

When waters get murky...

...or what's the buzz with clarity in Grand Lake?

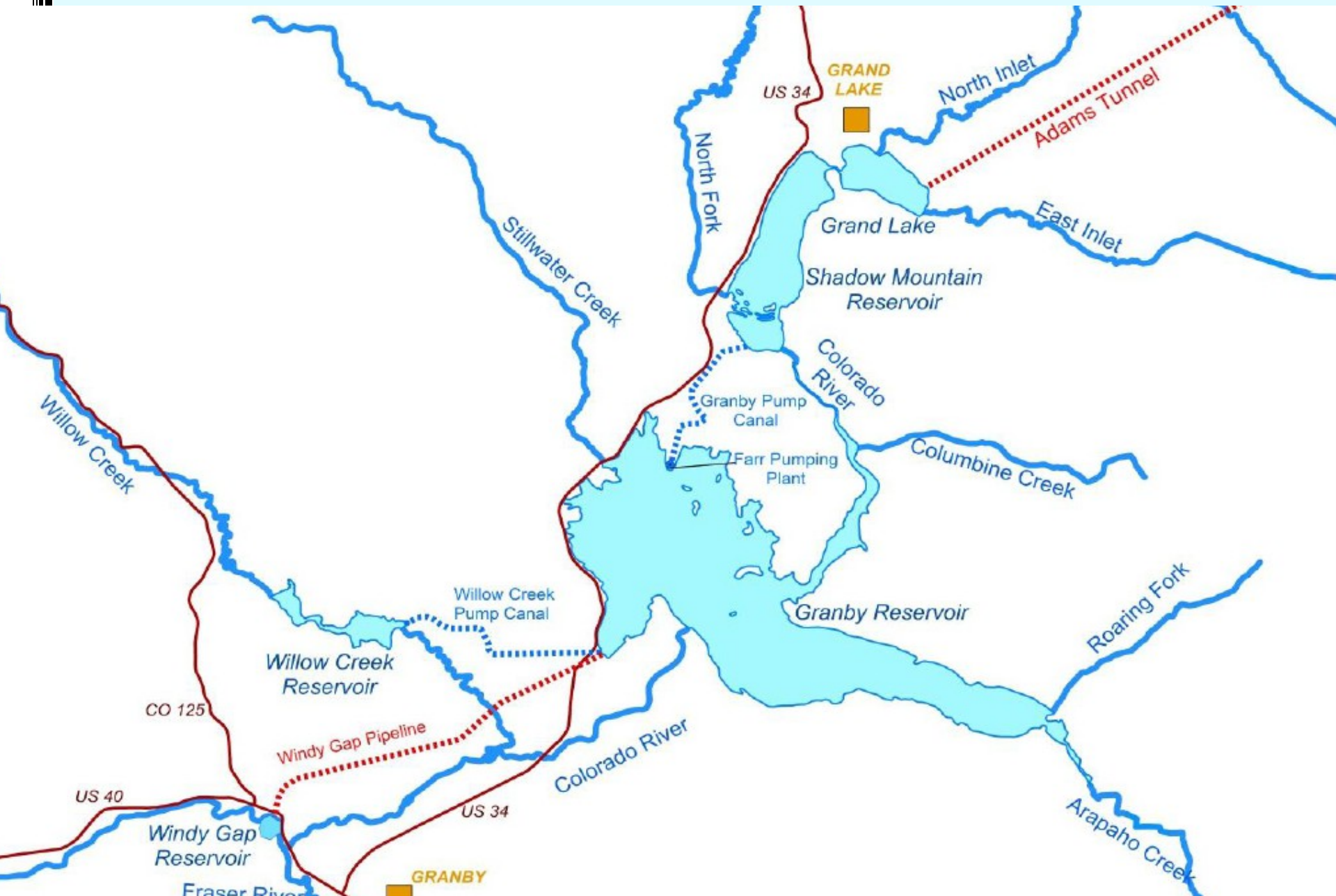
Esther Vincent, PE

Water Quality Manager

Northern Water



About Northern Water





Setting, Background & Issues





Summer 2007

Grand Lake Clarity and Colorado- Big Thompson Operations



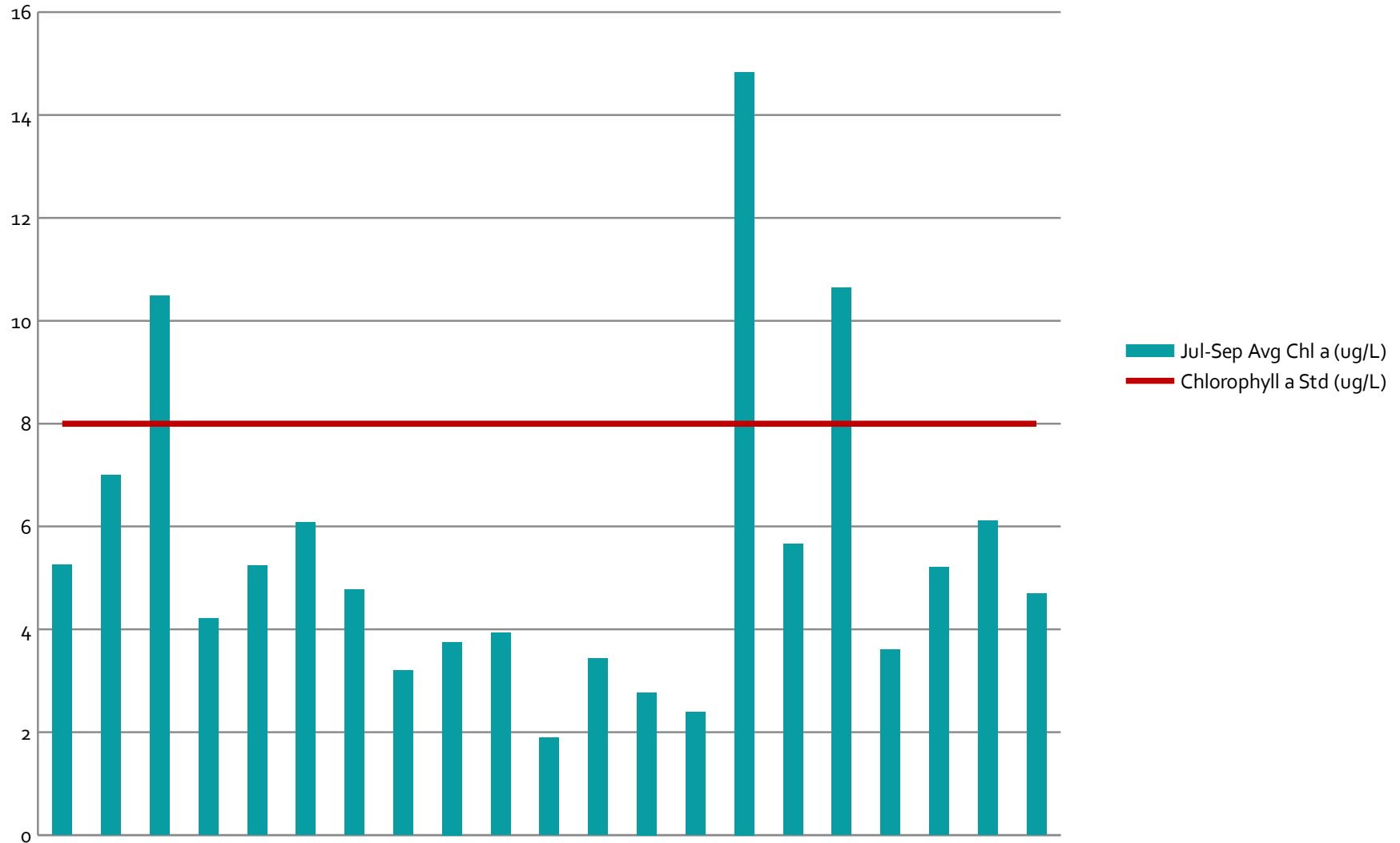
Shadow Mountain Reservoir Delta

- Click to edit Master text styles
 - ▣ Second level
 - ▣ Third level
 - Fourth level
 - Fifth level

