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Memorandum

To: Ross Bintner and Jessica Vanderwerff Wilson, City of Edina
From: Janna Kieffer (PE), and Louise Heffernan, Barr Engineering Co.
Subject: Lake Level Management Plan for Arrowhead and Indianhead Lakes
Date: April 18, 2023

1.0 Purpose and Background

The purpose of this memorandum is to support the development of lake level management plans for Arrowhead and Indianhead Lakes. These two lakes, located in the southwest portion of the City of Edina, Minnesota, are landlocked and have experienced higher-than-normal lake levels and groundwater levels during recent wet periods due to the wet climatic cycle. High lake levels and higher-than-normal regional groundwater levels pose an increased risk of flooding. In response to recent wet periods, temporary pumping from both lakes was conducted during portions of 2019 to alleviate high water levels and protect low primary structures. The City of Edina manages to the lowest primary structure for protection purposes at both Arrowhead and Indianhead Lakes. At Arrowhead Lake, the low primary structure is located at 6604 Indian Hills Road, with a low opening elevation at 877.7 feet. At Indianhead Lake, the low primary structure is located at 6901 Dakota Trail, where the home is supported by a structural retaining wall at elevation 864.9 M.S.L.

There are two main scenarios that trigger the need for pumping to protect structures at these lakes, which are evaluated and incorporated into the lake level management recommendations:

1. High groundwater levels combined with precipitation which can cause lake levels to rise over a longer duration of time, and;
2. Extreme precipitation events which result in a rapid rise in the lake levels.

In spring of 2020, the City of Edina (City) and the Nine Mile Creek Watershed District (NMCWD) contracted with Barr Engineering Co. (Barr) to perform a study to understand the factors contributing to high water levels at these two lakes, so that the City could consider development of a lake level management plan. Results of the study (Phase 1) were summarized in a June 2021 report. This memo summarizes the second phase of lake level management plan development (Phase 2) for Arrowhead and Indianhead Lakes, which included evaluation of groundwater elevation influence on high water levels, target lake level analysis, and evaluation of pumping operation scenarios. The Phase 2 analysis also included evaluation of water level augmentation at Indianhead Lake. The memo also includes a high-level review of potential Minnesota Department of Natural Resources (MDNR) permitting requirements, based on preliminary discussions with MDNR staff.

2.0 Groundwater Elevation Influence on High Water Levels

The influence of groundwater elevation on high water levels was evaluated to better understand the lakes' response to fluctuating groundwater elevations. Lake levels in Arrowhead and Indianhead Lakes were modeled over time under several constant groundwater elevation scenarios to understand how the fluctuation in water levels differs based on groundwater. The calibrated spreadsheet water balance models developed as part of the Phase 1 analysis were used to predict lake levels. The models include analysis from 2000 through 2020 at Arrowhead Lake, and from 2004 through 2020 at Indianhead Lake.

For the Arrowhead Lake analysis, fluctuation in lake levels was evaluated under four constant groundwater scenarios including elevation 872, 873, 874 and 875 feet. For the Indianhead Lake analysis, lake levels were evaluated under three constant groundwater scenarios including elevation 861, 862 and 863 feet. Table 2-1 and Table 2-2 summarize the results of this analysis for Arrowhead and Indianhead Lakes, respectively, including the frequency of exceeding the OHWL and low primary structure under the range of groundwater elevations. Results indicate that lake water surface levels at both Arrowhead and Indianhead Lakes are sensitive to varying groundwater levels, and higher groundwater levels can significantly increase flood potential during non-extreme rainfall conditions, as high groundwater levels limit the potential for seepage to occur through the bottom of the lake.

Example graphs for the "low" and "high" groundwater elevation scenarios are included as an attachment.

Table 2-1 Summary of exceedances of elevation thresholds in Arrowhead Lake under a range of constant groundwater elevations

	Groundwater Elevation[1]			
	872 feet	**873 feet**	**874 feet**	**875 feet**
Total number of years in analysis	21	21	21	21
Number of years with at least one exceedance of low structure	1	2	8	17
Total percentage of time water level exceeded low structure	0.04%	0.2%	2%	13%
Number of years with at least one exceedance of OHWL	10	19	21	21
Total percentage of time water level exceeded OHWL	3%	14%	43%	92%

[1] Modeling analysis assumed constant groundwater elevation

Table 2-2 Summary of exceedances of elevation thresholds in Indianhead Lake under a range of constant groundwater elevations

	Groundwater Elevation[1]		
	861 feet	**862 feet**	**863 feet**
Total number of years in analysis	16	16	16
Number of years with at least one exceedance of low structure	1	3	14
Total percentage of time water level exceeded low structure	0.1%	0.6%	14%
Number of years with at least one exceedance of OHWL	8	15	16
Total percentage of time water level exceeded OHWL	3%	24%	84%

[1] Modeling analysis assumed constant groundwater elevation

3.0 Target Lake Level Analysis

Flood risk in landlocked lakes from extreme precipitation events is often dependent on the initial water level at the onset of the event. This study included analysis to determine initial or "target" lake level elevations needed at Arrowhead and Indianhead Lakes to protect low primary structures from extreme precipitation events. The following extreme precipitation events were considered:

- 1% annual chance rainfall (100-year, 24-hour storm event = 7.5 inches)
- 1% annual chance snowmelt runoff (100-year, 10-day snowmelt event = 7.2 inches)
- 0.5% annual chance rainfall (500-year, 24-hour storm event = 10.5 inches)

Runoff volumes for the 100-year, 24-hour and 100-year, 10-day snowmelt events were determined based on the City's XP-SWMM model, and runoff volumes for the 500-year, 24-hour event were determined based on the NMCWD's XP-SWMM model. Tables 3-1 and 3-2 summarize the results of this analysis for Arrowhead and Indianhead Lakes, respectively. Figures 3-1 and 3-2 identify the ending lake levels (y-axis) for the precipitation and/or runoff events noted above, based on runoff volumes generated by the respective event, given an initial lake level (x-axis).

At Arrowhead Lake, the starting lake level needed to protect the low primary structure from flooding during the 100-year snowmelt event is 873.3 feet (2.5 feet below the OHWL). The starting lake level needed to protect the low primary structure from flooding during the 100-year, 24-hour rainfall event is 874.3 feet (1.5 feet below the OHWL). Figure 3-1 shows that the second lowest structure, located at elevation 880.8 feet (3.1 feet above the low primary structure), is not reasonably likely to be significantly impacted by flood exposure.

At Indianhead Lake, the starting lake level needed to protect the low primary structure from flooding during the 100-year snowmelt event is 859.9 feet (3.8 feet below OHWL). The starting lake level needed to

protect the low primary structure from flooding during the 100-year, 24-hour rainfall is 861.8 feet (1.9 feet below the OHWL). Figure 3-2 shows that the second lowest structure, located at elevation 870.1 feet (5.2 feet above the low primary structure), is not reasonably likely to be significantly impacted by flood exposure.

Table 3-1 Initial lake levels needed to protect the low primary structure at Arrowhead Lake for select precipitation events

Precipitation Event	Initial Lake Elevation to Accommodate Event Below Low Primary Structure (feet)	Initial Lake Elevation Relative to OHWL (feet below OHWL)	Initial Lake Elevation Relative to Low Primary Structure (feet below Low Structure)
100-year, 24-hour rainfall	874.3	-1.5	-3.4
100-year, 10-day snow melt	873.3	-2.5	-4.4
500-year, 24-hour rainfall	872.6	-3.2	-5.1

Table 3-2 Initial lake levels needed to protect the low primary structure at Indianhead Lake for select precipitation events

Precipitation Event	Initial Lake Elevation to Accommodate Event Below Low Primary Structure (feet)	Initial Lake Elevation Relative to OHWL (feet below OHWL)	Initial Lake Elevation Relative to Low Primary Structure (feet below Low Structure)
100-year, 24-hour rainfall	861.8	-1.9	-3.1
100-year, 10-day snow melt	859.9	-3.8	-5.0
500-year, 24-hour rainfall	859.2	-4.5	-5.7

