Coeur d'Alene Lake
Conceptual Site Model for Structure and Mixing

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CDA Basin Environmental Improvement Project Commission
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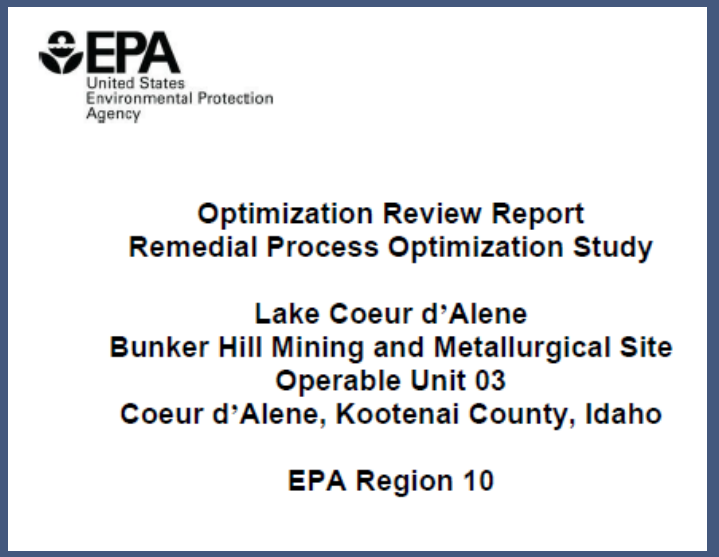
Project Background

2019 EPA Optimization Team Needs

- Include Lake in a CdA Basin CSM
- No recent Lake CSM published
- Describe metals biogeochemsitry
- Hydrodynamic mass balance



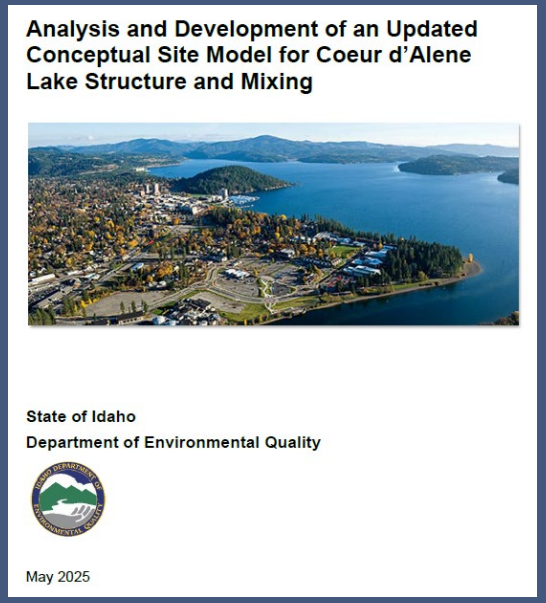
1st Step – better description of lake physics

- What factors influence lake hydrodynamics?
- What hydrodynamics do we need to describe?
- Incorporate historic data, modeling work
- Hydrodynamics foundation for ecology, chemistry

Project Highlights

Document key data from core sites

- Lake sonde, wind data from 2014-2019
- Basin hydrology from 2005-2020
- Stable isotope study from 2015 (^{18}O, ^{2}H)
- Summary of modeling studies

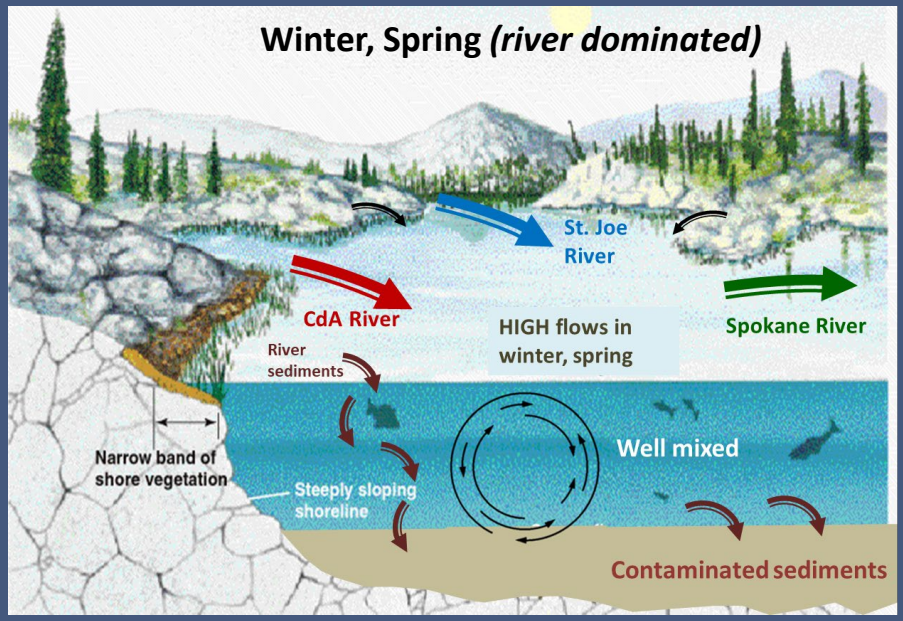


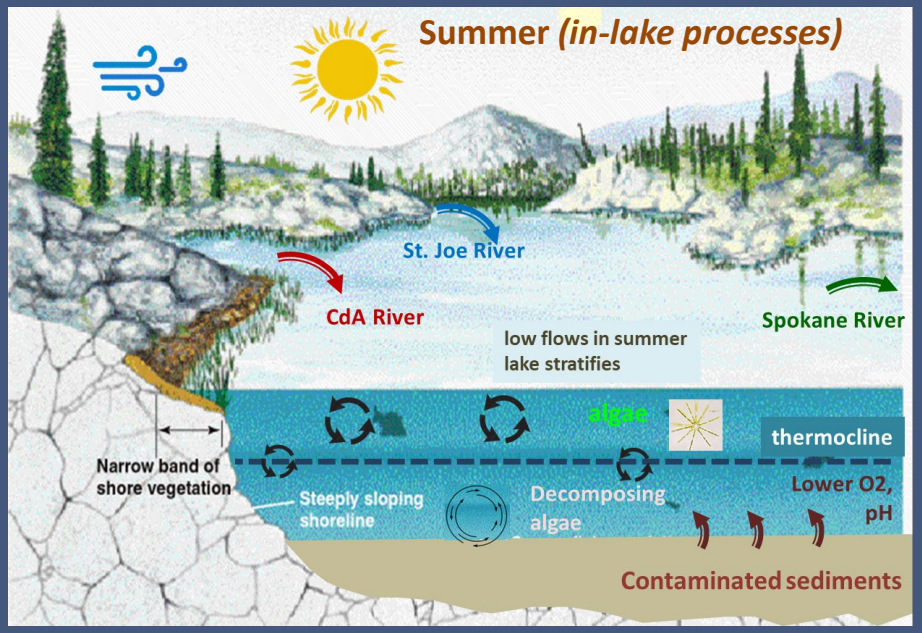
Document evaluates lake structure, mixing

- Lake seasonality
- River hydrology, wind patterns
- Internal mixing
- Importance of geography, bathymetry, seasonality on lake processes, sediment influences

What Physics Do We Need to Know?

