Lake Pleasant Operations and its Effect on Water Quality in the CAP Canal; Cooperation in Action
Background and History

• UA initiated first “taste and odor” project in 1996.

• Sponsors: CAP, SRP, Chandler, Glendale, Mesa, Phoenix, Scottsdale, Tempe.

• This project intensively monitored from both the SRP and CAP canals throughout the Valley in addition to limnological monitoring of Lake Pleasant.
Project Goals

• To determine if there was a causal relationship between the limnology or management of Lake Pleasant and taste and odor production in the CAP canal.

• Recommendations to alleviate the problem.
RIVERINE ZONE

- Narrow, channelized basin
- Relatively high flow
- High susp. solids, turbid, low light avail., $Z_p < Z_m$
- Nutrient supply by advection, rel. high nutrients
- Light-limited PPR
- Cell losses primarily by sedimentation
- Organic matter supply primarily allochthonous, $P < R$
- More "eutrophic"

TRANSITIONAL ZONE

- Broader, deeper basin
- Reduced flow
- Reduced susp. solids, less turbid, light avail. increased
- Advective nutrient supply reduced
- PPR/m^3 rel. high
- Cell losses by sedimentation and grazing
- Intermediate

LACUSTRINE ZONE

- Broad, deep, lake-like basin
- Little flow
- Rel. clean, light more avail. at depth, $Z_p > Z_m$
- Nutrient supply by internal recycling, rel. low nutrients
- Nutrient-limited PPR
- Cell losses primarily by grazing
- Organic matter supply primarily autochthonous, $P > R$
- More "oligotrophic"
A priori information

• Taste and odor complaints decreased dramatically when the CAP canal contained water directly from the Colorado River as opposed to water that had been stored in Lake Pleasant.

• Taste and odor complaints increased among utilities in the Phoenix Valley that were the farthest from Lake Pleasant.
Thermal Stratification

Temp. by Depth Site B 08/29/96

Depth

Temperature (°C)
Nutrient Loading

• *Allochthonous* (from canal into reservoir) during periods of annual refilling of reservoir.

• *Autochthonous* (from reservoir into canal) during periods of release into the canal.
Algal Divisions with Depth 12/04/96

- Sum of Chlorophyta
- Sum of Cyanophyta
- Sum of Chrysophyta
Algal Speciation During Filling With Water From CAP Canal

- Between dams at depth, mostly periphytic species that are usually found growing along the side of the CAP canal.

Sites to the north of the old dam more planktonic (true lacustrine) species.
Preliminary data from 1996 suggested an increase in dissolved and/or reduced forms of algal nutrients within the hypolimnion.
<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>D</th>
</tr>
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<tbody>
<tr>
<td>Mean Ferrous Iron (mg/L)</td>
<td>10.03</td>
<td>0.6</td>
</tr>
<tr>
<td>Mean Ortho P (mg/L)</td>
<td>5.45</td>
<td>0.65</td>
</tr>
<tr>
<td>Mean Ammonia-Nitrogen (mg/L)</td>
<td>5.56</td>
<td>0.63</td>
</tr>
</tbody>
</table>
Recommendation

• Prior to 1996, water was released from the top gate (epilimnion) into the canal.
• This left the hypolimnion intact to become anoxic and accumulate nutrients.
• These nutrients were slowly released into the canal when stratified and in a large pulse during turn over.
Hypolimnetic Withdrawal

- Recommended for the Spring/Summer of 1997 to try and siphon off the hypolimnion as early in the year as possible.
- Done to increase dissolved oxygen over the sediments especially in the area between the old and new Waddell dams.
The Goal of Hypolimnetic Withdrawal

- To make nitrogen less “limiting” for algal growth in the CAP canal.
- To decrease the total nutrient concentration in the CAP canal.
- Resource-ratio theory: Exploitative competition among taxa with different optimal nutrient ratios will cause changes in plant community structure (Tilman 1985).
• Low N:High P (relative) ratios tend to favor cyanobacteria due to their ability to fix atmospheric nitrogen.

• Can cause a community shift away from taste and odor-causing cyanobacteria by changing nutrient ratios that do not favor their growth i.e. bring the N:P ratio closer to one while striving for lower overall nutrient concentrations.
Comparison of release strategies between 1996 (primarily top release) and 1997 (primarily bottom release) on water quality in the CAP
<table>
<thead>
<tr>
<th>Year</th>
<th>Ammonia</th>
<th>Total P</th>
<th>Ortho P</th>
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<tbody>
<tr>
<td>1996</td>
<td>0.06 mg/L</td>
<td>0.21 mg/L</td>
<td>0.18 mg/L</td>
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<tr>
<td>1997</td>
<td>0.01 mg/L</td>
<td>0.14 mg/L</td>
<td>0.06 mg/L</td>
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</tbody>
</table>
Numbers of periphytic algae by division and distance from Lake Pleasant for 1996

Division by Distance from Lake Pleasant (km)

- Cyanophyta
- Chrysophyta
- Chlorophyta
- Pyrrophyta

Mean (Units/cm²)

0  5000  10000  15000  20000  25000  30000
Numbers of periphytic algae in the CAP canal by division and year

Pyrrophyta
Chlorophyta
Chrysophyta
Cyanophyta

1997

Pyrrophyta
Chlorophyta
Chrysophyta
Cyanophyta

1996

Mean (Units/cm²)
Mean levels of MIB by distance from Lake Pleasant during periods of release into the CAP canal during 1996 and 1997.
Mean levels of geosmin by distance from Lake Pleasant during periods of release into the CAP canal during 1996 and 1997.
Generalized Model of MIB and Geosmin Production in the CAP Canal

1) Increased sedimentation of material between the old and new Waddell dams during re-filling of Lake Pleasant with CAP water.

