Technical Memorandum

To: Terry Jeffery, RPBCWD
From: Jay Hawley & Scott Sobiech
Subject: Duck Lake Outlet Modification
Date: October 7, 2024
Project: Task Order 46: Duck Lake Outlet Modification (23270053.14)
c:

The purpose of this memorandum is to summarize Barr's evaluation of potential Duck Lake outlet modifications.

Background

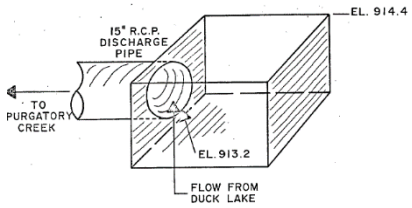
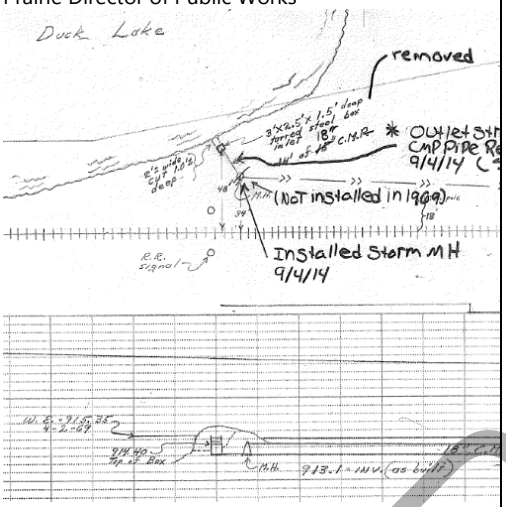
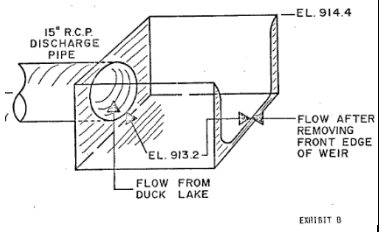
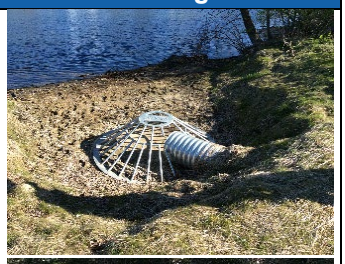
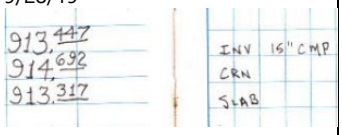
Duck Lake lies entirely within the boundaries of the City of Eden Prairie. The watershed area contributing to Duck Lake is 233 acres including the lake surface area of 41 acres. Duck Lake does not have any upstream lakes contributing flow. The three primary outflows from the lake are through a constructed outlet to Purgatory Creek, evaporation, and net groundwater outflow or seepage. Most of the watershed underwent development from agricultural use to residential land use between the early-1960's and late-1980's.

The Duck Lake outlet structure, located on property owned by Twin Cities & Western Railroad Company, was constructed in 1969 and consisted of a box weir structure upstream of a 15-inch CMP; the control elevation for the lake was 914.4. In 1979 the Department of Natural Resources denied an application to modify the structure. However, despite the denial, the outlet was modified sometime between 1979 and 2011 to remove the weir upstream of the outlet pipe and lower the control elevation to 913.2 (the invert of the 15-inch CMP) based on the 1969 as-built. In 2014 the city of Eden Prairie undertook the outlet replacement by surveying the elevation of the discharge pipe at the outlet (914.45 at the time) and replacing it with a new discharge pipe at the same elevation (913.45). DNR staff indicated to RPBCWD that no DNR permit was applied for or issued to modify the Duck Lake outlet in 2014. The details of these three outlets ("1969 As-built", "1979 Modified", and "2014 Existing") are summarized in Table 1.

At the November 3, 2021, board meeting RPBCWD managers heard comments from several residents about the control elevation of Duck Lake and its potential impact on the ecology of the lake. Following the November 2021 board meeting Barr completed an environmental impact review (Barr, 2021) that consisted of reviewing the history of the lake outlet, the lake's water surface level, water quality, vegetation, and fisheries.

Findings were discussed with the city of Eden Prairie, RPBCWD, and DNR staff on October 11, 2022. The DNR confirmed that the DNR goal is to establish runout elevations for lakes and, since it has been in place for so long, the DNR cannot approve raising the outlet elevation back to the 1969 elevation (914.4) without a significant public engagement process and riparian owner support. The DNR mentioned they might be able to permit a revised outlet if the runout elevation was unchanged but would need additional technical information before advancing the discussion.

