Grand Lake Adaptive Management Annual Report 2025

Grand Lake Adaptive Management Committee

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BACKGROUND AND PURPOSE

In January 2016, the U.S. Department of the Interior Bureau of Reclamation (Reclamation), Northern Colorado Water Conservancy District (Northern Water), Grand County Board of County Commissioners (Grand County), Northwest Colorado Council of Government (NWCCOG), and Colorado River Water Conservation District (River District) entered into the Grand Lake Clarity Stakeholders' Memorandum of Understanding (Clarity MOU) (Appendix A: Clarity MOU).

In this Clarity MOU, the parties agreed to establish an adaptive management process to implement the Water Quality Control Commission's (WQCC) narrative water quality standard for Grand Lake, which is:

> "The highest level of clarity attainable, consistent with the exercise of established water rights, the protection of aquatic life, and protection of water quality throughout the Three Lakes system."

Further, the parties agreed to implement clarity goals to guide the adaptive management process:

> "The annual clarity goals for Grand Lake from July 1 through September 11 are an average Secchi depth of 3.8 meters and a minimum Secchi depth of 2.5 meters."

The clarity goals and the adaptive management approach were subsequently endorsed by the WQCC in April 2016, and the clarity goals were adopted as goal qualifiers. In the June 30, 2016 Statement of Basis and Purpose for Regulation 33 (Appendix B: Statement of Basis and Purpose), the WQCC stated that "The Division [Water Quality Control Division] will assess consistency with the adopted narrative standard by monitoring whether the Proponents continue to implement the adaptive management process described in their Memorandum of Understanding and will review clarity measurements. Evaluation of the Clarity Goals will be accomplished by reviewing annual reports and summarizing progress at the Basin Issues Scoping Hearing."

The Clarity MOU established the preparation of an annual report to summarize what was learned about Colorado-Big Thompson (C-BT) Project operational approaches to meet the clarity goals, and resultant effects on water quality and clarity in Grand Lake. The MOU specifies consideration of three water quality indicator thresholds – Grand Lake Secchi depth at index sites, Shadow Mountain Reservoir dissolved oxygen (DO) at the bottom and surface, and pH in Shadow Mountain Reservoir near the surface.

This report meets the reporting requirements of Section V.C.5.d of the Clarity MOU and the Water Quality Control Commission.

2025 ADAPTIVE MANAGEMENT PROCESS

This section describes the 2025 Adaptive Management Process.

Adaptive Management Committee Representatives

The Adaptive Management Committee (AMC) comprises representatives from Reclamation, Northern Water, Grand County, NWCCOG and the River District. A list of the representatives that attended meetings in 2025 is included in Appendix C: Adaptive Management Committee Representatives.

Section V.C. of the Clarity MOU describes the process for developing an operational plan and for the adaptive management phase during the July 1 through September 11 Grand Lake Adaptive Management (GLAM) Season. This process is illustrated in Figure 1.

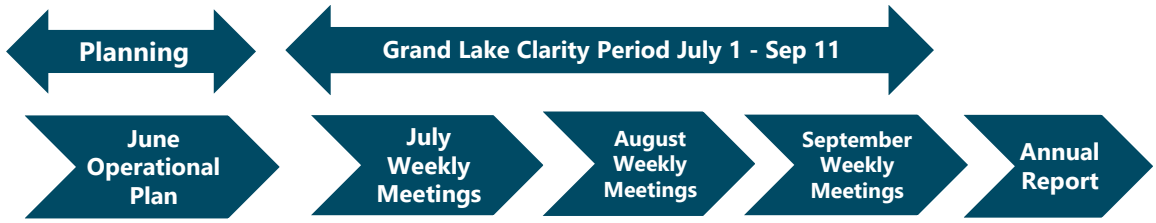

Figure 1. Adaptive Management Process

Section V.C of the Clarity MOU specifies that operational scenarios along with corresponding water quality model runs shall be presented to the AMC at a seasonal kick-off meeting by June 1 of each year.

East Troublesome Fire

On October 14, 2020, the East Troublesome Fire (ETF) started in Grand County. The fire burned 193,812 acres of forest and shrubland, as well as 366 residences in north-central Grand County and the Three Lakes Watershed, before it was declared contained on November 30, 2020. Some of the watersheds burned in the fire included Willow Creek, Stillwater Creek, North Fork Colorado River, and North Inlet (89, 90, 29, and 42% burned, respectively), all which flow into the Three Lakes and Willow Creek Reservoir. The most significant water quality changes observed in the Three Lakes and Willow Creek Reservoir have been increases in nutrient concentrations, specifically NO_3 and NO_2 as N and to a lesser degree ortho phosphorus. Some other parameters, including physical parameters and metals, have shown only small changes based on median concentrations. It is not clear if these changes are solely related to impacts from the ETF. Subsequent changes, such as increased algal and cyanobacteria growth, have been observed in many post-fire years and have the potential to continue.

While it is difficult to predict how long fire-related water quality effects will persist in the Three Lakes region, Figure 2 shows NO_3 and NO_2 as N concentrations at the surfaces of Shadow Mountain Reservoir and Grand Lake from 2009-2025, with the ETF shown as a vertical dotted red line in October 2020, as an example of post-fire water quality response. It is not yet known how long elevated concentrations will persist, although the data indicate that NO_3 and NO_2 as N may have reached a post-fire peak in Grand Lake and Shadow Mountain Reservoir as the 2025 pattern and concentrations were similar to pre-fire conditions. It is important to note that the data displayed in the graph represent discrete samples in time and do not account for increased concentrations that could have occurred during precipitation events or other nutrient loading events.

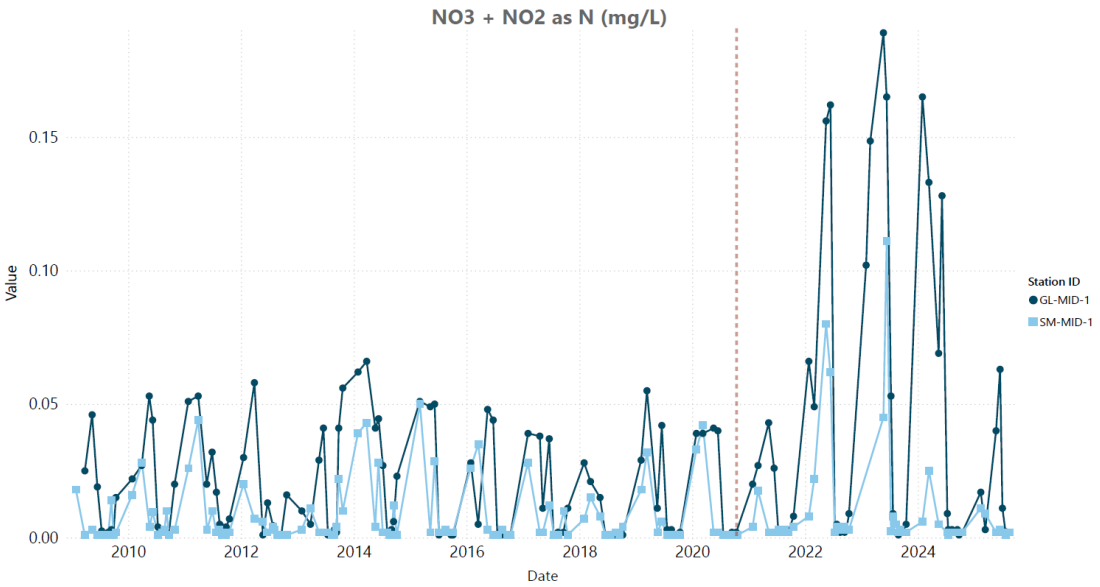

Figure 2. NO_3 and NO_2 as N (mg/L) at GL-MID surface and SM-DAM surface. The vertical dotted red line indicates the timing of the East Troublesome Fire in October 2020.

Planning Process

The AMC agreed to an amended GLAM process in each year from 2021-2024 because the Three Lakes Water Quality Model was not used during the GLAM planning process in these years. For more detail on the amended GLAM Process in 2021-2024, refer to the 2024 GLAM Annual Report. The model, however, was used in 2025 and an amended process was not needed. The following is a summary of the sequence of GLAM meetings in 2025. A schedule of all meetings is included in Appendix E: 2025 Meeting Schedule.

Kickoff Meeting – May 30, 2025

The AMC reviewed Reclamation's proposed operational scenarios, and the corresponding Annual Operational Plan (AOP) model results and water quality model runs and provided feedback to Reclamation. Following the Kickoff Meeting, Reclamation refined their operational plan and distributed it to the AMC. The plan is described in the 2025 Operational Plan section below and the Kickoff Meeting materials are included in Appendix D: Kickoff Meeting and Operational Plan Discussion.

Pre-Season Weekly Meetings – June 10-24, 2025

The AMC held weekly pre-season meetings to understand water quality, clarity, and operational conditions prior to the beginning of the GLAM Season.

GLAM Season Weekly Meetings – July 1-September 9, 2025

The AMC held weekly meetings to discuss water quality and operations in an effort to optimize clarity and gain insight about system dynamics. Meeting materials, notes and recordings are compiled in Appendix F: Compilation of Weekly Meeting Reports and Notes.

Debrief Meeting – October 22, 2025

The AMC held a debrief meeting to discuss possible improvements to the process, lessons learned and recommendations for future years. Meeting materials are in Appendix G: Debrief Meeting.

2025 Operational Plan

The Northern Water Board of Directors sets a C-BT Project water delivery quota each year, which quantifies the amount of C-BT water available to allottees, and is based on the need for supplemental water on the East Slope. Quotas are expressed as a percentage, in which a quota of 100% indicates that each share of C-BT receives the full allotment of one acre-foot, while a quota of 50% means that each share receives 0.5 acre-feet. The Northern Water Board set the quota at 70% in April 2025. Due to a warm and dry spring, particularly April, the Northern Water Board allocated an additional 5% in June 2025 for a total quota of 75%. The Northern Water Board also allocated 23,000 acre-feet of Regional Pool water in May, which comes out of unused and unclaimed quota allocations from the year prior.

Operational Scenarios

Reclamation prepared two proposed Operational Plans for presentation and discussion at the May 30, 2025, Kickoff Meeting. Both plans sought to:

- Conserve C-BT Project water and avoid unnecessary spill at Granby Dam,
- Meet demands of the Colorado-Big Thompson project, notably on the Big Thompson River,
- Generate clean hydropower,
- Capitalize on east slope skim water,
- Prepare for the planned filling of Chimney Hollow Reservoir, and
- Create the greatest suite of public benefits from the system.

Early season conditions were conducive to operational flexibility; no major outages were planned, and the forecasted meteorology showed a three-month weather outlook of slightly warmer and drier than average. Both operational plans were modeled under two analog years using meteorological and hydrological inputs to produce simulated operational results. Hydrological and meteorological data from the same year were used for modeling to better capture the relationship between meteorology and hydrology and to reduce the number of model runs and analysis. Analog years of 2006 and 2022 were chosen based on early season forecasts of snowpack and runoff. Willow Creek and Windy Gap pumping volumes were the same in each scenario as were Big Thompson daily flow and daily water demands on the East Slope. No scenario forecasted a spill out of Lake Granby. Modeled operational scenarios are described in Table 1.

Table 1. Operational scenarios modeled in Reclamation's operations model and in the Three Lakes Water Quality Model.

Scenario	Description
1a – Maximum Settling Period (2006)	Maintain flows greater than 40 cfs from Grand Lake to Shadow Mountain Reservoir in June. Some power concessions were made starting June 21 to maintain these flows. Begin Farr pumping July 1 when demands exceed North and East Inlet inflows and spill at Lake Granby becomes a possibility. Flows reverse between Shadow Mountain Reservoir and Grand Lake on July 1. Diversions through the Adams Tunnel will be large during the weekdays and reduced slightly on the weekends.
1b – Balanced Settling Period (2006)	Maintain flows greater than 40 cfs from Grand Lake to Shadow Mountain Reservoir in June. Farr pumping begins on June 21 and flows between Shadow Mountain Reservoir and Grand Lake reverse. East Slope skim is marginally less than in 1a due to additional diversions through the Adams Tunnel between June 23-30. Diversions through the Adams Tunnel will be large during the weekdays and reduced slightly on the weekends.

Scenario	Description
2a – Maximum Settling Period (2022)	Maintain flows greater than 40 cfs from Grand Lake to Shadow Mountain Reservoir in June. Some power concessions were made starting June 24 to maintain these flows. Begin Farr pumping July 7 when demands exceed North and East Inlet inflows and spill at Lake Granby becomes a possibility. Flows reverse between Shadow Mountain Reservoir and Grand Lake on July 7. Diversions through the Adams Tunnel will be large during the weekdays and reduced slightly on the weekends.
2b – Balanced Settling Period (2022)	Maintain flows greater than 40 cfs from Grand Lake to Shadow Mountain Reservoir in June. Beginning on June 23 Farr pumping begins and flows between Shadow Mountain Reservoir and Grand Lake reverse. East Slope skim is marginally less than in 2a due to additional diversions through the Adams Tunnel between June 23-30. Diversions through the Adams Tunnel will be large throughout the entire GLAM Season without the weekend reductions in pumping.

Water Quality Modeling

Each operational scenario (1a, 1b, 2a, and 2b) was simulated using the Three Lakes CE-QUAL-W2 Model (version 2.0) developed by Hydros Consulting. Model outputs for Secchi depth in Grand Lake, along with chlorophyll-a and dissolved oxygen in Shadow Mountain Reservoir, were compared across scenarios. Simulated water clarity was similar among all four scenarios, reflecting the overall similarity in operational conditions, particularly the magnitude and temporal pattern of Farr pumping during the clarity season. Results indicate that the simulated average Secchi depth for Grand Lake varied by less than 0.3 meters across scenarios.

