To: Rex Vaughn
Cedar Lake Improvement Board

Date: April 4, 2025

From: Mark Kieser, Senior Scientist
John Jacobson, PE, Senior Engineer
Kieser & Associates, LLC

cc: Files

RE: **Findings for 2024 Cedar Lake Groundwater/Surface Water Level Monitoring**

This memorandum presents 2024 results compiled by Kieser & Associates, LLC (K&A) related to the ongoing water level monitoring program at Cedar Lake, Alcona and Iosco Counties, MI. K&A staff were authorized to continue management and oversight of ongoing data collection efforts in 2024 on behalf of the Cedar Lake Improvement Board (CLIB). The purpose of this long-term monitoring program is to best understand critical needs and relevant influences on water levels in Cedar Lake.

Desirable summer month water levels in Cedar Lake are a function of both rainfall and management strategies designed to support water level maintenance in dry summer months. These management strategies, as defined in the approved Cedar Lake Watershed Management Plan (WMP), relate to ongoing efforts to bolster water retention in the northwest cedar swamp throughout the year. The CLIB has implemented and expanded water level control efforts in the Cedar Lake watershed, as summarized in this report, since 2017, including:

1) The wetland berm, parallel just to the south of Sherman Creek, constructed in 2017 to retain water in immediately adjacent areas of the northwest cedar swamp on CLIB property, while reducing out-of-watershed losses through King's Corner Culvert.
2) Sherman Creek instream grade structure controls, designed and permitted in 2018 and constructed in Fall 2019, serve to further retain water levels in the cedar swamp. This serves to promote extended surface water inflows and enhanced groundwater volume inputs to Cedar Lake, bolster lake level management during open-water recreational periods, and enhance northern pike spawning wetland habitat under spring-time flow conditions. K&A and CLIB representatives continue to monitor and observe flow conditions around these structures to ensure they are operating as designed and to verify benefits under a range of spring snowpack and summer-time precipitation conditions.
3) The Cedar Lake outlet structure, designed by the Drain Commission to maintain the lake at the legal lake level of 608.20 feet, was reconstructed in September of 2020. Since March 2021, a year-round logger has measured the lake outlet water level. Ongoing concerns regarding the loss of water from the outlet structure have been voiced by Cedar Lake stakeholders. Streamflow data collected throughout the monitoring period suggests low-flow groundwater is likely the culprit of the continual trickle exiting through the lake outlet structure. Future monitoring efforts will continue to closely inspect the outlet structure and will guide any action needed to correct the loss of water through the structure.

This technical memorandum presents findings of these water level conditions as observed in Cedar Lake and its watershed in 2024 with discussions of implemented, ongoing, and potential future water level management strategies. Find all tables and figures referenced in the body of this memorandum published at the end of the memo narrative.

Program Background

A volunteer water level monitoring program was initially developed at select groundwater and surface water monitoring sites around Cedar Lake in 2004. Since then, water level monitoring efforts have expanded to include additional critical areas using automated water level logger equipment in lieu of intermittent volunteer measurements. The 2024 water level monitoring totaled 32 level loggers in operation around the Cedar Lake from March to November. The location and addresses of the sites of the level loggers are provided in Figure 1.

The combination of surface water stations, shallow piezometers, and deep piezometers allow and facilitate observations of the interactions between surface water, groundwater, and Cedar Lake water levels. Monitoring continued at Sherman Creek and Jones Ditch as well as within their contributing wetlands in 2024, to calculate estimated surface water flows into Cedar Lake.

Monitoring also continues at the wetland berm on CLIB property, constructed as part of the ongoing efforts to retain water levels in the cedar swamp. The berm's stone-laden spillway design allows overflows above an elevation of 611.50 feet, so as not to permanently alter historic high-water levels in the swamp or alter any historic flooding or outflow southward out of this area and out of the Cedar Lake watershed. This provides critical information regarding water retention improvements in the northwest cedar swamp, including those related to the Sherman Creek instream grade structures and stream flows into Cedar Lake.

Monitoring in 2024 also included instream level loggers deployed at new sites in Jones Ditch since 2022, including within the contributing wetland complex. The Jones Ditch data loggers will help further define the Jones Ditch wetland contribution of surface and groundwater to the lake following several structural changes in the last six years of monitoring. In 2018 the Alcona County Road Commission replaced the creek culvert during reconstruction on W Cedar Lake Road, affecting flow estimates through Jones Ditch during the 2018-2020 reporting period. K&A modified the flow equation in 2021 to more accurately quantify measured flow data. These recent data suggest that Jones Ditch, under certain conditions, may contribute more surface water to Cedar Lake than Sherman Creek, a discovery with implications for potential future engineering designs and management efforts in and along the northwest corner of Cedar Lake.

The estimated lifespan of the level loggers is ten years. Replacement of aged-out level loggers around Cedar Lake began in 2018, with all thirty-two level loggers since updated to ensure a high degree of confidence in the dataset. This includes three loggers replaced in 2017, eleven in 2019, eight in 2020, seven in 2021, and three new loggers deployed in 2022 at Jones Ditch and the Timberlakes property on the northwest and northeast sides, respectively, of Cedar Lake. K&A rigorously evaluates logger data each year to ensure accuracy in the dataset. Table 1 illustrates the current age and predicted lifespan of the Cedar Lake level logger regime.

2024 Precipitation and Water Level Data

Precipitation Analysis:

Historic summer precipitation totals for the Cedar Lake area presented in Figure 2 show 2024 summer precipitation information available from the Cedar Lake volunteer rain gauge. Rain gauge data, analyzed for quality against other weather stations in the area, Harrisville 2 NNE (USC00203628) and Oscoda Wurtsmith Airport (Station #14808), was the most representative localized data available. From 2016 to 2020, reported rainfall data present triangulated data from these weather stations and the near-lake rain gauge. The Lake Board's volunteer rain gauge was replaced in April 2020. Available data from 1998 to 2024 (minus 2006 with no local functioning rain gauges) reflect a 27-year summer average (June-September) of 11.9 inches of rainfall.

The 2011 Cedar Lake Augmentation Feasibility Study conducted by K&A revealed that 2.75 inches of precipitation during each summer month is necessary to avoid a lake level drop of 3-inches per month (June-September). As such, in any summer month that does not exceed the 2.75-inches-of-precipitation threshold, Cedar Lake can expect a drop in lake level of 3-inches or more. Since 2011, this summer precipitation threshold of 11-inches (i.e., 2.75 inches multiplied by 4 months) has guided lake-wide assessments of summer conditions and their effect on desirable lake levels. Ongoing management efforts aim to lower this threshold or augment the water budget of the Cedar Lake watershed to limit the impact of low summer precipitation on lake level.

Figure 2 presents the critical precipitation threshold among the 27-year summer precipitation average. While Cedar Lake precipitation met this critical threshold of 2.75 inches (to avoid lake-elevation drop) in June and July of 2024, the monthly total precipitation in July, August, and September fell below the respective 27-year average for each month. June 2024 precipitation totaled 3.88 inches, exceeding the monthly average. July monthly precipitation totaled 2.81 inches, just below average; August totaled 1.9 inches, the lowest since 2019; and September precipitation totaled 2.23 inches, just-below the monthly average. The resulting summer precipitation total was 10.82 inches, a below-average value indicative of a dry summer season.

Cedar Lake Water Elevation:

Figure 3 plots the estimated 2024 Cedar Lake water elevation from March to mid-November, with daily precipitation data recorded from the Cedar Lake volunteer rain gauge to visualize the importance of precipitation on lake elevation. When the lake elevation exceeds 608.20, flow over the Cedar Lake outlet weir will occur. Lake stakeholders historically define elevations above 607.2 ft (within one foot below the legal lake limit) as presenting "desirable conditions."

Early-spring snowmelt induced lower-than-normal lake levels in March, followed by rainfall in April and May bringing spring lake level conditions just above the legal lake level, with about 99% of lake outflows (35.33 MGal) occurring between March 15 – May 15, 2024. It should be noted that the new outlet structure controls the lake level elevation closer to the legal lake elevation and as such the lake elevation is at legal as monitoring begins in March. By late May, Cedar Lake water elevations had dropped below the legal lake level. Below-average summer rainfall amounts from July – September pushed Cedar Lake levels to continue falling through the summer recreation months. The lake level fell below the desired minimum lake elevation threshold of 607.2 ft (1-ft below the legal level) in early-September and remained in this state to the end of the monitoring period in mid-November, reaching a minimum elevation of 606.5 ft.

Cedar Lake's mid to late-summer water levels followed a predictable pattern for a year with below-average summer rainfall. Periodic rises in summer lake elevation responded directly to rainfall and corresponding inflows from the Sherman and Jones wetlands well into the summer months. Both Sherman Creek and Jones Ditch flowed continuously until about mid-August despite less-than-average rainfall in July and August, underscoring the importance of water retention efforts implemented in the watershed.

Since construction of the Cedar Lake outlet structure in fall of 2020, Cedar Lake stakeholders have voiced concerns of an apparent constant "leak" of water coming from the outlet structure even when the lake elevation sits below the outlet weir of 608.20 ft. Site visits since 2021 confirm a very low flow of groundwater exiting through the north side of the outlet structure. K&A field staff periodically collected measurements of the velocity and channel area of the outlet structure, as well as downstream channel to understand the discharge of water flowing through the outlet structure during non-wet weather/weir overflow conditions. Based on low flow rates from the outlet structure box culvert, impacts on lake level associated with groundwater leakage into the box culvert can reasonably be described as negligible.

Figure 4 presents Cedar Lake outlet discharge data and calculated equivalent drops in Cedar Lake water elevations. Evaporation and discharge (leakage) to groundwater across the entirety of the lake's 1,050-acre surface area remain the leading causes of water losses from Cedar Lake during critical summer months. The average lake outflow in 2024 was 23,593 GPD, less than half of the average daily outflow over the past three years (since March of 2021) of approximately 70,000 GPD or 0.0002 ft/day in equivalent lake level.

Figure 4 also illustrates the relationship between summer precipitation and water elevation fluctuations with respect to the critical summer precipitation threshold, water level goals designed in the Cedar Lake WMP, and the legal lake level. The average summer-month water elevation of Cedar Lake in 2024 was 607.74 ft, less than the average level in 2023, a higher-rainfall year. Comparing the average summer-month lake level with the average summer-month rainfall shows some interesting trends, discussed in the next paragraph.

Following wetland augmentation implementations in Sherman Creek (2017-2020), average lake elevations increased despite a decline in average rainfall as compared to a decade earlier (2007-2010), showing the importance of such water retention efforts to improving lake levels. Average summer-month lake level in 2021, however, were much lower than average. This condition shows the important influence of winter snowfall and spring snowmelt amounts, which were far below average in early-spring 2021, causing reduced lake levels despite higher-than-average summer rainfall. Conditions from 2022-2024 show lake levels responding more normally to summer rainfall levels, but still lower than comparative summer-month rainfall years from 2017-2020. It should be noted that the new structure controls the winter and spring lake levels at an elevation closer to the legal lake elevation as opposed to pre-structure which allowed for additional lake levels above legal lake level.

Groundwater Levels and Gradients

Figures 5-18 present the 2024 groundwater elevation data from the groundwater monitoring Sites 1-12, as well as TL-2 and TL-Road, referenced with the estimated Cedar Lake water levels. Level loggers on the east side of Cedar Lake typically show groundwater elevations below the lake level, while those on the lake's west side show groundwater elevations above the lake level, showing in fine detail the surface and groundwater gradient movements in the watershed.

East Side of Cedar Lake

On the east-central section of Cedar Lake, at Sites 1 and 4 (Figures 5 and 8), level loggers continued to record groundwater elevations below Cedar Lake level, with no exceptions in 2024. With this gradient present throughout the summer, northeastward groundwater movement serves as a continual loss vector for Cedar Lake, well-documented since monitoring began.

Level loggers on the southeast section of Cedar Lake, at Sites 8, 9, 10, and 11 (Figures 12 – 15), report even steeper groundwater gradients consistently moving groundwater away from Cedar Lake, towards the southeast. This exemplifies the surface grades away from the lake and the groundwater-losing condition worsened by a subdrainage system designed to help keep house foundations and crawl spaces dry and residential septic systems functioning properly in the Lakewood Shores neighborhood.

K&A also installed two new stations in 2023 near the Timberlakes development on the lake's northeastern-most section, "TL Lake 2" (Figure 17) and "TL Road" (Figure 18). The goal for monitoring at these stations is to better understand northeasterly groundwater losses occurring near the Timberlakes residential development. Comparing these elevations and gradients to stations in the southeast allows for a comparison of the Timberlakes area to the Lakewood Shores residential district where subterranean drains already exist. Like the other eastern loggers (1, 4, and 8-10), TL Road showed a four to five ft loss in elevation compared to TL-2 which was within a ½-foot of the lake level throughout the year. This shows that a natural northeasterly groundwater gradient flow, away from the lake, already exists towards the Timberlakes district.

West Side of the Lake

On the southwest section of Cedar Lake, Site 3 (Figure 7) tracks the more-nuanced movement of shallow groundwater toward or away from Cedar Lake throughout the summer months. From mid-March to mid-June, shallow groundwater moved mostly toward Cedar Lake. Conversely, from mid-June to November, Site 3 shallow groundwater moved mostly away from Cedar Lake, except in response to occasional rain events which tilted gradients back toward the lake. This period of groundwater gradient tilting towards Phelan Creek (Van Etten Lake) shows water loss from Cedar Lake during the dryest summer months. Since construction of the wetland berm (2017) and instream Sherman Creek grade structures (2019), groundwater at Site 3 has periodically shown much greater contributions to Cedar Lake than were observed historically.

Similarly, prior to 2021, shallow groundwater at Site 6 (Figure 10) experienced intermittent flow patterns under dry or wet conditions, much like Site 3. Since 2021, groundwater has consistently moved towards Cedar Lake at this location, showing increased groundwater elevations resulting from the 2017 and 2020 Sherman wetland improvements. Under near-average rainfall conditions in 2024, groundwater flows at Site 6 still showed a strong gradient of flow toward Cedar Lake.

Site 12 (Figure 16), installed in 2018 approximately 1,750 ft south of Sherman Creek and 85 ft southeast from the intersection of West Cedar Lake Road and King's Corner Road, further illustrates effects on groundwater gradients from the Sherman wetland improvements. As in years past, the groundwater at Site 12 was consistently 2-feet above lake level during spring and the gradient remained flowing toward the lake all summer, flattening out a bit by late-summer.

Site 7 (Figure 11), along the western lakeshore just north of Sherman Creek, also continues to reflect an increase in groundwater recharge in the spring months, as compared to years prior to 2021, resulting from the wetland water-retention improvements. Like Site 12, groundwater at Site 7 was consistently 1 to 2-feet above the lake level throughout the 2024 monitoring period. This phenomenon was not evident at this location prior to 2017 and the berm installation.

The cedar swamp complex northwest of Cedar Lake continues to contribute a critical supply of groundwater throughout the recreational season, from both the Sherman and Jones Ditch. On the northwest side of the lake nearest to Jones Ditch, Site 2 (Figure 6) shows groundwater levels above the lake elevation in both the shallow and deep wells with a natural gradient of shallow groundwater toward the lake throughout the monitoring period. Groundwater levels at Site 2 continue to consistently and closely-mirror surface water fluctuations at the Lake Outlet.

2024 Estimated Surface Flows

Water level loggers located in or near the Cedar Lake outlet, Sherman Creek, Jones Ditch, and the King's Corner culverts were used to monitor incoming and outgoing surface water discharge. Sherman Creek and Jones Ditch are critical vectors by which surface water flows from the northwest wetland complex into Cedar Lake. The King's Corner Road culvert historically diverted water from the southernmost portion of the wetland complex away from the Cedar Lake watershed to the south towards Phelan Creek and Van Etten Lake. The wetland enhancement berm constructed in 2017 serves to retain surface water in the Cedar Lake swamp and limit surface water losses through the King's Corner culvert. The new Cedar Lake outlet structure constructed in September 2020 functions to maintain the legal lake level of 608.2 feet. If the lake elevation exceeds this limit, water spills over the outlet and eventually drains to Lake Huron.

Efforts regarding water retention improvements in Sherman Creek were conducted in September 2019 with the implementation of three instream grade structures. Large stone instream grade structures were installed at approximately 50 ft, 100 ft and 150 ft upstream of the Sherman Creek culvert. These instream barriers serve to retain water in the northwestern wetland complex by slowing discharge rates into Cedar Lake during snowmelt and rain events in the spring. By lengthening the time needed for surface water in the wetland complex to reach Cedar Lake, the high flows present in spring can be extended into the summer when lake inputs become critically important for lake level.

Surface water discharge rates and total volumes associated with the full 2024 monitoring period at Jones Ditch, Sherman Creek, Cedar Lake outlet, and the King's Corner culvert are presented in Figures 20, 21, 22, 23, and 24, respectively in addition to the wetland berm in Figure 25. All flow data are derived from water level stage-discharge relationships specific to each monitoring station that have been calibrated and validated using previous data collected on Cedar Lake. The discharge data and estimated total volumes are graphically displayed together in Figure 26.

The water level stage-discharge relationship for Jones Ditch was re-calibrated in 2018 following the installation of the new culvert that allowed increased flows under King's Corner Road. The stage-discharge equation was updated in 2021 to quantify the increased flow more accurately through the larger diameter culvert. New logger stations installed upstream and downstream of the culvert in 2022 helped to further refine the flow equation over time.

Surface Water Inflows and Outflows:

The following discussion of estimated surface water flows and volumes focuses on the late-spring to late-summer period of May 1 to September 30 to assess the impact of inflows and outflows on lake levels during the summer recreational months. Table 2 summarizes estimated inflow or outflow volumes for surface water stations from May-September of each year 2014-2024 for a decade of comparison.[1] Jones Ditch and Sherman Creek provide inflows of surface water into Cedar Lake from the northwest cedar swamp contributing area, while King's Corner culvert and the Lake Outlet represent surface water leaving the watershed, flowing toward Phelan Creek and Lake Huron, respectively.

From May 1 to September 30, 2024, inflows for Jones Ditch and Sherman Creek totaled 260.4 million gallons (MGal) and 253.0 MGal, respectively. Flows from both creeks slowed to a trickle, with only some periodic flows, by August of 2024. Inflow volumes from these two sources were less in 2024 than the previous year due to lesser rainfall amounts. Comparing 2024 inflow volumes to 2015, a year with similar summer month rainfall prior to the Sherman Creek wetland enhancements and Jones Ditch culvert replacement, shows a marked increase in inflow volumes from both Sherman and Jones Ditch. This comparison confirms how inflow volumes have improved because of these wetland water retention and infrastructure improvement efforts.

Connectivity in the Jones Ditch wetland generally allows precipitation to runoff rather than being infiltrated as groundwater. This geomorphic feature and the larger surface area of the Jones Ditch wetland complex represent the difference in outflows between the Sherman Creek and Jones Ditch cumulative discharges. A small beaver dam exists in the upstream of Jones Ditch, which may have an effect of holding back water in the wetland and thereby reducing surface flows.

During the same May 1 – September 30 timeframe, 6.6 MGal discharged through the outlet from Cedar Lake. This cumulative discharge exited Cedar Lake between May 1 and June 1, 2024. For the remainder of the monitoring period, no surface water flowed over the outlet weir and the lake elevation remained below the legal lake limit of 608.2 ft.