Table 1. Duck Lake Outlet Configurations

1969 As-built Outlet	1979 Modified Outlet	2014 Existing Outlet
 Source: Exhibit B in Duck Lake Outlet Control Level memo dated2/12/79 from Carl Jullie, City of Eden Prairie Director of Public Works  Source: Marked up 1969 As built 2355 provided by Eden Prairie 9/28/18 Note: The outlet pipe diameter is 15 inches based on dimensions from the original 1969 as-built, the 2/12/79 Duck Lake Outlet Control Level memo and scaling the diameter from site photos.	 Source: Exhibit B in Duck Lake Outlet Control Level memo dated 2/12/79 from Carl Jullie, City of Eden Prairie Director of Public Works   Photo source: Email Mary Krause, Sr. Project Engineer, dated 9/28/19 Note: The outlet pipe diameter is 15 inches based on dimensions from the original 1969 as-built, the 2/12/79 Duck Lake Outlet Control Level memo and scaling the diameter from the above site photos.	  Photo source: Email Mary Krause, Sr. Project Engineer, dated 9/28/19  Source: Barr Survey dated 7/2/19 Note: outlet pipe diameter and control elevation based on 7/2/19 Barr Survey.
Control Feature: Box Weir Structure with 15-inch CMP **Control Elevation:** 914.4 M.S.L. (Top of Box Weir Structure)	**Control Feature:** 15-inch CMP **Control Elevation:** 913.2 M.S.L. (Invert of 15-inch CMP)	**Control Feature:** 15-inch CMP **Control Elevation:** 913.45 M.S.L. (Invert of 15-inch CMP)

RPBCWD has continued collaborating with the city of Eden Prairie about potential implementation of modifications. The city indicated a willingness to implement modification if RPBCWD would assist with identifying the needed improvements. In addition, the city approached the Twin Cities & Western Railroad Company, the property owner where the outlet is located, to inquire about access permission. At this time, it remains unclear if Twin Cities & Western Railroad Company would allow access to implement any modifications.

In 2023, the Eden Prairie Duck Lake Association advocated for RPBCWD to undertake a holistic lake management, including an analysis to determine what could potentially be done detain more water in the lake, similar to conditions before the 2014 modification. The holistic lake management plan was discussed at the December 13, 2023, Board of Mangers meeting. One outcome of this discussion was an interest in potentially looking at the lake level management separate from the holistic study.

In 2024, RPBCWD asked Barr to evaluate potential modifications to the Duck Lake outlet that consist of maintaining the existing runout elevation of 913.45, but better approximating the elevation-duration curve before the outlet was modified in 2014. Four outlet configurations would be considered:

1. The 1979 Modified outlet configuration assuming the outlet was free from debris and plugging.
2. The 1979 Modified outlet configuration assuming the outlet was partially plugged, if appropriate, to match as closely as possible the observed lake levels between 1979 and 2014.
3. A potential outlet configuration that approximates the elevation-duration curve for Duck Lake assuming the outlet is fully open and free from debris between 1979 and 2014.
4. A potential outlet configuration that approximates the elevation-duration curve for Duck Lake assuming the outlet is partially plugged, if appropriate, between 1979 and 2014.

Modeling Methodology

RPBCWD's stormwater management model (PCSWMM model) was used to simulate the variability in lake levels under different outlet conditions over a continuous period (1979-2024) presuming existing conditions in the Duck Lake watershed. The model uses rainfall and watershed characteristics to generate watershed runoff (hydrology), which is routed simultaneously through pipes and overland flow paths (hydraulics). The model also accounts for detention in ponding areas, backflow in pipes, and tailwater conditions that may exist and affect upstream storage or pipe flows. Because historic climate data have not been collected within the Duck Lake subwatershed the climatic data (i.e., measured precipitation and temperature data) from the Minneapolis-St. Paul International Airport (MSP) weather station were used for the scenario simulations. To improve the model's ability to simulated observed lake levels, RPBCWD's existing model was update using the University of Minnesota's 2015 land cover dataset (UM Land Cover, 2015) and revised seepage rates out of the lake.

Modeled Scenarios

The following three modeling scenarios were analyzed to assess the performance of the outlet and the resulting lake levels under different conditions:

- **Free-Flowing Outlets (i.e., Open)** - Barr first ran the three outlet configurations shown in Table 1 assuming they were free-flowing (i.e., not blocked, partially plugged, or obstructed by debris) to establish baselines for how the lake might respond with these various outlets with active maintenance programs. The results of these three model runs ("1969 As-built-Open", "1979 Modified-Open", and "2014 Existing-Open") are compared to the observed water surface

elevations in Figure 1. Figure 1 also shows the outlet control elevations for these three outlet conditions and the MSP daily rainfall totals.