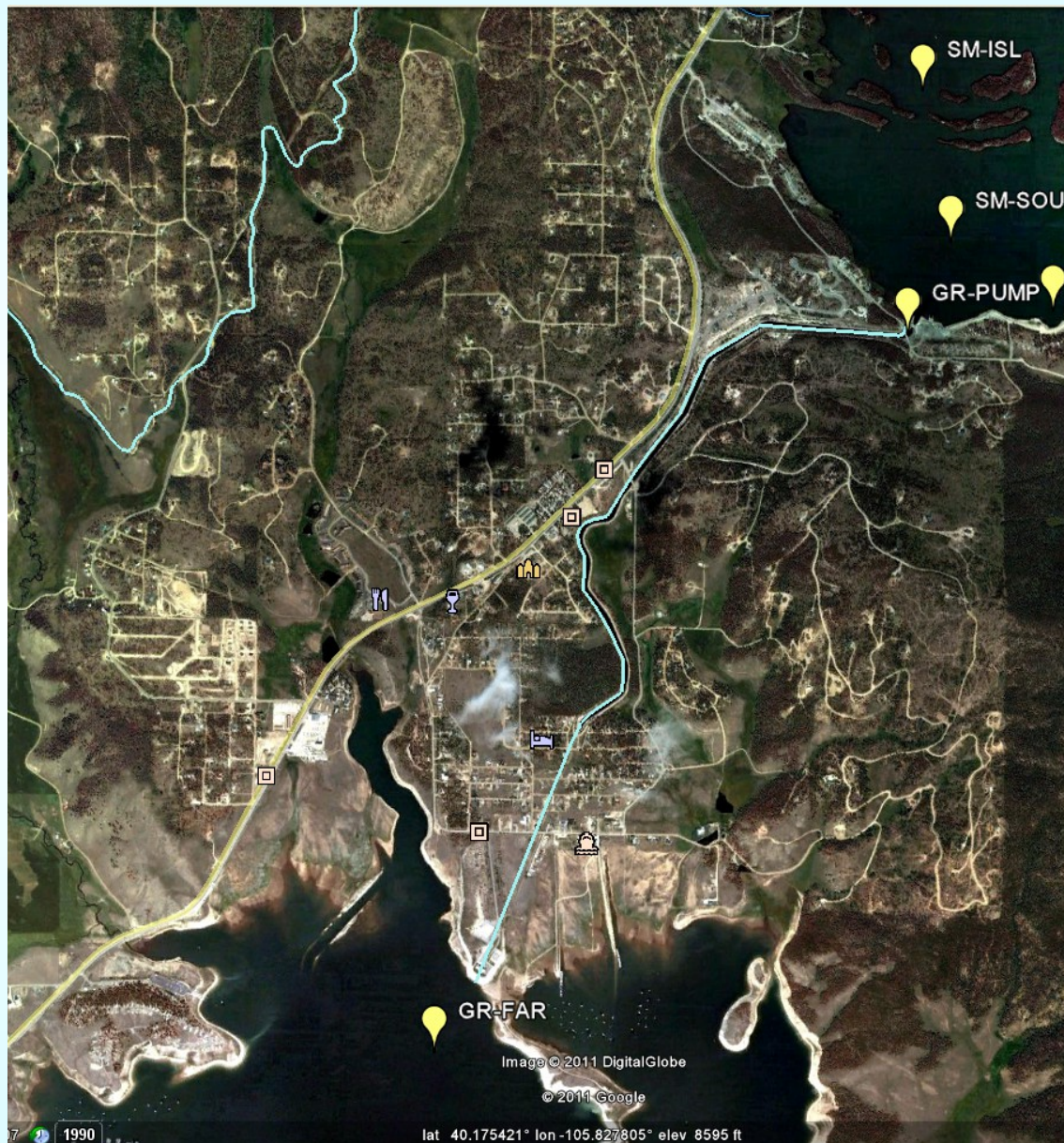
Sep 8, 2011



Jul-Sep Average Corrected Chlorophyll a (ug/L) & Cold water Chl a standard

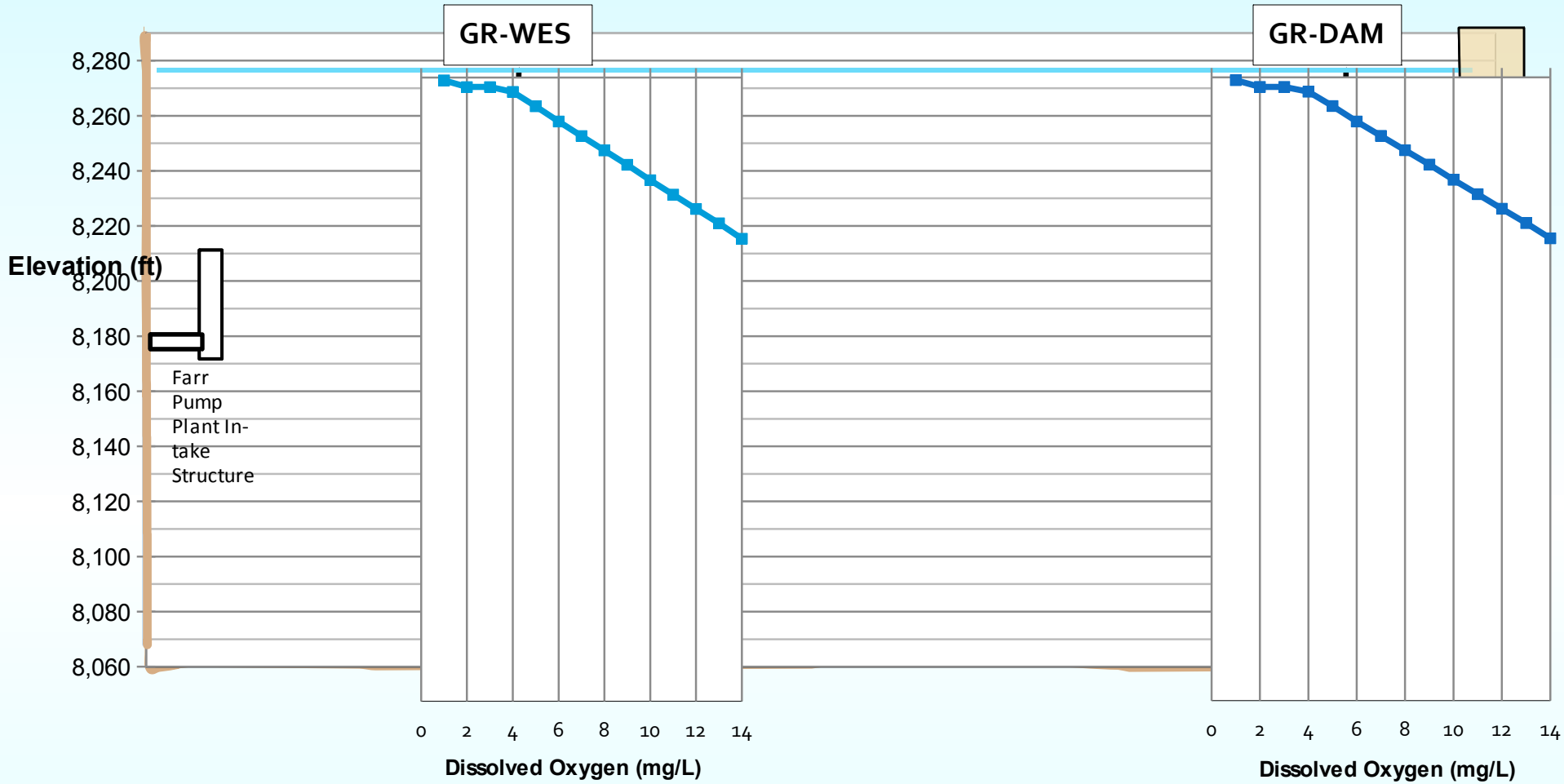


Dissolved Oxygen Levels in Shadow Mountain Reservoir



Granby Res Dissolved Oxygen Profiles - November 2, 2010

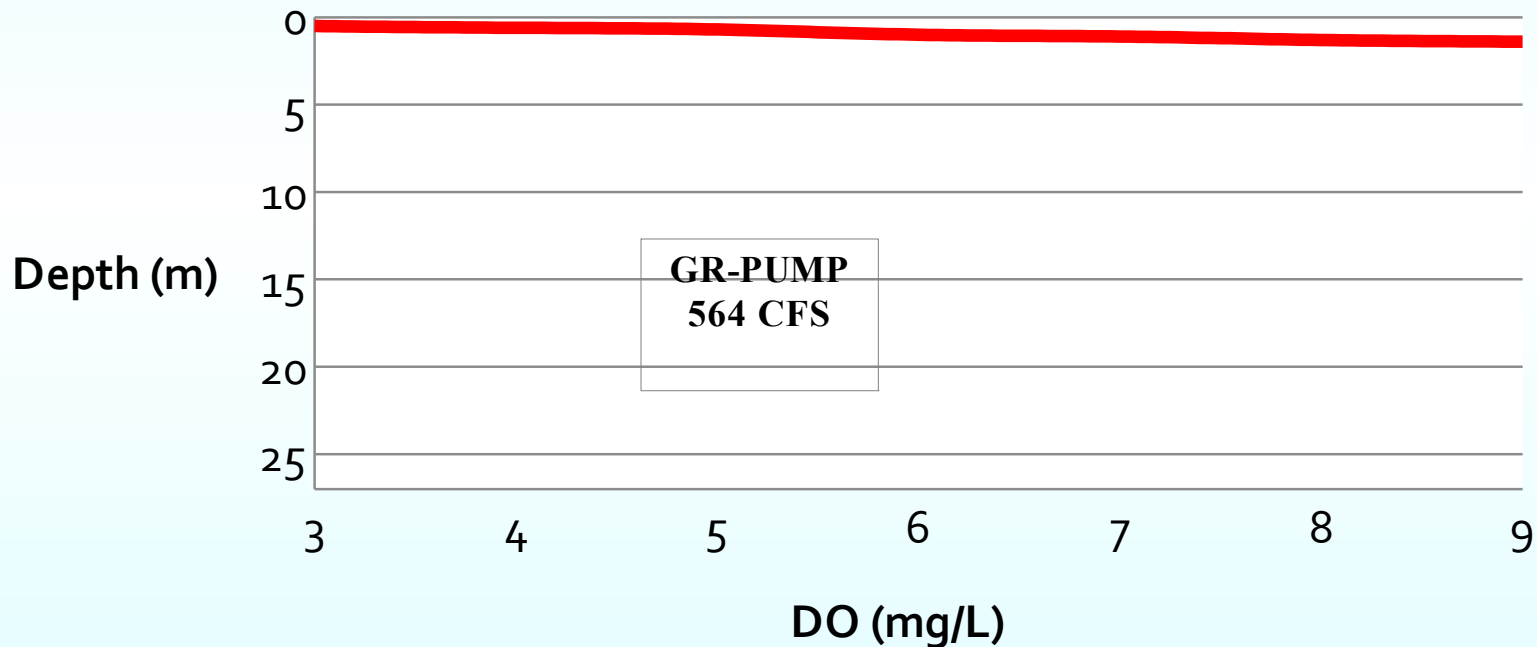
Conceptual cross-section of Granby Reservoir from Farr Pump Plant to GR-WES and GR-DAM