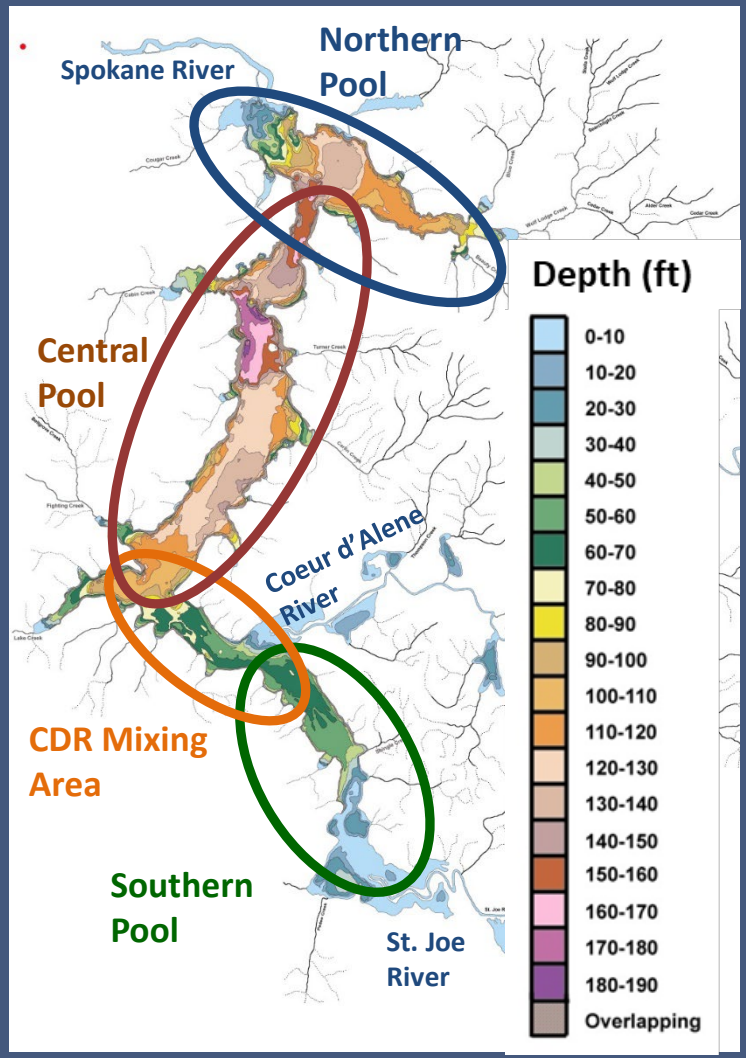
- Seasonality
  - When processes occur
- River Hydrology
  - Timing, magnitude of flows
- Lake Currents
  - Where the water goes
- Internal Mixing
  - How isolated are the sediments?
- Influences of Bathymetry





Structural Perspective: Two Different Lake Types

- Northern Lake
  - Deeper (> 100 ft deep)
  - Colder, more oligotrophic
  - Larger volume
  - Less sediment influence
  - 2 orientations (NW/SE, NE/SW)
- Southern Lake
  - Shallower (< 60 ft deep)
  - Warmer, more mesotrophic
  - Smaller volume
  - More sediment influence
  - N-NW/S-SE orientation

