January 2026
Study of Physical Data Gaps to Inform the Implementation of Nur Rematriation Upstream of Shasta Dam
(AB 211 Drought Grant Agreement Number – Q2396040)

Appendix O
Summary of Juvenile Salmonid Collection System Pilot Study

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Summary of Juvenile Salmonid Collection System Pilot Study

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ABBREVIATIONS

Background Compendium	*Background Compendium and Design Criteria Report for the Feasibility of Volitional Fish Passage Above Keswick and Shasta Dams*
°C	Celsius
CDFW	California Department of Fish and Wildlife
Consultant Team	Anchor QEA; HDR Engineering, Inc.; U.S. Geological Survey; and QEDA Consulting, LLC
DWR	Department of Water Resources
Head of reservoir	The upstream limits of a water body within an impoundment that experiences fluctuation between riverine and lacustrine conditions as storage levels increase and decrease throughout its range of operation.
JSCS	Juvenile Salmonid Collection System
NAVD 88	North American Vertical Datum 1988
NMFS	National Marine Fisheries Service
Nur	Winnemem Wintu word for Chinook Salmon
USBR	U.S. Bureau of Reclamation
Winnemem Waywaket	Winnemem Wintu words for McCloud River
WSE	water surface elevation

1 Introduction

A team of engineering and fisheries science consultants consisting of Anchor QEA; HDR Engineering, Inc. (HDR); U.S. Geological Survey (USGS); and QEDA Consulting, LLC (QEDA) known herein as the "Consultant Team," has received funding from the California Department of Fish and Wildlife (CDFW) to implement studies to gather data, compile information, and identify data gaps related to physical and biological conditions in the Study Area. These studies will be referred to within this document as the "Project." The results of the Project will support an investigation of the feasibility of providing volitional passage for fish, particularly Chinook Salmon (*Oncorhynchus tshawytscha*), above Keswick and Shasta dams on the Nomtipom Waywaket (also known as the Sacramento River) and into the Winnemem Waywaket (also known as the McCloud River) in northern California. In this document, Chinook Salmon is used to generally describe the species because once connectivity is re-established through reintroduction, fish will adapt to the new environments and could display run timing consistent with multiple runs. It is inclusive of Nur, which the Winnemem Wintu Tribe uses for Chinook Salmon that have been raised by the Tribe. The formal, Evolutionarily Significant Unit (ESU)-specific name (e.g., Sacramento River winter-run Chinook Salmon) is used when discussing federal Endangered Species Act (ESA)-listed Chinook Salmon or steelhead (*O. mykiss*). This document is an appendix to the overarching report documenting the results of the Project, which is called the *Background Compendium and Design Criteria Report for the Feasibility of Volitional Fish Passage Above Keswick and Shasta Dams* (Background Compendium). This larger report contains additional background information for the Project and this document should be considered within this context.

The Project Study Area extends from the confluence of Cow Creek and the Nomtipom Waywaket and includes the Winnemem Waywaket from Shasta Reservoir to the McCloud Dam (Figure 1). It includes portions of the Winnemem Waywaket; the Nomtipom Waywaket, including Keswick and Shasta dams and reservoirs; Cow Creek; Little Cow Creek; and Dry Creek. These water bodies vary in hydrology, geomorphology, and water quality, with seasonal fluctuations in temperature and flow; these parameters are being measured during this Project to evaluate habitat suitability and passage for salmonids. Understanding these physical conditions is essential to evaluating the feasibility of restoring fish passage to historical spawning and rearing areas upstream of the dams.

As part of a separate reintroduction study, the Department of Water Resources (DWR) deployed and operated a juvenile salmonid collection system (JSCS) on the McCloud Arm of the Shasta Reservoir in 2022, 2023, and 2024. The purpose of this document is to collect and synthesize information from the JSCS study including the following aspects of the pilot deployment:

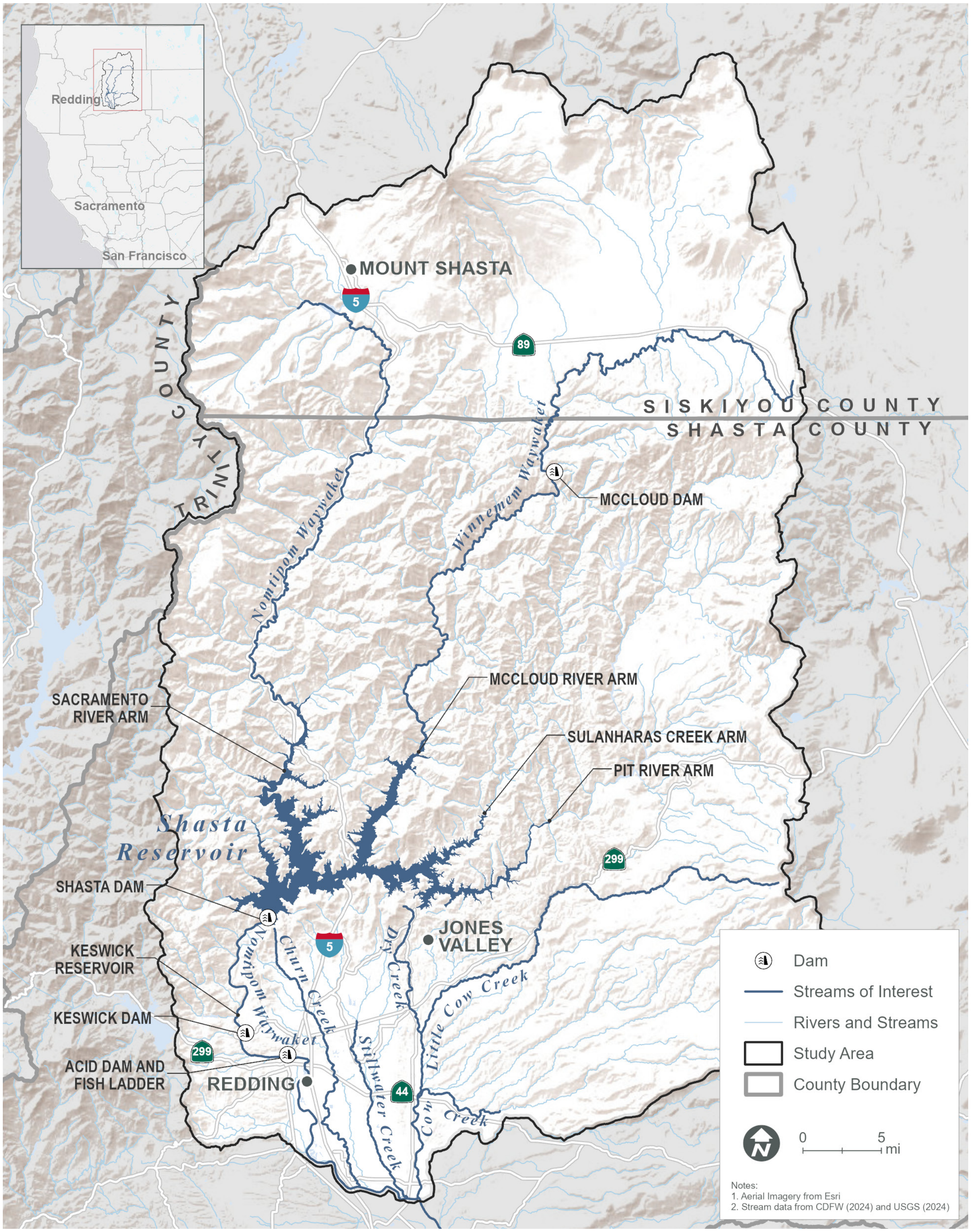
- JSCS study background and objectives
- Site selection and deployment logistics
- Facility configuration
- Collection performance

- Hydraulic characteristics
- Recommendations that will be used to inform future JSCS pilot deployments

This summary will help inform the formulation of Project volitional fish passage alternatives and related feasibility studies.

Readers should understand that on December 12, 2025, the Consultant Team received an email stating that the Winnemem Wintu Tribe does not endorse these reports (referring to the Background Compendium and appendices and *Alternatives Formulation and Evaluation Report* [Anchor QEA and HDR 2026]).

Figure 1
Study Area, Key Features, and Vicinity



2 Data Sources

This document is a summary of the following information sources:

- Department of Water Resources. Juvenile Salmonid Collection System: Report on Field Operations 2023. 2024.
- Department of Water Resources. Juvenile Salmonid Collection System: Report on Field Operations 2024 – 2025.
- Environmental Science Associates. Water Temperature Considerations for Head-of-Reservoir Juvenile Salmonid Collection Systems, undated.
- Department of Water Resources. Juvenile Salmonid Collection System for Shasta Dam Fish Passage Yuba Reintroduction Working Group Presentation. May 8, 2024.
- Department of Water Resources. Juvenile Salmonid Collection System for Shasta Dam Fish Passage Winnemem Wintu Nur/Salmon Rematriation Project Monthly Scientific Meeting Presentation. July 31, 2024. Department of Water Resources and Winnemem Wintu Tribe. Bringing Salmon Home: Lessons Learned from the Juvenile Salmonid Collection System on the Winnemem Waywaket.