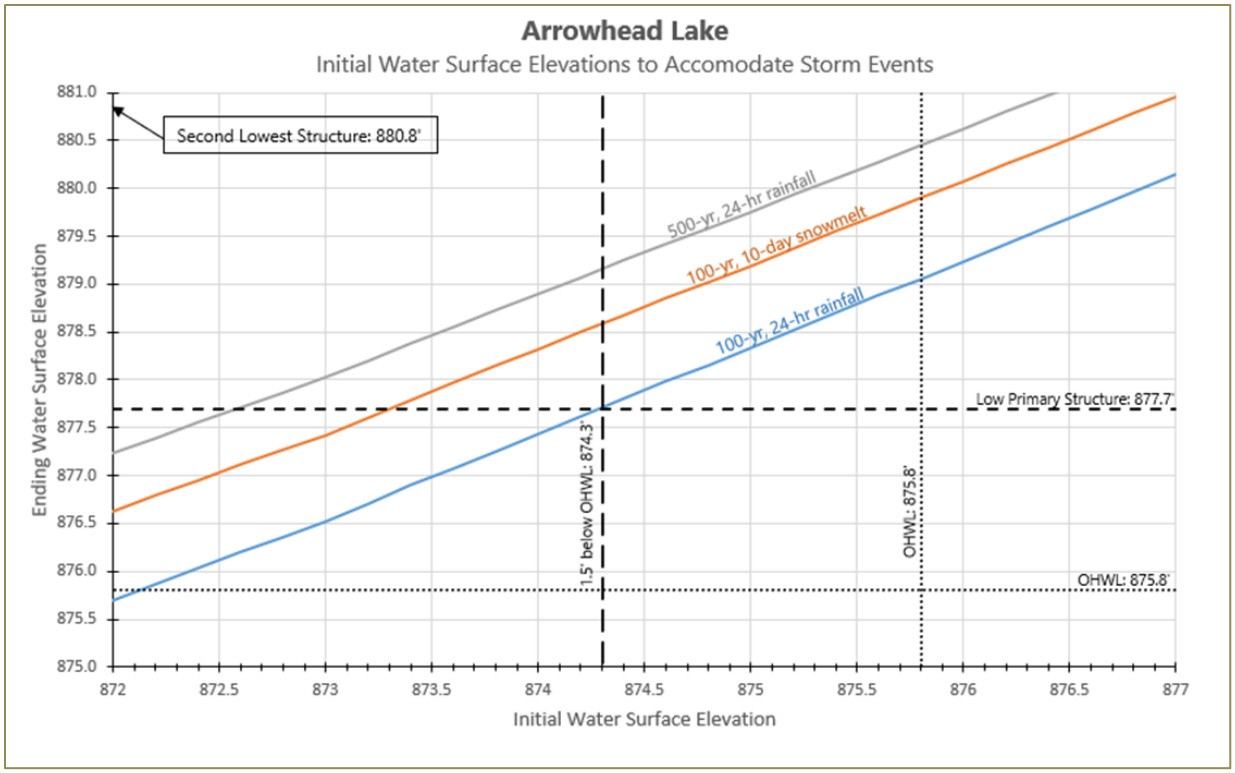


Figure 3-1 Arrowhead Lake Initial Water Surface Elevations Needed to Accommodate Select Precipitation Events

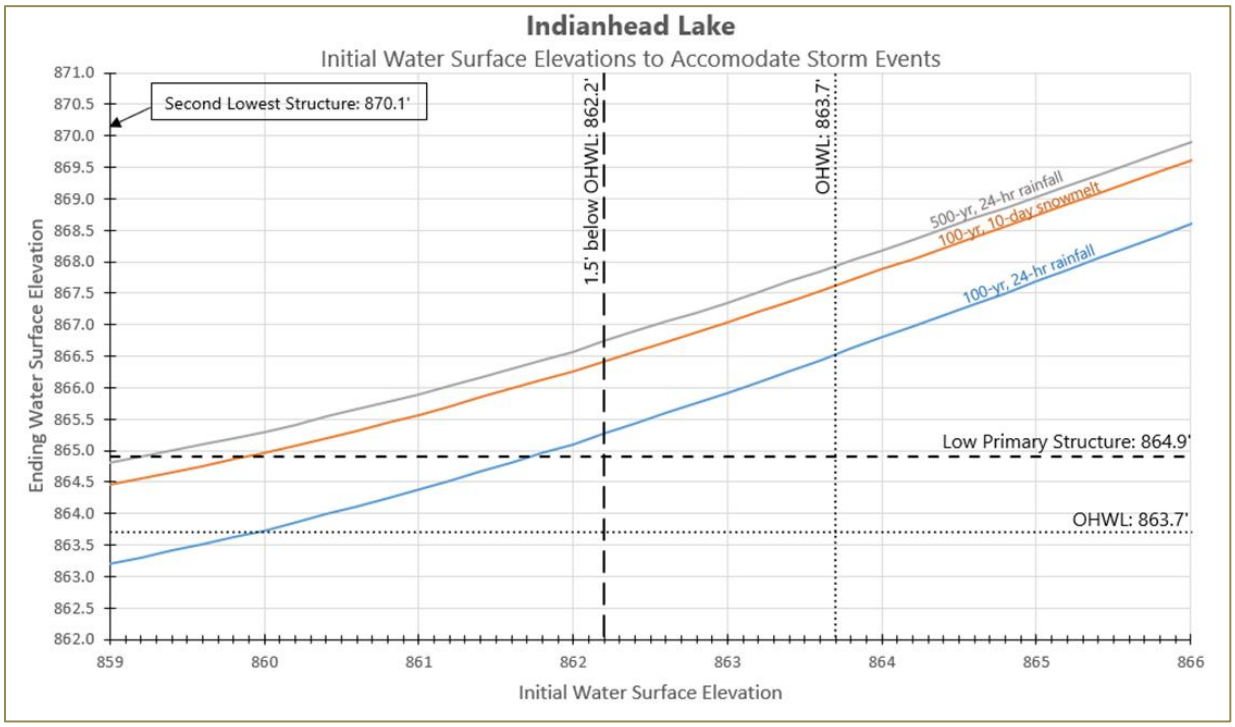


Figure 3-2 Indianhead Lake Initial Water Surface Elevations Needed to Accommodate Select Precipitation Events

4.0 Pumping Program Development

The objective of the pumping program is to reduce flood exposure for residences around the lakes, while also balancing the frequency of pump deployments and impacts to water levels during dry weather conditions. The following section summarizes the evaluation of pumping scenarios to inform development of a pumping program that seeks to balance these factors.

4.1 Evaluation of Pumping Scenarios

Several pumping scenarios were evaluated to assess the potential for lake levels to reach elevations that could impact low primary structures at Arrowhead and Indianhead Lakes, as well as the frequency of pump deployments and impacts to water levels during dry weather conditions. Four pumping programs with varying pump "on" and "off" elevations were modeled for each lake using the calibrated spreadsheet water balance models developed as part of Phase I to predict lake levels.

The following assumptions were incorporated into analyses of the pumping scenarios:

- The water balance models incorporated fluctuating groundwater elevations at Arrowhead and Indianhead Lakes estimated as part of Phase 1. The groundwater elevations were approximated based on data from NMCWD monitoring wells located near Bredesen Park (Well 7) and Braemar Golf Course (Well 35).
- The lake-specific stage-storage relationships were based on bathymetry survey data collected for each lake in May 2017 by the City of Edina.
- Precipitation data from 2000 to 2020 was utilized to evaluate lake levels for varying hydrologic conditions. Daily precipitation totals from 2000 to 2020 were obtained from the weather station at the Minneapolis-St. Paul International Airport.
- A pump rate of approximately 800 gallons per minute (GPM) or 2 cubic feet per second (cfs) was used, based on the temporary pumping conducted in 2019.
- The number of pumping deployments was estimated for each of the pumping scenarios, with the modeled pumping deployment event beginning the day the pumping scenario "on" elevation is exceeded and ending after 14 days with no pumping (i.e. the pump is assumed to be removed following 14 days with no pumping).

Tables 4-1 and 4-2 summarize the results for the no pumping scenario and four pumping scenarios with various "on" and "off" elevations for Arrowhead and Indianhead Lakes, respectively. Figures 4-1, 4-2, 4-4 and 4-5 show a comparison of the days of pumping required per year and the number of pump deployments per year for each scenario during the modeled time period.

At Arrowhead Lake, the modeling identifies two low primary structure exceedances during the modeled time period if no pumping is done. Results from the four pumping scenarios indicate that flood exposure is reduced in comparison with the no pumping scenario. The modeling identifies zero low primary structure exceedances during the period of the analysis for all four pumping scenarios. Pumping scenarios

3 and 4 produce the lowest number of deployments required to maintain target lake levels (17 deployments for scenario 3 and 16 deployments for scenario 4). Scenario 3 requires maintaining the lake level at the OHWL, which requires frequent short duration pumping events. Scenario 4 achieves sustained pumping durations to maintain target lake levels in comparison to the other scenarios.

At Indianhead Lake, the modeling identifies three low primary structure exceedances during the modeled time period if no pumping is done. Results from the four pumping scenarios indicate that flood exposure is reduced in comparison with the no pumping scenario. The modeling identifies zero low primary structure exceedances during the period of the analysis for all four pumping scenarios. Pumping scenarios 3 and 4 result in the lowest number of deployments required to maintain target lake levels (32 deployments for scenario 3 and 21 deployments for scenario 4). Scenario 3 requires maintaining the lake level at the OHWL, which requires frequent short duration pumping events. Scenario 4 achieves sustained pumping durations to maintain target lake levels in comparison to the other scenarios.

City staff has indicated that pumping scenario 4 is the preferred alternative for both lakes as the modeled operations require the fewest number of deployments per year balanced with the greatest level of protection. Additionally, pumping scenario 4 does not require maintaining a target lake level at the same "on" and "off" elevation. Figures 4-3 and 4-6 show the inundation extents for the pump "off" elevation of pumping scenario 4 (i.e., lake level 1.5 feet below the OHWL) in comparison with the inundation extents at the OHWL for Arrowhead and Indianhead Lakes, respectively.