The outflow volume that exited the Cedar Lake watershed through the King's Corner culvert during the May-September period totaled 0.05 MGal. This volume is the lowest observed to date, reflecting the overall low summer rainfall and retention improvements in the wetland. The

[1] Note that the 2023 hydrology report incorrectly presented 2023 flow volumes for a period of Mar 30 - Sep 30 (Table 2 in this 2024 report corrects these data to compare volumes for May 1 - Sep 30 only).

implementation of the wetland berm continues to retain water within the Sherman Creek wetland and limits losses through the King's corner culvert.

Surface Water Retention Design Implications:

The wetland berm continues to prove highly effective in limiting losses through the King's Corner culvert and out of the Cedar Lake watershed. The ratio of water volume passing through Sherman Creek versus King's Corner culvert has increased more than five times since installation of the wetland berm. Water elevations and flows through the wetland enhancement berm on the Lake Board parcel should continue to be closely monitored to definitively demonstrate additional long-term improvements to water retention in the wetlands via reductions to water volume lost through King's Corner culvert.

Sherman Creek cumulative discharge in 2024 (253 Mgal) was slightly lower than the historic 10-year average of 274.8 MGal. Snowpack and spring precipitation are the biggest factors in Sherman Creek contributions. Improvements to water retention bolstered by the wetland berm and instream grade structures prevent further decreases in the cumulative summer discharge in dry years such as 2024, extending the spring discharge period well-into July.

Figure 27 presents the surface/groundwater elevations at the Sherman Creek culvert and upstream wetland (Sherman 2) stations. These data are consistent with observations from previous years of improved water retention and storage in the wetland complex even in years of below-average precipitation. Figure 28 illustrates the 2024 water elevations at the wetland berm monitoring station, positioned at the upstream side of the berm spillway, compared to lake levels. Figure 29 compares water elevations at the wetland berm spillway, King's Corner culvert, and Sherman 2, located in the cedar swamp upstream of the Sherman Creek culvert. Figure 30 compares surface water flows and volumes for the 2024 monitoring season at the wetland berm spillway to outflows at King's Corner Culvert and inflows to Cedar Lake via Sherman Creek.

Surface water flowed through the wetland berm spillway from early spring to early summer, after which no flows occurred. Surface outflows through the spillway totaled 33 MGal from March 30 to June 15, while only 0.05 MGal flowed out of the watershed through King's Corner culvert. These data, in conjunction with previously discussed groundwater gradients on Cedar Lake's west side, show how 99% of berm spillway surface flows were absorbed into the ground before reaching the King's Corner culvert, indicating gains in groundwater flows to Cedar Lake.

These observations once again underscore the importance of precipitation as the ultimate factor in limiting substantial decline in lake level throughout the monitoring period. Continued monitoring is necessary to determine additional viable lake level augmentation strategies and improve on previously implemented projects and their effectiveness in maintaining Cedar Lake's water elevation within the desirable range.

Conclusions and Recommendations

Despite overall low precipitation levels during the monitoring period, improvements in water retention continue to prove effective in limiting outflow losses from the watershed as reported by previous years' findings. Water retention improvements have led to limiting outflows through King's Corner culvert as a percentage of the total Sherman Creek outflow (Sherman Creek and King's Corner culvert). King's Corner culvert routinely made up 20% of this flow prior to the installation of the wetland berm, after which this percentage now averages less than 2%.

Jones Ditch continues to supply an increased amount of discharge following the culvert replacement in 2018. The purchasing of the parcel through which Jones Ditch originates will allow the CLIB to continue to protect Jones Ditch and further improve connectivity between the northwest wetland complex and Cedar Lake. The piezometers placed in Jones Ditch in 2022 will continue to help K&A improve the current discharge-stage relationship and work to quantify incoming flows more accurately from Jones Ditch. These data monitoring efforts should help guide any future action in augmenting Jones Ditch to improve Cedar Lake water levels throughout the summer recreation months.

Precipitation, spring snow melt, and evaporation remain as the three dominant factors that influence the Cedar Lake elevation throughout the summer. Twenty-six years of rainfall data show how precipitation in the Cedar Lake area oscillates between multi-year periods of dryer and wetter years. While lake level has improved despite declining or stagnant precipitation totals in past years, drier conditions in the future may require new or novel management implementations. Planning and coordination by the CLIB and K&A should always consider emerging trends within the watershed and implement engineering design as needed. As such, K&A recommends the continuation of the hydrology monitoring program in 2025.

Recommendations for the 2025 Monitoring Program:

1. Identify additional hydraulic improvements for Sherman Creek and Jones Ditch areas including the maintenance of railroad culverts for watershed flows, and identify improvements to Sherman and Jones swamps to provide ecological improvements such as fish passage and flow management.

2. Further calibration of the Jones Ditch discharge equation with level data and wetland topographic data to determine volume control options for surface and groundwater flow enhancements.

3. Redeployment of groundwater piezometers in Sherman Creek, especially with potential grant funding for fish passage improvements at the creek mouth, to better assess flow and groundwater retention, particularly in light of fish passage assessments planned for 2026.

2024 Cedar Lake Hydrology Report: List of Tables and Figures.

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Figure 30	May-Sep rainfall and combined surface water volumes, 2014-2024

Table 2. Comparison of Surface Water Volumes from May 1 to Sep 30, 2014 to 2024.

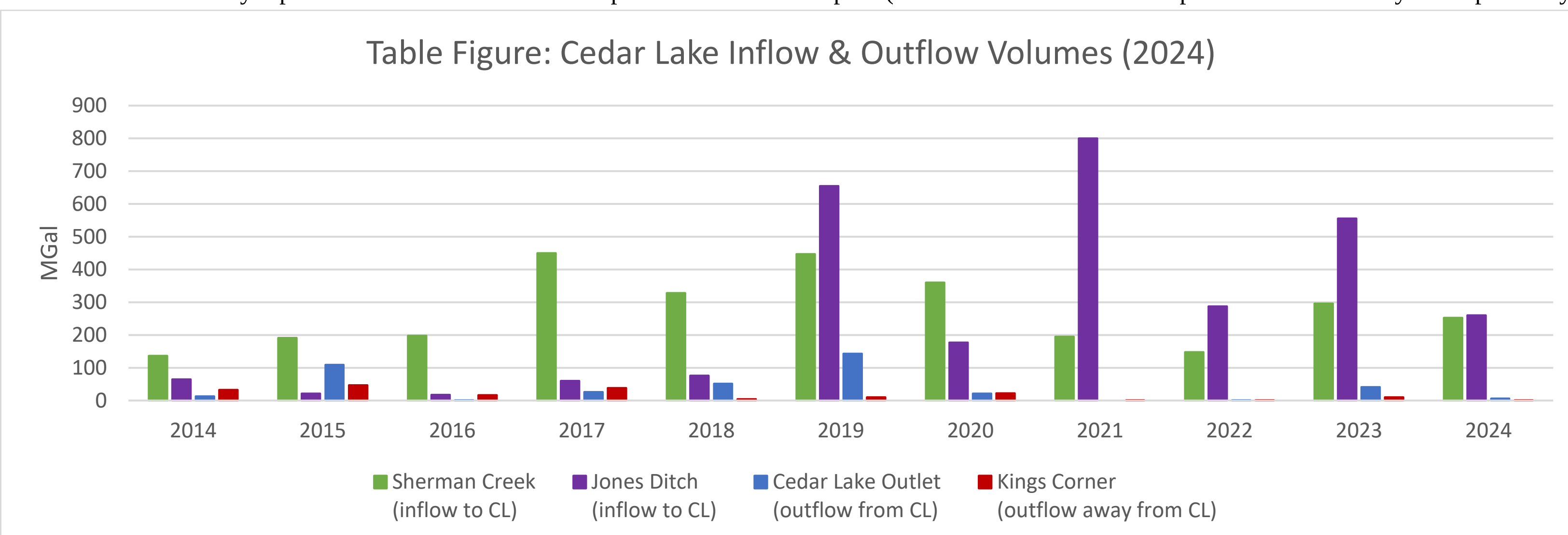
Site	Volume (MGal)										
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Sherman Creek (inflow to CL)	136.040	190.929	198.126	449.441	328.134	446.753	359.857	195.171	147.428	[4] 296.374	252.977
Jones Ditch (inflow to CL)	64.817	21.587	17.964	[1] 59.784	75.712	654.691	[3] 177.250	[3] 799.967	287.755	[4] 555.566	260.380
Cedar Lake Outlet (outflow from CL)	13.003	109.500	[2] 0.162	[2] 26.123	51.975	143.156	21.560	0.000	0.145	[4] 40.991	1.110
Kings Corner (outflow away from CL)	32.208	46.862	17.049	38.053	4.384	10.161	21.819	0.158	0.156	10.373	0.050

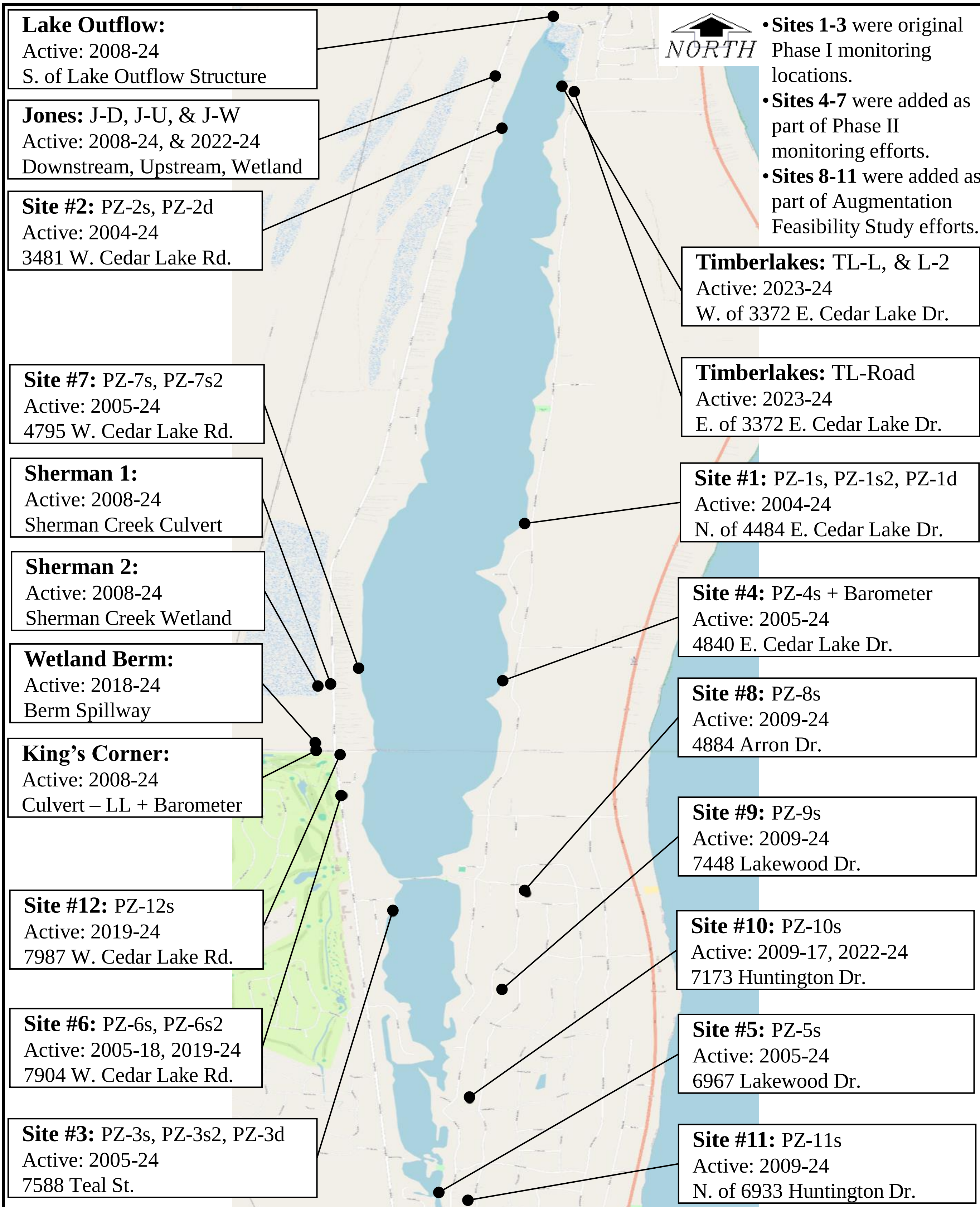
[1] Jones Ditch 2017 flows from 5/1/17 to 9/1/17 only.

[2] Lake elevations affected by presence of beaver dam upstream of Cedar Lake outlet, mechanically removed in fall 2017.

[3] Jones Ditch volume calculations affected by sediment accumulation resultant of beaver activity within Jones Ditch culvert after its replacement in 2018.

[4] 2023 table incorrectly reported 2023 flow volumes for a period of Mar 30 - Sep 30 (Table 2 corrects this to compare volumes for May 1 - Sep 30 only).





KIESER & ASSOCIATES ENVIRONMENTAL SCIENCE & ENGINEERING 536 E. Michigan Avenue, Suite 300, Kalamazoo, Michigan 49007 Phone (269) 344-7117 | Fax (269) 344-2493 | www.kieser-associates.com	Map of 2024 groundwater and surface water elevation monitoring sites with piezometers & level loggers, located around the perimeter of Cedar Lake.	**FIGURE** **1**

Figure 2. Historic Summer (Jun - Sep) Precipitation Totals for Cedar Lake

(*Precipitation Sources:* Cedar Lake Rain Gauge, Alcona County, MI,
Harrisville 2 NNE (USC00203628), Alcona County, MI
Oscoda Wurtsmith Airport (Station #14808), Iosco County, MI

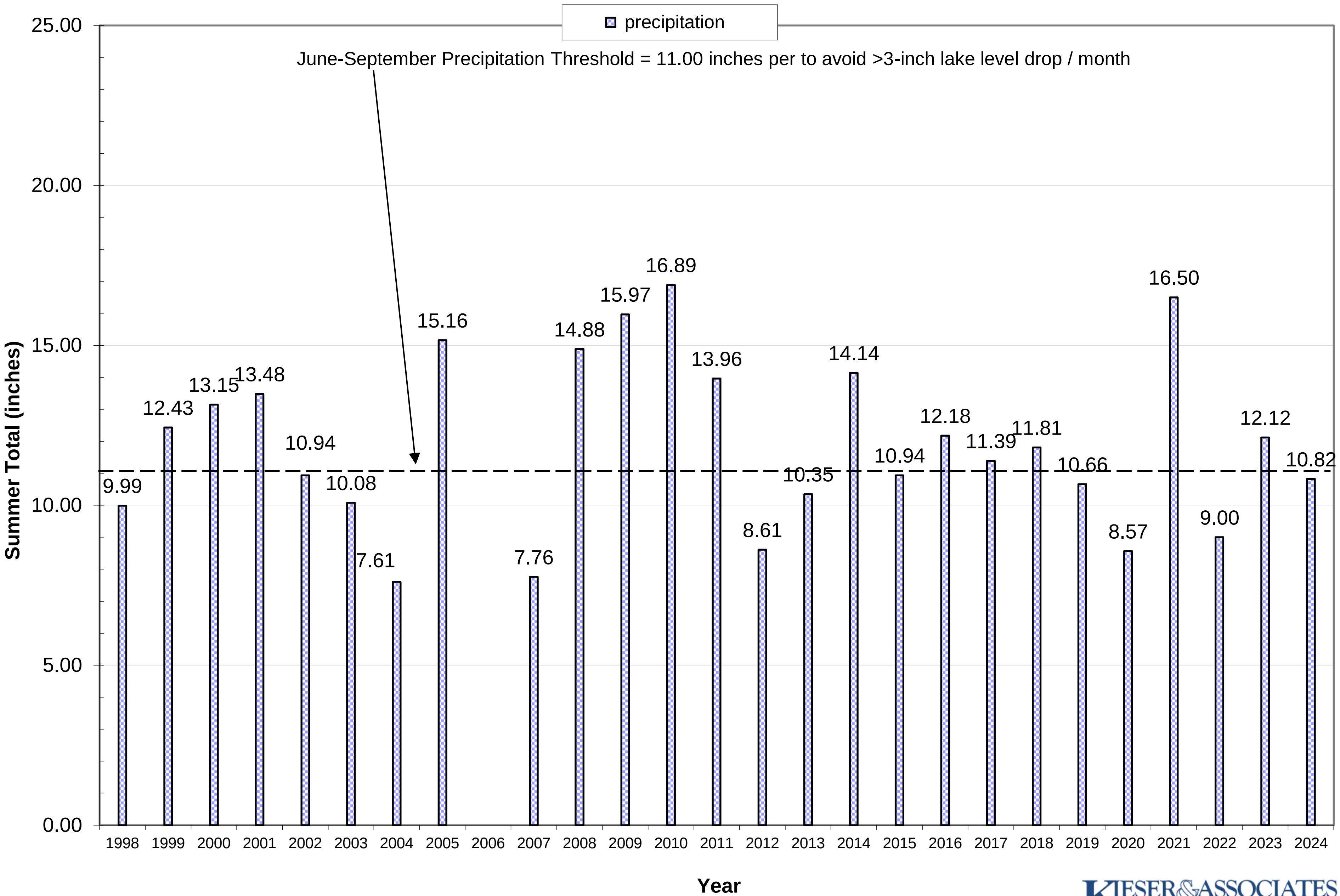


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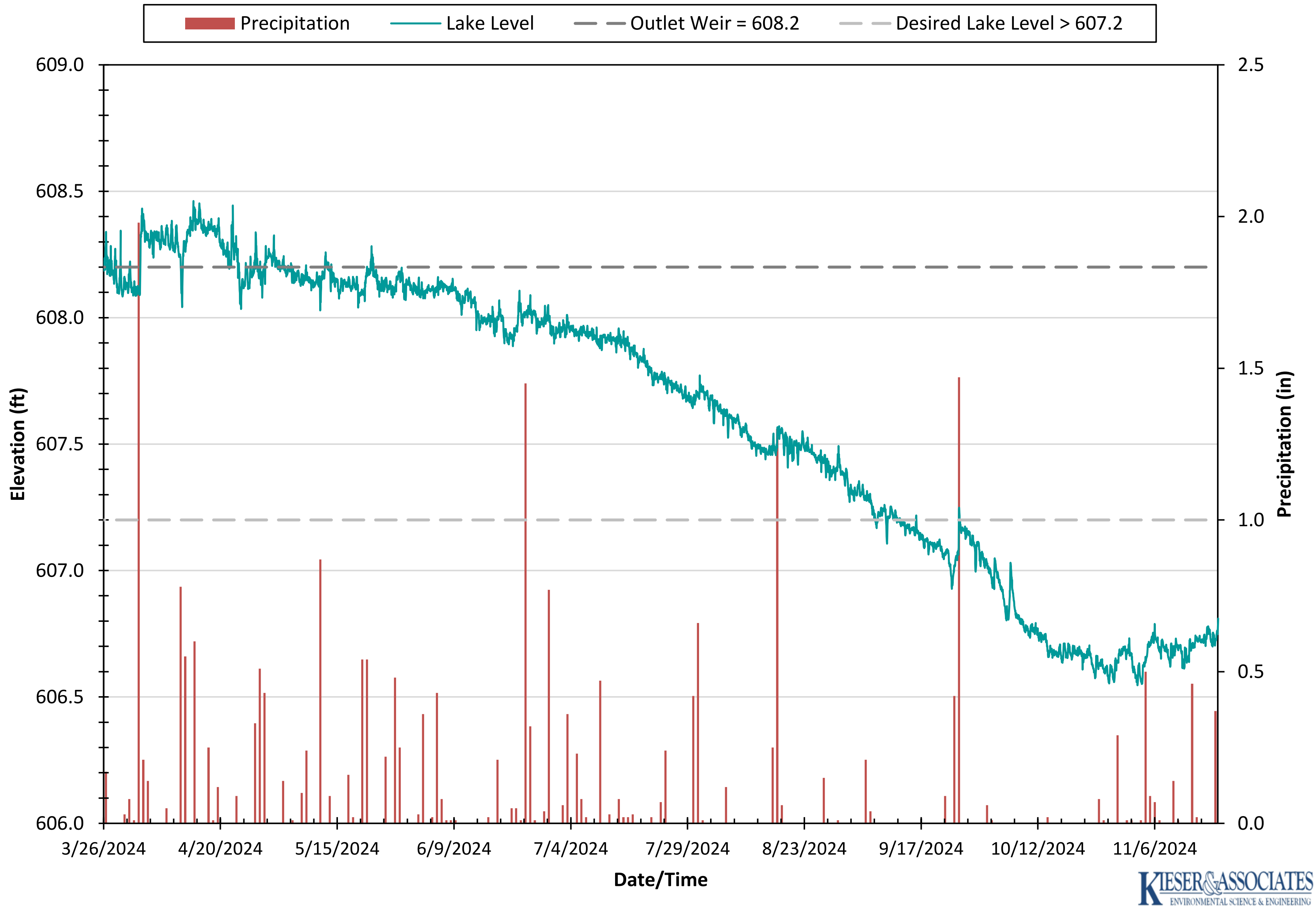
Figure 3. 2024 Cedar Lake Elevation and Measured Rainfall