3 JSCS Background and Study Objectives

The purpose of the JSCS is to evaluate the feasibility of passive collection of juvenile winter-run Chinook Salmon in the upper McCloud arm of Shasta Reservoir via a pilot program. Effective collection of juveniles is an important step in the reintroduction of winter-run Chinook Salmon to historical spawning and rearing tributaries above Shasta Dam.

In 2015 agency experts from California, Oregon, and Washington brainstormed design concepts for a juvenile collection system. Previously, the Steering Committee for the Shasta Dam Fish Passage Evaluation determined a collection system at or near the dam would likely be unsuccessful for reintroduction efforts due to low juvenile Chinook Salmon survival rates migrating through the Shasta Reservoir (USBR 2016 as cited in DWR 2024a). Therefore, brainstorming concepts focused on siting a collection facility at in-river and head of reservoir locations. Several design challenges needed to be taken into consideration for the JSCS, including a cost-effective, passive system that utilizes fish behavior instead of pumps; high collection efficiency; low risk of predation; and a system that was safe for operators and the public. The chosen system had to also be adaptable for varying flow conditions to account for wet water years and drought conditions and be movable and removable to different locations on the McCloud arm. Since incline plane traps and rotary screw traps are not likely to withstand the potential higher flows that occur in the McCloud system, a head of reservoir system was chosen.

The chosen pilot system consists of a 15-foot-long passive trap on a 40-foot by 24-foot platform with guidance that relies on induced velocity and fish behavior for attraction instead of pumped attraction flows. Components were fabricated between 2018 and 2023 and deployed in the fall of 2022, 2023, and 2024 as discussed below.

The main objectives of the JSCS deployments were to test the efficiency of the trap; study the effects of deployment and operation on biota and habitat of the McCloud arm; and collect juvenile Chinook Salmon for relocation.

4 Site Selection

For the 2022 deployment, the JSCS was installed at the river to reservoir transition (head of reservoir) location (Figure 2).

For the 2023 deployment, the McCloud arm between the McCloud Bridge and Hirz Bay was determined to be a feasible location for the JSCS based on hydrology, water level forecasts, and anchoring requirements per the U.S, Bureau of Reclamation (USBR) Shasta Dam Fish Passage Evaluation Habitat Assessment and the 2014 Recover Plan (USBR 2014, NMFS 2014 as cited in DWR 2024a). The goal of the 2023 site selection was to locate the JSCS as close to the head of reservoir as possible, while attempting to minimize the number of relocations during the collection season.

Regional hydrology determines where the JSCS is placed for each field season since the water surface elevation (WSE) of Shasta Reservoir can vary greatly season to season, which results in the head of reservoir changing locations. Once a month, the USBR issues WSE forecasts for future months based on probable inflows from natural flow conditions. For the 2023 deployment, suitable JSCS sites were determined by estimating the head of reservoir location using USBR monthly WSE forecasts that most closely matched observed data and a bathymetric map of the Winnemem Waywaket and Shasta Reservoir (DWR 2024a). The forecasted WSEs were overlayed on the bathymetric map to estimate water depths during the deployment season at the riverine-reservoir interface. Ideal depths for deployment (approximately between 6 feet and 20 feet) were noted in the section of river approximately 0.5 to 1 mile downstream of the McCloud Bridge. Specific sites within this stretch of the McCloud arm were then reviewed by DWR and the Winnemem Wintu Tribe to avoid culturally sensitive areas. Two sites within this section of the McCloud arm were chosen for the 2023 deployment season (Figure 3).

A similar approach was used to determine an appropriate location for the 2024/2025 deployment, with the ideal conditions anticipated between 1.5 to 2 miles downstream of McCloud Bridge. The reach between Ellery Creek Campground and Pine Point Campground was ultimately selected for deployment. The first 2024/2025 site was selected based on water depths at the time of deployment and was subsequently moved twice throughout the study period to adapt to changing reservoir levels (Figure 4).

The Hirz Bay Boat Ramp parking lot was used during mobilization, site relocation, and demobilization because of its large parking area and multiple boat ramps for the 2022,2023, and 2024/2025 deployments. Table 1 summarizes of deployment locations.

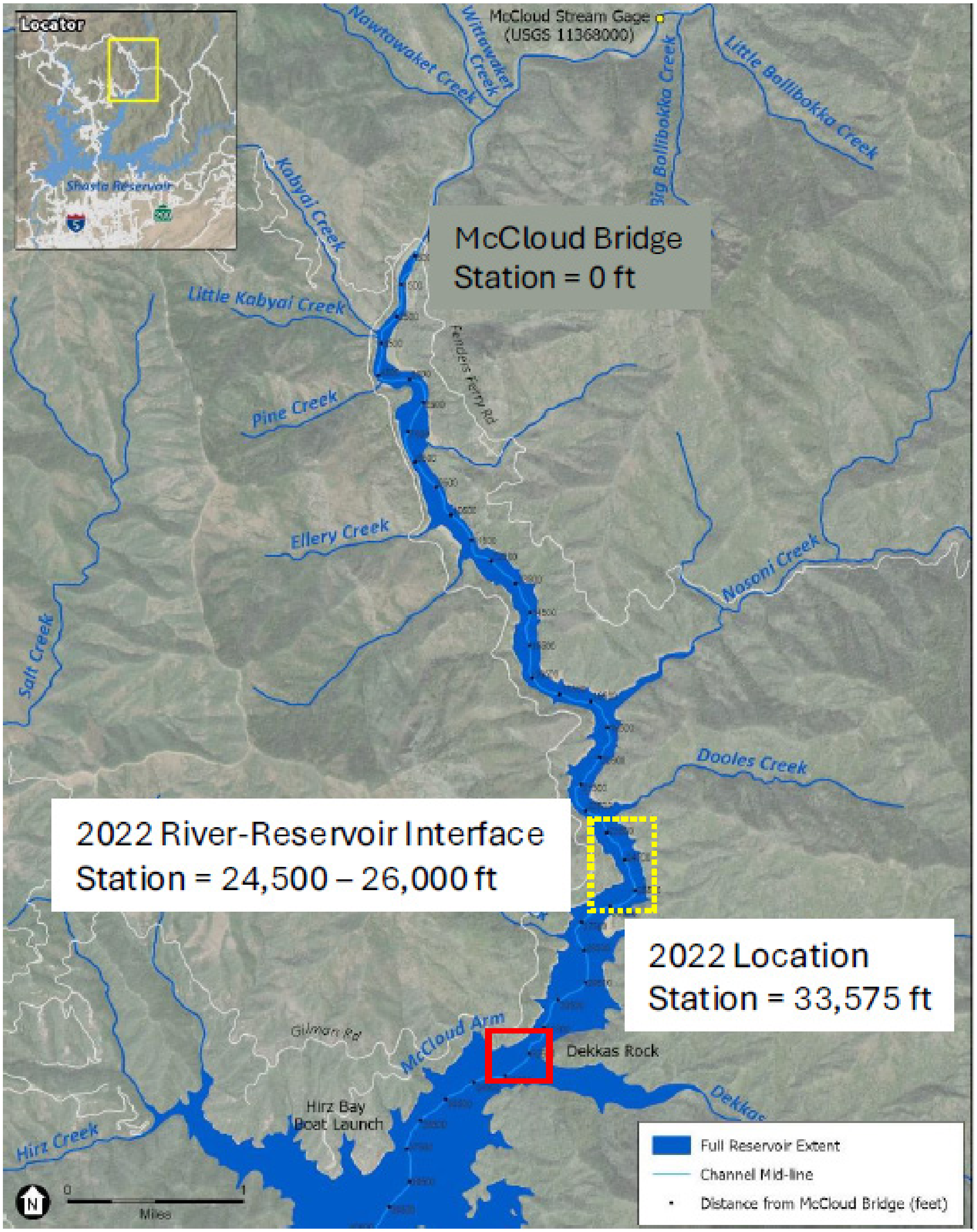
Table 1
Summary of JSCS Deployment Locations

	2022 Location	2023 1st Location	2023 2nd Location	2024/2025 1st Location	2024/2025 2nd Location	2024/2025 3rd Location
JSCS trap (feet from McCloud Bridge)	33,575	2,900	5,800	8,925	10,050	8,825
River/reservoir interface (feet from McCloud Bridge)	Start: 24,500 End: 26,000	Start: 1,800 End: 2,700	Start: 2,700 End: 2,750	Unknown[1]	Unknown[1]	Unknown[1]
Distance from river (feet)	Start: 9,000 End: 7,600	Start: 1,100 End: 200	Start: 3,100 End: 3,050	Unknown[1]	Unknown[1]	Unknown[1]