- **1979 Modified-Partially Plugged** - Barr then considered several options for restricting the outflow to simulate plugging of the of the 1979 Modified outlet to better approximate the observed water surface elevations. We found that restricting the outflow to a small, 1-inch diameter orifice at an elevation of 913.45 while still allowing unrestricted overflows at 914.4 resulted in the best match between the modeled and the observed elevations during this period. This scenario is called “1979 Modified-Partially Plugged” and the model results are shown in Figure 2. Some of the differences between the observed and modeled water surface elevations are likely due to differences in the amount of localized precipitation in the Duck Lake watershed versus the amount at the MSP weather station, the amount of outlet plugging from debris or ice, changes in the seepage rate out of the lake, and variability in outlet maintenance (i.e., no maintenance records are available).
- **Potential V-Notch** - Barr next considered potential outlet designs that would approximate the elevation-duration curve for Duck Lake assuming the potential outlet was unplugged. We considered several configurations with small orifices or v-notch weirs controlling the low flows. We found that an outlet configuration with either a 1-inch diameter orifice or a 1-inch wide v-notch weir was best able to approximate the elevation-duration curve for Duck Lake. The 1-inch diameter orifice was rejected as being too impractical and we proceeded with the 1-inch wide v-notch weir design (“Potential 1.0-in V-notch”). A conceptual profile sketch of this potential outlet configuration is shown in Figure 3 and the continuous model results are shown in Figure 2.