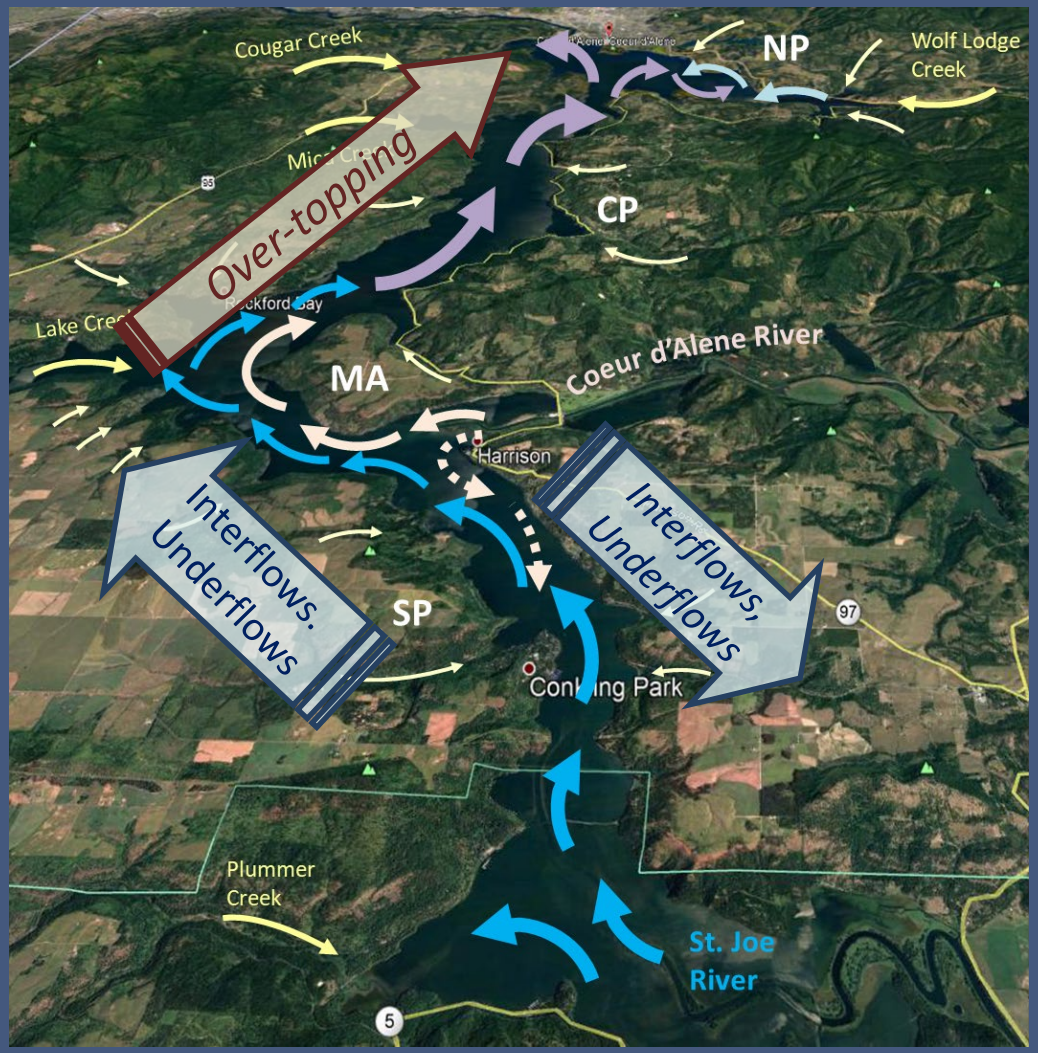


Geography and General Spring Currents

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

Evidence for over-topping in early spring

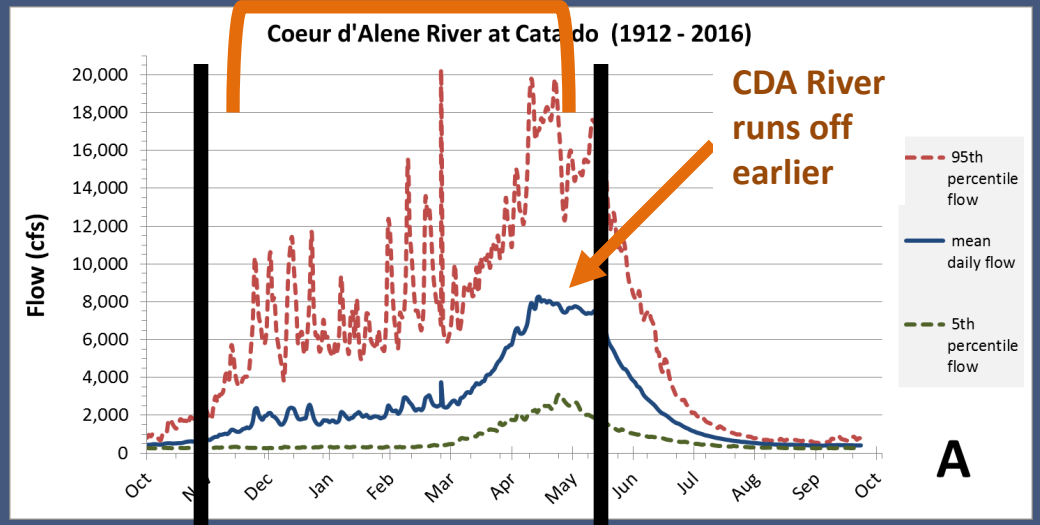
interflows, underflows also occur

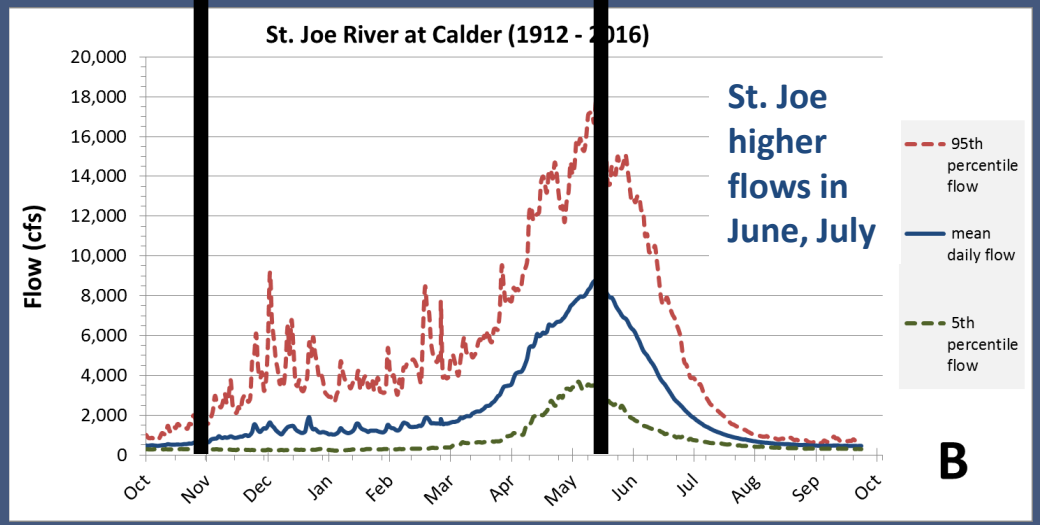


Key Aspects of River Hydrology

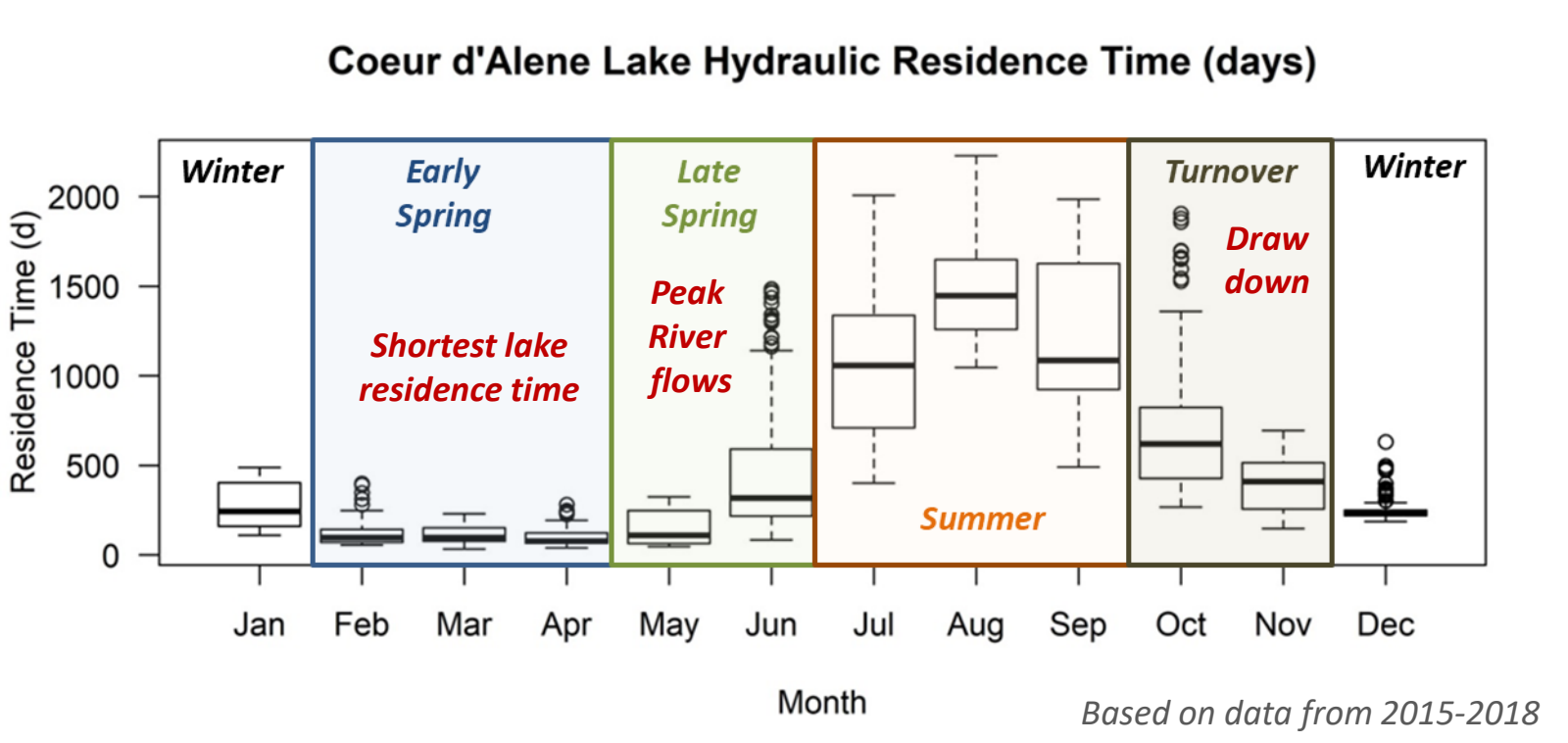
Spring flood event (May, 2008)

CDA River runoff is "flashier"





Hydrology Drives the Lake's Seasonality



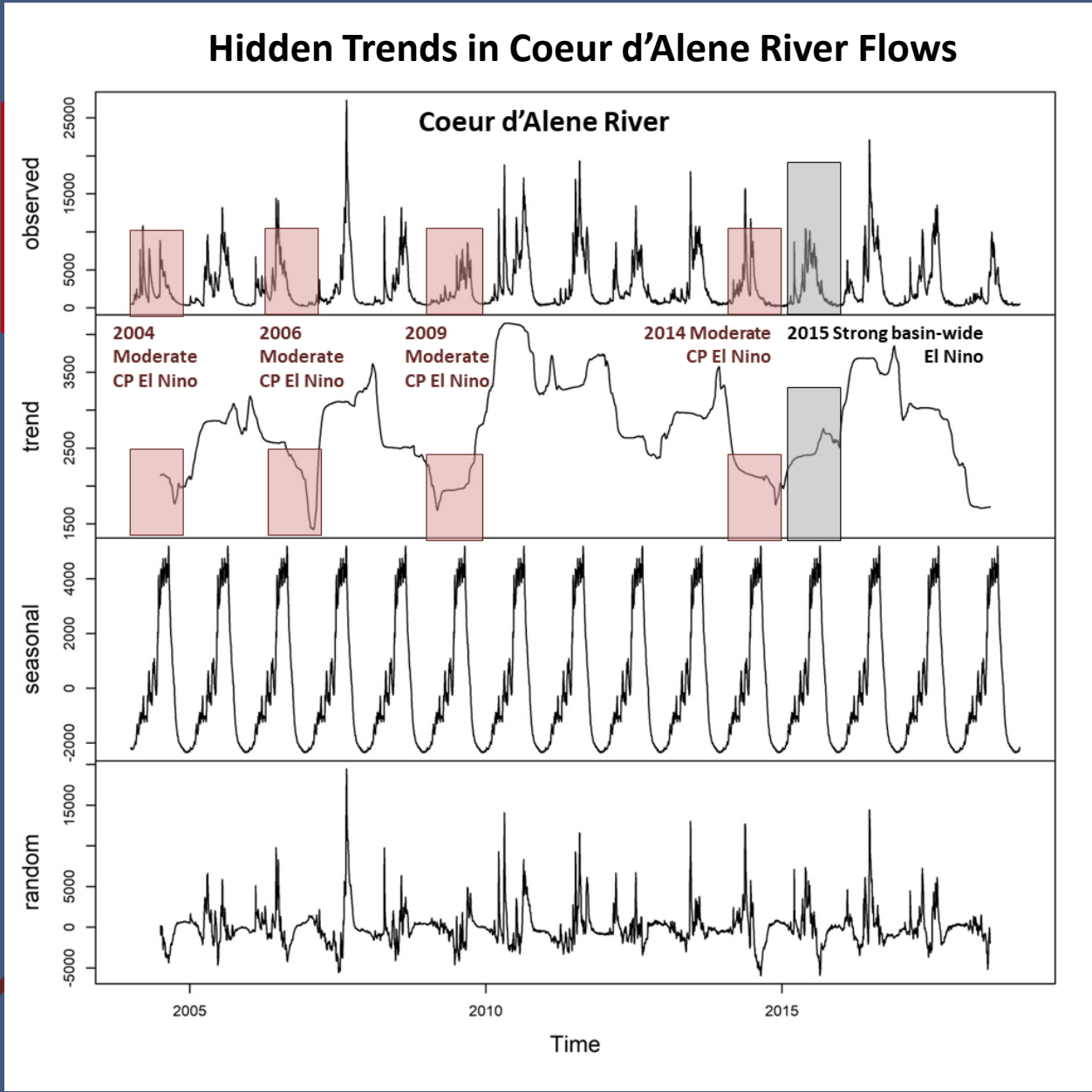
- 5 "lake seasons" (balance of residence time, river flows, weather)
- Median residence time: ~ 90 days (Spring) to 1,100 days (Summer)
- Lake can empty and refill each spring

Knowing the Seasons Unlocks a Lot!

