Hydrology and Seasonality in Coeur d'Alene Lake

Craig Cooper, Ph.D.
Idaho Department of Environmental Quality
Senior Limnologist, Coeur d'Alene Lake Management
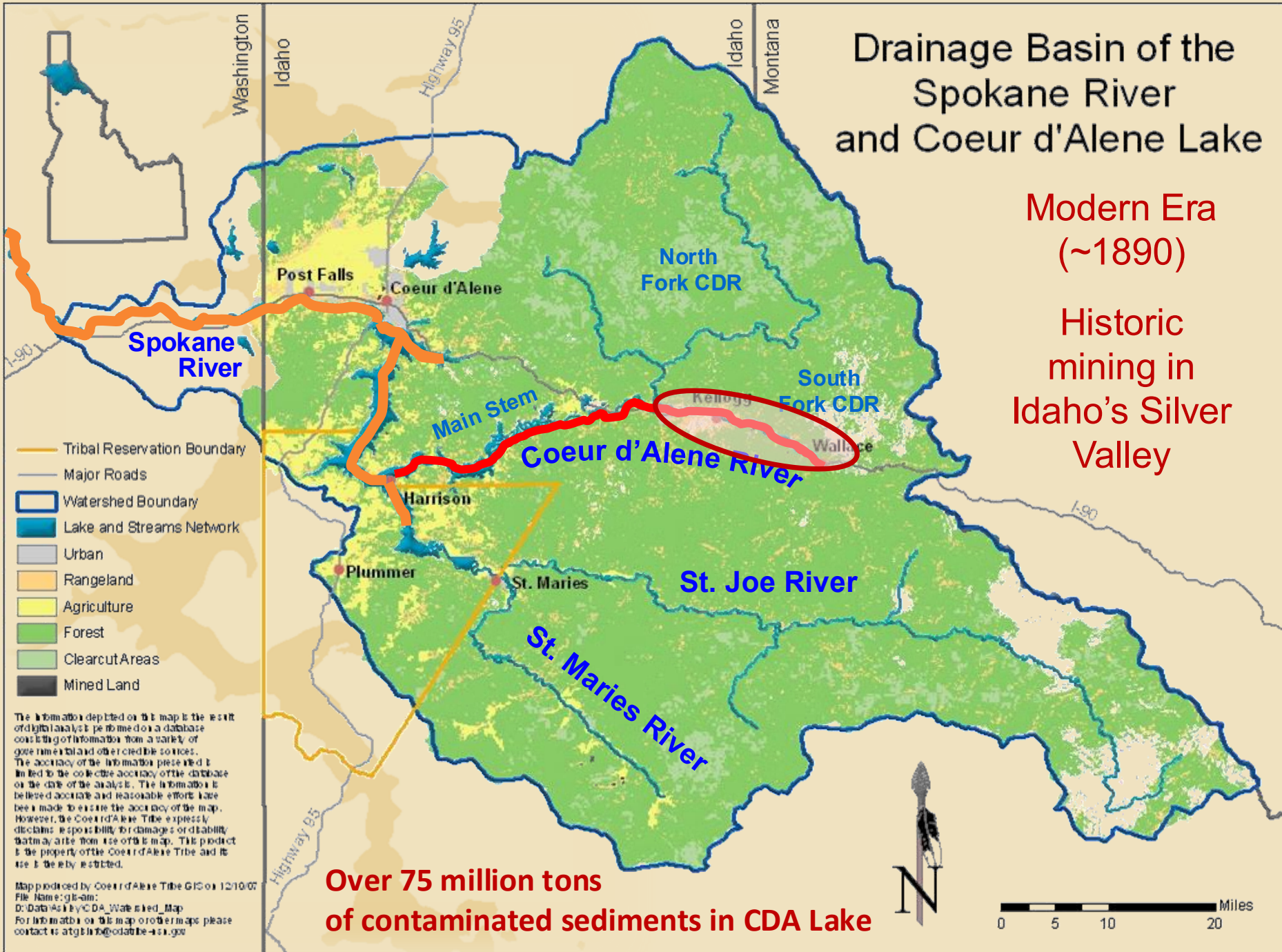Spokane River Forum
April 2025

Drainage Basin of the
Spokane River
and Coeur d'Alene Lake

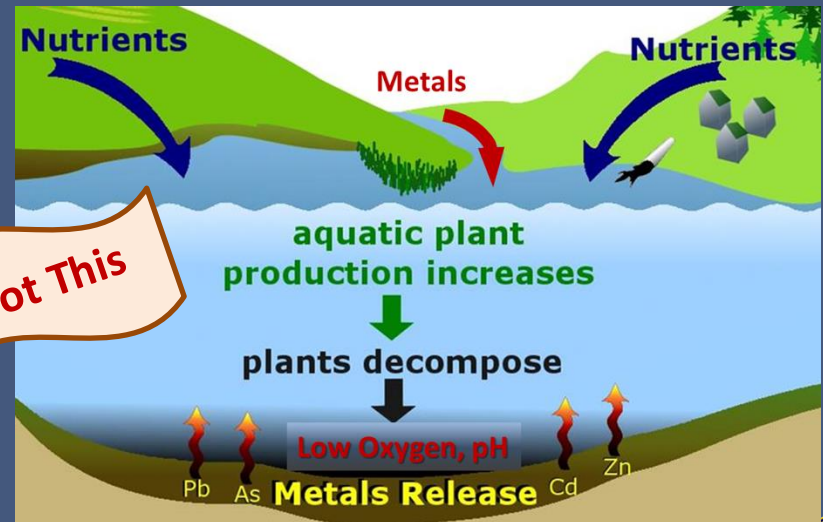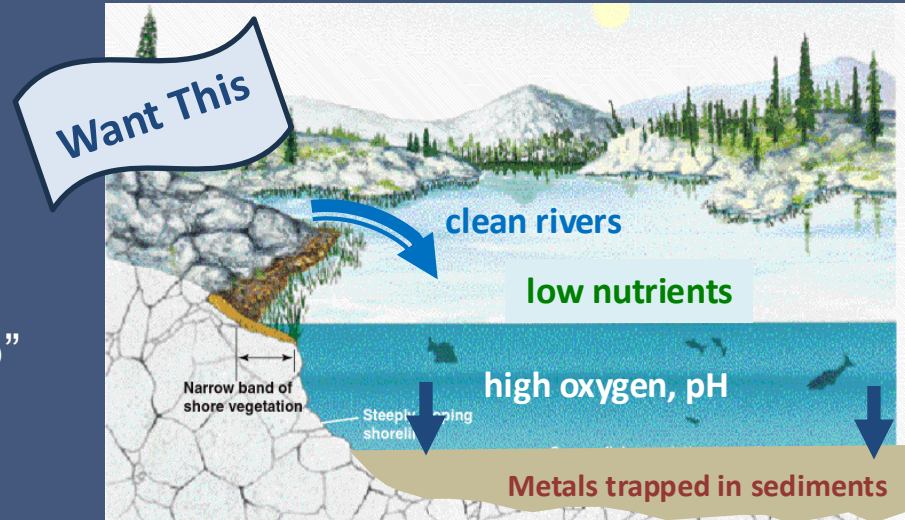Modern Era
(~1890)

Historic
mining in
Idaho's Silver
Valley

North
Fork CDR

South
Fork CDR

Spokane
River

Main Stem

Coeur d'Alene River

St. Joe River

St. Maries River

Post Falls

Coeur d'Alene

Kellogg

Wallace

Harrison

Plummer

St. Maries

Washington | Idaho

Highway 95

Idaho | Montana

I-90

Tribal Reservation Boundary
Major Roads
Watershed Boundary
Lake and Streams Network
Urban
Rangeland
Agriculture
Forest
Clearcut Areas
Mined Land

The information depicted on this map is the result
of digital analysis performed on a database
consisting of information from a variety of
governmental and other credible sources.
The accuracy of the information presented is
limited to the collective accuracy of the database
on the date of the analysis. The information is
believed accurate and reasonable efforts have
been made to ensure the accuracy of the map.
However, the Coeur d'Alene Tribe expressly
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Map produced by Coeur d'Alene Tribe GIS on 12/10/07
File Name: gis-am
D:\Data\Ashley\CDA_Watershed_Map
For information this map or other maps please
contact us at gisinfo@cdatribe-nsn.gov

Over 75 million tons
of contaminated sediments in CDA Lake

Miles
0   5   10   20

Managing Sediment Contamination

- Want the metal contaminants locked in sediments, *if*
  - Lake's bottom waters have high pH, O_2
  - Geochemistry works as a "cap"

- Keep metals in sediments

- CDA River clean-up reduces metals supply to the lake ☺

- Want to keep nutrients low to keep algae low.

- If lake productivity goes up, then pH, O_2 get lower ☹

Want This

clean rivers

low nutrients

Narrow band of shore vegetation

high oxygen, pH

Metals trapped in sediments

Nutrients

Metals

Nutrients

Not This

aquatic plant production increases

plants decompose

Low Oxygen, pH

Pb   As   **Metals Release**   Cd   Zn

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What Physics Do We Need to Know?

- Seasonality
  - When the lake stratifies

- River Hydrology
  - Timing, magnitude of flows

- Currents
  - Where the water goes

- Internal Mixing
  - How isolated are the sediments?