Notes:
Source: DWR 2024b, DWR 2025

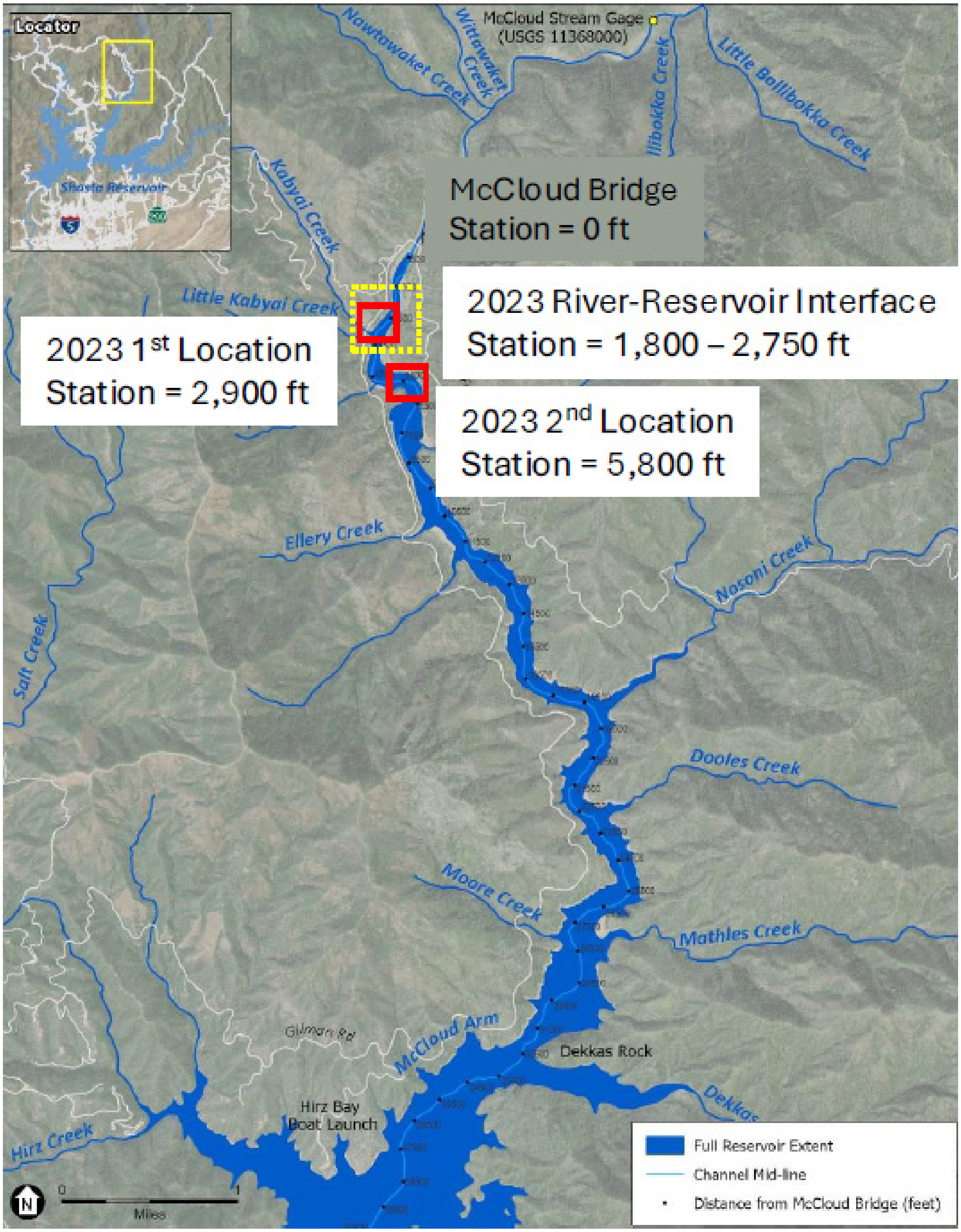
1. Distances relative to river/reservoir interface not provided in DWR 2025. DWR 2025 indicates that initial deployment started near the river/reservoir interface, but high flows substantially increased the reservoir levels which positioned the JSCS in the reservoir.