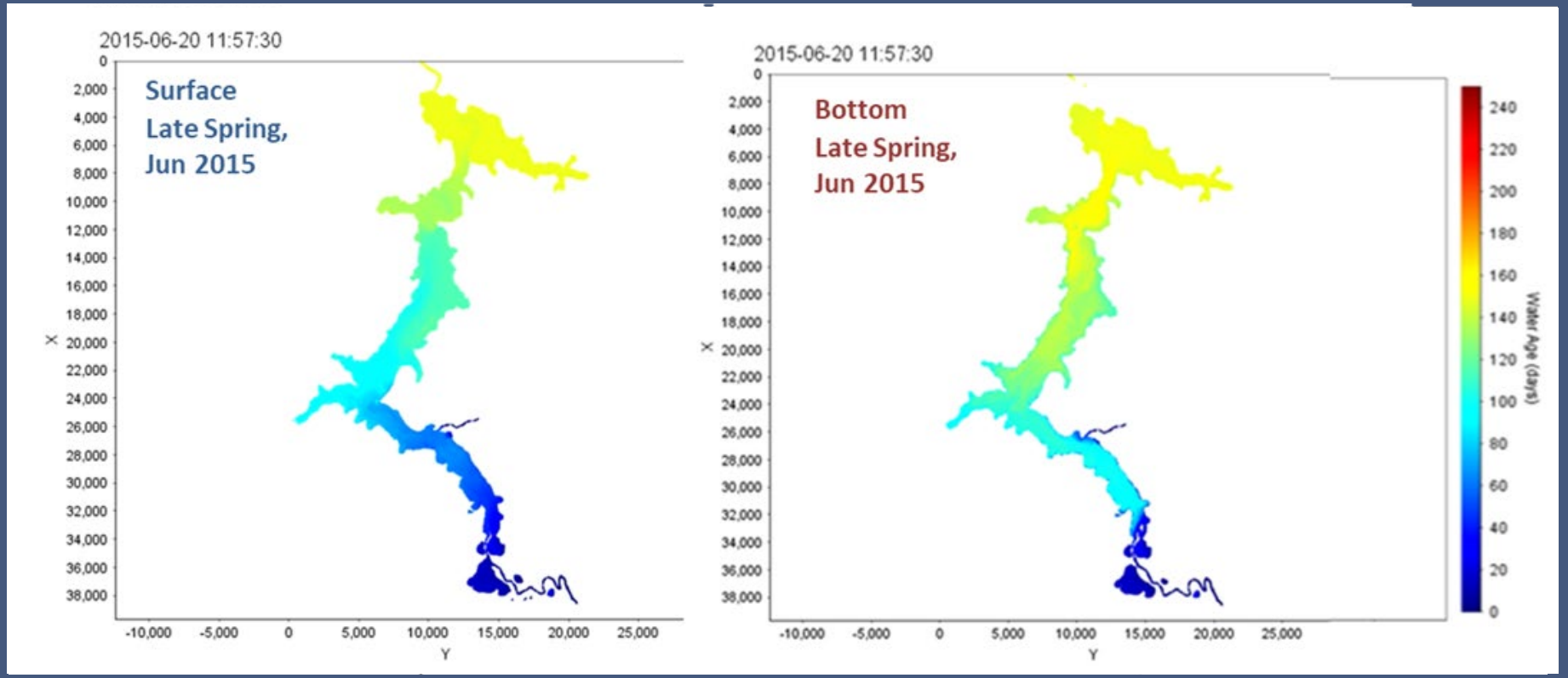
Unlock hidden patterns in the rivers

Map Climate Cycles onto trends

- Take CdA River flows
- Break out patterns of 5 equal seasons
  - El Nino ~ lower flows
  - La Nina ~ higher flows
- Subtract seasons, calculate a trend using the long-term median
- Remainder is random variability