- Influences of Bathymetry
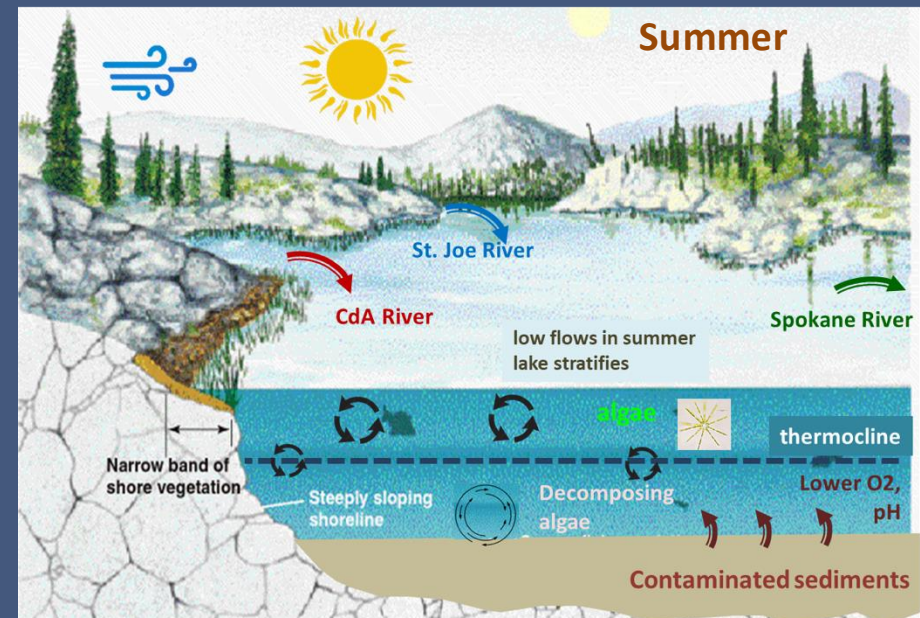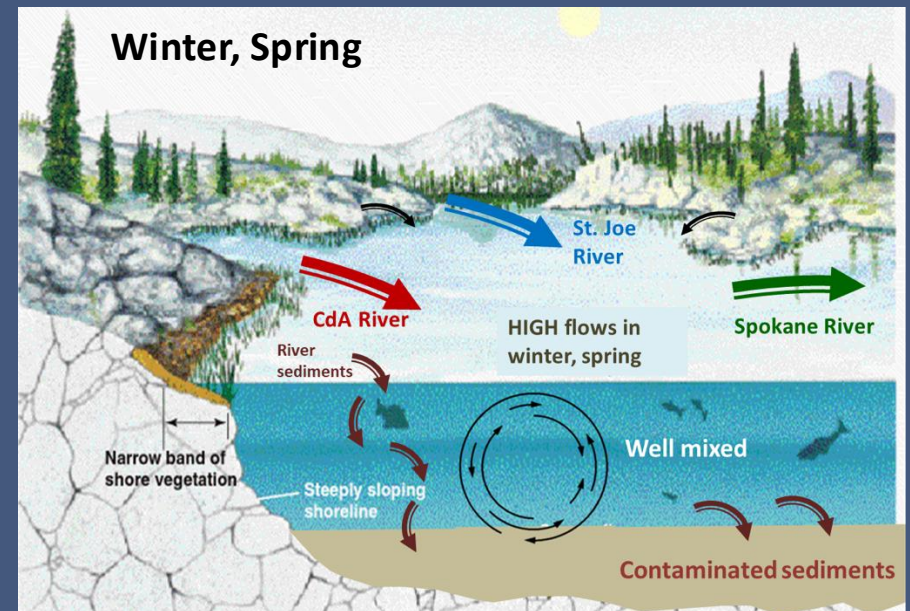
Bathymetry and Geography

- Northern Lake
  - Deeper (> 100 ft deep)
  - Larger volume
  - Less sediment influence
  - NW/SE orientation in Northern
  - NE/SW orientation in Central

- Southern Lake
  - Shallower (< 60 ft deep)
  - Smaller volume
  - More sediment influence
  - NW/SE orientation
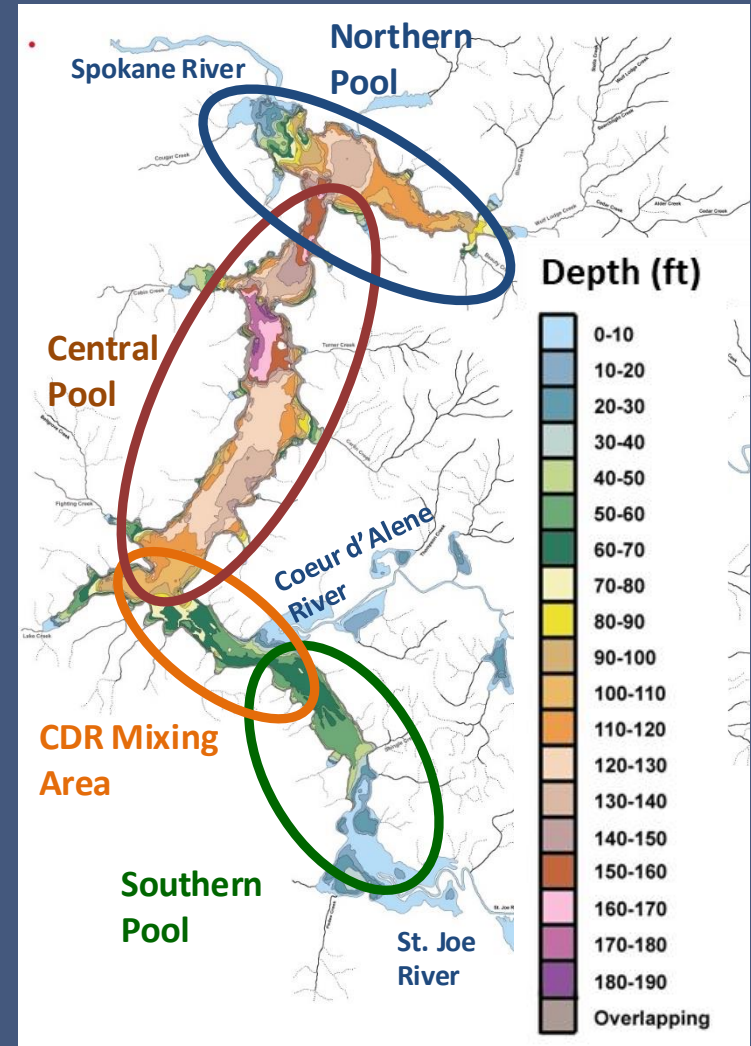
Geography and General Currents

- Primarily South → North
  - Very short residence time in Southern Pool (a few weeks)
  - Some southward flows from CDA River
  - Don't get full mixing of CDA and St Joe River until further north
  - Preferential flow towards outlet

Inflowing waters can skim along the surface, and "over-top"
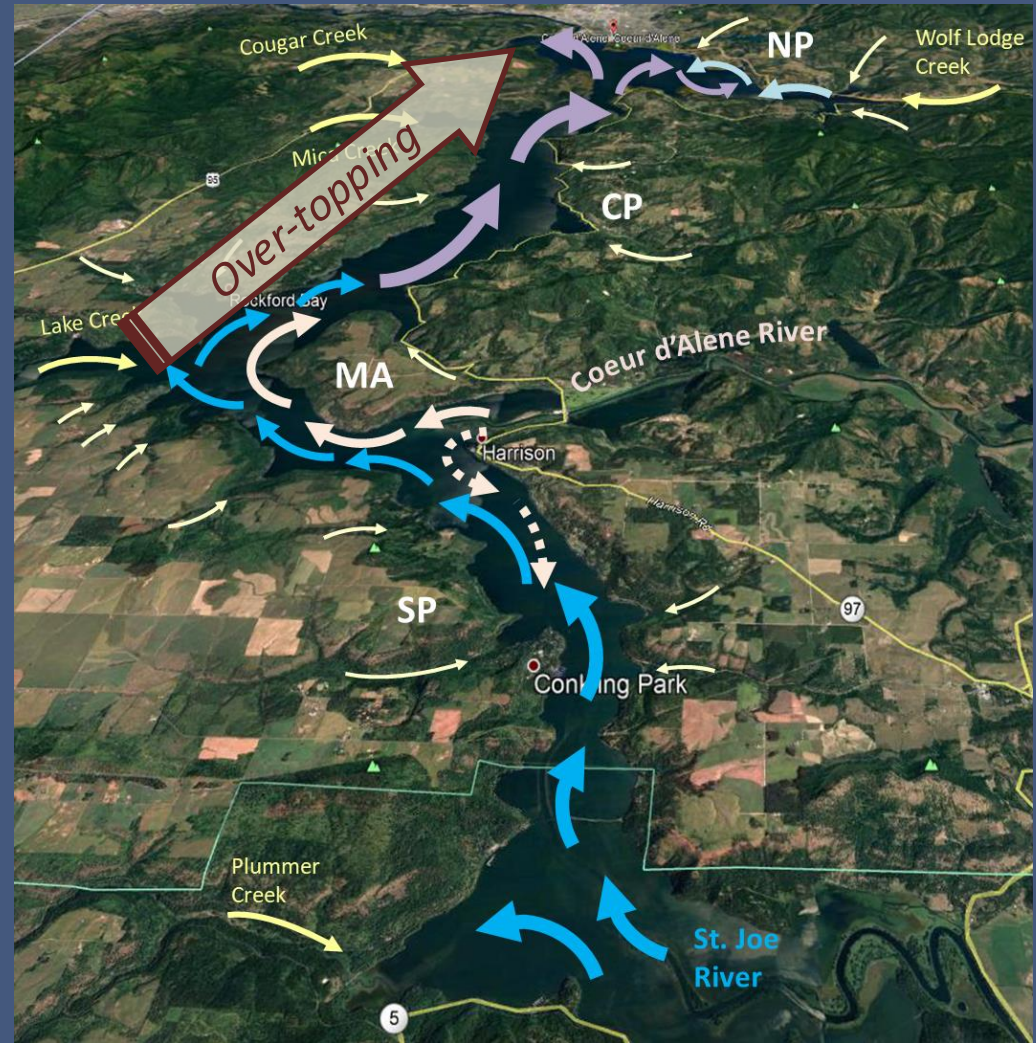
River Hydrology

CDA River runoff is "flashier"

CDA River runs off earlier

Coeur d'Alene River at Cataldo (1912 - 2016)

A

St. Joe River at Calder (1912 - 2016)

B
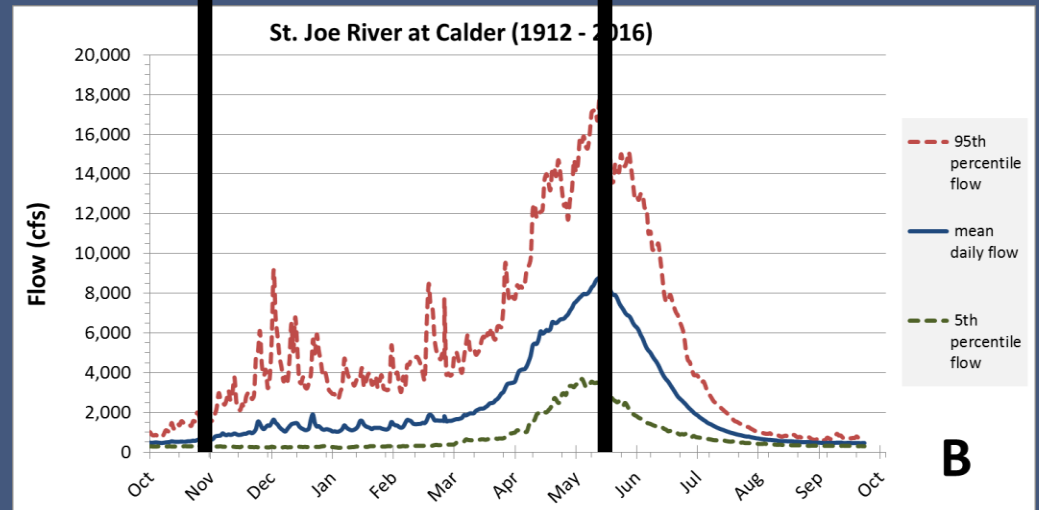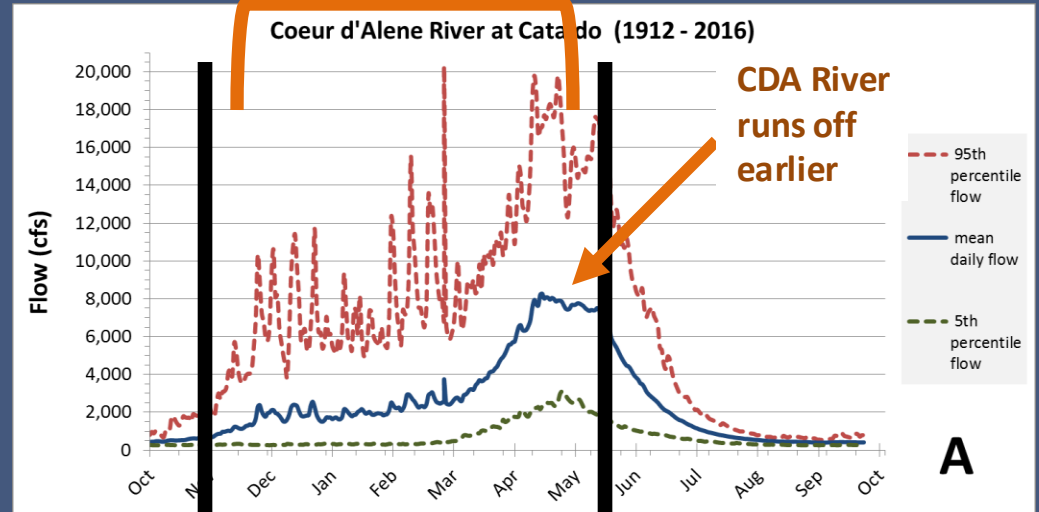
Hydrology Drives the Lake's Seasonality