Figure 2
2022 JSCS Deployment Location



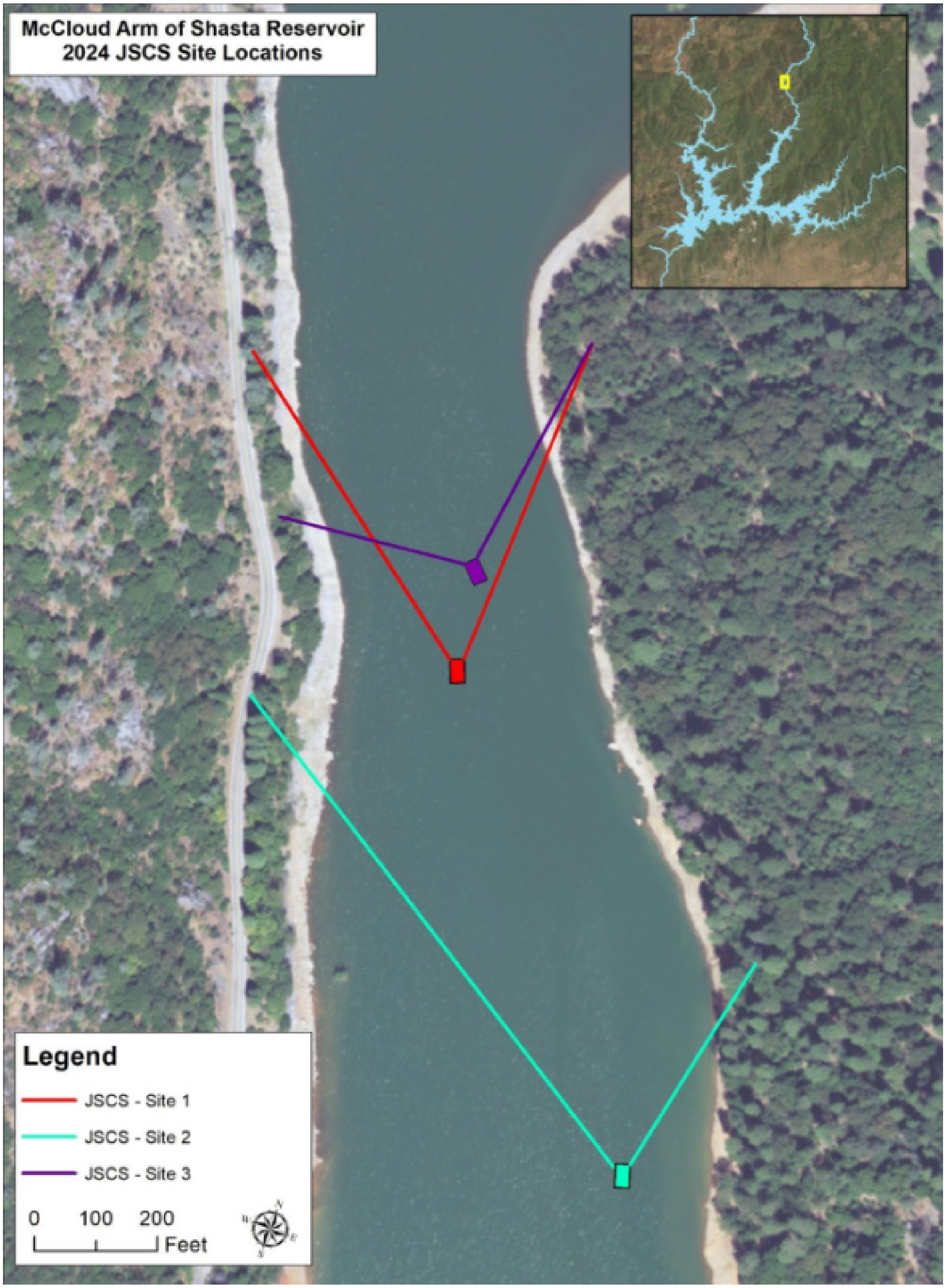
Source: DWR 2024b

Figure 3
2023 JSCS Deployment Locations



Source: DWR 2024b

Figure 4
2024/2025 JSCS Deployment Locations



Source: DWR 2025

5 JSCS Deployment, Facility Configuration, and Sampling Protocols

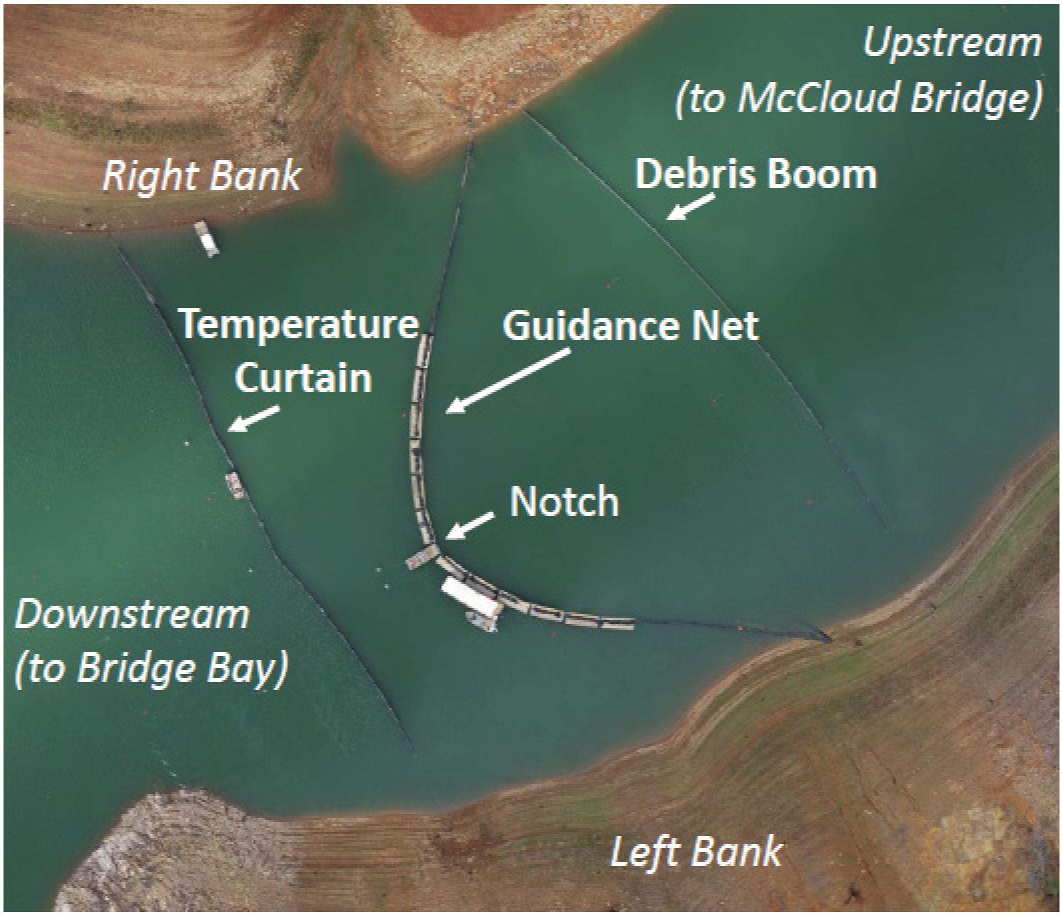
5.1 2022 Deployment

The purpose of the 2022 JSCS deployment was to assess the feasibility of the system and ensure that the system could successfully be deployed (ESA n.d.). The first deployment of the JSCS occurred from September 19 to November 12, 2022, approximately 1.5 miles downstream of the riverine-reservoir interface in water approximately 20 to 40 feet deep (Figure 2). The initial WSE of the reservoir was 930 feet North American Vertical Datum 1988 (NAVD 88) at the start of deployment (DWR 2024a).

This 2022 JSCS consisted of a debris boom, guidance net, notch with six docks on each side, and a temperature curtain. The purpose of the temperature curtain was to retain cooler water at the notch, and the guidance net had optional impermeable panels installed to alter the flow velocity at the notch to direct juveniles towards a trap. However, no trap was in place during the 2022 deployment, and no fish were collected. Portions of the temperature curtain, guidance nets, and debris boom were left open for boat passage. Figure 5 shows the 2022 JSCS components and layout.

In-situ water temperature data was also collected at 20 locations via continuous loggers deployed along the head of reservoir and placed on fixed buoys. Additional water data, including dissolved oxygen, water temperature, pH, turbidity, and conductivity, were collected via a water-quality sonde that was cast daily from the notch during the deployment season. Other data collected during the 2022 deployment included meteorological data, JSCS structure movement, and fish abundance and behavior.

Figure 5
Aerial Image of JSCS Components - Fall 2022 Deployment



Source: DWR 2024c

5.2 2023 Deployment

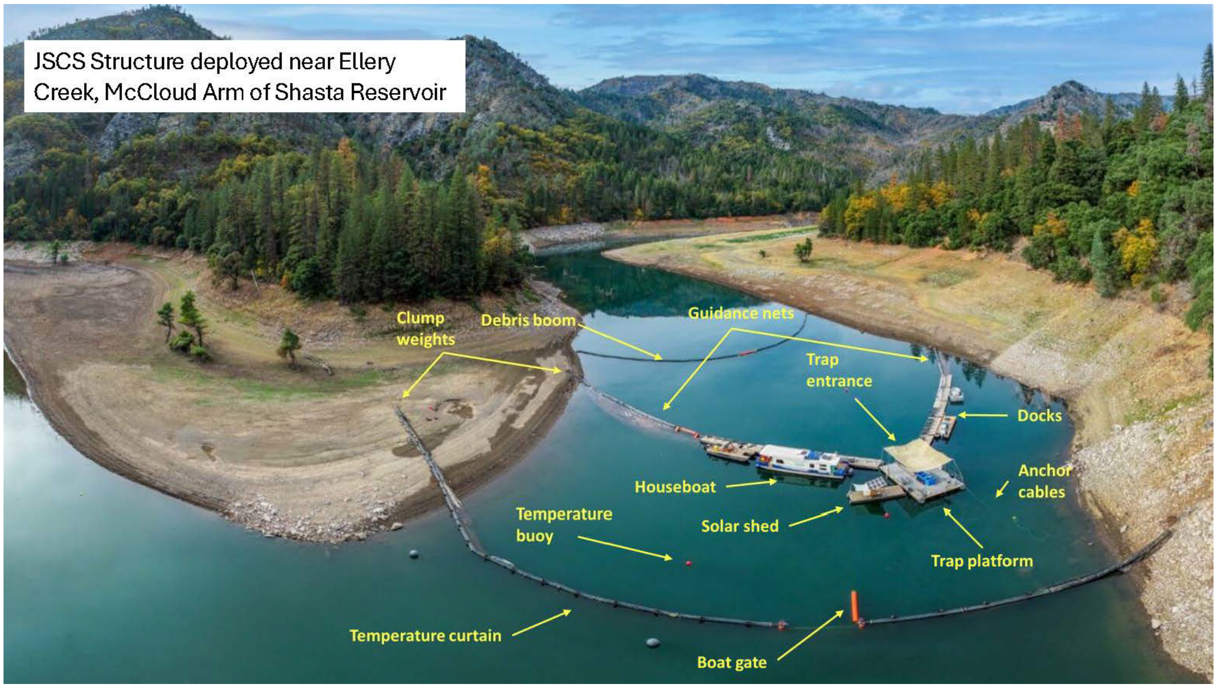
For the 2023 deployment, the JSCS was relocated between Ellery Creek Campground and the McCloud Bridge Campground to operate as close to the Winnemem Waywaket as possible and was deployed at two different locations during the season (Figure 3). With a WSE of 1,028 feet NAVD 88 at the start of the 2023 season (compared to 930 feet for the 2022 deployment), the head of reservoir was located farther upstream in 2023 compared to 2022 (DWR 2024a).

The first deployment of the JSCS occurred from September 20 to October 25, 2023, and it was operated until reservoir depths dropped to approximately 6 feet, which was too shallow for operation. The JSCS operated at the second, upstream location from November 1 through November 15, 2023.

For the 2023 collection season, the JSCS consisted of the fish trap, platform, guidance nets, debris booms, temperature curtain, and boat gates. Since the facility was located in a narrower portion of the reservoir compared to 2022, fewer docks (nine in total compared to 12 in the 2022 deployment) were required along the guidance nets. Impermeable panels were installed in the guidance net that could be lowered on top of the guidance nets to block flow and increase velocity through the trap if necessary due to low river flows. The fish trap consisted of a 15-foot-long stainless steel and aluminum passive trap set into the notch of the JSCS platform. The trap consisted of an aluminum frame, 10 side wedgewire screen panels, 10 perforated porosity control panels, two impermeable closure panels, a wedgewire exit screen panel, a debris exclusion grate, entrance fyke, trap box, internal fyke that only allowed smaller fish into the trap box, and fry box (DWR 2024a). Sampling and debris removal occurred once daily. A gantry crane was used to raise the fry box. Figure 6 shows the 2023 facility layout.

Similar to the 2022 deployment, environmental data were collected including hydrology, water quality data, meteorological data, water velocity, structure depth, and aerial imagery on either a daily, weekly, or continuous basis. Velocity data were collected using an acoustic Doppler current profiler mounted to a watercraft and also via point velocity measurements along the JSCS trap inlet using a handheld acoustic Doppler velocimeter. Acoustic Doppler current profiler data were collected at four cross-sectional transects prior to deployment of the JSCS, and data were collected weekly. The acoustic Doppler velocimeter data were collected at discrete locations at two depths (1 foot below water surface and 3 feet below water surface) at 2 – 4 horizontal positions along the trap inlet. Acoustic Doppler velocimeter data were collected daily.