Plan Selection

No specific scenario was chosen during the May 30, 2025, Kickoff Meeting, but feedback was presented to Reclamation emphasizing interest in a settling period, preservation of high quality spring runoff in Grand Lake without mixing of water from Shadow Mountain Reservoir for as long as possible by maintaining at least 40 cfs flow from Grand Lake to Shadow Mountain Reservoir in the Connecting Channel until Farr pumping began, and in maintaining good water quality in Shadow Mountain Reservoir. The group discussed which scenario provided greater operational flexibility throughout the GLAM Season to adapt to ongoing conditions; neither scenario provided significantly different operational flexibility. These oral and written comments from the AMC were compiled and considered by Reclamation.

On June 13, 2025, Reclamation released a Draft Operational Plan and followed up with a Final Operational Plan on June 23, 2025, via email to the AMC. A summary of their plan is provided below.

The Operational Plan is intended to meet the primary purposes listed in Senate Document 80:

1. *To preserve the vested and future rights in irrigation.*
2. *To preserve the fishing and recreational facilities and the scenic attractions of Grand Lake, the Colorado River, and the Rocky Mountain National Park.*
3. *To preserve the present surface elevations of the water in Grand Lake and to prevent a variation in these elevations greater than their normal fluctuation.*
4. *To conserve and make use of these waters for irrigation, power, industrial development, and other purposes, as to create the greatest benefits.*
5. *To maintain conditions of river flow for the benefit of domestic and sanitary uses of this water.*

The Operational Plan took into consideration system inflows, facility outages, system maintenance, operations that help optimize Grand Lake clarity, power generation and East Slope water capture. The culmination of these limitations and feedback from the AMC resulted in the plan described below.

The 2025 Operational Plan, as outlined in an email from Reclamation on June 23, 2025, is below. This Operational Plan is a guiding document and is not prescriptive.

Operations were constrained by the following operation and maintenance projects:

1. *Pole Hill Power Plant damage limiting power operations to 24 MW (approximately 425 cubic feet per second (cfs)) to full load while minimizing operations between speed no-load and 24 MW. This causes Reclamation to bypass the power plant or maintain flows greater than 425 cfs. Bypassing results in lost power opportunity.*
2. *Mary's Lake Power Plant was returned to operation in 2025 with a minimum generation requirement of 200 cfs.*
3. *Hansen Feeder Canal to Horsetooth Reservoir constrained to less than 475 cfs.*

The following is an excerpt from the Bureau of Reclamation's Operational Plan in May 2025 and constitutes a "best case scenario":

1. *Carter Lake*
    a. *Pumping to Carter Lake is delayed until July 7, to enhance the "settling period" for Grand Lake. June 1 simulated hydrology has sufficient inflows to Grand Lake and Shadow Mountain Reservoir to allow this scenario, however, the same simulation shows generation will need to cease at Pole Hill Power Plant on June 28 due to insufficient Adams Tunnel flow and east slope power skim to maintain greater than 420 cfs at the powerplant.*
    b. *Adams Tunnel flows are increased on July 7 and pumping to Carter Lake resumes for the season on the same day.*
    c. *We expect to continue pumping to Carter Lake through September 17.*
    d. *No planned outages exist on the system during the 2025 GLAM Season.*

2. *Horsetooth Reservoir*
    a. *Horsetooth Reservoir receives as much water as reasonable. "Reasonable" means we have a storage target for May 2026 at Horsetooth Reservoir and water moved to Horsetooth Reservoir during the 2025 GLAM Season allows us to achieve the storage target next year (see power and east slope water discussion section; having sufficient space in Horsetooth Reservoir for 2026 runoff season's east slope priority water is consideration for the June AOP).*
    b. *Regardless of water source, deliveries to Horsetooth Reservoir cannot exceed CHFC 550 section capacity, simulated to be approximately 475 cfs. When pumping to Carter Lake is not happening, this limitation results in some marginal opportunity for east slope skim operations through Olympus Tunnel, using Olympus Tunnel remaining capacity up to 550 cfs.*
    c. *Horsetooth Reservoir surface elevation is at 5927.0 feet at end of June, 2.5 feet from full, which reserves space for altering the base case scenario (such as ending the "settling period" early) and some temporary storage for local storms and runoff.*
    d. *From its peak, Horsetooth Reservoir storage declines through the summer as driven primarily by demands met through delivery.*

e. *On July 7, Olympus Tunnel diversions are set to maintain approximately 425 cfs at Pole Hill Powerplant on weekends and about 550 cfs on weekdays. Adams Tunnel flows generally follow the same pattern, although from July 7–July 24 Adams Tunnel flows are mildly less than Olympus Tunnel because east slope skim water is still available in the simulation.*
f. *These operations position Horsetooth Reservoir very well going into winter refill operations, beginning in December 2025.*

3. *Adams Tunnel*
    a. *Starting on July 7, flows begin at approximately 480 cfs through the Adams Tunnel and reach 550 cfs by July 24 on weekdays. Diversions continue from west to east through the end of February 2026. Leading up to the beginning of the GLAM Season through July 7, the diversion rates generally decline as west slope hydrology drives the available flows given the goal of maintaining the Grand Lake to Shadow Mountain Reservoir flow direction.*
    b. *Weekend reductions in diversion through Adams Tunnel commence July 19, with reduced flows ranging from 400 cfs and upward as the season progresses (less skim becomes available and Big Thompson River demands increase). Weekday flows will work with east slope flows to take advantage of remaining skim opportunities while keeping the system running near capacity.*
    c. *The shutdown of pumping to Carter Lake is expected to occur after the GLAM Season is complete (shutdown is simulated to occur on September 17).*
4. *Grand Lake / Shadow Mountain Reservoir Connecting Channel*
    a. *Highly dependent on the shape of uncertain west slope hydrographs, flows remained from Grand Lake into Shadow Mountain Reservoir from June 1 through July 6. By June 22, Adams Tunnel flows begin adjustment downward to maintain Grand Lake to Shadow Mountain Reservoir flow direction at about 45–50 cfs. This continues through July 6. Reversal of flows from Shadow Mountain Reservoir into Grand Lake begins on July 7. Simulated flow reversal is ~300 cfs on July 7 and increases to more than 400 cfs by mid-July. Lake Granby reaches peak storage at the end of the day on July 6, about 7.5 KAF from full or 0.5 feet short of fill.*
5. *Chimney Hollow Operations*
    a. *Since meeting in May, Chimney Hollow Reservoir's beginning of first fill has been delayed from July 14. Some minor filling (approximately 180 AF) may begin on August 19 at rates from 2 to 30 cfs, with first phase beginning in earnest on August 29.*

The full operational plan and comments from GLAM entities are included in Appendix D: Kickoff Meeting and Operational Plan Discussion.

2025 Adaptive Management

During the June 24 pre-season GLAM meeting, participants noted a slight decline in Secchi depths and water temperatures that were above target levels. Although Hydros Consulting indicated that temperature targets are intended to apply only in July and August, Reclamation noted that flows were dropping below the minimum required for power generation. As a result, Reclamation identified an opportunity to implement an operational change by reducing diversions to the Adams Tunnel and retaining more native inflows in Grand Lake.

Historically, Reclamation has maintained minimum flows from Grand Lake to Shadow Mountain Reservoir and diverted any excess water through the Adams Tunnel. In this instance, however, Reclamation allowed all available water to flow from Grand Lake into Shadow Mountain Reservoir to improve temperature conditions in Shadow Mountain Reservoir. While it is difficult to directly attribute subsequent improvements in clarity to this action, the operational change represents an adaptive management action implemented under the GLAM framework to optimize clarity.

Discussions during the weekly GLAM meetings in 2025 addressed conditions in the connecting channel, temperature in Shadow Mountain Reservoir, and power generation considerations relating to ongoing and planned C-BT Project operations. Discussions emphasized that preserving water quality in Shadow Mountain Reservoir and the connecting channel could maximize water quality entering Grand Lake once Farr pumping began.

Adams Tunnel flows were reduced to 50 cfs starting on June 24 to maximize flow in the connecting channel in the direction from Grand Lake to Shadow Mountain Reservoir. Pole Hill Power Plant was shut down for much of this period given that flows were well below the 425 cfs minimum for power generation. Farr pumping began on July 8, flows in the connecting channel reversed, and flow from Shadow Mountain Reservoir into Grand Lake remained for the rest of the GLAM Season. Pole Hill Power Plant resumed generation on July 11 as Adams Tunnel flows ramped back up following the start of Farr pumping. Relatively consistent operations took place throughout the remainder of the GLAM Season with periodic weekend flow reductions when Big Thompson River demands, satisfied by the Adams Tunnel, were low enough to allow this operation.

In 2025, both goal qualifiers, the season average of 3.8 meters and season minimum of 2.5 meters, were met. The average Secchi depth in Grand Lake during the GLAM Season was 4.1 meters and the minimum daily Secchi depth was 2.9 meters.

The AMC also discussed coordination with the Red Top Ditch to shut off their headgate slowly to avoid a sharp increase in flows in the North Fork of the Colorado River that in the past has increased turbidity and suspended sediments flowing into Shadow Mountain Reservoir, impacting clarity. The ditch operators have been contacted, and this coordination will occur in 2026.

GRAND LAKE & SHADOW MOUNTAIN RESERVOIR CLARITY

This section describes observed water quality and clarity in Shadow Mountain Reservoir and Grand Lake during the 2025 GLAM Season (July 1 - September 11). Figure 3 shows the monitoring sites where data were collected. The Grand County Water Information Network (GCWIN) is contracted to conduct the Secchi monitoring and other data collection efforts for the GLAM Season; the summary of this program is in Appendix H: Secchi Monitoring Program Summary. Secchi measurements were recorded at seven lake/reservoir sites, and two buoys equipped with real-time sensors collected profile data every four hours at SM-MID and SM-DAM. Real-time data collection also occurred at GR-PUMP, CR-SMU, and SM-CMK (USGS site). GCWIN also collected weekly profiles at GL-MID. Farr pump flows are measured at Farr Pump Plant.

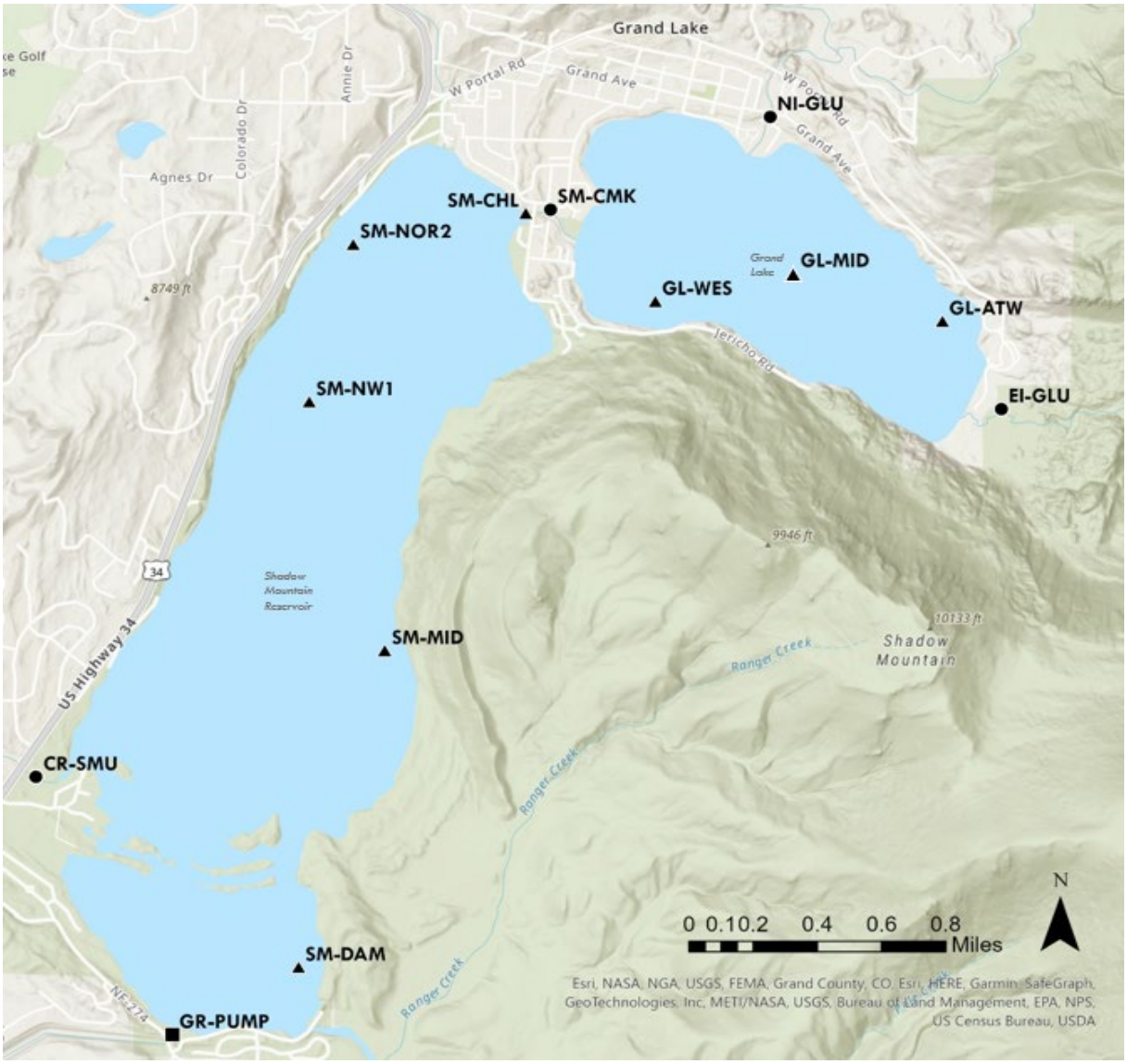

Figure 3. Map of Sampling and Monitoring Locations used during the GLAM Season and Weekly GLAM Meetings. Triangles represent reservoir/lake sites, circles represent flowing sites, and the square represents a canal site.

