DRAFT Summary for proposed monitoring platform at Shasta Reservoir

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This report is a summary of plans to deploy an environmental monitoring system in Shasta Reservoir. This document is outlined as follows. 1) general description of the system, 2) rationale for deployment, and 3) discussion points.

1. System Description

The concept is to provide a long-term monitoring platform able to collect a variety of environmental data (currently includes reservoir vertical temperature and surface meteorological data) used to characterize the thermal and storage dynamics in Shasta Reservoir. The pontoon design was chosen to provide ample stability and space, for one person to walk around the perimeter of the craft, in order to tend the mooring lines and the thermistor array as necessary to adjust for lake level changes, and for maintenance of the equipment. A four-point mooring is planned for the system (Figure 1), but deployment with fewer points is possible. The data logging capacities of the system were designed to collect data at 15-minute intervals and transmit data every 12 hours via a cellular modem for near real-time monitoring of Shasta Reservoir.

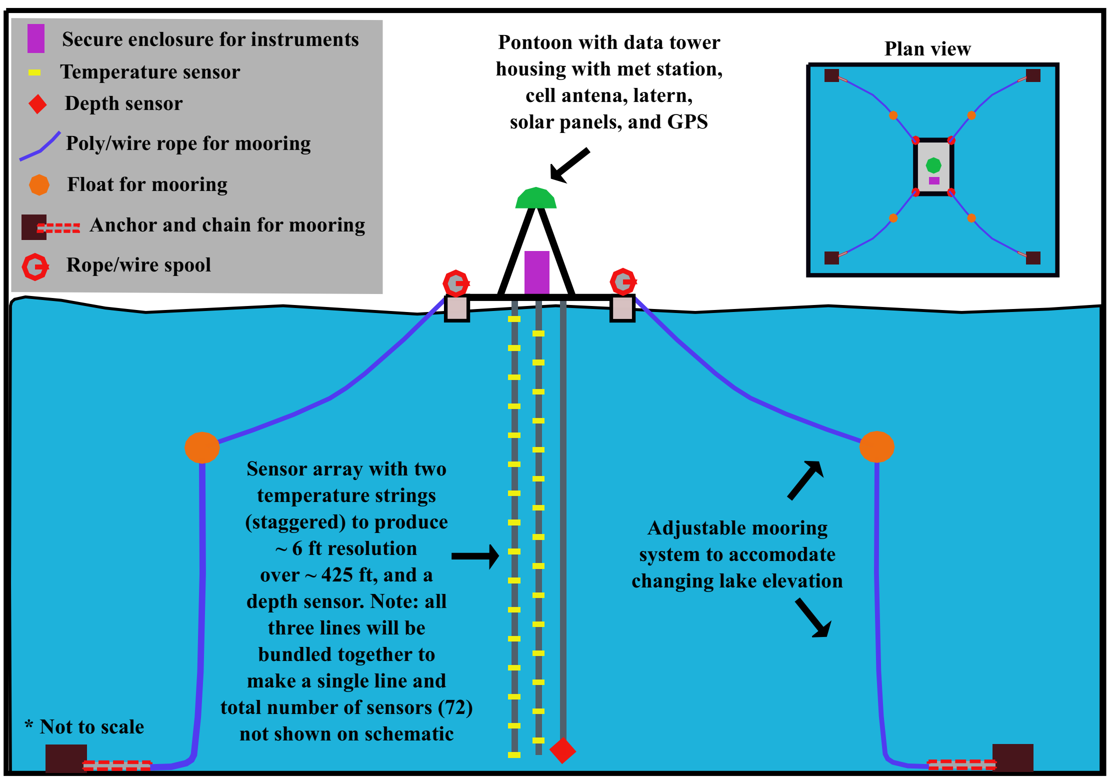

Figure 1: Schematic of pontoon monitoring platform and associated sensors, showing how two staggered temperature strings with sensors every ~ 12 ft will result in 6 ft resolution. The mooring design is also shown, which allows for line to be adjusted (i.e. pulled in or let out) via spools to ensure proper mooring under fluctuating reservoir levels. Note: platform can be anchored at four points as shown in inset plan view.

Table 1: Primary equipment of the monitoring platform.