Figure 6
Aerial Image of JSCS Components - Fall 2023 Deployment



Source: DWR 2024c

5.2.1 *Sampling Protocol*

Part of the 2023 study objectives were to collect data on JSCS collection efficiency, collection efficiency, and juvenile salmon survival. DWR used mark-recapture efficiency trials designed according to standard CDFW methods: a known number of dual-marked fish are released a set distance upstream from the JSCS trap. For each week of operation (five weeks total), 300 juvenile winter-run Chinook Salmon were released as part of the efficiency trials. The trap was sampled at least once a day and all species in the trap were identified and counted. The target salmon species and predators were held for sampling. Fork length measurements were also taken. Black bass caught in the JSCS had stomach contents sampled starting on October 16, 2023. Non-target species were released downstream of the trap.

In addition to trap sampling, hook and line sampling was conducted twice a week at 16 areas around the trap and was used to characterize predator presence around the JSCS structure.

5.3 2024/2025 Deployment

For the 2024/25 deployment, the JSCS was located between Ellery Creek Campground and the Pine Point Campground to target the reservoir/river interface and was deployed at three different locations during the season (Figure 4). The WSE was 1,040 feet NAVD 88 at the start of the 2024/2025 field season, which is approximately 12 feet lower than at the start of the 2023 field season. As a result, the head of reservoir was located further downstream than in 2023 (DWR 2025).

The duration of the 2024/2025 deployment extended from September 3, 2024 to January 28, 2025. Installation of the JSCS began on September 3, 2024. Fishing at Site 1 occurred from September 17 through October 28, 2024 when it was determined that water depths at the site were too shallow (approximately 7 feet) for operation. The JSCS was moved to Site 2 where operations began on October 31. The JSCS operated at Site 2 from November 21 through December 3, 2024 but paused due to storm conditions. Operations resumed after conditions were determined to be safe; however, the storm resulted in a significant increase in reservoir WSE, and operations at Site 2 ceased on December 19 as water depths at the site were approaching 30 feet. The JSCS was then moved back upstream to Site 3, approximately 100 feet upstream of Site 1 between December 20, 2024 and January 1, 2025. During this time, another storm occurred, increasing the reservoir WSE by approximately 25 feet, resulting in water depths of approximately 40 feet the Site 3 throughout the remainder of operations. Operations for the 2024/2025 deployment ceased on January 19, 2025. Demobilization was complete by January 28, 2025. A summary of the 2024/2025 deployment timeline is provided in Table 2.

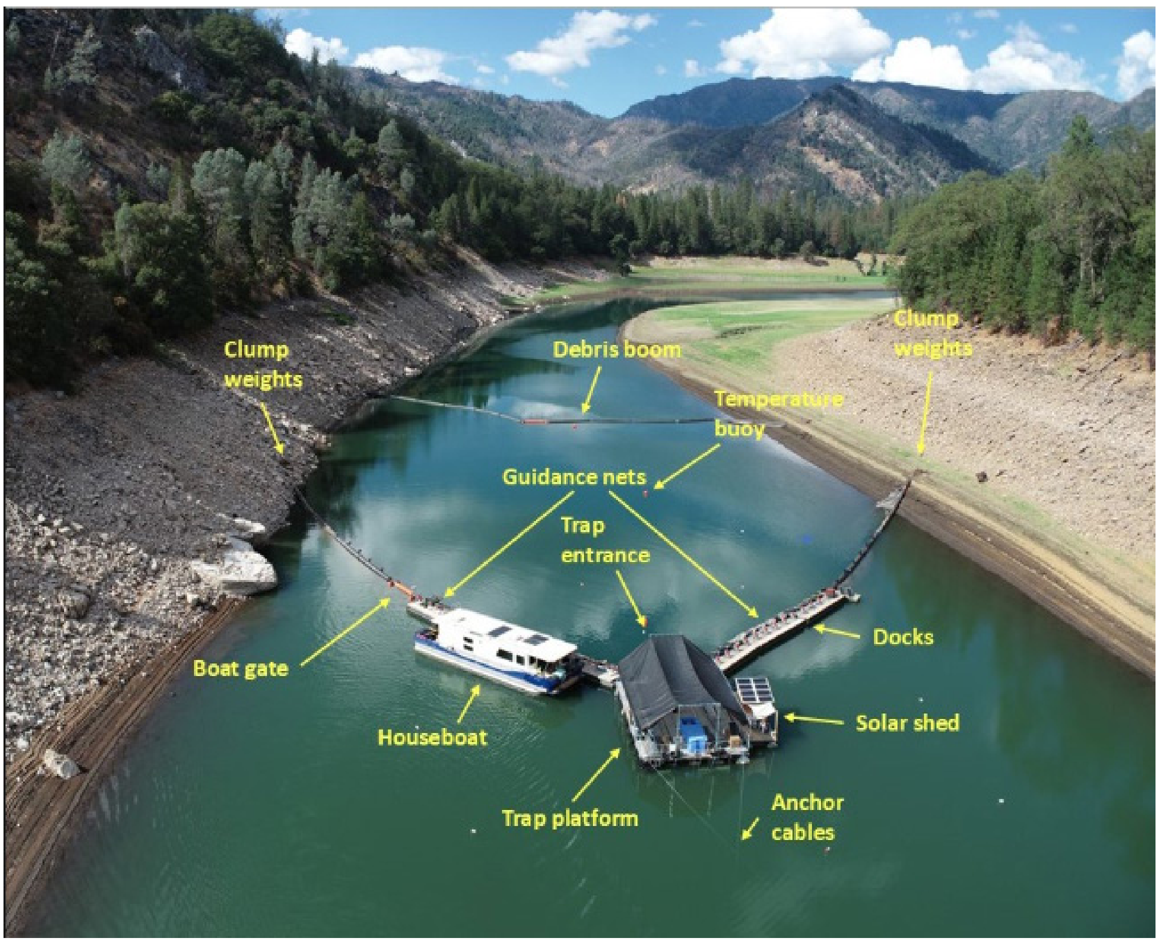
Table 2
2024/2025 Deployment Timeline

Event	Date
Installation	September 3 – September 16, 2024
Fishing at Site 1	September 17 – October 28, 2024
Move (not fishing)	October 29 – October 30, 2024
Fishing at Site 2	October 31 – November 20, 2024
Storm (not fishing)	November 21 – December 3, 2024
Fishing at Site 2	December 4 – December 19, 2024
Move + Major Storm (not fishing)	December 20, 2024 – January 1, 2025
Fishing at Site 3	January 2 – January 19, 2025
Demobilization	January 21 – January 28, 2025

Source: DWR 2025

For the 2024/2025 collection season, the JSCS configuration was similar to that of the 2023 configuration, with some minor changes. The trap, platform, debris boom, and guidance system from the 2023 deployment were used for the 2024/2025 deployment. The primary change was replacement of the temperature curtain with a less expensive and simpler alternative referred to as a "trap wrap." The trap wrap consisted of 10-foot-deep impermeable vinyl panels wrapped along the sides and back of the trap platform to regulate temperatures at the trap entrance and within the trap. Following observation of trap operations, the vinyl panels along the back (downstream end) of the platform were raised out of the water to maintain higher velocities within the trap. Minor modifications were also made to improve trap operations. Steel frames were added to the front of the docks and the vinyl panels were removed from the bottom of the guidance nets to reduce billowing and allow for easier adjustment throughout the season. Other minor changes included reducing the number of docks from nine to six, modifying the gate pin closure mechanism for easier opening/closure, and replacement of the manual hoist to a batter powered hoist for lifting the fry box to reduce noise and vibration. Additionally, during the winter months, an additional debris boom was added upstream of the entrance of the trap to improve interception of the large debris loads. Figure 7 shows the 2024/2025 facility layout.

Figure 7
Aerial Image of JSCS Components - Fall 2024/2025 Deployment



Source: DWR 2025

5.3.1 *Sampling Protocol*

Similar to the 2022 and 2023 deployments, environmental data were collected including hydrology, water quality data, meteorological data, water velocity, structure depth, and aerial imagery on either a daily, weekly, or continuous basis. For the 2024/2025 deployment, the priority questions targeted by environmental data collection included:

- What are the water temperatures inside and around the trap?
- Is water temperature lower upstream of the guidance net and ¾ vinyl wrapped trap platform compared to downstream of the trap and ¾ vinyl wrapped trap platform?
- How do temperature, dissolved oxygen, and turbidity vary over time at the entrance to the trap?
- The water column is stratified at the beginning of deployment with regards to water temperature within and upstream of the trap; where upstream does the stratification begin horizontally (depth) and longitudinally (distance from McCloud Bridge); how does stratification change over the sampling season at each deployment site?
- How do temperature, dissolved oxygen, pH, conductivity, and turbidity vary over depth and time around the trap's major components: guidance net entrance upstream of the fish trap, guidance net downstream of the fish trap, and within the fish trap?
- What is the Winnemem Waywaket inflow and water temperature during sampling?
- What are the range of flows in the river that are most conducive to JSCS operation (vs another type of in-river or in reservoir collection system)?
- How do changes in water depth affect the velocity structure in and around the trap?
- How do flow patterns and velocities change as guidance net panels are manipulated?
- How does the configuration change in relation to site conditions and over time?
- What is the likely debris loading as a function of season, wind, and other factors?