Operations Summary

Peak naturalized (undepleted) runoff into the Three Lakes in 2025 was reached on June 2 at a daily average of 2,369 cfs (Figure 4). The total April through July runoff volume of 199 thousand acre-feet (KAF) nearly matched the May most-probable forecast of 200 KAF. The C-BT Project's east slope Big Thompson River water right did not come into priority in 2025, so no east slope water was collected.

Carter Lake and Horsetooth Reservoir were both filled to their planned elevations to meet projected seasonal demands prior to the 2025 GLAM Season. The C-BT Collection System did not spill at either Lake Granby or Willow Creek Reservoir. During the GLAM Season, the weather was slightly warmer than average (Figure 5) with slightly below average precipitation (Figure 6). The period of the GLAM Season with the most precipitation was August 22 to 30, with approximately 1.1 inches of rain falling in the Grand Lake area during that time.

During runoff, water flows from Grand Lake into Shadow Mountain Reservoir and is shown as negative flow in Figure 8. Once Adams Tunnel diversions exceed natural Grand Lake inflows, the flow reverses, moving water from Shadow Mountain Reservoir into Grand Lake, shown as positive flow in Figure 8. This switch in flow direction generally corresponds with the start of Farr pumping. Post-runoff pumping operations began on July 8, just one day after Reclamation's forecasted date of July 7 from the Operational Plan (Figure 8, Appendix D: Kickoff Meeting and Operational Plan Discussion). The decision to start pumping was based on several factors including available storage on the east slope, maximizing the length of the settling period in Grand Lake, system water quality, minimizing the chance of spill out of Lake Granby, and the availability of skim water for East Slope power generation. Skim water is native Big Thompson River water that is diverted into the C-BT Project system for power generation and then returned to the river shortly thereafter.

During the GLAM Season, water was pumped at Farr Pump Plant at an average daily rate of between 223 cfs and 658 cfs, and when possible, during off-peak power cost hours. Over three weekends of the GLAM Season, Reclamation reduced diversions at the Adams Tunnel to 400 cfs. This approach has been used in previous years with the intention of improving clarity but could not be implemented consistently because of high demands on the Big Thompson River that needed to be met by Adams Tunnel diversions.

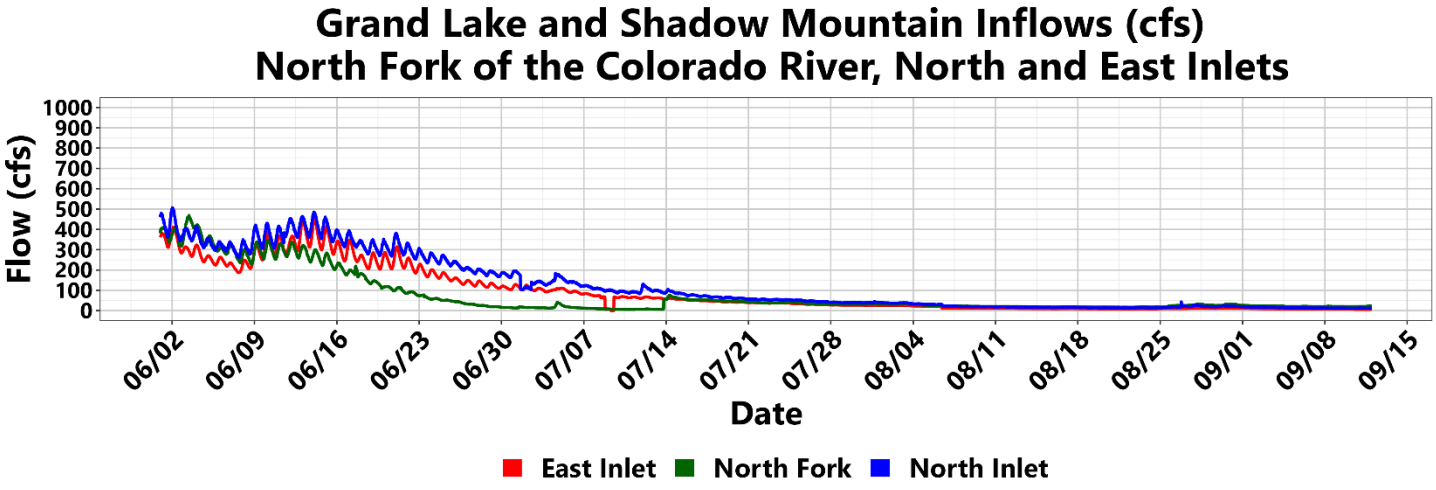

Figure 4. Inflows (cfs) into Grand Lake and Shadow Mountain Reservoir including the North Fork, North and East Inlets.

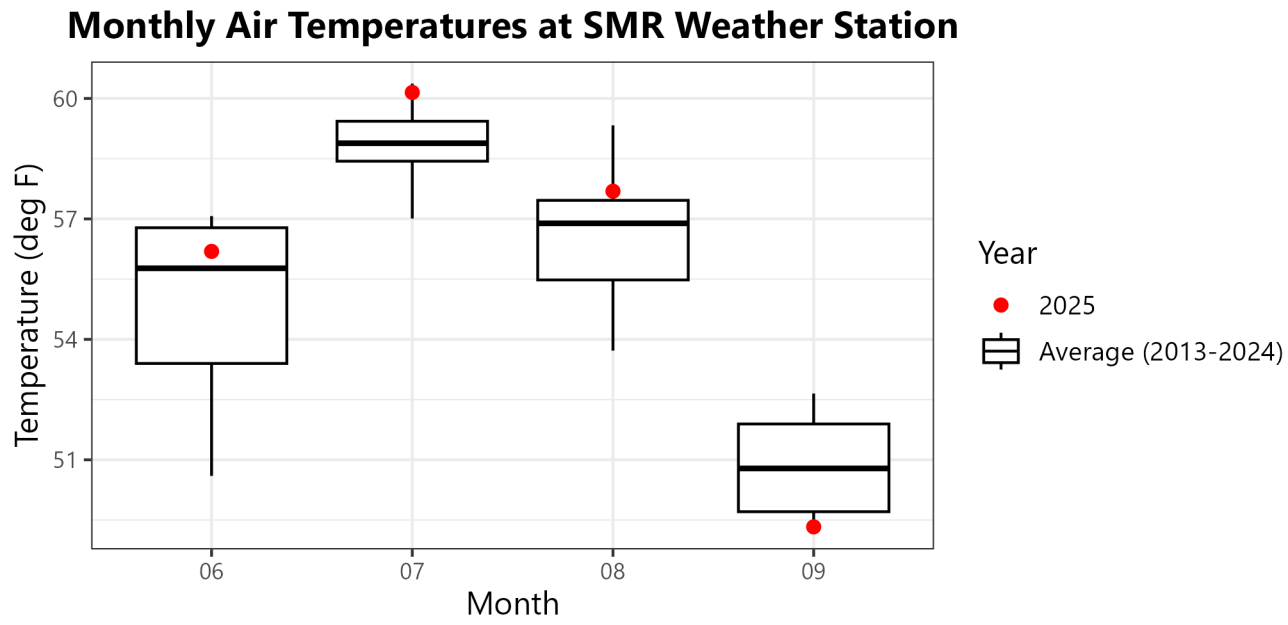

Figure 5. Average air temperatures (Deg F) (June-September) by month at Shadow Mountain Reservoir Weather Station with 2013-2024 average in black and 2025 monthly averages in red.

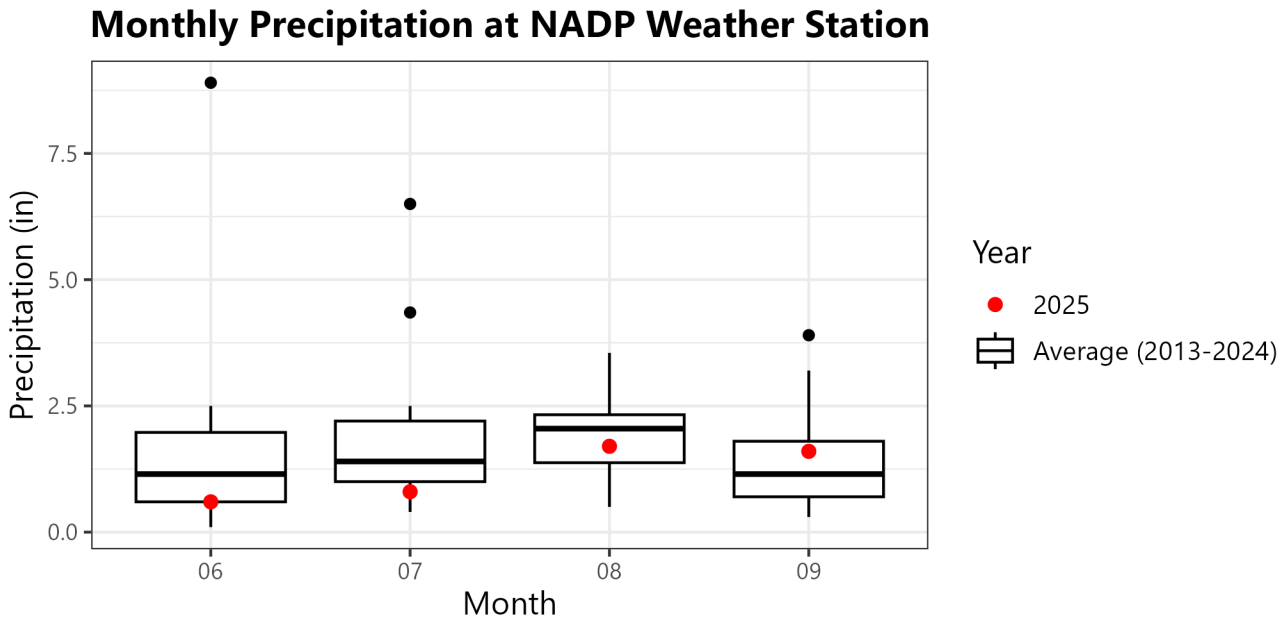

Figure 6. Average monthly precipitation (in) (June-September) by month at Shadow Mountain Reservoir Weather Station. 2013-2024 shown in black boxplot, 2025 average monthly precipitation indicated in red.

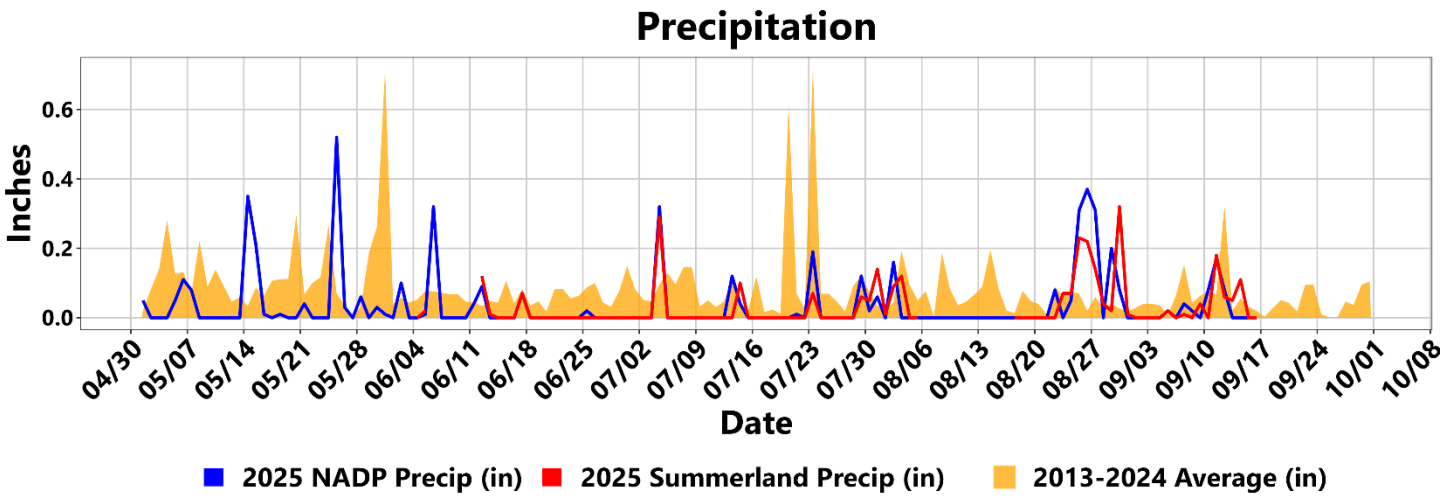

Figure 7. 2025 Precipitation (in) at the NADP Precipitation Station and Summerland Park with 2013-2024 average precipitation in orange.