Figure 1: Duck Lake Unplugged Outlet Comparisons

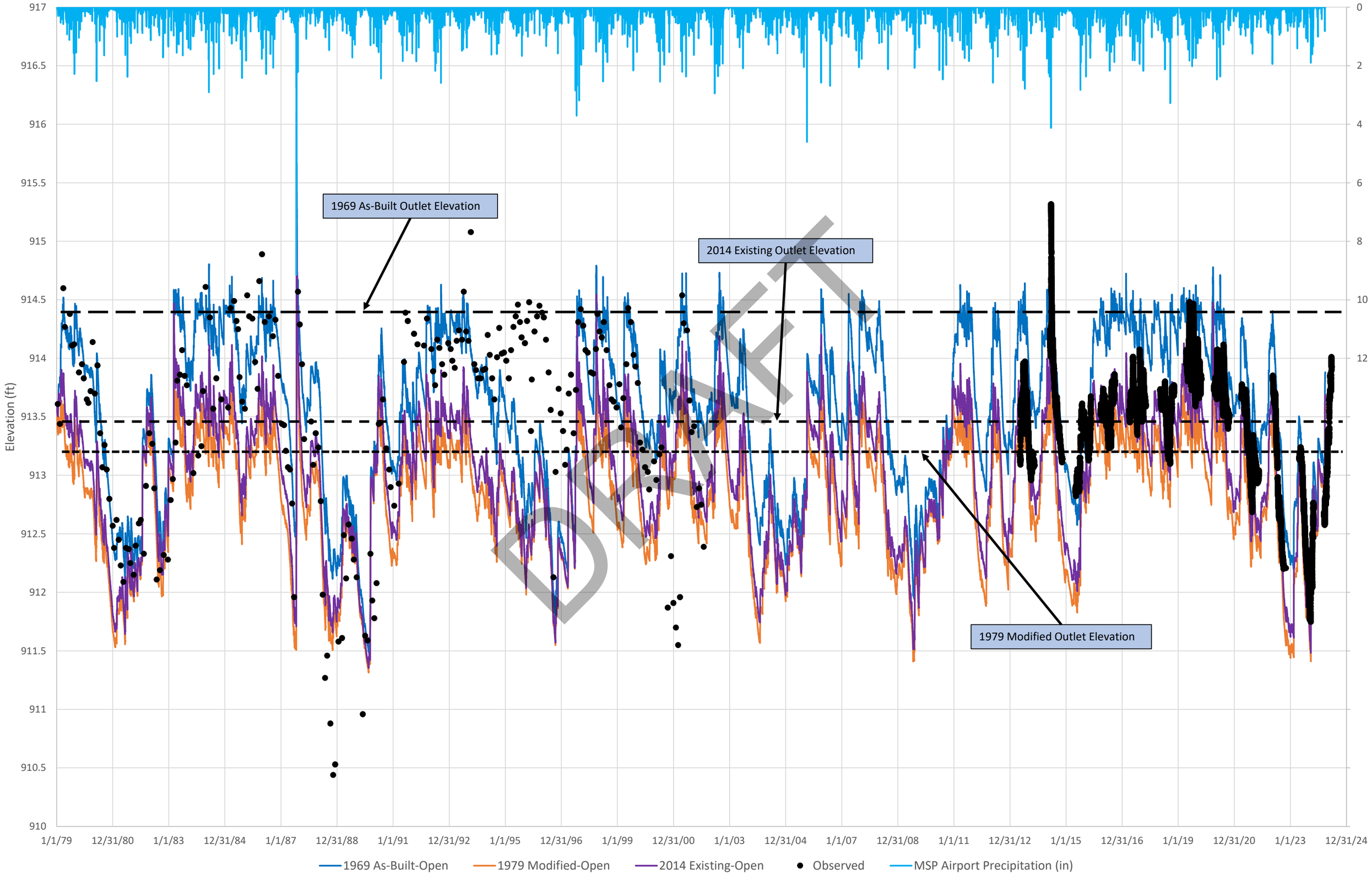
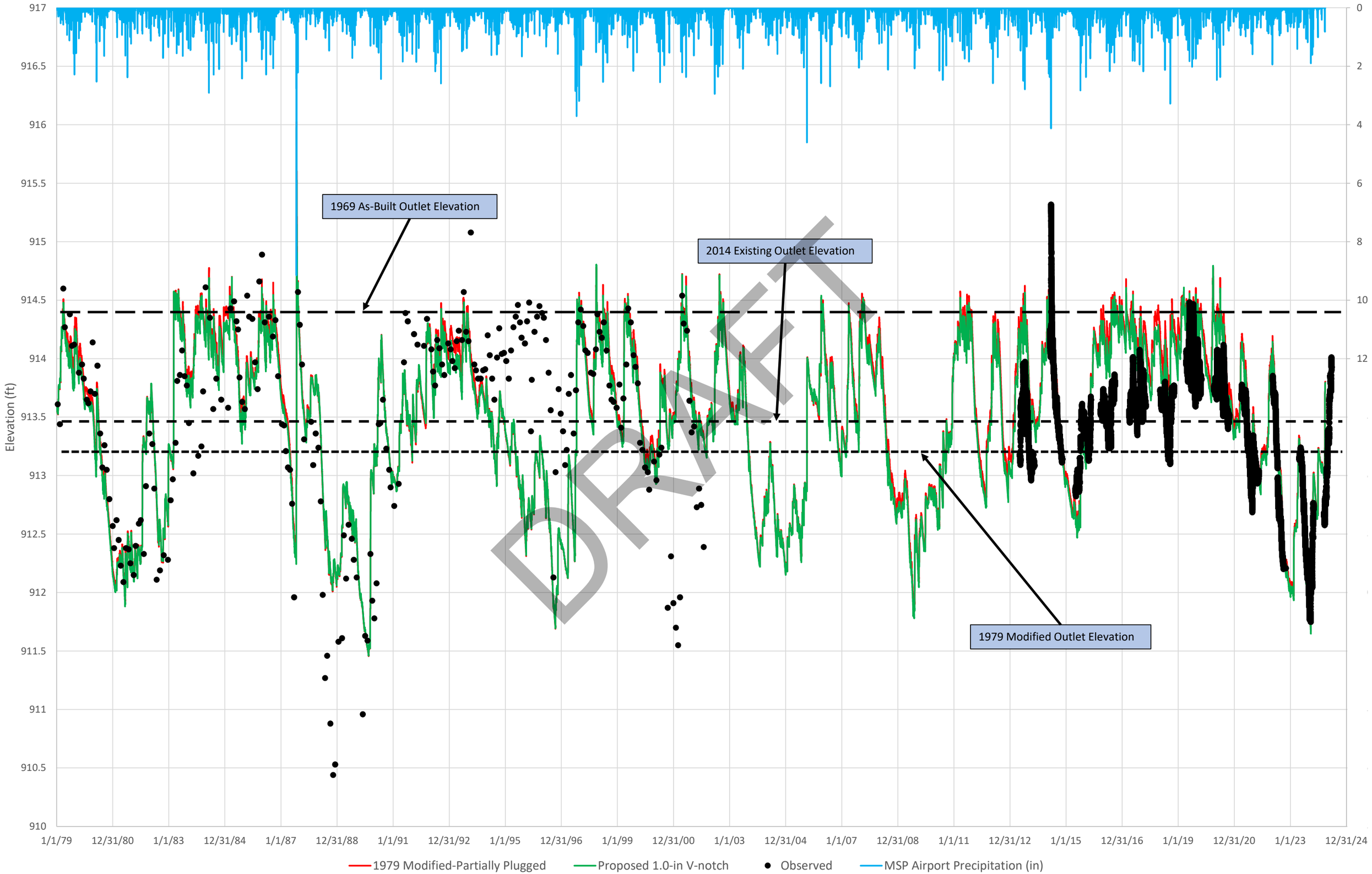