Table 4-1 Comparison of results for four pumping program scenarios at Arrowhead Lake

Pumping Scenario	No Pumping	1	2	3	4
Pumping Program On/Off Elevations	N/A	On Elevation: 874.3 ft Off Elevation: 874.3 ft	On Elevation: 875.3 ft Off Elevation: 875.3 ft	On Elevation: 875.8 ft Off Elevation: 875.8 ft	On Elevation: 875.8 ft Off Elevation: 874.3 ft
Pumping Program On/Off Elevations Relative to OHWL[1]	N/A	On/Off 1.5 ft below OHWL	On/Off 0.5 ft below OHWL	On/Off at OHWL	On at OHWL; Off 1.5 ft below OHWL
Total Number of Years Pumping Program Applied to Calibrated Water Balance Model (years)	21	21	21	21	21
Number of Years OHWL is Exceeded (years)	9	2	8	9	9
% Time OHWL is Exceeded	7.8%	0.03%	0.3%	1.4%	0.6%
Number of Years Low Primary Structure is Exceeded[2] (years)	2	0	0	0	0
% Time Low Primary Structure is Exceeded	0.9%	0%	0%	0%	0%
Number of Years with Pumping (years)	0	19	14	9	9
Pumping Required Over Analysis (days)	0	452	185	107	205
% Time Pumping Occurred	0	5.9%	2.4%	1.4%	2.7%
Total Number of Pump Deployments	0	65	29	17	16

[1] Arrowhead Lake Ordinary High Water Level is 875.8 ft M.S.L.
[2] Arrowhead Lake Low Primary Structure elevation is 877.7 ft M.S.L.

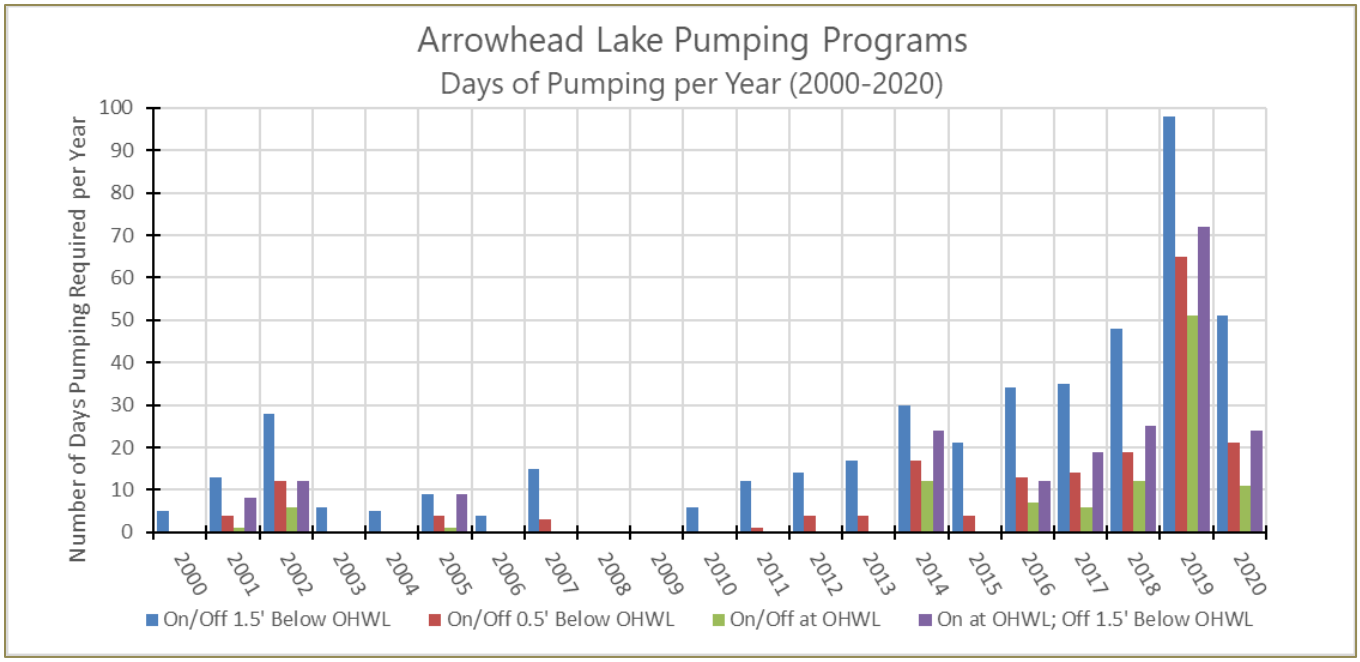


Figure 4-1 Days of Pumping per Year for Arrowhead Lake Pumping Programs from 2000-2020

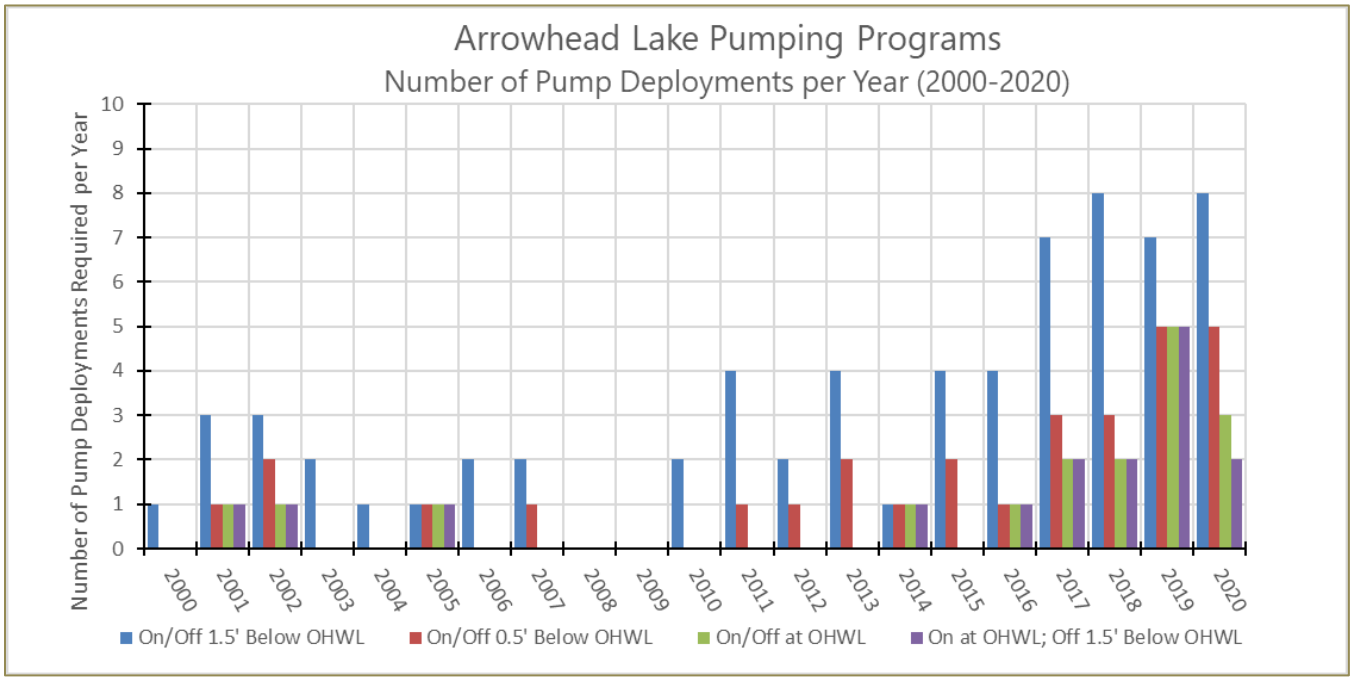


Figure 4-2 Pump Deployments per Year for Arrowhead Lake Pumping Programs from 2000-2020