Water quality data collected included temperature, dissolved oxygen, turbidity, pH, salinity, and conductivity. Onset senor model MX2203 temperature loggers with a sampling interval of 15 minutes were installed at various locations at, upstream, and downstream of the JSCS, as well as in the river to evaluate spatial variations in temperature and effectiveness of the trap wrap for temperature control. Vertical water temperature and water quality profiles were taken between 8:00 AM and 11:00 AM each day using a YSI ProDSS to provide an understanding of water quality variation within the water column.

Hydrologic and meteorological data collected included riverine flow rate, air temperature, rainfall, wind speed, wind direction, pressure, dew point, relative humidity, and solar radiation. Daily average flow data was obtained from a PG&E-operated stream gauge (CDEC gage MSS) a few miles upstream of the maximum reservoir extent. Hourly meteorological measurements were obtained from two weather stations installed near Hirz Bay and on the left bank upstream of Site 1.

Velocity data were collected using an acoustic Doppler current profiler mounted to a watercraft and also via point velocity measurements along the JSCS trap inlet using a handheld acoustic Doppler velocimeter. Acoustic Doppler current profiler data were collected at four cross-sectional transects (upstream of guidance net, at guidance net entrance, just upstream of the trap entrance, and downstream of the trap) prior to deployment of the JSCS, and data were collected weekly. The acoustic Doppler velocimeter data were collected at discrete locations at two depths (1 foot below water surface and 3 feet below water surface) at 2 horizontal positions along the trap inlet (downstream of first fyke at the trap inlet, and downstream of the second fyke inside the fry box). Acoustic Doppler velocimeter data were collected daily in the morning.

5.3.2 Fish Sampling Protocol

As with the 2023 deployment, evaluating trap efficiency remained a primary goal for the 2024/2025 deployment. Additionally, findings from the 2023 deployment led to the development of the following research questions that were prioritized during the 2024/2025 deployment:

- What is the outmigration timing of Chinook Salmon in the Winnemem Waywaket? When should JSCS be deployed to capture juveniles and yearlings (juveniles that overwintered in the river)?
- What are the positions and configurations trap (e.g., screen openings, fyke type, etc.) of the JSCS which allow for optimal capture probability? What reservoir conditions (e.g., depth, velocity, position in channel) allow for optimal capture probability?
- What physical (e.g., temperature) or biological (e.g., predation) factors play a role in trap efficiency and capture probability? What is the relationship between these factors?
- What is the survival rate of juvenile Chinook Salmon in the McCloud Arm of Shasta Reservoir and what is the relationship between physical and environmental variables and survival rate?
- What is the composition (species, age class) of the resident fish assemblage in the vicinity of the JSCS? How does this change across timing, reservoir conditions, and siting locations?
- What are the diets of resident target predator species (e.g., Black Bass, Rainbow Trout, Brown Trout)? What is the frequency with which target predator species consume Chinook Salmon in and around the JSCS trap?
- What pathogens are present among resident fish in the McCloud Arm of Shasta Reservoir? Do resident fish pose a pathogen risk to juvenile winter-run Chinook Salmon?

To help answer these research questions and improve well-being of sampled juvenile Chinook Salmon throughout the process, the following changes were made to the 2023 fish sampling protocol:

- Trap efficiency trials were divided into paired releases ("standard" and "near") to assess the impact of predation upstream of the structure versus in the immediate trap vicinity. The "standard" release group consisted of approximately 150 dual-marked fish that were released

0.5 kilometer upstream of the JSCS. The “near” release group consisted of 50 to 150 fish marked only with Bismarck Brown-Y dye that were released 300 feet upstream of the JSCS. A total of nine trap efficiency trials were conducted with a total of 2,147 fish released.

- Expansion of target predator species to include Spotted Bass, White Crappie, Bluegill Sunfish, Rainbow Trout, and Brown Trout. The Winnemem Wintu Tribe performed lethal stomach sampling of collected target predator species on a daily basis throughout the operational period. Personnel from University of San Cruz NOAA Southwest Fisheries Science Center performed non-lethal diet sampling (gastric lavage) on adult trout and bass species caught by hook and line on a weekly basis between September and November. Hook-and-line sampling was not used to measure catch per unit effort.
- Implementation of pathogen sampling of juvenile trout was intended for the 2024/2025 deployment; however, insufficient trout were captured to adhere to the pathogen testing protocol. Thus, JSCS crews photographically documented observed clinical signs of disease among captured resident fish species and submitted observations to Ken Nichols at the Cal-Nevada Anderson Fish Health Center.
- Use of the “fish viewer” for morphometric sampling of Chinook Salmon (collaboratively developed by the Winnemem Wintu Tribe and University of California, Davis) to reduce handling stress and the need for out-of-water measurements. Measuring boards were only used to determine fish length in instances where the fish viewer proved nonviable.

6 Results

6.1 2022 Deployment

As noted above, no collection of fish occurred during the 2022 deployment of the JSCS. WSEs during the 2022 deployment were some of the lowest on record, and inflow into the McCloud Arm were characterized as a low-inflow period between September 19 and October 24, 2022, followed by a high inflow period. Air data showed a late summer hot period between September 19 and October 16, 2022, with temperatures ranging between approximately 13° and 36° Celsius (C). This was followed by a fall cooling period where temperatures ranged between approximately 1° and 35° C (ESA n.d.).

Water temperatures were stratified in the McCloud Arm during the late summer hot and low-inflow period, with near surface temperatures during this time in excess of 20° C. While the guidance net and temperature curtain maintained cooler temperatures upstream of the JSCS, lower temperatures were only observed below depths of 10 feet. Temperatures in the top 10 feet of the water column throughout the head of reservoir area were not suitable for juvenile salmon during the hot and low-inflow period with temperatures above 15.5° C. Temperatures upstream of the guidance net became less stratified during the cool and high-inflow period, and temperatures dropped below 15.5° C.

6.2 2023 Deployment

6.2.1 Temperatures

Stratified temperature conditions were noted again in the McCloud Arm at the deeper locations during the 2023 deployment. It was noted that the JSCS structure elements affected the stratification, with water temperature and velocity stratification reduced at the locations of the JSCS. Temperatures remained stratified downstream of the trap which resulted in stratified temperatures within the fry box during the first 10 days of operation at the initial deployment location. The average river temperature during the 2023 deployment was 10° C with temperatures ranging from 14° C at the start of the deployment to 8.6° C when the JSCS was removed from operation. Air temperatures ranged from approximately 4.2° C to 33° C (DWR 2024a).

6.2.2 Velocity

Velocity became more uniform with the addition of the guidance net; however, the guidance net also reduced its streamwise (longitudinal) magnitude. The velocity structure at the trap entrance was relatively uniform over depth with most flow in the streamwise direction. The velocity magnitude at the trap entrance steadily increased over the period of deployment at Site 1 and high diffusion of velocity was evident between the trap inlet and the fry box, even at the highest velocity magnitudes.

At Site 2, the velocities within the trap did not change appreciably over time and were less than 1 foot per second at the inlet and less than 0.3 foot per second at the fry box (DWR 2024a).

6.2.3 Capture Efficiency

Table 3 summarizes the collection efficiency and associated velocity and water depth for the 2023 deployment.

Table 3
Summary of 2023 Capture Efficiency Trials

Efficiency Release #	JSCS Site	Fish Released	Number Recaptured	Collection Efficiency (%)	Water Depth at Trap Entrance (ft)	Velocity Magnitude at Trap Entrance[1] (ft/s)	Velocity Magnitude in Fry Box[2] (ft/s)
1	1	300	129	43.0	13	1.3	0.1
2	1	299	154	51.5	10	2.1	0.2
3	1	299	27	9.0	9	3.1	1.5
4	2	299	23	7.7	28	0.7	0.4
5	2	300	1	0.3	28	0.7	0.4
Total		1,497	334	22.3 (Avg)	-	-	-

Notes:
Source: DWR 2024a

1. Calculated as the average of the velocity magnitude at 1 foot and 3 feet below water surface at the location downstream of the trap entrance fyke.
2. Calculated as the average of the velocity magnitude at 1 foot and 3 feet below water surface at the location downstream of the fry box fyke.

As shown in Table 3 the highest collection efficiencies correlate to reservoir depth at the trap site between 10 to 13 feet and velocities at the trap entrance between 1.3 to 2.1 feet per second. The average trap efficiency over the entire collection period was 22.3 percent.