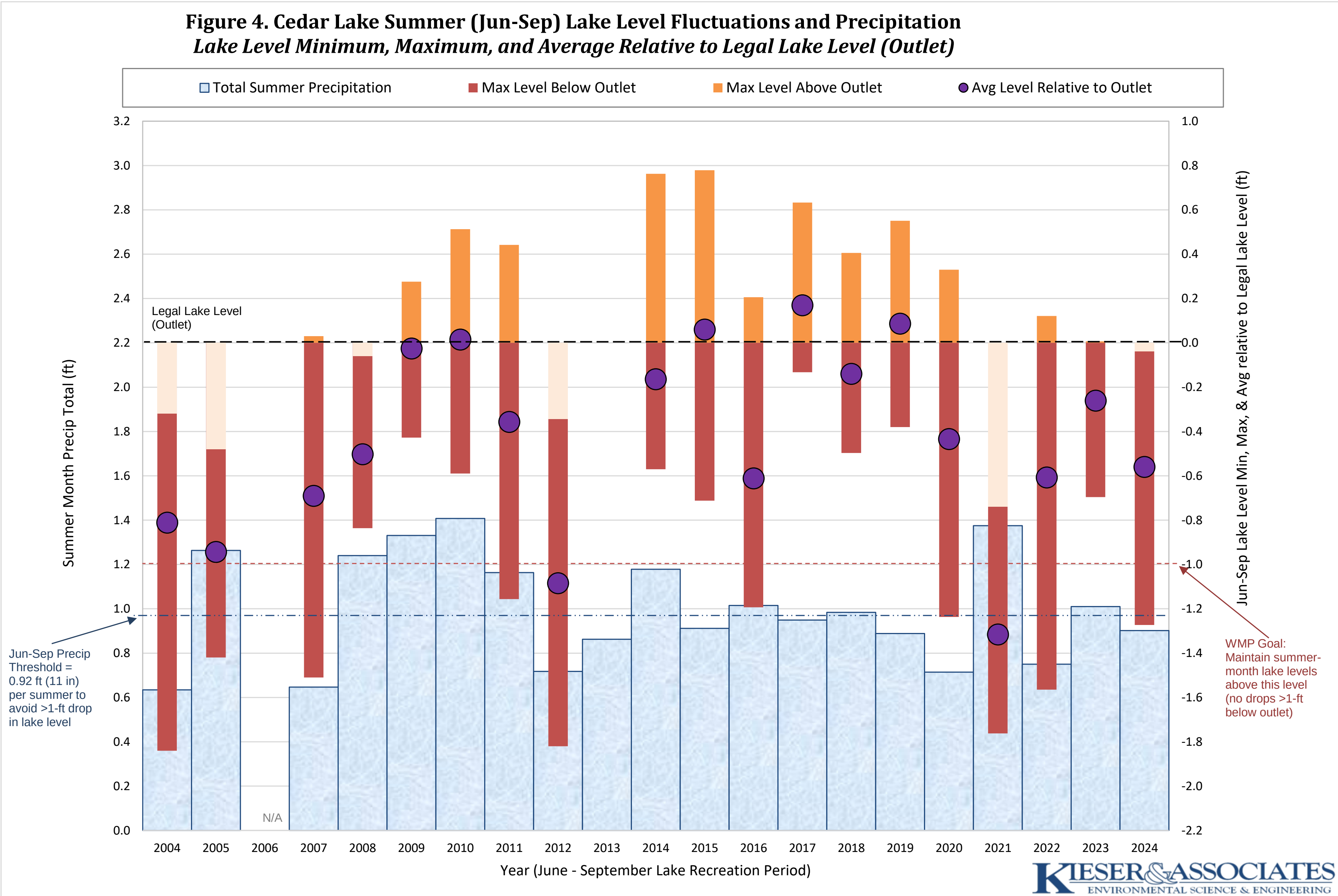


Figure 4. Cedar Lake Summer (Jun-Sep) Lake Level Fluctuations and Precipitation
Lake Level Minimum, Maximum, and Average Relative to Legal Lake Level (Outlet)
Total Summer Precipitation
Max Level Below Outlet
Max Level Above Outlet
Avg Level Relative to Outlet
Legal Lake Level (Outlet)
Summer Month Precip Total (ft)
Jun-Sep Lake Level Min, Max, & Avg relative to Legal Lake Level (ft)
Jun-Sep Precip Threshold = 0.92 ft (11 in) per summer to avoid >1-ft drop in lake level
WMP Goal: Maintain summer-month lake levels above this level (no drops >1-ft below outlet)
N/A
Year (June - September Lake Recreation Period)
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2
-2.2 -2.0 -1.8 -1.6 -1.4 -1.2 -1.0 -0.8 -0.6 -0.4 -0.2 0.0 0.2 0.4 0.6 0.8 1.0
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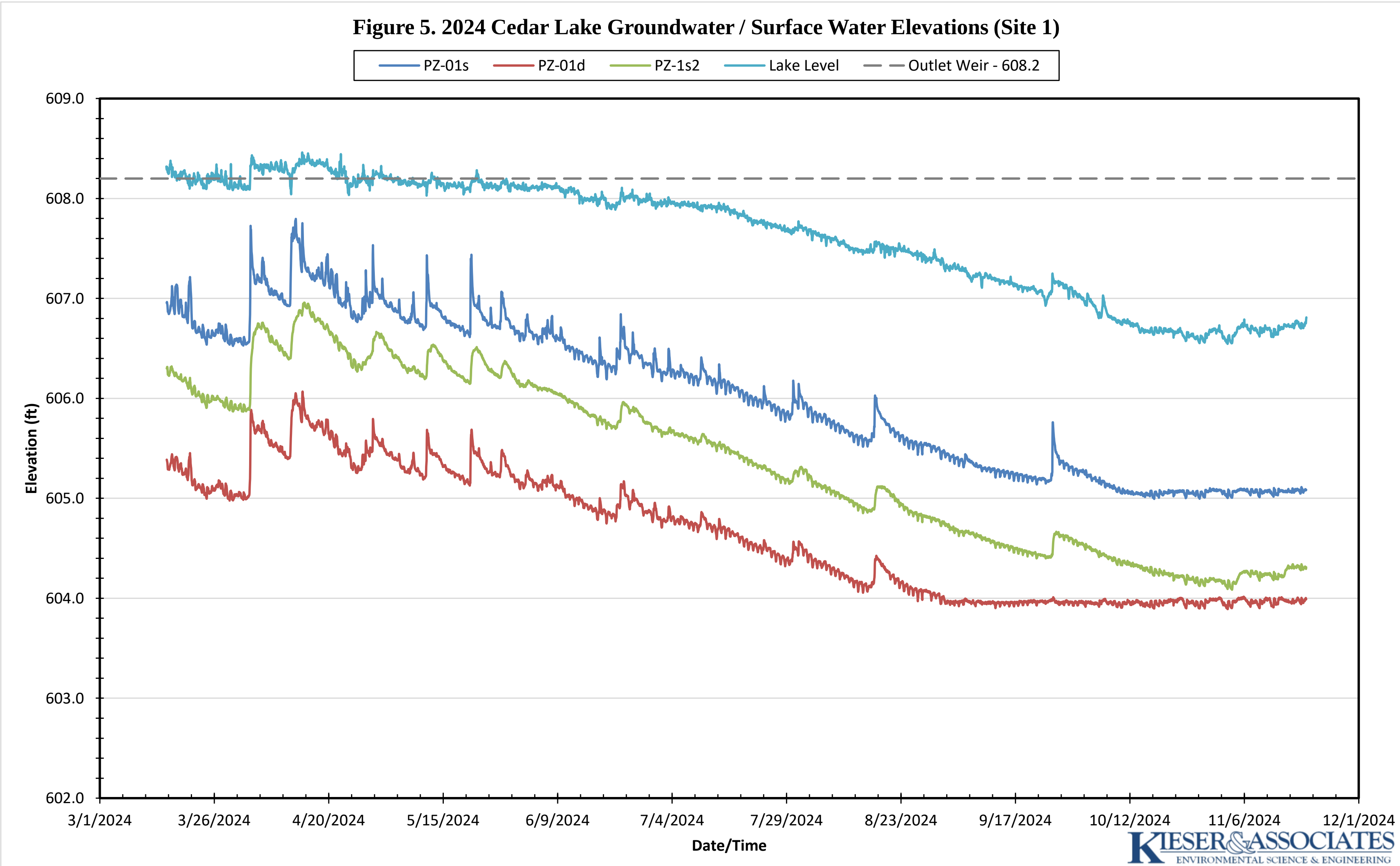
Figure 5. 2024 Cedar Lake Groundwater / Surface Water Elevations (Site 1)
PZ-01s
PZ-01d
PZ-1s2
Lake Level
Outlet Weir - 608.2
Elevation (ft)
609.0
608.0
607.0
606.0
605.0
604.0
603.0
602.0
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time

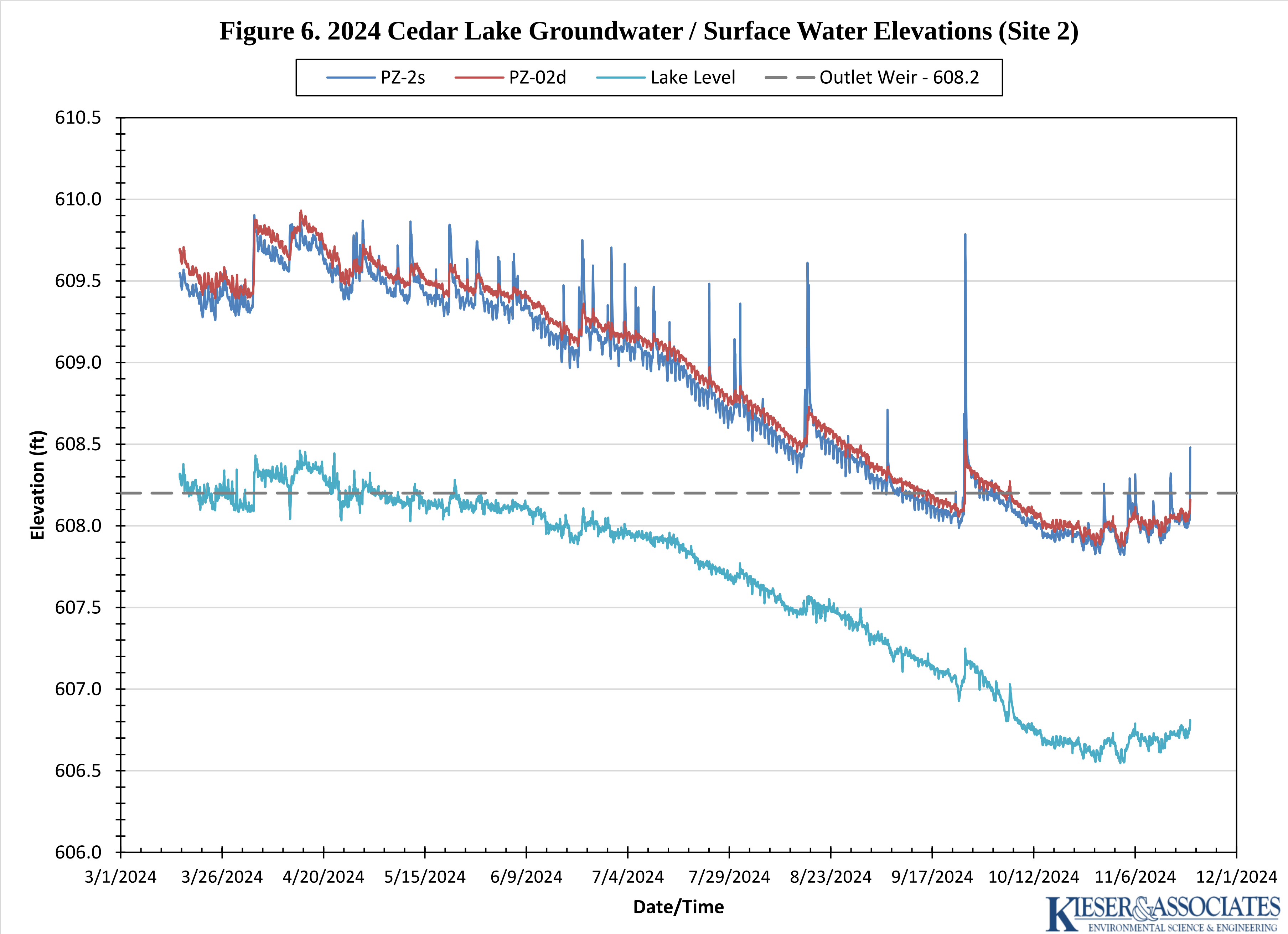
Figure 6. 2024 Cedar Lake Groundwater / Surface Water Elevations (Site 2)
PZ-2s
PZ-02d
Lake Level
Outlet Weir - 608.2
610.5
610.0
609.5
609.0
608.5
608.0
607.5
607.0
606.5
606.0
Elevation (ft)
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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Figure 7. 2023 Cedar Lake Groundwater / Surface Water Elevations (Site 3)

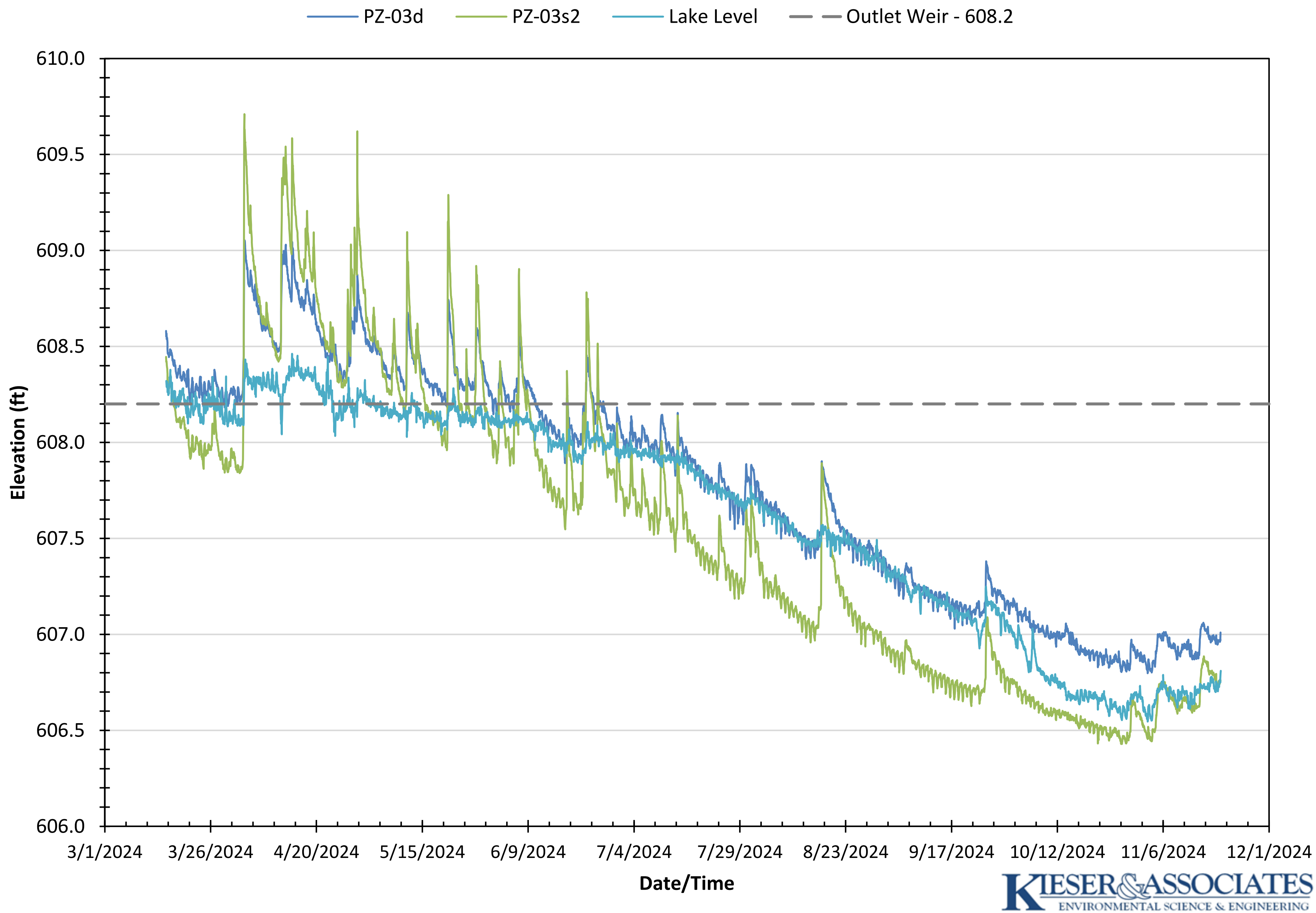
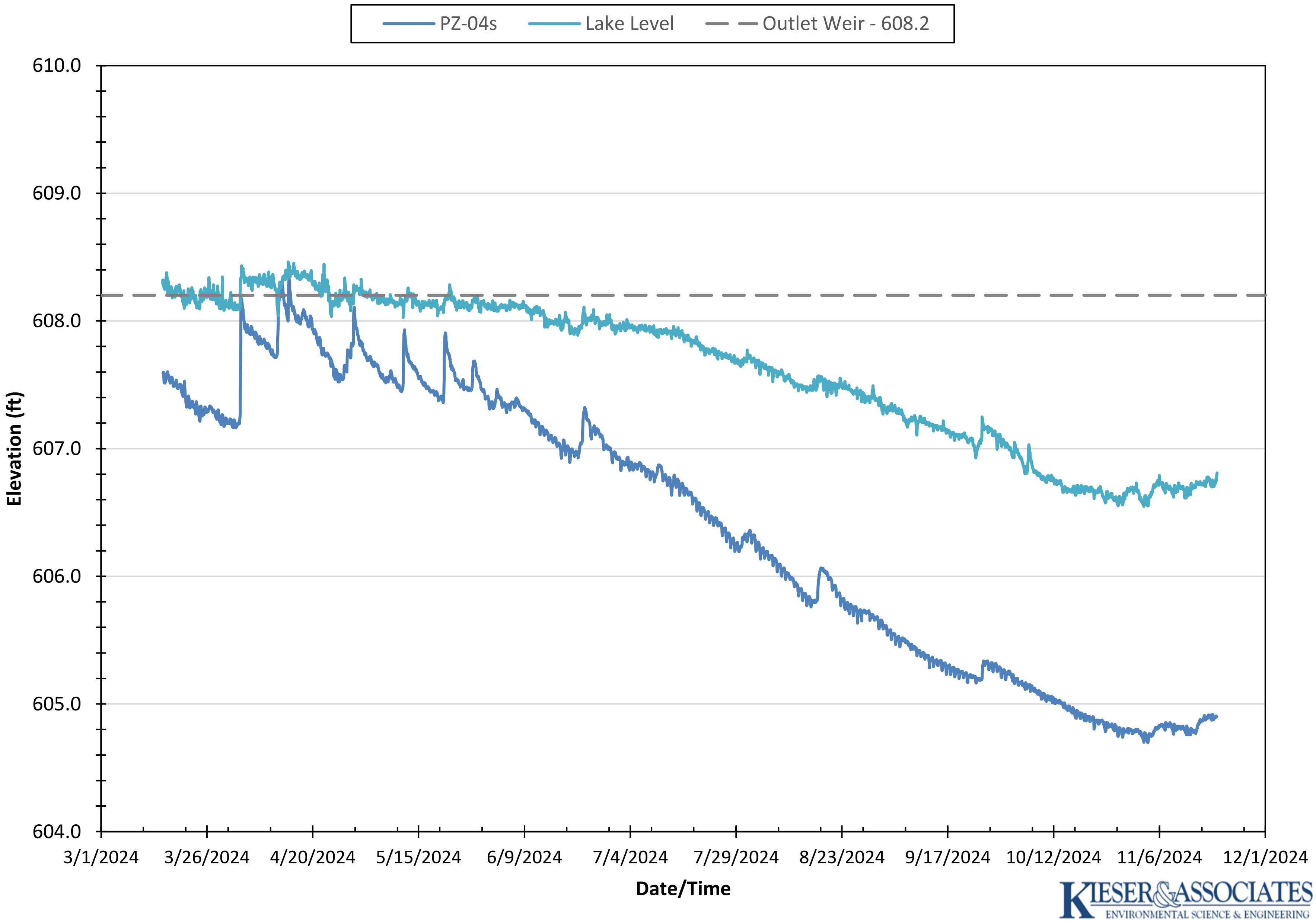