Water Movement in Spring



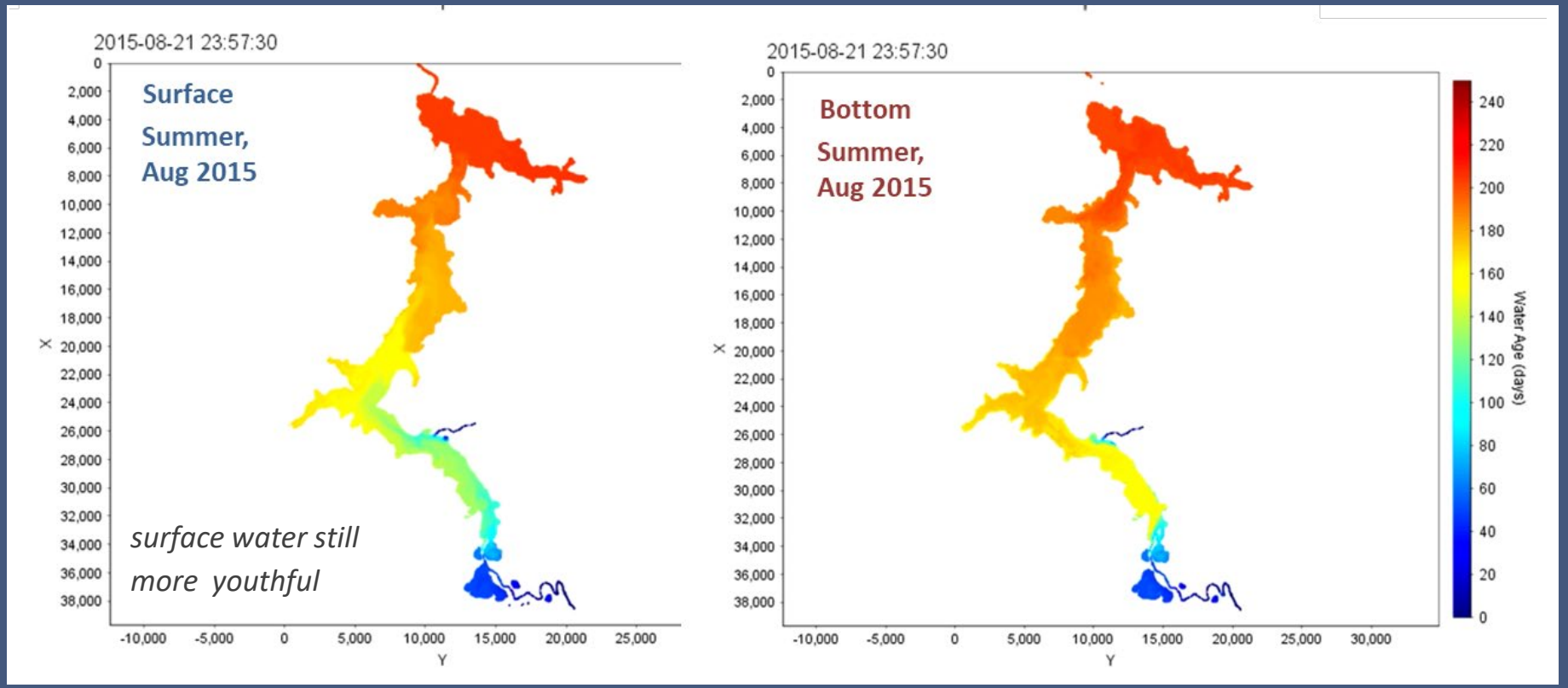
Modeled age of water in the lake

- Blue = recently entered
- Yellow = entered ~5 mo ago

over-topping in early spring

more equal by late spring

Water Movement in Summer

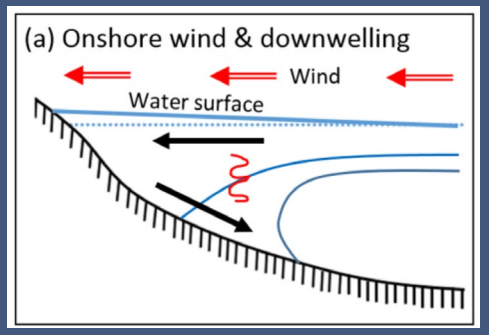


Modeled age of water in the lake

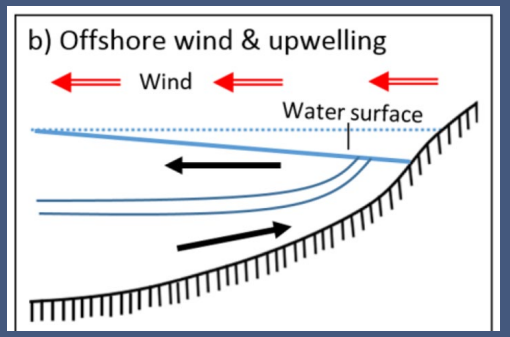
- Yellow = entered ~5 mo ago (~March)
- Red = entered ~7 mo ago (~January)

minimal river influence

Wind and Summer Currents



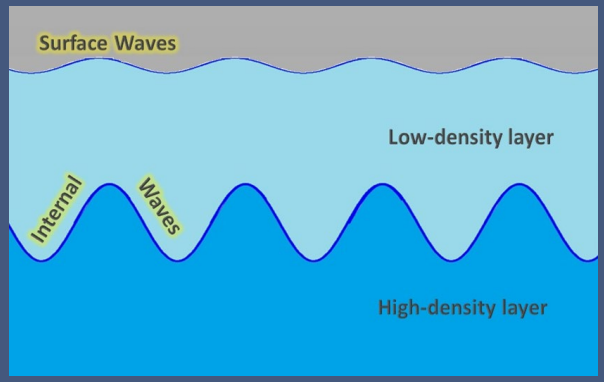
Downwelling



Upwelling

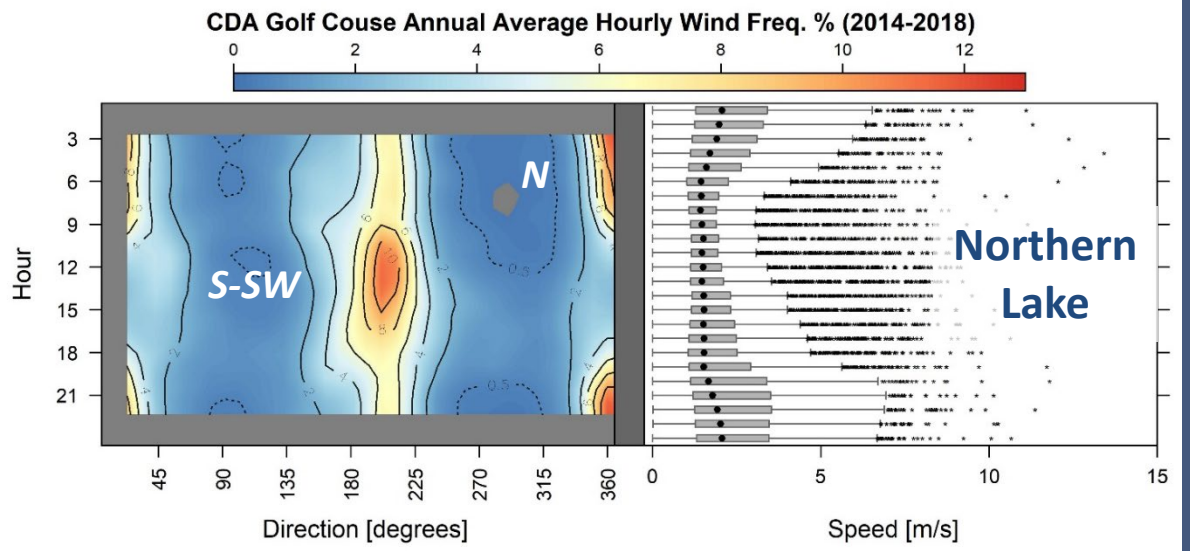
Winds creates currents, mixing

- Currents move in weird ways
- Can cause differential water cooling
- Substantial mixing in the lake
- Both spatially and vertically