Dissolved Oxygen Levels in Shadow Mountain Reservoir

Shadow Mt. DO profiles

9/22/2010



● GR-PUMP

■ SM-DAM


■ SM-SOU

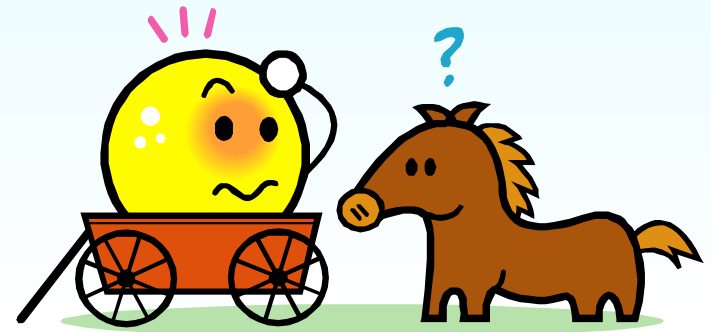
■ GR-FAR

■ Standard



Issues Summary

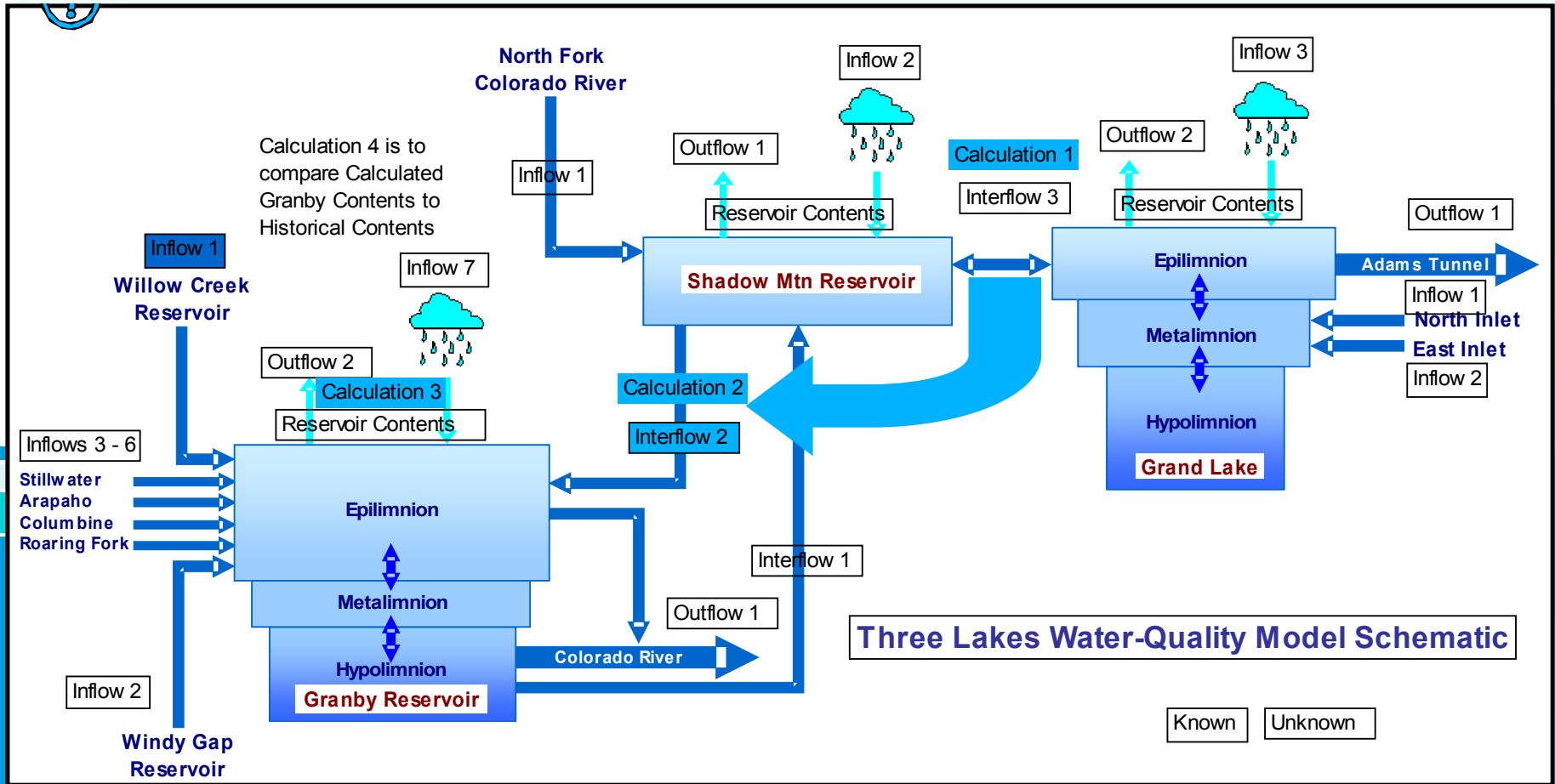
- Algae Blooms
 - Decreased Clarity
 - Low dissolved oxygen
 - High pH
 - Algae Toxins
 - East Slope drinking water quality
- 