Item	Description
Pontoon platform (see Figure 2 for photo)	The platform is an 8-ft x 12-ft x 2.5-ft (w x l x draft) aluminum pontoon-catamaran hull. The span between pontoons will act as a moonpool to deploy the thermistor and pressure sensor array. A 4-ft x 4-ft x 6-ft (l x w x h) open frame tower spans the center of the moonpool to act as a suspension point for the array, as well as elevated mounting for solar panels, cellular antenna, meteorological sensors, GPS, and lantern. A secure aluminum enclosure is used to protect a Campbell fiberglass electronics enclosure and separate battery box.
Thermistor string (x2)	The thermistor string is a Campbell Scientific product (CS225-L). The maximum number of sensors on each string is 36, therefore to maximize spatial resolution of the array and provide some redundancy, we are using two temperature stings, each with a length of ~ 430 ft and sensor spacing at 12.12 ft. When staggered (Figure 1), the array will have a spatial resolution of 6.06 ft. Typical accuracy of each thermistor is +/- 0.2°C. Further information is available at https://www.campbellsci.com/cs225-l.
Pressure transducer	The pressure transducer is manufactured by Keller (ACCULEVELl/81355), with a 200 PSIG rating and 450 ft of cable. Accuracy is +/- 0.1% FS. The transducer also has an internal thermistor with an accuracy of +/- 0.2°C. The pressure transducer will be placed at the deep end of the temperature string to help determine the proper deployment of the sting when adjusting the array as reservoir levels fluctuate.
Meteorological Station	The meteorological station is manufactured by Meter Environment (ATMOS 41). For comparison with a standard a RAWS meteorological station from Campbell Scientific, accuracy values for the ATMOS are in BLUE and RAWS in RED The station measures solar radiation (+/- 5%, +/- 5%), precipitation (+/- 5%, +/- 1%), vapor pressure (+/- 0.2 kPA, NA), relative humidity (+/- 3%, +/- 0.8%), air temperature (+/- 0.6°C, +/- 0.1°C), barometric pressure (+/- 0.1 kPA, NA), horizon wind speed (+/- 3%, +/- 1%), wind gust (+/- 3%, NA), wind direction (+/- 5°, +/- 4°), compass heading (+/- 5°, NA), tilt (+/- 1°, NA). Additional details can be found at https://www.metergroup.com/environment/products/atmos-41-weather-station/
Data logger	The data logger is a Campbell Scientific product (CR1000X). The current configuration of the logger is to collect data at 15-minute intervals and additional ports are available for adding more sensors in the future. More information about the logger can be found at https://www.campbellsci.com/cr1000x.
Cellular modem	The cellular modem is made by Sierra Wireless (RV50 Airlink) with 4G LTE capabilities.
Power	120 watts of solar panels and 200 Ah of battery for > 2-week battery backup.

Figure 2: Photograph of pontoon, showing the data tower (sensors not installed), spools for poly-rope, and secure enclosure for instruments, such as data logger and cellular modem.

2. Rationale

There are three primary areas of rationale for deploying this system: redundancy for thermal profile data, surface meteorological data, and higher spatiotemporal resolution

Rationale 1: The platform will provide valuable redundancy for the existing temperature monitoring system with two electronically independent temperature strings.

Rationale 2: The platform will house a meteorological station able to record and transmit conditions relevant to better understanding reservoir dynamics, such as wind speed and direction, and add to existing meteorological data at the reservoir.

Rationale 3: The platform will provide increased temporal (15-minute) and spatial (~ 6 ft) monitoring of temperature dynamics in the reservoir. An example of how increased resolution may aid in monitoring temperature in Shasta Reservoir is provided below.

This example uses a high resolution distributed temperature sensor (DTS) dataset from August 2015 to February 2016. The DTS was installed ~ 500ft upstream of Shasta Dam and measured water temperatures from the surface to ~ 300 ft. An assumption of this analysis is that the high resolution (< 1ft and < 1 day) dataset perfectly measured temperature in Shasta Reservoir.
The DTS data were compiled and resampled (linear interpolation over space and time) at different spatial and temporal resolutions: 1 ft vertical resolution (y-axis) and 1 day spatial resolution (x-axis); 6 ft

vertical resolution and 1 day temporal resolution (the output expected from the pontoon platform); and 25 ft vertical intervals once per week (the current monitoring protocol at Shasta Dam). The figure shows how information about temperature dynamics is reduced as spatial and temporal resolution is reduced.