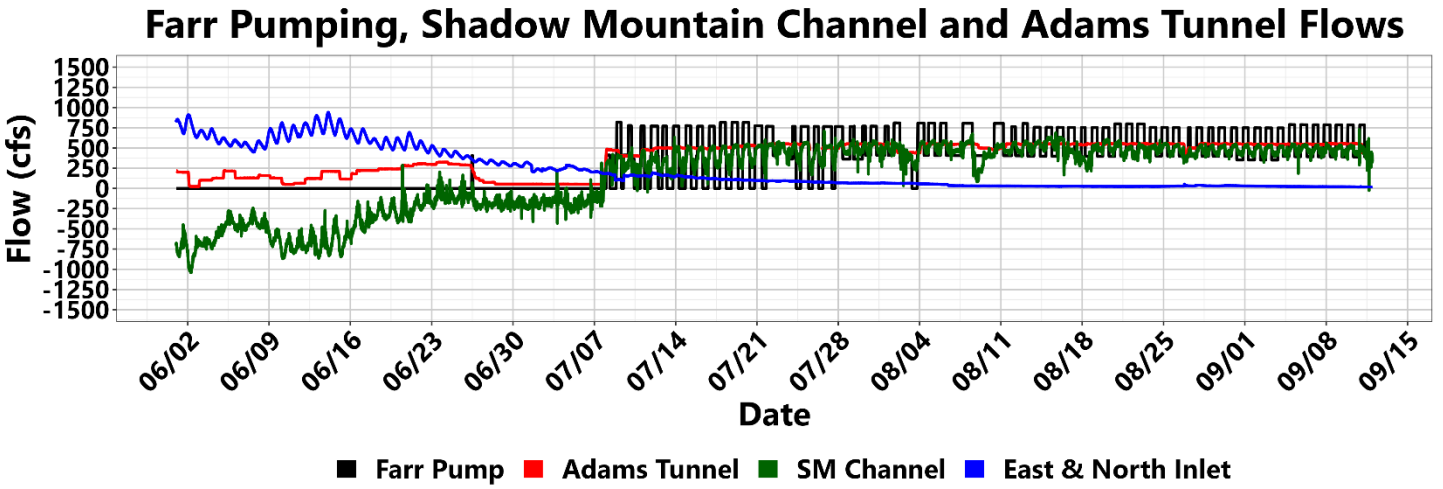

Figure 8. Farr pumping, Shadow Mountain Channel, North and East Inlet flows, and Adams Tunnel Flows

Clarity and Water Quality Summary

Secchi monitoring three times per week took place at seven sites in Grand Lake and Shadow Mountain Reservoir beginning on May 28, 2025, and concluding on September 29, 2025. This additional pre- and post-GLAM Season Secchi data collection supports a holistic understanding of system conditions and informs early GLAM Season operations. Due to summer holidays, the group approved alternative monitoring dates on a few occasions to accommodate staff schedules while still achieving a sampling frequency of three times per week. Daily average Secchi depth is calculated by averaging both viewscope readings for each site on a given day: GL-WES, GL-ATW and GL-MID in Grand Lake and SM-MID, SM-DAM, SM-NOR2, and SM-NW1 in Shadow Mountain Reservoir. On August 8, GCWIN was unable to collect Secchi measurements because of very windy conditions that did not meet data collection protocol. No data is included in the minimum or average calculations for August 8.

Both Grand Lake and Shadow Mountain Reservoir saw improvement in average daily clarity between peak runoff and the beginning of the GLAM Season (Figure 9). Clarity in Grand Lake was generally greater than clarity in Shadow Mountain Reservoir prior to the start of the GLAM Season and similar to that in Shadow

Mountain Reservoir throughout the GLAM Season. Daily average clarity in both water bodies was greater than 3 meters for the entire GLAM Season with one exception in each water body: July 23 in Shadow Mountain Reservoir and July 30 in Grand Lake. Clarity in Grand Lake appeared to "trail" clarity in Shadow Mountain Reservoir in 2025 by two or three days until mid-August when clarity in Grand Lake surpassed clarity in Shadow Mountain Reservoir (Figure 9).

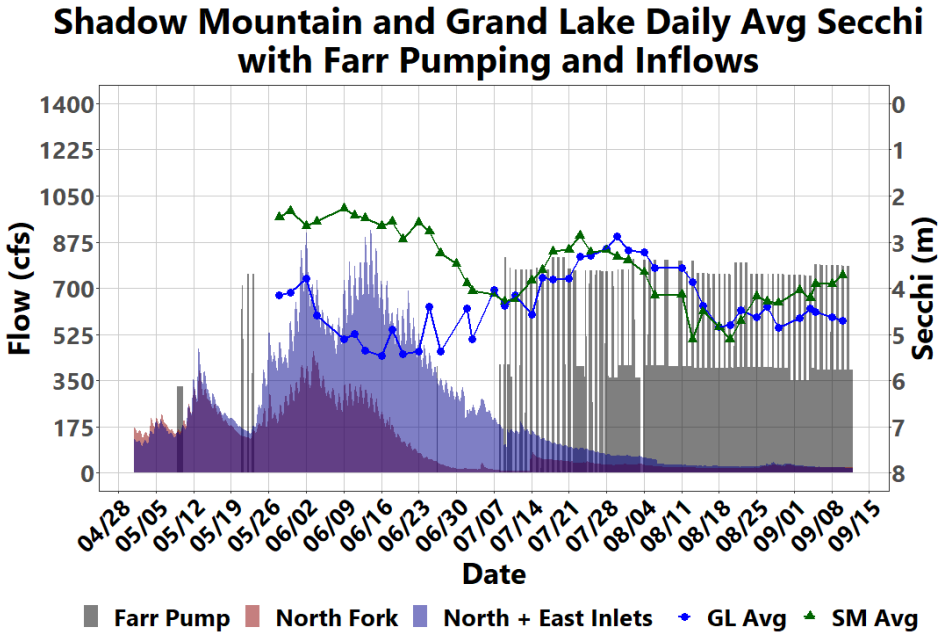

Figure 9. Shadow Mountain Reservoir and Grand Lake daily average Secchi with Farr pumping inflows. Note: hit-bottom measurements were not included in SM Avg calculation.

Clarity in Grand Lake began with Secchi depths around 4 meters in early June during peak runoff and increased as runoff tapered off with a Grand Lake daily average Secchi depth of 4.4 meters on July 2, the first sampling event of the clarity season (Figure 10). Clarity in Grand Lake declined during the early GLAM Season until it reached its minimum value on July 30. After that point clarity began to improve again, reaching a generally consistent Secchi depth between 4.4 and 4.9 meters for each sampling event between August 18 and September 11. Clarity was generally consistent across the three monitoring locations in Grand Lake, but early season events showed the least clarity at GL-WES. The daily average Secchi depth in Grand Lake exceeded 5 meters on one occasion: July 3, and 33% of daily average Secchi depths in Grand Lake exceeded 4.5 meters. The final average clarity in Grand Lake during the GLAM Season was 4.1 meters.

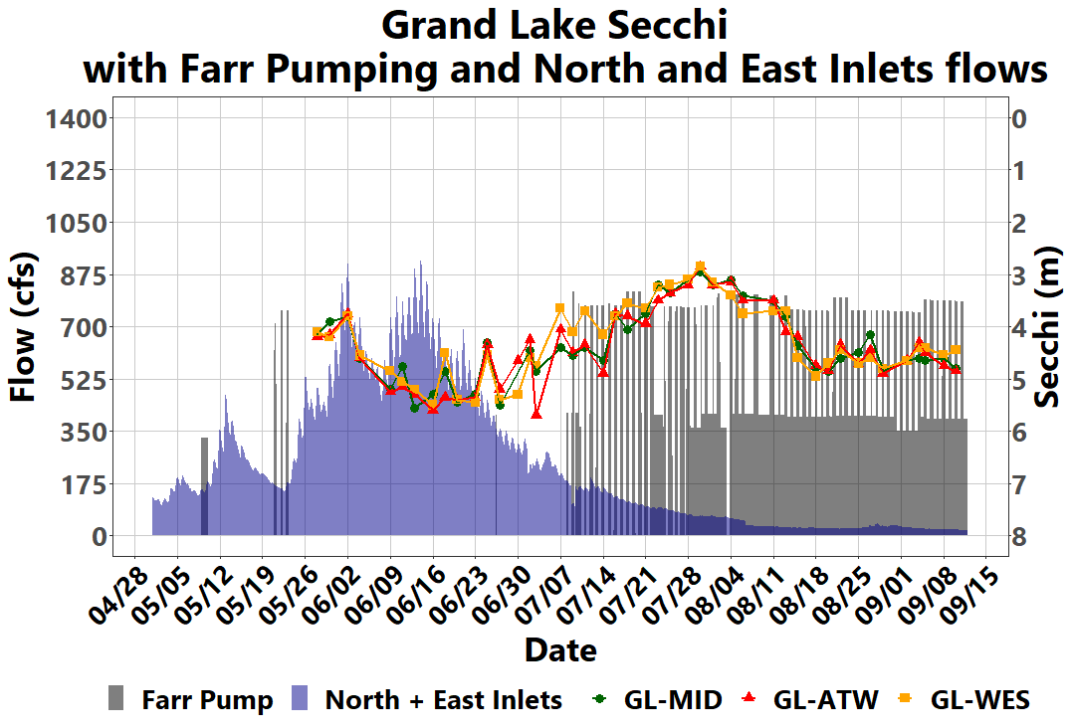

Figure 10. Grand Lake Secchi depth with Farr pumping and North and East Inlet flows

Shadow Mountain Reservoir had a GLAM Season average Secchi depth of 3.9 meters. The maximum daily average Secchi depth was 5.1 meters on August 13 (Figure 11). The bottom of Shadow Mountain Reservoir was hit during several sampling events at SM-NOR2 and on two occasions at SM-MID. Per the monitoring protocol (Appendix H: Secchi Monitoring Program Summary), those measurements are disqualified and are excluded from figures and calculations. Clarity in Shadow Mountain Reservoir was less than 3 meters in early June prior to the start of the GLAM Season but increased into early July. Once pumping began in July, clarity in Shadow Mountain Reservoir declined until the end of July when clarity began to improve, reaching its best clarity in mid-August. After mid-August, clarity in Shadow Mountain Reservoir declined slightly but was still greater than 3.5 meters throughout the rest of the GLAM Season.

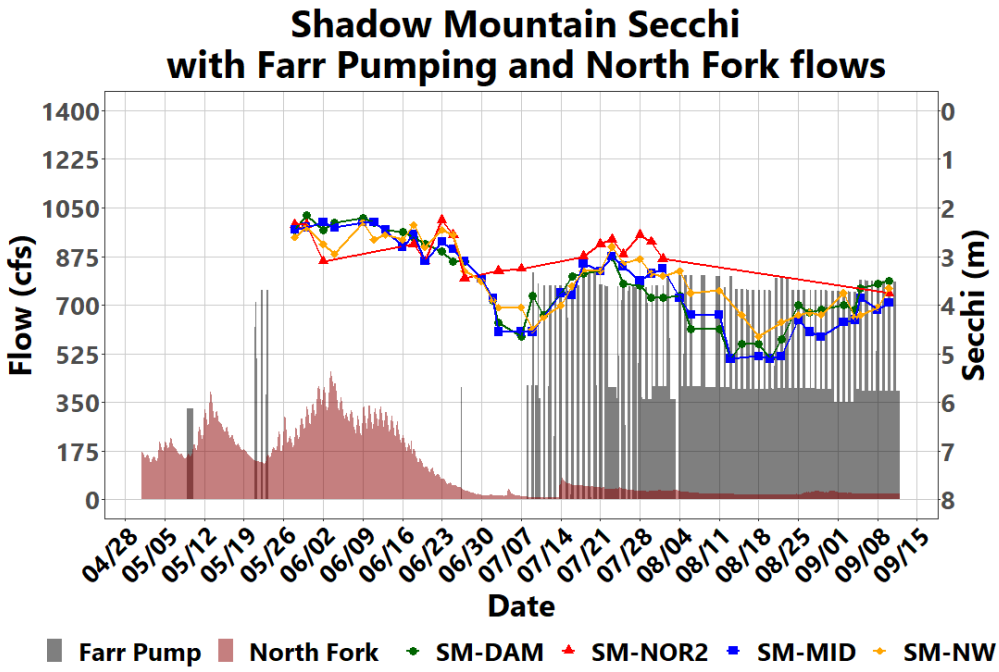

Figure 11. Shadow Mountain Reservoir Secchi depth with Farr pumping and North Fork flows. Missing points indicate a measurement that hit bottom.

Conditions in the connecting channel between Grand Lake and Shadow Mountain Reservoir are shown in Figure 12. The chlorophyll *a* relative fluorescence units (RFU) timeseries in the connecting channel indicated some algal growth in late-June and early July prior to the start of Farr pumping on July 8, but minimal chlorophyll *a* RFU and little to no phycocyanin and turbidity throughout the remainder of the GLAM Season (Figure 13). Specific Conductivity (SpC) is a good indicator of flow direction in the connecting channel; increases in SpC correlate closely with direction of flow from Shadow Mountain Reservoir to Grand Lake (Figure 13).

