SAN JOAQUIN RIVER RESTORATION PROGRAM

Restoration Goal Technical Feedback Meeting

Thermal Refugia Study

Nathaniel L. Butler

March 21, 2013

Overview

- Motivation & Objectives
- Background on thermal refugia
- Study Location
- Methodology
- Results
- Take home messages

Motivation

photo credit: Alan Sorum, Alaska Chinook Salmon Research Initiative

Motivation

- Water temperature is a critical water quality parameter for Chinook salmon.
- High stream water temperatures increase metabolic demands which can reduce growth and overall survival.
- High stream water temperatures can also act as thermal barriers fragmenting habitat.
- Cold water habitat or thermal refugia is recognized as potentially enabling passage through warmer reaches of the San Joaquin River historically.

Objectives

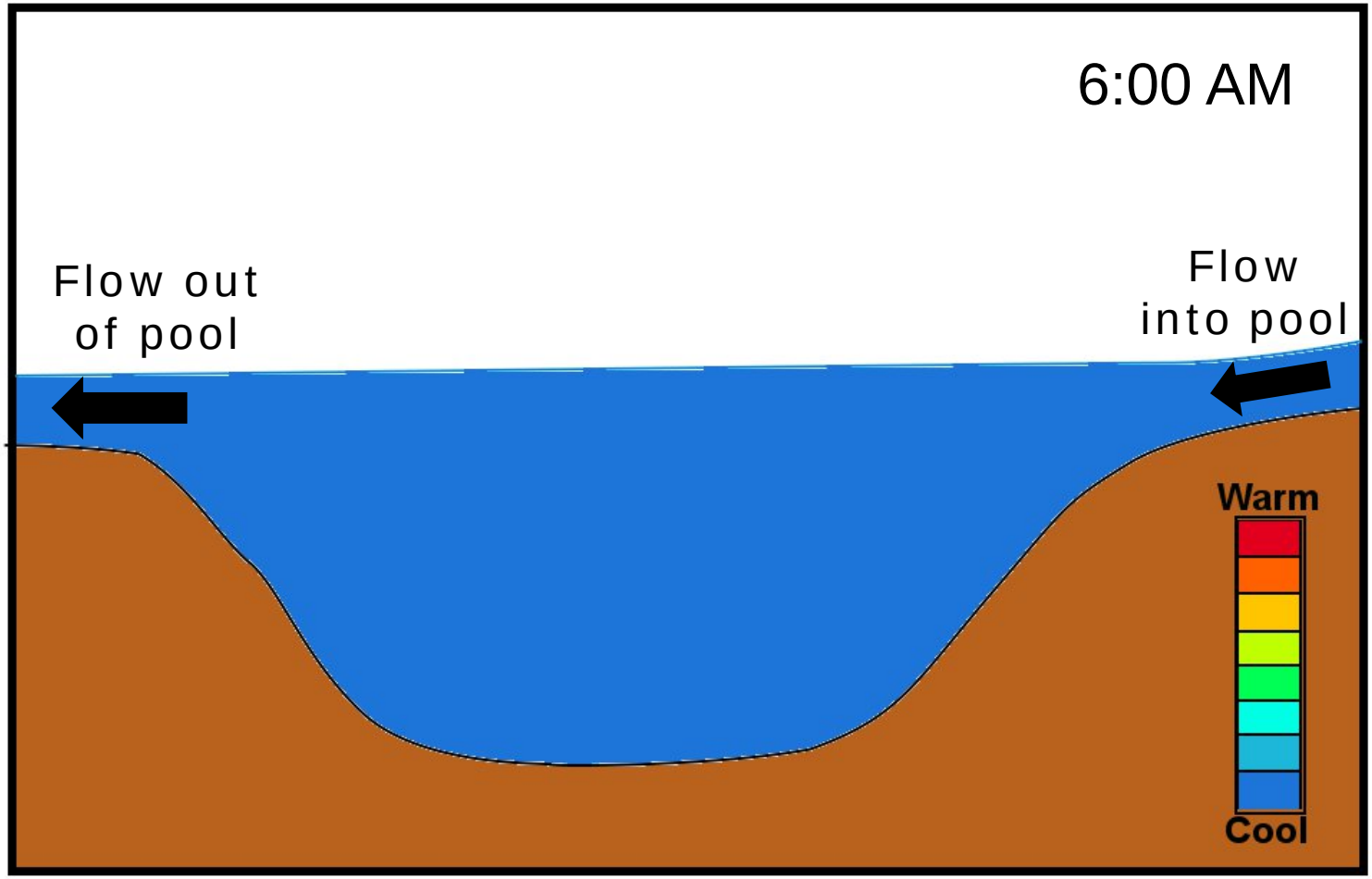
- Assess water temperature conditions in the Eastside Bypass, Reach 4B2, and Reach 5

- Determine frequency of thermal stratification and if it can provide thermal refugia for Chinook

- Determine the main causes(s) of thermal refugia

Background

Thermal Stratification



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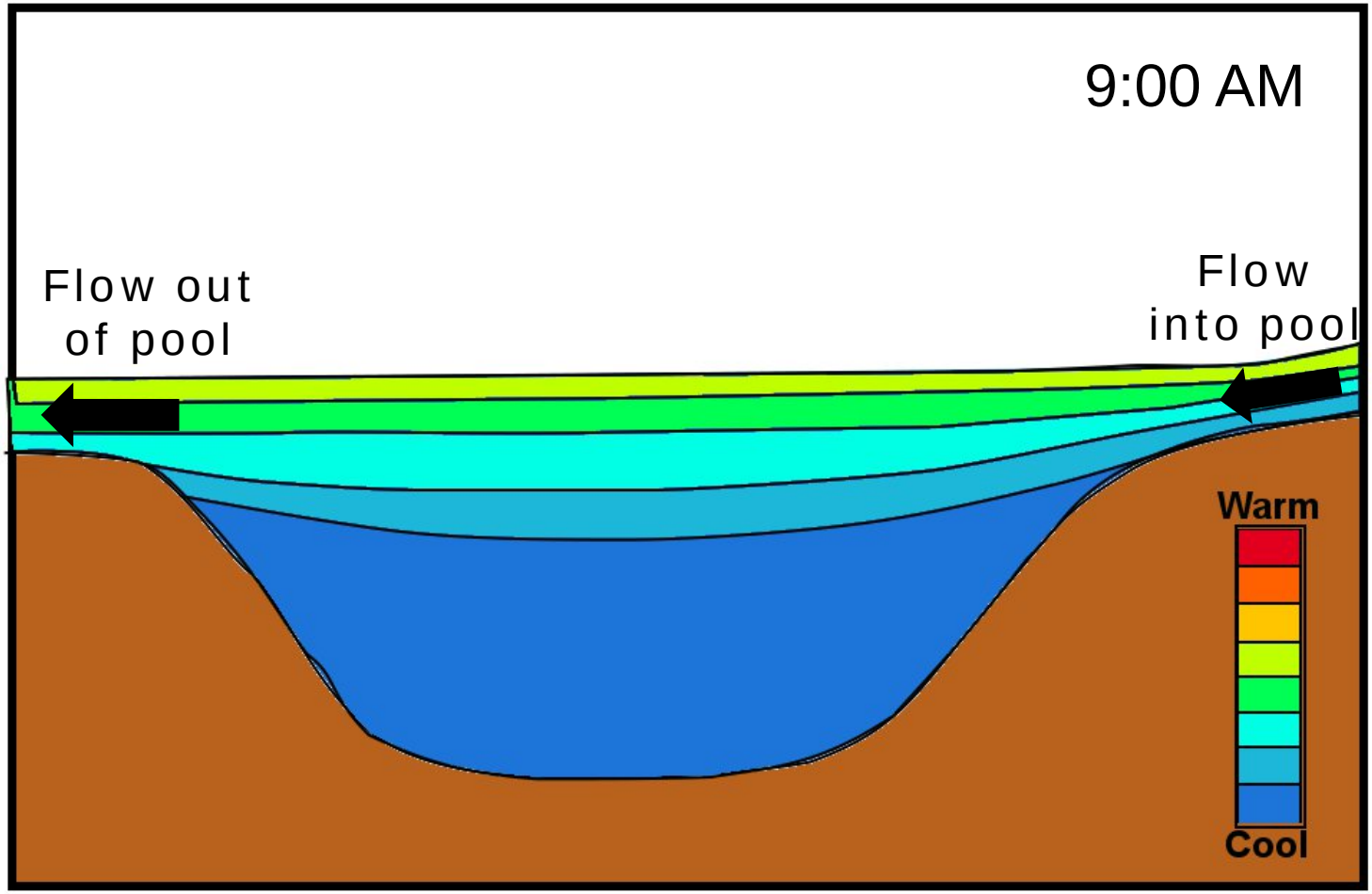
Thermal Stratification



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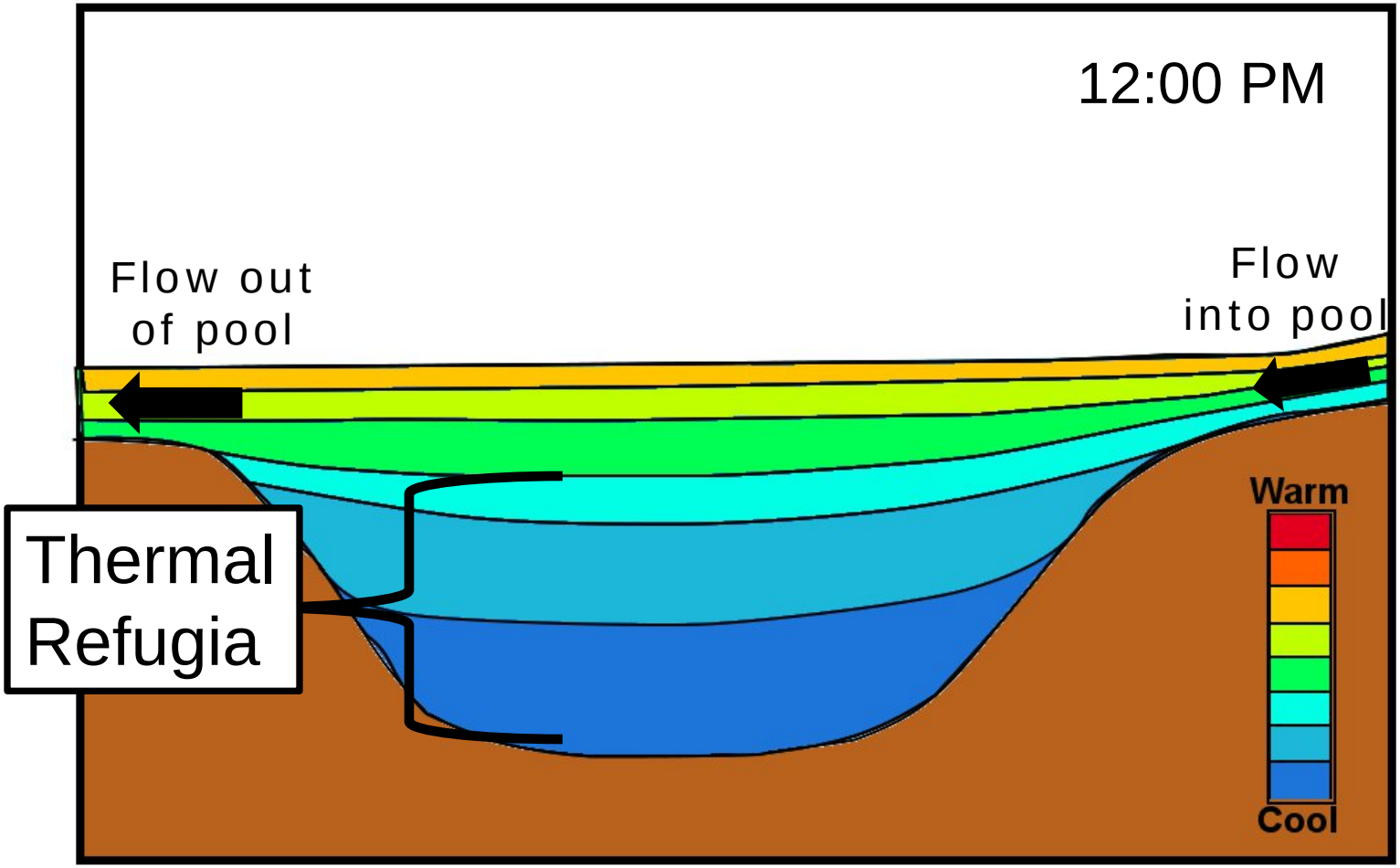

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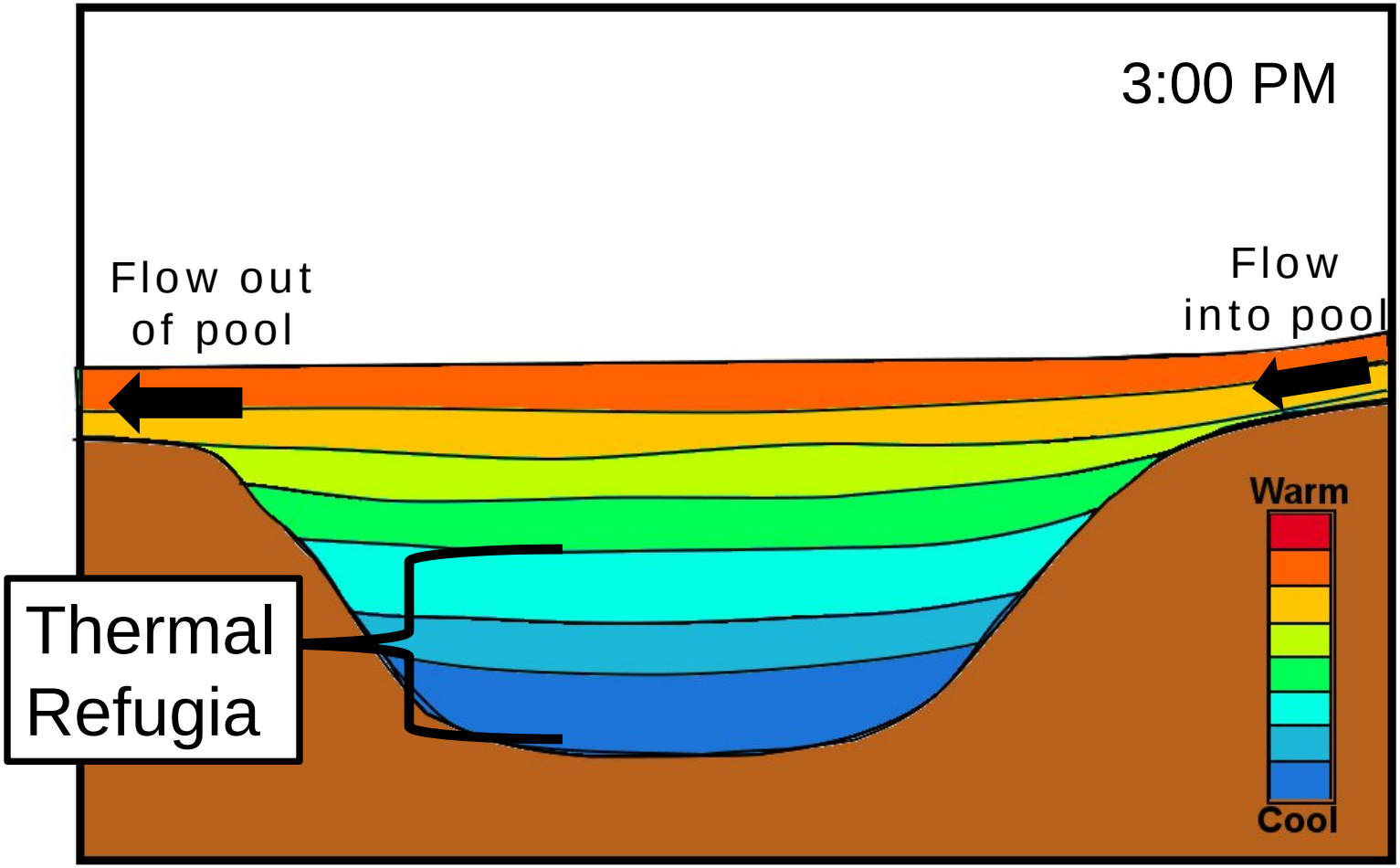

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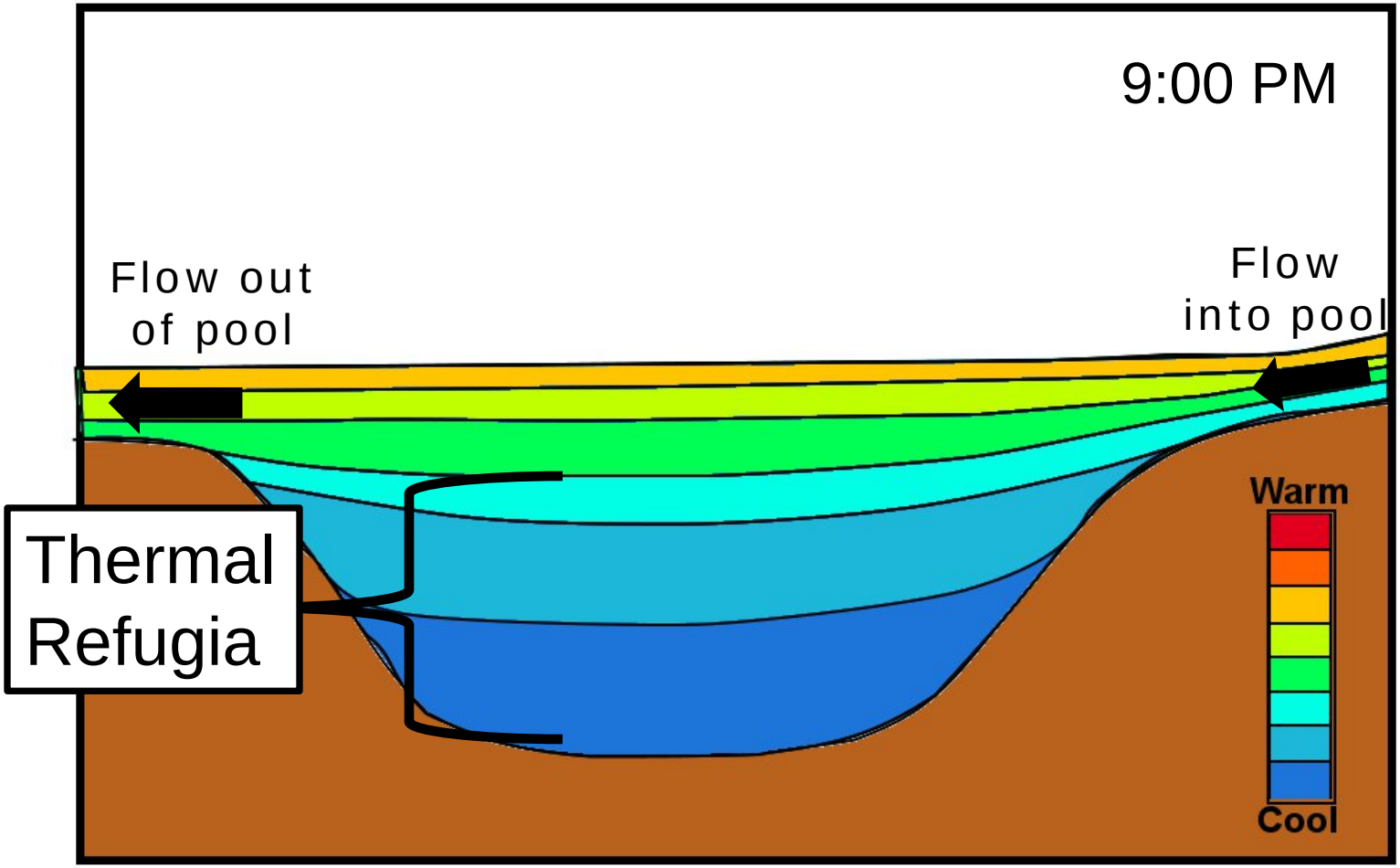