Figure 8. 2022 Cedar Lake Groundwater / Surface Water Elevations (Site 4)



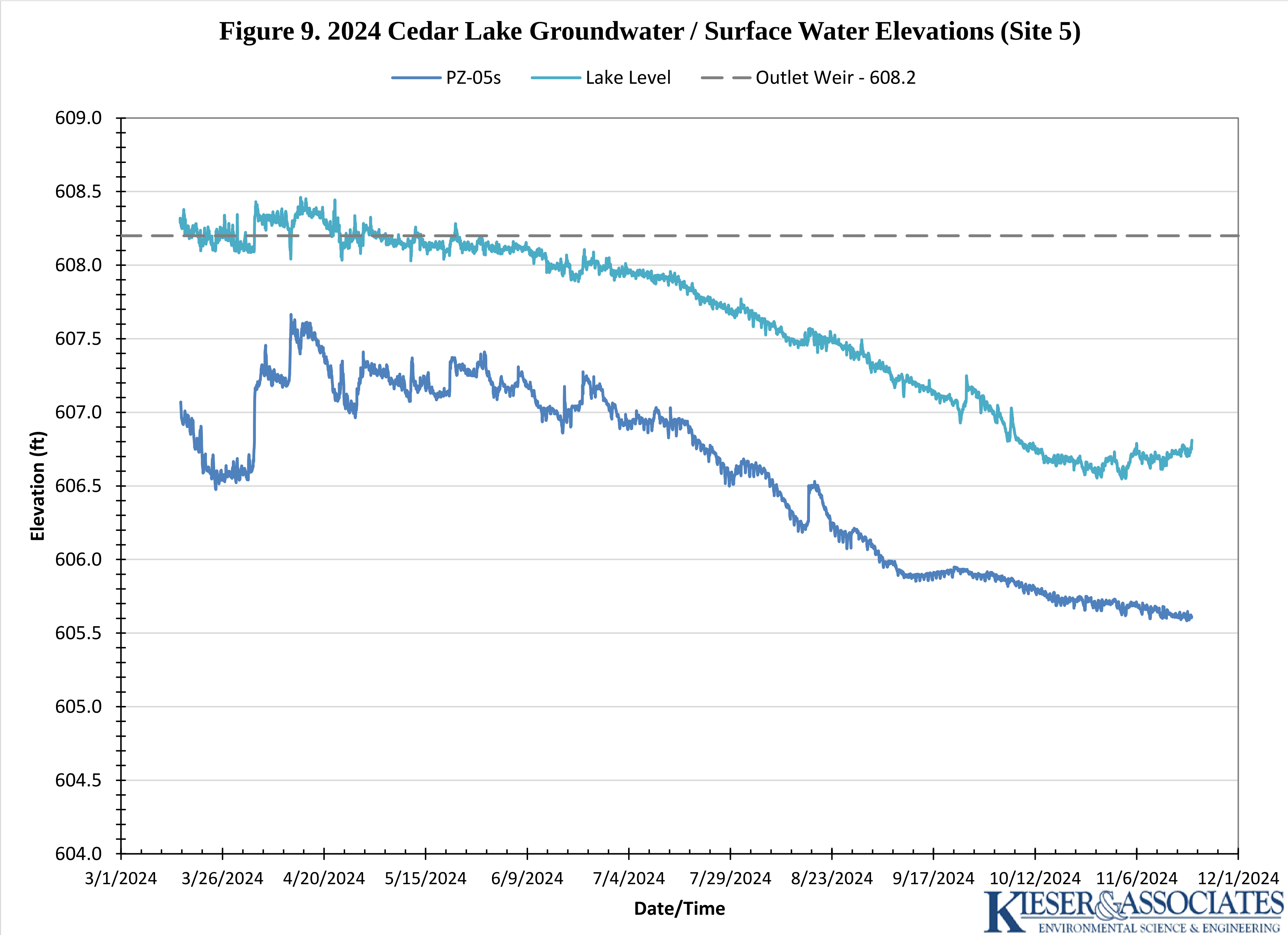


Figure 9. 2024 Cedar Lake Groundwater / Surface Water Elevations (Site 5)
PZ-05s
Lake Level
Outlet Weir - 608.2
609.0
608.5
608.0
607.5
607.0
606.5
606.0
605.5
605.0
604.5
604.0
Elevation (ft)
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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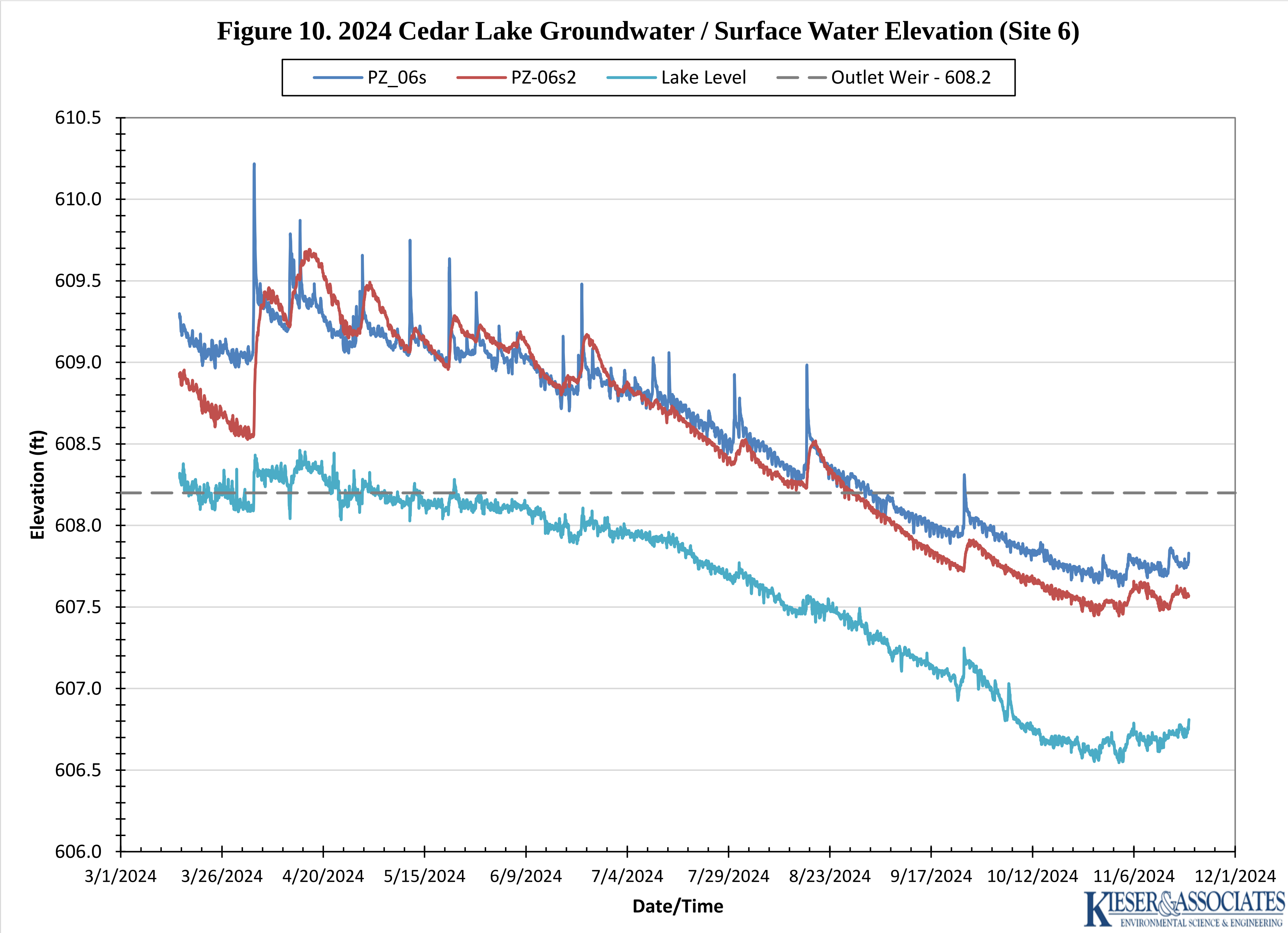