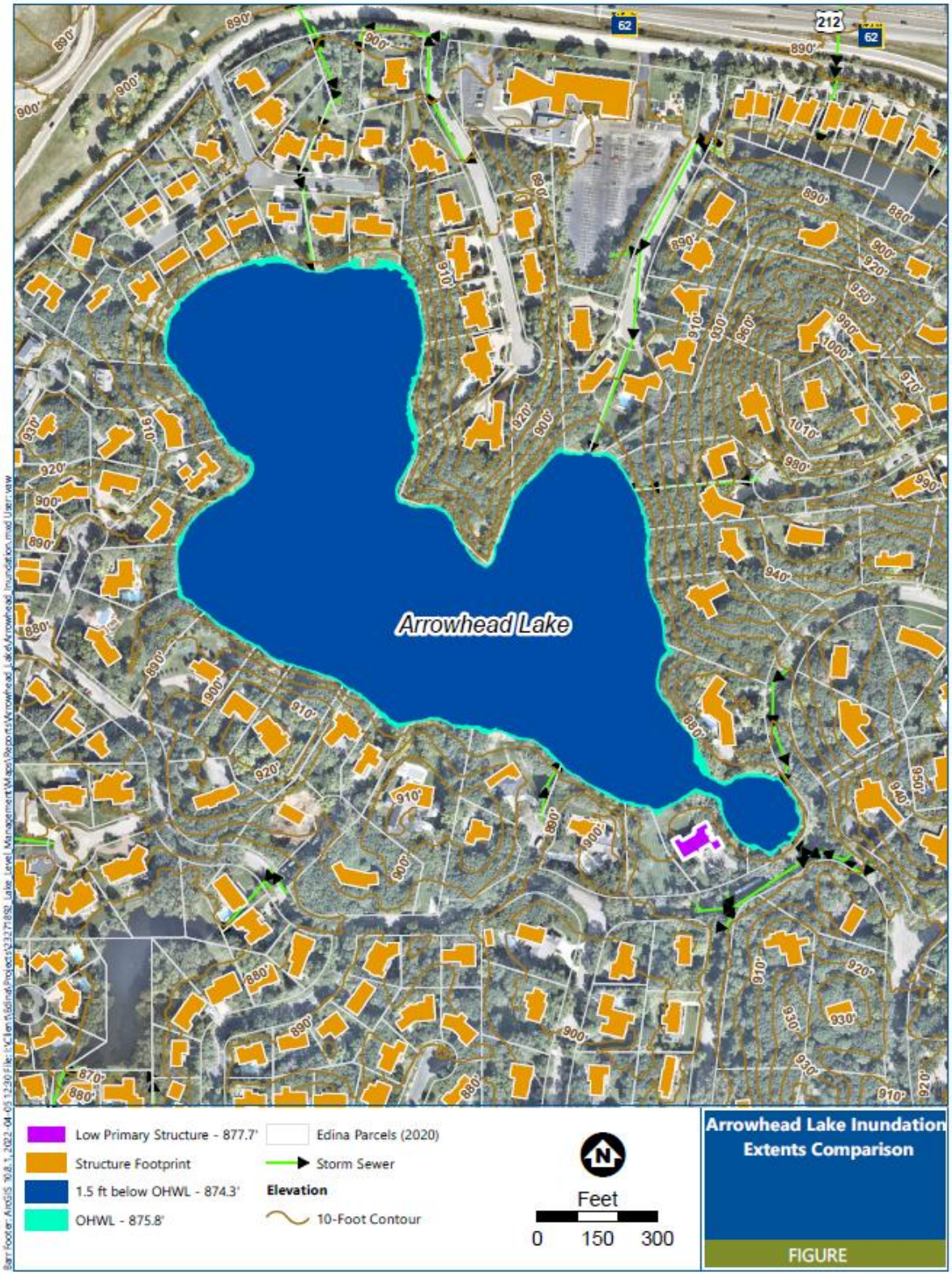


Figure 4-3 Arrowhead Lake Inundation Extents Comparison

Table 4-2 Comparison of results for four pumping program scenarios at Indianhead Lake

Pumping Scenario	No Pumping	1	2	3	4
Pumping Program On/Off Elevations	N/A	On Elevation: 862.2 ft Off Elevation: 862.2 ft	On Elevation: 863.2 ft Off Elevation: 863.2 ft	On Elevation: 863.7 ft Off Elevation: 863.7 ft	On Elevation: 863.7 ft Off Elevation: 862.2 ft
Pumping Program On/Off Elevations Relative to OHWL[1]	N/A	On/Off 1.5 ft below OHWL	On/Off 0.5 ft below OHWL	On/Off at OHWL	On at OHWL; Off 1.5 ft below OHWL
Total Number of Years Pumping Program Applied to Calibrated Water Balance Model (years)	17	17	17	17	17
Number of Years OHWL is Exceeded (years)	12	0	5	12	11
% Time OHWL is Exceeded	15.4%	0%	0.2%	1.6%	0.8%
Number of Years Low Primary Structure is Exceeded[2] (years)	3	0	0	0	0
% Time Low Primary Structure is Exceeded	1.5%	0%	0%	0%	0%
Number of Years with Pumping (years)	0	17	14	12	11
Pumping Required Over Analysis (days)	0	397	175	97	175
% Time Pumping Occurred	0	6.4%	2.8%	1.6%	2.8%
Total Number of Pump Deployments	0	97	47	32	21

[1] Indianhead Lake OHWL is 863.7 ft M.S.L.
[2] Indianhead Lake Low Primary Structure elevation is 864.9 ft M.S.L.

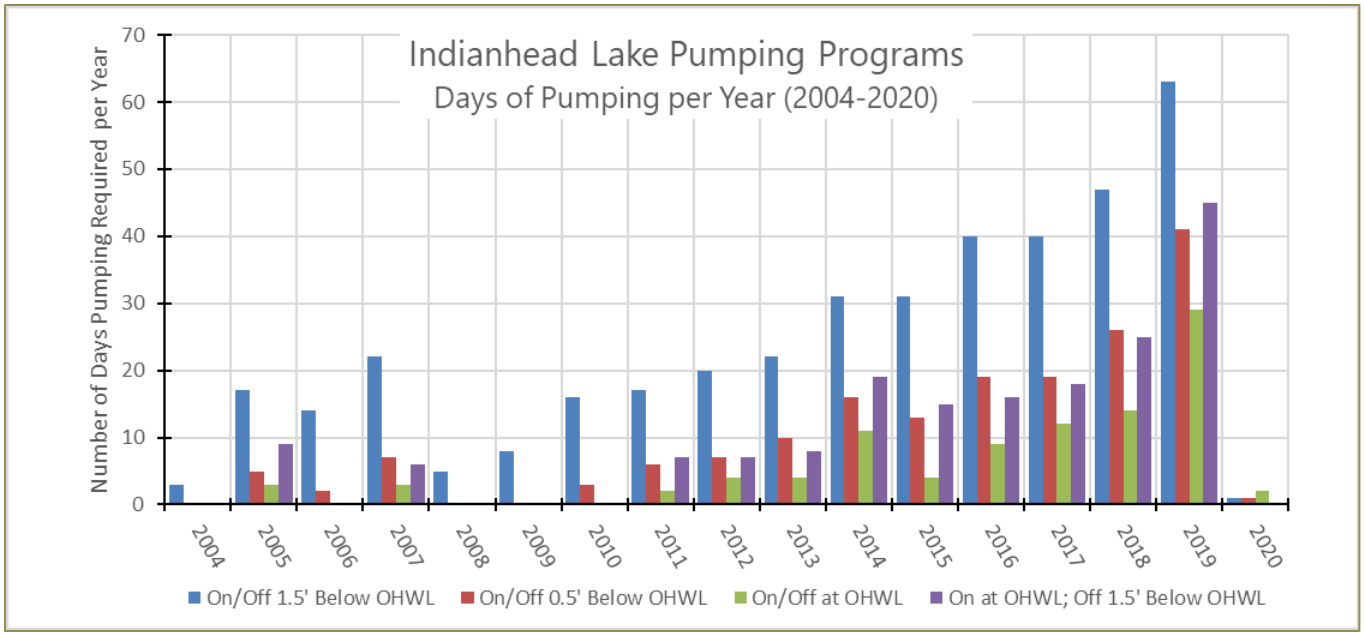


Figure 4-4 Days of Pumping per Year for Indianhead Lake Pumping Scenarios from 2004-2020

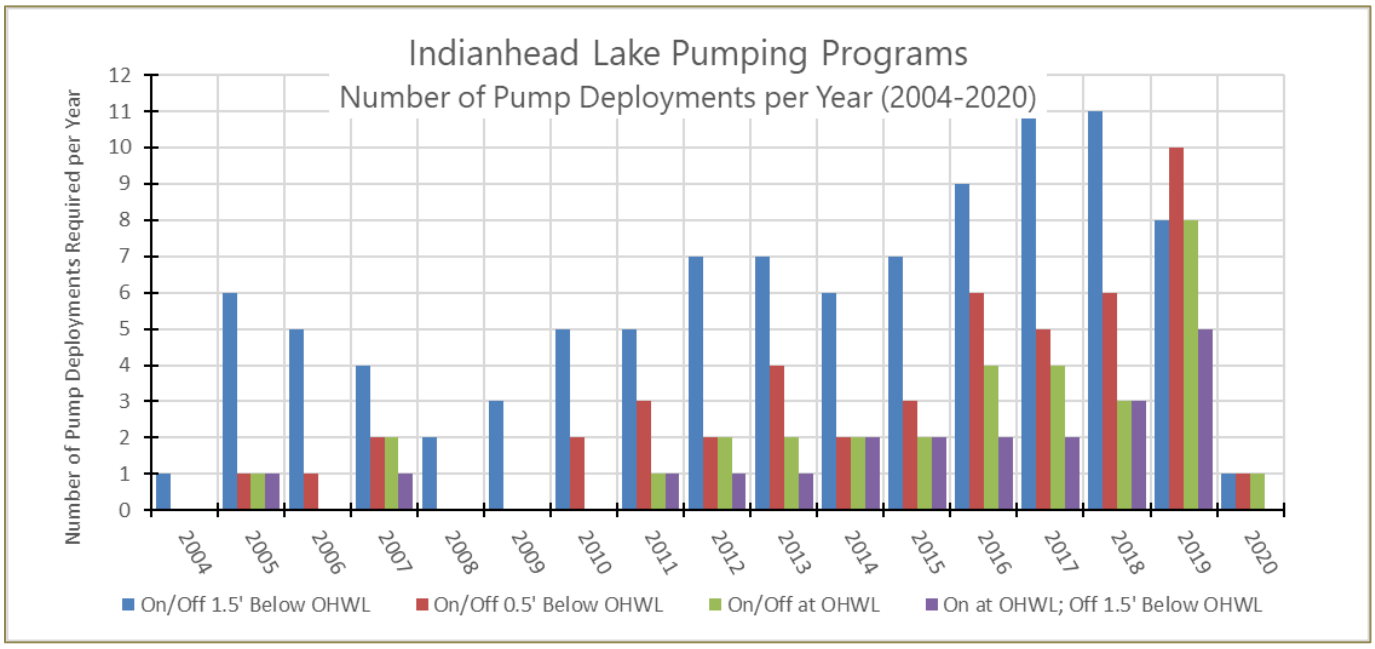


Figure 4-5 Pump Deployments per Year for Indianhead Lake Pumping Scenarios from 2004-2020