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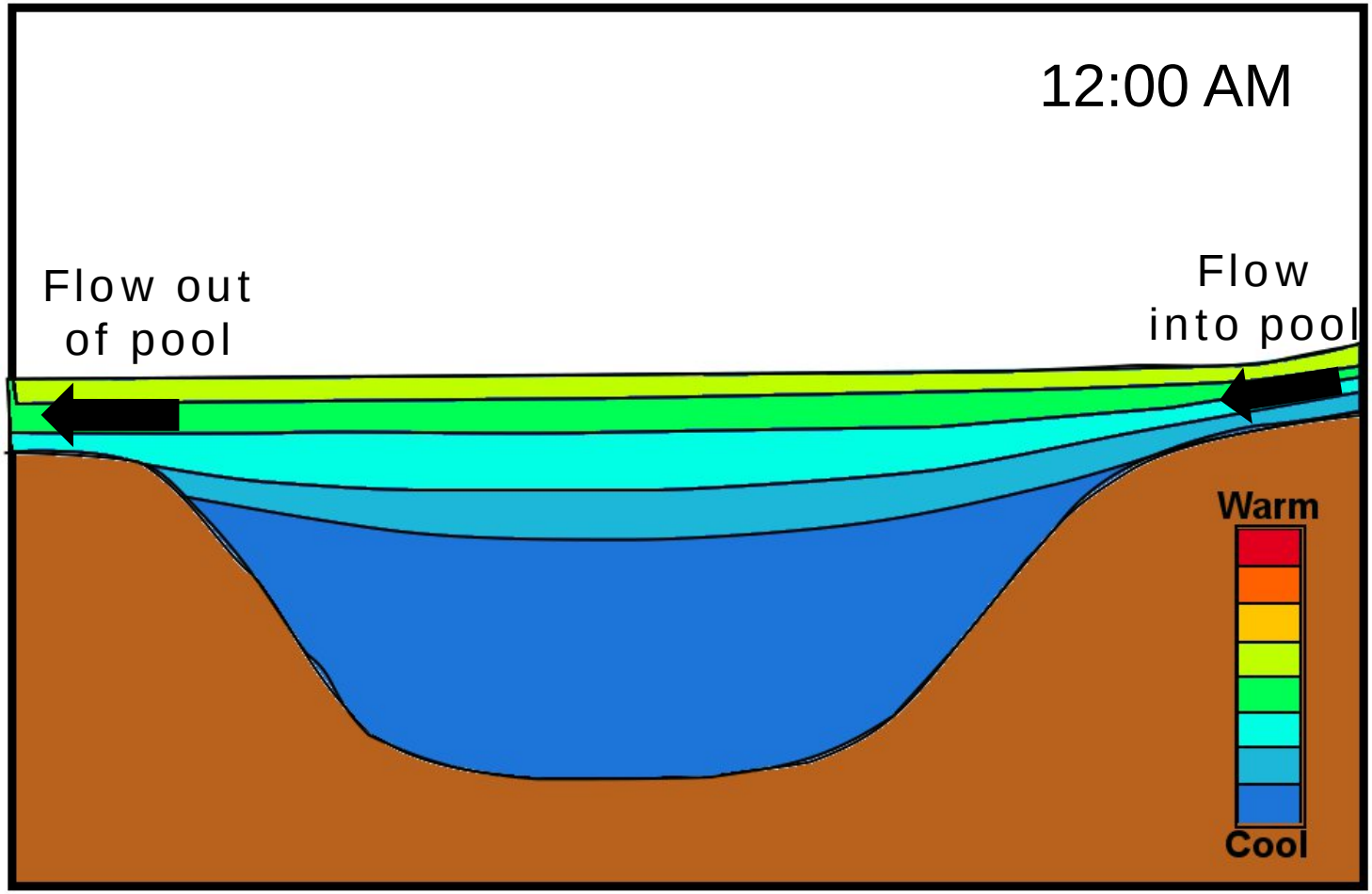
Thermal Stratification



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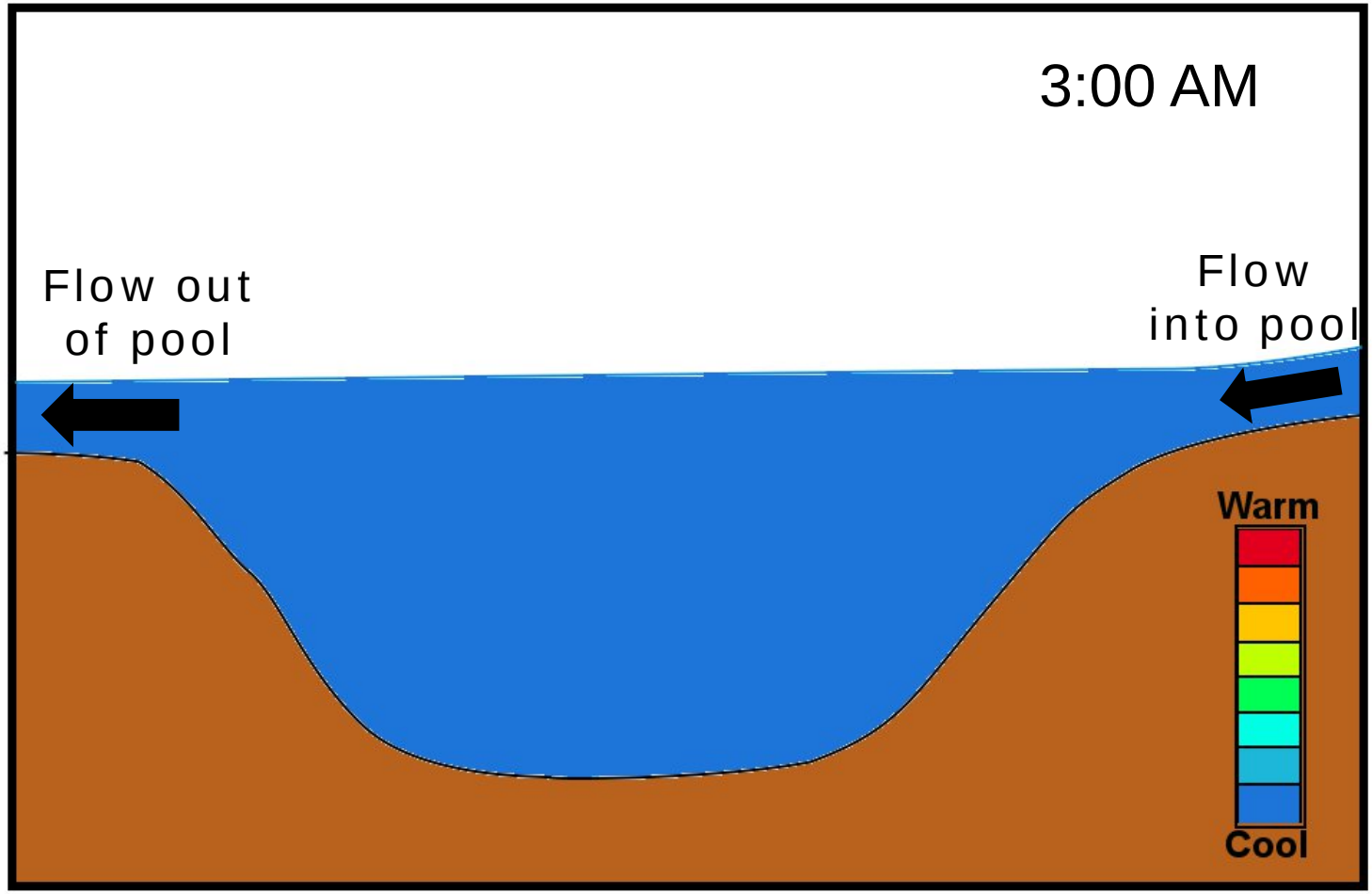
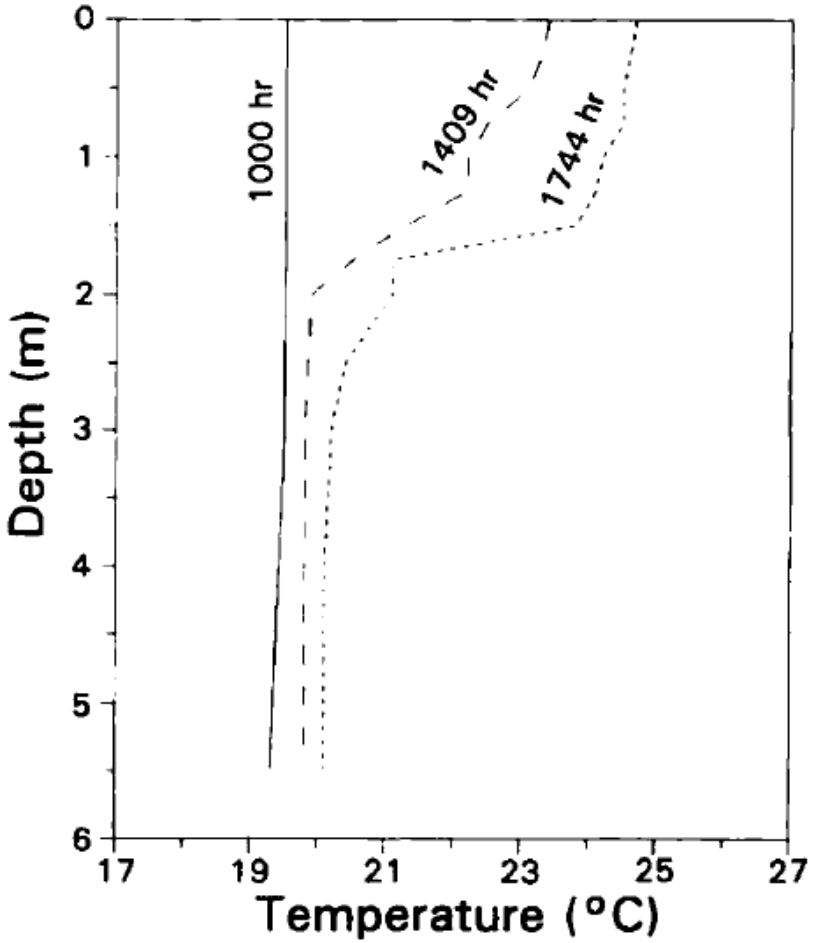
Thermal Stratification



Background

- Water temperature in pools varies in time and with depth
- Thermal stratification preserve cold water habitat at pool bottom



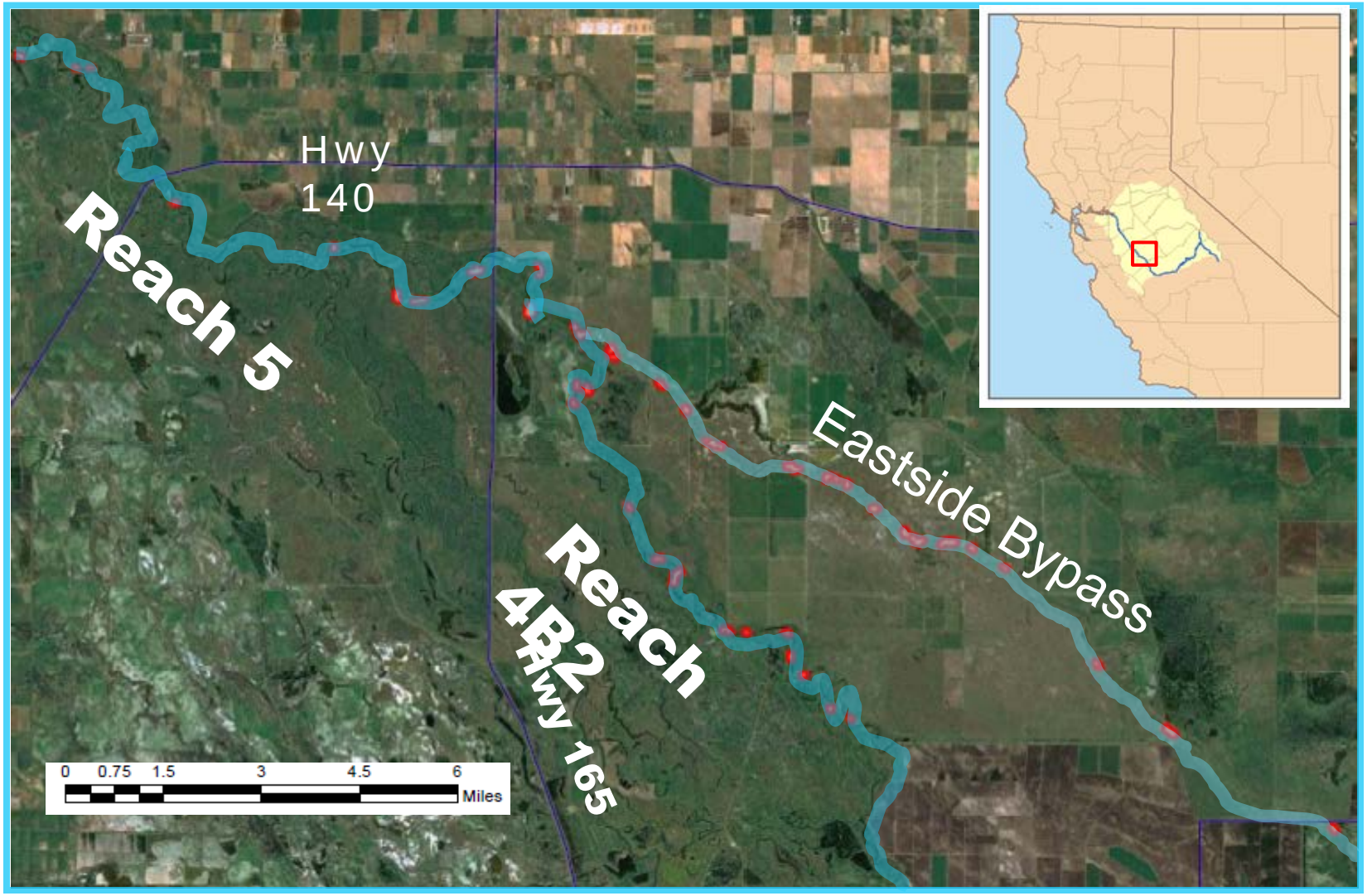
Nielsen and Lisle, *Trans. of Am. Fisheries* (1994)

Background

Thermal stratification is a temperature difference in the vertical water column

Thermal refugia is thermal stratification coupled with temperature tolerances that indicate cold water habitat for salmon

Study Location



METHODLOGY

Summer Thermal Refugia Survey

Fall Thermal Refugia Sites

Methodology

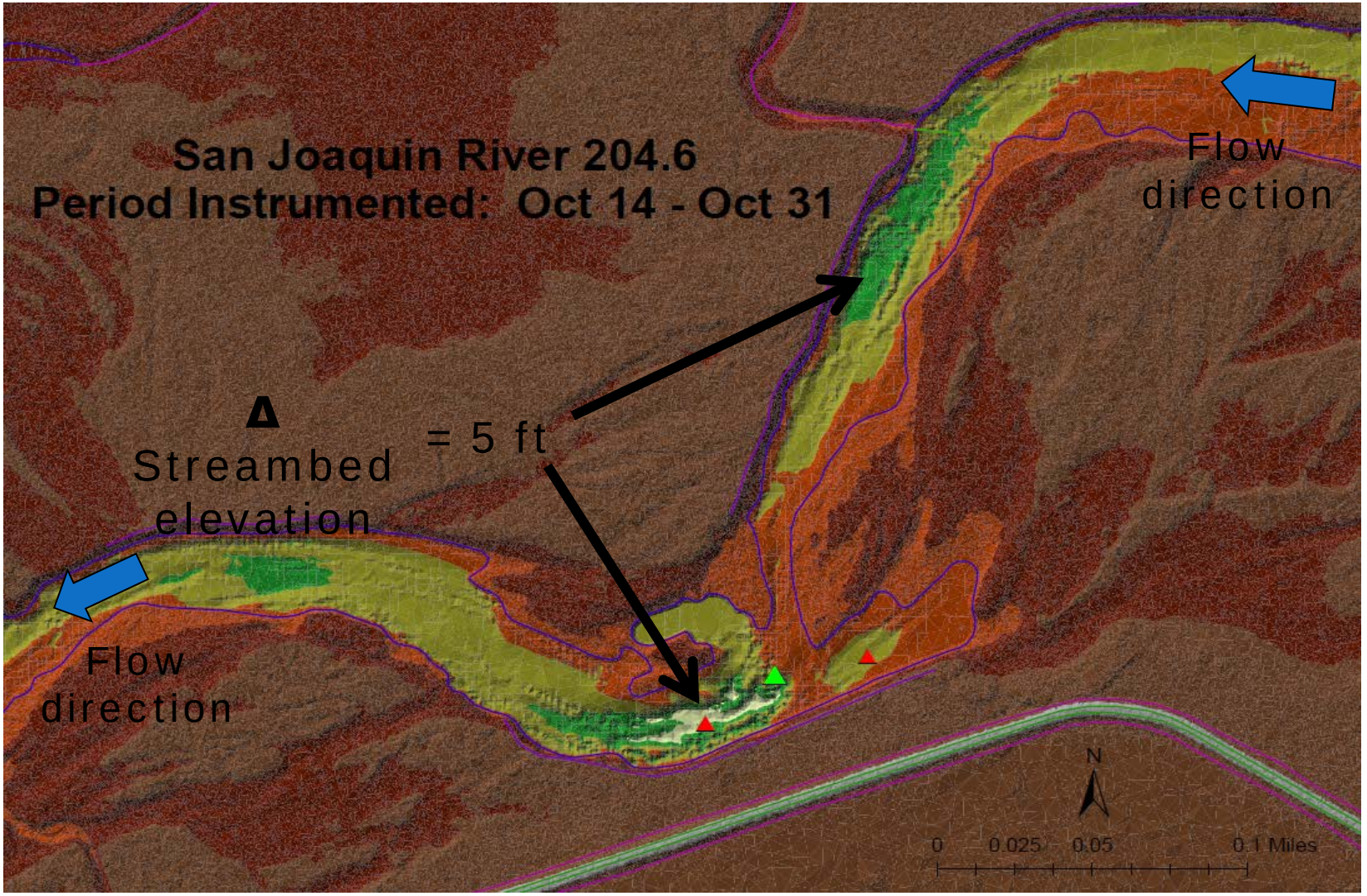
Summer Thermal Refugia Survey Study

- Pools identified from LIDAR and bathymetry data

- Pools with best potential for thermal refugia selected
  - change in streambed elevation
  - pool depth
  - pool shape