Internal Waves

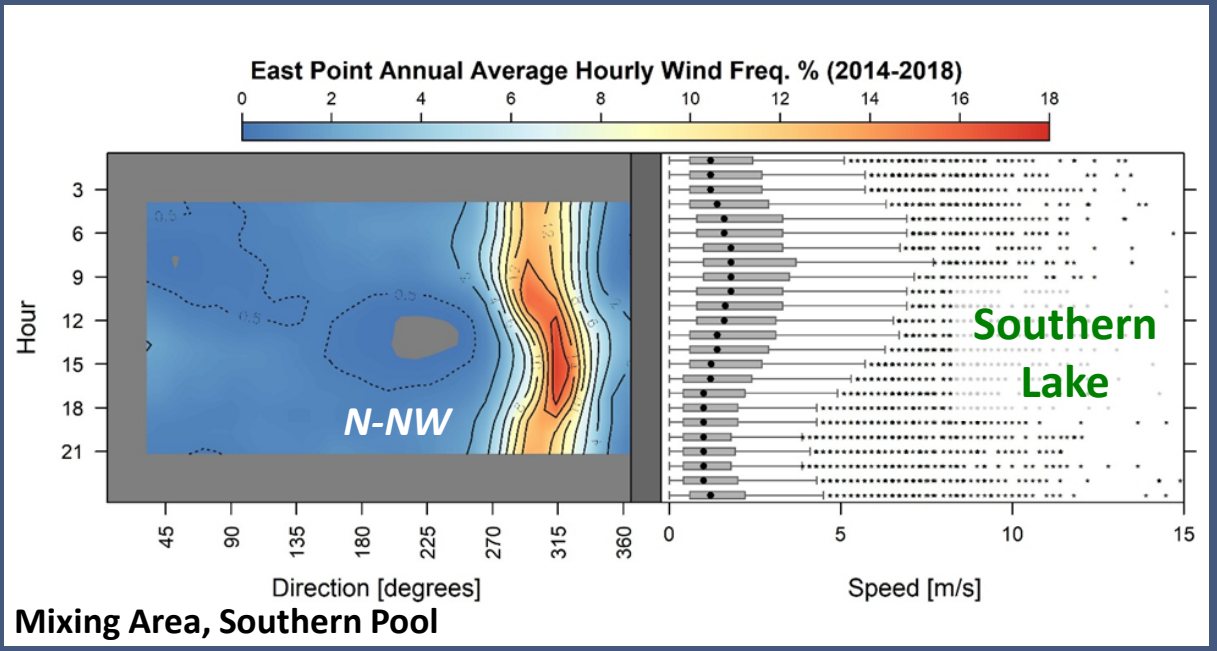
Wind



Northern, Central Pools

Daily patterns

- shifting direction
- variable speed



Mixing Area, Southern Pool

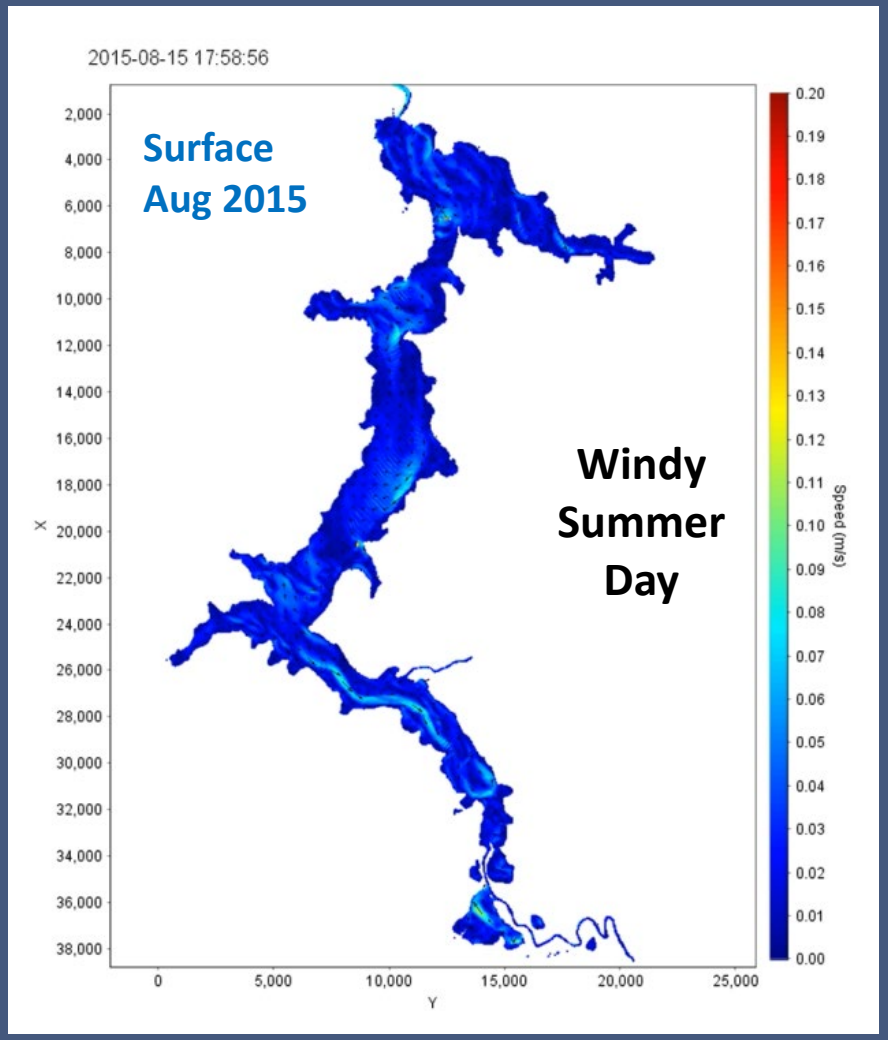
Daily patterns

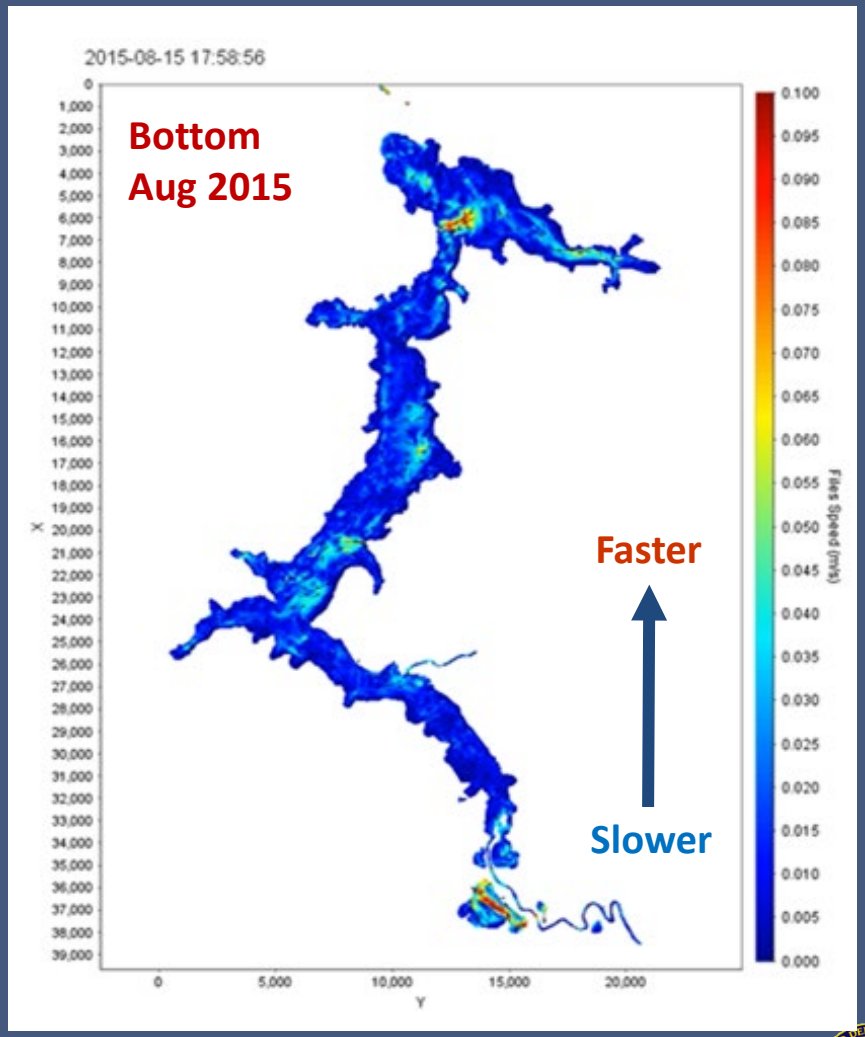
- consistent direction
- variable speed

Seasonal differences in wind patterns

Mixing on a Windy Summer Day
(Modeled Lake Currents)

Note different color scales





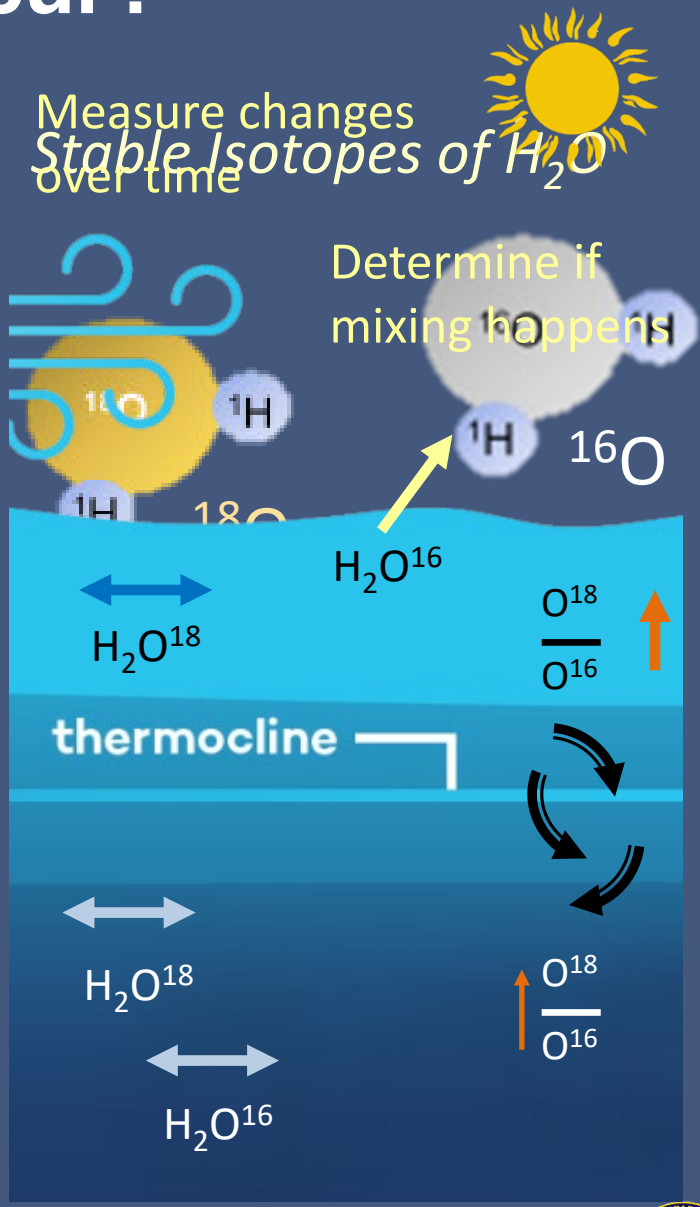
Does Vertical Mixing Occur?