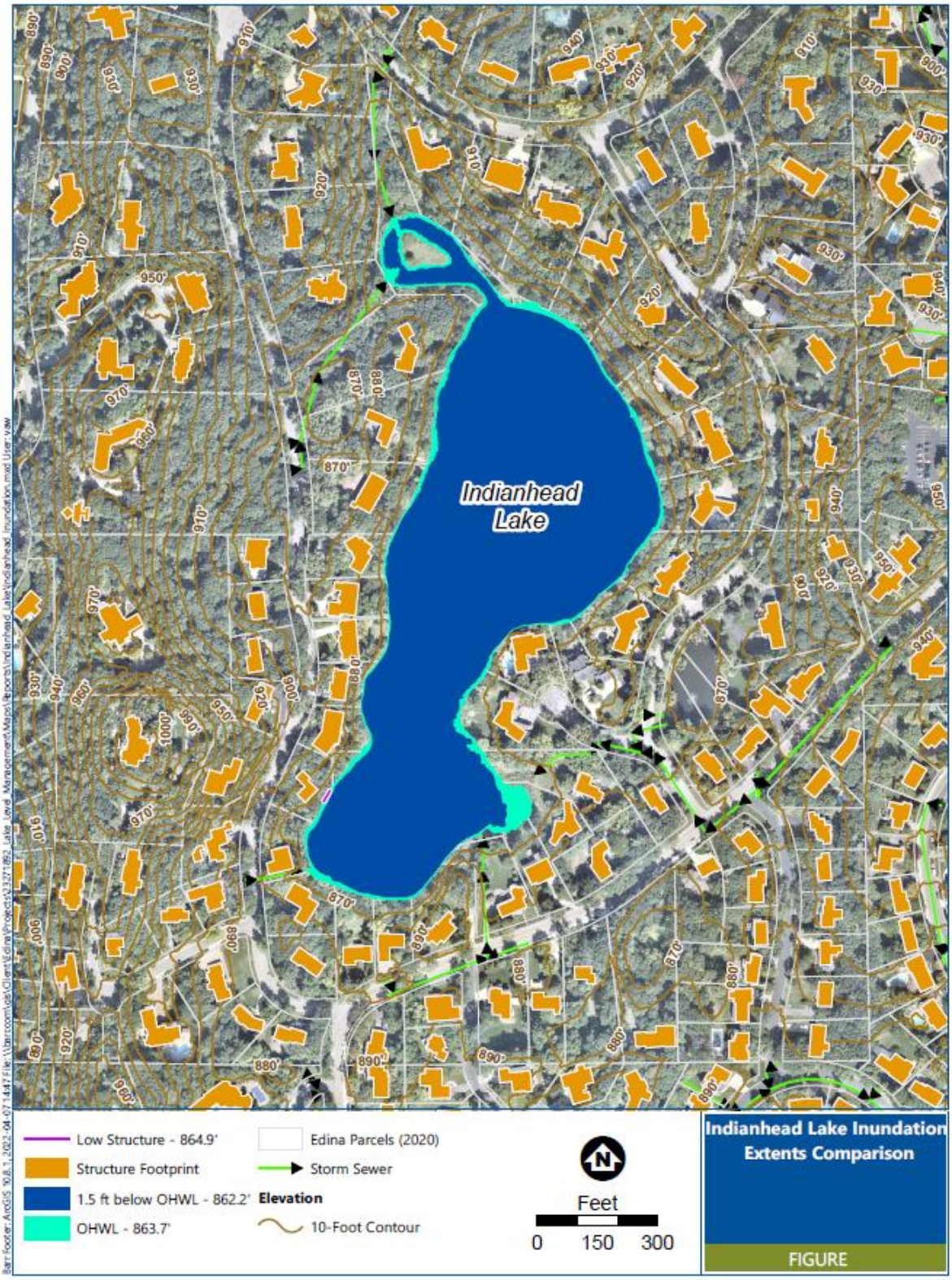


Figure 4-6 Indianhead Lake Inundation Extents Comparison

4.2 Snowmelt Considerations

In landlocked lakes, runoff from snowmelt can cause significant increases in springtime water levels. The lake level target analysis identified that the 100-year, 10-day snowmelt results in lake levels that exceed the low primary structure for a significant range of initial water surface elevations for both Indianhead and Arrowhead Lakes. Given this, the potential impacts of more frequent snowmelt events were also evaluated. Figures 4-7 and 4-8 show the predicted water surface elevations in Arrowhead and Indianhead Lakes, respectively, for a range of initial water surface elevations and snowmelt/runoff events. The figures include snowmelt/runoff events ranging from 2 inches to 7.2 inches (the 100-year, 10-day snowmelt event). Note that to estimate the ending surface water elevations, the volume of runoff is calculated by assuming that the given snowmelt/runoff occurs consistently over the entire watershed area, and that underlying soils are frozen and do not allow infiltration.

The graphs in Figures 4-7 and 4-8 summarize the potential for lake levels to rise above the low primary structure due to snowmelt runoff for both Arrowhead and Indianhead Lakes, depending on the initial water surface elevations and amount of snowmelt (or runoff on frozen ground). Consideration of snowpack and frozen ground conditions in conjunction with these graphs is recommended in late-February or early-March to assess the need for springtime pumping outside of the "regular" pumping program.

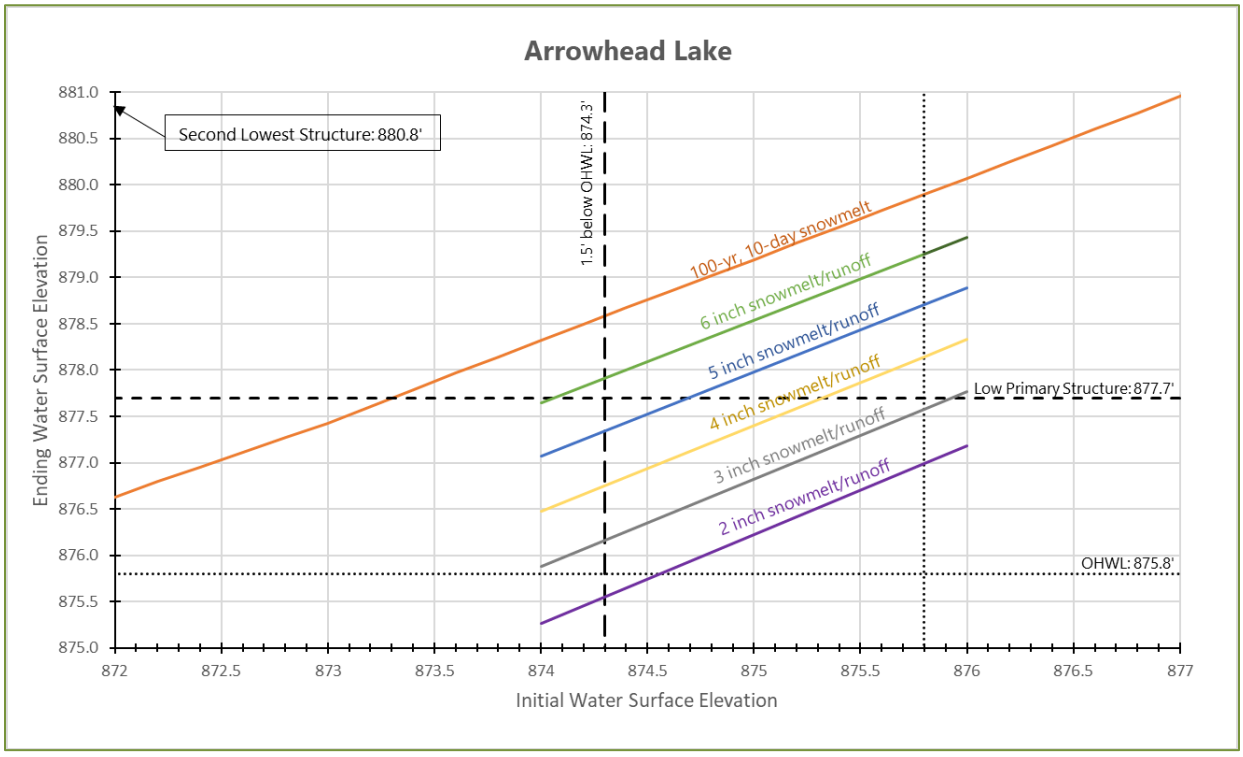


Figure 4-7 Arrowhead Lake predicted water surface elevations for a range of snowmelt/runoff events