- Pools profiled from boat or canoe during July 2012
  - water temperature
  - water conductivity

Methodology



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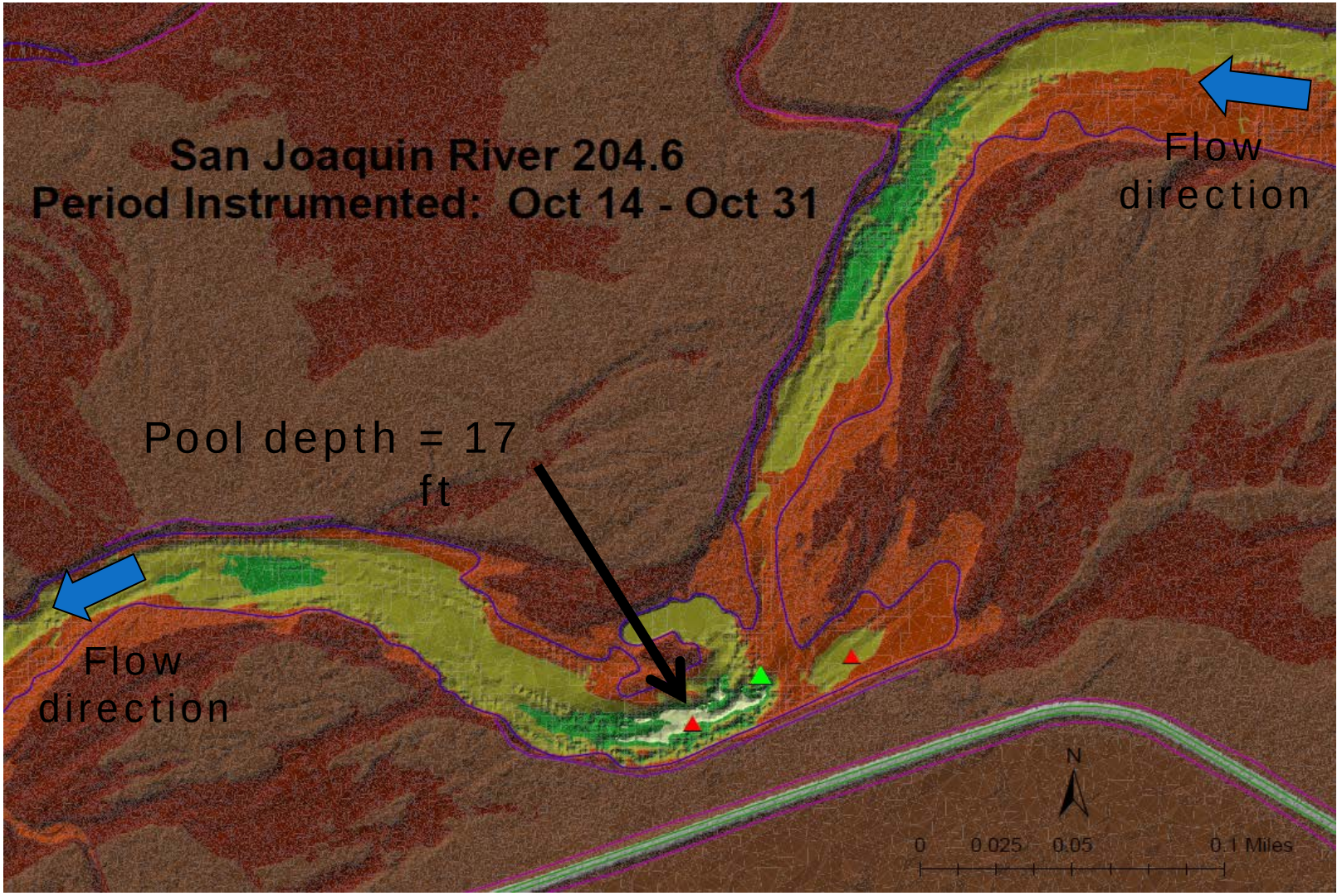

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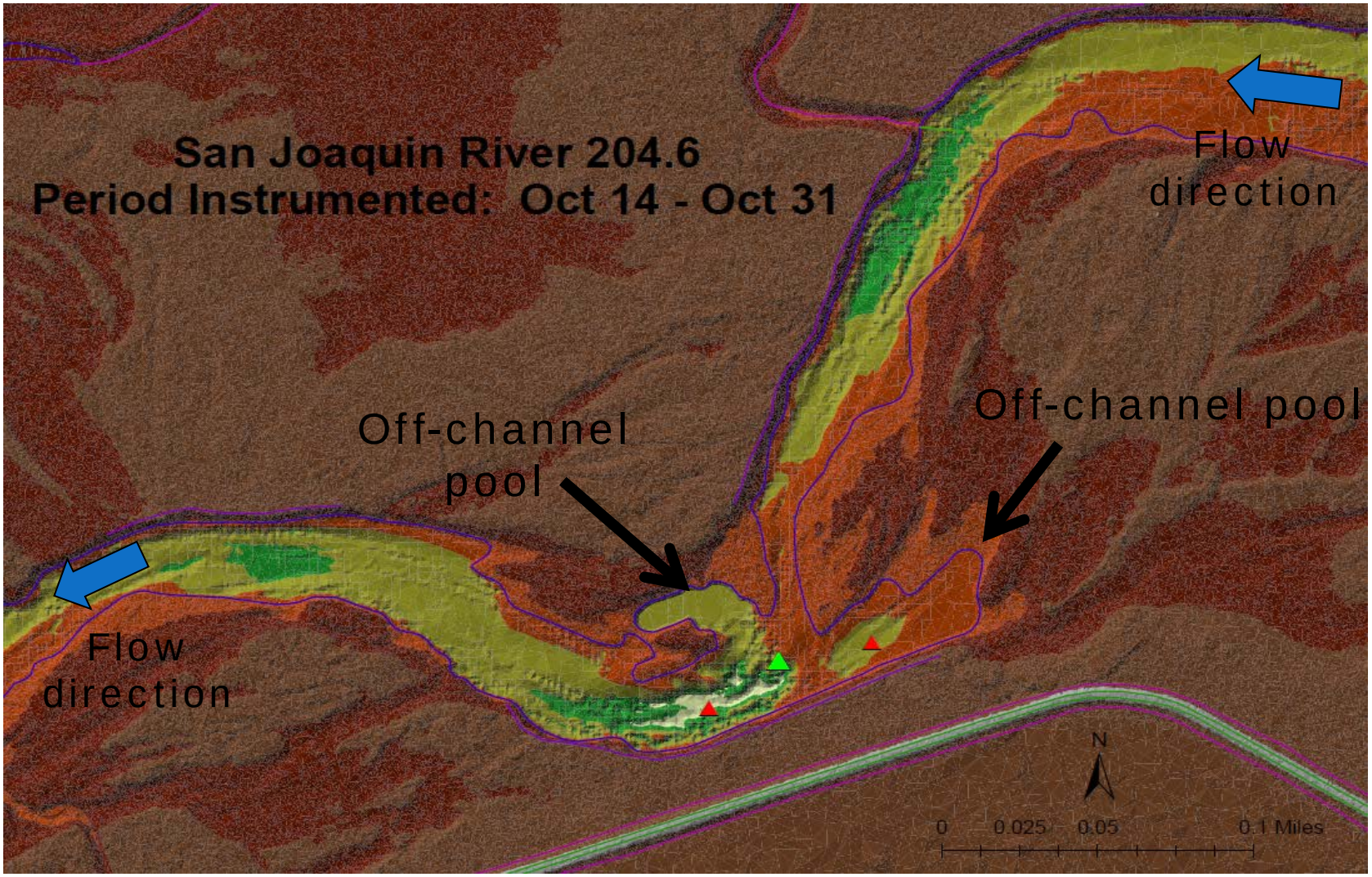

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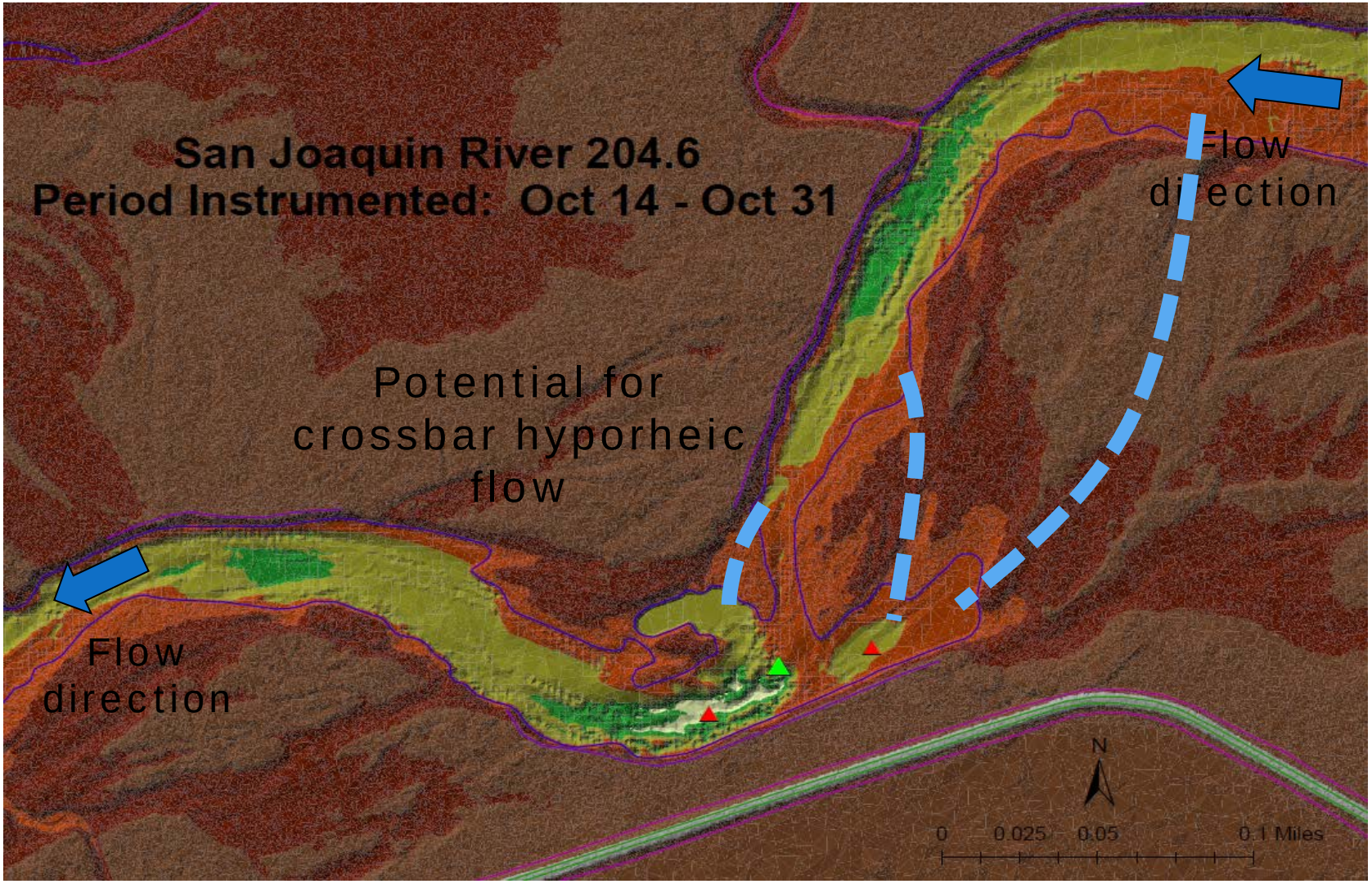
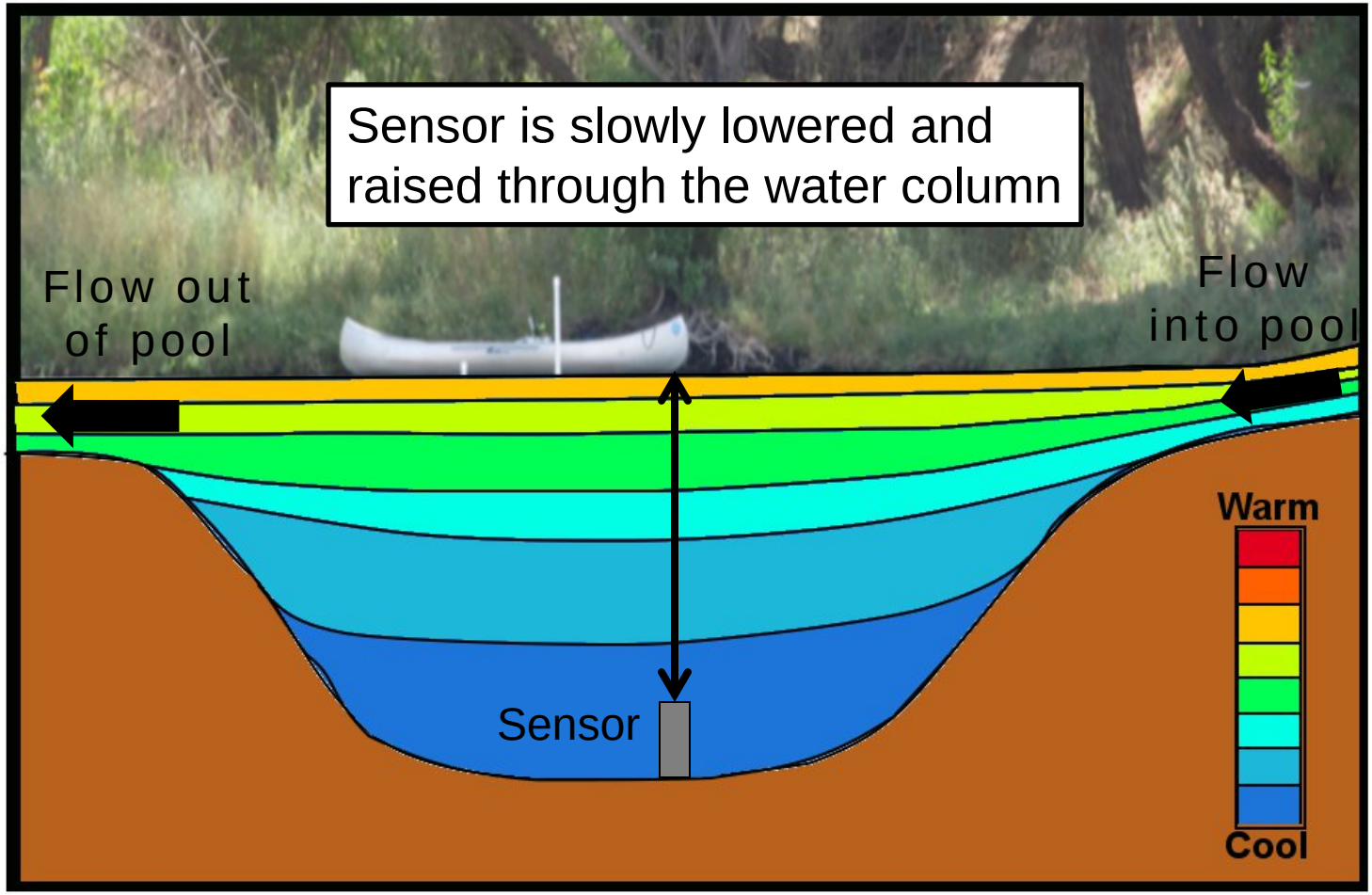