Figure 10. 2024 Cedar Lake Groundwater / Surface Water Elevation (Site 6)
PZ_06s
PZ-06s2
Lake Level
Outlet Weir - 608.2
Elevation (ft)
610.5
610.0
609.5
609.0
608.5
608.0
607.5
607.0
606.5
606.0
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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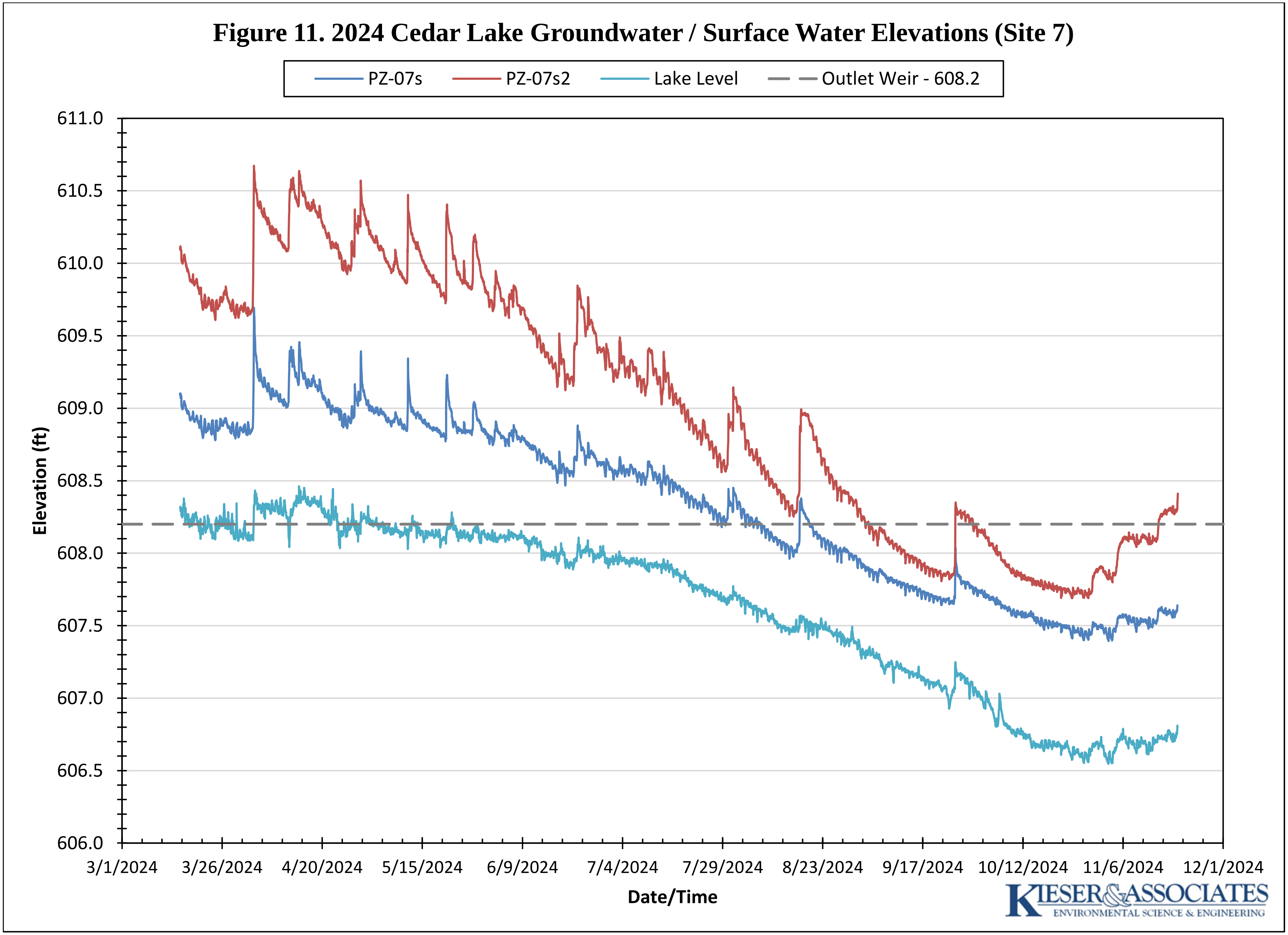
Figure 11. 2024 Cedar Lake Groundwater / Surface Water Elevations (Site 7)
PZ-07s
PZ-07s2
Lake Level
Outlet Weir - 608.2
611.0
610.5
610.0
609.5
609.0
608.5
608.0
607.5
607.0
606.5
606.0
Elevation (ft)
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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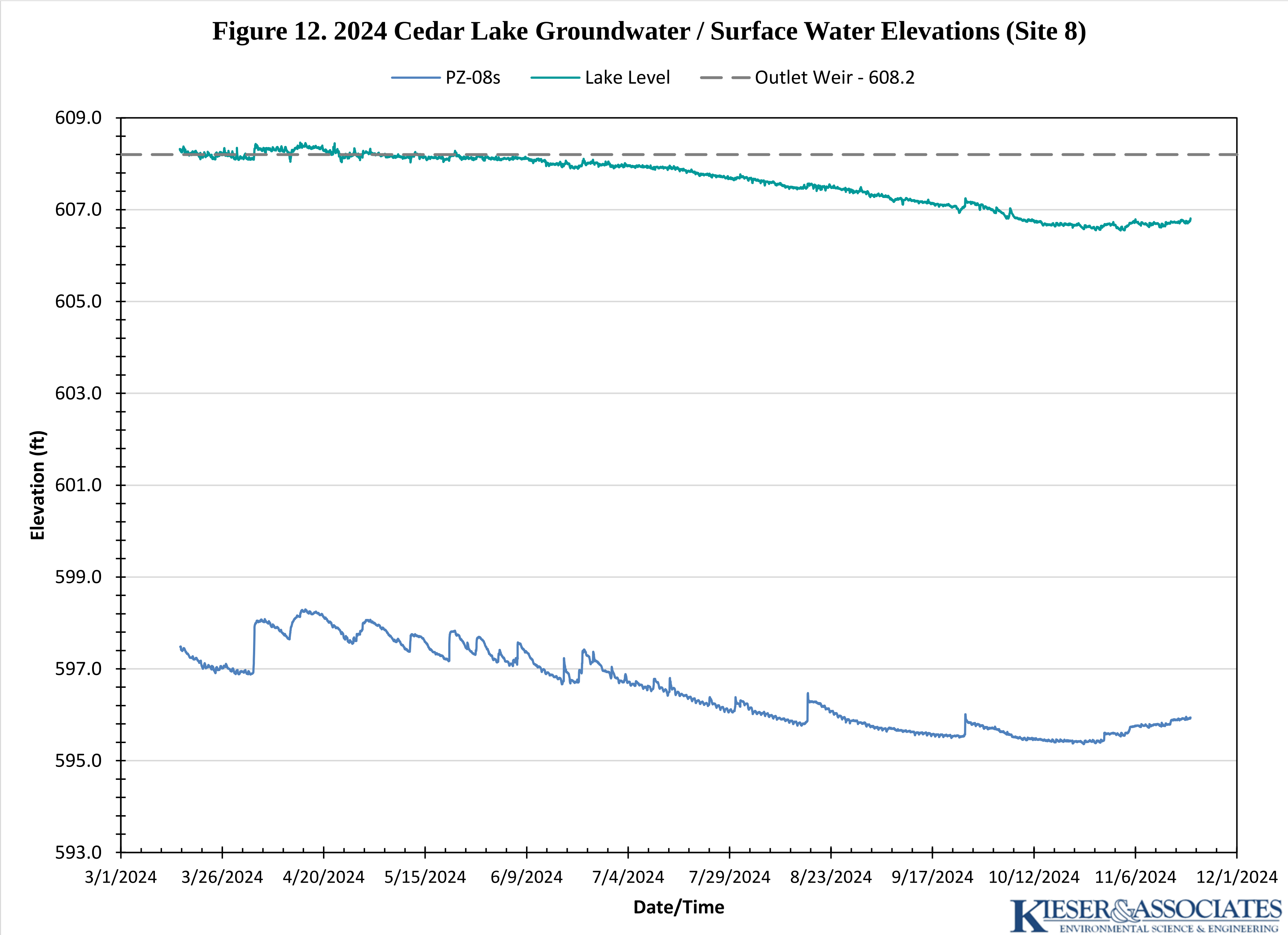
Figure 12. 2024 Cedar Lake Groundwater / Surface Water Elevations (Site 8)
PZ-08s
Lake Level
Outlet Weir - 608.2
609.0
607.0
605.0
603.0
601.0
599.0
597.0
595.0
593.0
Elevation (ft)
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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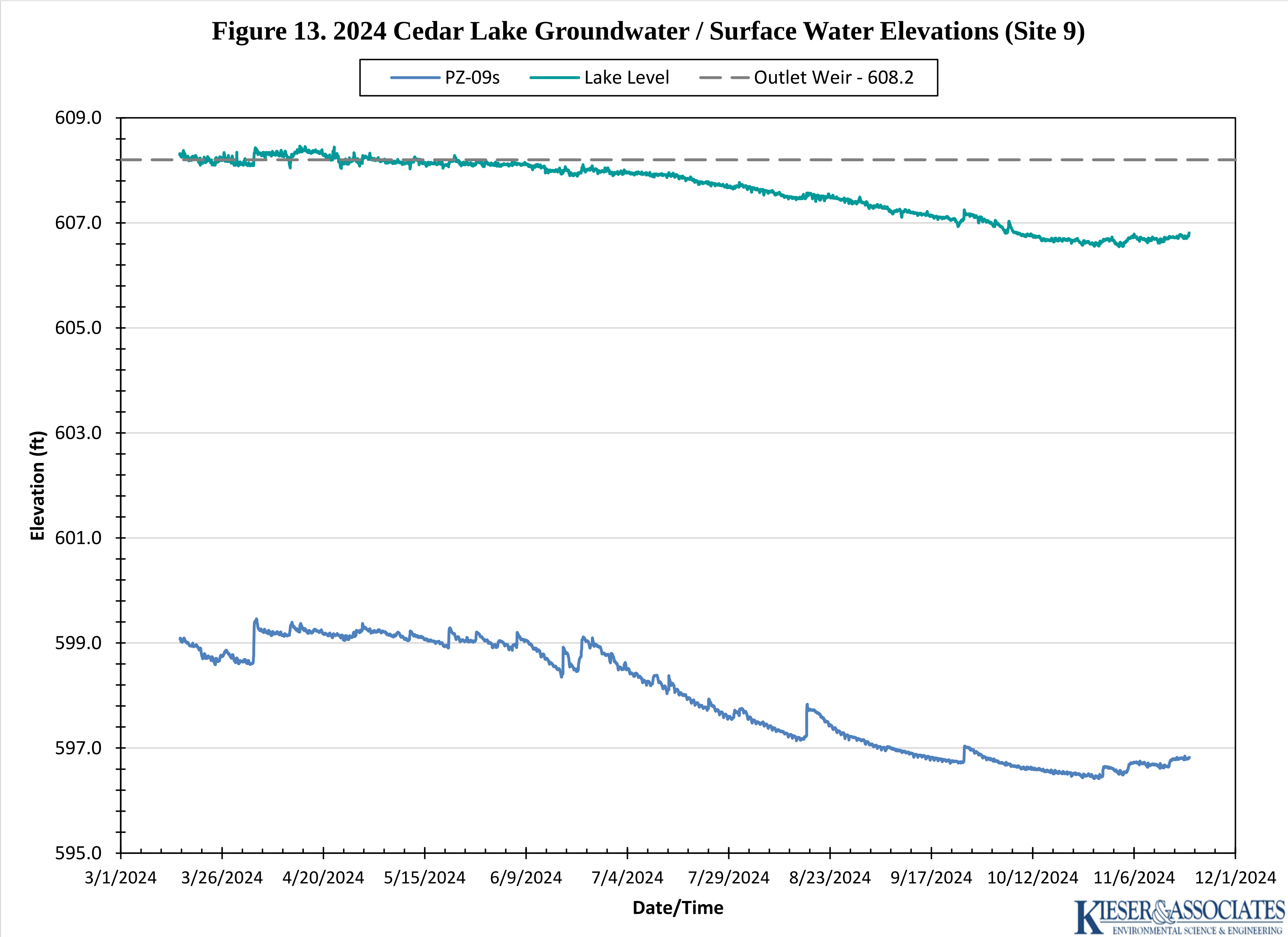
Figure 13. 2024 Cedar Lake Groundwater / Surface Water Elevations (Site 9)
PZ-09s
Lake Level
Outlet Weir - 608.2
609.0
607.0
605.0
603.0
601.0
599.0
597.0
595.0
Elevation (ft)
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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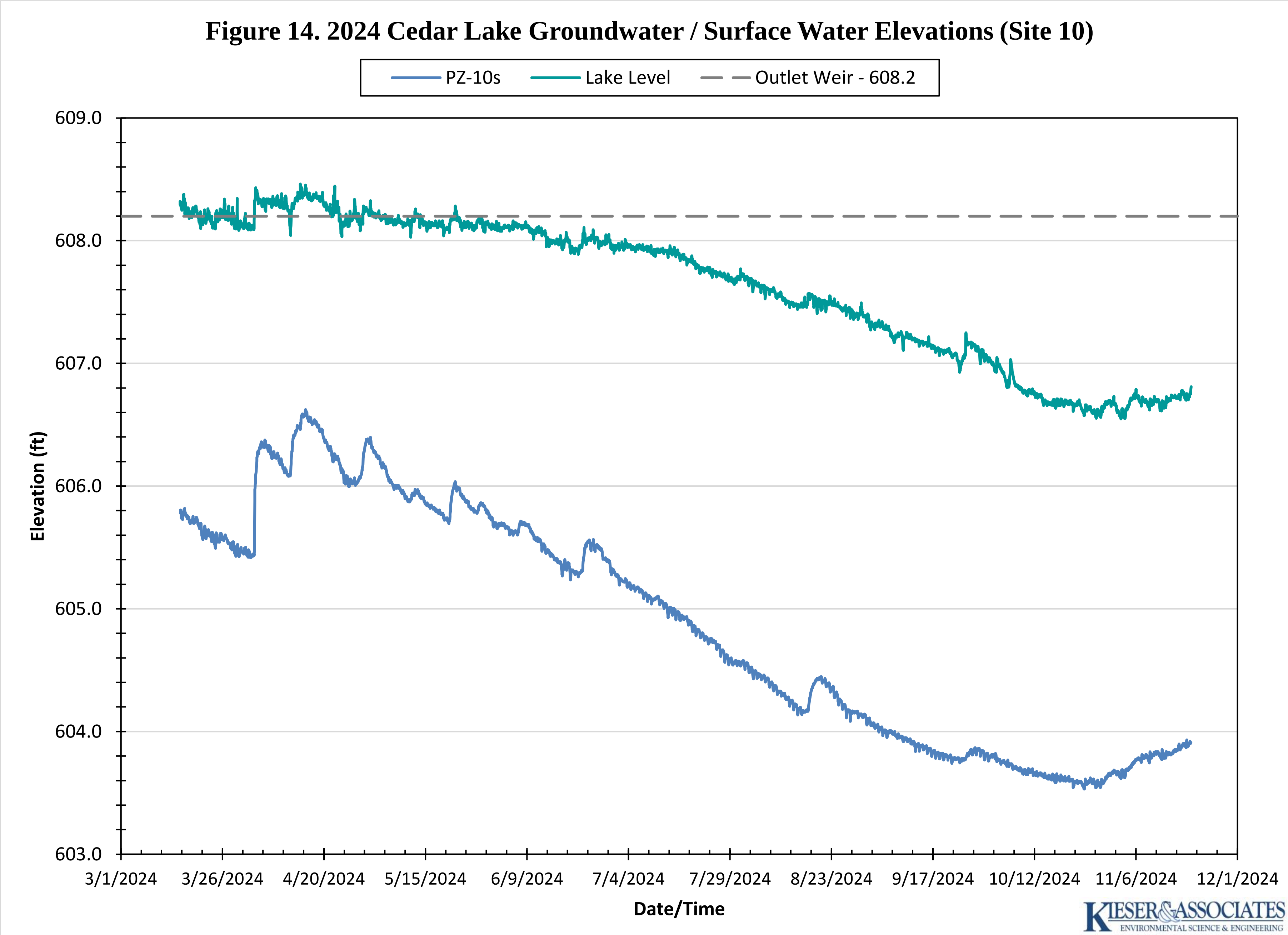
Figure 14. 2024 Cedar Lake Groundwater / Surface Water Elevations (Site 10)
PZ-10s
Lake Level
Outlet Weir - 608.2
Elevation (ft)
609.0
608.0
607.0
606.0
605.0
604.0
603.0
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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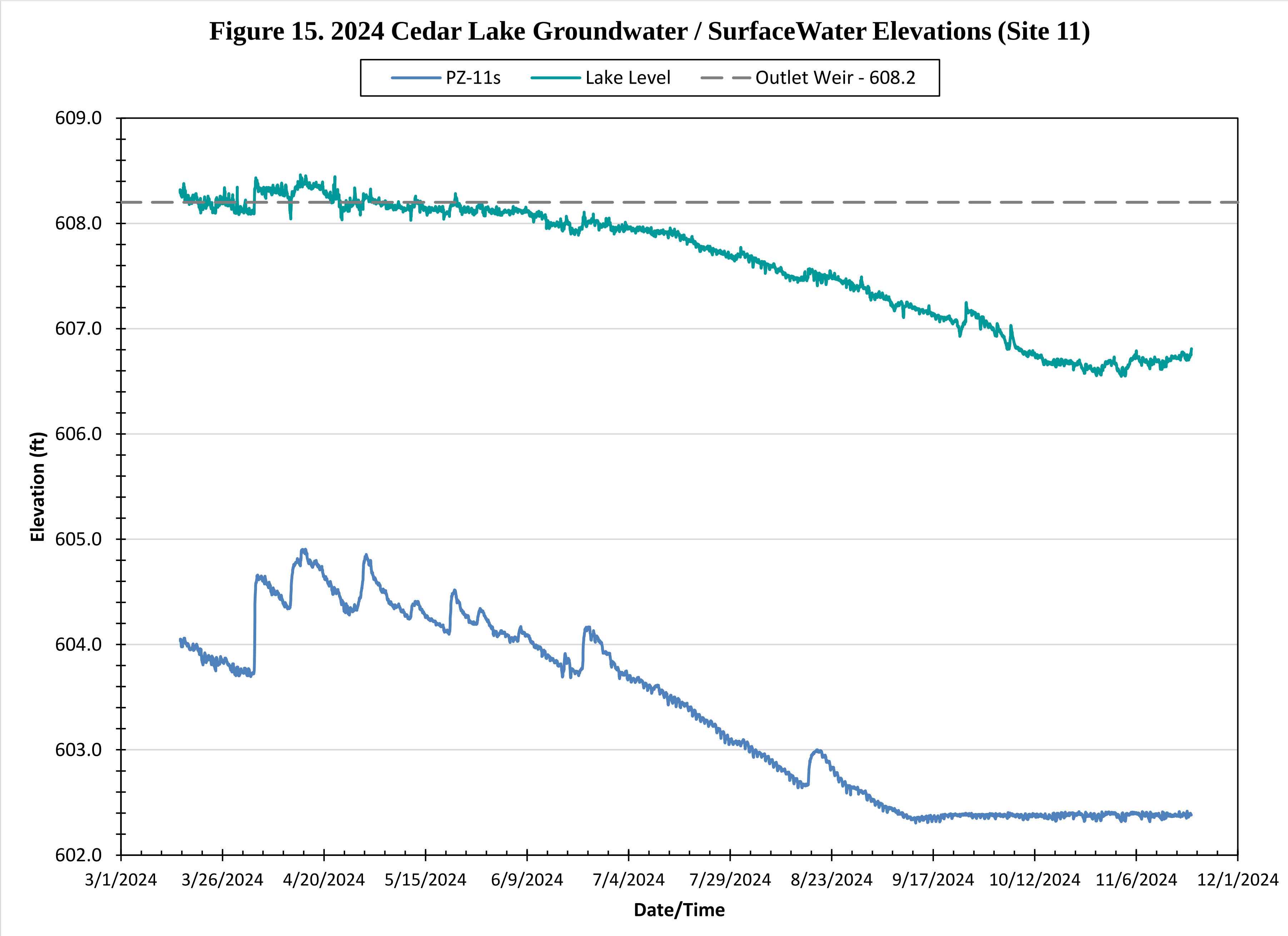


Figure 15. 2024 Cedar Lake Groundwater / SurfaceWater Elevations (Site 11)
PZ-11s
Lake Level
Outlet Weir - 608.2
609.0
608.0
607.0
606.0
605.0
604.0
603.0
602.0
Elevation (ft)
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time

Figure 16. 2024 Cedar Lake Groundwater / Surface Water Elevations (Site 12)

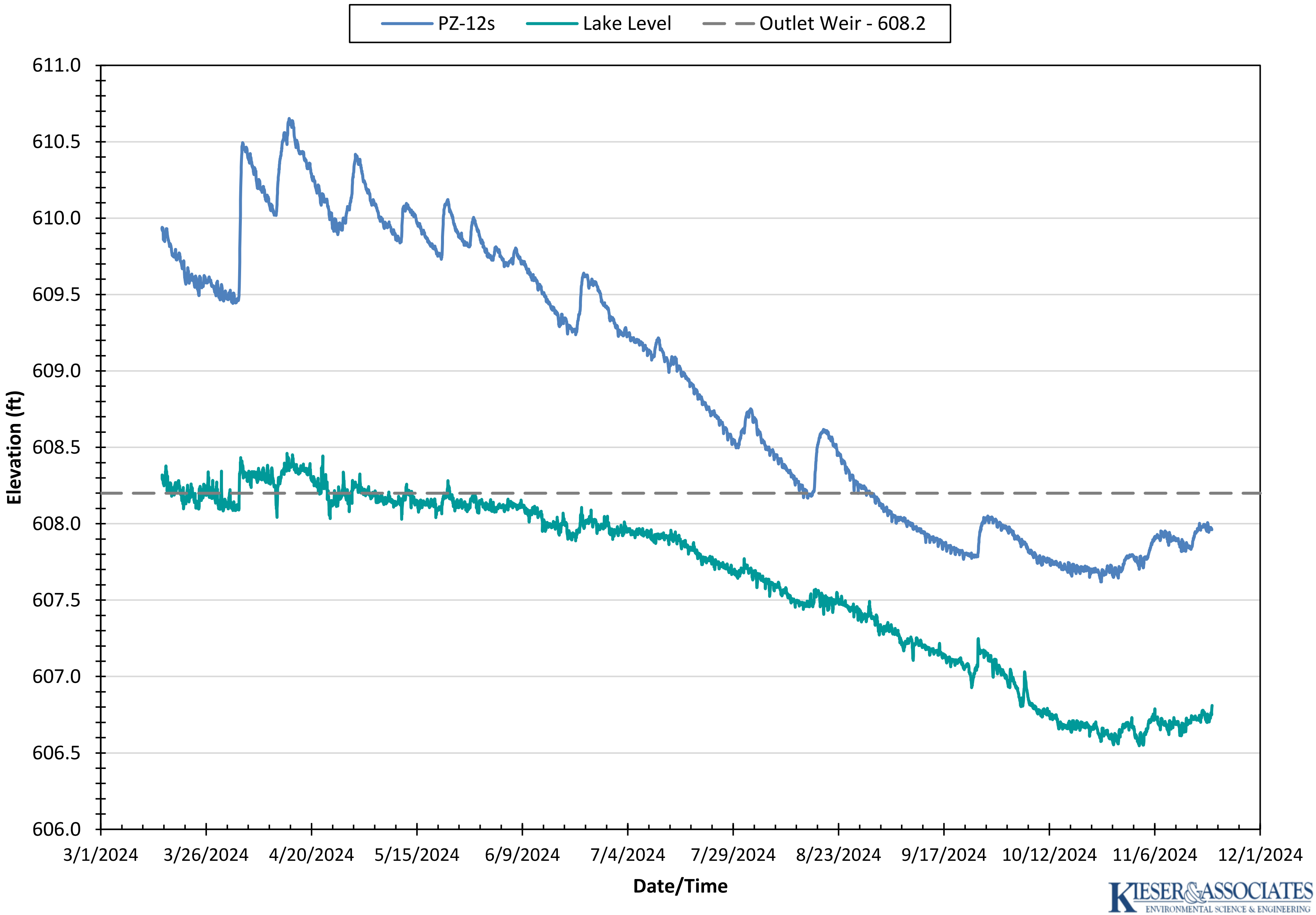


Figure 17. 2024 Cedar Lake Groundwater / Surface Water Elevations (TL Lake 2)

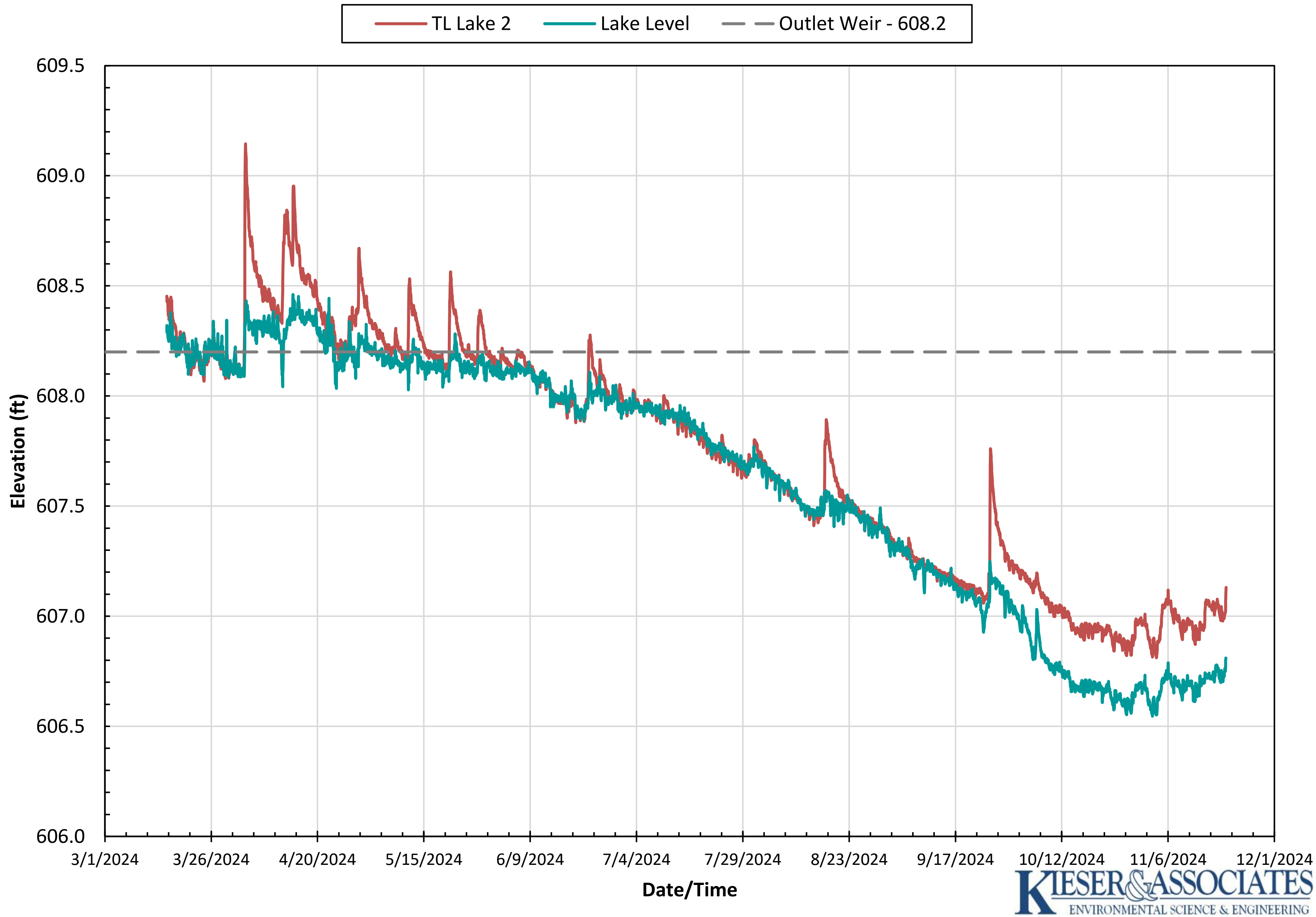
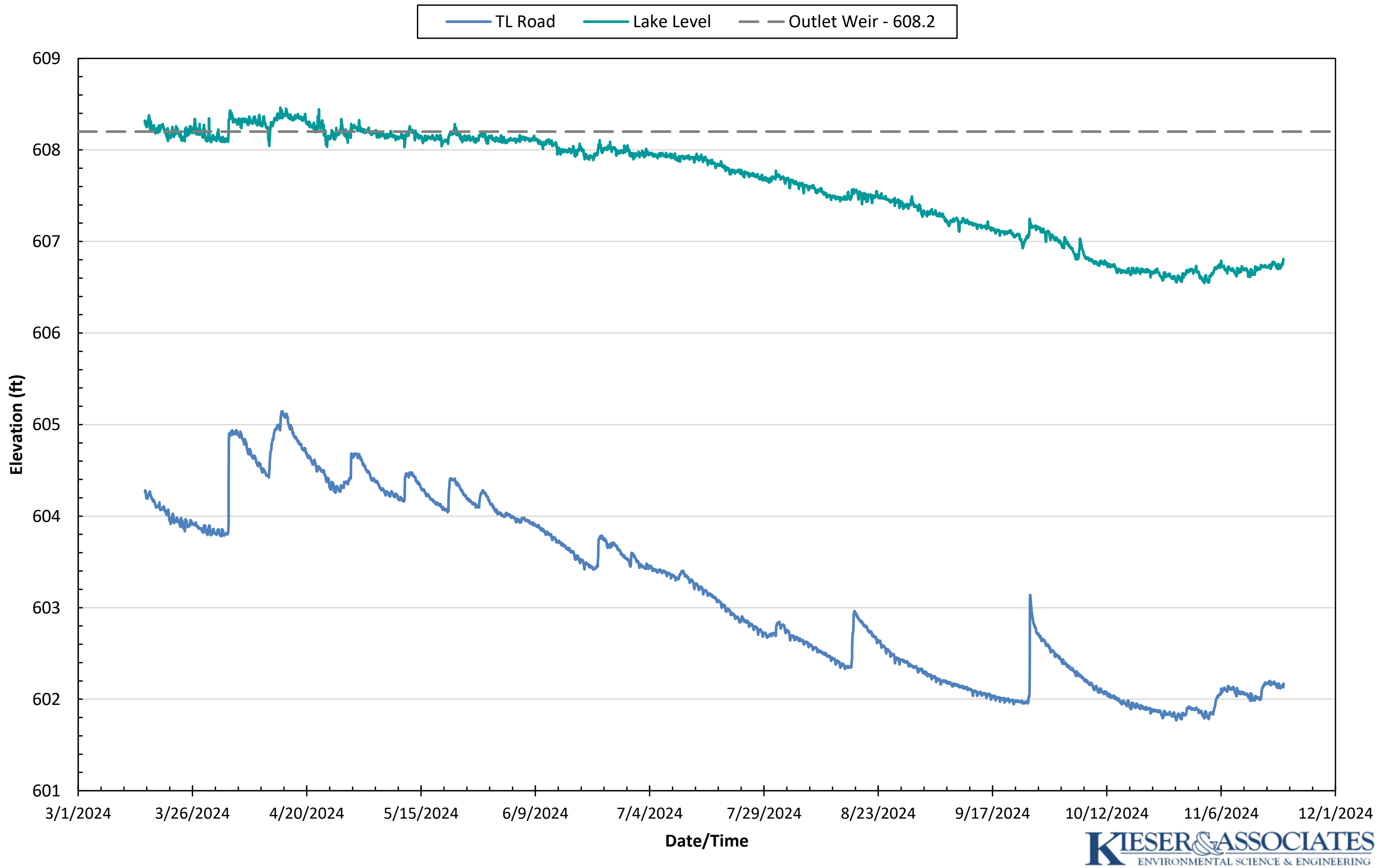