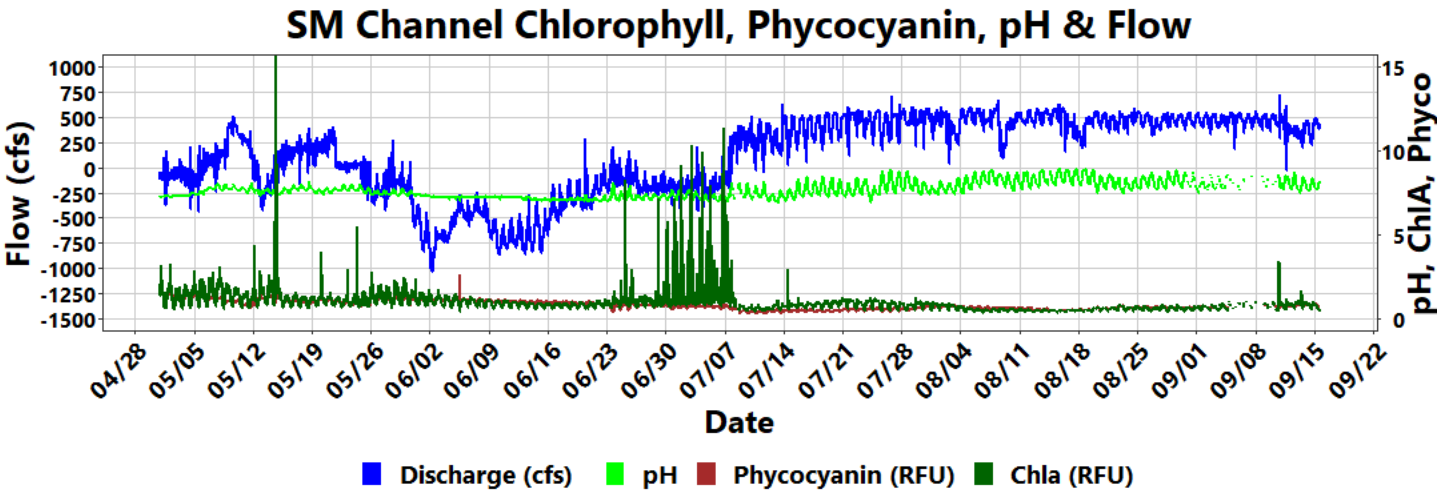

Figure 12. Water quality in the connecting channel between Grand Lake and Shadow Mountain Reservoir showing flow, pH, phycocyanin and chlorophyll a.

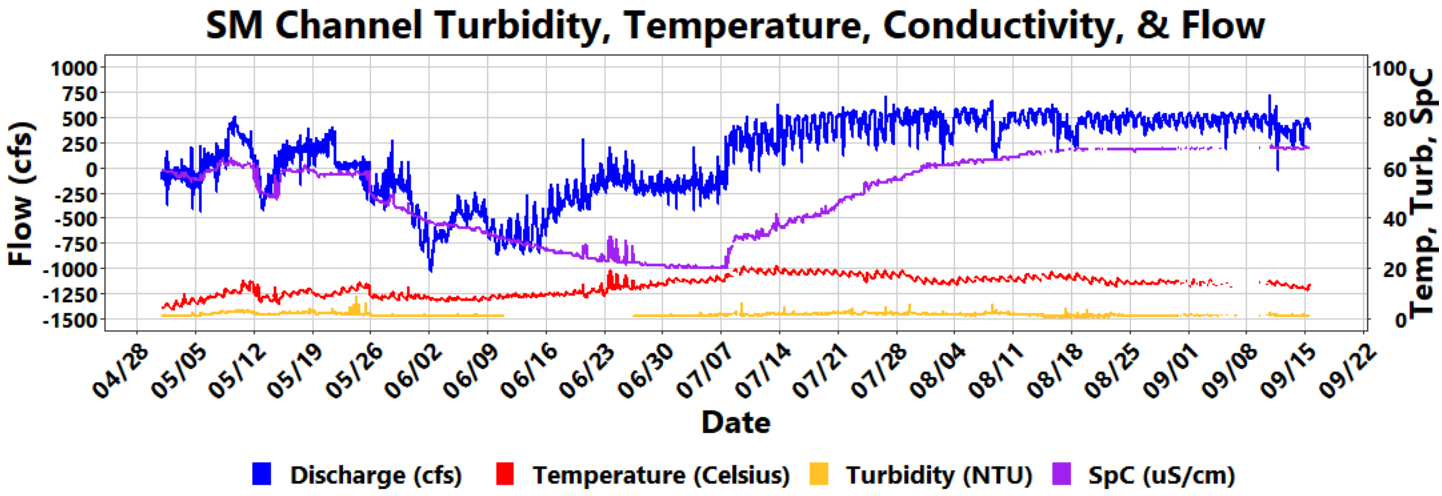

Figure 13. Water quality in the connecting channel between Grand Lake and Shadow Mountain Reservoir showing flow, temperature, turbidity and specific conductivity.

Water quality data collected in Grand Lake and Shadow Mountain Reservoir include physical profiles measuring temperature, DO, pH, chlorophyll *a* RFU, turbidity and SpC. Discrete chlorophyll *a* and phytoplankton samples were taken weekly in Grand Lake and Shadow Mountain Reservoir and bi-weekly at SM-CMK by the USGS. The SM-DAM buoy was not reporting data from June 13-18 and 21-25 due to equipment failure. A summary of these water quality conditions is listed below followed by the respective figures. (Figure 14 - Figure 37).

- Water quality profiles in Grand Lake indicate generally low chlorophyll *a* RFU and turbidity as well as pH below 8 throughout the GLAM Season. There were a few instances of elevated chlorophyll a RFU between 2 and 7 meters with peaks around 2-2.5 RFU. While these are low values, they may indicate some algal growth occurring below the surface in Grand Lake. Similarly, small peaks in turbidity are observed with the most significant on August 27, with a peak of 4 NTU measured at 5 meters.
- Water temperatures in Grand Lake follow the 2025 meteorological trends with the warmest surface temperatures during the last week of July followed by cooling into mid-September (Figure 5). pH, DO and water temperature show evidence of thermal stratification with the highest pH in late August at 2-3 meters below the surface and minimum DO in the thermocline (~10 meters) in early September, indicating consumption of oxygen by respiration. (Figure 14).
- Water temperatures throughout the water column at both SM-DAM and SM-MID showed the warmest period at the end of June and first few days of July just before Farr pumping began. Following the start of Farr pumping, SM-DAM cooled quickly and remained generally below 15 degrees C for the remainder of the GLAM Season. Water temperatures at SM-MID cooled after the start of Farr pumping but still exhibited warm temperatures at the surface for many days in July and August (Figure 15, Figure 16).
- Daily average water temperatures in Shadow Mountain Reservoir from 0-1 meters and 0-5 meters were evaluated in 2025. Water temperatures were generally cooler than 14 degrees C for the 0–5-m interval and generally cooler than 16 degrees C for the 0-1 meters interval. For both sites and both intervals, warmer-than-typical temperatures were observed during the first few weeks of July prior to Farr pumping. This correlates with a warm July in Grand County. Despite the cool water temperatures, significant growth of Asterionella was not observed (Figure 17, Figure 18, Figure 19, Figure 20).
- DO in Shadow Mountain Reservoir followed typical surface concentrations and did not show prolonged low concentrations at the bottom of the reservoir. DO concentrations were lowest at the SM-DAM site

prior to the onset of Farr pumping. DO concentrations fell below the indicator threshold of 3 mg/L with a minimum value of 1.8 mg/L on July 7. Once Farr pumping began, bottom DO concentrations increased and remained above the 3 mg/L threshold, as typical of years with high summer Farr pumping (Figure 21, Figure 22, Figure 23, Figure 24).

- pH in Shadow Mountain Reservoir was not remarkable throughout the GLAM Season, remaining between 7 and 8 for almost the entire period. The one exception was in mid-August when pH exceeded the indicator threshold of 8 on four different days with a maximum value of 8.4 (Figure 25, Figure 26).
- Chlorophyll *a* RFU, chlorophyll *a* grab samples, and phycocyanin RFU remained low throughout the entire GLAM Season with no significant peaks or indications of significant algal growth. Some biovolume data from phytoplankton samples in Grand Lake and Shadow Mountain Reservoir indicated high cyanobacteria and diatom biovolumes, however, high concentrations were not observed during the same period in chlorophyll *a* and phycocyanin measurements. This will be a continuing point of investigation (Figure 27, Figure 28, Figure 29, Figure 30, Figure 31, Figure 32).
- Turbidity in Shadow Mountain Reservoir remained low through the GLAM Season with no noticeable effects from inflow turbidity.
- Specific conductivity in Shadow Mountain Reservoir followed typical trends in 2025, increasing throughout the GLAM Season with the consistent inflow of water from Lake Granby (Figure 36, Figure 37).
- The chlorophyll *a* RFU from the September 10 profile has been disqualified after the sonde did not pass post-calibration checks, other data from that profile were retained (Figure 14).

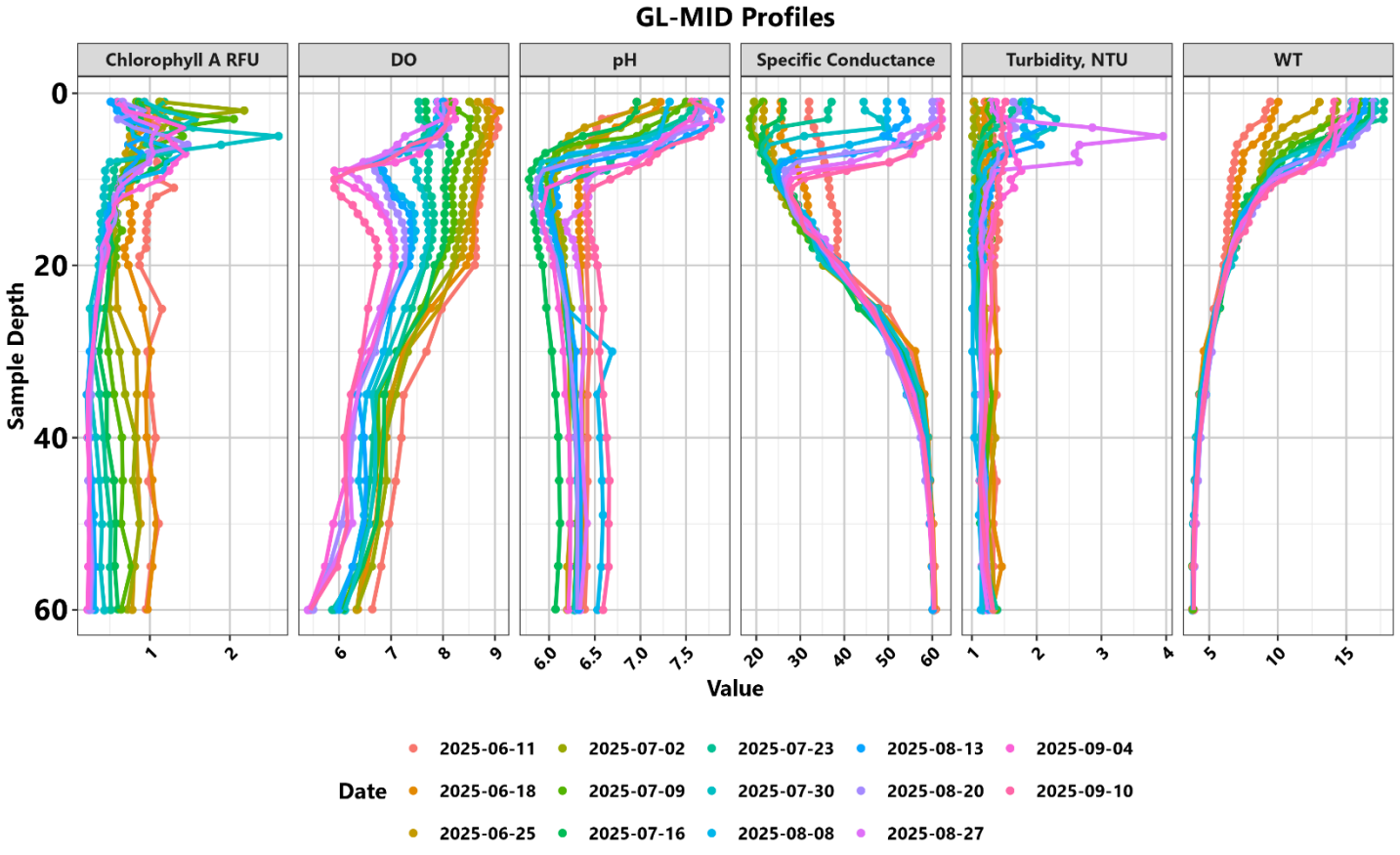

Figure 14. Discrete water quality profiles at GL-MID in 2025.

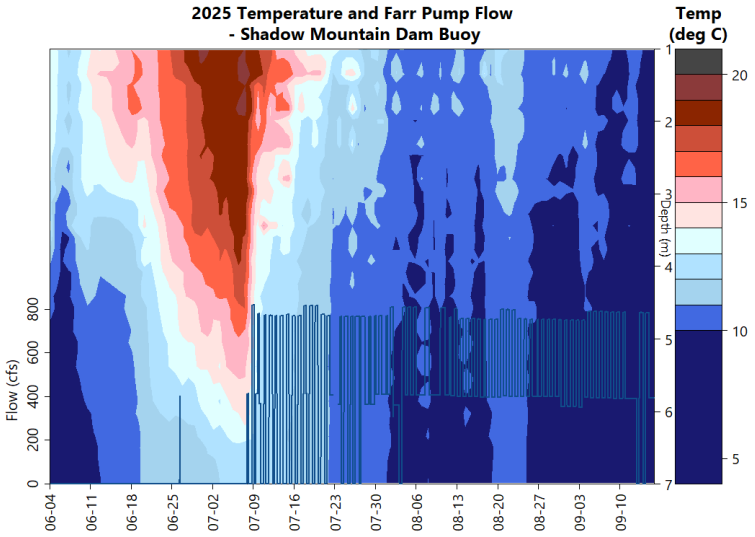

Figure 15. 2025 Water temperature (color) and Farr Pump flow (line) at SM-DAM.