Background

Profiling Thermal Stratification

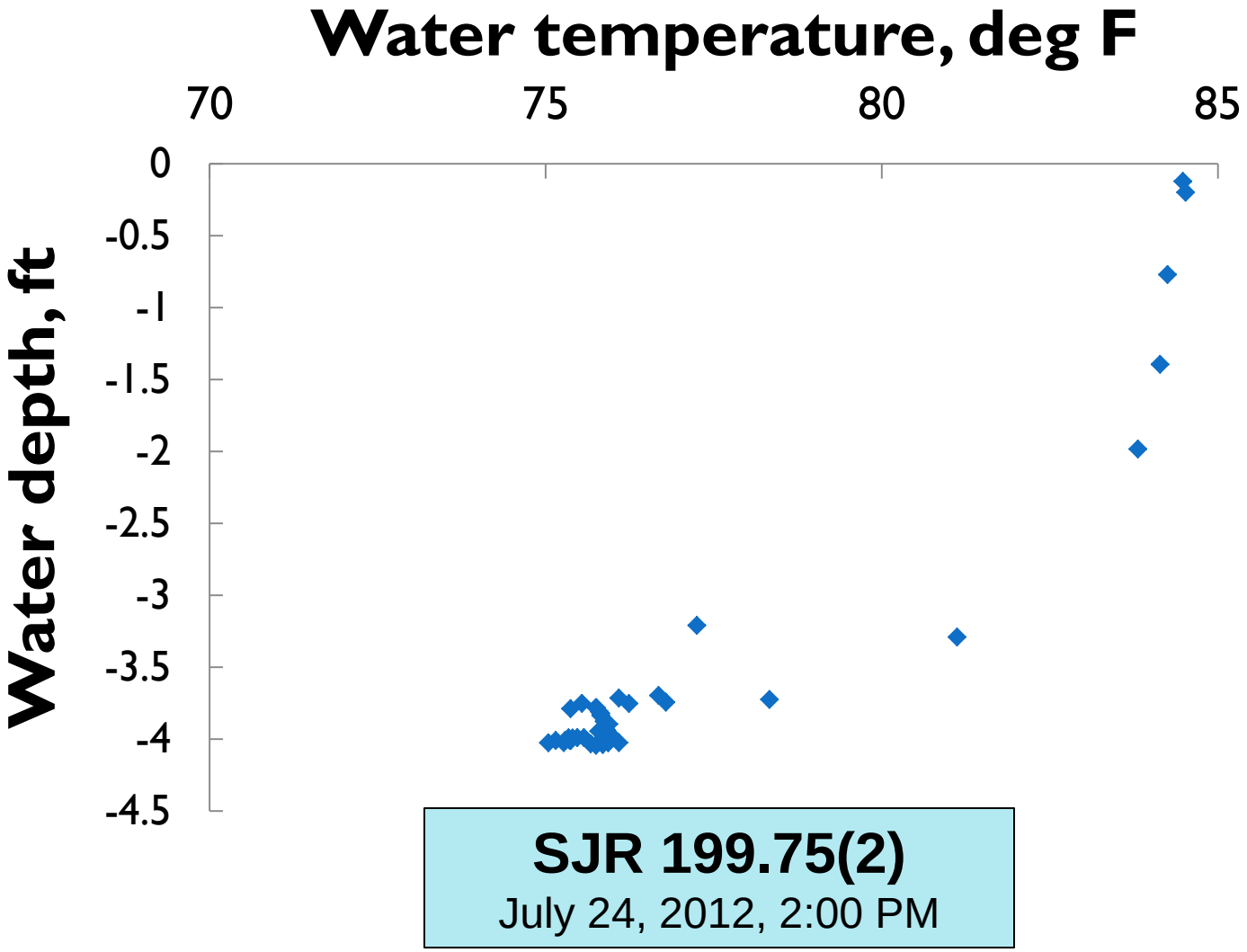


RESULTS

Summer Thermal Refugia Survey

Fall Thermal Refugia Sites

Summer Survey Results



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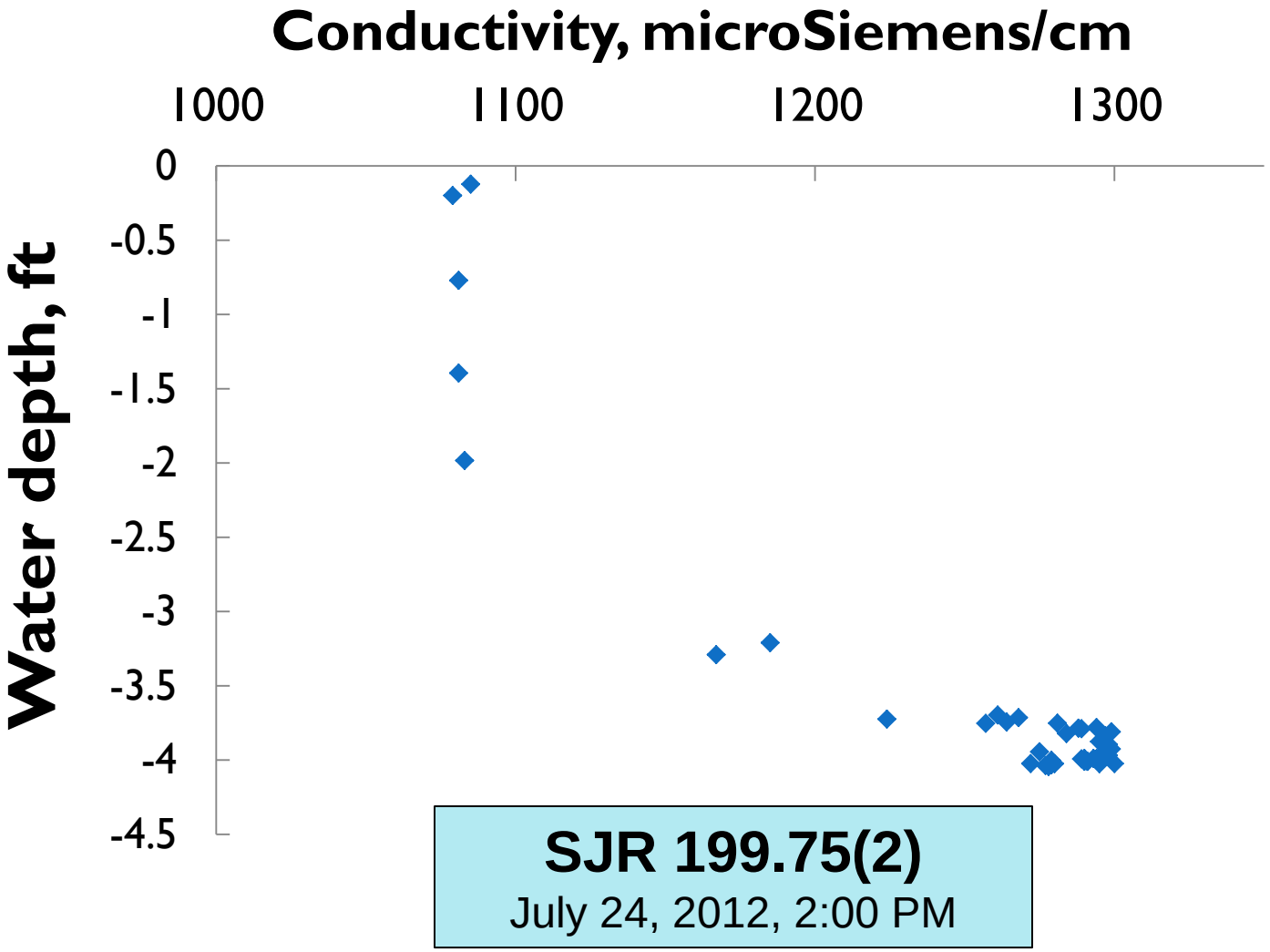
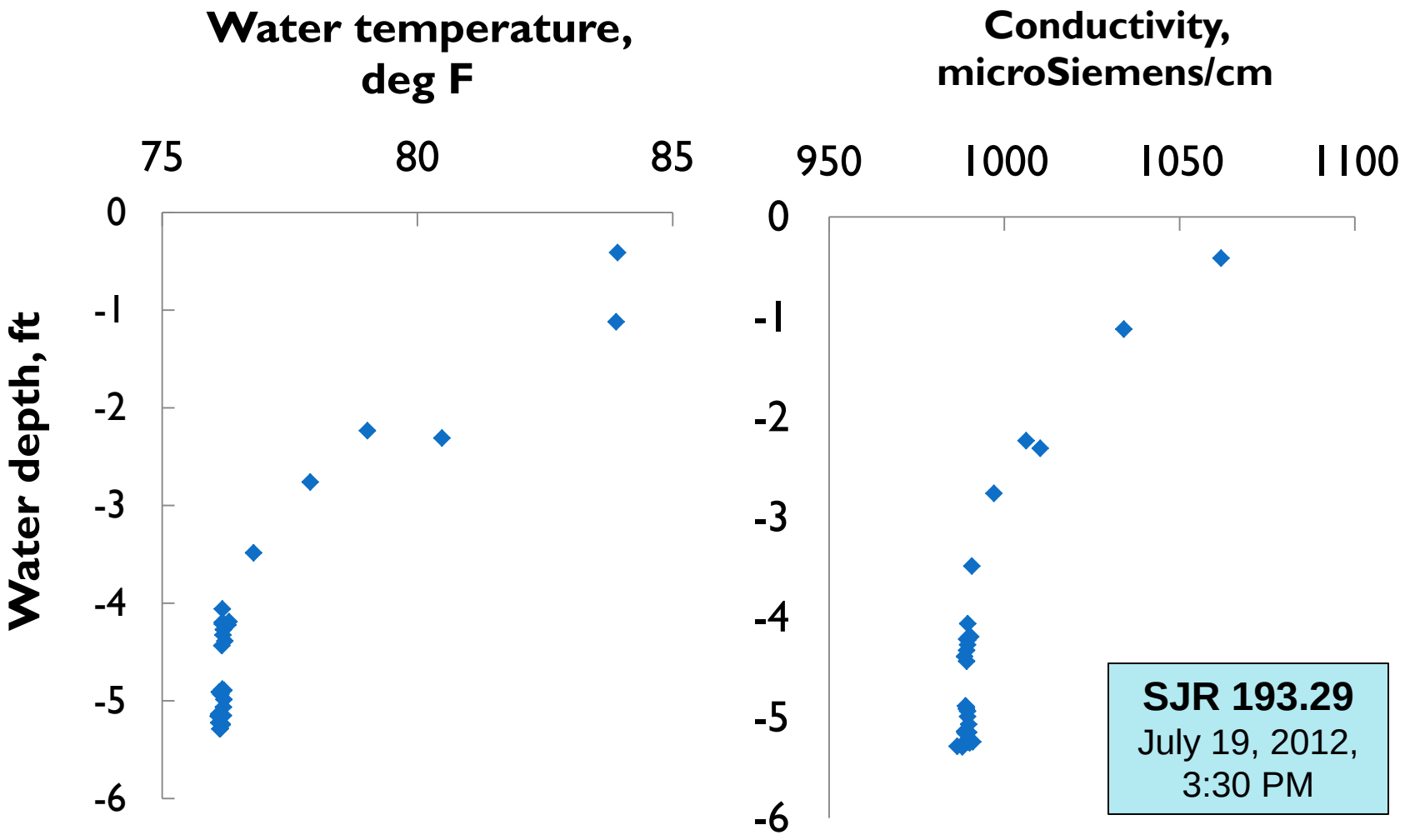


Summer Survey Results



Summer Survey Results

Avg. Distance Between Pools (miles)

	Eastside Bypass	Reach 4B2	Reach 5
Pools $T_{min} \leq 70$ °F	-	-	3.7
Pools $T_{min} \leq 75$ °F	1.1	2.4	2.4
Pools $T_{min} \leq 80$ °F	0.7	0.5	1.1

Summer Survey Results

- Maximum distance between pools with thermal refugia is important because that can indicate if thermal barriers exist for migration

- For pool with $T_{min} \leq 75$ °F

ESB $_{\text{max distance}}$	~ 4 miles
Reach 4B2 $_{\text{max distance}}$	~ 7 miles
Reach 5 $_{\text{max distance}}$	~ 4 miles

Summer Survey Results

Eastside Bypass 28.32

Temperature at water surface = 76 °F

Temperature at pool bottom = 71 °F

Summer Survey Results

Eastside Bypass 28.32

Temperature at water surface = 76 °F

Temperature at pool bottom = 71 °F

Summer Survey Results

Take home messages

Thermal stratification is frequently found in pools in the Eastside Bypass, Reach 4B2, and Reach 5

Minimum water temperatures in pools average 75°F ± 3°F, while ambient surface water temperatures average 83°F ± 3°F.

Eastside Bypass had more cool pools more frequently than Reach 4B2 or Reach 5, but it's pools were not connected.

Distances between thermally stratified pools in Reach 4B2 and Reach 5 may result in thermal barriers in the summer.

METHODLOGY

Summer Thermal Refugia Survey

Fall Thermal Refugia Sites

Methodology

Fall Thermal Refugia Site Study

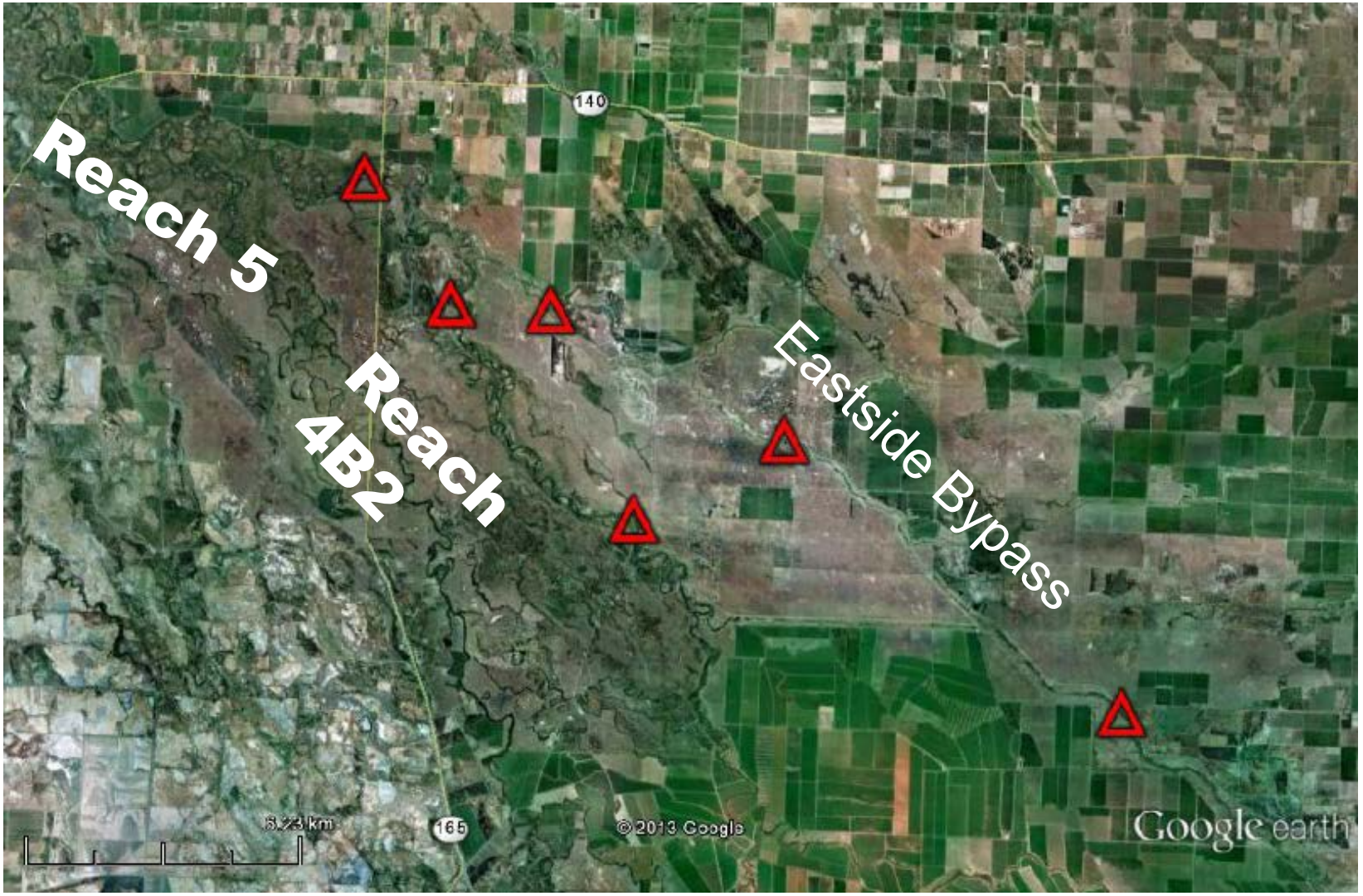
- Six pool-riffle-pool sites from summer survey selected

- Pools instrumented with sensor arrays that measured
  - Water temperature
    - In the pool
    - In the ground below the pool
  - Pressure (water depth)
  - Conductivity

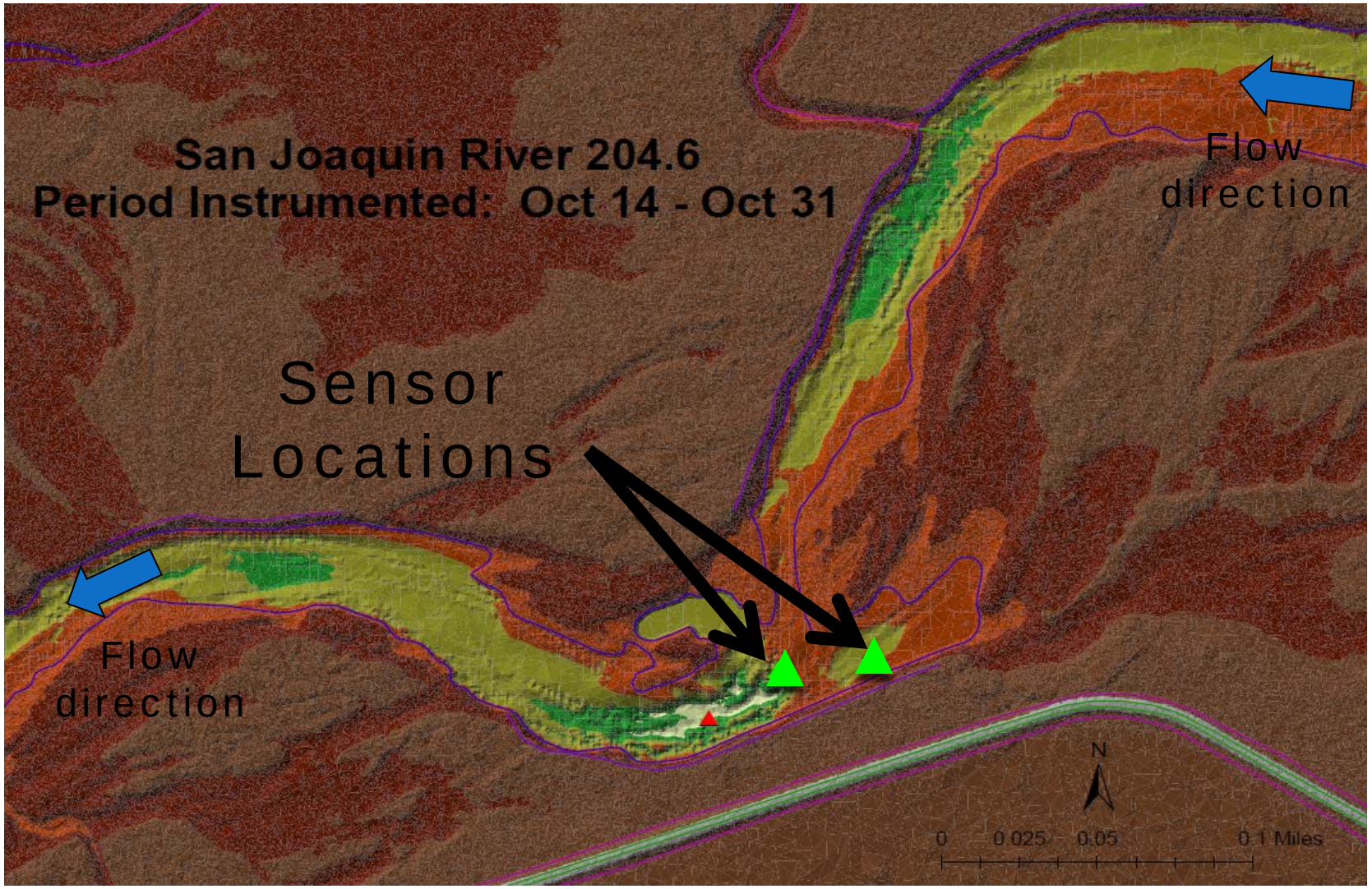
- Sensors recorded every 15 minutes for 2 weeks