2) This sedimentation may lead to increased oxygen demand and anoxia within the hypolimnion during thermal stratification.
3) Under anoxic (and reducing) conditions, this sediment may release nutrients at a faster rate than other areas of the reservoir.

4) These nutrients accumulate within the hypolimnion. If water is released from the top gate, the hypolimnion remains undisturbed for long periods and this may lead to further nutrient accumulation.

5) Geosmin or MIB may be quickly degraded in the turbulent release water.
6) Release of nutrient-rich water from the hypolimnion into the CAP canal may lead to the proliferation of taste and odor causing organisms in the canal, especially in areas 70 km or more away from Lake Pleasant.
• The cost associated with releasing water from the bottom gates of Lake Pleasant was virtually, nothing.
Current Problems

• Increased biomass of periphyton growing alongside the CAP canal.
• Hydrogen sulfide emissions upon release during mid-late summer.
• Manganese in canal water from Lake Pleasant.
Increases in Periphytic Biomass

- Nutrient ratios still do not favor cyanobacteria and taste and odor problems (from mib or geosmin) are relatively minor.
- However, mechanical problems arise from heavy growths of Chlorophytes (filamentous green algae e.g. *Cladophora*) and diatoms.
Biofilm Formation

- Initial formation of a biofilm (polysaccharide mucous) by diatoms such as *Cymbella*, *Gomphonema*, *Cocconeis*, *Navicula*, etc.
- Many of these diatoms can be heterotrophic but all have an absolute requirement for silica.
• Diatoms are the original colonizers of substrate through either sexual reproduction or mucous secreted through their raphe for movement.

• The biofilm laid down by the diatoms are then colonized by other types of algae, in this case, primarily *Cladophora*
Division Chrysophyta
Sub-Phylum Bacillariophyceae
Order Pennales
Family Achnanthaceae
Genus: Cocconeis

Division Chrysophyta
Sub-Phylum Bacillariophyceae
Order Pennales
Family Gomphonemaceae
Genus: Gomphonema
### Oneway Analysis of Periphyton UnitsPer_cm2 By Site

![Graph showing the distribution of Periphyton UnitsPer_cm2 by Site CAP1 and CAP2.](image)

### Analysis of Variance

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F Ratio</th>
<th>Prob &gt; F</th>
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<tbody>
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<td>C. Total</td>
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### Means for Oneway Anova

<table>
<thead>
<tr>
<th>Level</th>
<th>Number</th>
<th>Mean</th>
<th>Std Error</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
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<tbody>
<tr>
<td>CAP1</td>
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<td>3772.3</td>
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Std Error uses a pooled estimate of error variance.
Oneway Analysis of MIB_ppb By Site

Analysis of Variance

<table>
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<tr>
<th>Source</th>
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<th>F Ratio</th>
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<tbody>
<tr>
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<td>C. Total</td>
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<th>Upper 95%</th>
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<tbody>
<tr>
<td>CAP1</td>
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Std Error uses a pooled estimate of error variance
### Oneway Analysis of Geosmin_ppb By Site

#### Analysis of Variance

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<th>Mean</th>
<th>Std Error</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
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Std Error uses a pooled estimate of error variance.
Oneway Analysis of DO_mg_per_L By Sampling_Period

Oneway Anova

Analysis of Variance

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<tr>
<th>Source</th>
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<tr>
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<td>C. Total</td>
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Means for Oneway Anova

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<th>Level</th>
<th>Number</th>
<th>Mean</th>
<th>Std Error</th>
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<th>Upper 95%</th>
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<td>Summer 02</td>
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<td>2.75651</td>
<td>0.36294</td>
<td>2.0394</td>
<td>3.4736</td>
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</tbody>
</table>

Std Error uses a pooled estimate of error variance
Dissolved Mn, hydrogen sulfide, and increased periphyton biomass in the CAP are all related to increased anoxia due to prolonged stratification within Lake Pleasant.
Does the increase in hypolimnetic anoxia from the summer of 2002 to the summer of 2003 represent a trend or is natural variability?
Possible Causes

• Climatic variability (e.g. ongoing drought).
  – Could lead to earlier stratification and prolonged hypolimnetic anoxia
  – Difficult to manage for but if a trend is established, new recommendations can be made
Changes in trophic state (i.e. eutrophication)

- Currently classified as mesotrophic (using Carlson’s TSI) but wide ranges exist within any single classification
- A change in trophic state is not a one-way ticket and difficult to quantify short-term changes
• Increased sediment oxygen demand.
  – Are the oxygen-consuming sediments previously found between the dams spreading to other parts of the reservoir?
Lake Pleasant Water Quality Workshop on 1/15/04

• CAP hosted to discuss Lake Pleasant water quality with M&I customers.
• This meeting spelled out what was just presented and sought feedback from customers about suggestions to increase water quality in light of all that we know about the limnology of Lake Pleasant and how it affects the CAP canal.
Meeting Results

• CAP will discuss, with the SRP energy department, the possibility of moving the annual release/fill season up to two months sooner.

• If DO drops below 0.5 ppm, CAP will consider releasing water from the bypass instead of generators.

• CAP will perform a feasibility study for aeration of Lake Pleasant.
This is an excellent example of what can be accomplished when information is exchanged freely between resource managers, municipalities, and researchers.
Questions?