Two ways to test

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

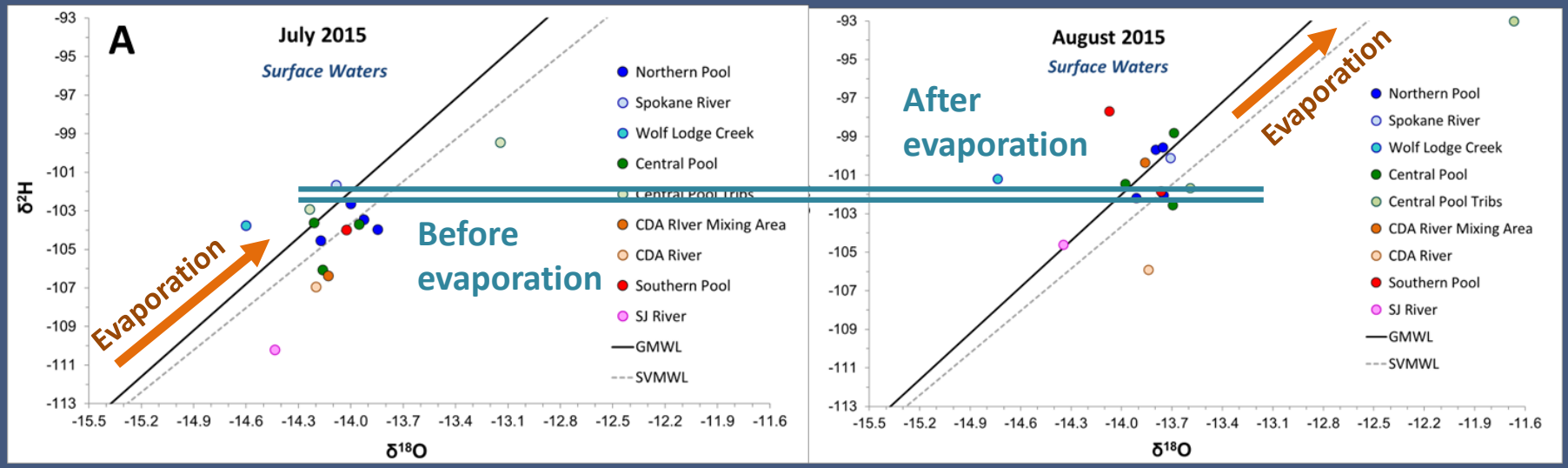
To Look for Signs in the Water

- 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

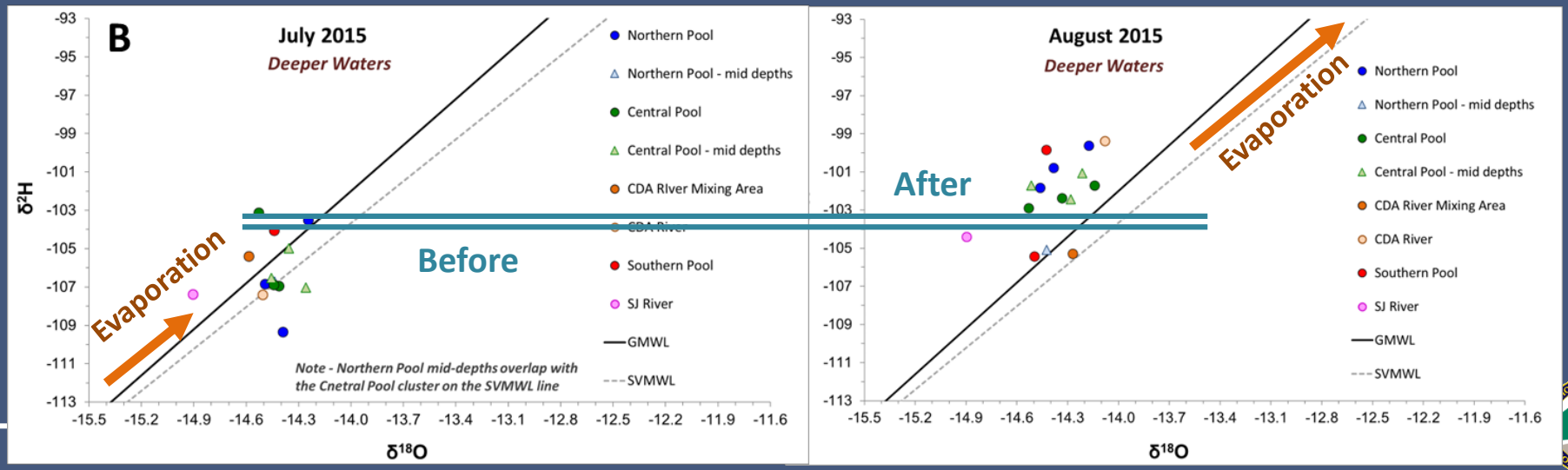


Lake Mixing: Data from Stable Isotopes (∂^2H, $\partial^{18}O$)

Surface Waters

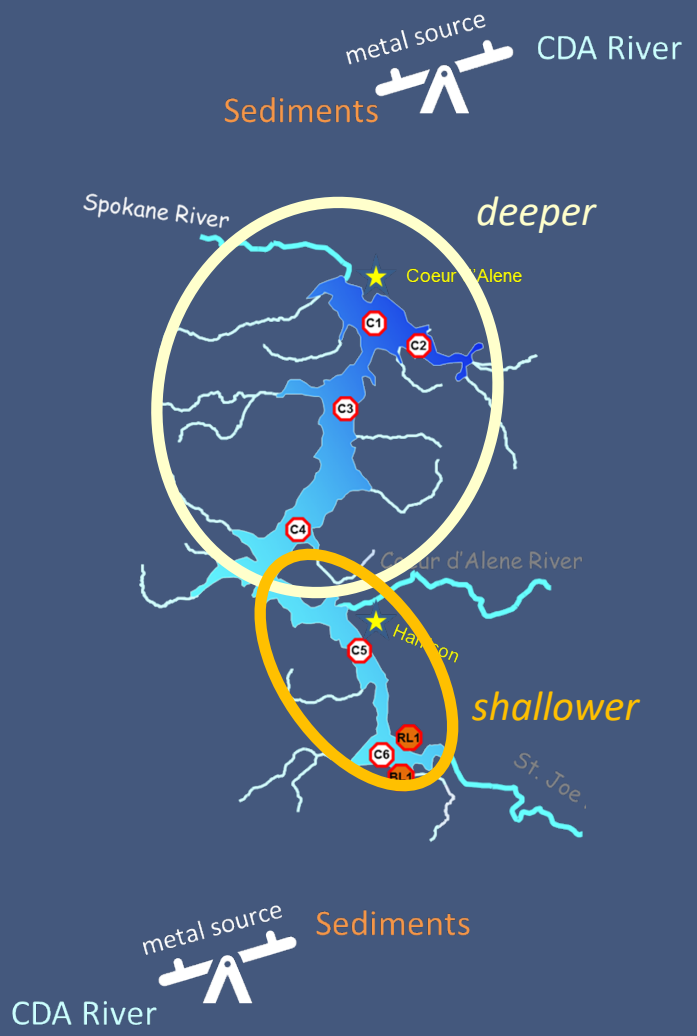


Deeper Waters (> 20 m depth)