- Sensors checked for consistency and data quality

Methodology

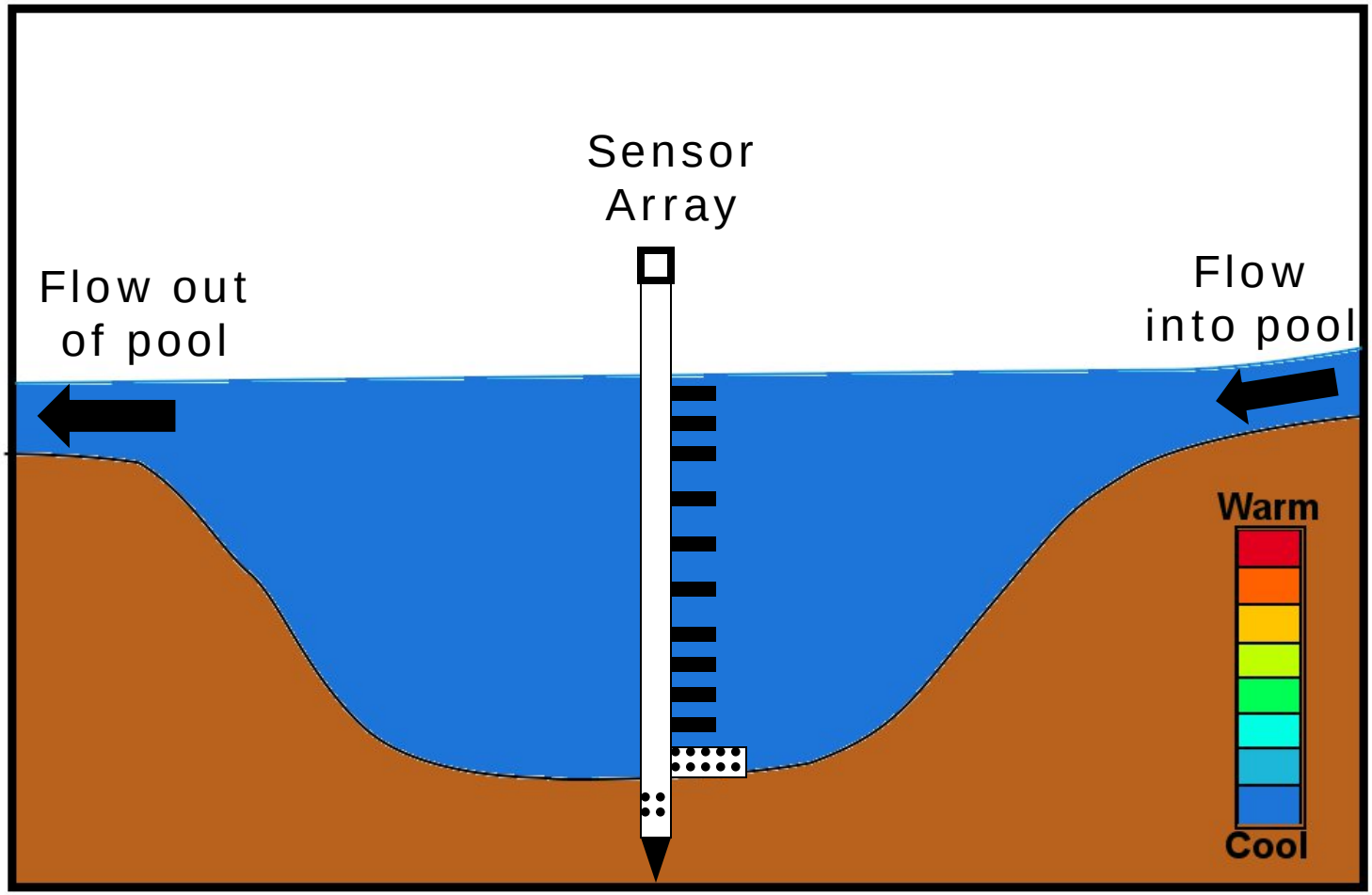


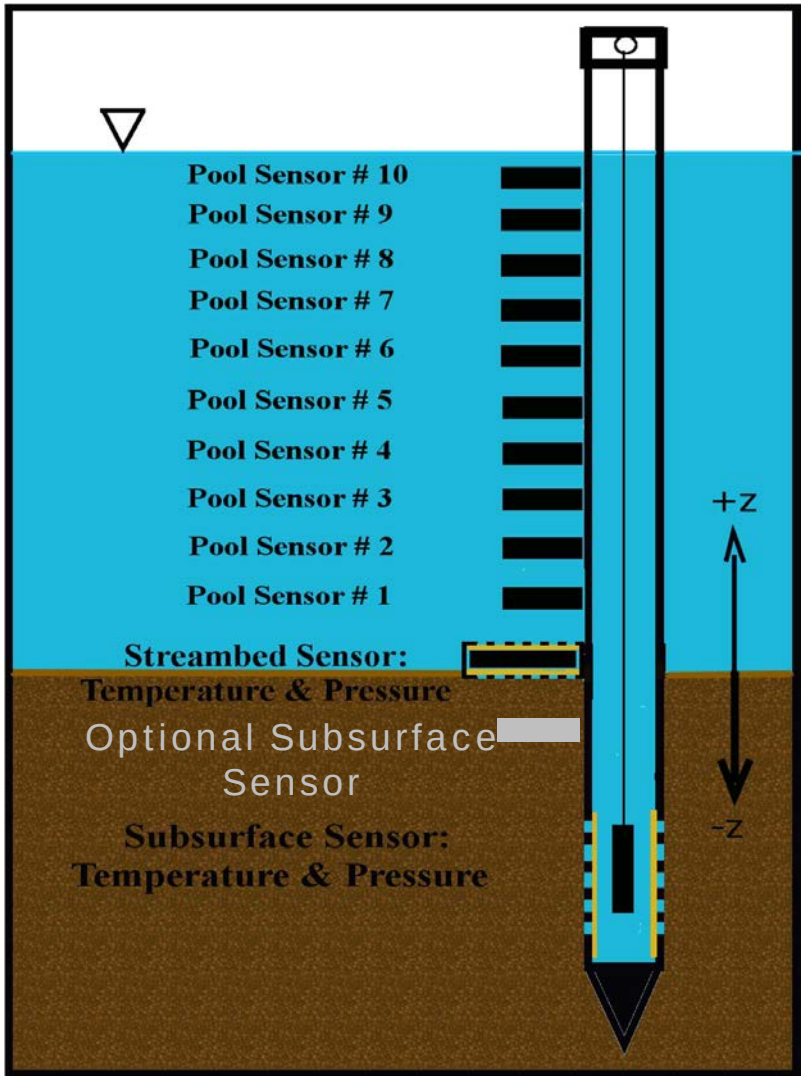
Methodology



Background

Sensor Array Placement

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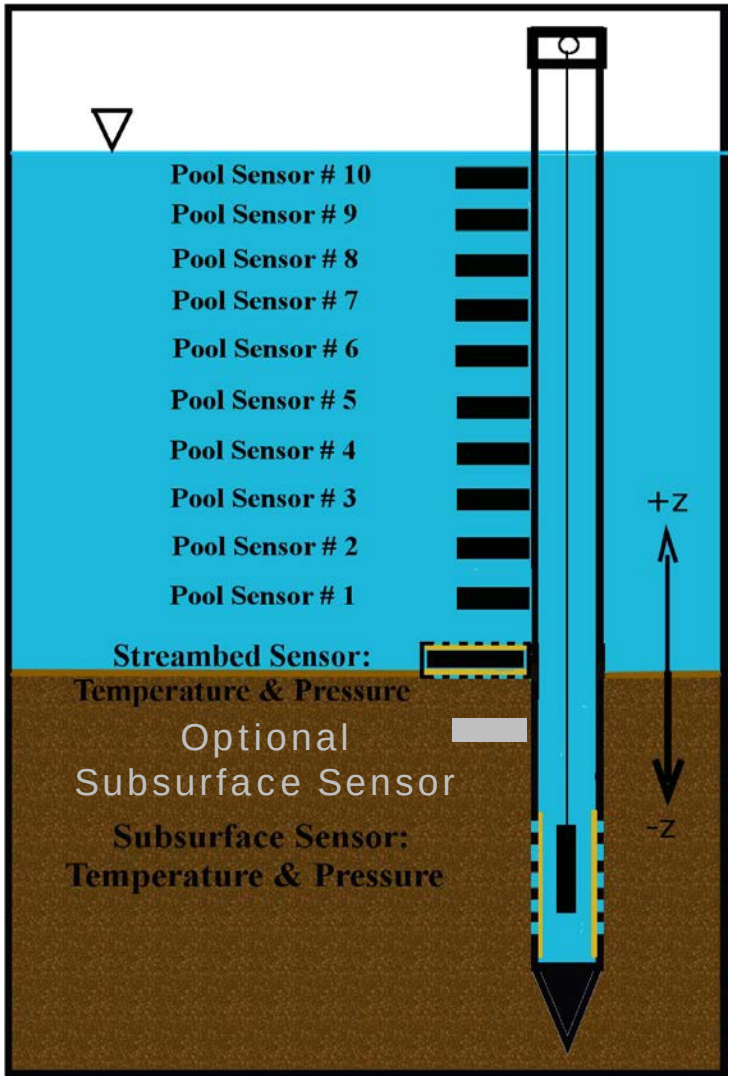
Pool Sensor # 9
Pool Sensor # 8
Pool Sensor # 7
Pool Sensor # 6
Pool Sensor # 5
Pool Sensor # 4
Pool Sensor # 3
Pool Sensor # 2
Pool Sensor # 1
Streambed Sensor:
Temperature & Pressure
Optional Subsurface Sensor
Subsurface Sensor:
Temperature & Pressure
+z
-z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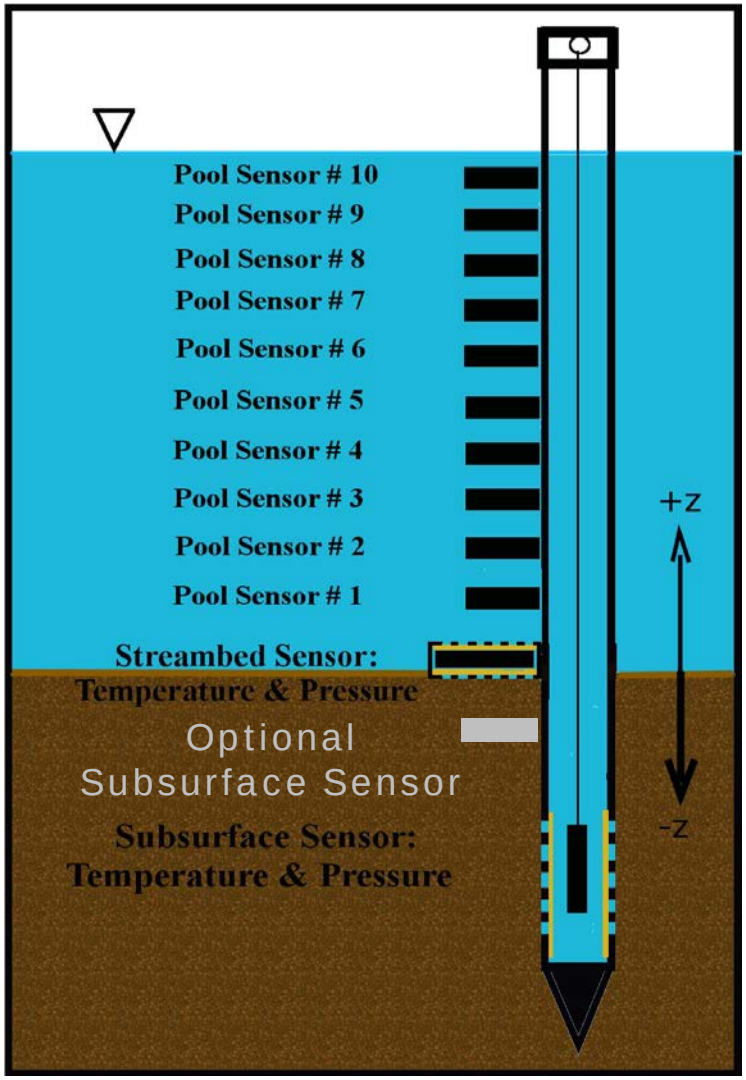
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Methodology

Methodology

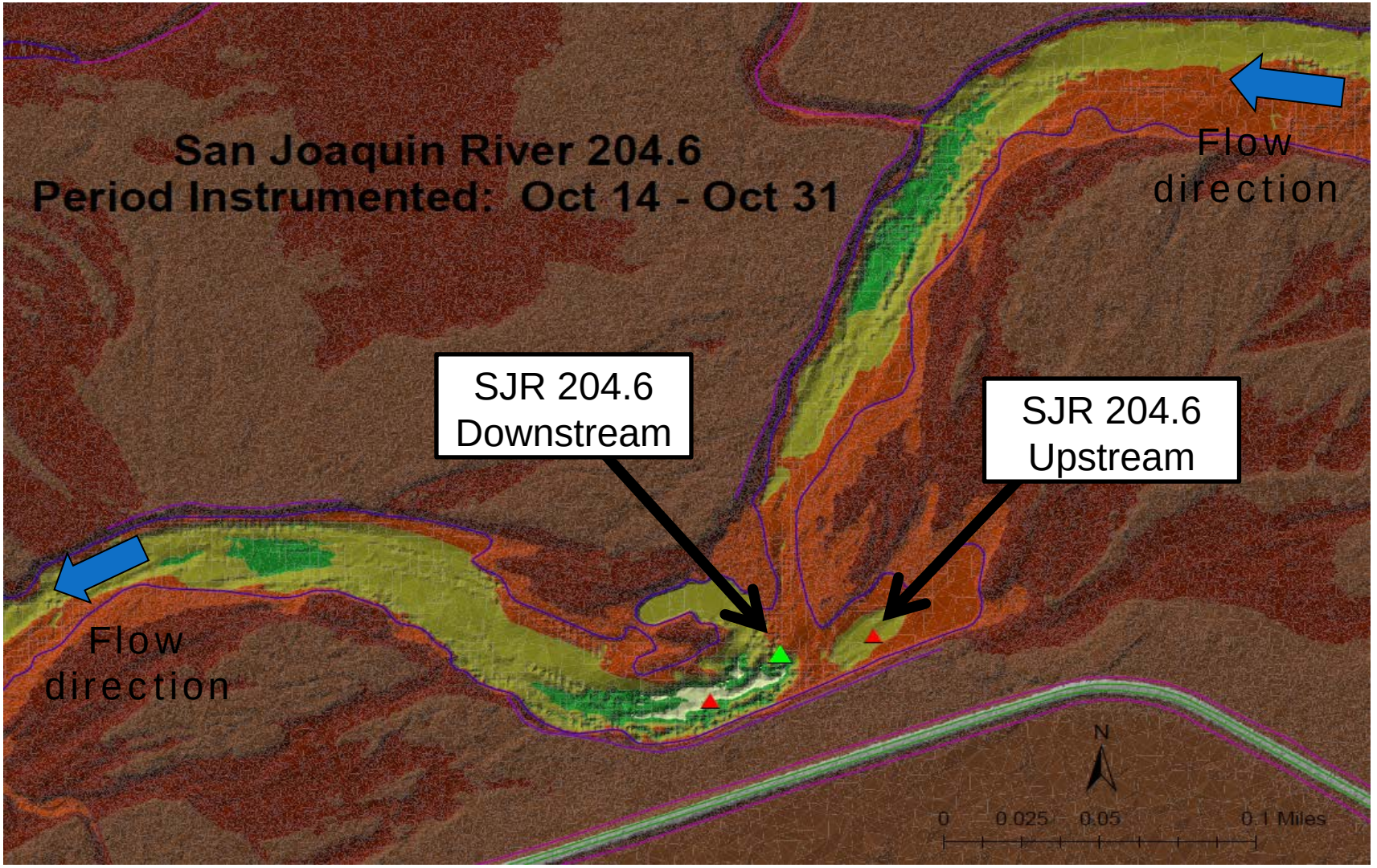
Methodology

RESULTS

Summer Thermal Refugia Survey

Fall Thermal Refugia Sites

Fall Thermal Refugia Results



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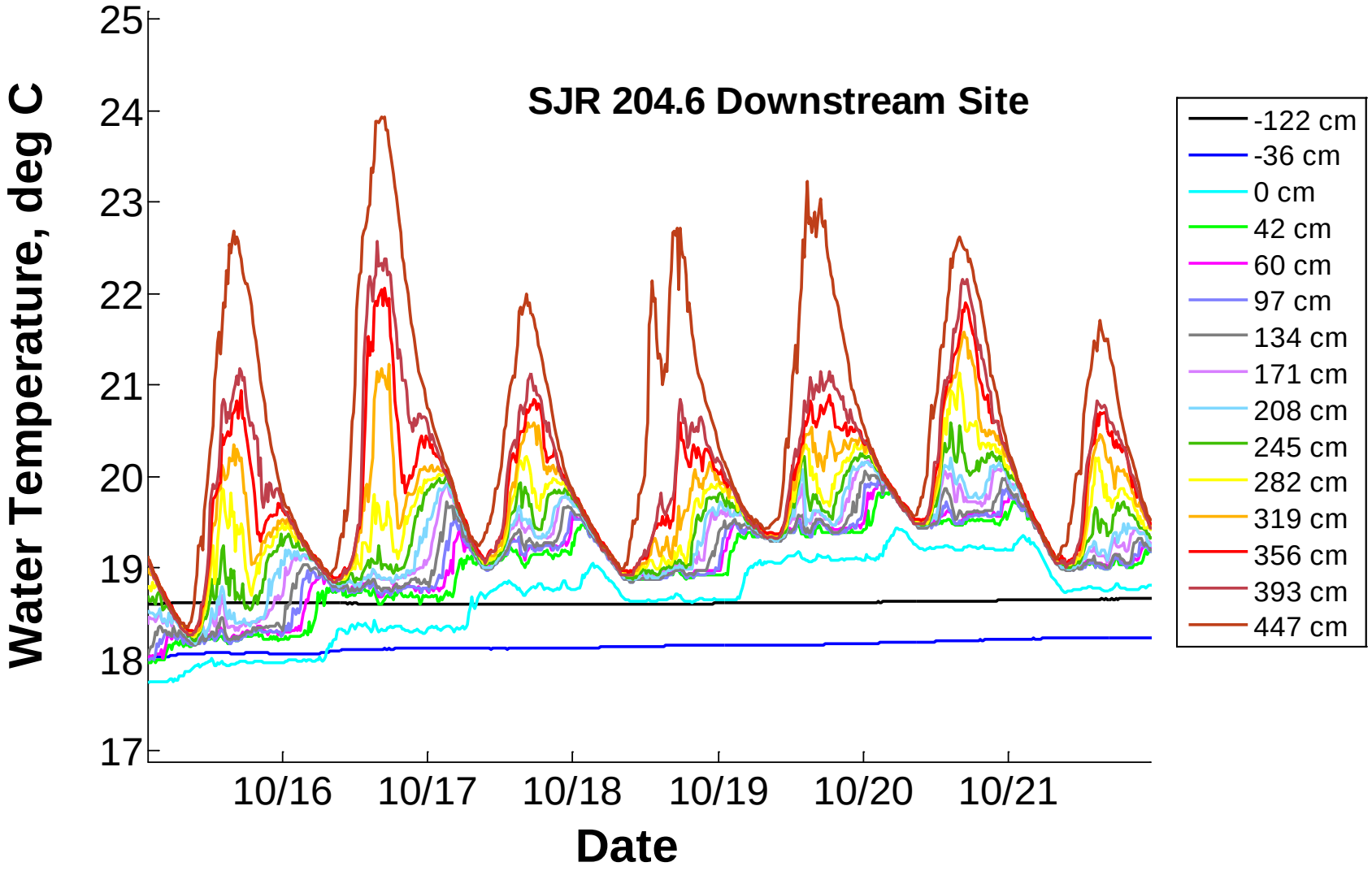