...or how to put the horse before the cart

Technical Tools & Studies

TOOL #1: Water Quality Model



Water Quality Model Uses

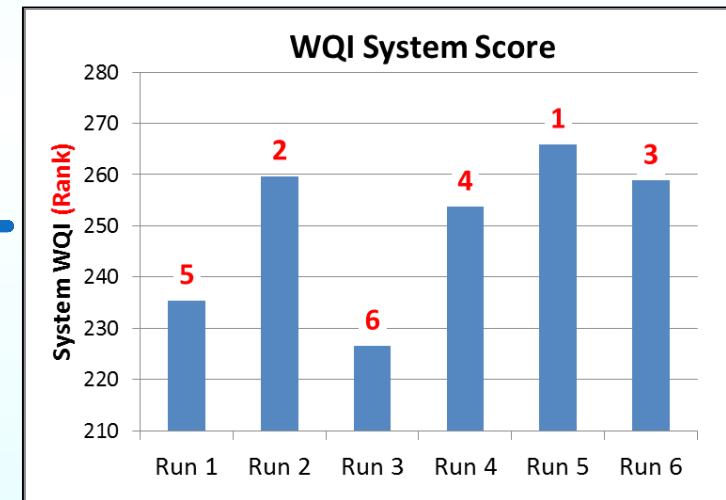
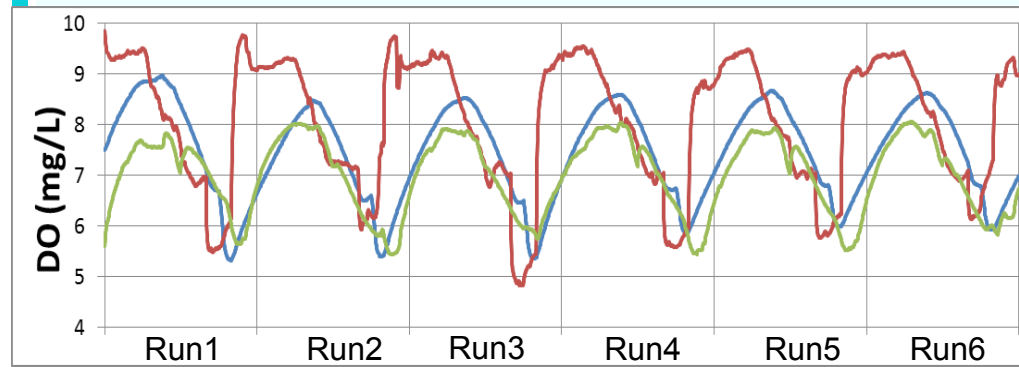
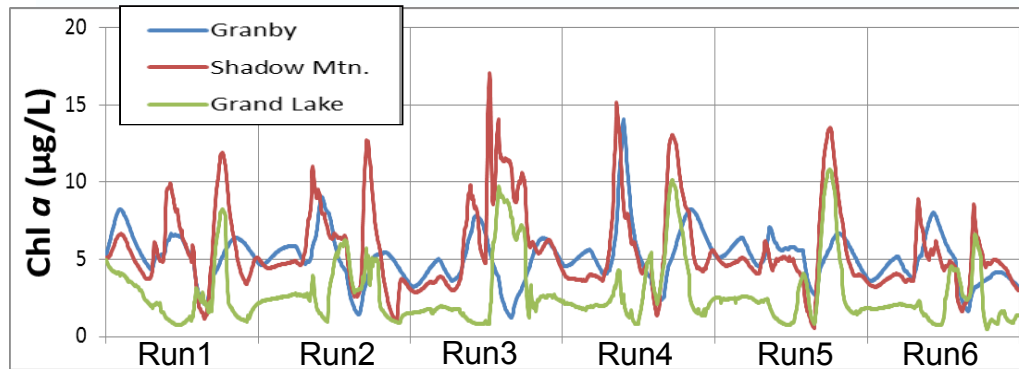
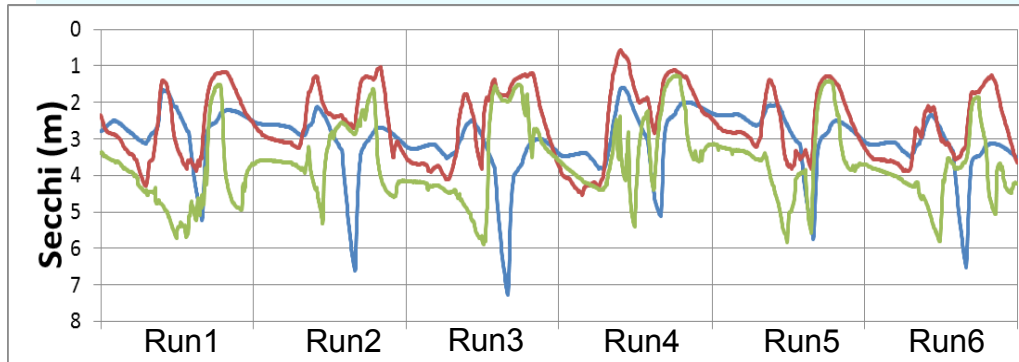
- Operations/water quality relationship
- Nutrient Sensitivity Analysis
- Structural and non-structural alternatives



TOOL #2: Water Quality Index

Key Parameters of Model Output

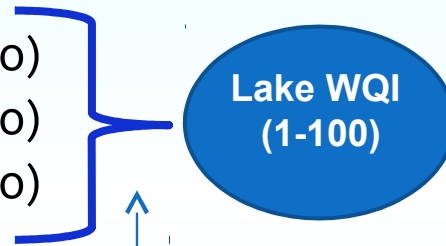
Ranking of Runs



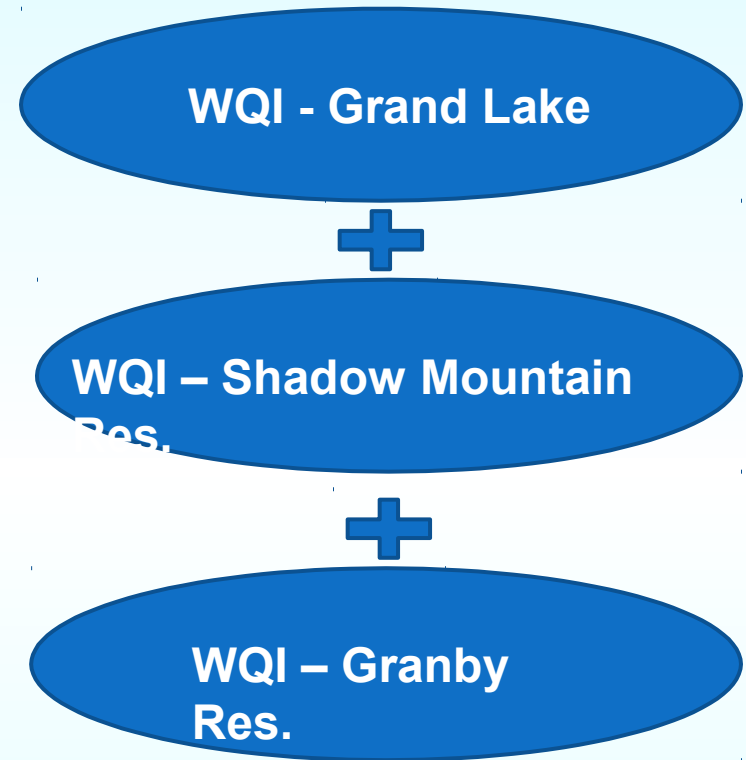
Development

Each Lake/Reservoir:

- Secchi → SI (1-100)
- Chl a → SI (1-100)
- DO → SI (1-100)



$$\bar{X} = X \left[\sum_{i=1}^n \left(\frac{1}{\bar{X}} \right) \right]^{-1}$$



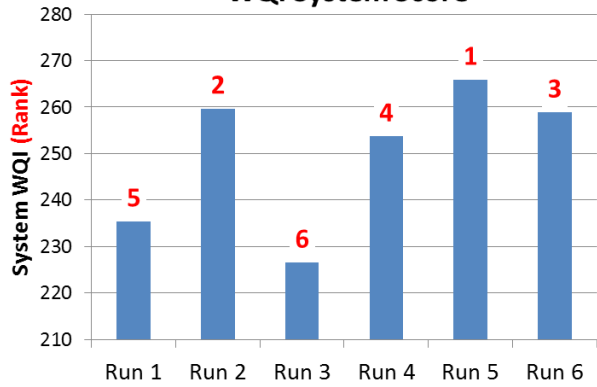
System WQI (3-300)