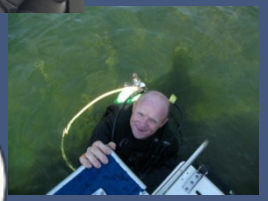


Some Implications for Lake Management

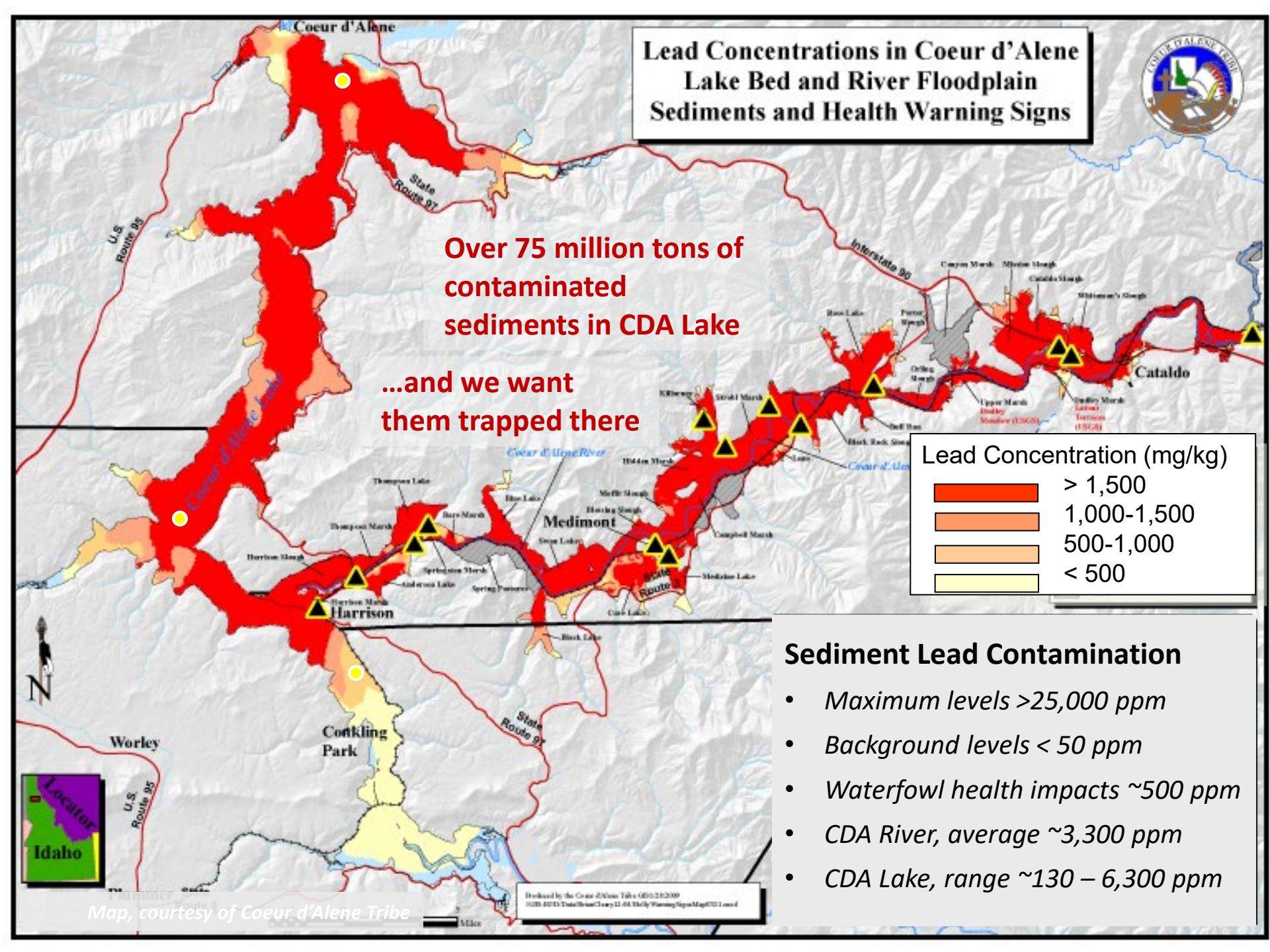
- Lake Composition
  - Dominated by rivers. "Reset" each spring
  - Lots of variability (annual, seasonal)
  - Sensitive to changes in watershed
  - Sensitive to El Niño / La Niña cycles
- Internal Mixing
  - Mixing across thermocline in summer
  - More susceptible to influences of metals released from sediments?
- Effectiveness of Recovery Actions
  - Different in lake's north, south
  - More sediment influence on the lake in the south (shallower)



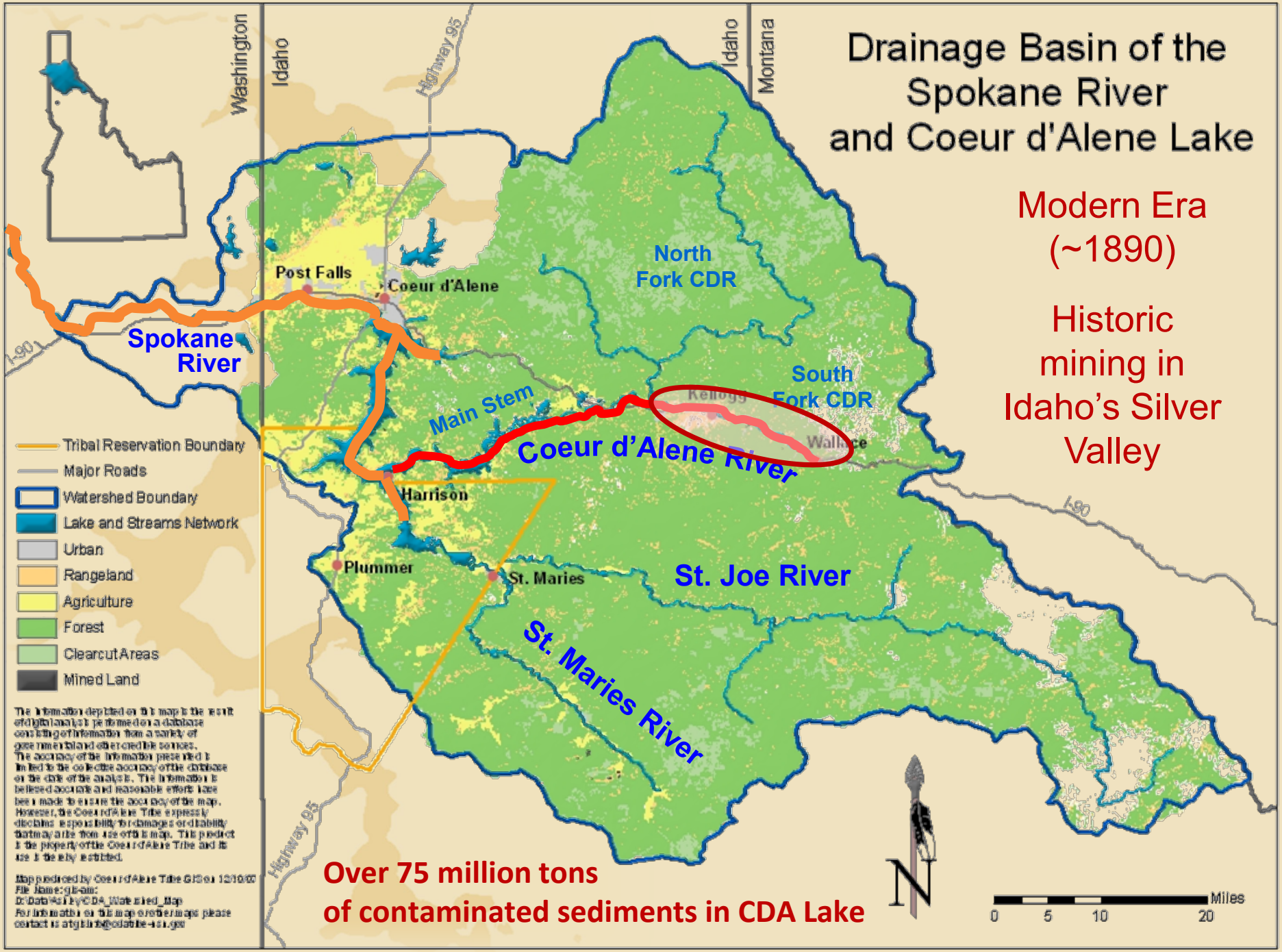
Thank you



The Concept of Five Seasons is Consistent with CDA Tribal Knowledge


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
Coeur d'Alene
Harrison
Medimont
Cataldo
Conkling Park
Worley
Idaho
Locator
U.S. Route 95
State Route 97
Interstate 90
Coeur d'Alene River
Coeur d'Alene Lake
N
Map, courtesy of Coeur d'Alene Tribe

Mixing Patterns (2008 Floods)


Drainage Basin of the
Spokane River
and Coeur d'Alene Lake
Modern Era
(~1890)
Historic
mining in
Idaho's Silver
Valley
Washington
Idaho
Montana
Highway 95
I-90
Post Falls
Coeur d'Alene
Spokane
River
North
Fork CDR
South
Fork CDR
Kellogg
Wallace
Main Stem
Coeur d'Alene River
Harrison
Plummer
St. Maries
St. Joe River
St. Maries River
Tribal Reservation Boundary
Major Roads
Watershed Boundary
Lake and Streams Network
Urban
Rangeland
Agriculture
Forest
Clearcut Areas
Mined Land
Over 75 million tons
of contaminated sediments in CDA Lake
N
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