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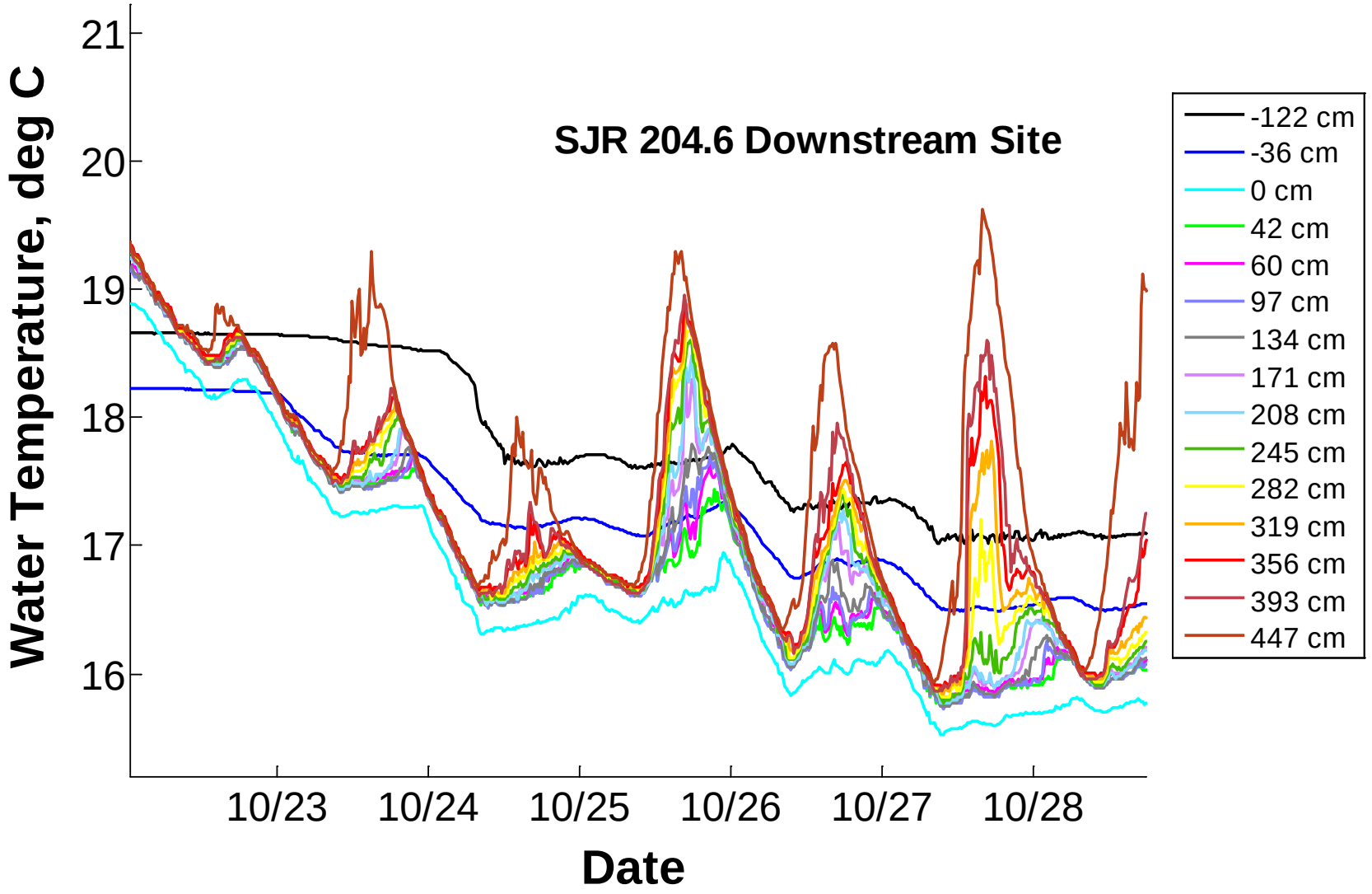

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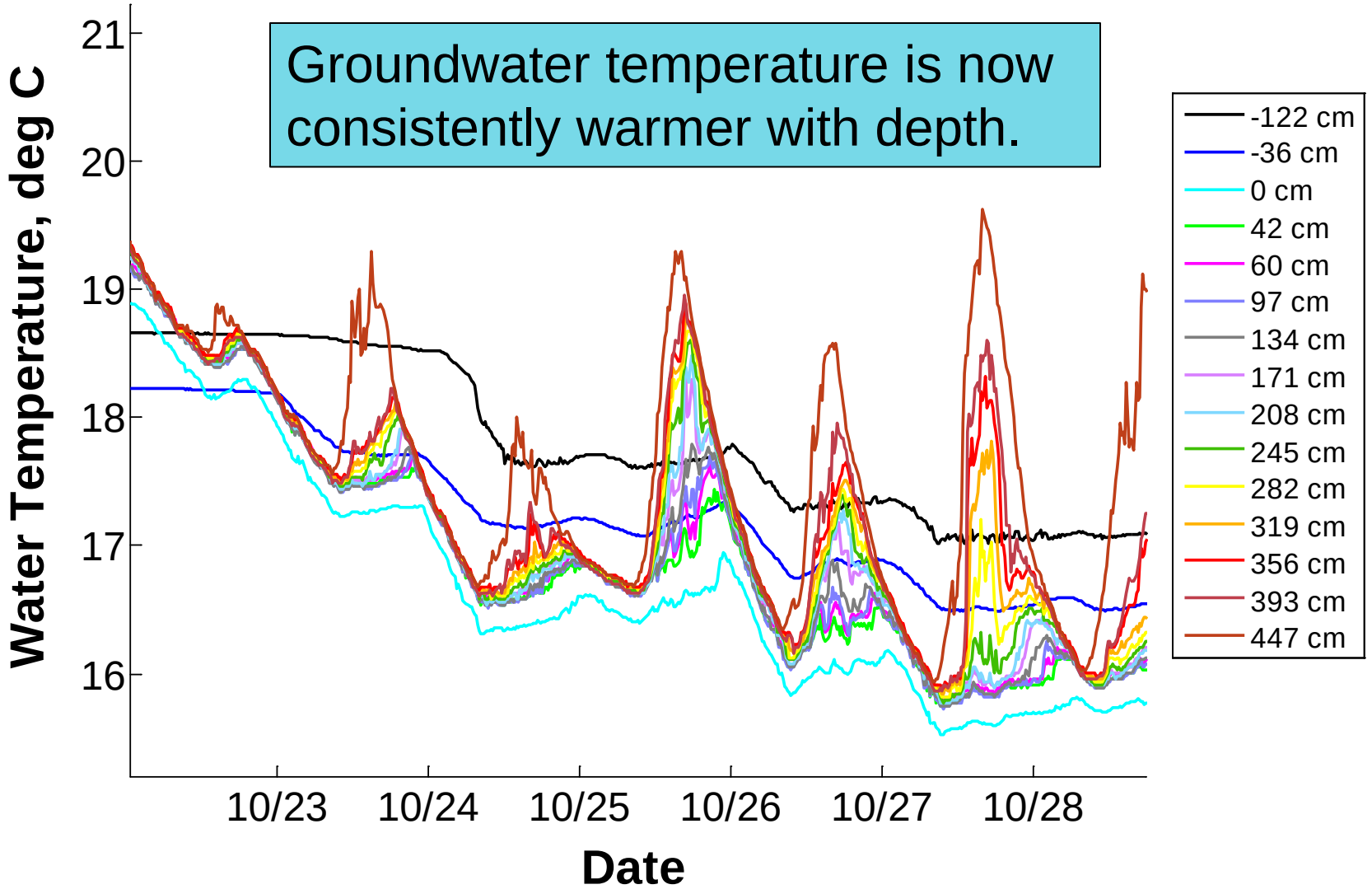
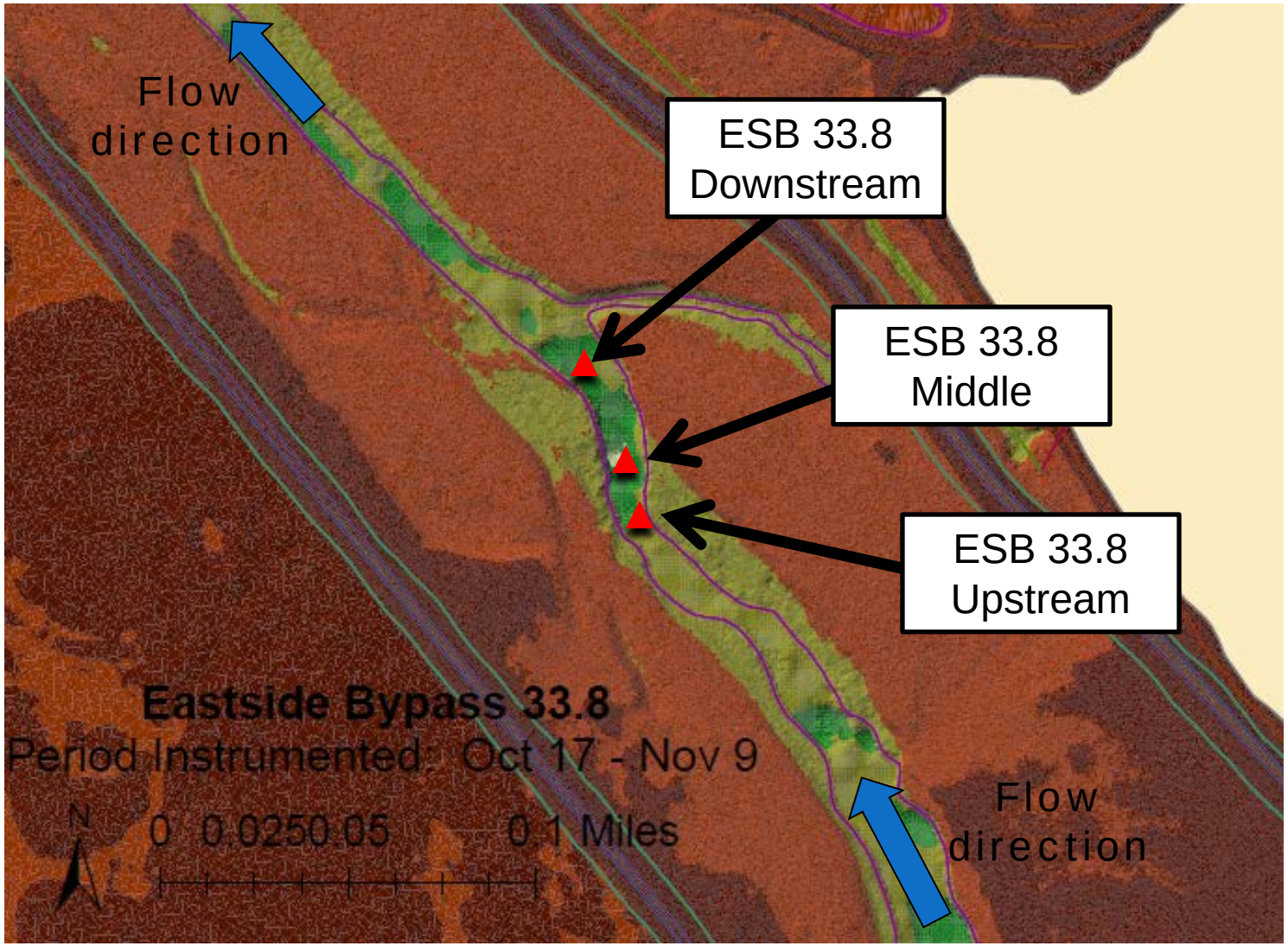


Fall Thermal Refugia Results

Key Observations – Reach 4B2 & Reach 5

- Pool stratification develops each day then mixes overnight
- Not all pools stratify
- Pool stratification can provide thermal refugia
- Groundwater temperatures vary from site to site and over the course of weeks. Deep groundwater is frequently warmer than the pool minimum temperature
- Degree of stratification varies from day to day

Fall Thermal Refugia Results



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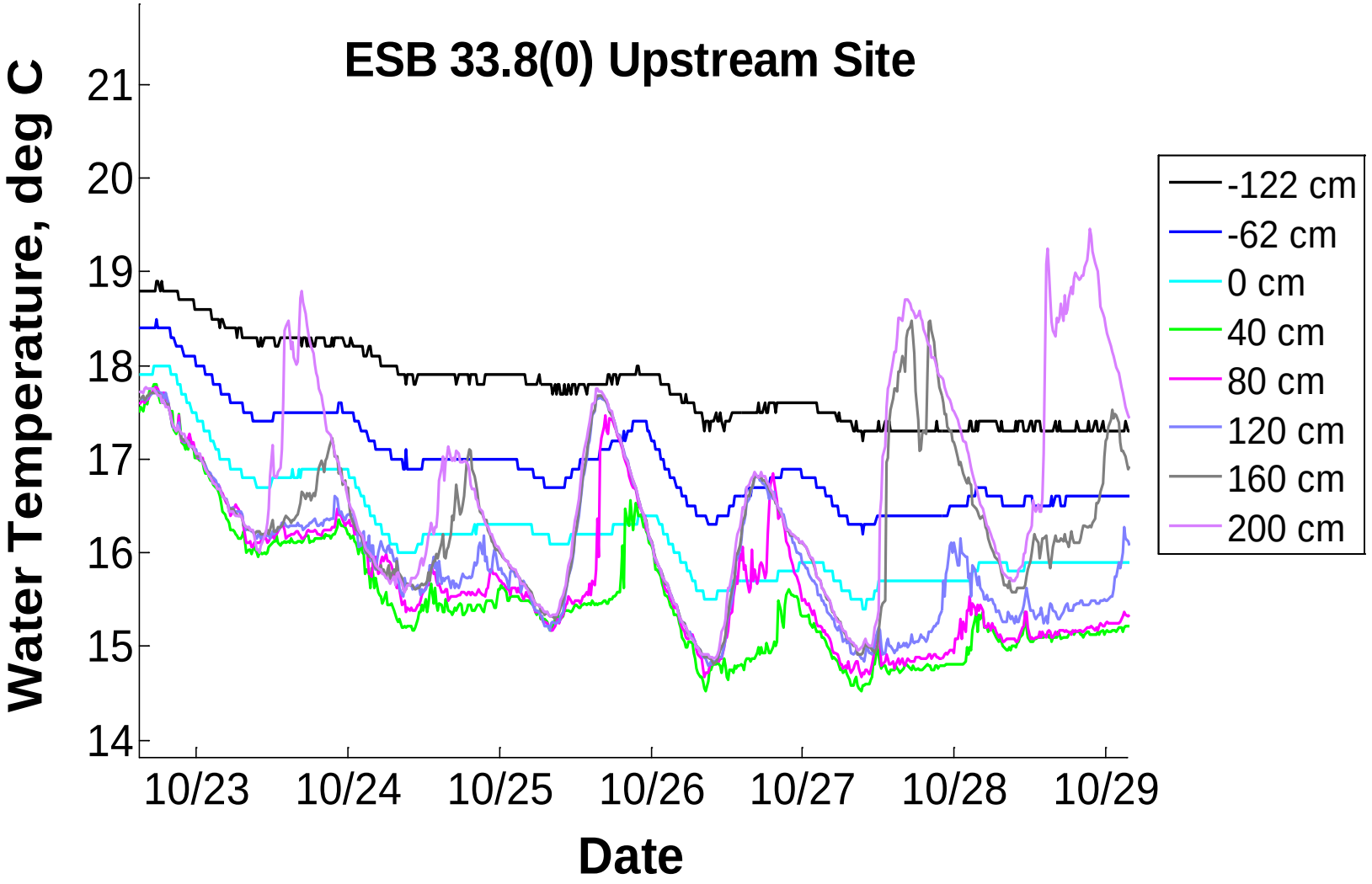

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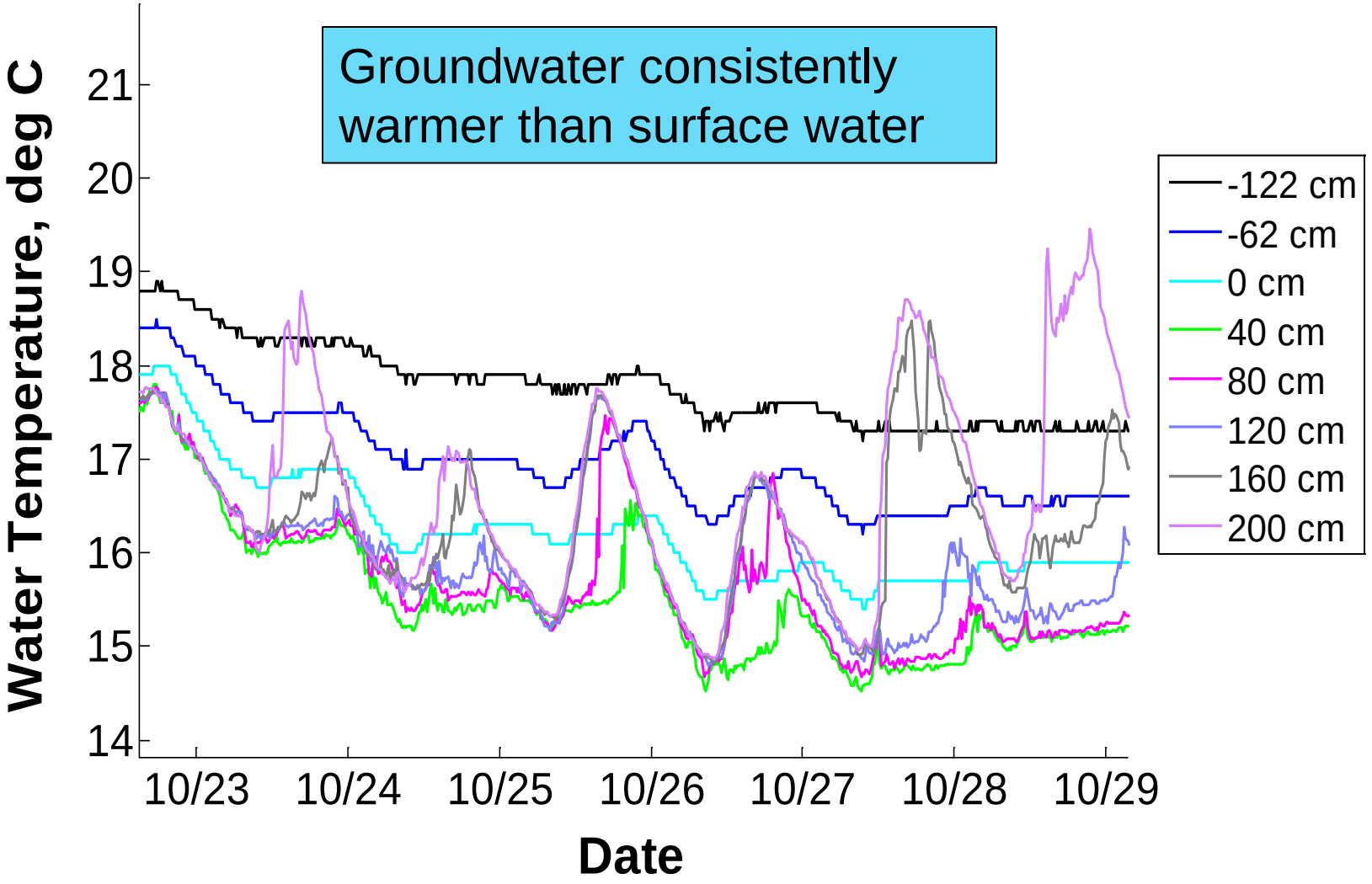