Coeur d'Alene Lake Hydraulic Residence Time (days)
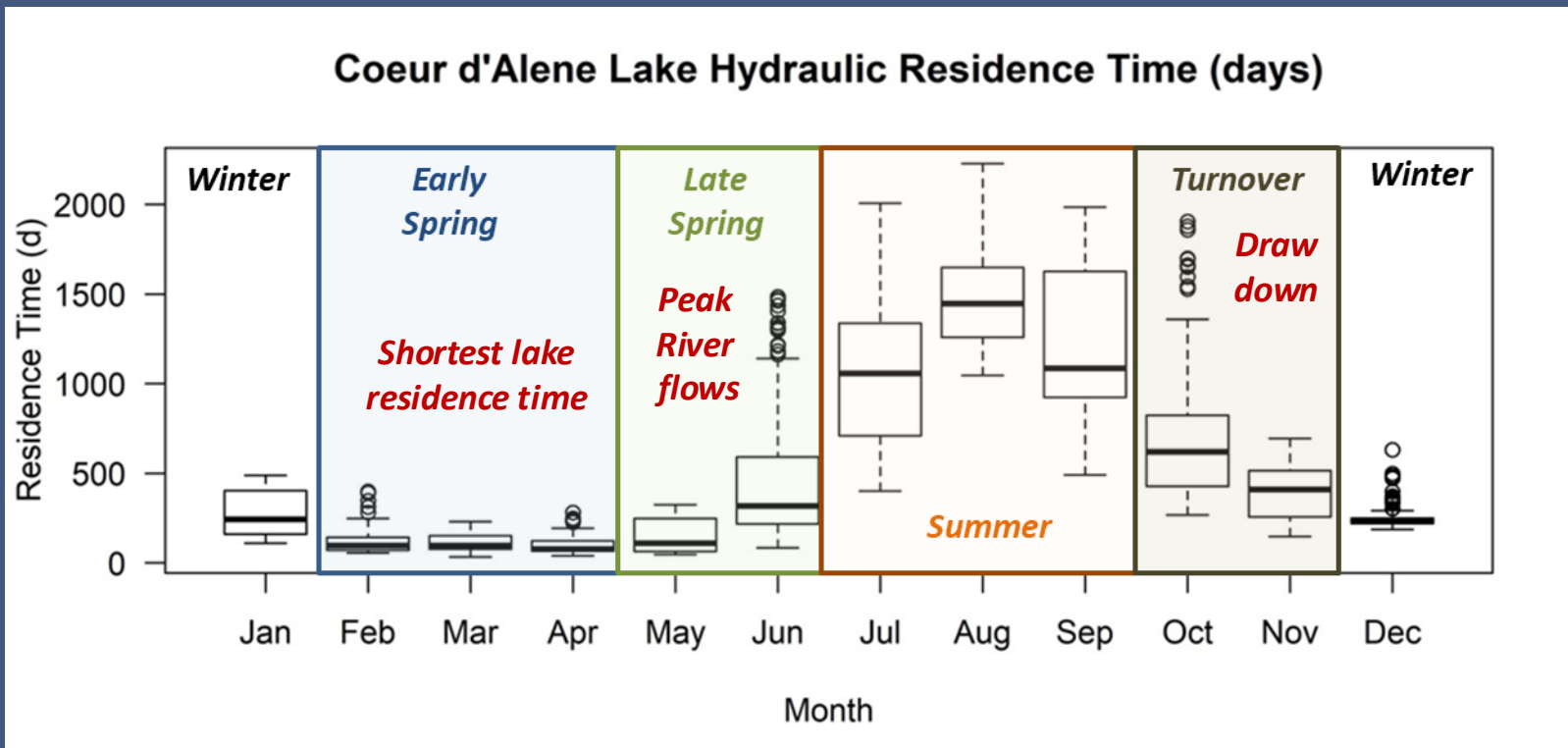
- 5 "lake seasons" (balance of residence time, river flows, weather)

- Median residence time: ~ 90 days (Spring) to 1,100 days (Summer)
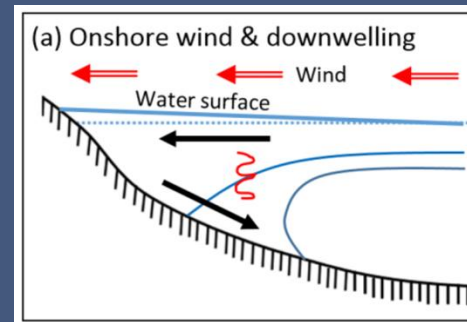
- Lake can empty and refill each spring

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Knowing the Seasons Unlocks a Lot!

Unlock hidden patterns in the rivers

- Take CdA River flows

Map Climate Cycles
- Break out patterns of
onto trends
  5 equal seasons

  - El Nino ~ lower
- Subtract seasons,
    flows
  calculate a trend using
  - La Nina ~ higher
  the longer term median
    flows
- Remainder is random variability

Hidden Trends in Coeur d'Alene River Flows

Coeur d'Alene River

2004 Moderate CP El Nino
2006 Moderate CP El Nino
2009 Moderate CP El Nino
2014 Moderate CP El Nino
2015 Strong basin-wide El Nino
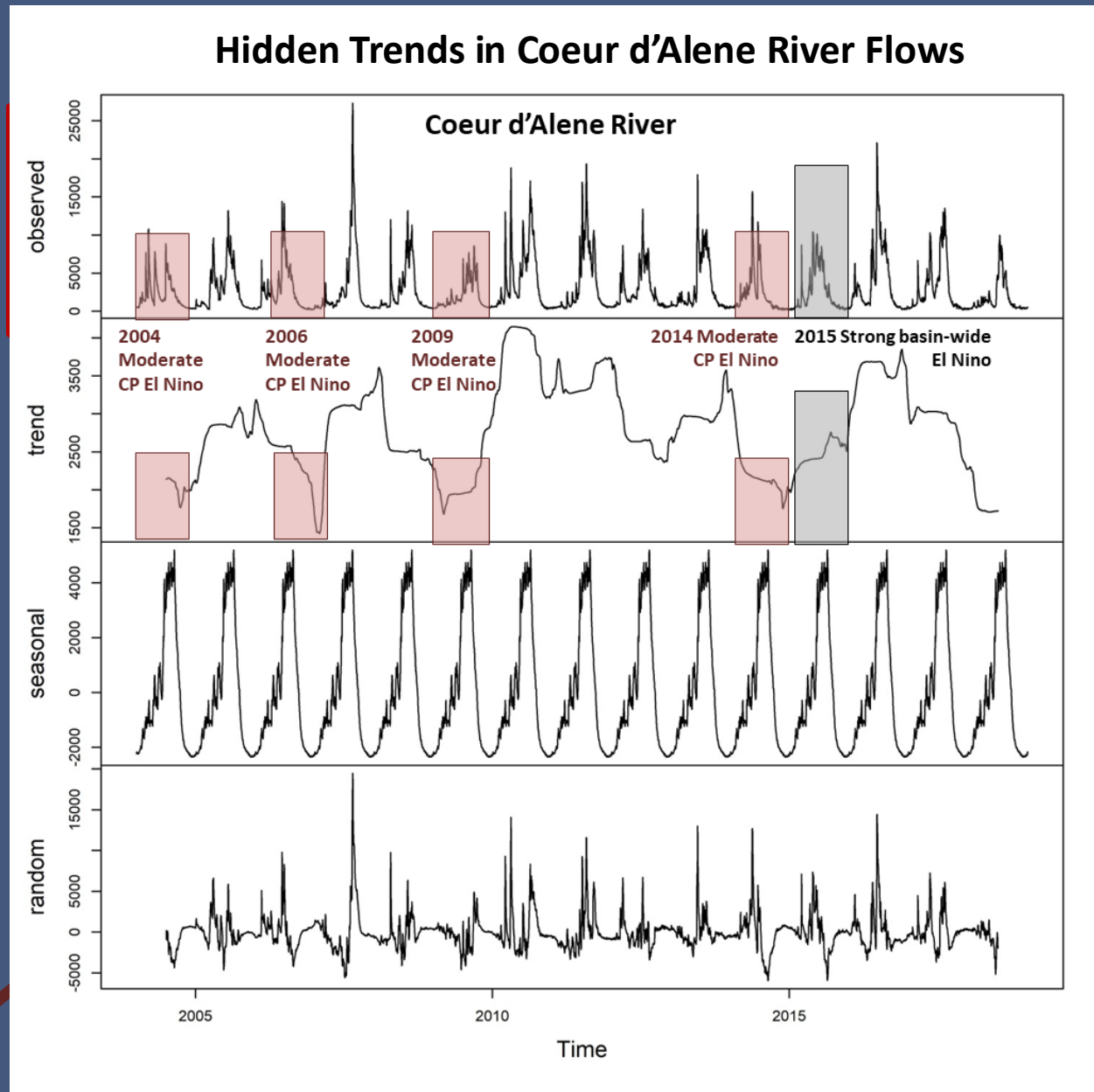
Wind and Summer Currents