6.2.4 Predation

During the deployment, 382 black bass were captured in the JSCS. Of the 299 black bass euthanized and examined, 32 (or 11 percent) had juvenile winter-run Chinook Salmon in their stomachs, with 56 juvenile winter-run Chinook Salmon carcasses recovered (DWR 2024b. The 56 Chinook Salmon carcasses accounted for 6.2 percent of the total winter-run catch (DWR 2024a). A total of 44 hook and line surveys were conducted, with a total of 114 fish caught. Spotted bass, rainbow trout and brown trout made up 97 percent of the catch (DWR 2024a).

6.3 2024/2025 Deployment

6.3.1 Hydrology and Meteorology

During the 2024/2025 field season, the study watershed received a total of 41.8 inches of rainfall. The majority of rain fell in November (18.5 inches) and December (20.7 inches), during which several large storm events occurred. The storm events contributed to large magnitude flows on Winnemem Waywaket (up to 10,579 cfs) that interrupted JSCS operation and resulted in substantial increases to the reservoir WSE. At the start of the field season, Shasta Reservoir WSE was at an elevation of 1001.9 feet and then decreased steadily until mid-November, when it reached a minimum elevation of 985.5 feet. Storm events throughout November and December resulted in a series of rapid WSE increases of 11 feet, 7 feet, and 25 feet. The final water surface at the end of the 2024/2025 field season was 1027.9 feet (DWR 2025).

6.3.2 Temperatures and Water Quality

Stratified temperature conditions were noted again in the McCloud Arm during the 2024/2025 deployment. It was noted that the JSCS guidance net, impermeable panels installed over the net, and the trap wrap reduced temperature stratification upstream of the trap entrance upon installation, and eliminated stratification upstream of the entrance within 6 days of installation. Temperatures remained stratified downstream of the trap which resulted in stratified temperatures within the fry box during September and October operations at Site 1; however, the mean monthly water temperature within the fry box remained below 21.5 ^{o} C throughout the operational period, and stratification within the fry box was extremely weak during the cooler months (November – January). The average river temperature during the 2024/2025 deployment was 8.5^{o} C with temperatures ranging from 12.4^{o} C at the start of the deployment to 5.3^{o} C when the JSCS was removed from operation. Comparatively, the average temperature at the trap entrance during the 2024/2025 deployment was 9.5^{o} C with temperatures ranging from 18.4^{o} C at the start of the deployment to 4.8^{o} C mid-December. Dissolved oxygen concentrations correlated negatively with temperature, as expected, and maintained a range acceptable for juvenile salmonids throughout the operational period. No significant correlation was observed between other measured water quality variables. Measured turbidity and specific conductivity generally remained within safe ranges except for spikes observed following storm events. The measured pH generally remained within a safe range; however, observations indicate that pH increased throughout the operational period at each site, resulting in several days of pH values outside the range considered safe for juvenile salmonids. The gradual increase in pH is potentially a result of biological interactions at the guidance net, which fouled over time (DWR 2025).

6.3.3 Velocity

Cross-sectional and point velocity measurements indicate that velocities generally increase (as reservoir depths decreased. While the increased flowrates on Winnemem Waywaket associated with storm events briefly increased flow velocities, the ultimate result was a substantial decrease in flow velocities, even at higher flow rates, as Shasta Reservoir filled and its backwater influence extended further upstream. Average cross-sectional velocity measurements taken upstream of the guidance net and immediately upstream of the trap ranged from 0.02 foot per second to 1.2 feet per second, with minimal variation between the two locations. The impermeable panels resulted in slight increases in velocity approaching the trap; however instances at Site 1 in which preferential flow paths formed beneath the left guidance net reduced the effect of the impermeable panels. Point velocity measurements within the trap showed that fykes within the trap had the desired effect of increasing velocities at the trap entrance and decreasing velocities in the fry box. Velocities at the trap entrance fyke reached up to 3 feet per second in early November at Site 2; however, after the first major storm event in mid-November velocities generally remained below 1 foot per second, and then dropped to less than 0.25 foot per second following relocation to Site 3. High diffusion of velocity was evident between the trap inlet and the fry box, even at the highest velocity magnitudes (roughly 2 to 3 times lower at the fry box). Velocities exhibited a similar pattern to velocities at the inlet, with a maximum velocity of 1.9 feet per second in late October at Site 2, and subsequently reducing to less than 0.6 foot per second following the first major storm event and to less than 0.1 foot per second following relocation to site 3 (DWR 2025).

6.3.4 Capture Efficiency

Capture efficiencies during the 2024/2025 deployment were significantly lower than during the 2023 deployment. Table 4 summarizes the collection efficiency for the "standard" and "near" release groups during 2024/2025 capture efficiency trials. As shown in Table 4, the highest collection efficiencies were observed at Site 1 with a maximum collection efficiency of 6.0 percent and an average site collection efficiency of 3.5 percent. Collection efficiencies declined over the remainder of the deployment with minimum collection efficiency of 0.0 percent at Site 3. The average trap efficiency across all capture efficiency trials was 1.4 percent. A comparison of capture efficiencies with depth and velocity observations (Figure 8) shows that most juvenile Chinook Salmon were captured when flow velocities through the trap were 0.25 – 1.5 feet per second and water depths were less than 15 feet, with depth being a stronger indicator of capture (DWR 2025).

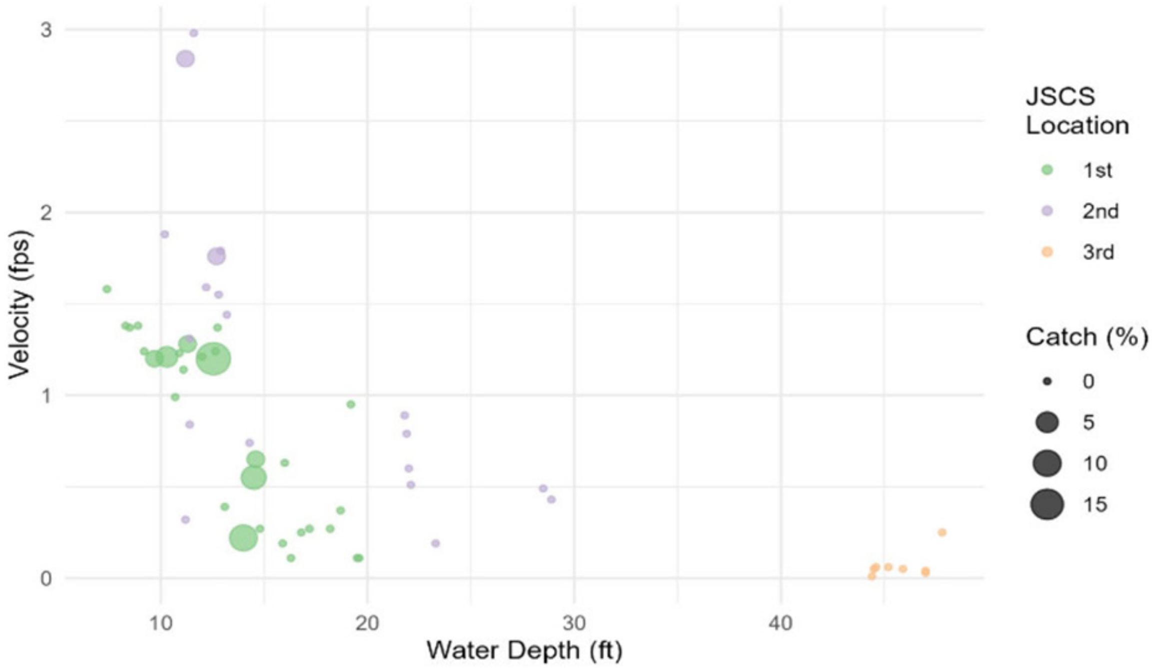
In addition to the juvenile Chinook Salmon capture efficiency trials, NOAA Fisheries and USGS released PIT- and JSAT-tagged yearling late fall-run Chinook Salmon upstream of the JSCS and monitored their movement. Detections indicated that the JSCS did not effectively intercept yearling Chinook Salmon, as a significant portion of yearlings out-migrated during winter pulse flows while trap operations were suspended and only 2 (or approximately 1 percent) of 186 yearlings detected at the trap were captured (Figure 8; DWR 2025).