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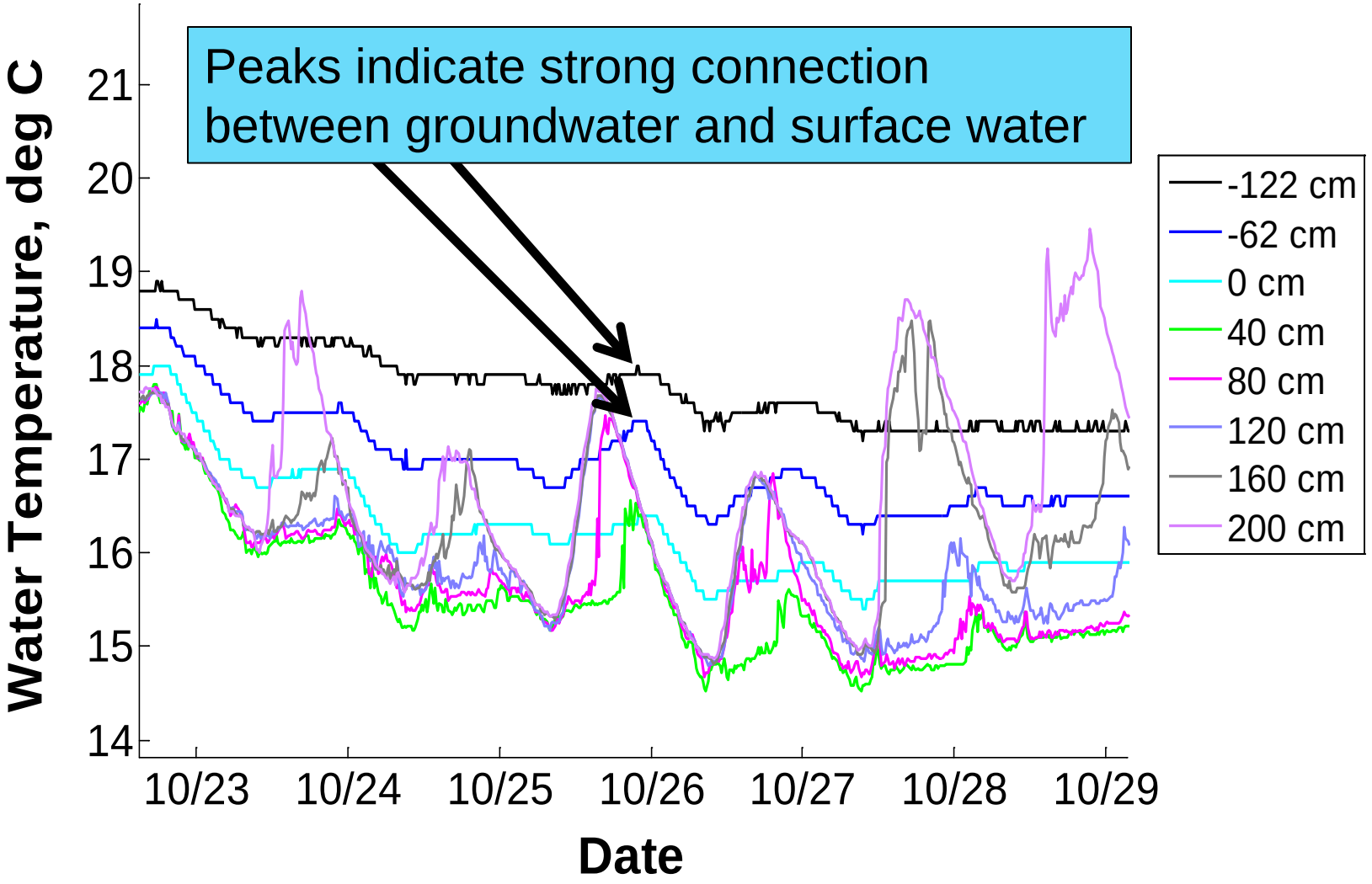

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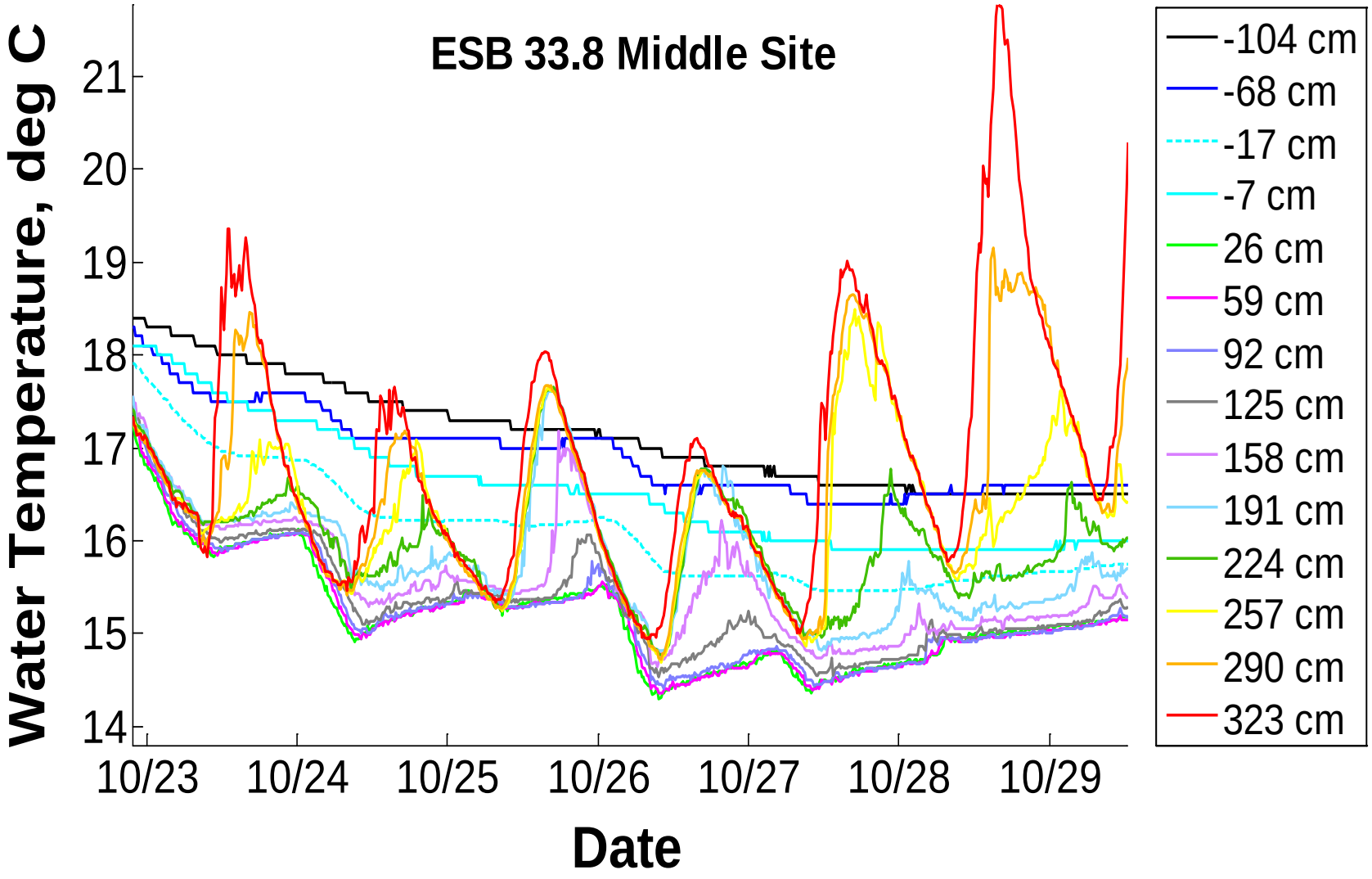

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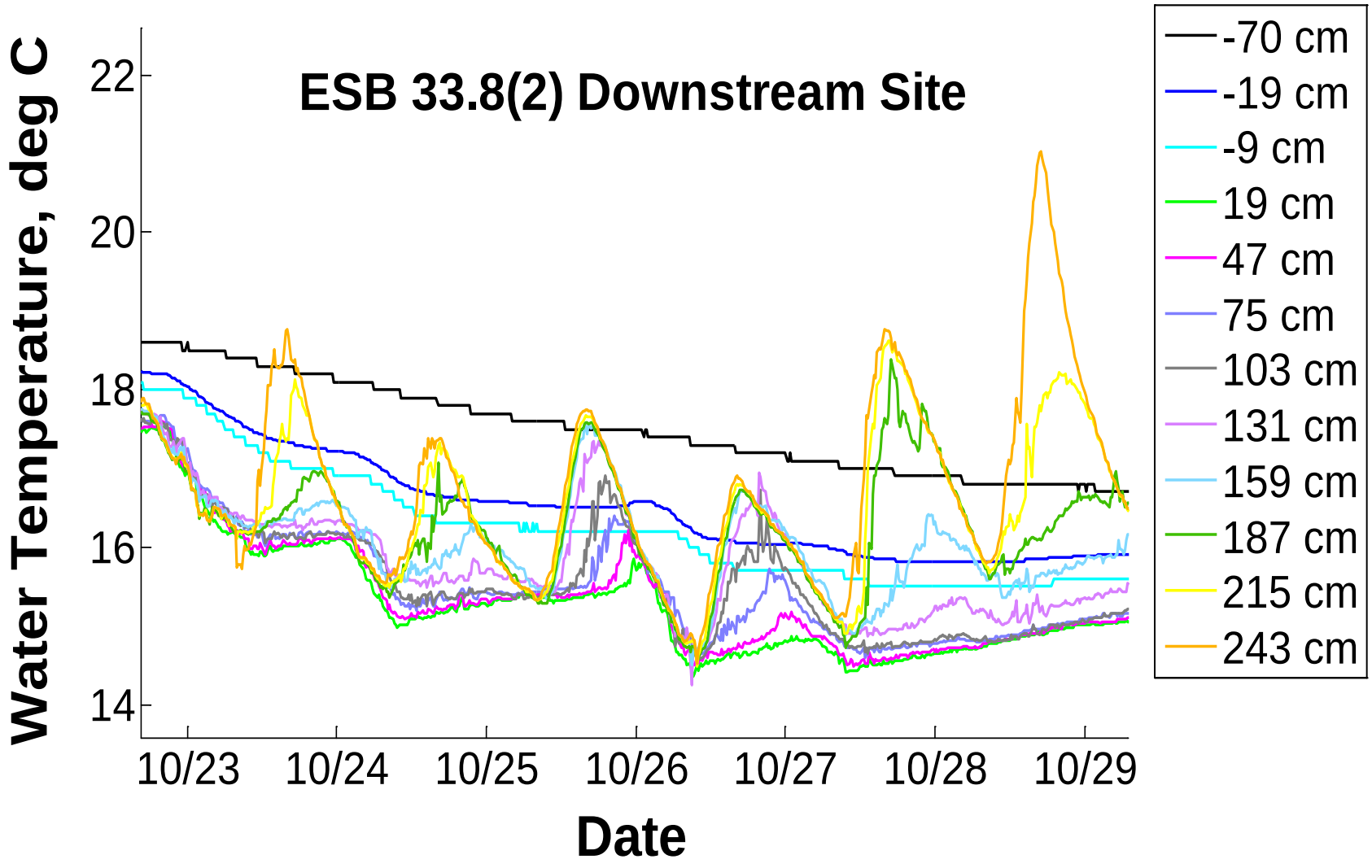


Fall Thermal Refugia Results

Key Observations – Eastside Bypass

- Pool stratification develops each day then mixes overnight
- Stratification depth is consistent throughout the pool
- Pool stratification can provide significant thermal refugia
  Pool bottom temperatures remain near 15 °C even when pool surface temperature approaches 21 °C
- Water temperature increases with depth into the ground
- Degree of stratification varies from day to day

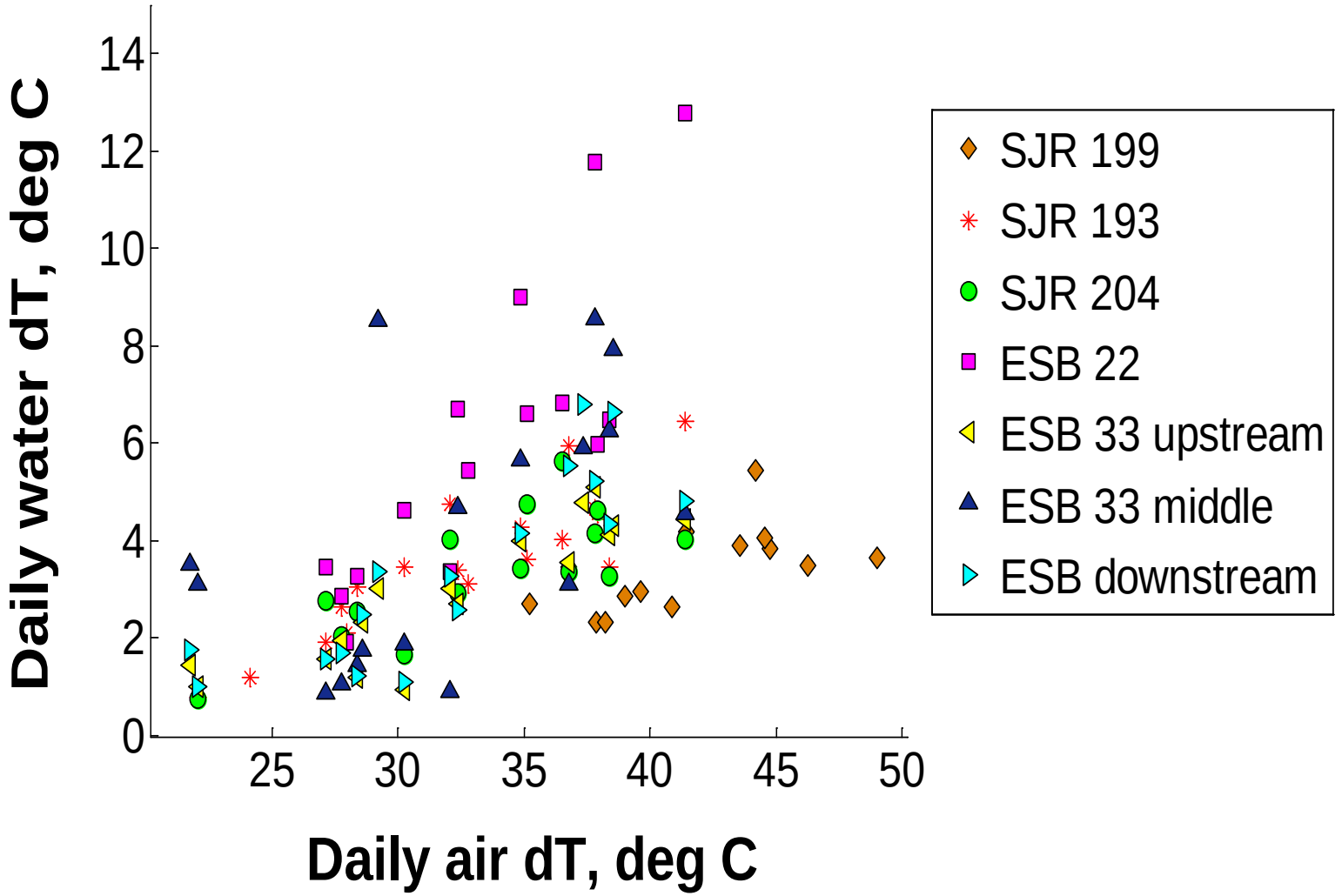
Fall Thermal Refugia Results

Consistency of daily variation in thermal stratification for pools in both the Eastside Bypass, Reach 4B2, and Reach 5 indicates a regional cause of the water temperature variation.

What influences water temperature?

Air temperature
Water temperature
Wind
Solar radiation
Cloud/canopy cover
Groundwater

Fall Thermal Refugia Results



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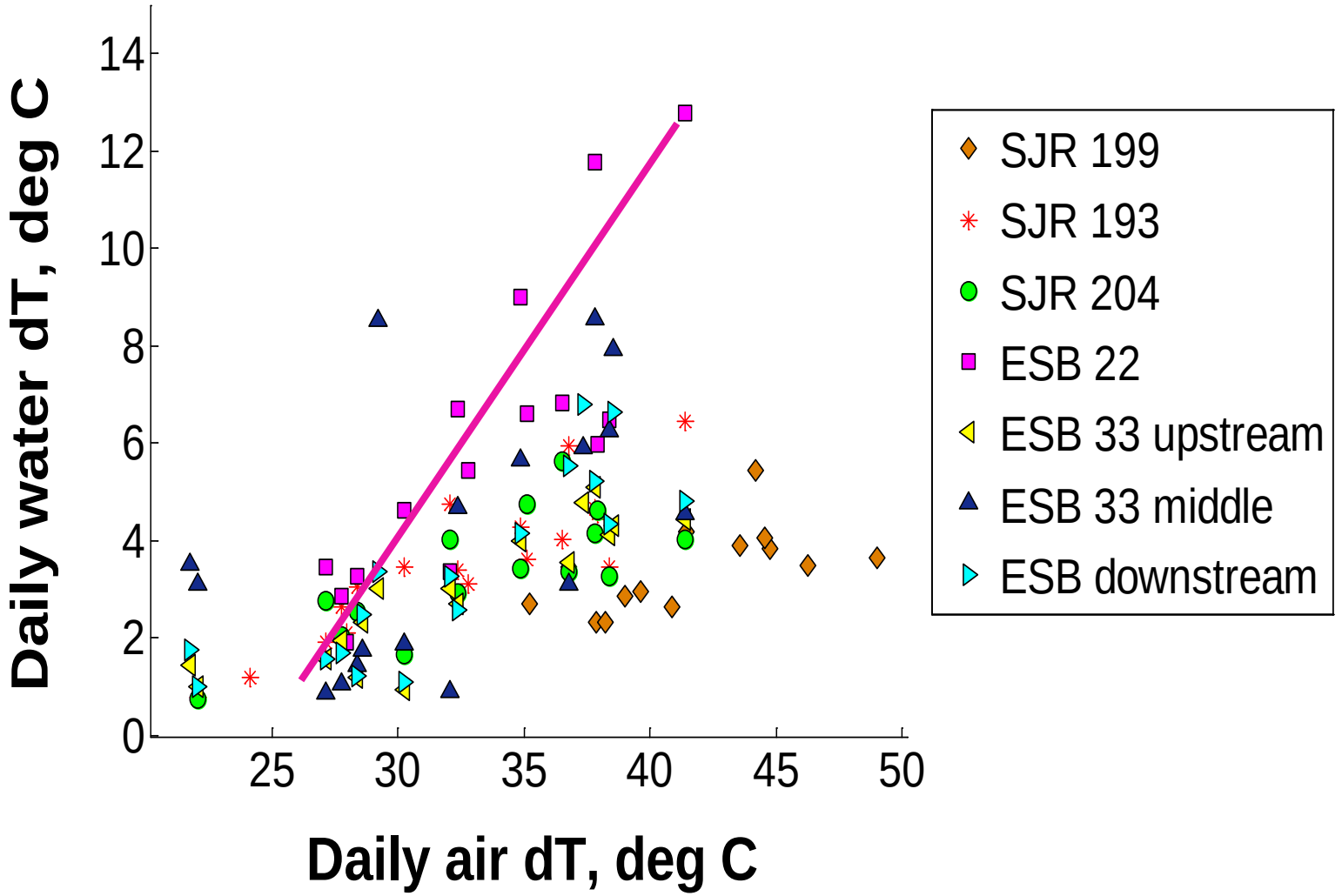