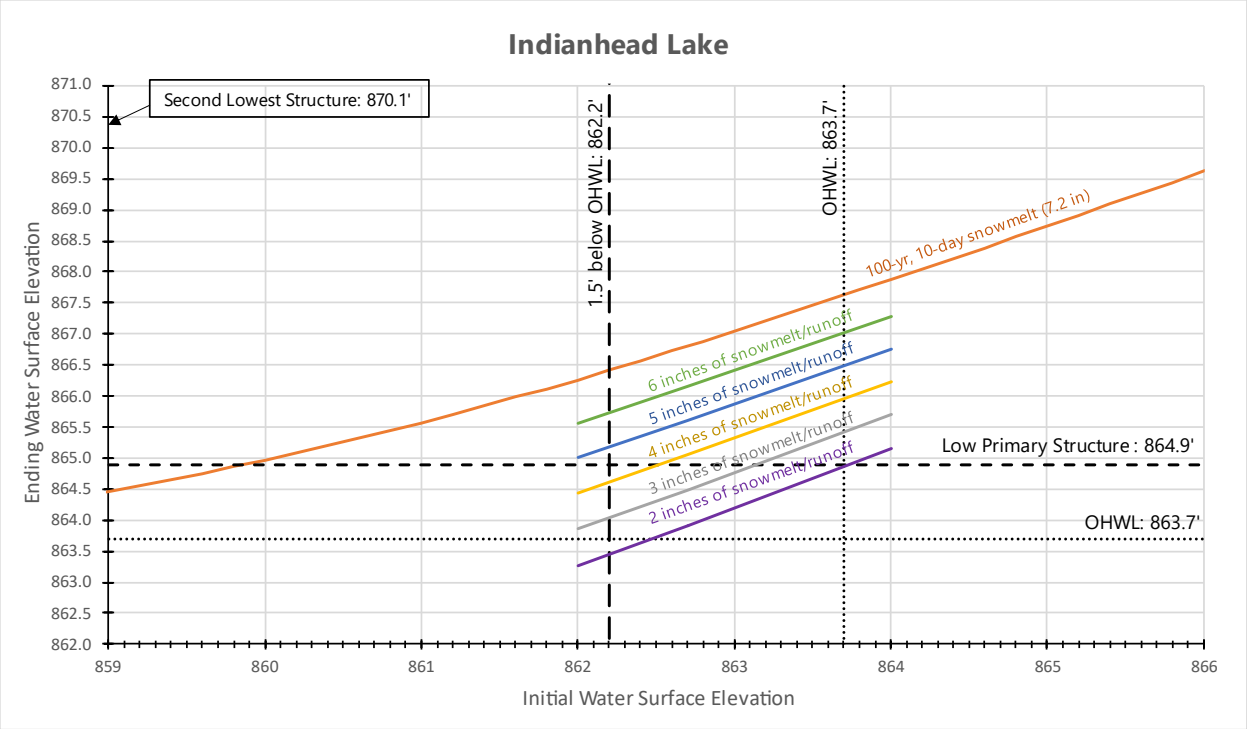


Figure 4-8 Indianhead Lake predicted water surface elevations for a range of snowmelt/runoff events

5.0 Indianhead Lake Level Augmentation

As part of the development of a lake level management plan for Indianhead Lake, lake level augmentation was evaluated relative to flood management objectives. As a landlocked basin with no natural surface outlet, Indianhead Lake is dependent on evaporation, seepage and pumping as a water removal mechanism. Annual fluctuations in the lake level at Indianhead Lake are generally two feet over the course of the last 20 years. The results of the Phase I analysis indicated that groundwater elevations are the main factor accounting for the annual "lows" in the models, as lower groundwater levels promote increased seepage through the bottom of the lake.

MDNR water use reports indicate that local residents have historically augmented lake levels in Indianhead Lake through groundwater appropriation to achieve a more desirable lake level when lake levels are lower. Table 5-1 provides a summary of the annual water use from 2004 through 2020. For comparison, Figure 5-1 illustrates monthly observed lake levels in Indianhead Lake, collected as part of the NMCWD monitoring program. Based on MDNR monthly water use reports from 2004 through 2020 and observed water levels, water appropriations have generally been initiated when lake levels reach elevations ranging from 861.5-862.5 feet.

Table 5-1 Indianhead Lake water appropriation from 2004-2020

Year	Annual Water Appropriation (Million Gallons Per Year)	Year	Annual Water Appropriation (Million Gallons Per Year)
2020	0	2011	0
2019	0	2010	3.4
2018	0	2009	6.7
2017	0	2008	3.2
2016	0	2007	4.1
2015	0	2006	1.0
2014	0	2005	2.6
2013	1.0	2004	2.4
2012	5.4		

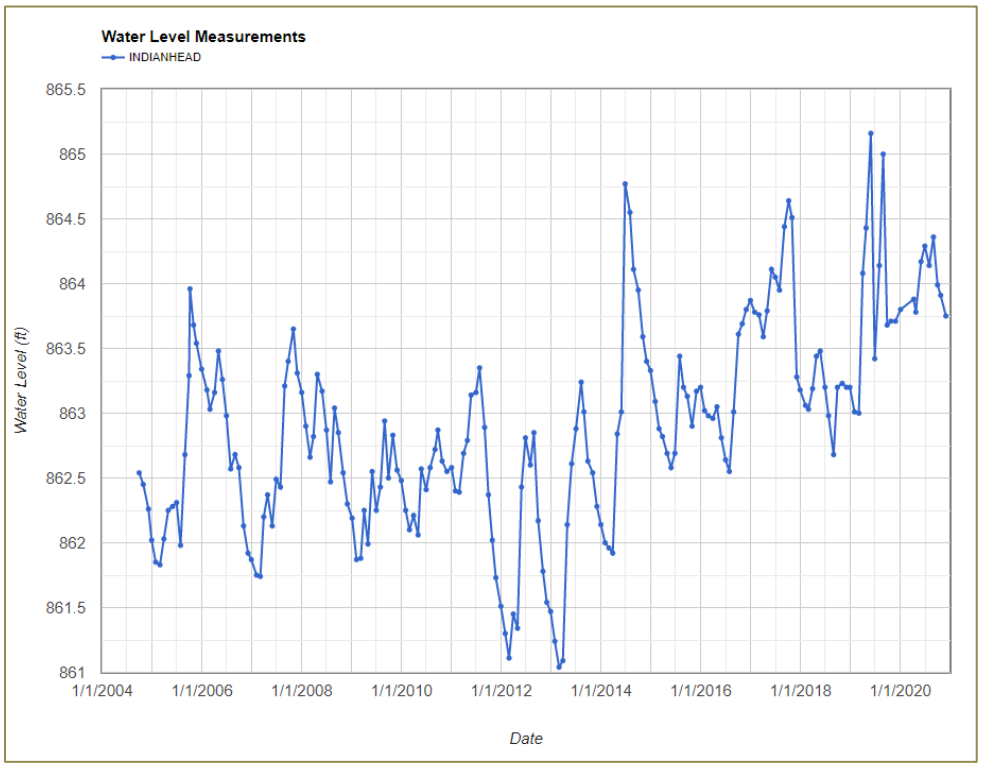


Figure 5-1 Indianhead Lake Levels From 2004-2020

Augmentation of lake levels in Indianhead Lake increases flood risk. As described in section 3, the starting lake level needed to protect the low primary structure from flooding during the 100-year, 24-hour rainfall is 861.8 feet or below. Augmentation of the lake level above elevation 861.8 feet increases flood risk to the low primary structure during the 100-year, 24-hour rainfall event and should be avoided.

Additionally, the starting lake level needed to protect the low primary structure from flooding during a 100-year snowmelt event is 859.9 feet. Water appropriations should be avoided prior to spring snowmelt to ensure alignment with flood risk management objectives.