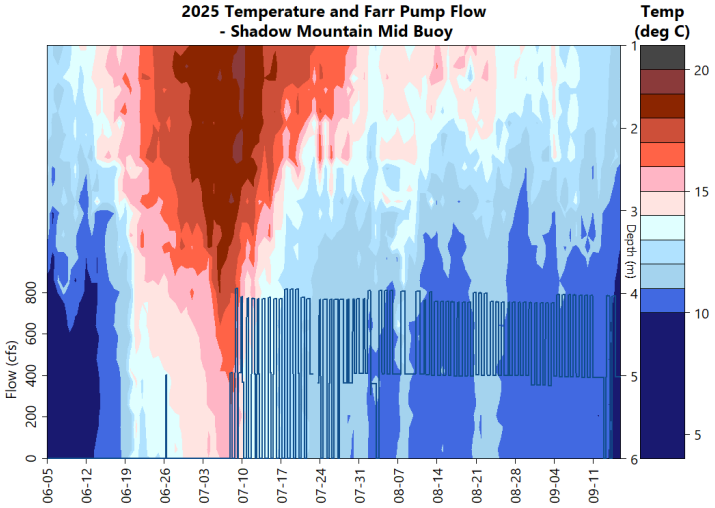

Figure 16. Water temperature (Deg C) (color) and Farr pump flow (line) at SM-MID.

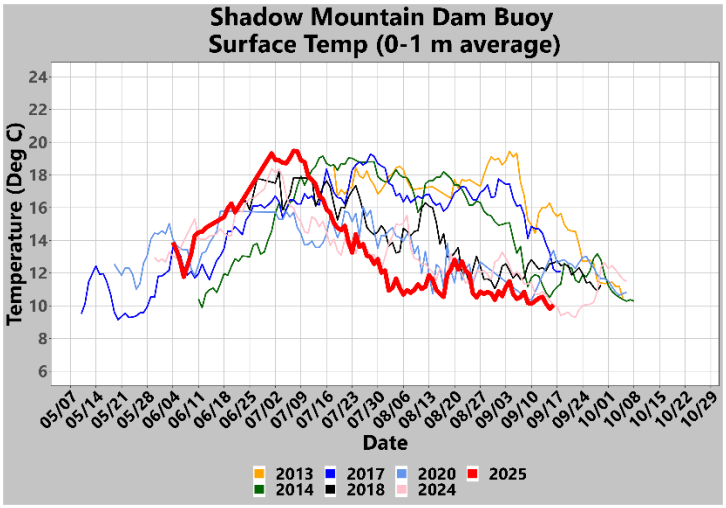

Figure 17. Average daily surface water temperature from 0-1 meters in Shadow Mountain Reservoir at SM-DAM. 2025 data is shown in red with other colors showing reference years.

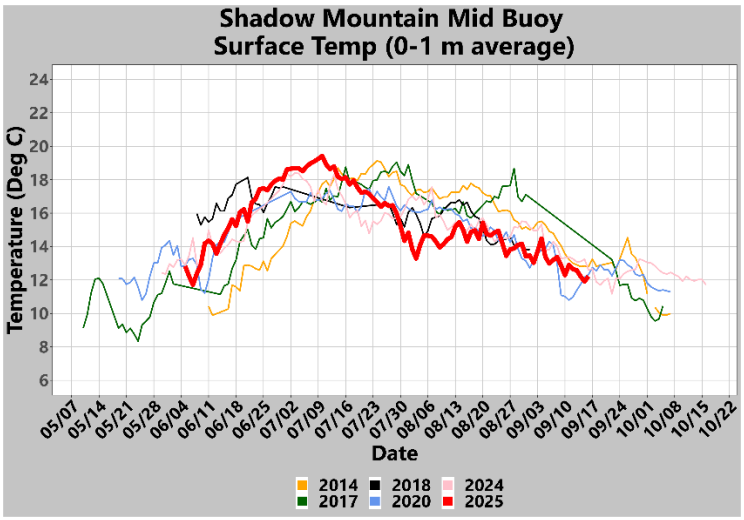

Figure 18. Average daily water surface temperature from 0-1 meters in Shadow Mountain Reservoir at SM-MID. 2025 data is shown in red with other colors showing reference years.

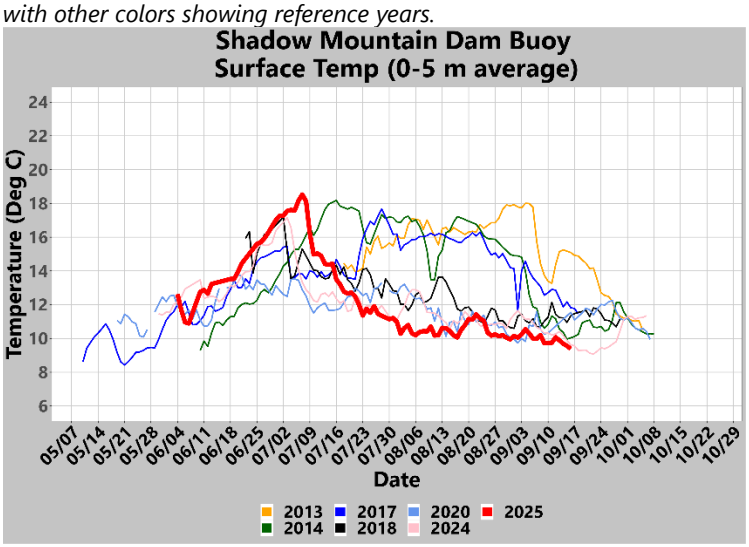

Figure 19. Average daily water surface temperature from 0-5 meters in Shadow Mountain Reservoir at SM-DAM. 2025 data is shown in red with other colors showing reference years.

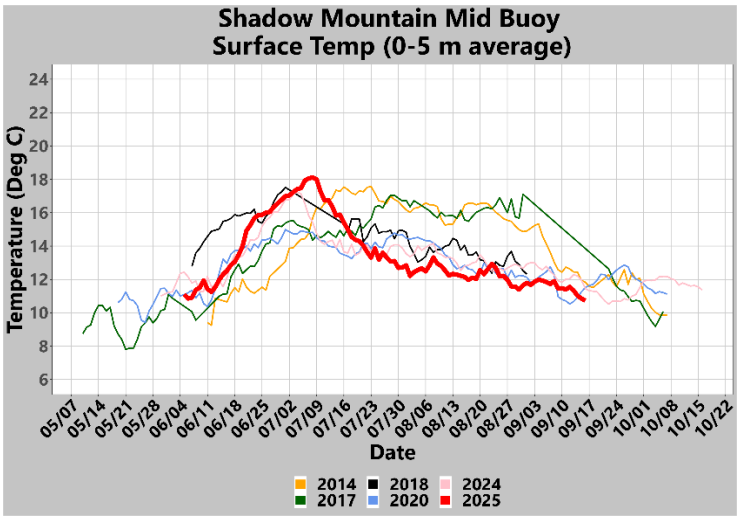

Figure 20. Average daily water surface temperature from 0-5 meters in Shadow Mountain Reservoir at SM-MID. 2025 data is shown in red with other colors showing reference years.

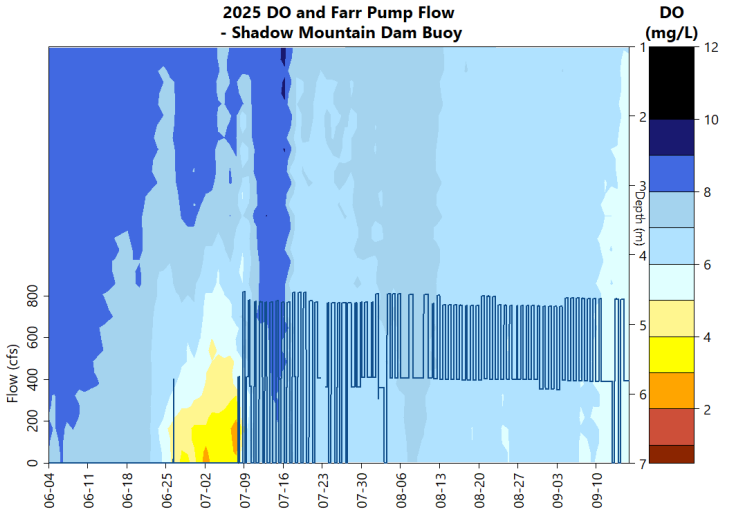

Figure 21. 2025 Dissolved Oxygen (color) and Farr pump flow (line) at SM-DAM.

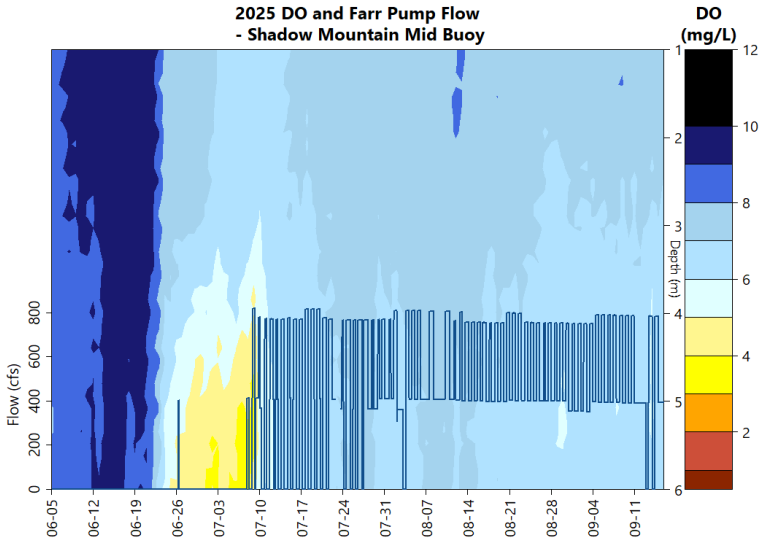

Figure 22. Dissolved Oxygen (mg/L) (color) and Farr pump flow (line) at SM-MID.

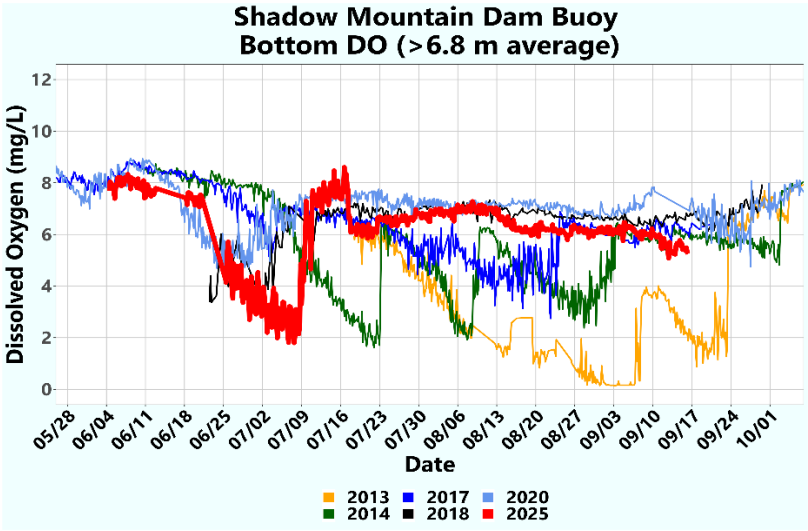

Figure 23. Dissolved Oxygen at the bottom of Shadow Mountain Reservoir (SM-DAM). 2025 data is shown in red with other colors showing reference years.

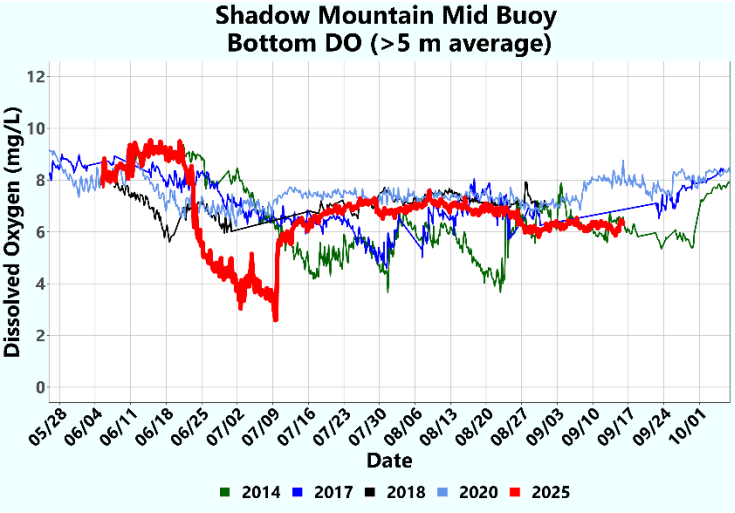

Figure 24. Dissolved Oxygen at the bottom of Shadow Mountain Reservoir (SM-MID). 2025 data is shown in red with other colors showing reference years.

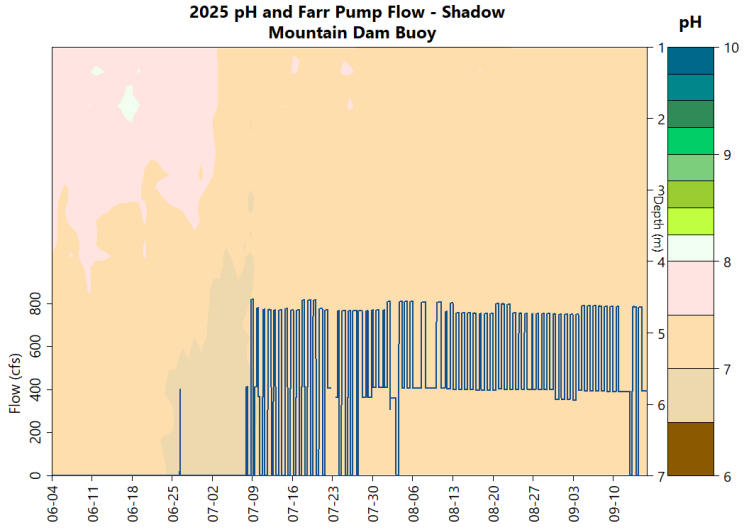

Figure 25. 2025 pH (color) and Farr pump flow (line) at SM-DAM.