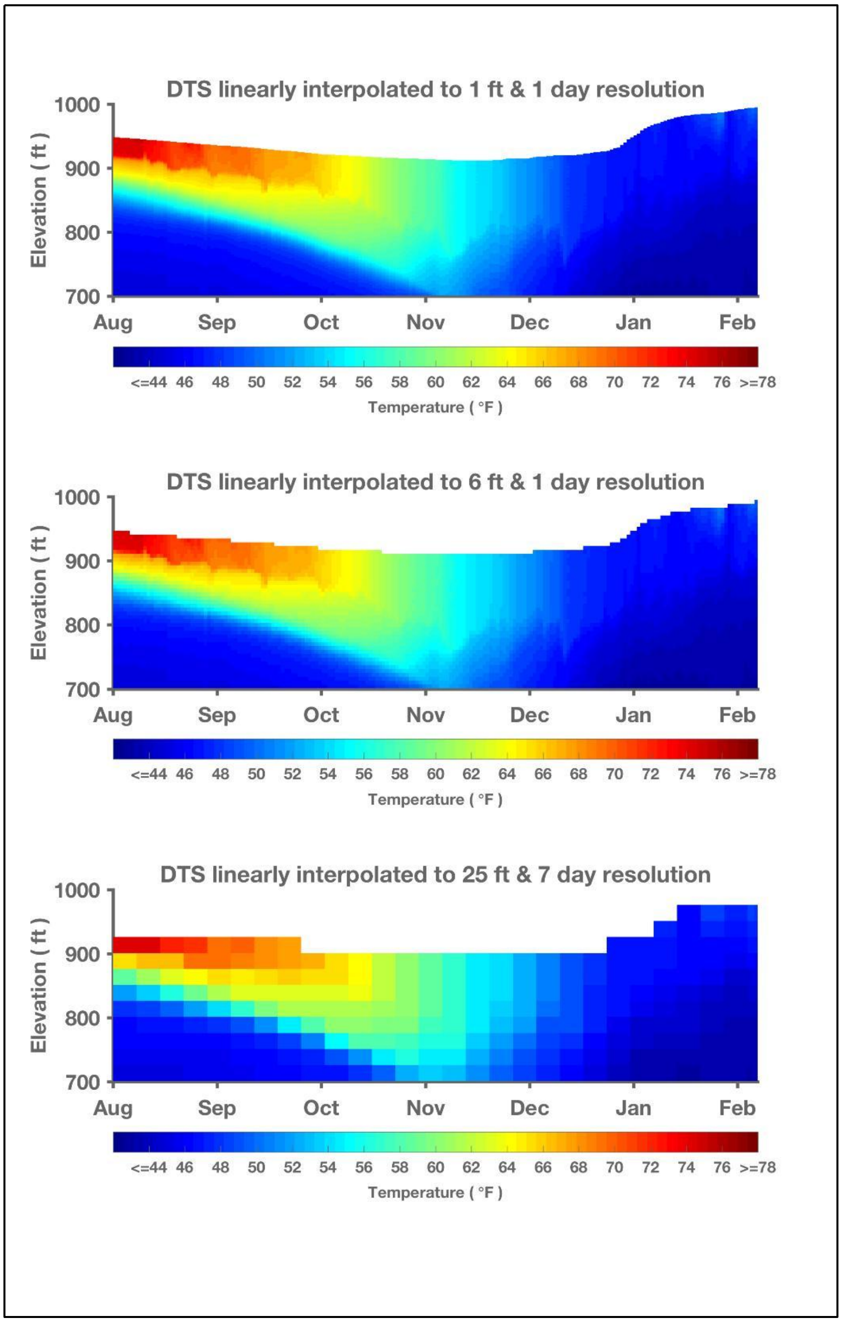

Figure 3: Time series of vertical temperature distributions upstream of Shasta Dam over three scenarios covering varying spatial and temporal resolution. The upper plot has a resolution of 1 ft and 1 day, the middle as 6 ft and 1 day (similar to pontoon expectation), and the lower plot as 25 ft and 1 week (similar to current sampling protocol). All data was generated from the DTS data collected at Shasta Dam from August 2015 to February 2016.

To evaluate the benefit of higher spatial and temporal sampling for the characterization of Shasta Reservoir, the volume of water in the reservoir (i.e. storage in TAF) at or below four cold water temperature thresholds (48°, 50°, 52°, and 54° F) was calculated for each of the datasets (1 ft, 6 ft, and 25 ft). Figure 4 is a plot of the relationship between the 1 ft data estimate and the 6 ft and 25 ft data estimates of storage for the different cold water temperature thresholds. The figure shows how increasing spatial resolution to 6 ft from 25 ft and temporal resolution to 1 day from 1-week reduced error and bias under all cold water temperature thresholds.