(a) Onshore wind & downwelling

Downwelling

b) Offshore wind & upwelling
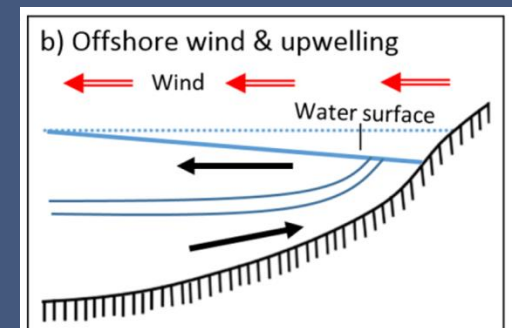
Upwelling

Winds creates currents, mixing

- Currents move in weird ways

- Can cause differential water cooling

- Substantial mixing in the lake

- Both spatially and vertically

Internal Waves

Surface Waves
Low-density layer
Internal Waves
High-density layer

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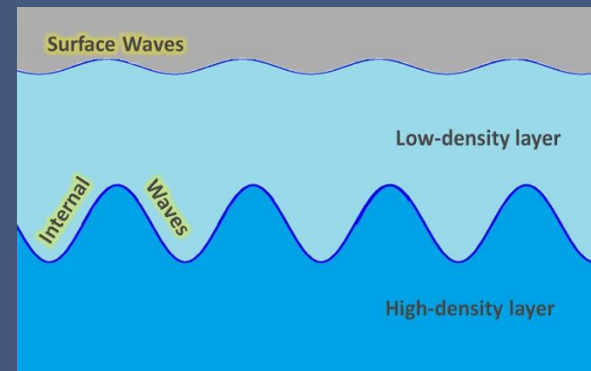
Wind

CDA Golf Couse Annual Average Hourly Wind Freq. % (2014-2018)

Northern Lake

S-SW *N*
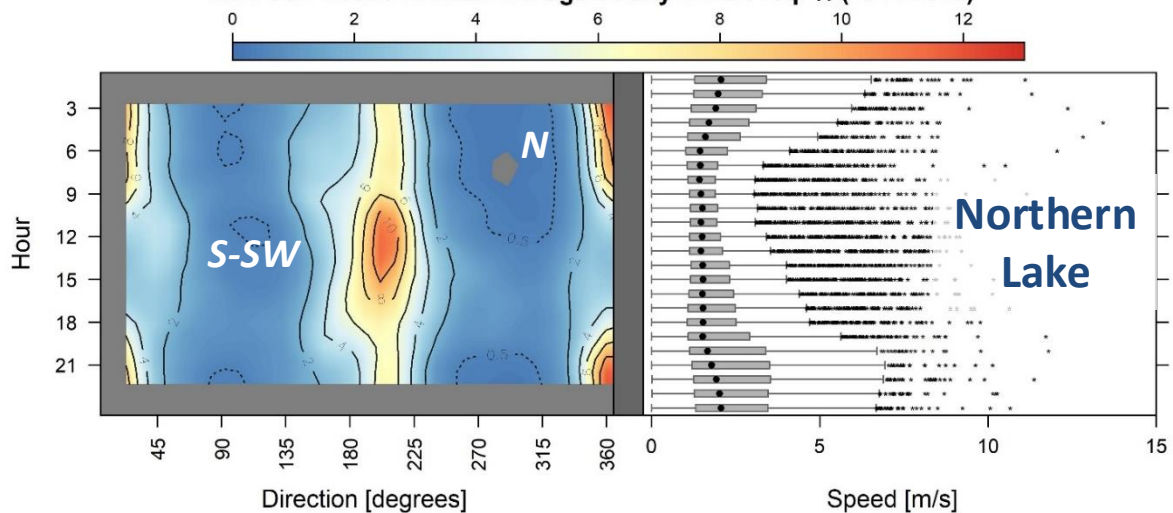
Northern, Central Pools

Daily patterns

- shifting direction

- variable speed

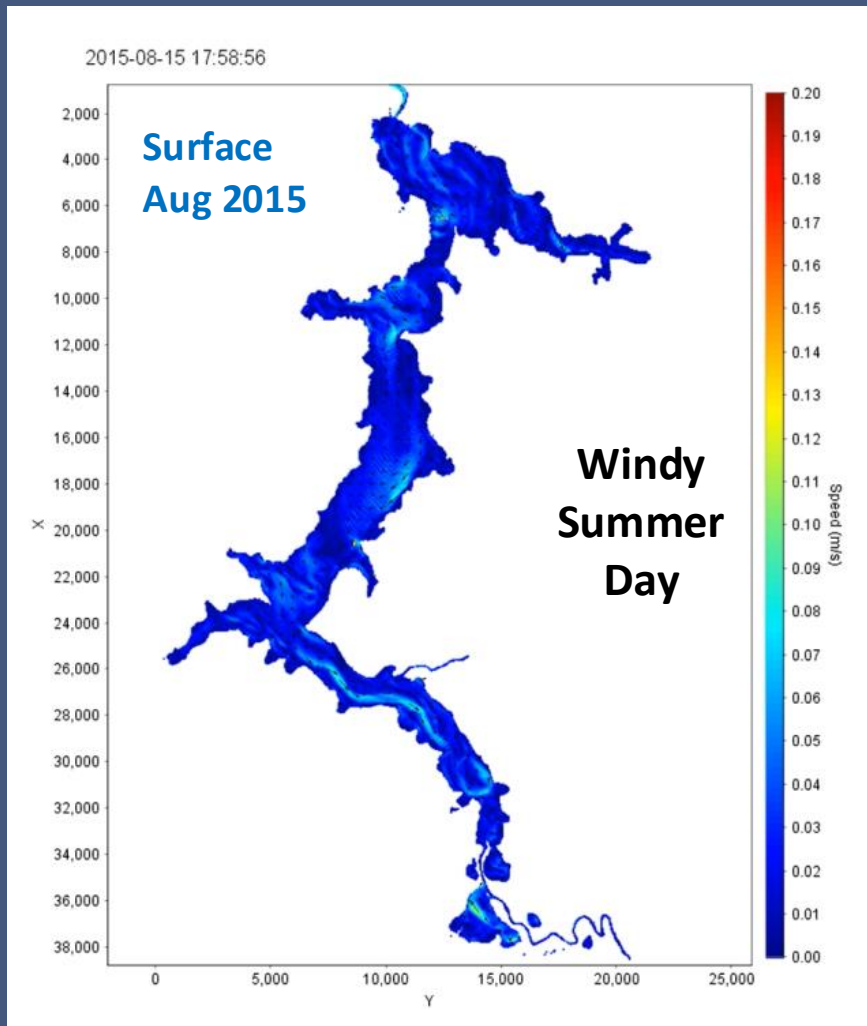East Point Annual Average Hourly Wind Freq. % (2014-2018)

Southern Lake

N-NW
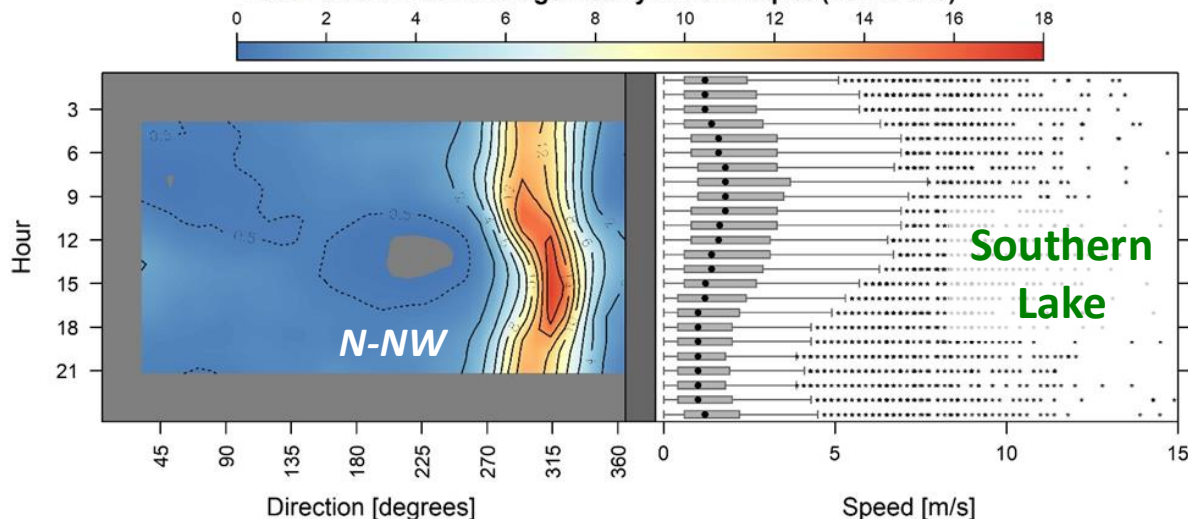
Mixing Area, Southern Pool

Daily patterns

- consistent direction

- variable speed

Seasonal differences in wind patterns

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Mixing on a Windy Summer Day
(Modeled Lake Currents)
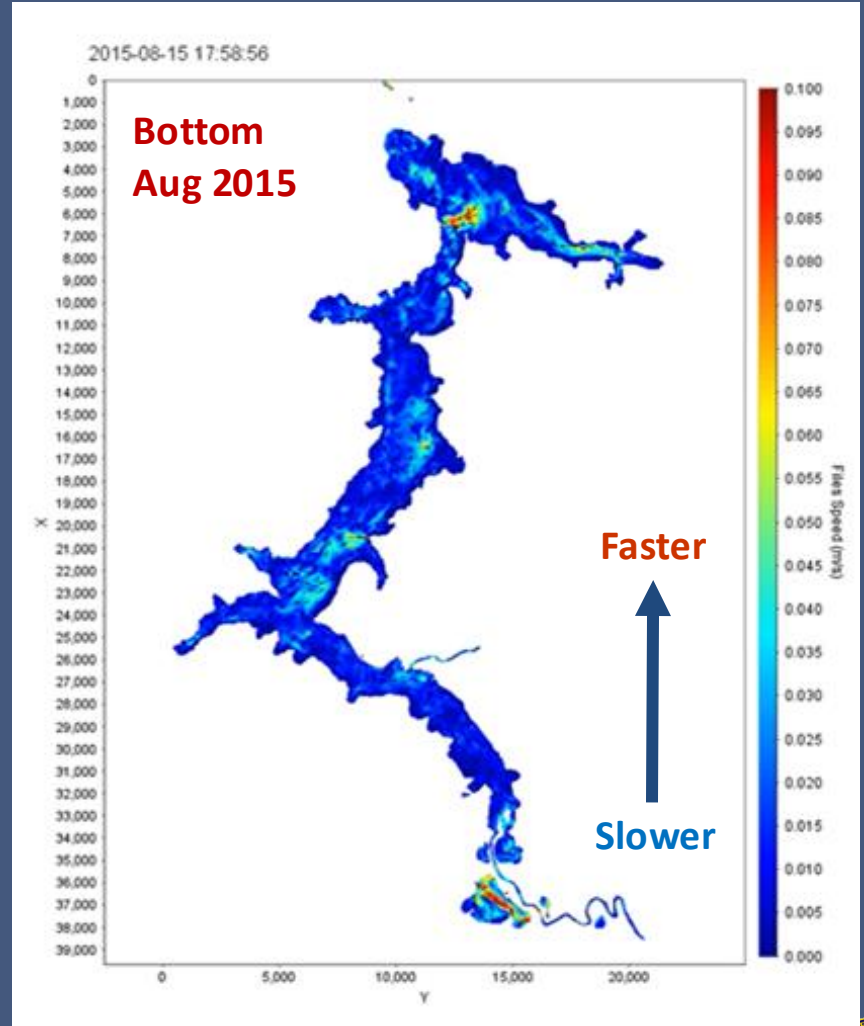
Does Vertical Mixing Occur?