Development

Ranking of Runs

Review of Additional Metrics

WQI System Score

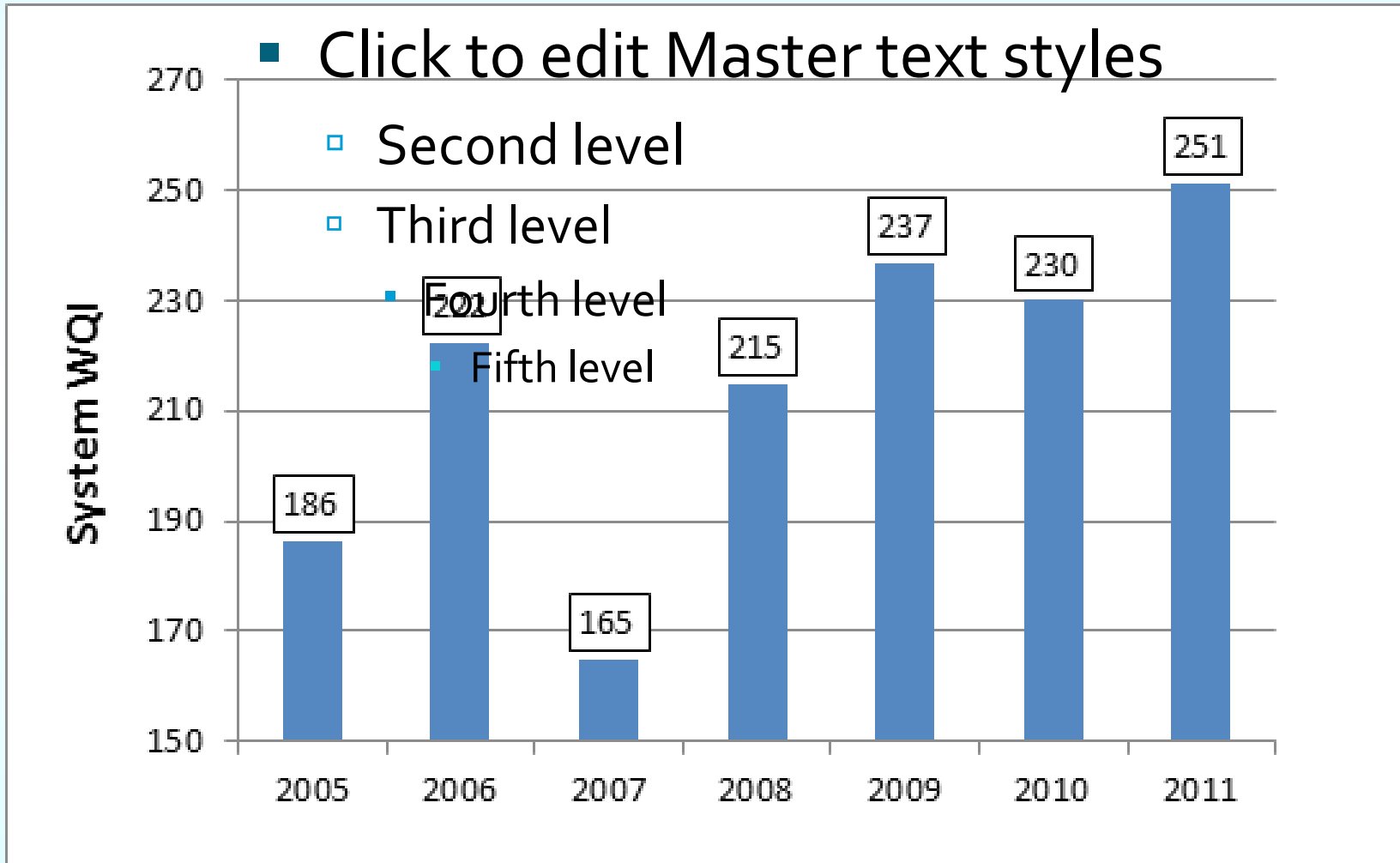


+ Chlorophyll *a*

Metric	Units	Run1	Run2	Run3	Run4	Run5	Run6
Dissolved Oxygen							
Grand Lake, # days >6	mg/L	9.4	9.9	9.7	10.1	9.3	8.4
Shadow Mtn, # days >6	mg/L	11.1	10.0	10.3	10.0	9.5	9.2
Granby Res, # days >6	mg/L	7.9	8.2	8.2	9.4	8.1	8.2
Grand Lake, # days >8	µg/L	0	13	38	9	0	7
Shadow Mtn, # days >8	µg/L	22	24	47	10	18	12
Granby, # days >8	µg/L	0	0	28	0	7	0
Grand Lake, max	µg/L	12.9	12.3	28.0	9.9	8.3	13.4
Shadow Mtn, max	µg/L	39.5	12.3	28.2	9.4	10.0	12.9
Granby, max	µg/L	7.9	6.4	7.9	6.0	6.9	5.1
Grand Lake, # days <4	m	92	90	92	92	87	92
Grand Lake, max	m	3.6	4.3	4.9	4.6	4.9	4.8
Grand Lake, min	m	1.8	2.5	1.4	1.5	2.0	1.6
Grand, 15th %ile, Jul-Sept	m	2.4	2.7	1.7	1.9	2.0	2.4


Selection of Best Run

System wide WQI (preliminary results)

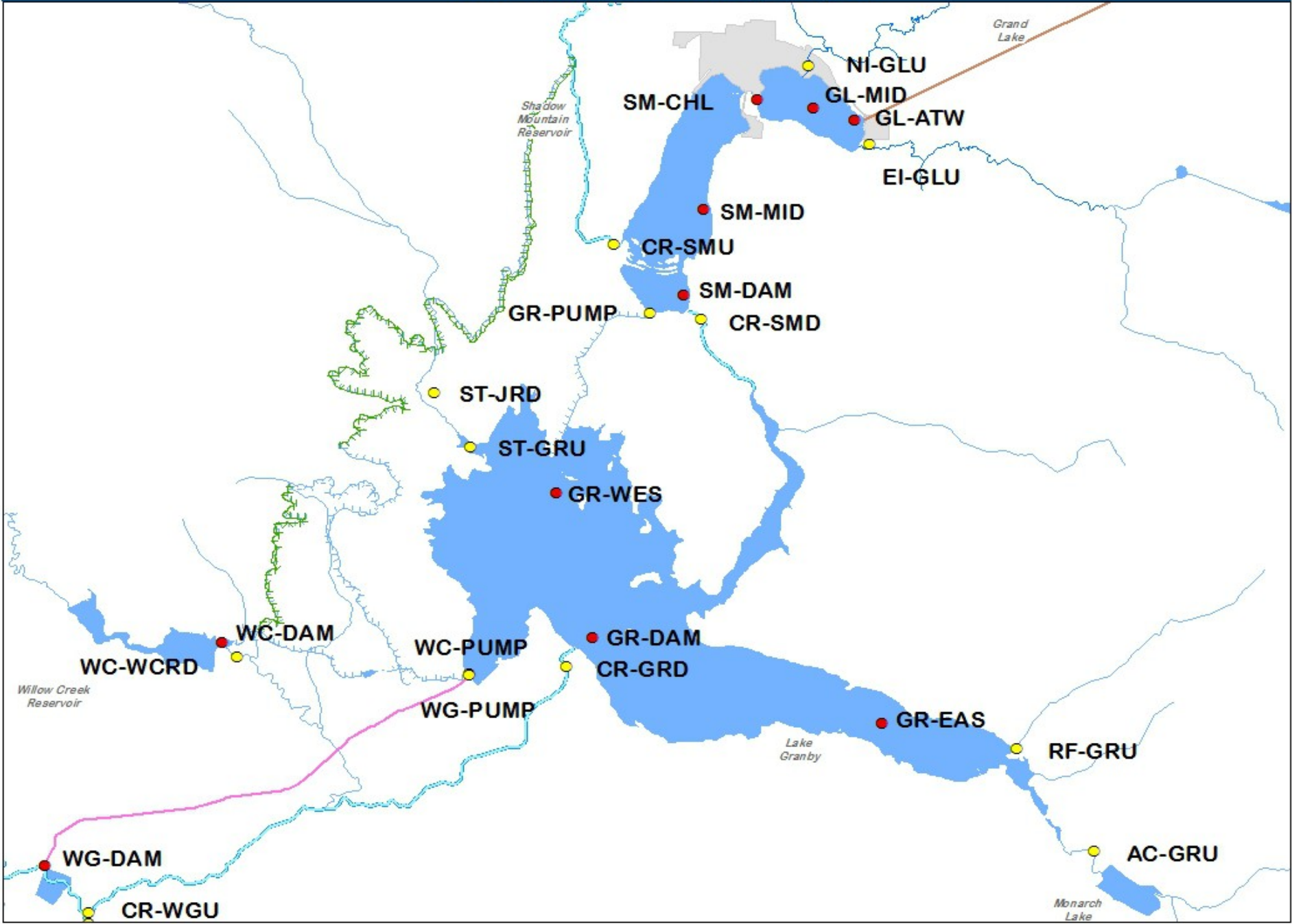




TOOL #3: Data Collection

- Baseline water quality monitoring
 - ADVN in Shadow Mountain Channel
 - Specific Conductance and Temperature continuous monitoring at all inflows
 - NADP site installation (RMNP)
 - Weather station installation (2)
 - Real time streamflow gaging
 - DO real time monitoring in Granby Pump Canal and Shadow Mountain Reservoir
 - Particulate study (CU)
- 

Water Quality Monitoring Program





What we have learned

2010 Clarity Report

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- Second level
 - Third level
 - Fourth level
 - Fifth level
- Annual and Water Quality Summary Report for Grand Lake and Shadow Mountain Reservoir