6.0 MDNR Permitting

Several regulatory agencies may be involved in the planning and permitting process related to implementation of a pumping program at Arrowhead and Indianhead Lakes. On January 17, 2023, Barr and City staff met with MDNR to present preliminary lake level management findings. On February 23, 2023, Barr and the City staff discussed permitting paths for the two landlocked lakes with MDNR staff. A bulleted summary of the discussion items and correspondence is provided below:

- The MDNR provided a summary of the previous temporary water appropriations permit items at these two lakes:
    - A temporary water appropriation permit for flood management was authorized for Arrowhead Lake in 2019 and 2020, and for Indianhead Lake in 2017 and 2019.
    - Arrowhead Lake is infested with Eurasian watermilfoil. The MDNR permit included a requirement to filter the discharge from Arrowhead Lake to a size of 500 microns.
    - The temporary water appropriation did not allow pumping below the lakes' OHWLs.
- The MDNR indicated that pumping below the OHWLs of the lakes requires a Public Water Work permit, and rules for establishing a water level control (i.e., an outlet) would be the framework guiding the review of such an application. Authorization of lake water level controls would require application of multiple regulatory standards, including both rule and statute.
- The MDNR staff referenced general standards for water level controls, including MN Rule 6115.0220; subpart 5F. Note that specific criteria may be found in MN Rule 6115.0221, subpart 4 for landlocked basins. MN Statute 103G.405 also addresses landlocked basins. Standards may vary depending on the site-specific proposal.
- A detailed operating plan in accordance with MN Rule 6115.0221, subp. 2A(5) would be required. Criteria required as part of the operations plan may include but not be limited to:
    - Summary of operating conditions.
    - Evaluation of adverse impacts to downstream properties and/or waterbodies, water quality, lake ecology, and aquatic or riparian habitat.
    - Field survey data to evaluate aquatic vegetation fringe, the elevation of the tree line, groundwater elevations (if appropriate), and other information as requested by MDNR.
    - A public hearing, including presentation of the proposed operations plan and findings.
- The MDNR indicated that pumping up to approximately 1.5 feet below the OHWL of a landlocked basin is typically within an allowable range. In accordance with MN Rule 6115.0221, subp. 2A(2b), for landlocked basins, the water level control elevation shall not be more than 1-1.5 feet below the OHWL, unless it is found that:
    - the control is necessary to prevent adverse impacts to the lake or adjoining property;

- other reasonable or cost-effective alternatives are not available;
- natural resource or hydrologic conditions exist in the watershed that would limit the potential for continuous discharge of excess waters from the lake; and
- the outlet and discharge of excess waters is addressed in an approved water management plan under Minnesota Statutes, chapter 103B or 103D; and
- the commissioner may issue a permit to restore the existing control elevation to a historic natural water elevation if detailed engineering surveys establish that the proposed control elevation does not exceed the estimated natural control elevation;

Following site-specific operation plan development, MDNR requirements, including rules and statues, should be further evaluated prior to design and deployment of a pump system.

7.0 Summary and Conclusions

This memorandum provides analysis and conclusions in support of the second phase of the lake level management plan development for Arrowhead and Indianhead Lakes, completed to identify lake level management strategies to guide pumping decisions. The City of Edina's Water Resources Management Plan indicates that the City will place a high priority on reducing flood exposure of primary structures in the 1-percent-annual-chance event.

7.1 Arrowhead Lake

A bulleted summary of the findings presented in this memorandum for Arrowhead Lake is provided below:

- At Arrowhead Lake, the low primary structure is located at 6604 Indian Hills Road, with a low opening elevation at 877.7 feet.
- Results of the groundwater elevation influence analysis indicate that lake levels are sensitive to varying groundwater levels, and higher groundwater levels can significantly increase the potential for impact to the low primary structure during non-extreme rainfall conditions. Higher groundwater levels tend to keep the lake levels higher, increasing the likelihood of flood exposure.
- Preemptive pumping in the fall was evaluated in an effort to lower lake levels and accommodate spring snowmelt. Results of the analysis indicate that lake levels tend to rise over the winter months when groundwater levels are high, making preemptive pumping ineffective. When groundwater levels are low, lake levels naturally decline over the winter months.
- The results of the target lake level analysis (as shown on Table 3-1 and Figure 3-1) indicate that the low primary structure would be protected from a 100-year frequency (1% annual probability), 24-hour storm if the initial lake level is below 874.3 feet, approximately 1.5 feet below the OHWL. The low primary structure would be protected from the impact of the 100-year, 10-day snowmelt

event if the initial lake level is below 873.3 feet, approximately 2.5 feet below the OHWL. Note that these elevations assume no freeboard.

- The results of the pumping scenario analysis indicate that pumping scenario 4, in which the pump turns "on" at the OHWL (875.8 feet) and "off" 1.5 feet below the OHWL (874.3 feet), produces the combination with the fewest number of pump deployments balanced with the greatest level of flood protection. City staff have indicated that pumping scenario 4 is their preferred alternative.
- There is potential for lake levels in Arrowhead Lake to rise above the low primary structure due to snowmelt runoff (or rain on frozen ground), depending on the initial water surface elevation and amount of runoff. Consideration of snowpack conditions using the graph provided in Figure 4-7 is recommended in late-February or early-March to assess the need for springtime pumping outside of the "regular" pumping program.
- Based on preliminary discussions, MDNR staff has indicated that pumping up to 1.5 feet below the OHWL (e.g., the preferred pumping scenario) of a landlocked basin is typically within an allowable range.

7.2 Indianhead Lake

A bulleted summary of the findings presented in this memorandum for Indianhead Lake is provided below:

- At Indianhead Lake, the low primary structure is located at 6901 Dakota Trail, where a structural retaining wall at elevation 864.9 feet supports the home.
- Results of the groundwater elevation influence analysis indicate that lake water surface levels are sensitive to varying groundwater levels, and higher groundwater levels can significantly increase the potential for impact to the primary low structure during non-extreme rainfall conditions. Higher groundwater levels tend to keep the lake levels higher, increasing the likelihood of flood exposure.
- Preemptive pumping in the fall was evaluated in an effort to lower lake levels and accommodate spring snowmelt. Results of the analysis indicate that lake levels tend to rise over the winter months when groundwater levels are high, making preemptive pumping ineffective. When groundwater levels are low, lake levels naturally decline over the winter months.
- Results of the lake level target analysis (as shown on Table 3-2 and Figure 3-2) indicate that the low primary structure would be protected from a 100-year frequency (1% annual probability), 24-hour storm if the initial lake level is below 861.8 feet, approximately 1.9 feet below the OHWL. The low primary structure would be protected from the impact of the 100-year, 10-day snowmelt event if the initial lake level is below 859.9 feet, approximately 3.8 feet below the OHWL. Note that these elevations assume no freeboard.
- The results of the pumping scenario analysis indicate that pumping scenario 4, in which the pump turns "on" at the OHWL (863.7 feet) and "off" 1.5 feet below the OHWL (862.2 feet), produces the

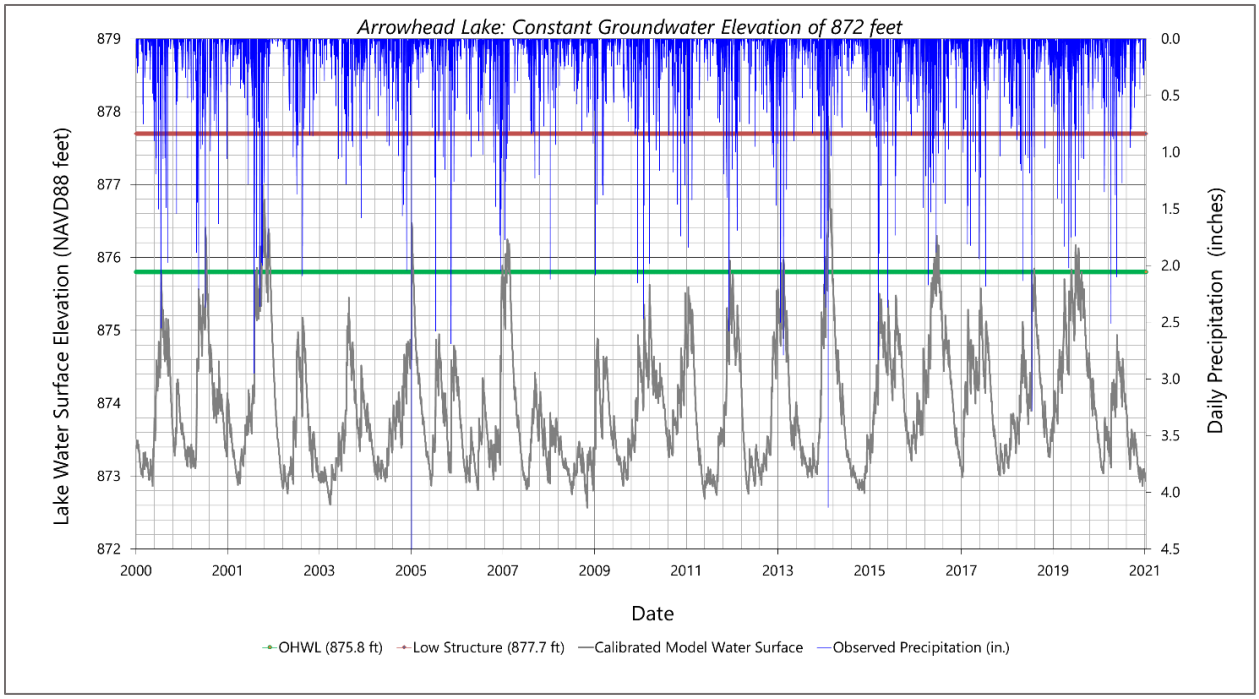
combination with the fewest number of pump deployments balanced with the greatest level of flood protection.

- There is potential for lake levels in Indianhead Lake to rise above the low primary structure due to snowmelt runoff (or rain on frozen ground), depending on the initial water surface elevation and amount of runoff. Consideration of snowpack conditions using the graph provided in Figure 4-8 is recommended in late-February or early-March to assess the need for springtime pumping outside of the "regular" pumping program.
- Based on preliminary discussions, MDNR staff has indicated that pumping up to 1.5 feet below the OHWL (e.g., the preferred pumping scenario) of a landlocked basin is typically within an allowable range.
- Augmentation of lake levels in Indianhead Lake increases flood risk. Augmentation of lake levels above elevation 861.8 feet should be avoided, as water levels above 861.8 feet are not protective of the low primary structure for the 100-year, 24-hour rainfall. Additionally, water appropriations should be avoided prior to spring snowmelt to ensure alignment with flood risk management objectives.