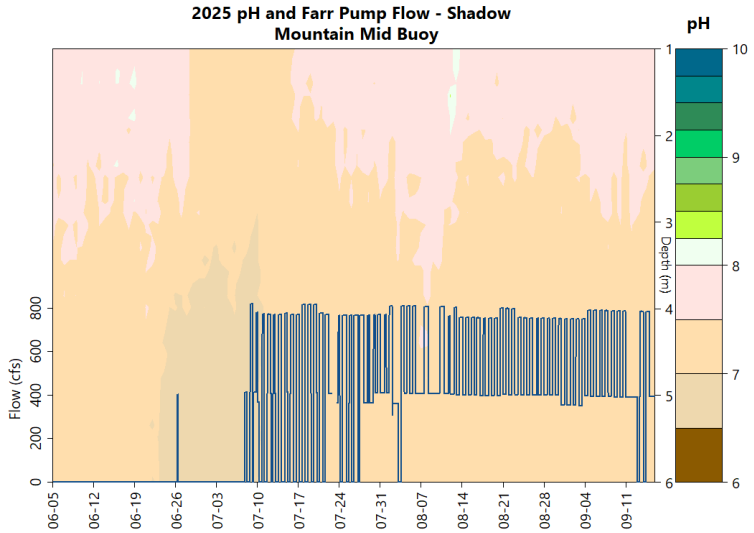

Figure 26. pH (color) and Farr pump flow (line) at SM-MID.

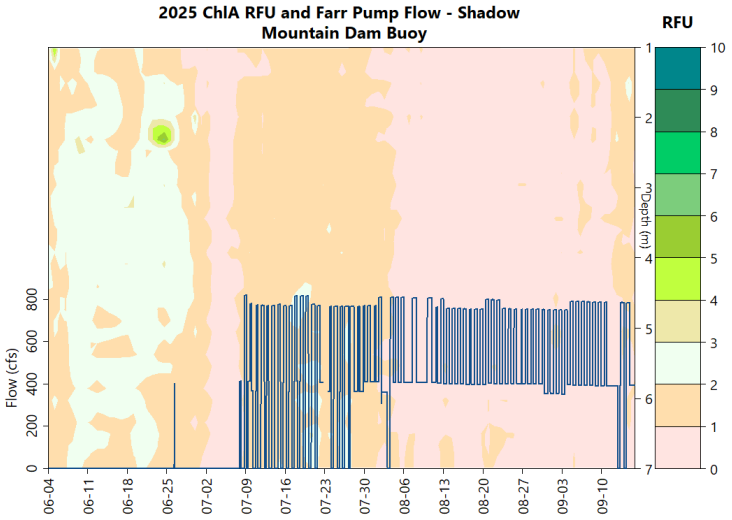

Figure 27. 2025 Chlorophyll a RFU (color) and Farr pump flow (line) at SM-DAM.

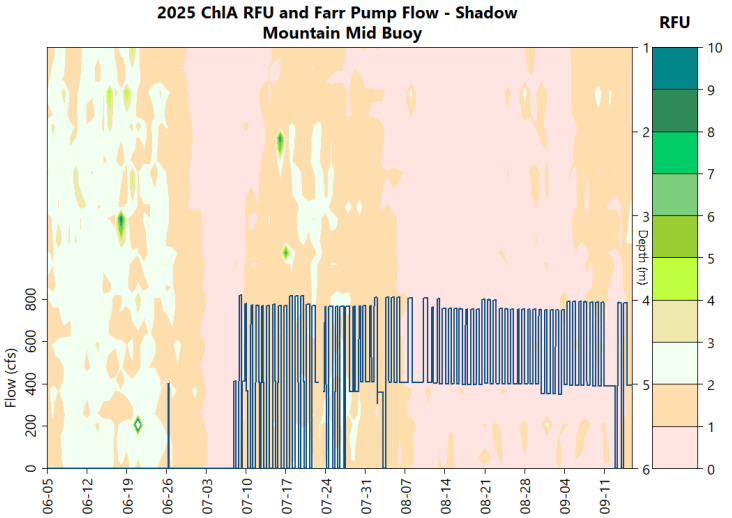

Figure 28. Chlorophyll a RFU (color) and Farr pump flow (line) at SM-MID.

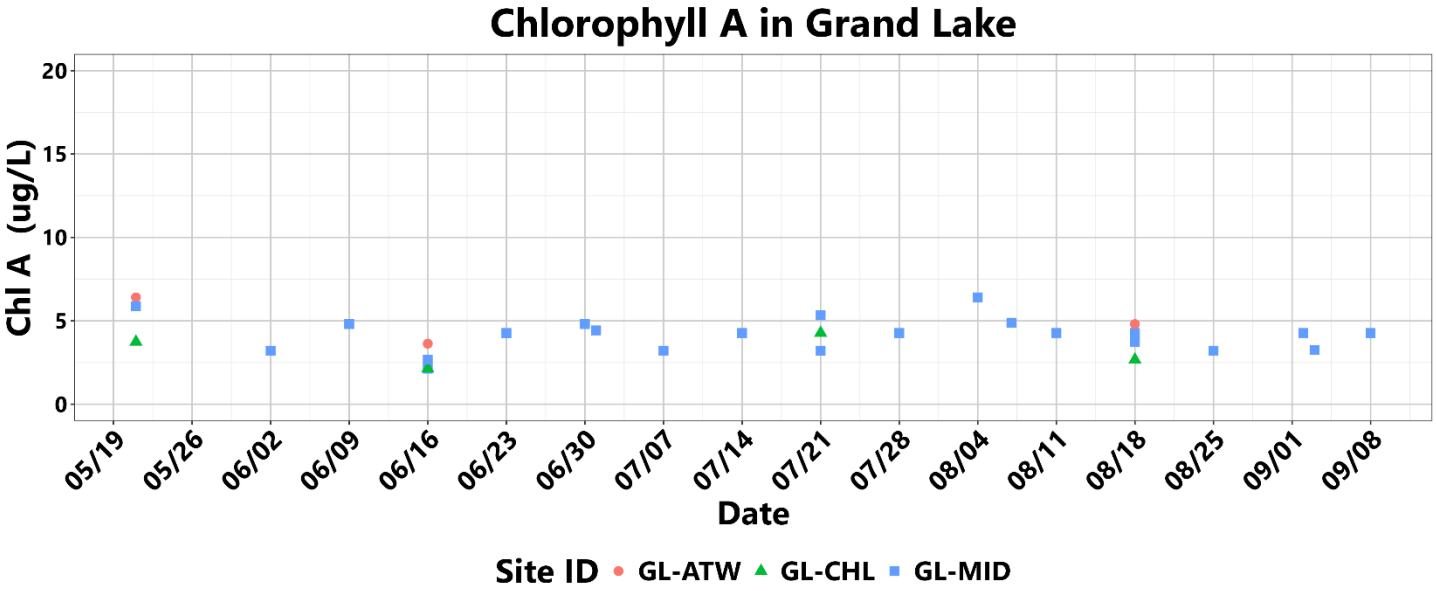

Figure 29. Discrete chlorophyll a concentration in Grand Lake.

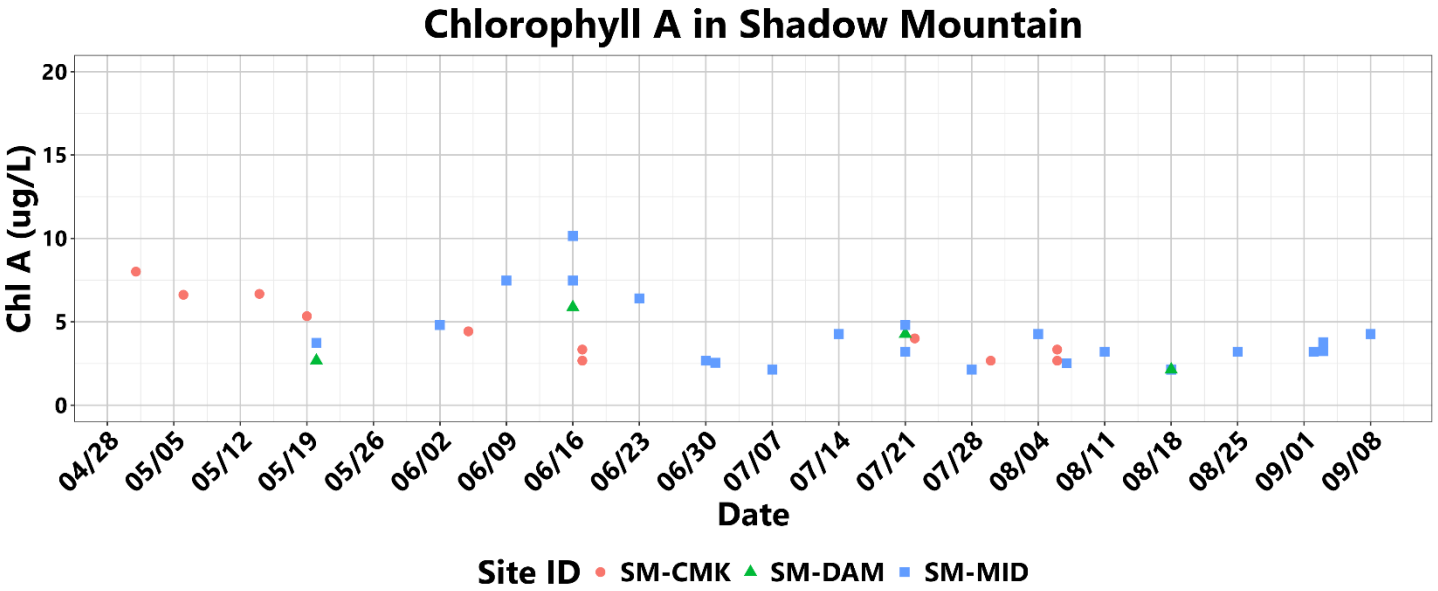

Figure 30. Discrete chlorophyll a concentration in Shadow Mountain Reservoir.

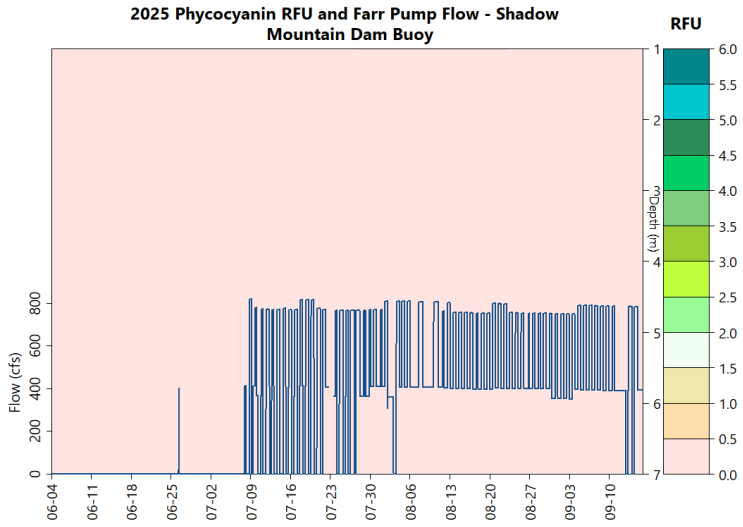

Figure 31. 2025 Phycocyanin RFU (color) and Farr pump flow (line) at SM-DAM.

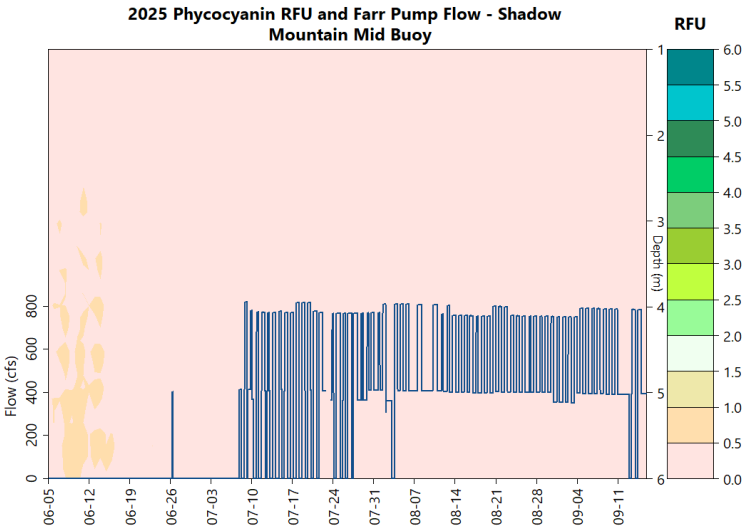

Figure 32. Phycocyanin (RFU) (color_ and Farr pump flow line at SM-MID.

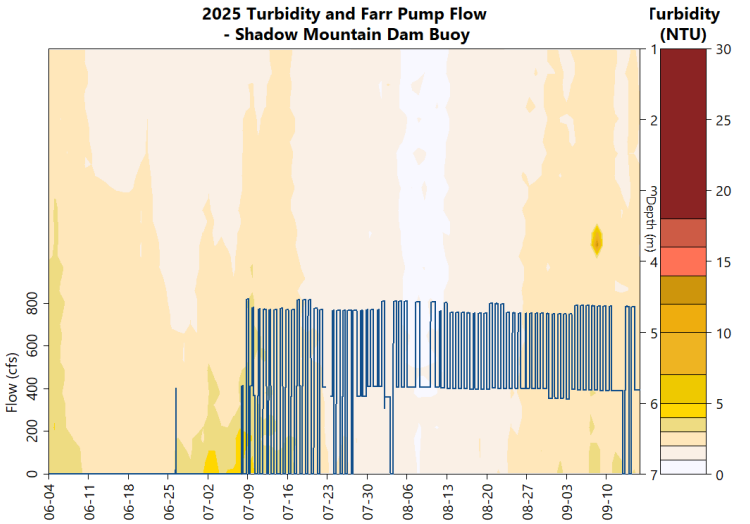

Figure 33. 2025 Turbidity (color) and Farr pump flow (line) at SM-DAM.