Table 4
Summary of 2024/2025 Capture Efficiency Trials

Site	Efficiency Release #	Release Group	Fish Released By Release Group	Number Recaptured By Release Group (%)	Collection Efficiency by Release Group (%)	Total Efficiency by Release Date (%)	Total Efficiency by Site (%)
Site 1	9/24/2024	Standard	149	2	1.3	4.52	3.52
		Near	50	7	14		
	10/01/2024	Standard	149	0	0	0.00	
		Near	49	0	0		
	10/25/2024	Standard	150	3	2	6.00	
		Near	50	9	18		
Site 2	11/05/2024	Standard	150	6	4	2.33	0.92
		Near	150	1	0.06		
	11/12/2024	Standard	150	3	2	1.00	
		Near	150	0	0		
	12/05/2024	Standard	150	0	0	0.03	
		Near	150	1	0.06		
	12/10/2024	Standard	150	0	0	0.00	
		Near	150	0	0		
Site 3	01/07/2025	Standard	150	0	0	0.00	0.00
		Near	150	0	0		
	01/14/2025	Near	150	0	0	0.00	
Total	-	-	2,246	32	-	-	1.42

Source: DWR 2025

Figure 8
Relationship between Chinook Salmon Catch, Average Daily Water Velocity, and Water Depth at the JSCS Trap



Symbol size indicates the percentage of Chinook Salmon catch on that date
Source: DWR 2025

6.3.5 *Predation*

During the 2024/2025 field season, a total of 1,200 predator fish species were captured in the JSCS. Bluegill Sunfish made up the majority (approximately 88 percent) of predators caught in the JSCS trap, followed by Spotted Bass (approximately 9 percent); other species each accounted for roughly 1 percent or less of the total catch. Table 5 provides a breakdown of the total JSCS catch by predator species. Of the 101 Spotted Bass euthanized and examined by the Winnemem Wintu Tribe, 6 (5.9 percent) had intact juvenile Chinook Salmon carcasses in their stomachs DWR 2025).

A total of 49 predator fish species were caught with hook and line throughout the 2024/2025 field season (refer to Table 5). Of the 42 fish sampled using gastric lavage, none had intact juvenile Chinook Salmon carcasses in their stomachs; however, a DNA analysis performed on the stomach contents indicated that 13 (approximately 31 percent) of the sampled fish may have consumed Chinook Salmon (DWR 2025).

Table 5
Total Catch of Predator Species during the 2024/2025 deployment

Predator Species	Total JSCS Trap Catch	Total Hook and Line Catch
Spotted Bass	111	6
Black Bass spp.	15	0
Bluegill Sunfish	1,056	0
Catfish spp.	3	0
Sacramento Pikeminnow	12	0
Rainbow Trout	2	34
Brown Trout	0	9
Riffle Sculpin	1	0
Total	**1,200**	**49**

Source: DWR 2025

6.3.6 Disease

Visual observations of clinical signs of disease were made during the 2024/2025 field season, with the majority of clinical disease signs observed in October. Approximately 25.2 percent of Spotted Bass and 0.3 percent of sunfish species observed in the trap exhibited signs of disease. Personnel at the JSCS did not observe clinical signs of disease among other species captured. It was noted that trout in the vicinity of the guidance nets (not captured) showed signs of spawning stress and fungal infection.

7 Discussion

In 2022, the JSCS was set up in a very wide portion of the reservoir, which resulted in a very large angle between the guidance nets (see Figure 5). This location resulted in greater pressure on the guidance nets and docks since they were almost perpendicular to flow and caused deformation of these components. The 2023 locations allowed for the siting of the JSCS in narrower and shallower portions of McCloud Arm compared to 2022 and alleviated this issue by resulting in a more v-shaped guidance system at the narrower locations (Figure 2). Other issues noted during the 2022 deployment included the following (DWR 2024b):

- The guidance net would not stay on the bottom, even when additional weight was added.
- Cold water would pass under the guidance net. Cold water passage would occur even with the impermeable panels set to a downward position.
- Although the temperature curtain worked as designed, it did not provide enough cooling for juvenile collection.

Other operational issues were noted during the 2023 JSCS deployment. The boat gates were difficult to open with one gate becoming inoperable due to the attached guidance net forming billows as the water level dropped, causing the gate to lean dramatically. At the initial 2023 deployment site, the guidance nets formed billows as the force of the water against the impermeable panels bowed the net and panels out to behind the docks, particularly in mid-October when upstream velocities were high. Also, the docks on the ends closest to the banks at became beached as water levels dropped. This caused some bank disturbance and created some minor tears in the impermeable panels below these docks. The management of guidance nets and permeable panels should be modified in future deployments to ensure they remain taunt as velocity increases during later stages of deployment.

Operational issues experienced during the 2024/2025 deployment were primarily the result of winter storms and associated high flows. Uncertainty regarding load on the system and safety for staff resulted in temporary suspension or delay of operation during and following three large storm events that occurred during the field season. Additionally, the high magnitude flows on Winnemem Waywaket resulted in substantial increases in the reservoir WSE and very deep and slow-moving water at the JSCS, which is suboptimal for operation. Time and effort associated with moving the JSCS make it infeasible to relocate every time that reservoir conditions change. Debris loading during and following storm events also became a significant obstacle, as the debris boom and JSCS is not currently configured to handle large amounts of debris, and trap operation was delayed during debris removal.

No correlation was identified between meteorological factors and fish catch in the 2023 and 2024/2025 field seasons. Additional data from additional JSCS deployments in the future may help identify any relationship between meteorological conditions and winter-run Chinook Salmon outmigration. However, based on the temperature data collected during the 2022 deployment, high air temperatures and low inflow during head-of-reservoir deployment of the JSCS may result in unsuitable temperature conditions for juvenile salmonid with temperatures potentially above 15.5^{o} C.

Water depth and velocity appear to influence trap efficiency. As noted in Table 3 and Table 4 and Figure 8, capture efficiency appears to correlate to certain reservoir depths and velocities. Average collection efficiency across the 2023 season was 22.3 percent, with a maximum recapture rate of 51.5 percent and a minimum recapture rate of 0.3 percent. Conversely, average collection efficiency across the 2024/2025 season was 1.4 percent, with a maximum recapture rate of 6.0 percent and a minimum recapture rate of 0.0 percent. In 2023, the JSCS operated at peak collection efficiency when reservoir depth at the trap site was between 10—12 feet and water velocity at the trap entrance was within the range of 1.3—2.1 feet per second (DWR 2024a). Similarly, peak collection efficiency during the 2024/2025 field season occurred when depths at the trap entrance were shallower than 15 feet and velocities through the trap were approximately 0.3—1.5 feet per second (DWR 2025), increasing confidence in the range of conditions for successful JSCS operation. The substantial increases in reservoir depths throughout the 2024/2025 field season that resulted in greater than optimal depths (up to 40 feet) and suboptimal velocities (less than 0.25 foot per second) and ambiguous water currents at the JSCS are assumed to have contributed to the significantly lower trap efficiencies during the 2024/2025 field season. This conclusion is also supported by the acoustic telemetry data which indicated yearling Chinook Salmon tend to hold upstream in Winnemem Waywaket until flushed downstream by high flow events (DWR 2025).

Future sitings of the JSCS system should take into account variables such as water depth and velocity when siting the facility and considering improvements to the JSCS configuration. Configurations that create preferential flow pathways beneath the JSCS should be avoided. Findings from both the 2023 and 2024/2025 deployments suggest that the capture efficiency may improve if the JSCS is installed at the riverine/reservoir interface where water velocities, depths, and temperatures are more optimal in comparison to head of reservoir. DWR recommends a thorough hydraulic modeling analysis be conducted to provide information regarding the range of reservoir conditions and positions of the riverine-reservoir interface expected throughout the operating season to inform site selection.

Predation may also have affected capture efficiency and Chinook Salmon survival at the JSCS. During the 2023 deployment juvenile Chinook Salmon were found in 11 percent of the black bass captured and DWR recommended that further research and data collection to understand the effects of predation should be the focus of future JSCS deployments. The trap efficiency trials during the 2024/2025 deployment were set up to provide a better understanding of the impact of predation effects on Chinook Salmon survival and capture efficiency. While recapture of “near” release groups was significantly higher than recapture of “standard” release groups, trap efficiencies were too low to draw clear conclusion regarding the effects of predation on juvenile Chinook Salmon survival.

Predator diet sampling during the 2024/2025 field season indicated that Spotted Bass are a primary predator threat to juvenile Chinook Salmon at the head of reservoir within the vicinity of the JSCS site. Further study will be require to understand the impact of predation on juvenile Chinook Salmon in the Winnemem Waywaket and McCloud Arm of Shasta Reservoir.

8 Conclusions

Per the JSCS study, facility siting plays a key role in the performance of a collection facility. If Project alternatives include a downstream juvenile collection facility similar to the JSCS system, care should be taken to site the facility in a location with appropriate water depths, velocities, and channel width to maximize the collection efficiency. This may include the option to reconfigure the JSCS to operate at the riverine-reservoir interface as opposed to the head of reservoir, or inclusion of active hydraulic controls (e.g., attraction pumps) to create more favorable hydraulics at the trap entrance and reduce likelihood of fish bypassing the trap. In addition, a portable facility may be more suitable compared to a fixed facility as the water levels may fluctuate substantially throughout the collection season and redeployment of a juvenile collection facility may be required. Modifications to the configuration to handle larger debris loads should also be considered. Once additional research into predation of Chinook Salmon and pathogen-related risks have been completed, the findings should also be taken into account for the design and location of a Project juvenile collection facility, if carried forward during the alternatives analysis.

9 References

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