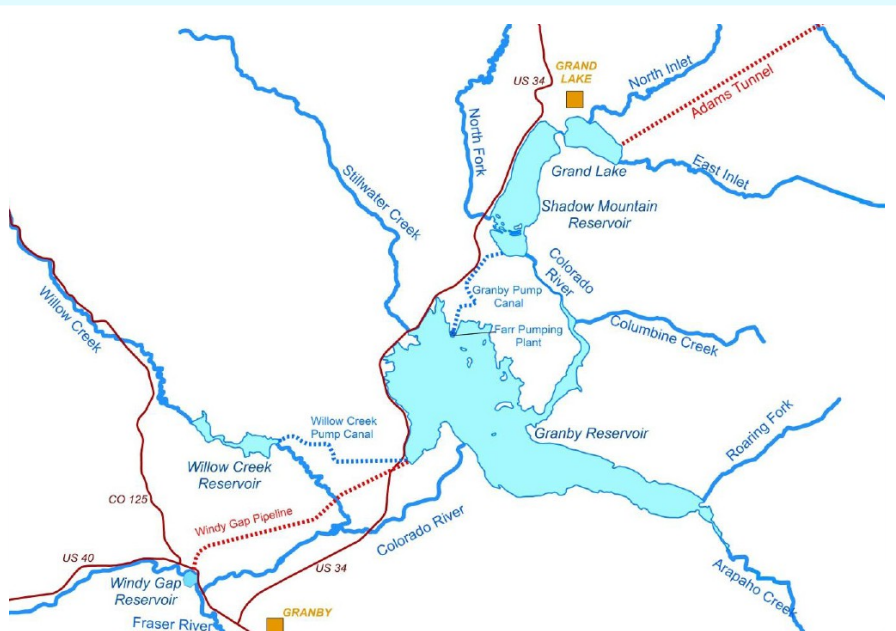


2010



- 4m standard not met
- Pumping interruptions improved clarity in Grand Lake
- Pumping interruptions can negatively impact Shadow Mountain
- Clarity gradient in Shadow Mountain
- Wind events and precipitations events are important to water quality/clarity

TP loading in the Three Lakes System



Average Annual TP Load into Grand Lake

(2007-2009 Average Total - 5,844 kg/yr)

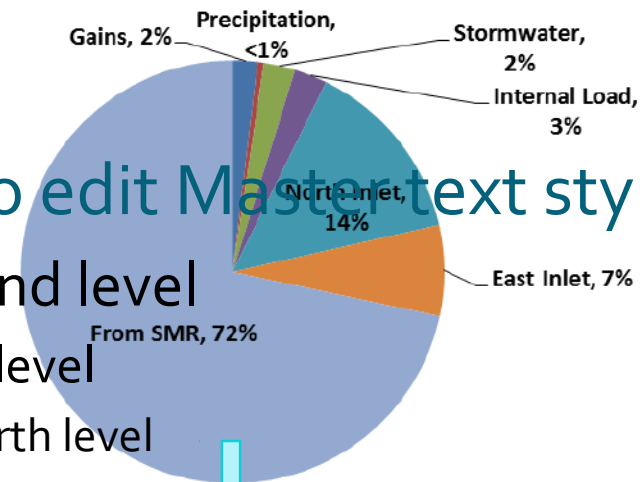
Click to edit Master text styles

- Second level

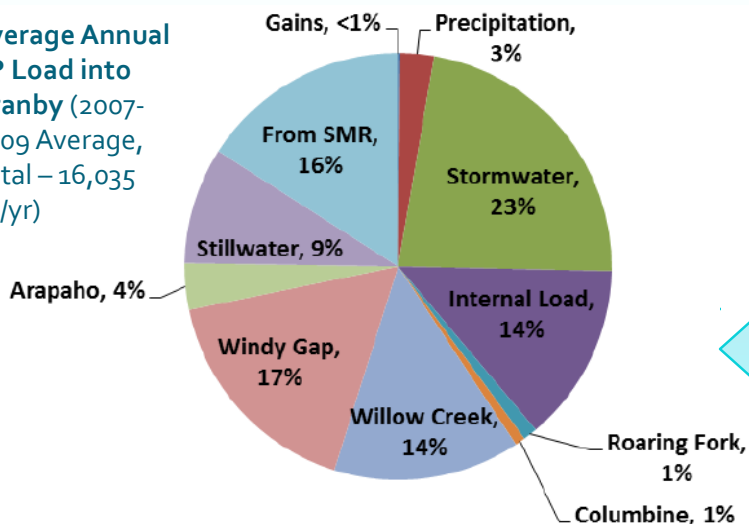
- Third level

- Fourth level

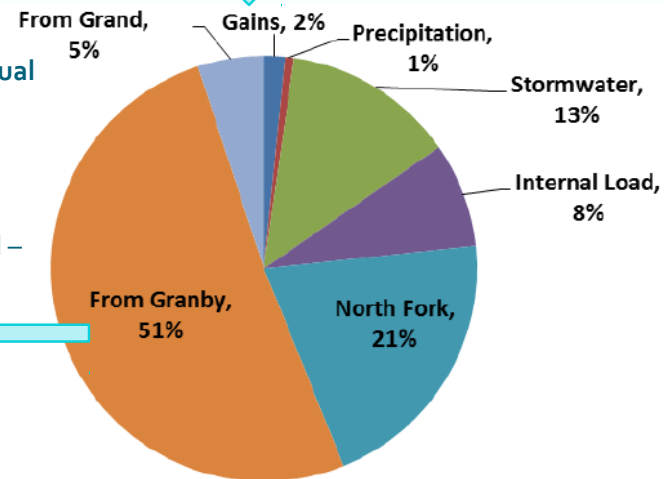
- Fifth level



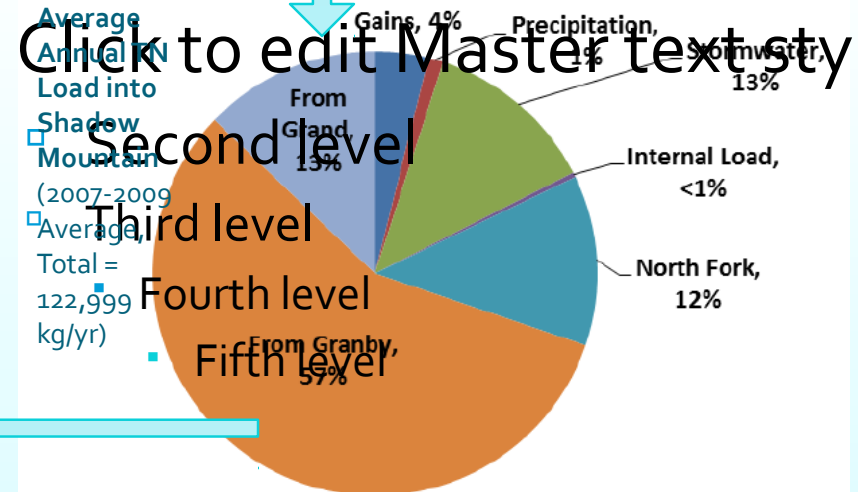
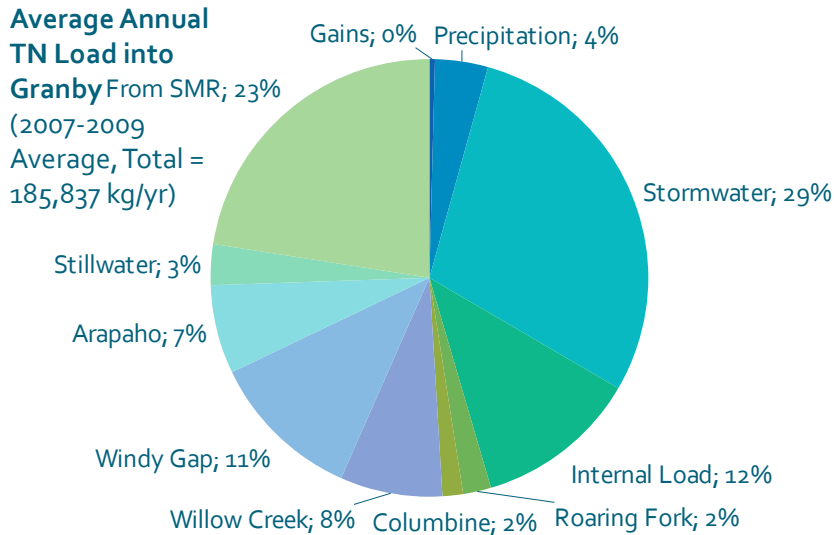
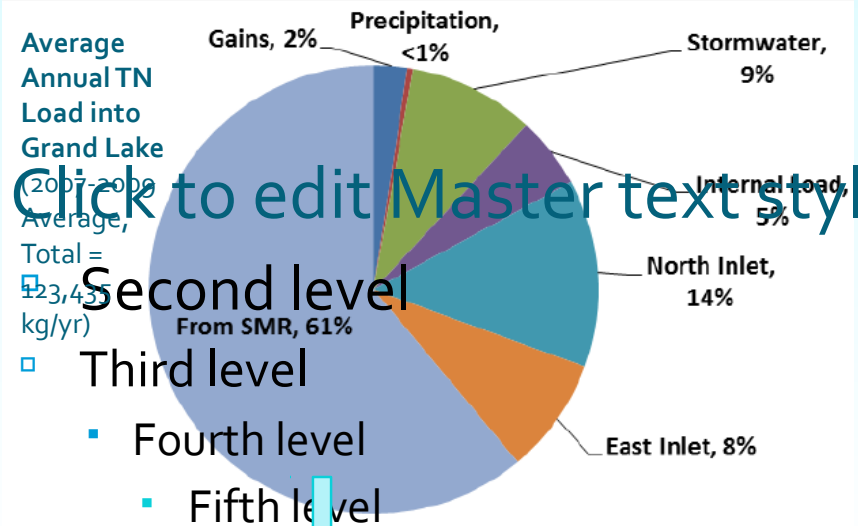
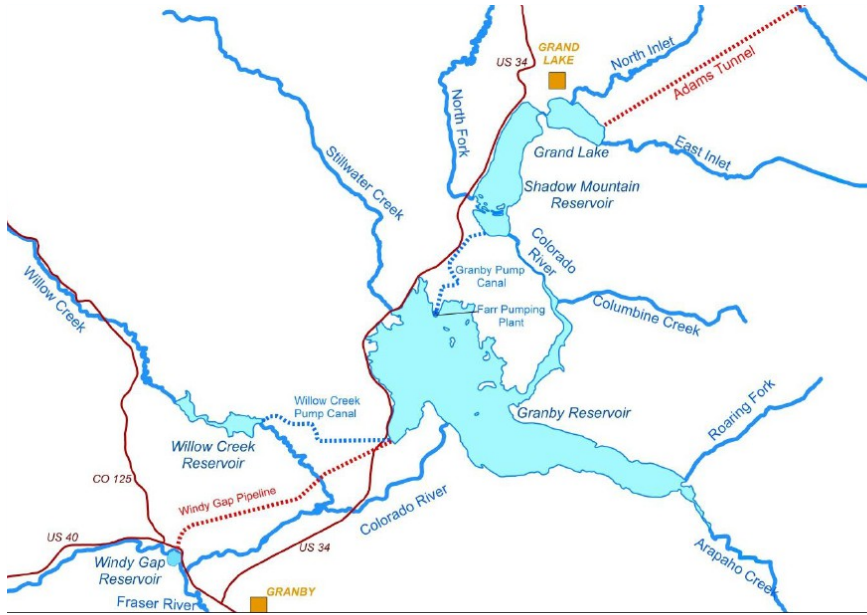
Average Annual TP Load into Granby (2007-2009 Average, Total - 16,035 kg/yr)



