |     |     |     |     |     |     |     |     |     |     |
| Copepoda         |              |     |     |     |     |     |     |     |     |     |     |
| *Lernaea cyprinacea* |              |     |     |     |     |     |     |     |     |     | X   |
| Acari            |              |     |     |     |     |     |     |     |     |     | X   |
| Total            |              | 2   | 0   | 4   | 4   | 8   | 0   | 2   | 1   | 1   |     |
Life Cycle of *Bothriocephalus acheilognathi*

- **Eggs released**
- **Eggs hatch**
- **Larva ingested by copepod**
- **Procercoid develops in copepod**
- **Copepod consumed by host**
- **Little Colorado River, Kanab Creek, Colorado River?**

Source: AGFD 1999
<table>
<thead>
<tr>
<th>Non-native species</th>
<th>Humpback chub</th>
<th>Razorback sucker</th>
<th>Flannelmouth sucker</th>
<th>Bluehead sucker</th>
<th>Speckled dace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common carp</td>
<td>P,D</td>
<td>P</td>
<td>P,D</td>
<td>P,D</td>
<td>P,D,H</td>
</tr>
<tr>
<td>Brown trout</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Black bullhead</td>
<td>P</td>
<td></td>
<td>P</td>
<td>P</td>
<td>P</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>P</td>
<td></td>
<td>P?</td>
<td>P</td>
<td>P?</td>
</tr>
<tr>
<td>Rainbow trout</td>
<td>P</td>
<td></td>
<td>P?</td>
<td>P?</td>
<td>P?</td>
</tr>
<tr>
<td>Golden shiner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Threadfin shad</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P = Predation; D = Disease and Parasites; C = Competition; H = Habitat Alteration
Expert Panel Workshop

• Bring together modeling and empirical data gathering efforts
• Purpose to develop a sound framework for the TCD science plan
• Integrate into NEPA effort as an accompanying document to the environmental assessment
TCD Workshop Results

• Concern: Ability to Detect Change has not been Determined for many Resources

• Concern: Hydrology and Water Temperature Effects need to be Considered Jointly in Planning

• Concern: Scientists Need Better Communication with Water Managers in Planning Research and Monitoring
TCD Science Plan and AMP Monitoring

- 4 Primary Issues Associated with TCD.
- Role of PEP in Reviewing the TCD Science Plan.
- What supplemental scientific activities might be needed to address TCD issues.
Primary Biological Issues with TCD

- Entrainment of Fish from Reservoir/Reservoir dynamics.
- Changes in productivity in Lees Ferry and downstream (increase/decline or just change?)
- Increased predation on native fish by introduced species (warm water fish species as well as trout (browns & rainbows)).
- Increased risk of exposure to disease and parasites for all fish and rainbow trout exposure to whirling disease.
## Time Line for Monitoring

<table>
<thead>
<tr>
<th>Fish Monitoring</th>
<th>PEP – May</th>
<th>RFP - September</th>
<th>Age2+ abundance &amp; trends (stock synthesis &amp; assessment) Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anticipate 3 years from 2002 to see trends in populations.</td>
<td>Report – July</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipate 3 years from 2002 to evaluate utility of monitoring approach and to see trends.</td>
<td>RFP - September</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lees Ferry Trout</td>
<td>PEP – completed</td>
<td>RFP - Funded</td>
<td>Age 2+ abundance &amp; trends, condition, &amp; PSD.</td>
</tr>
<tr>
<td>Anticipate 3 years from 2001 to see trends</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Additional considerations associated with the TCD

Time scales related to different research questions:

• Risk analysis associated with the level of effort and causal relationship needs.

• Short vs. long-term response: Larval fish info can be costly and may not indicate long-term success. But will answer mainstem spawning question sooner.

• Monthly productivity measures vs. quarterly or some other scale. Provides different levels of information. One can approach potential mechanisms, while the other may not provide such refinement.
Additional work/considerations associated with the TCD

- Predator control either by physical means or with operations (fluctuations or other methods) and the effect of this in the short term.
- Relationships between increased metabolism and predation rates?
- Within reservoir community dynamics and downstream inputs.
Additional work/considerations associated with the TCD

Food quality shifts in foodbase and effectively measuring this.

Further development of CE Qual Model for Reservoir (more inputs and calibration/validation).

Set-up of radio-telemetered profiling stations to see short-term response and to determine if target temperatures are met.

Capability of TCD to accommodate blocked design or continuous operation vs. single year test.

Downstream thermal stratification and associated implications.