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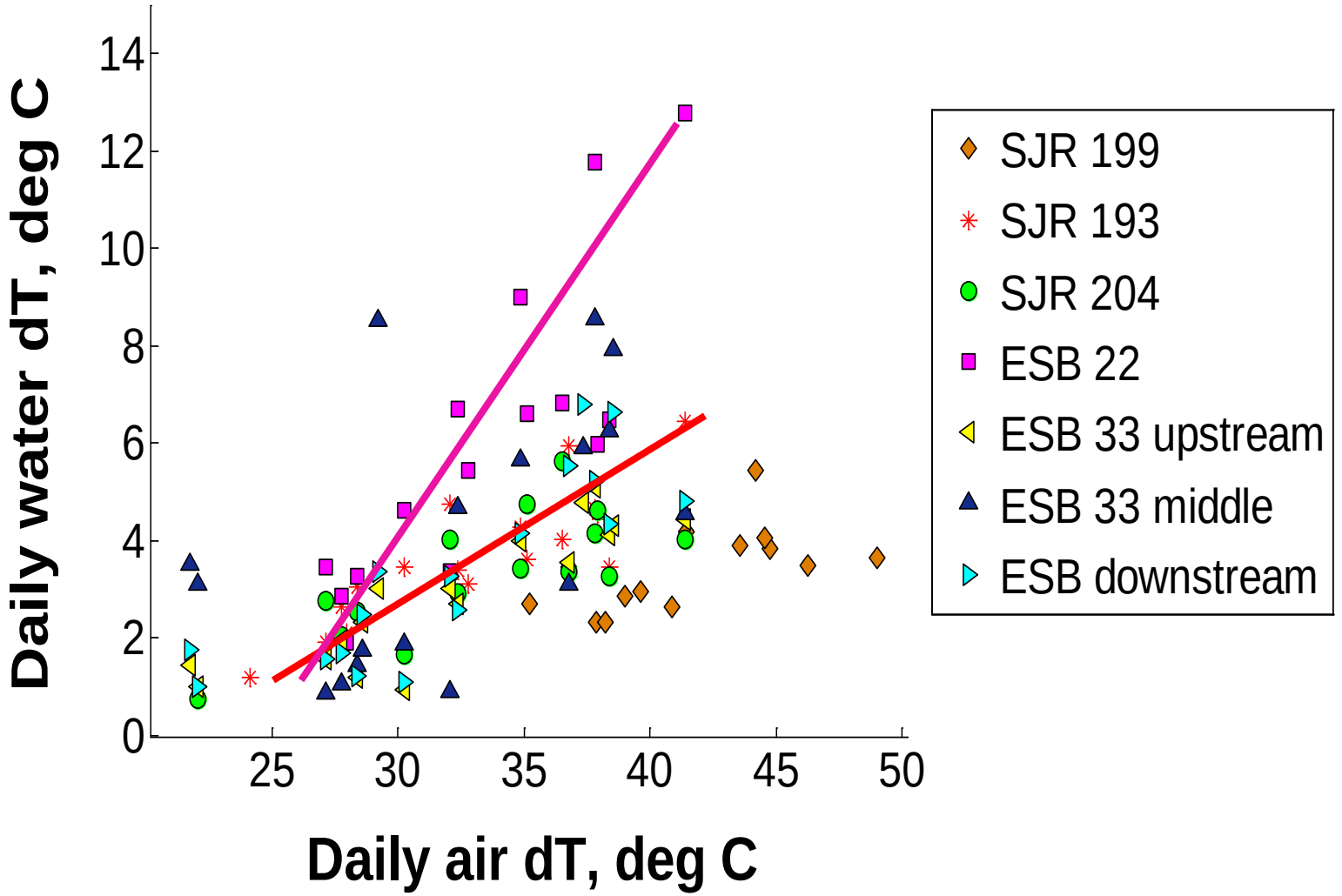

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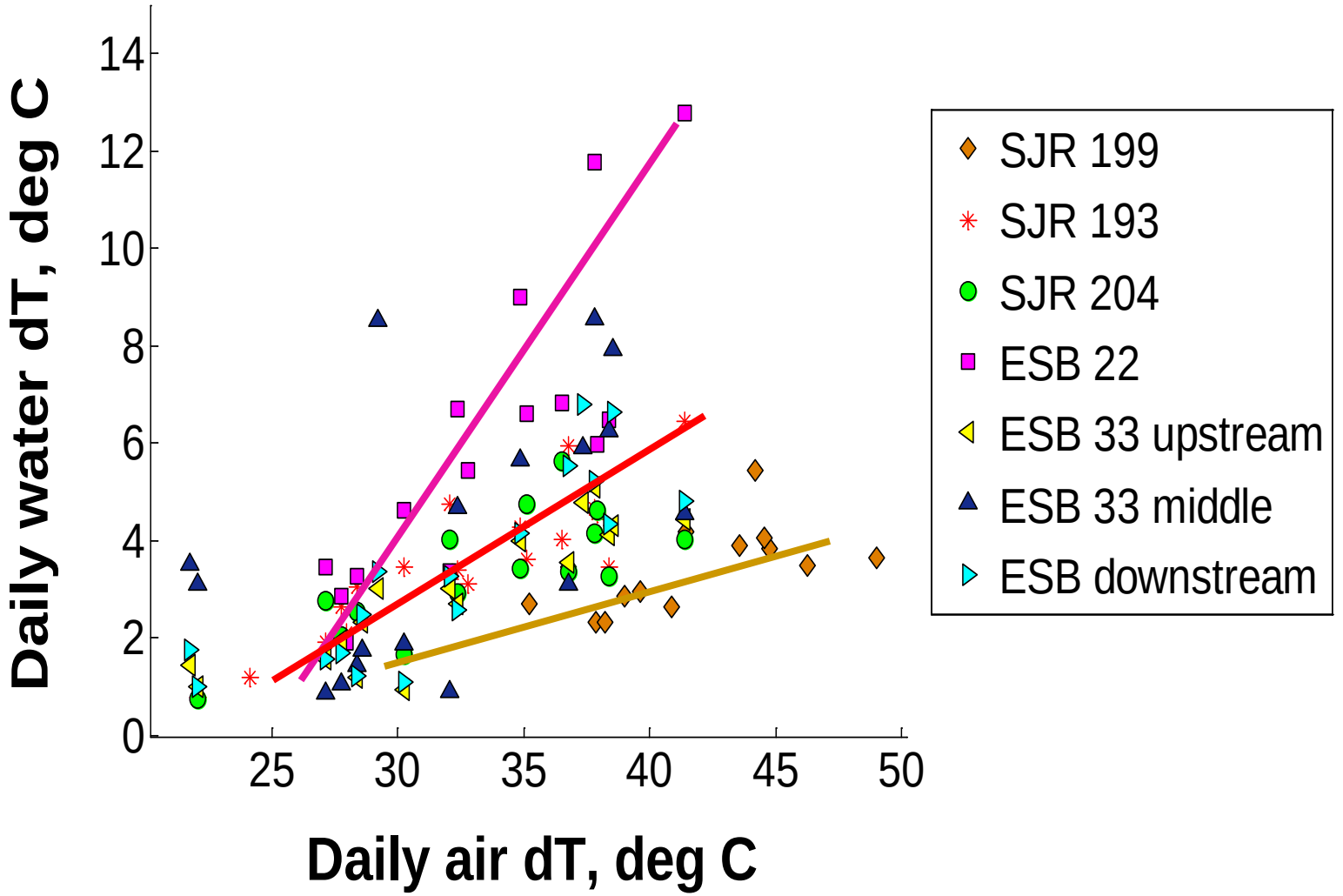

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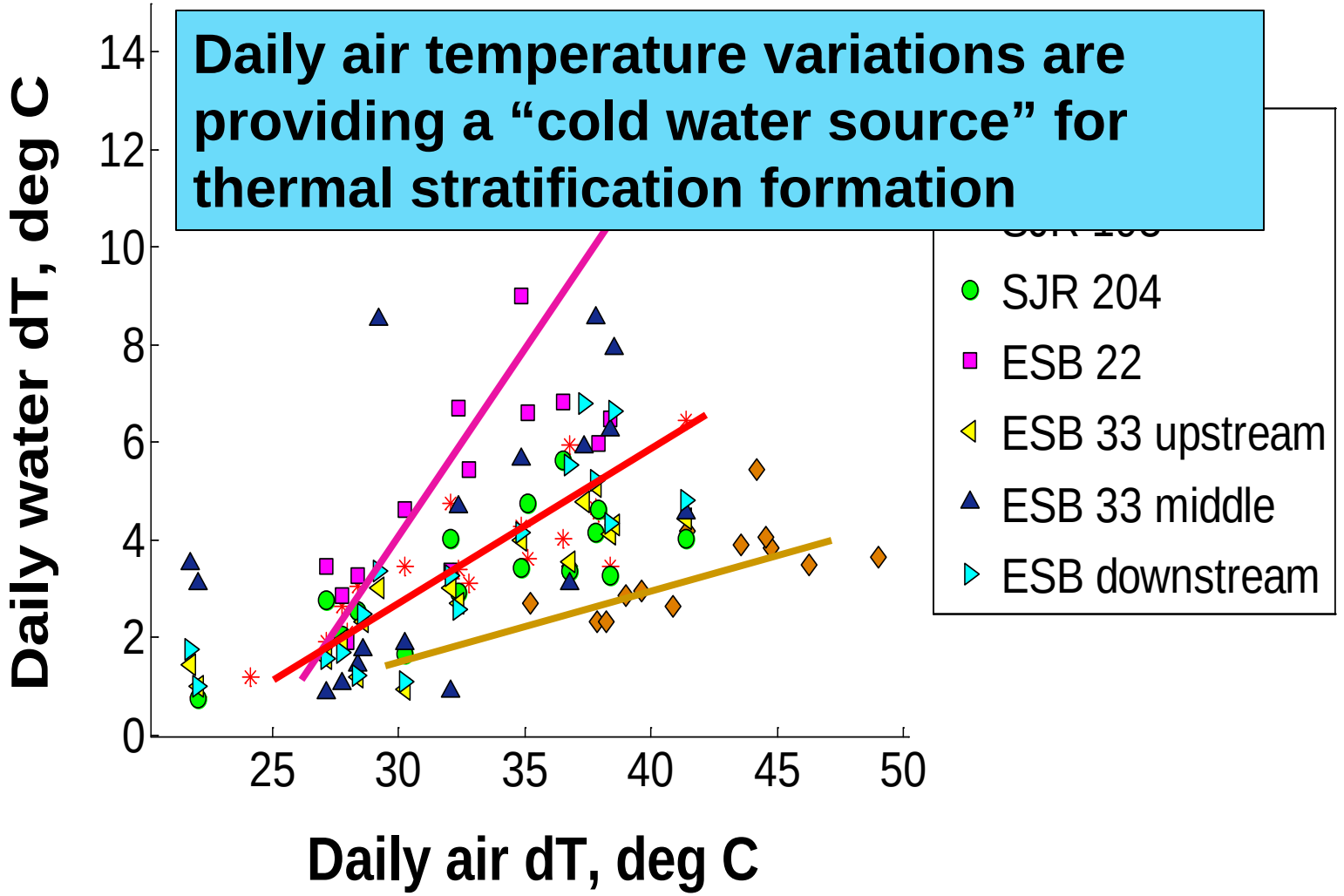
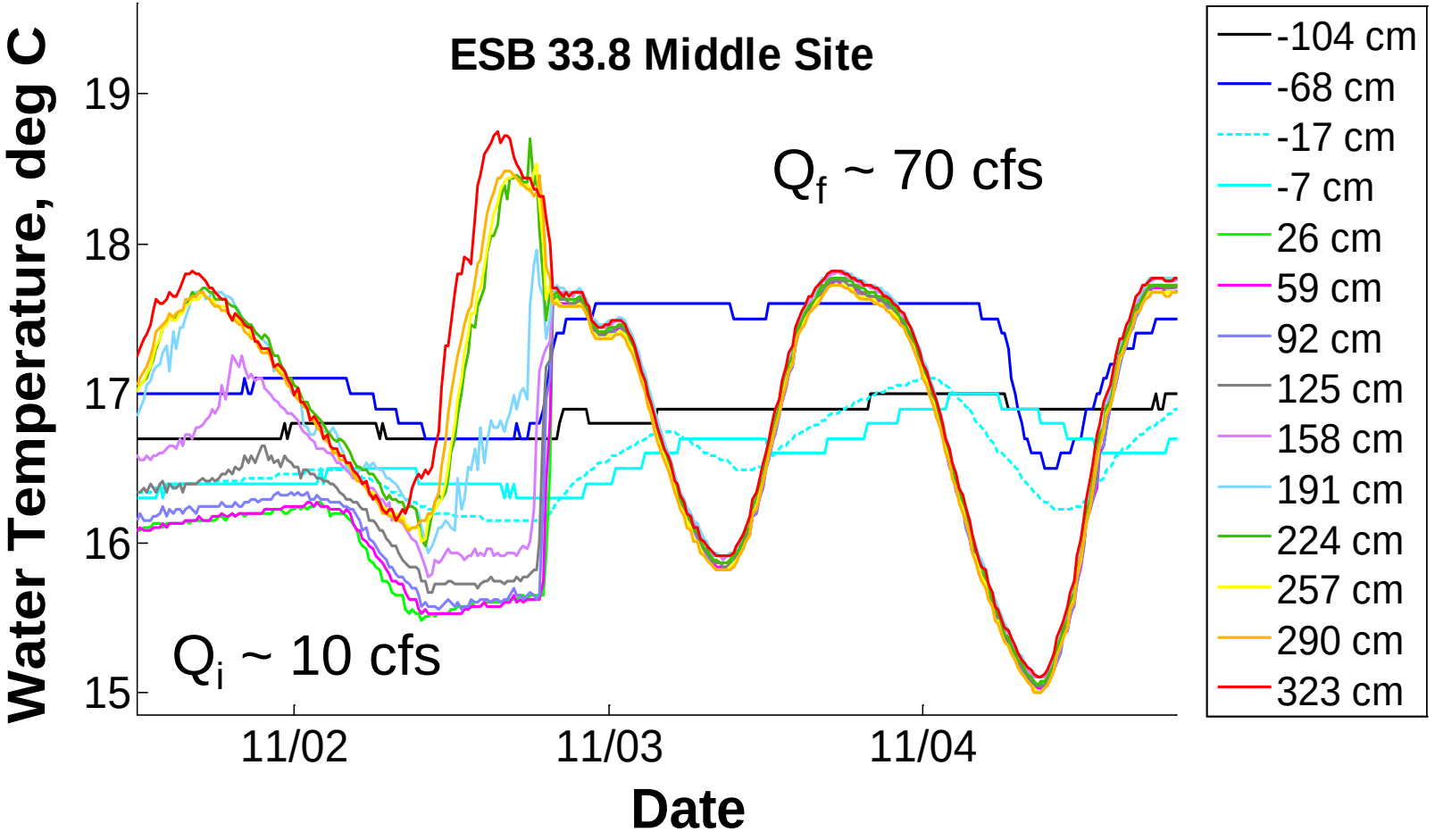


Fall Thermal Refugia Results

Influence of flow on thermal refugia



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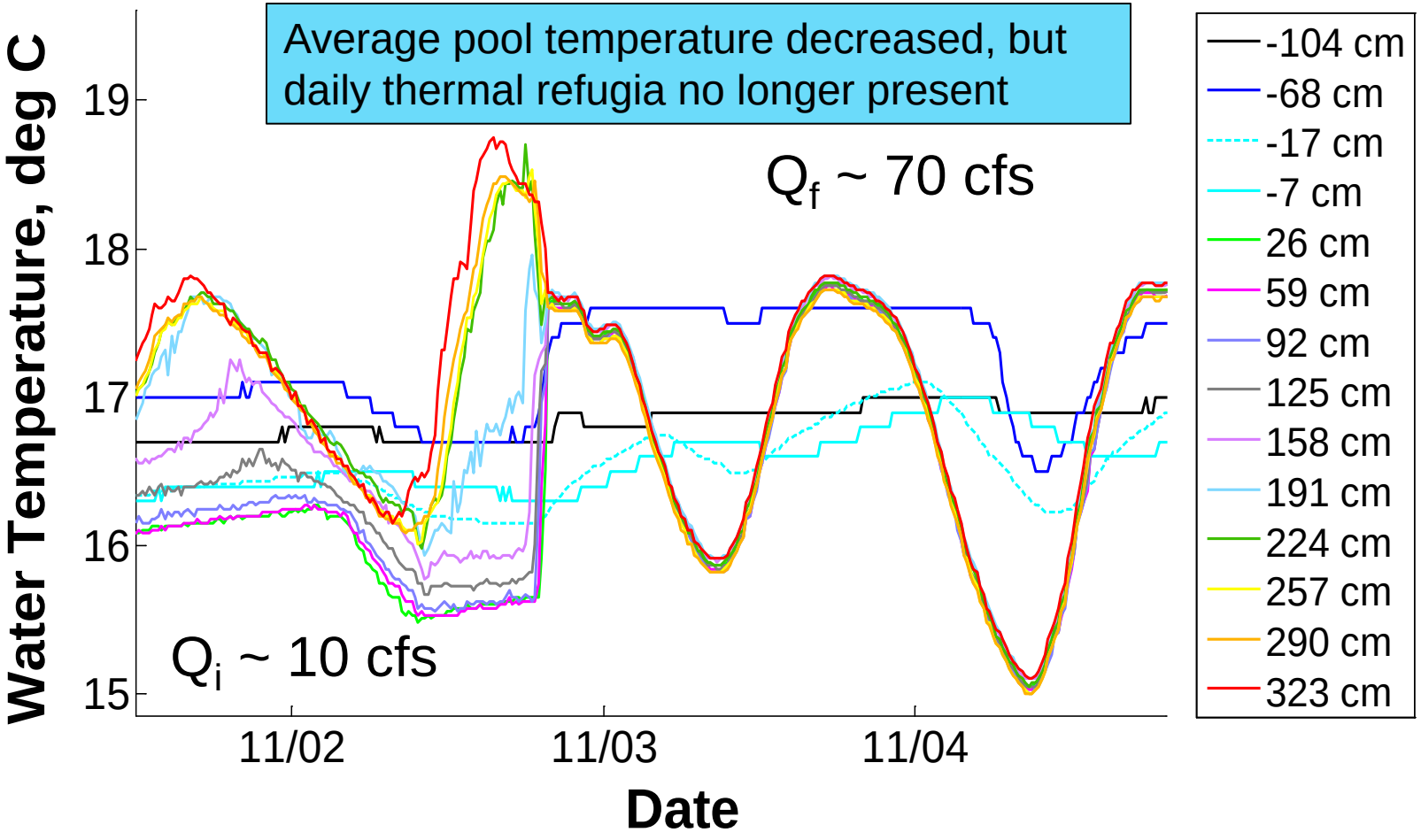
Influence of flow on thermal refugia



Fall Thermal Refugia Results

Take home messages

Thermal stratification creates thermal refugia in pools in the Eastside Bypass, Reach 4B2, and Reach 5

Groundwater temperature was variable between sites, but frequently warmer than surface water temperatures thus not providing a source of cold water to the pools

Air temperature is primary driver of thermal refugia and daily variation in degree of thermal stratification

Increased flow caused complete mixing of Eastside Bypass pool and the elimination of thermal refugia in the pool

Acknowledgements

Thank you to the organizations and numerous people who have supported this research, contributed feedback, helped build and install the sensors arrays, and especially those who withstood the clouds of mosquitoes .

A special thank you for those directly involved in the field effort: Jim Hunt, Matt Kondolf, Stephanie Carlson, Christine Hatch, Ted Baker, Stephen Lee, Michael Wolf, Karl Stromayer, Bob Parris, Ted Baker, Stephen Lee, Jessica Fontaine, Kristi Seabrook, and the USBR Friant Dam folks.

Contact

- Nate Butler
- 916-978-5455
- nbutler@usbr.gov

Contact

Questions?