Figure 18. 2024 Cedar Lake Groundwater / Surface Water Elevations (TL Road)



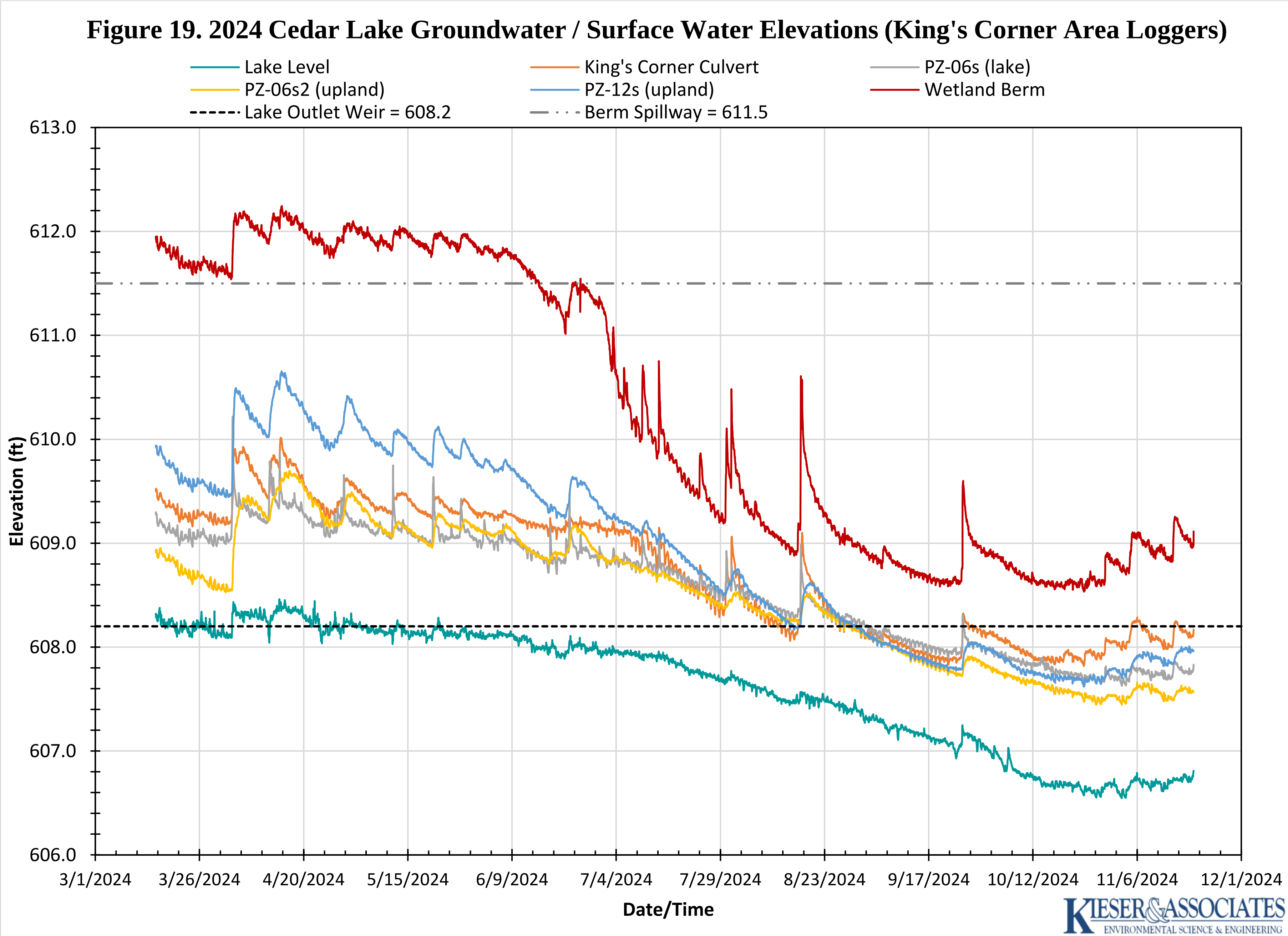


Figure 19. 2024 Cedar Lake Groundwater / Surface Water Elevations (King's Corner Area Loggers)
Lake Level
King's Corner Culvert
PZ-06s (lake)
PZ-06s2 (upland)
PZ-12s (upland)
Wetland Berm
Lake Outlet Weir = 608.2
Berm Spillway = 611.5
613.0
612.0
611.0
610.0
609.0
608.0
607.0
606.0
Elevation (ft)
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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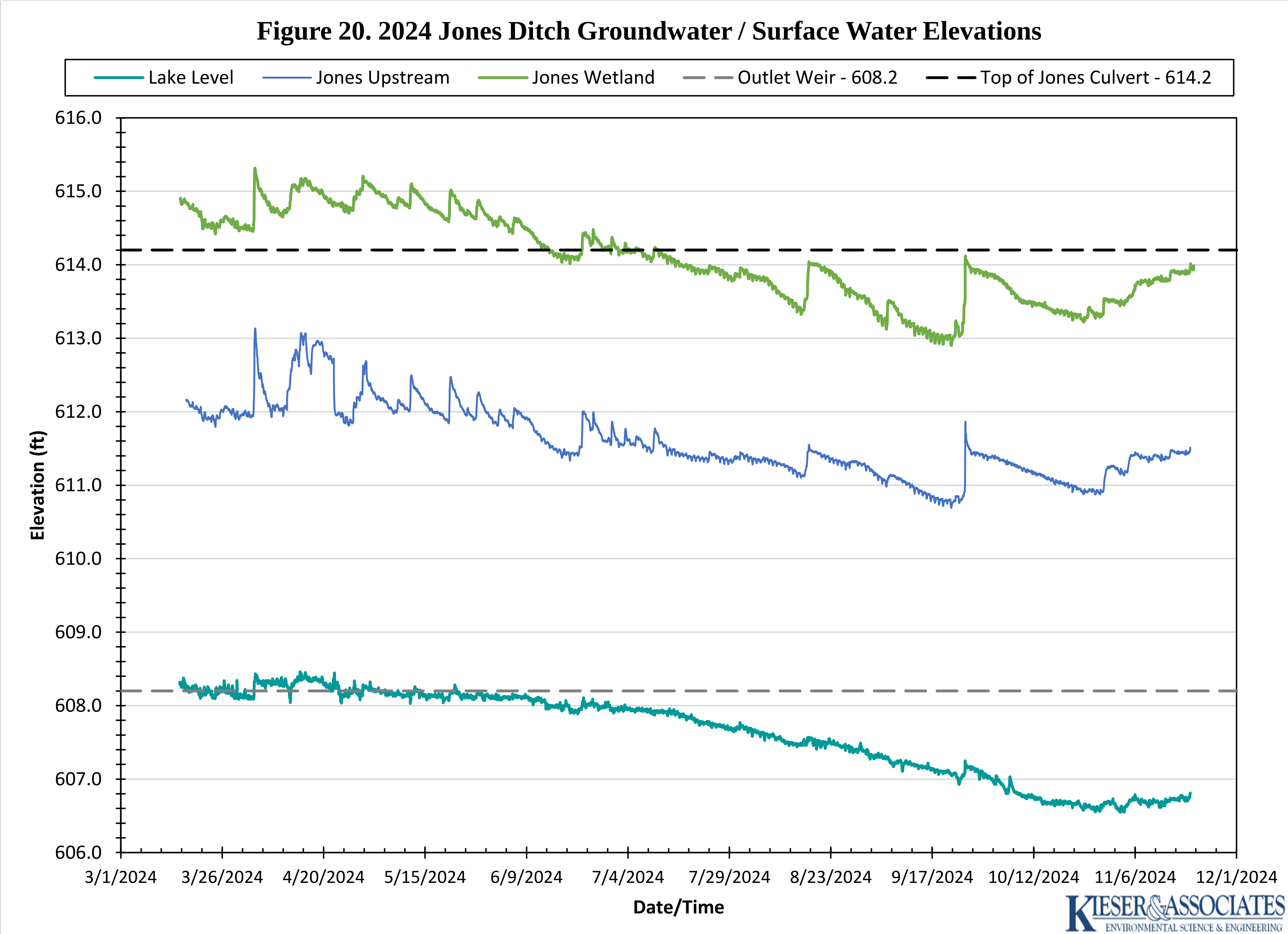
Figure 20. 2024 Jones Ditch Groundwater / Surface Water Elevations
Lake Level
Jones Upstream
Jones Wetland
Outlet Weir - 608.2
Top of Jones Culvert - 614.2
Elevation (ft)
616.0
615.0
614.0
613.0
612.0
611.0
610.0
609.0
608.0
607.0
606.0
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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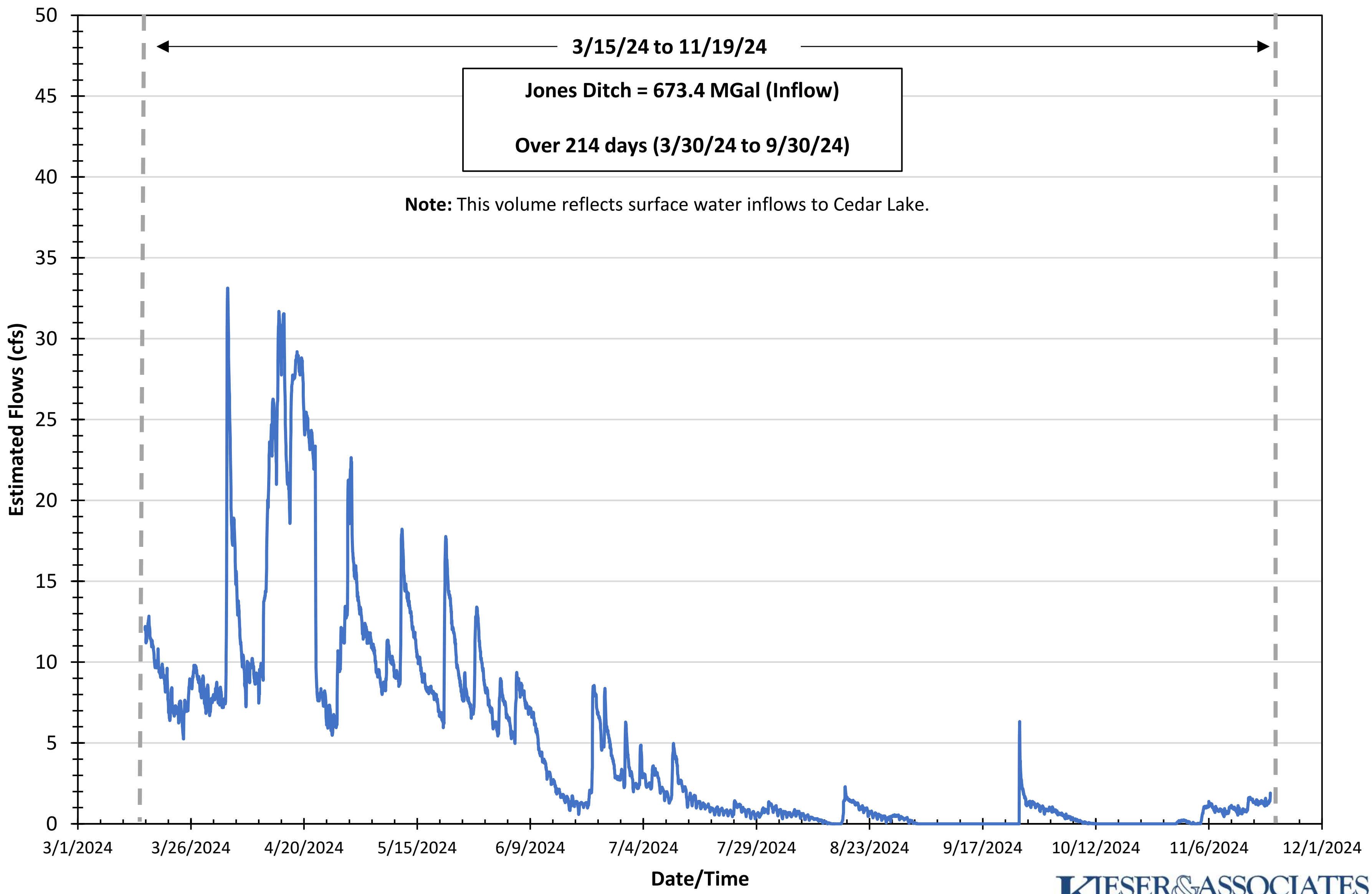
Figure 21. 2024 Estimated Jones Ditch Flows



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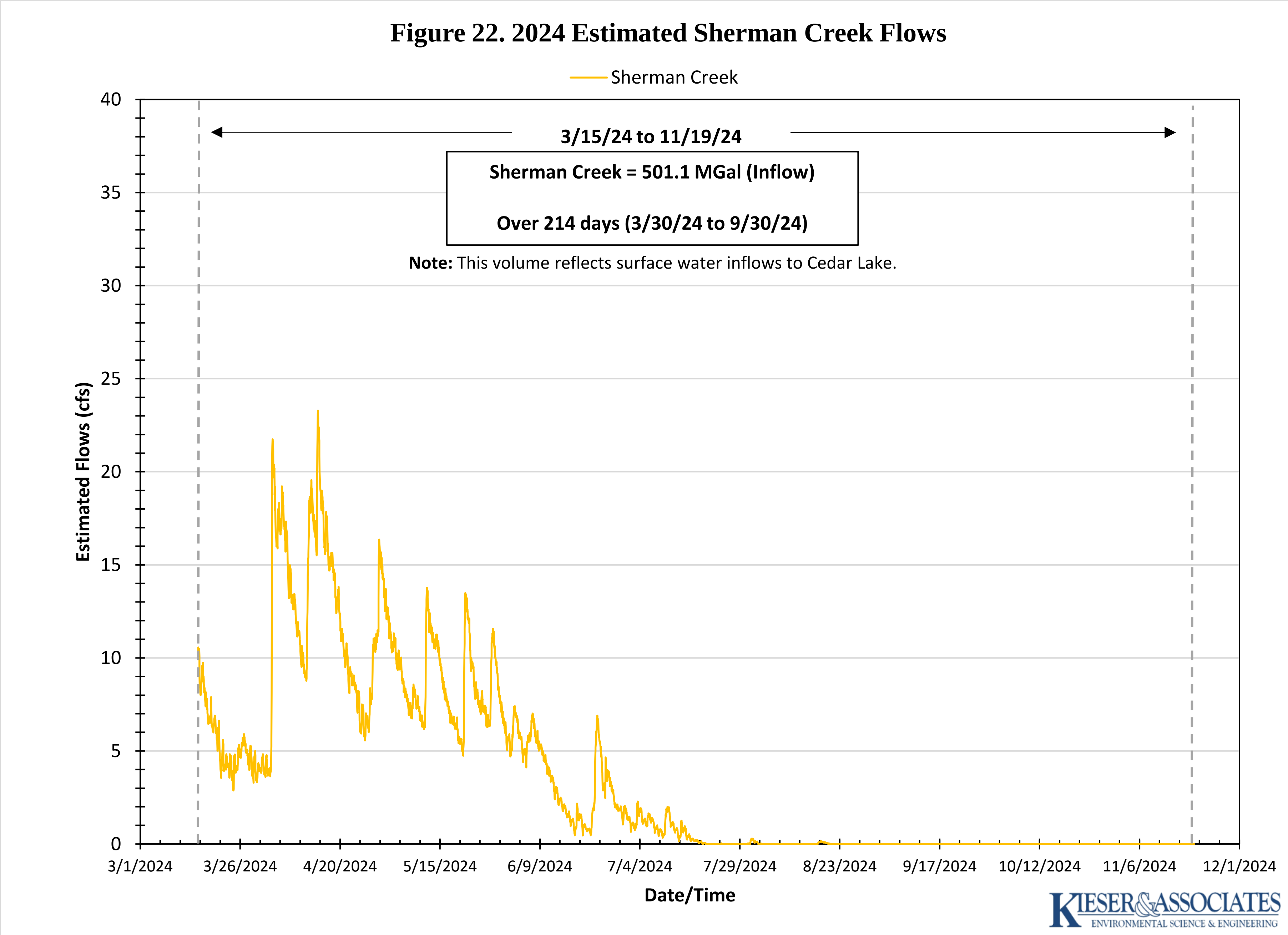