Two ways to test

1. Measure currents directly
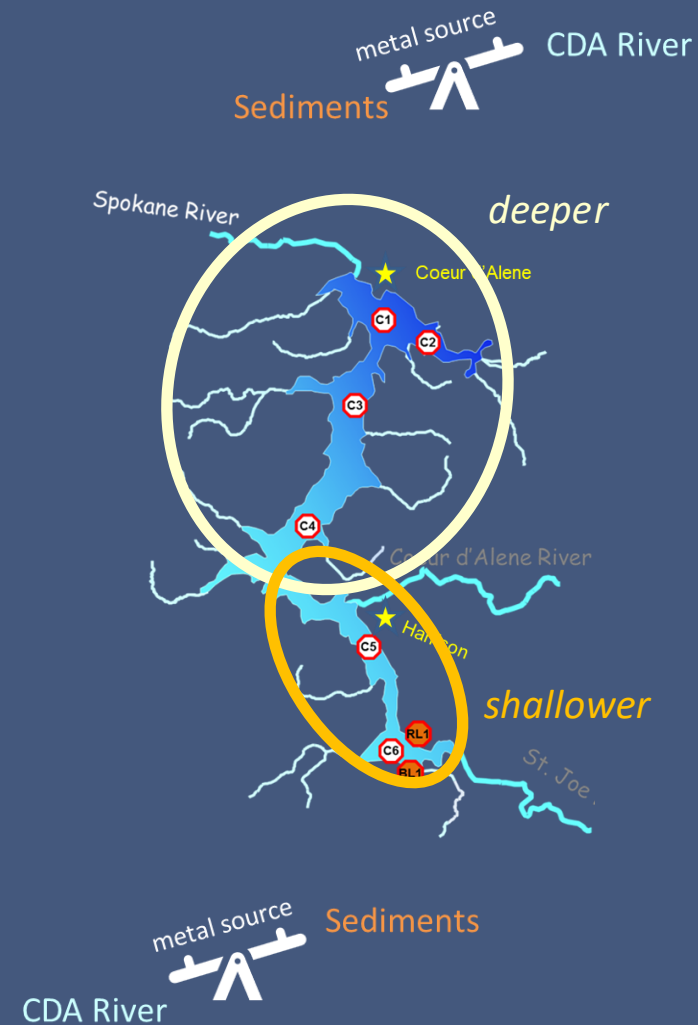2. Look for signs of mixing in the water

To Look for Signs in the Water

- Fingerprint water in the lake and rivers
- Measure different types of O, H atoms
- O and H have a small proportion of heavier "isotopes" that have more neutrons.
- Isotopes react at different rates
  - Water sources have "fingerprints"
  - Evaporation, precipitation change the ratios in known ways
- Can trace water masses and how they change by measuring relative amounts

Measure changes over time

Stable Isotopes of H_2O

Determine if mixing happens

^{16}O

^1H

H_2O^{16}

H_2O^{18}

$\dfrac{O^{18}}{O^{16}}$

thermocline

H_2O^{18}

H_2O^{16}

$\dfrac{O^{18}}{O^{16}}$
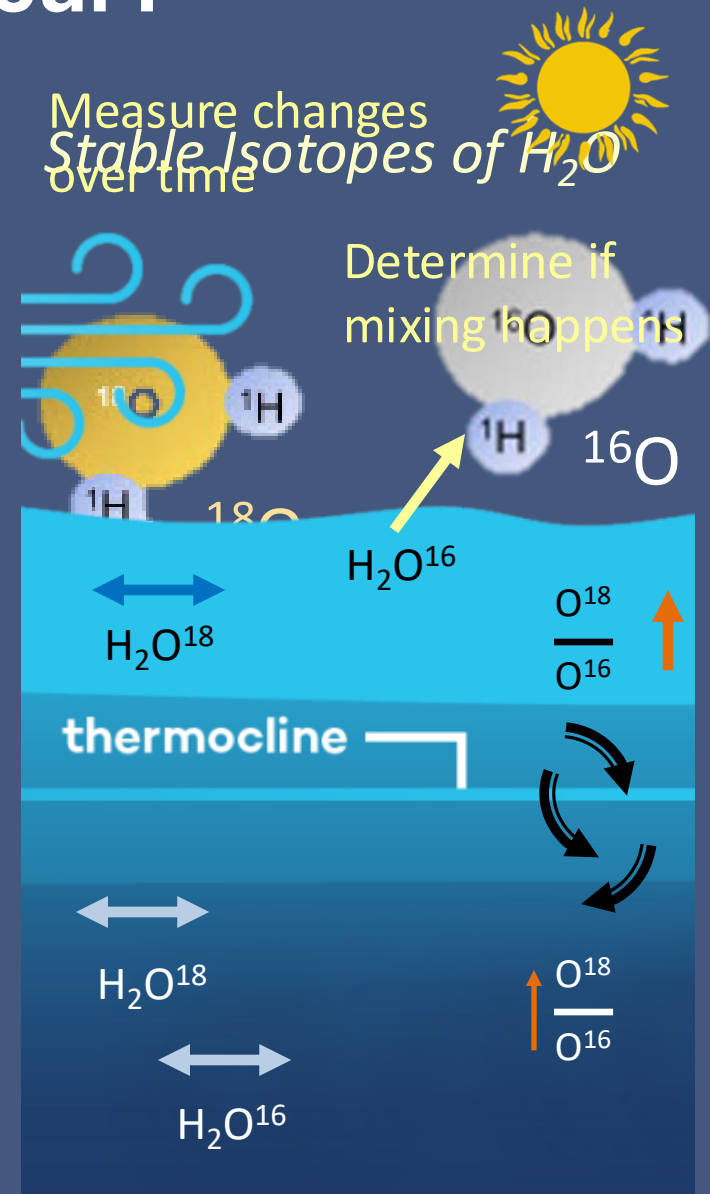
Some Implications for Lake Management

- Lake Composition
  - Dominated by rivers. "Reset" each spring
  - Lots of variability (annual, seasonal)
  - Very sensitive to watershed
  - Sensitive to El Niño / La Niña cycles

- Internal Mixing
  - Mixing across thermocline in summer
  - More susceptible to influences of metals released from sediments?

- Effectiveness of Recovery Actions
 - Different in lake's north, south
  - More sediment influence on the lake in the south (shallower)

metal source   CDA River
Sediments

Spokane River   *deeper*

Coeur d'Alene
C1   C2
C3
C4   Cœur d'Alene River
          Harrison
C5
                     shallower
     RL1
C6
RL1   St. Joe

metal source   Sediments
CDA River

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Thank you

Lake Mixing: Data from Stable Isotopes ($\partial^2 H$, $\partial^{18} O$)

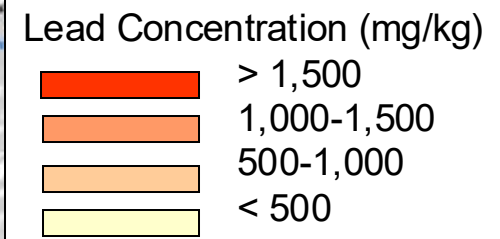**Surface Waters**
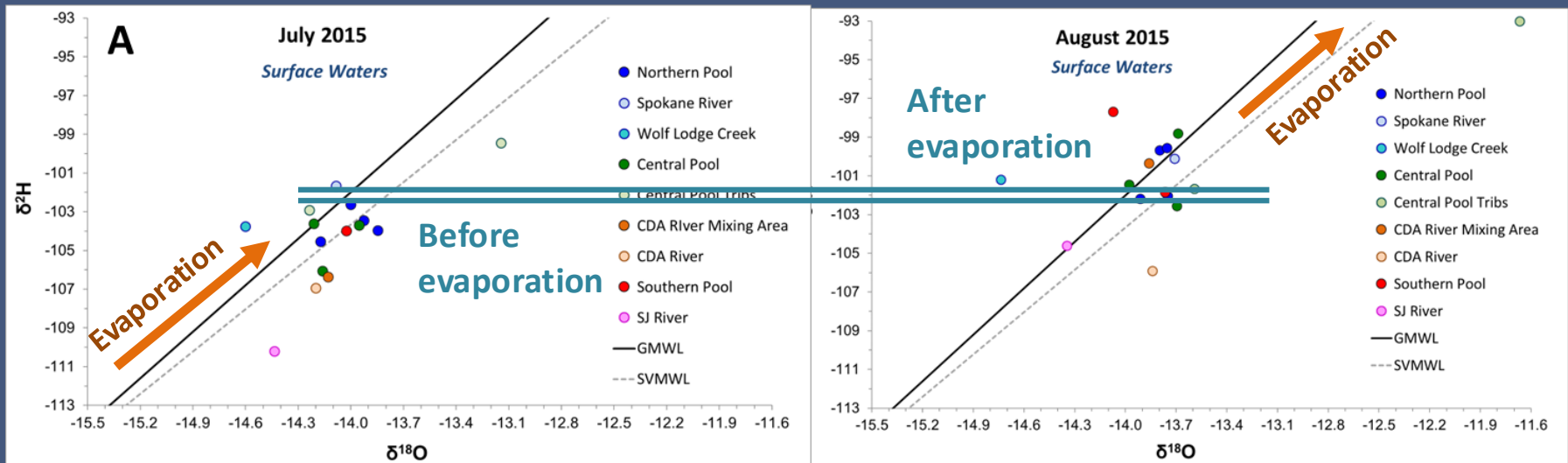
Deeper Waters (> 20 m depth)
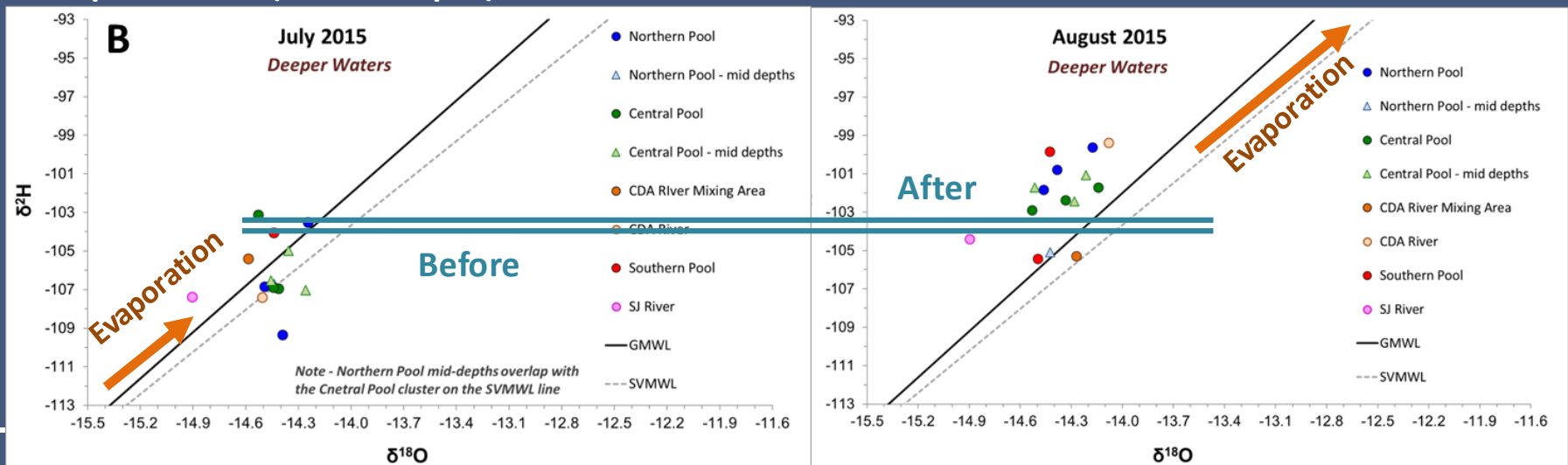
Lead Concentrations in Coeur d'Alene Lake Bed and River Floodplain Sediments and Health Warning Signs