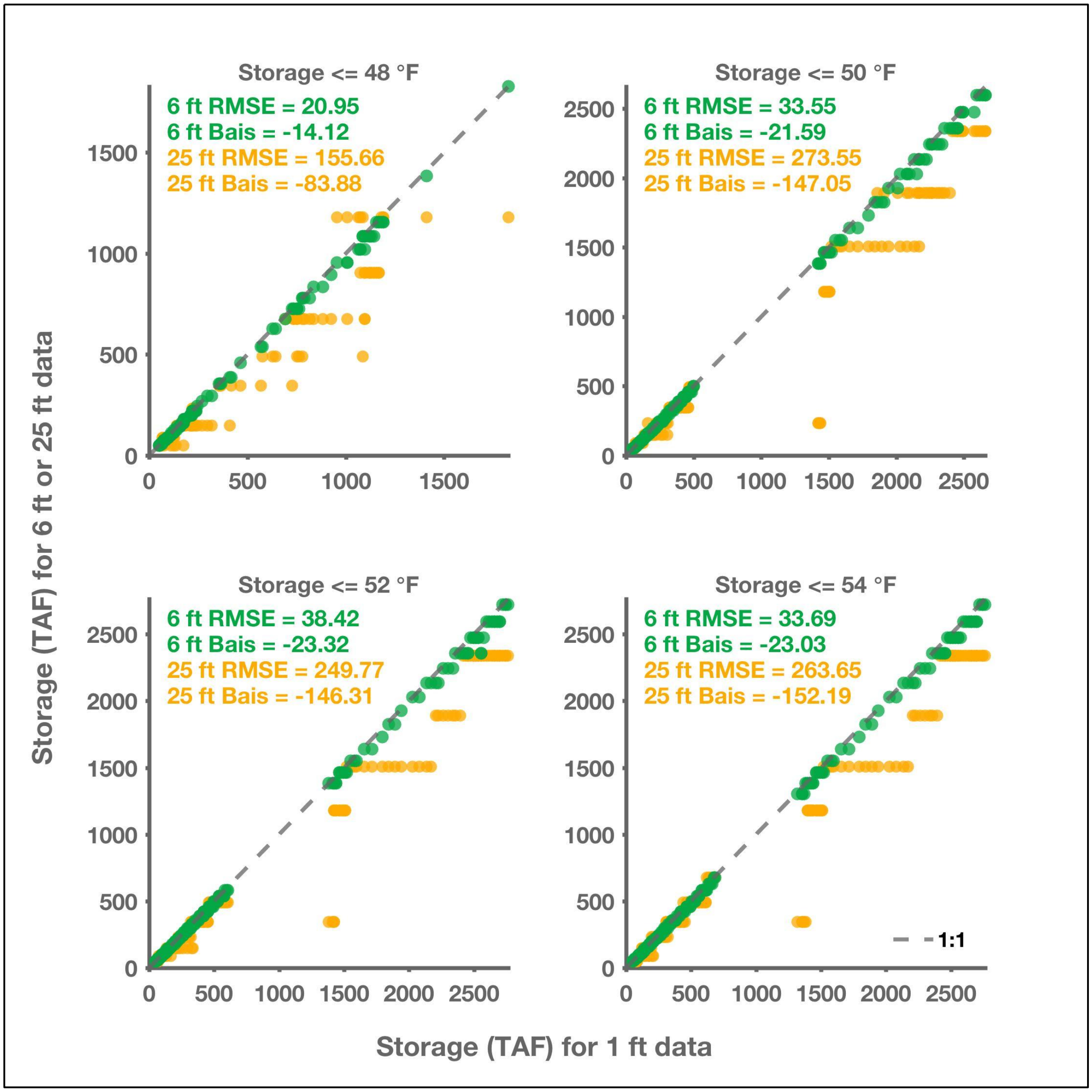

Figure 4: Relationship between the 1 ft DTS data (storage in TAF on x-axis) and the 6 ft (green dots) and 25 ft (orange dots) DTS data on the y-axis from August 2015 to February 2016, with error statistics (root mean square error (RMSE) and bias) printed under four different cold water temperature thresholds (48°, 50°, 52°, and 54° F).

3. Discussion points

A) Appropriate communications protocols for data transmission.

B) Pontoon and mooring placement.

C) Deployment schedule.

D) Maintenance.