Figure 22. 2024 Estimated Sherman Creek Flows
Sherman Creek
3/15/24 to 11/19/24
Sherman Creek = 501.1 MGal (Inflow)
Over 214 days (3/30/24 to 9/30/24)
Note: This volume reflects surface water inflows to Cedar Lake.
Estimated Flows (cfs)
0
5
10
15
20
25
30
35
40
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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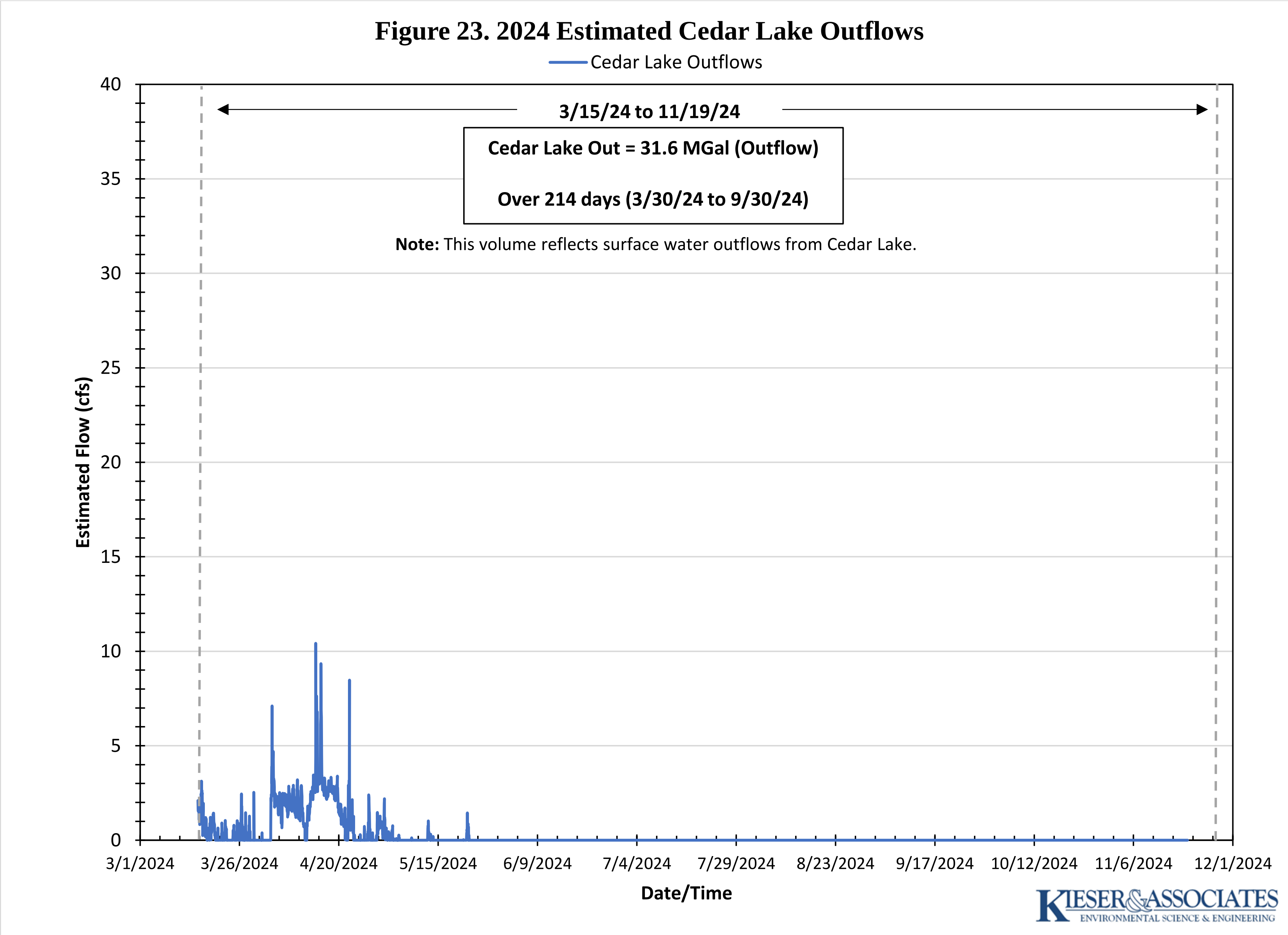

Figure 23. 2024 Estimated Cedar Lake Outflows
Cedar Lake Outflows
3/15/24 to 11/19/24
Cedar Lake Out = 31.6 MGal (Outflow)
Over 214 days (3/30/24 to 9/30/24)
Note: This volume reflects surface water outflows from Cedar Lake.
Estimated Flow (cfs)
0
5
10
15
20
25
30
35
40
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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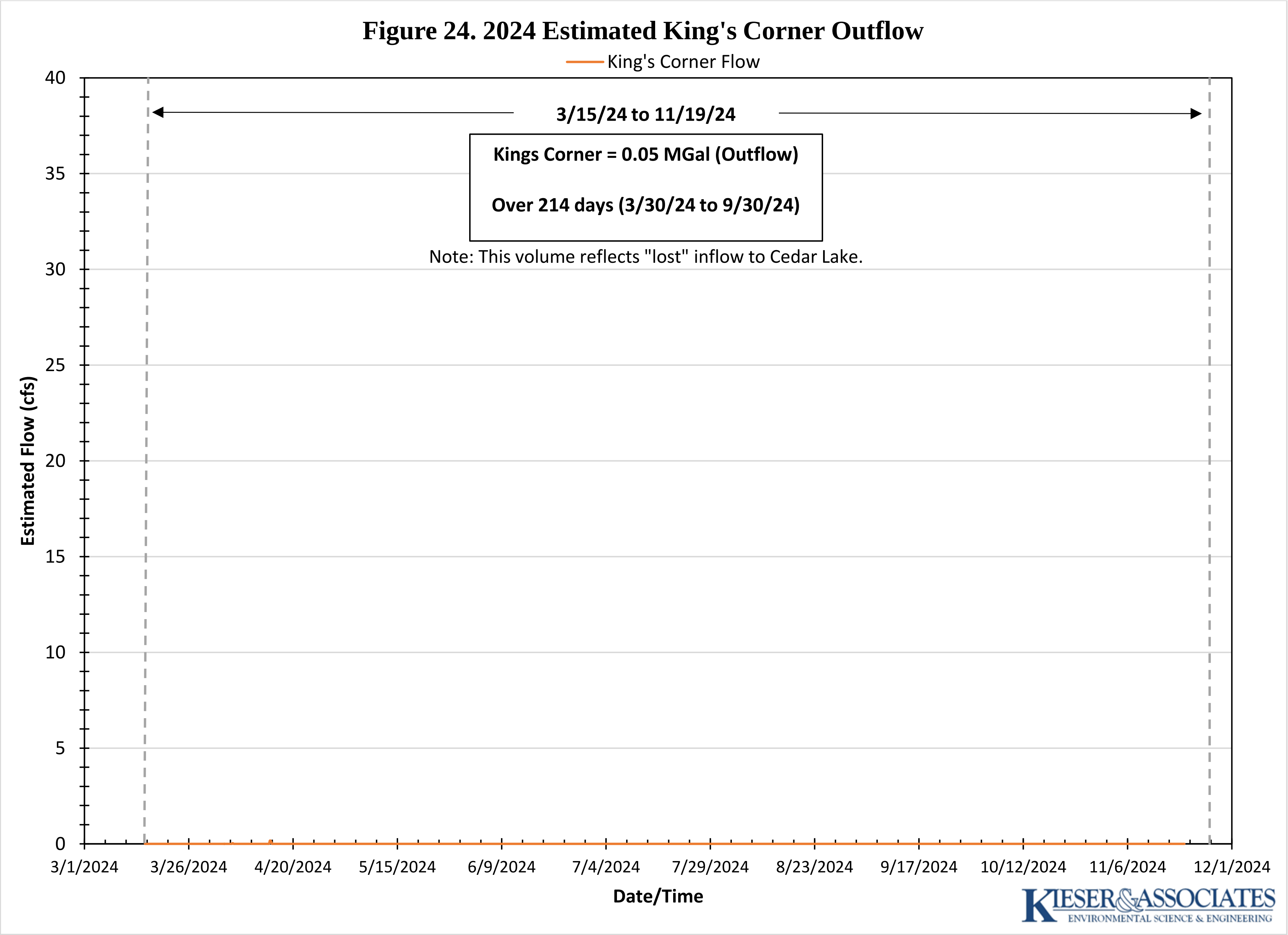
Figure 24. 2024 Estimated King's Corner Outflow
King's Corner Flow
3/15/24 to 11/19/24
Kings Corner = 0.05 MGal (Outflow)
Over 214 days (3/30/24 to 9/30/24)
Note: This volume reflects "lost" inflow to Cedar Lake.
Estimated Flow (cfs)
40
35
30
25
20
15
10
5
0
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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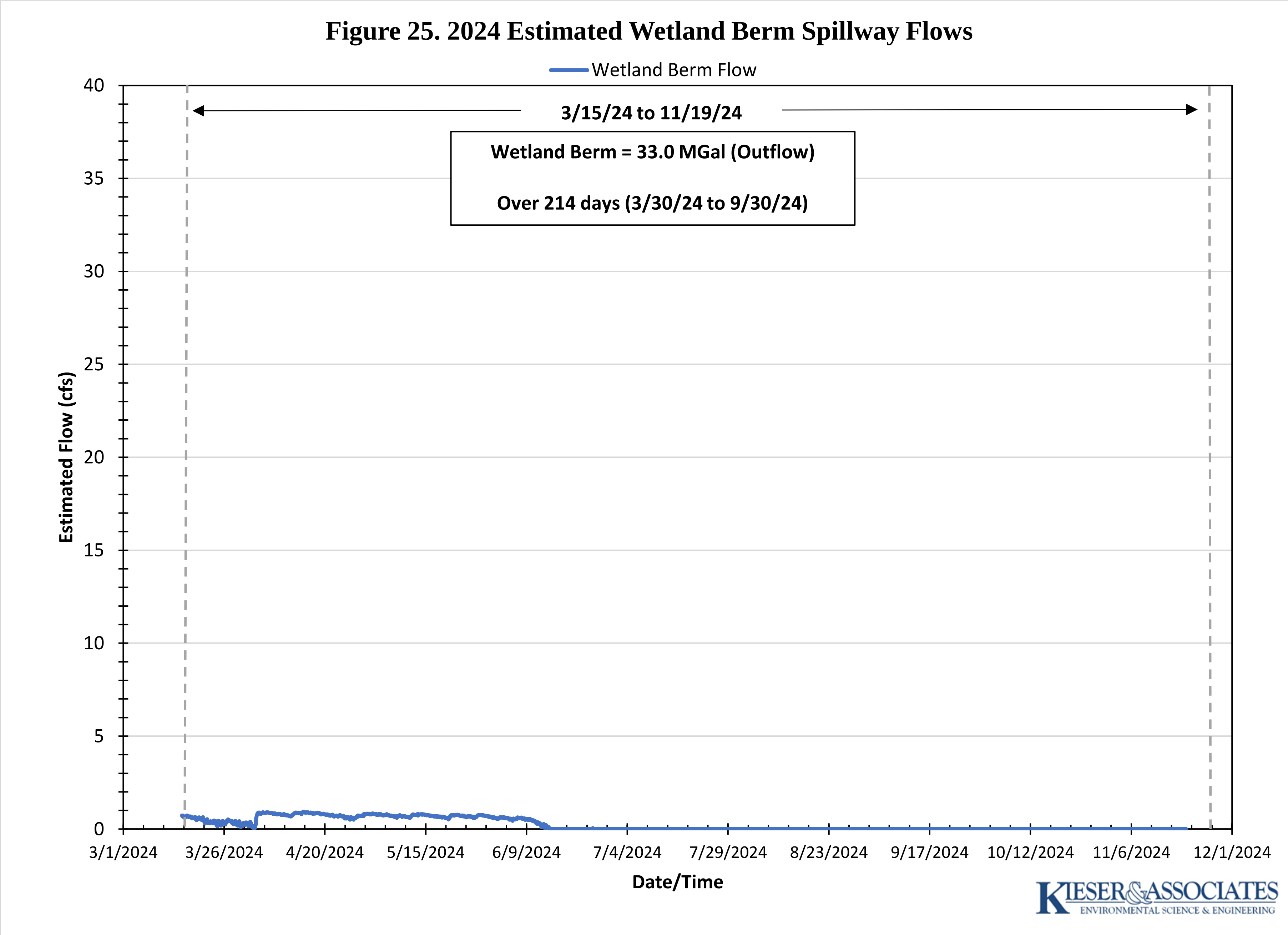
Figure 25. 2024 Estimated Wetland Berm Spillway Flows
Wetland Berm Flow
3/15/24 to 11/19/24
Wetland Berm = 33.0 MGal (Outflow)
Over 214 days (3/30/24 to 9/30/24)
Estimated Flow (cfs)
40
35
30
25
20
15
10
5
0
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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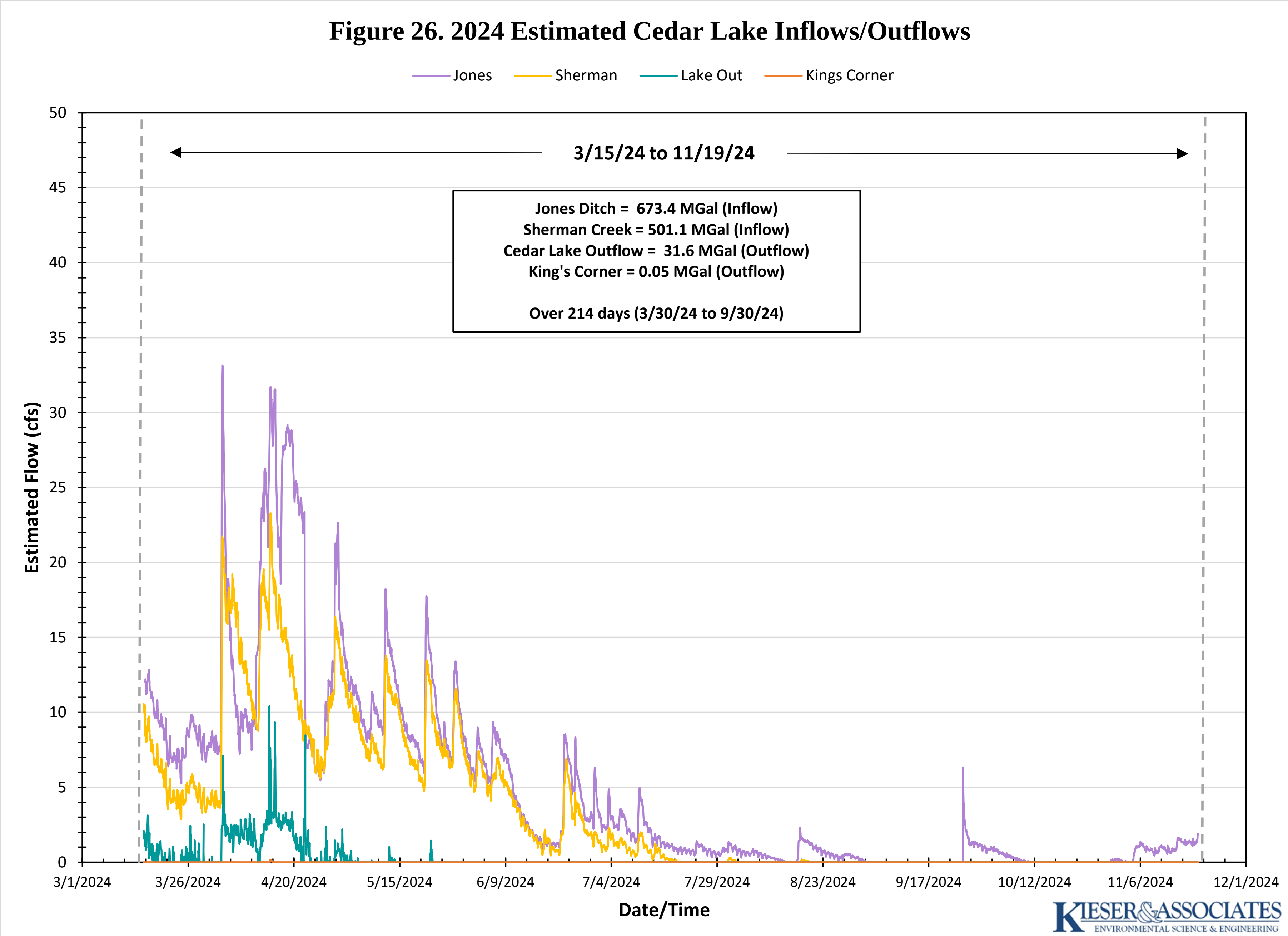

Figure 26. 2024 Estimated Cedar Lake Inflows/Outflows
Jones
Sherman
Lake Out
Kings Corner
3/15/24 to 11/19/24
Jones Ditch = 673.4 MGal (Inflow)
Sherman Creek = 501.1 MGal (Inflow)
Cedar Lake Outflow = 31.6 MGal (Outflow)
King's Corner = 0.05 MGal (Outflow)
Over 214 days (3/30/24 to 9/30/24)
Estimated Flow (cfs)
50
45
40
35
30
25
20
15
10
5
0
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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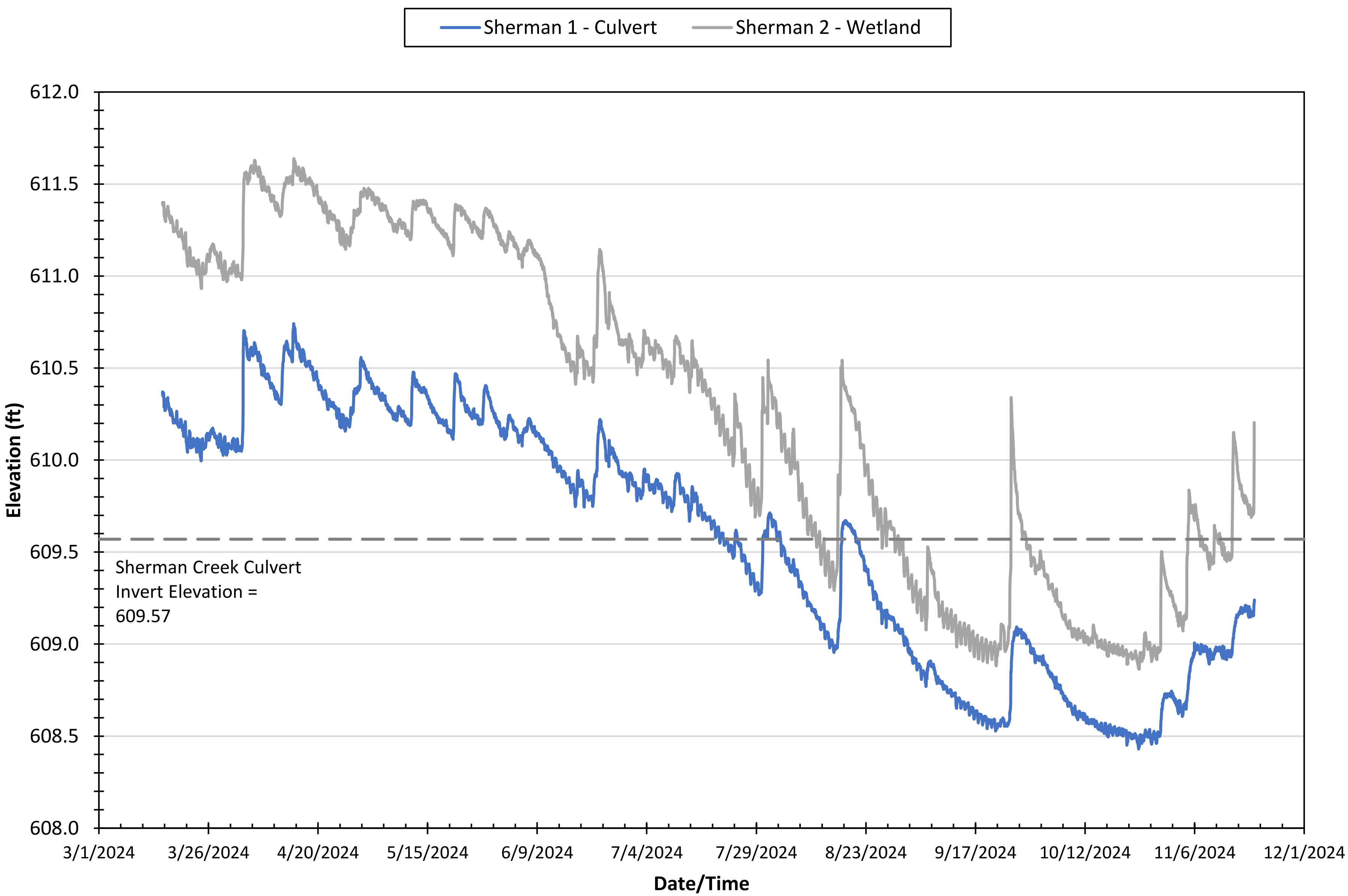
Figure 27. 2024 Sherman Creek Stations: Groundwater / Surface Water Elevations