Over 75 million tons of contaminated sediments in CDA Lake

...and we want them trapped there

Lead Concentration (mg/kg)

- > 1,500
- 1,000–1,500
- 500–1,000
- < 500

Sediment Lead Contamination

- *Maximum levels >25,000 ppm*
- *Background levels < 50 ppm*
- *Waterfowl health impacts ~500 ppm*
- *CDA River, average ~3,300 ppm*
- *CDA Lake, range ~130 – 6,300 ppm*

Map, courtesy of Coeur d'Alene Tribe

The Concept of Five Seasons is Consistent with CDA Tribal Knowledge

Mixing Patterns (2008 Floods)

Surface
Early Spring,
Feb 2015

Bottom
Early Spring,
Feb 2015

Surface
Early Spring,
Mar 2015

Bottom
Early Spring,
Mar 2015

Blue = slower
Red = faster
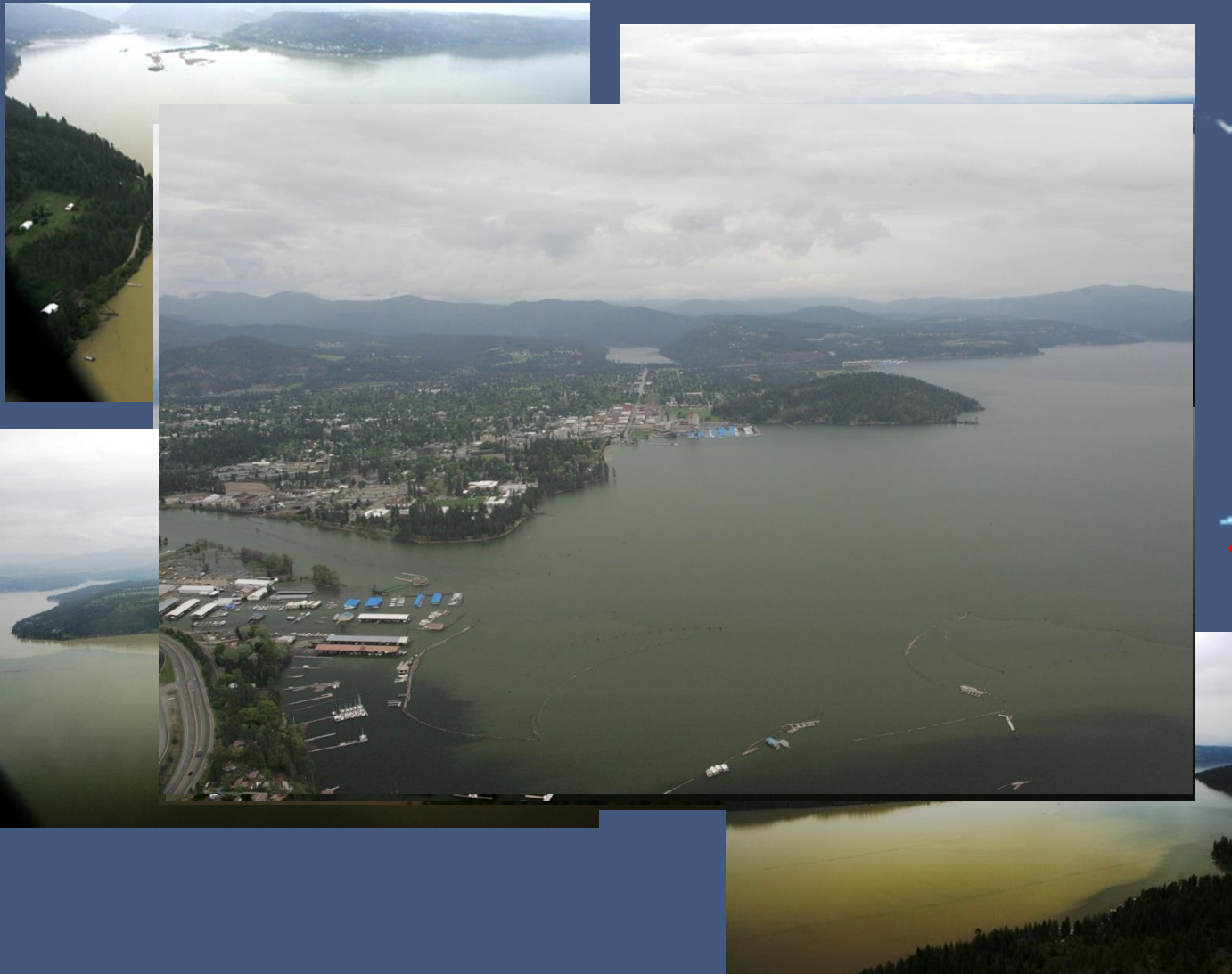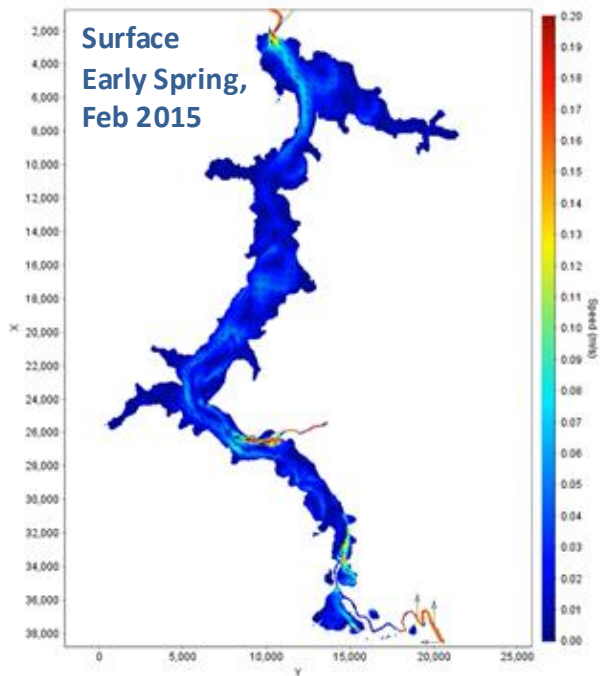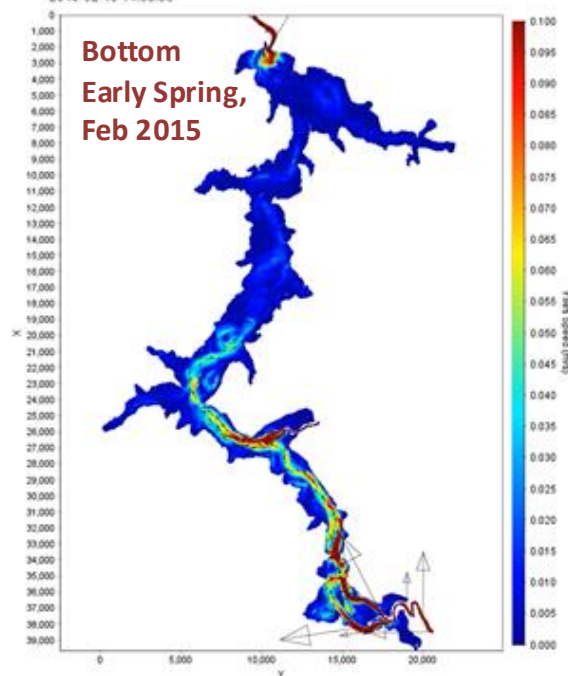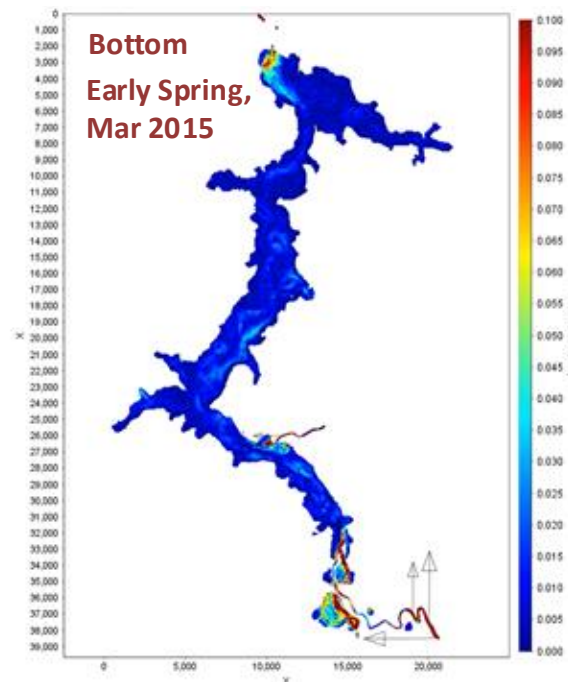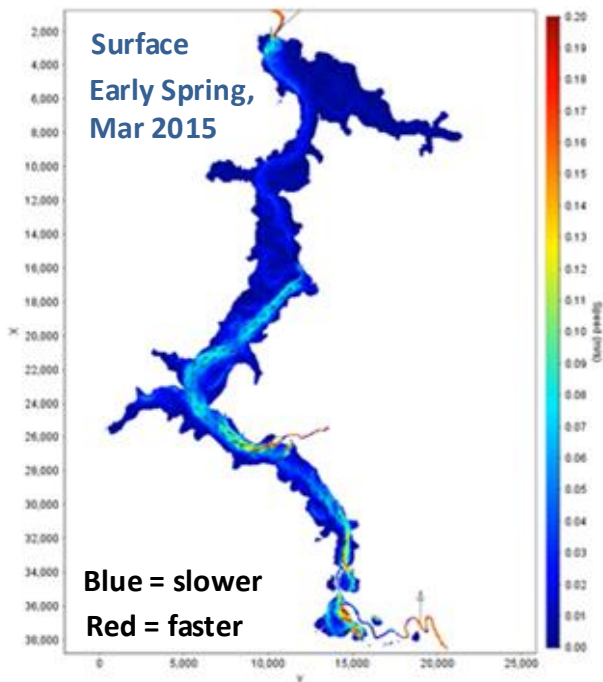
Water Velocity –
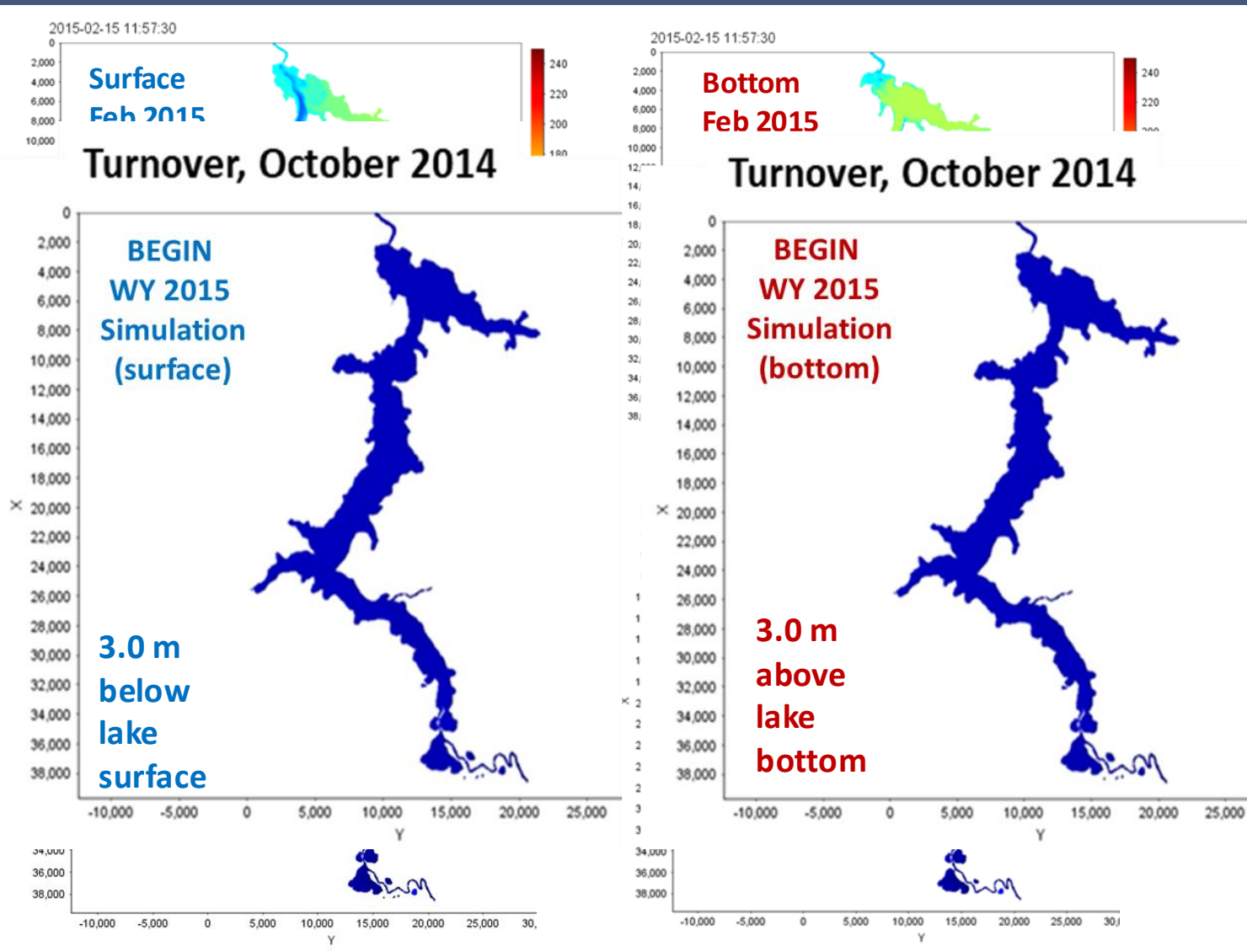Early Spring
WY 2015