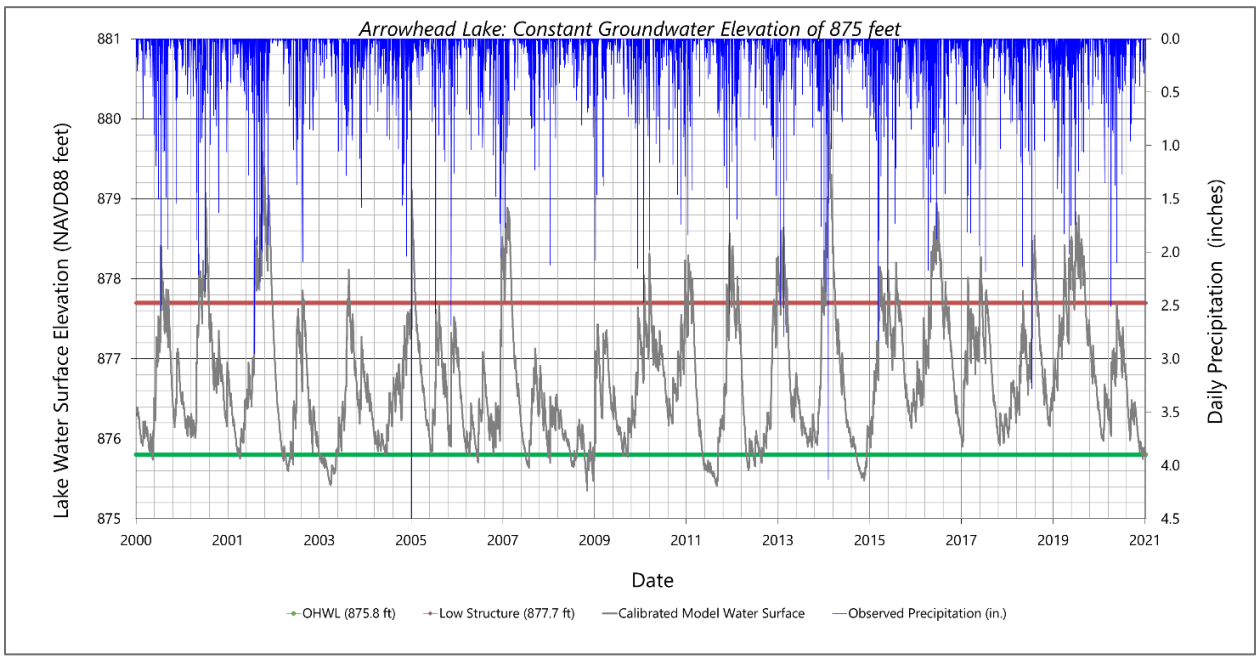
Based on the importance of groundwater elevations in the model predictions of flooding at both lakes, it is recommended that the future management plan include groundwater monitoring wells installed near Arrowhead Lake and Indianhead Lake and that the level of the groundwater be monitored as part of that plan.

Attachment

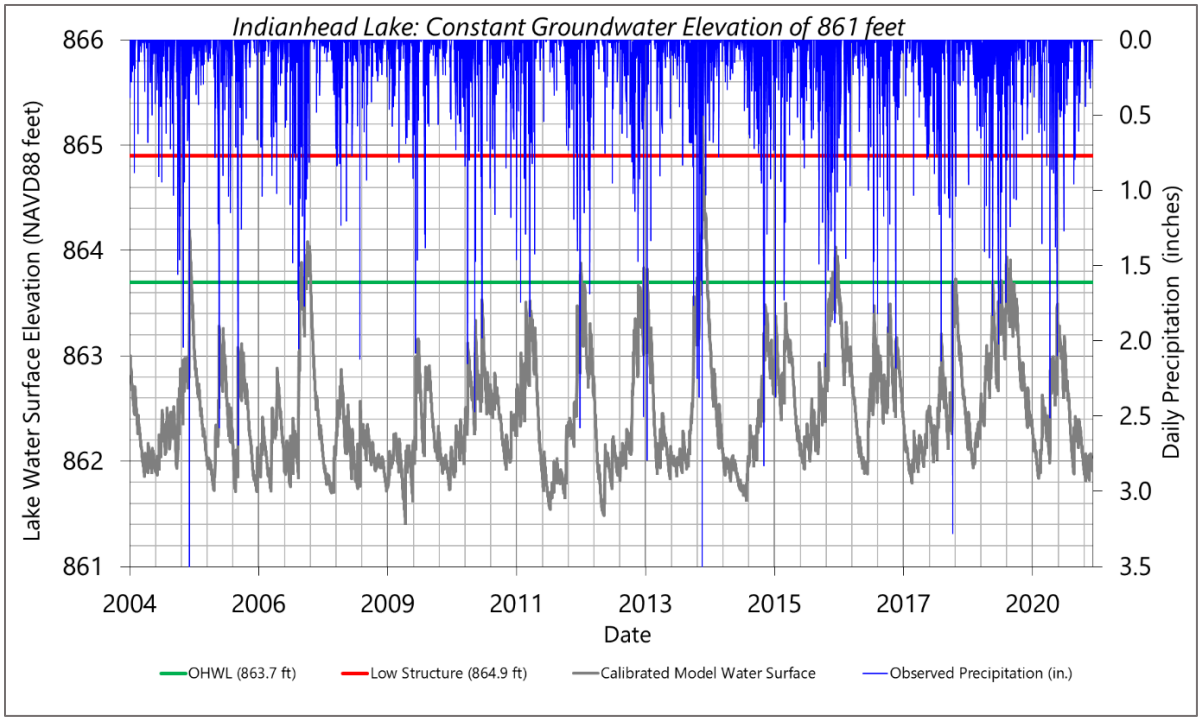
Predicted water surface elevation graphs in Arrowhead and Indianhead Lakes with “low” and “high” constant groundwater elevation scenarios



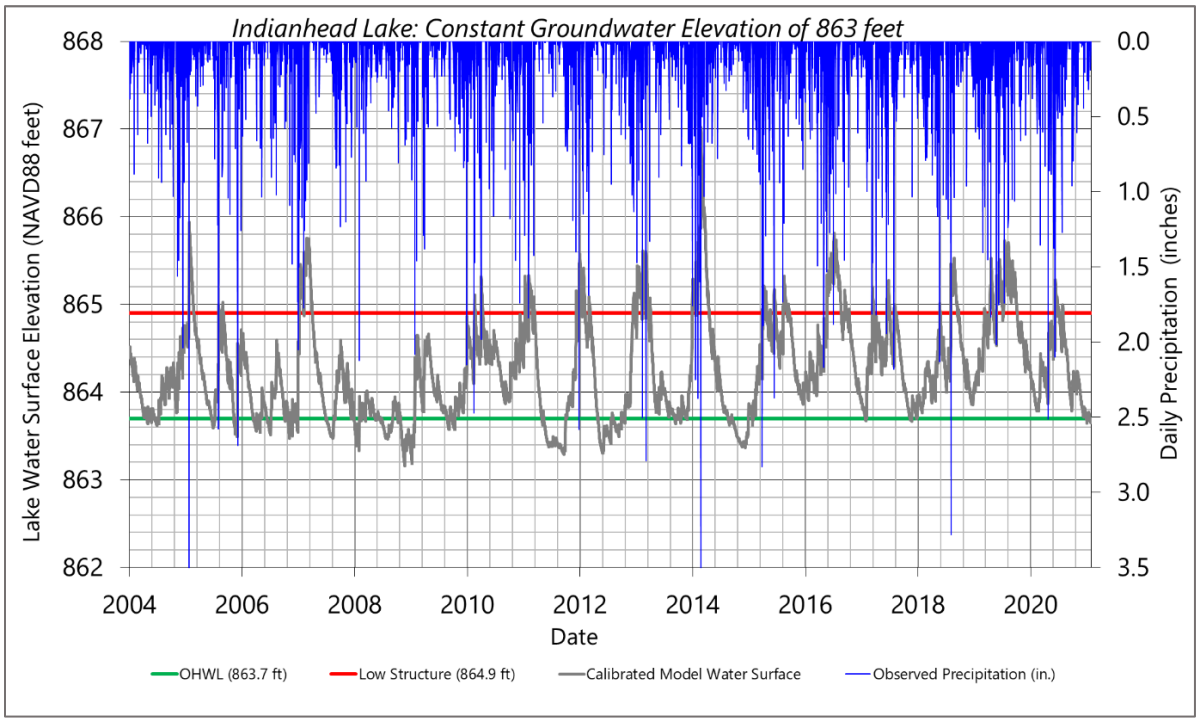
Predicted water surface elevation in Arrowhead Lake with constant groundwater level at 872 M.S.L.



Predicted water surface elevation in Arrowhead Lake with constant groundwater level at 875 M.S.L.



Predicted water surface elevation in Indianhead Lake with constant groundwater level at 861 M.S.L.



Predicted water surface elevation in Indianhead Lake with constant groundwater level at 863 M.S.L.