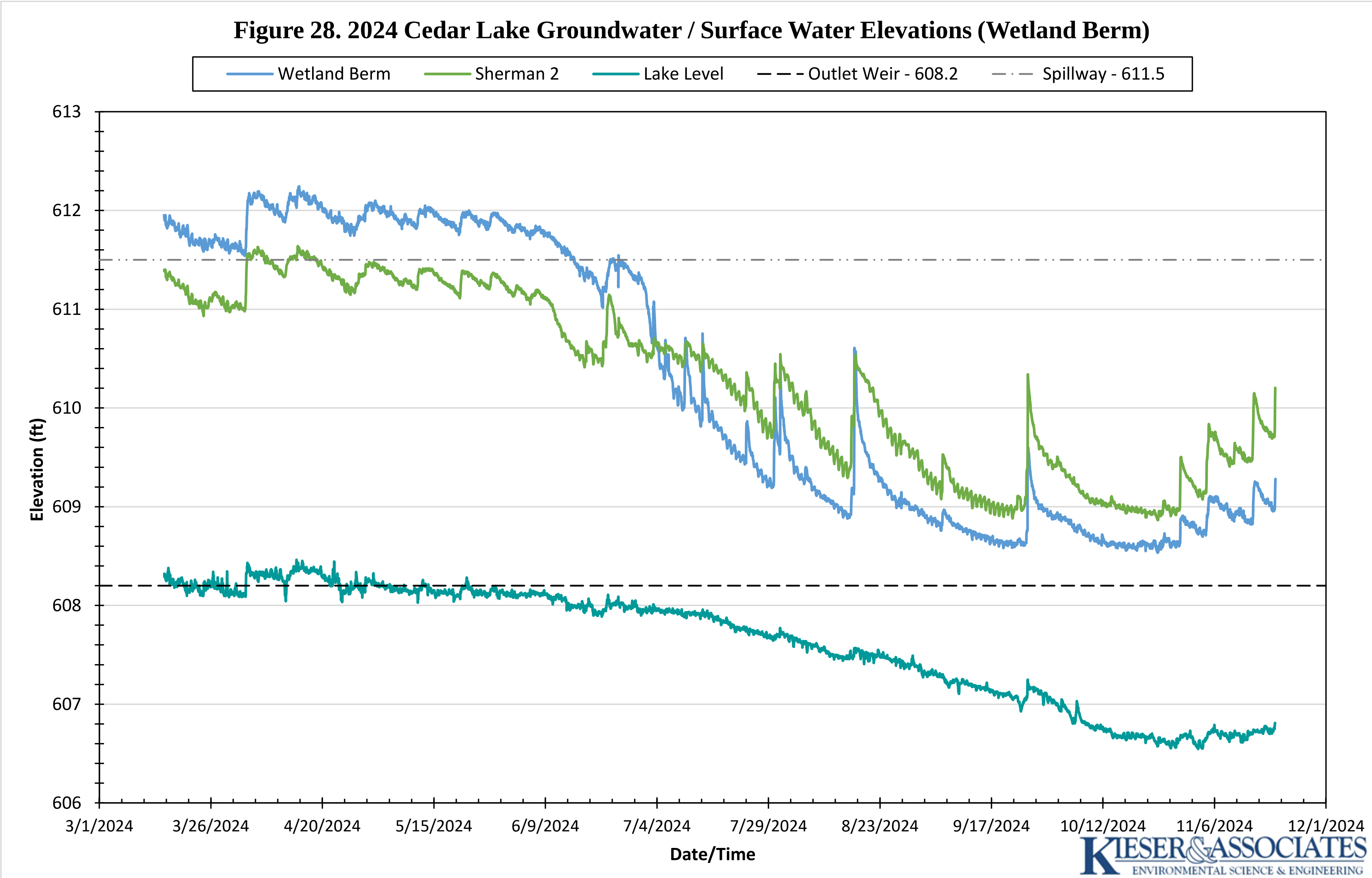


Figure 28. 2024 Cedar Lake Groundwater / Surface Water Elevations (Wetland Berm)
Wetland Berm
Sherman 2
Lake Level
Outlet Weir - 608.2
Spillway - 611.5
Elevation (ft)
613
612
611
610
609
608
607
606
3/1/2024
3/26/2024
4/20/2024
5/15/2024
6/9/2024
7/4/2024
7/29/2024
8/23/2024
9/17/2024
10/12/2024
11/6/2024
12/1/2024
Date/Time
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Figure 29. 2024 Cedar Lake Groundwater / Surface Water Elevations
(Wetland Berm, King's Corner, and Sherman 2)

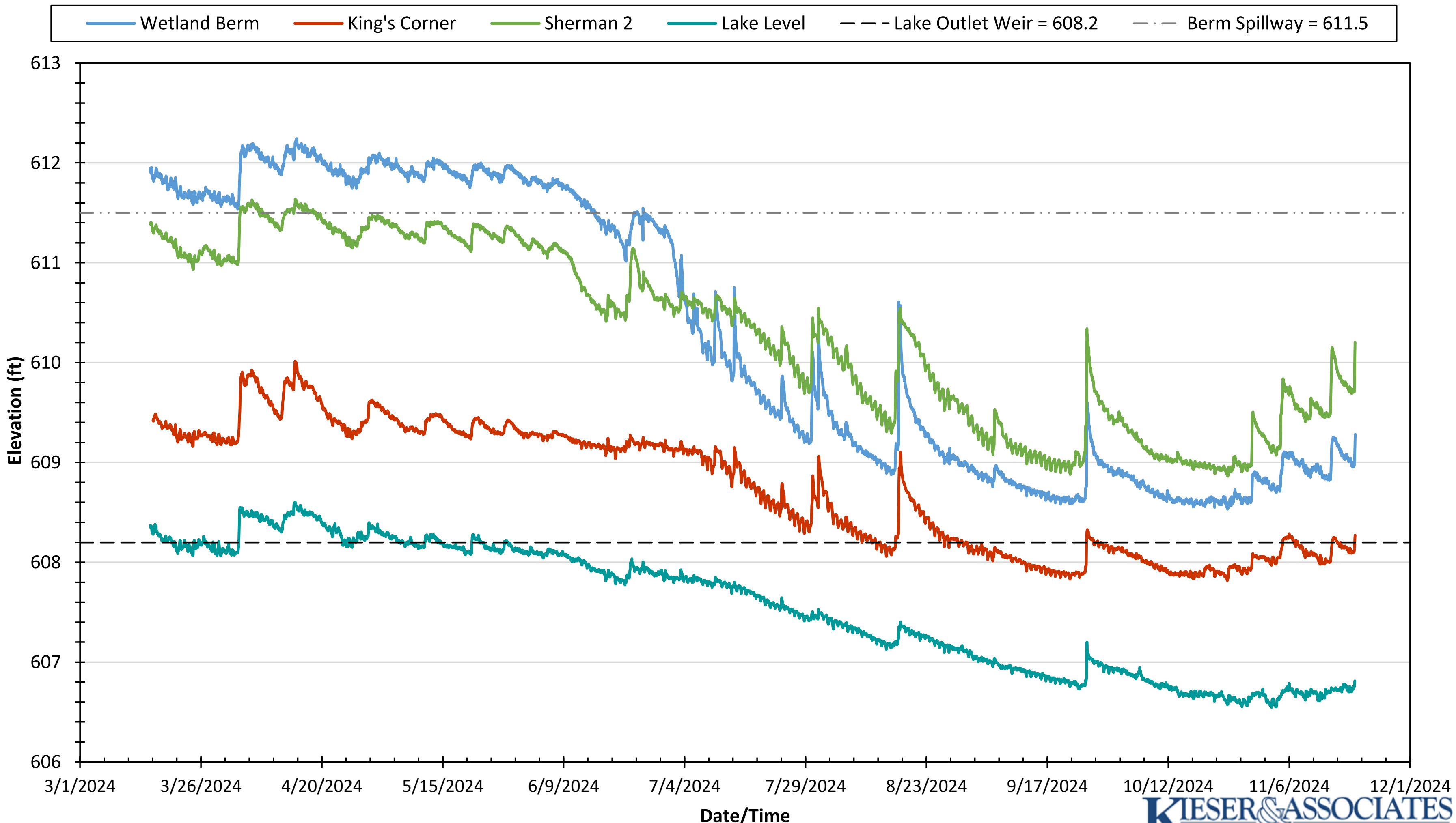

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Figure 29. 2024 Cedar Lake Groundwater / Surface Water Elevations (Wetland Berm, King's Corner, and Sherman 2)

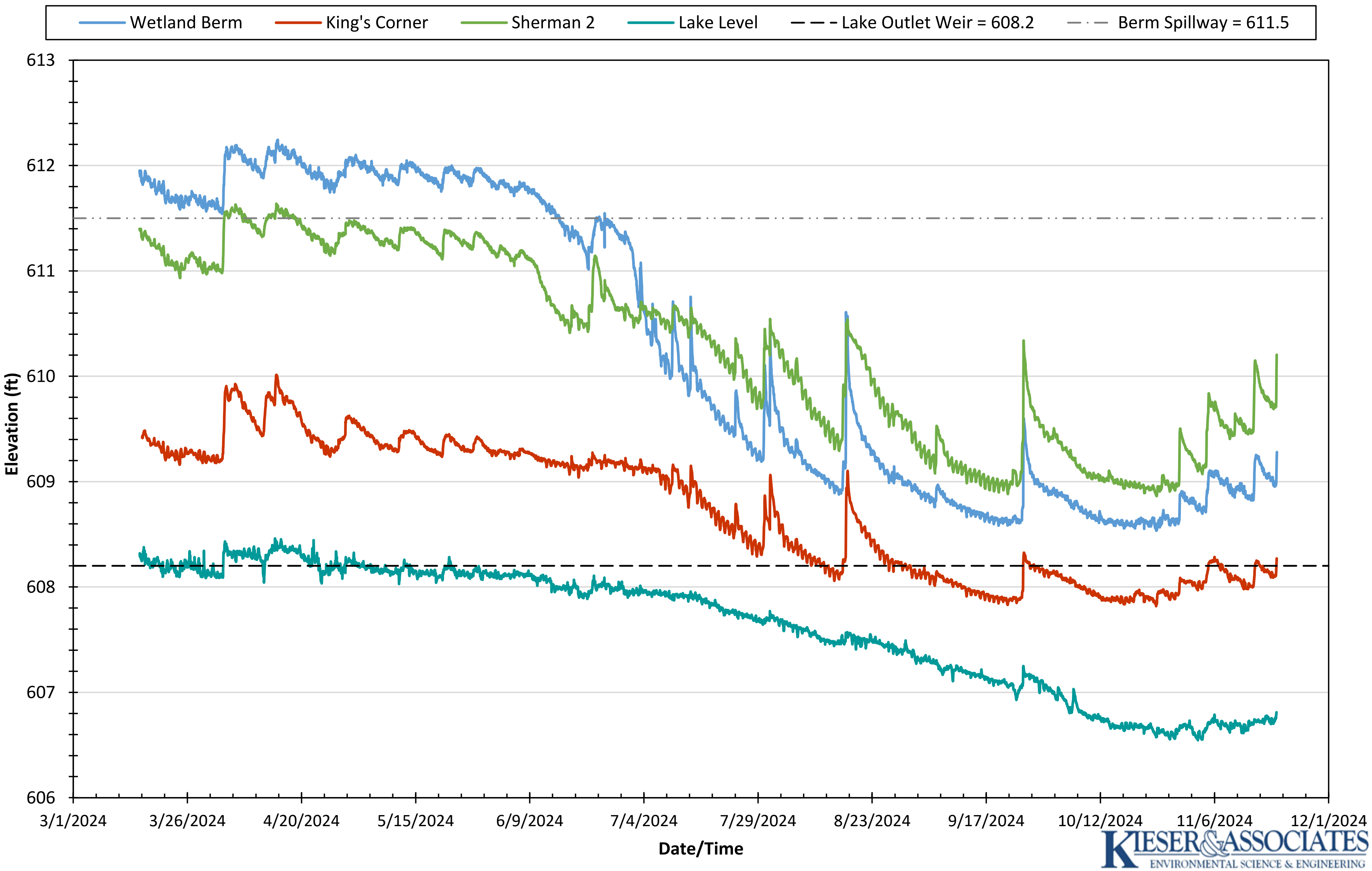
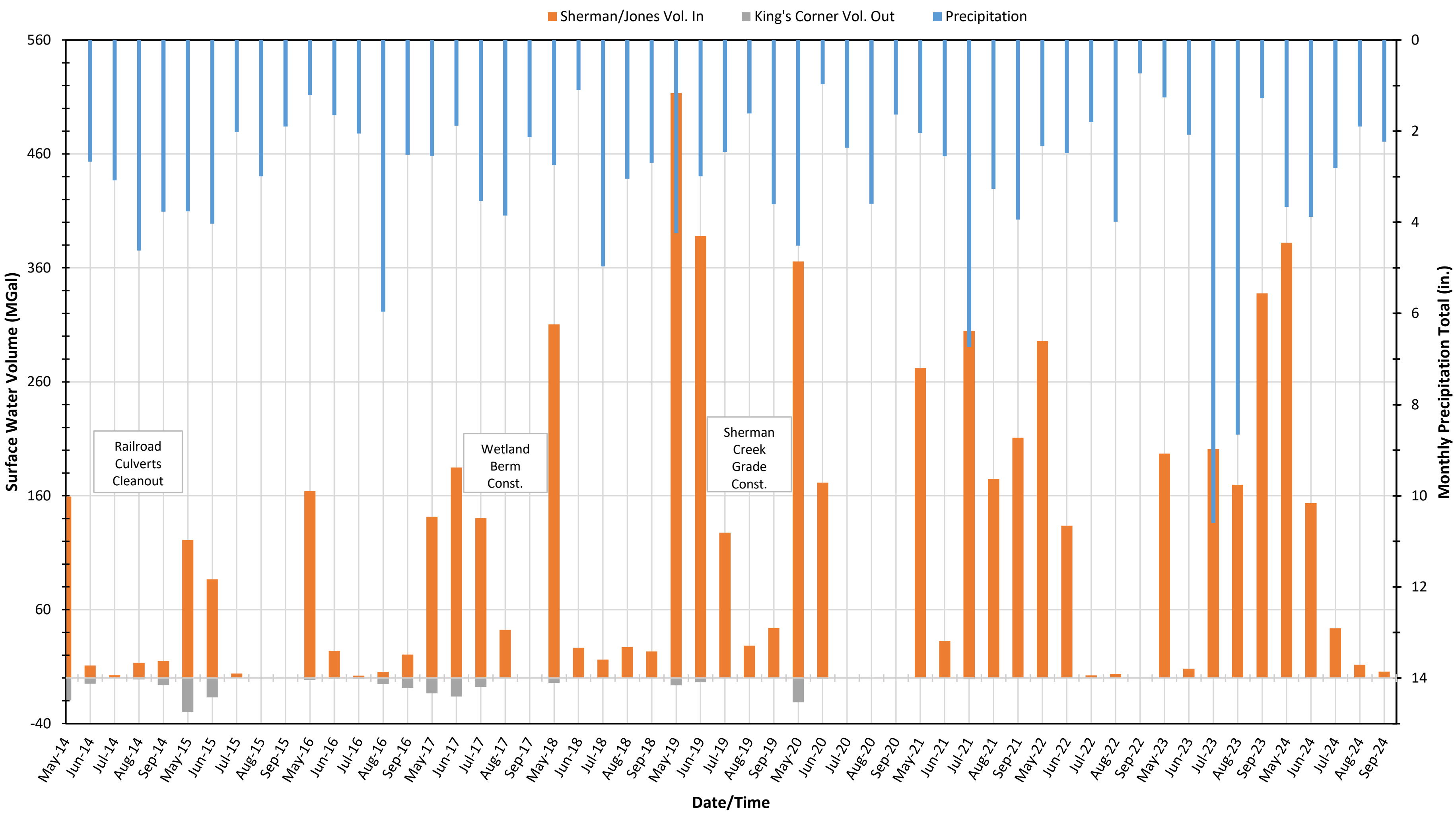


Figure 30. May- Sept, 2014-2024: Precipitation, Sherman/Jones Creek Combined Surface Water Volume into Cedar Lake, and King's Corner Water Volume Away from Cedar Lake



2014 May-Sep:	2015 May-Sep:	2016 May-Sep:	2017 May-Sep:	2018 May-Sep:	2019 May-Sep:	2020 May-Sep:	2021 May-Sep:	2022 May-Sep:	2023 May-Sep:	2024 May-Sep:
Precip: 14.14 in	***Precip:*** 14.70 in	***Precip:*** 13.39 in	***Precip:*** 13.93 in	***Precip:*** 14.55 in	***Precip:*** 14.90 in	***Precip:*** 13.08 in	***Precip:*** 18.54 in	***Precip:*** 11.33 in	***Precip:*** 23.88 in	***Precip:*** 14.48 in
Inflow Vol.: 200.9 MGal	***Inflow Vol.:*** 212.5 MGal	***Inflow Vol.:*** 216.1 MGal	***Inflow Vol.:*** 509.2 MGal	***Inflow Vol.:*** 338.3 MGal	***Inflow Vol.:*** 534.3 MGal	***Inflow Vol.:*** 383.5 MGal	***Inflow Vol.:*** 995.1 MGal	***Inflow Vol.:*** 435.2 MGal	***Inflow Vol.:*** 1,477.1 MGal	***Inflow Vol.:*** 1,121.2 MGal
King's Vol. Out: 32.2 MGal	***King's Vol. Out:*** 46.9 MGal	***King's Vol. Out:*** 17.1 MGal	***King's Vol. Out:*** 38.1 MGal	***King's Vol. Out:*** 4.3 MGal	***King's Vol. Out:*** 10.2 MGal	***King's Vol. Out:*** 21.8 MGal	***King's Vol. Out:*** 0.158 MGal	***King's Vol. Out:*** 0.156 MGal	***King's Vol. Out:*** 10.373 MGal	***King's Vol. Out:*** 0.050 MGal