Surface = 3.0 meters below surface;

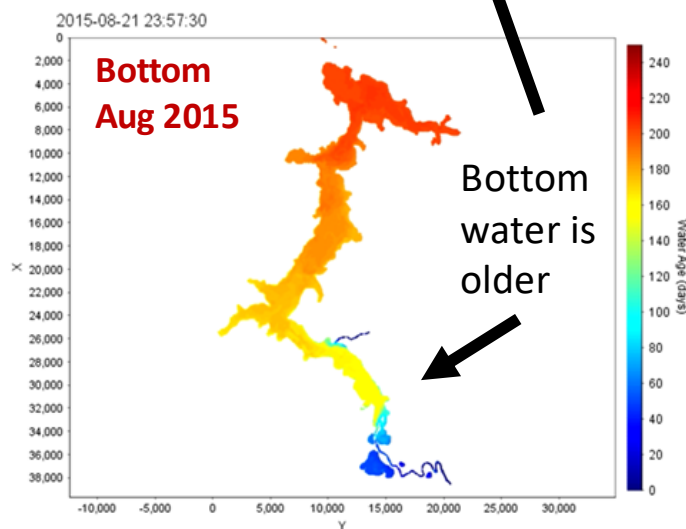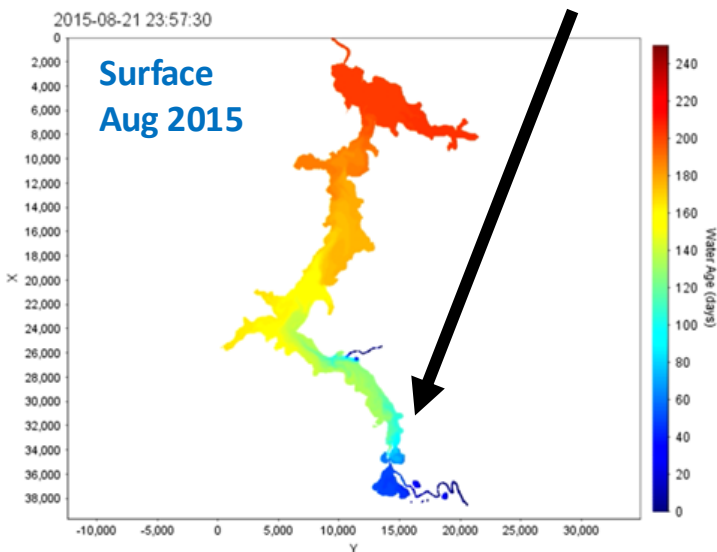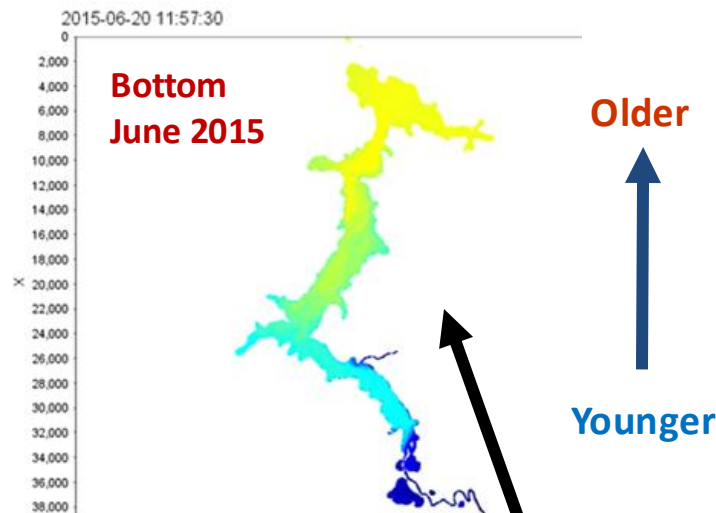Bottom = 3.0 m above bottom

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Modeled Water "Age" during Spring Runoff

Surface Feb 2015

Bottom Feb 2015

- Start at time = 0

- River inflows are new water

- Lake water ages from initial

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Water "Age" as Seasons Progress

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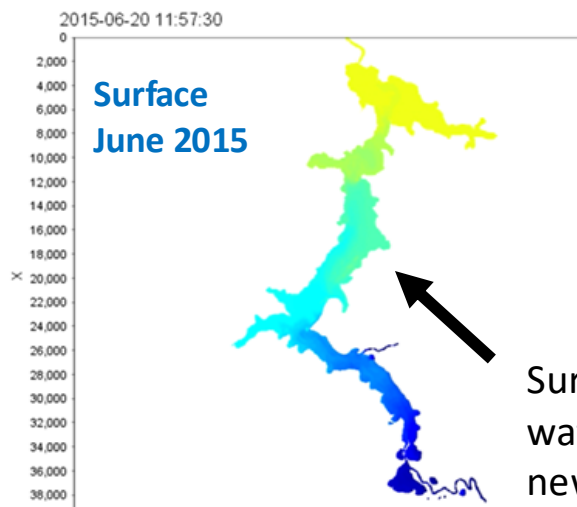
What About the Lake's Future?