Average Annual TP Load into Shadow Mountain (2007-2009 Average Total - 11,098 kg/yr)



TN Loading



Sensitivity Analysis



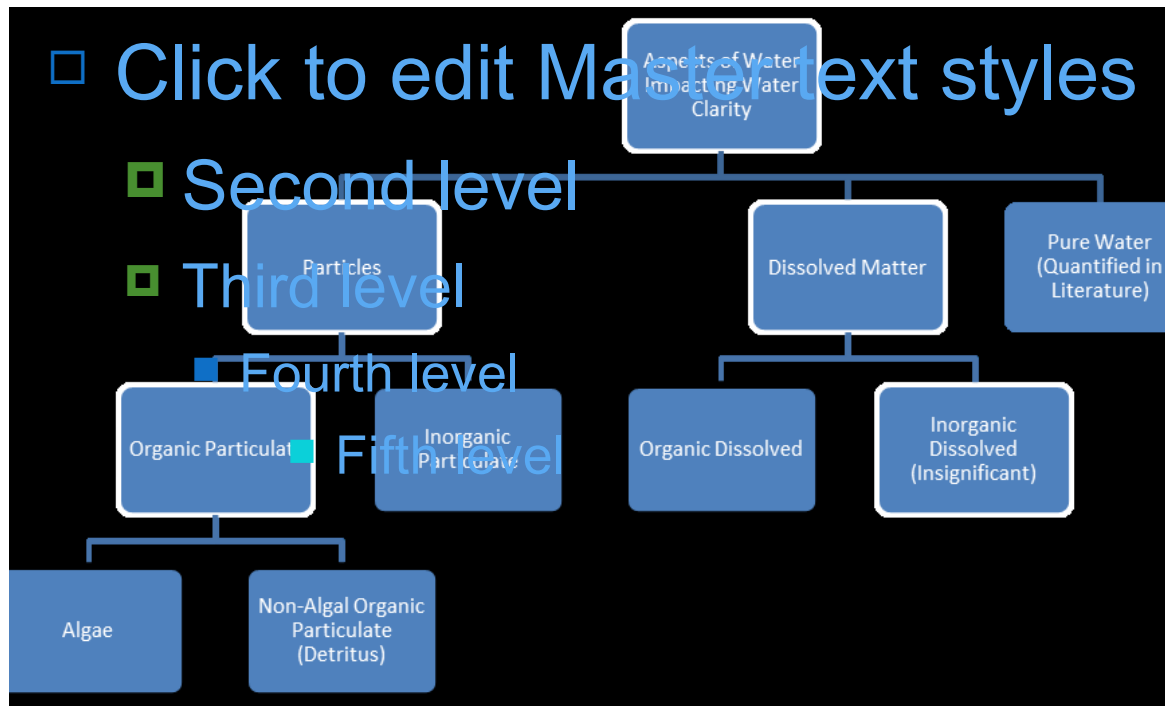
Three Lakes Water-Quality Model Nutrient Sensitivity Analysis

Draft

July 6, 2012

- Nutrient loading is a significant driver for water quality in Three Lakes
- Even under “ultra-clean” conditions, the clarity standard is not met.
- Although stormwater is the biggest contributor in loading, the system is significantly more responsive to internal loading reductions
- Out of all inflows, North Fork has the most impact on water quality in Grand Lake and Shadow Mountain although Windy Gap has a greater impact on Granby
- System is sensitive to N and P reductions but Granby and Shadow only respond to P reductions greater than 50%

2009 CU Report



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Second level

Third level

Fourth level

Fifth level

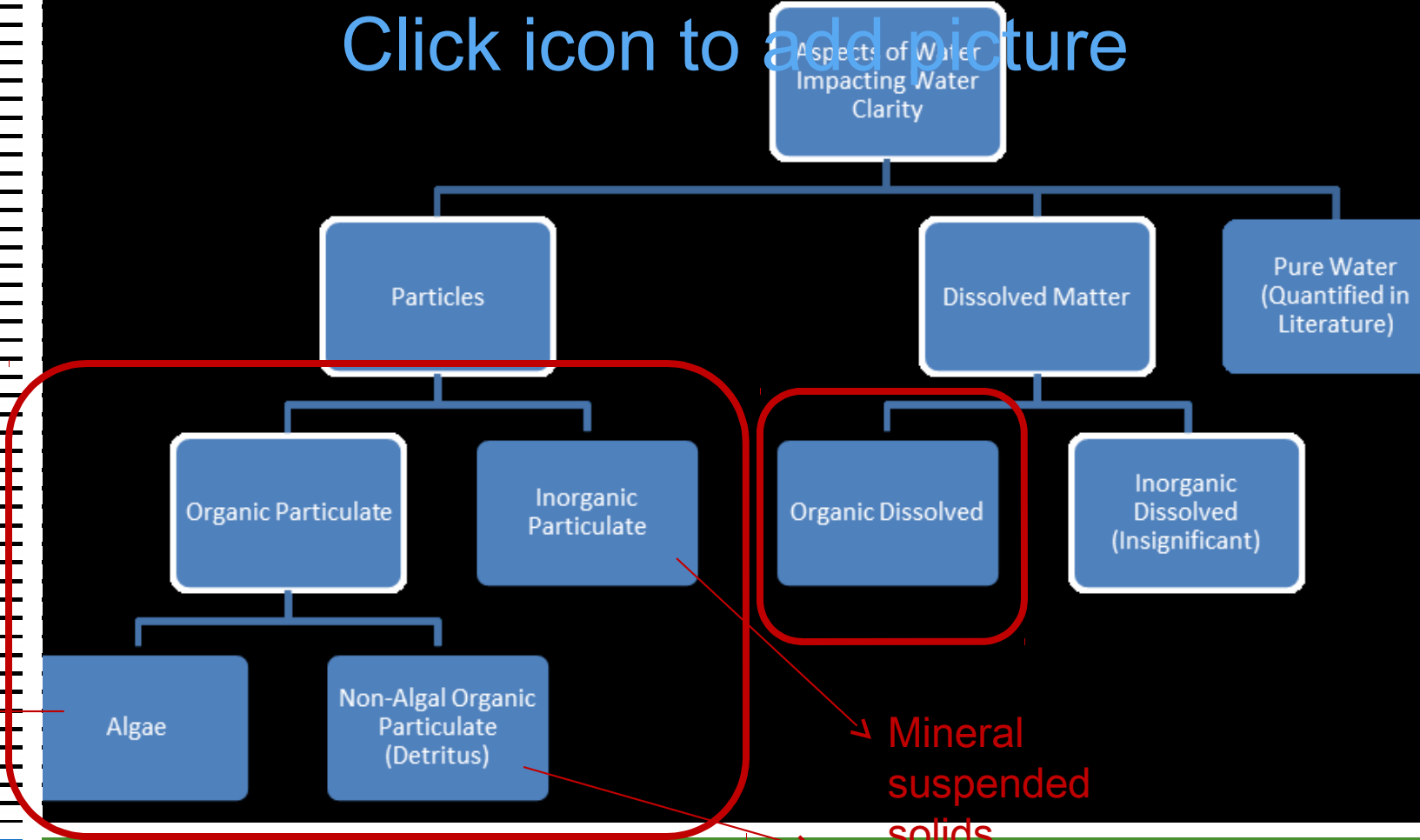
Shadow Mountain:

- 50-65% of light attenuation due to non algal particles (detritus + inorganic particulates)

Grand Lake:

- 40-60% of light attenuation due to non algal particles (detritus + inorganic particulates)

Click icon to add picture



Chl a ←

Mineral suspended solids

Dead weeds?
Dead Algae?

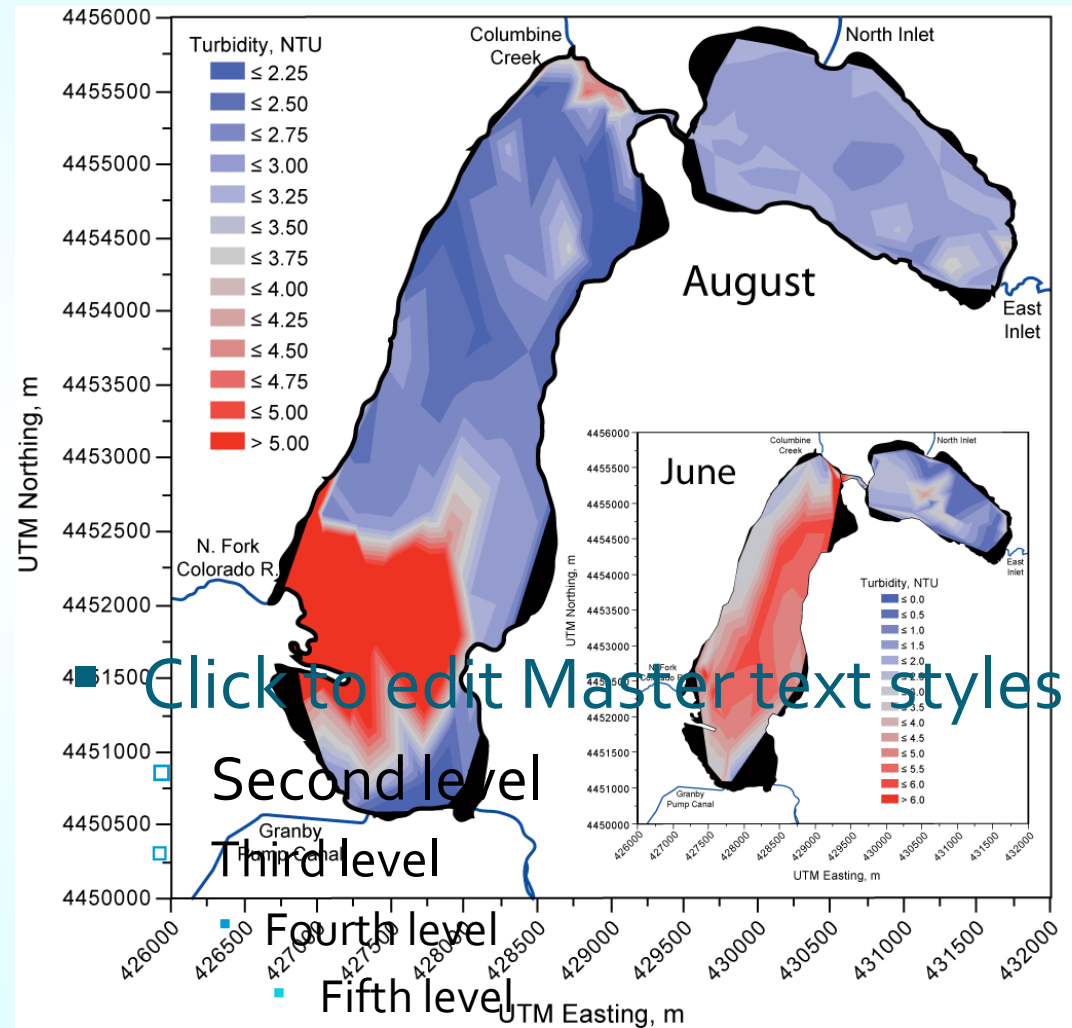
Sources of Light Attenuation

Major light-attenuating constituents (other than water itself):

- *Dissolved Matter*
- *Particulate Matter*

Particulate Study

- 2-year study - Work in progress
- Characterize particulate matter
- Mapping studies + routine monitoring
- Investigating
 - Resuspension of sediments in Shadow Mountain/Grand Lake
 - Impact from North Fork + Delta
 - Contributions from Aquatic Weeds



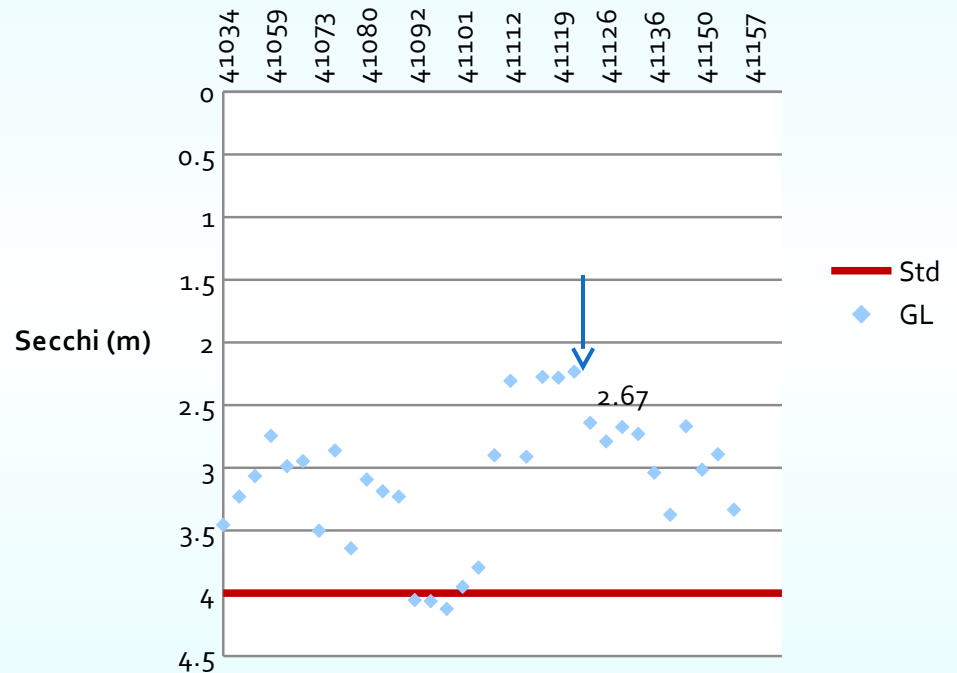
Final Comments

- Very complex and dynamic system
 - Changes can cause unintended consequences
- Studies and monitoring are fundamental to
 - understand system
 - inform decision process
- No simple fix
- Funding of alternatives very problematic
- Attainability of clarity standard questionable

Quiz: what Secchi depth the day of this picture?



2012 Average Secchi Depth (m) w/viewscope



- Answer: 2.6 m



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Thank you



Questions? Comments?