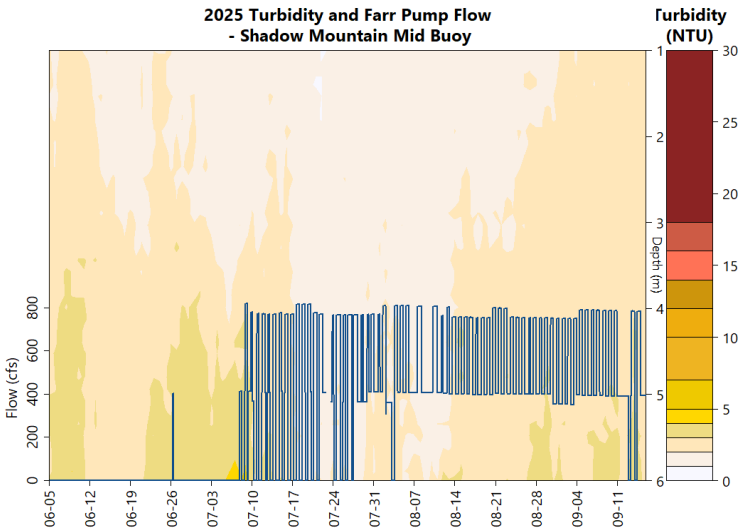

Figure 34. 2025 Turbidity (NTU) (color) and Farr pump flow (line) at SM-MID.

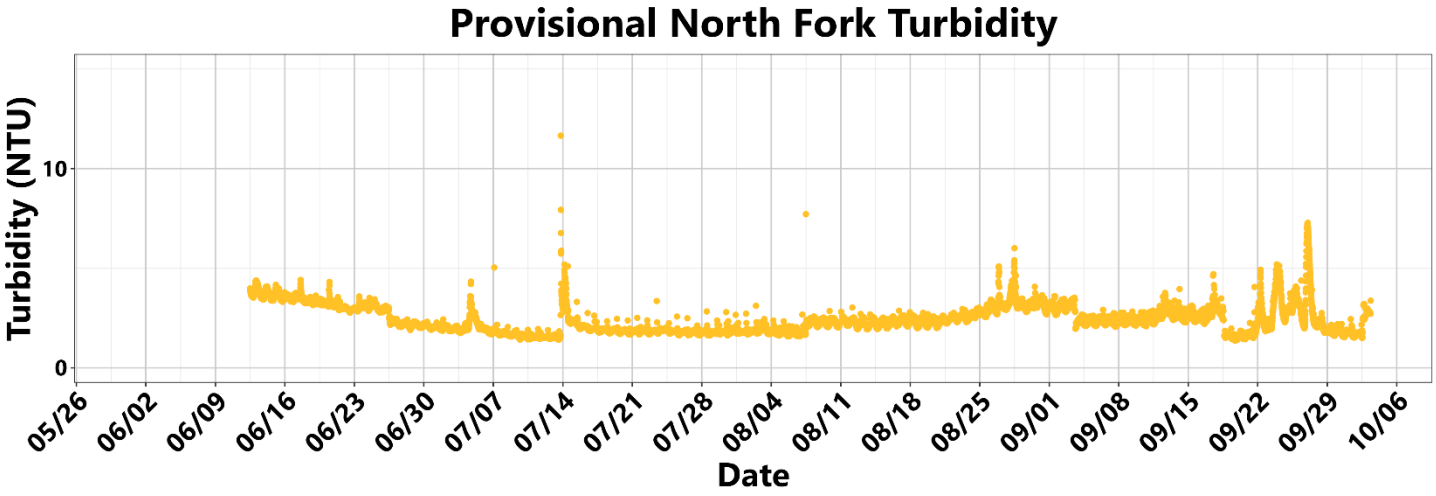

Figure 35. Turbidity (NTU) in the North Fork of the Colorado River just upstream of Shadow Mountain Reservoir.

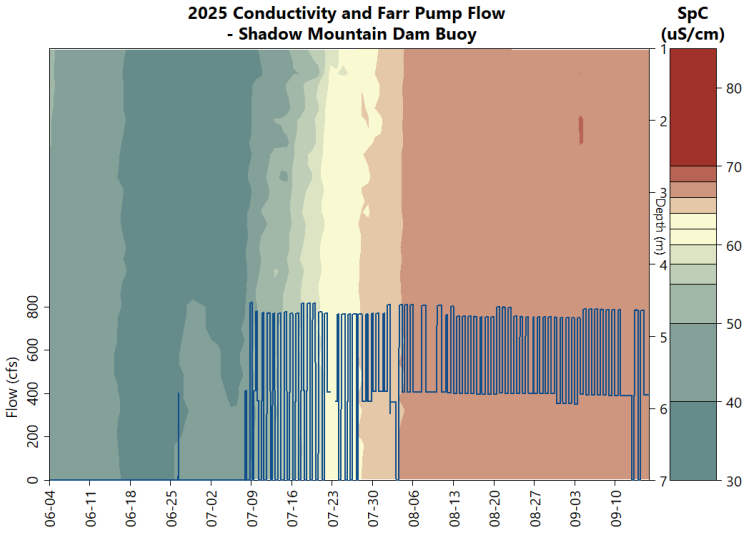

Figure 36. 2025 Specific Conductivity (uS/cm) (color) and Farr pump flow (line) at SM-DAM.

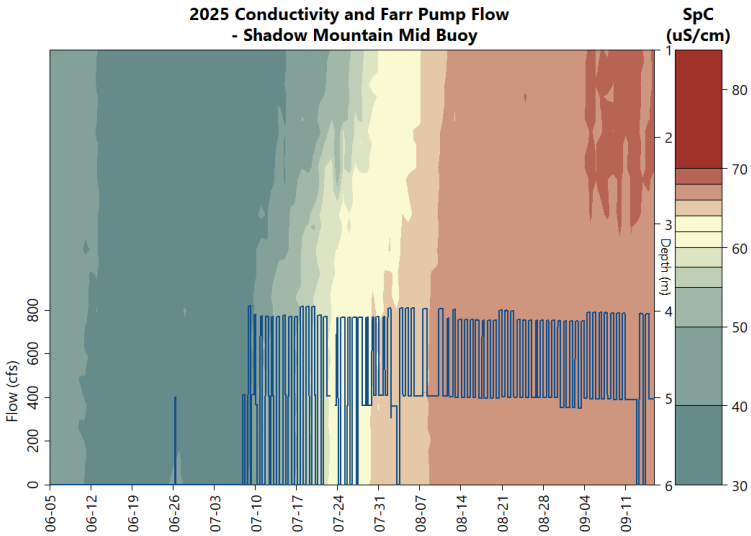

Figure 37. 2025 Specific Conductivity (uS/cm) (color) and Farr pump flow (line) at SM-MID.

Goal Qualifier Assessment and Water Quality Indicators

In 2025, both the 3.8-meter average Secchi depth goal qualifier and the 2.5-meter minimum Secchi depth goal qualifier were met as shown in Table 1. The GLAM Season average Secchi depth in Grand Lake was 4.1 meters and the minimum Secchi depth in Grand Lake was 2.9 meters. Between 2016 and 2025 the average and minimum goal qualifiers have been met 60% and 80% of the years, respectively (Table 4, Table 5). As outlined by the Clarity MOU, the AMC tracks DO and pH as water quality indicators in the system throughout the GLAM Season. The minimum DO value in Shadow Mountain Reservoir was below the threshold of 3 mg/L, 1.8 mg/L on July 7, just before Farr pumping began moving water through Shadow Mountain Reservoir, which resulted in increased DO concentrations in the water body. Surface pH in Shadow Mountain Reservoir also crossed the pH indicator of 8 at the SM-MID site, with values above 8 on August 12 and 13 as well as August 19 and 20, reaching a maximum value of 8.4 on the evening of August 12. The pH indicator was not triggered at the SM-DAM site. Both the DO and pH values minimally surpassed the thresholds, aligning with the other water quality parameters described above that generally indicate conditions for good clarity in Shadow Mountain Reservoir in 2025. In 2016, the AMC noted that percent saturation of DO greater than 100% was not a helpful indicator and has not been used in a significant way since.

Table 2. Clarity Goal Qualifiers Summary

	Goal Qualifier	Qualifier Met?	Qualifier Exceedance Date	Final Goal Qualifier Values
Grand Lake Clarity Running Average Jul-To Date (m)	3.8 m	**Yes**	NA	4.1 m
Grand Lake Clarity Running Minimum Jul-To Date (m)	2.5 m	**Yes**	NA	2.9 m

Table 3. Summary of Water Quality Indicators

	Indicator Threshold	Threshold Exceeded?	Exceedance Value	Date Indicator Threshold Exceeded (2025)
Shadow Mountain Reservoir Surface pH	8	**Yes**	8.4	8/12-8/13, 8/19-8/20
Shadow Mountain Reservoir Bottom DO (mg/L)	3 mg/L	**Yes**	1.8	7/1-7/7

Table 4. Summary of Grand Lake average daily Secchi depths since MOU implementation in 2016.

Year	Jul-Sep 11 Annual Average Secchi (viewscope) (m)	Clarity Goal (m)	Actual minus Goal (m)	Goal Met?
2016	3.3	3.8	-0.5	N
2017	3.9	3.8	0.1	Y
2018	4.6	3.8	0.8	Y
2019	4.8	3.8	1.0	Y
2020	3.0	3.8	-0.8	N
2021	3.6	3.8	-0.2	N
2022	3.2	3.8	-0.6	N
2023	4.2	3.8	0.4	Y
2024	4.5	3.8	0.7	Y
2025	4.1	3.8	0.3	Y

# Years Goal Met	6
Total # of Years	10
% of Years Goal Met	60%

Table 5. Summary of Grand Lake minimum daily Secchi depths since MOU implementation in 2016.

Year	Jul-Sep 11 Annual Minimum Secchi (viewscope) (m)	Clarity Goal (m)	Actual minus Goal (m)	Goal Met?
2016	2.4	2.5	-0.1	N
2017	2.7	2.5	0.2	Y
2018	3.9	2.5	1.4	Y
2019	4.0	2.5	1.5	Y
2020	2.4	2.5	-0.1	N
2021	2.7	2.5	0.2	Y
2022	2.6	2.5	0.1	Y
2023	3.0	2.5	0.5	Y
2024	3.7	2.5	1.2	Y
2025	2.9	2.5	0.4	Y

# Years Goal Met	8
Total # of Years	10
% of Years Goal Met	80%

LESSONS LEARNED & RECOMMENDATIONS

Changes Implemented During 2025 GLAM Season

1. The Three Lakes Water Quality model was used in the preseason planning process for the first time since 2019. This model was updated during the 2024-2025 offseason and included an updated version of the CE-QUAL-W2 software and incorporation of recent water quality data.
2. Phytoplankton biovolume data was looked at more regularly throughout the GLAM Season increasing the understanding of drivers for algal growth and the subsequent impact to clarity.

2025 Important Observations

1. East Slope water deliveries were higher than average during the GLAM season, and the Adams Tunnel ran mostly full (550 cfs) through much of the 2025 GLAM Season. The 2025 GLAM Season saw one of the largest volumes of Farr pumping and Adams Tunnel diversions and exhibited the second year in a row where high Farr pumping and Adams Tunnel flows correlated with good clarity and water quality in both Shadow Mountain Reservoir and Grand Lake. The other year with both notably high Farr pumping and Adams Tunnel volumes was 2012, an especially dry year, but 2012 did not have the same good water quality and clarity exhibited in 2024 and 2025. In years like 2019, high Adams Tunnel volumes and good clarity were observed, but there was lower Farr pumping than in 2024 and 2025. The relationship between Farr pumping, Adams Tunnel volumes, and water quality has been and will continue to be studied.
2. Inflow nutrient concentrations into the Three Lakes continue to exhibit signs of recovery following the 2020 East Troublesome Fire. While these indicate a return to baseline concentrations, these landscapes are still very susceptible to storm events, and it is unknown how long these fire-impacts are likely to persist.

Recommendations

1. Continue to improve the approach to Three Lakes Water Quality modeling to further understand the impact of operations and hydrological conditions on water quality and clarity.
2. Explore the use of near-term forecasting tools to understand the potential effect of short-term operational changes on water temperature and water quality.
3. Initiate coordination with the Red Top Ditch operators to shut off the diversion gradually over the course of several days and prevent subsequent increases in turbidity in the North Fork.
4. Continue to investigate the relationship between phytoplankton biovolume, chlorophyll *a* (ug/L) and chlorophyll *a* and phycocyanin RFU.
5. Explore changes to the GLAM monitoring schedule to maximize efficiency for GCWIN and to provide more recent data at the weekly GLAM meetings. This could include rearranging days for phytoplankton, chlorophyll *a* and physical data collection as well as the time of day for physical data collection.

APPENDICES

REFERENCES

Hydros Consulting Inc. 2025. 2024 Operational and Water-Quality Summary Report for the Three Lakes. Prepared for Grand County, Northern Water, and the US Bureau of Reclamation.