Climate Change and Development: Beginning to see some effects

- Air temperatures are warming

- CDA Lake surface water temperatures are increasing as well

- Earlier river runoff in Idaho, lower summer inflows, more evaporation

- Wildfires
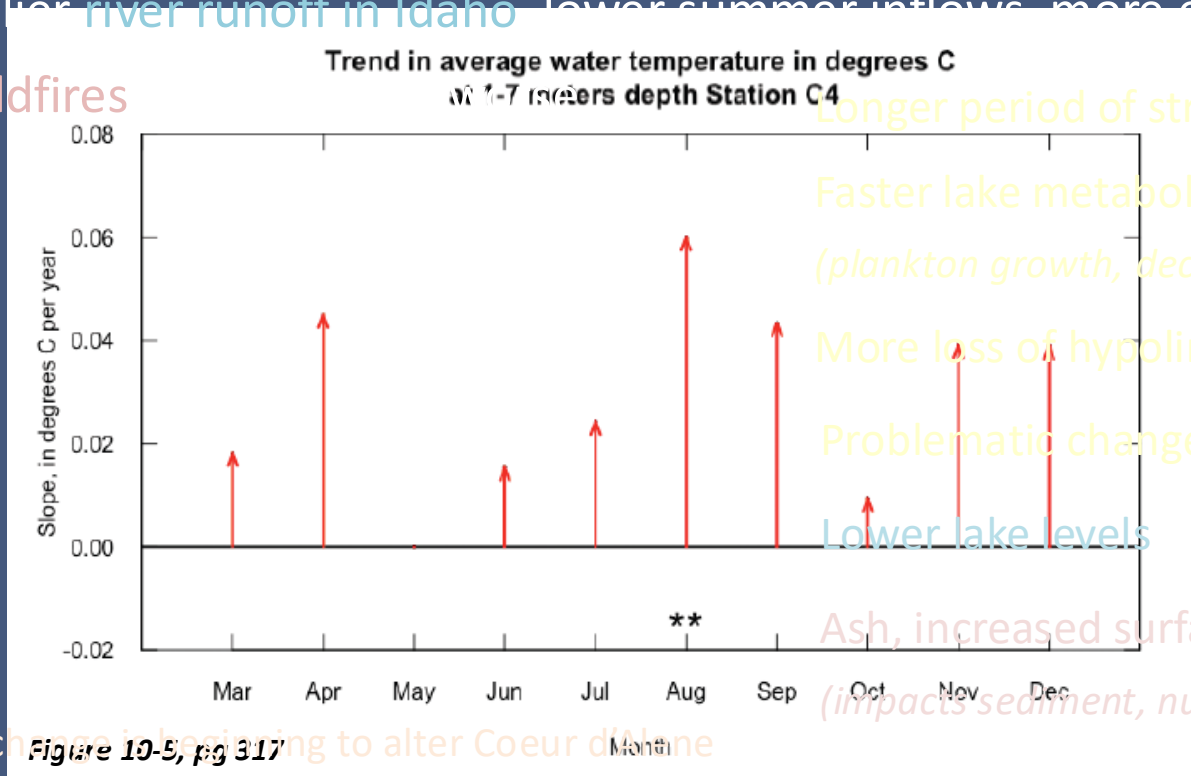
Longer period of stratification

Faster lake metabolism
(plankton growth, decomposition)

More loss of hypolimnetic O2

Problematic changes in lake ecology

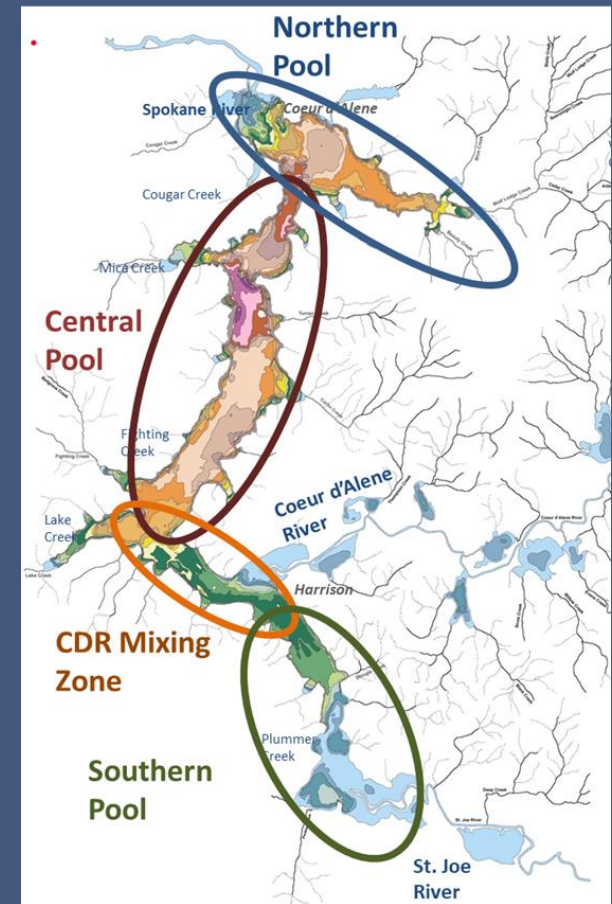Lower lake levels

Ash, increased surface run-off
(impacts sediment, nutrient loading)

Trend in average water temperature in degrees C at 1-7 meters depth Station C4

Figure 10-5, pg 317

Climate change is beginning to alter Coeur d'Alene Lake and will make it harder to manage

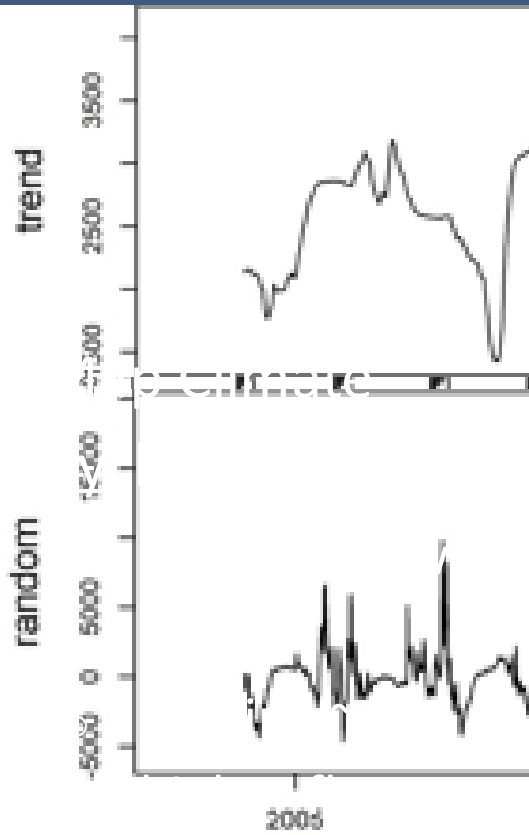Idaho Department of Environmental Quality
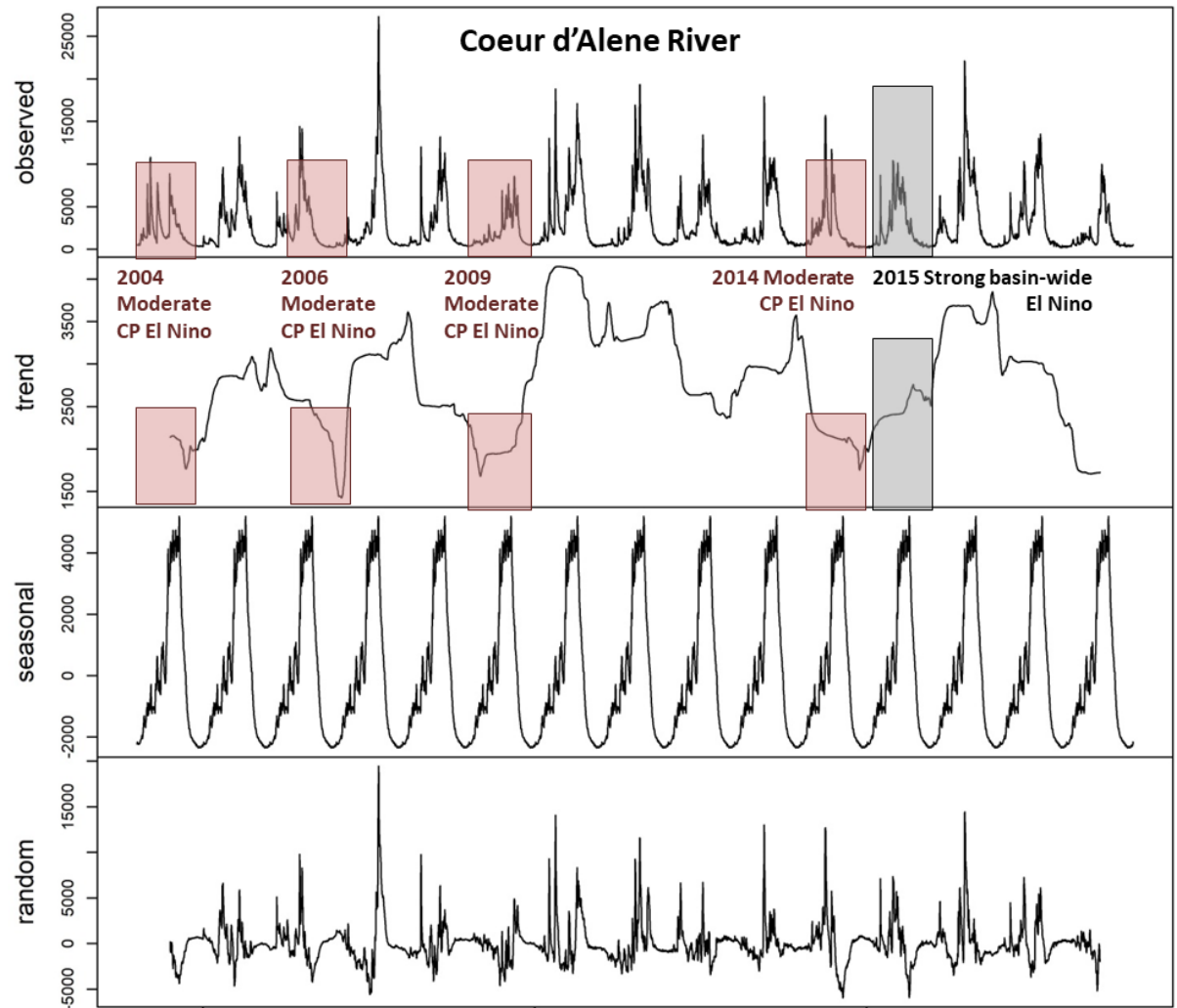
Summary of Management Implications

- Different recovery strategies may be needed in the lake's different regions

- Water composition can "reset" each year

- Sensitive to inflow dynamics; overflows, interflows, underflows in Spring

- Important influences in Early Spring

- Wind driven currents and vertical mixing can influence lake composition

- Multiple factors influence oxygen

- Post Falls dam may influence metals risk

- Ice and precipitation in Winter and Early Spring are important factors

- Forecast lake conditions with improved river, weather monitoring ???

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Knowing the Seasons Unlocks a Lot!

Break Time Series of River Flows into Components Parts

Coeur d'Alene River

2004 Moderate CP El Nino
2006 Moderate CP El Nino
2009 Moderate CP El Nino
2014 Moderate CP El Nino
2015 Strong basin-wide El Nino

Big random events are much larger than seasonal variations