Figure 2: Duck Lake "1979 Modified-Partially Plugged" and "Proposed 1.0-inch V-notch" Outlet Comparions



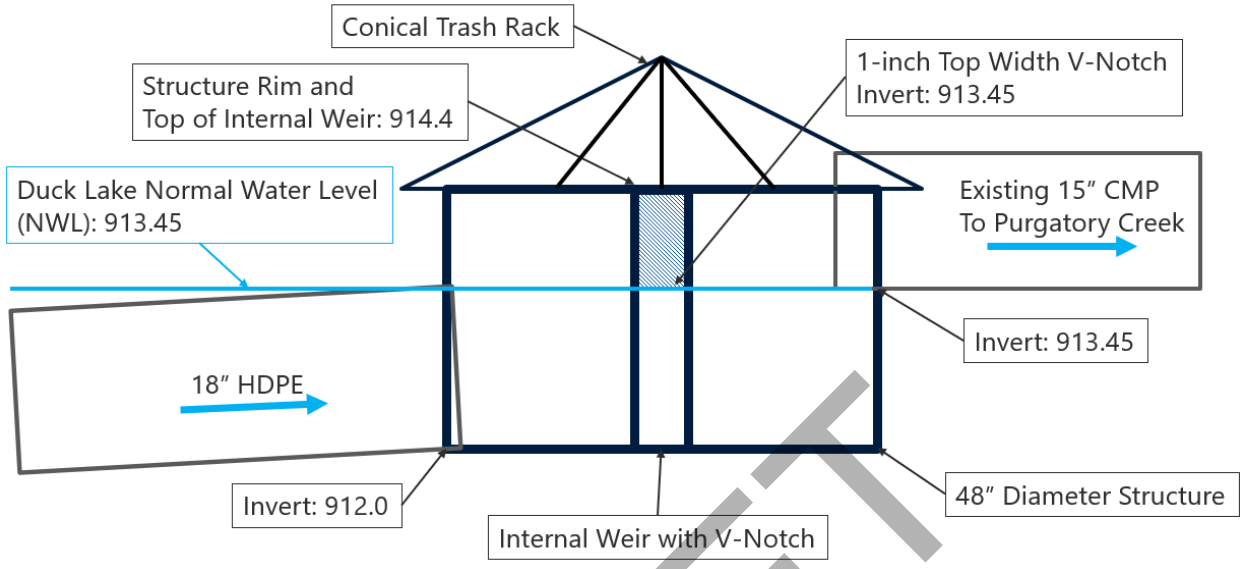


Figure 3: Sketch of the potential "Potential 1.0-inch V-notch" outlet configuration.

Results

The elevation-duration curves for the five modeled scenarios and the observed lake elevations are shown in Figure 4. The elevation-duration curves for Duck Lake use the 1979 through March 2024 modeled results and observed data to help visualize how frequently the lake is above a certain elevation during the various outlet scenarios.

Barr also summarized the 1979 through March 2024 minimum, maximum and average water surface elevations for the observed data and modeled results in Table 2 and the percentage of time water levels in the Duck Lake exceeded the three outlet elevations in Table 3.

Table 1. 1979 through March 2024 Minimum, Maximum and Average Duck Lake Water Surface Elevations

Scenario	Minimum Elevation (NGVD29)	Maximum Elevation (NGVD29)	Average Elevation (NGVD29)
Observed	910.44	915.32	913.45[1]
1979 Modified-Partially Plugged	911.46	916.02	913.50
Potential 1.0-inch V-notch	911.46	915.98	913.45
1969 As-built-Open	911.49	916.10	913.59
1979 Modified-Open	911.32	915.51	912.82
2014 Existing-Open	911.36	915.64	913.01

[1] Water surface elevations were collected at approximately monthly intervals from 1979-2002, not at all from 2002-2011 and in 15 minute intervals after 2011. Because there are many more data points in the post-2011 data, the average elevation shown here was computed using the elevation at the end of each month during the post-2011 period to match the measuring frequency of the 1979-2002 data.

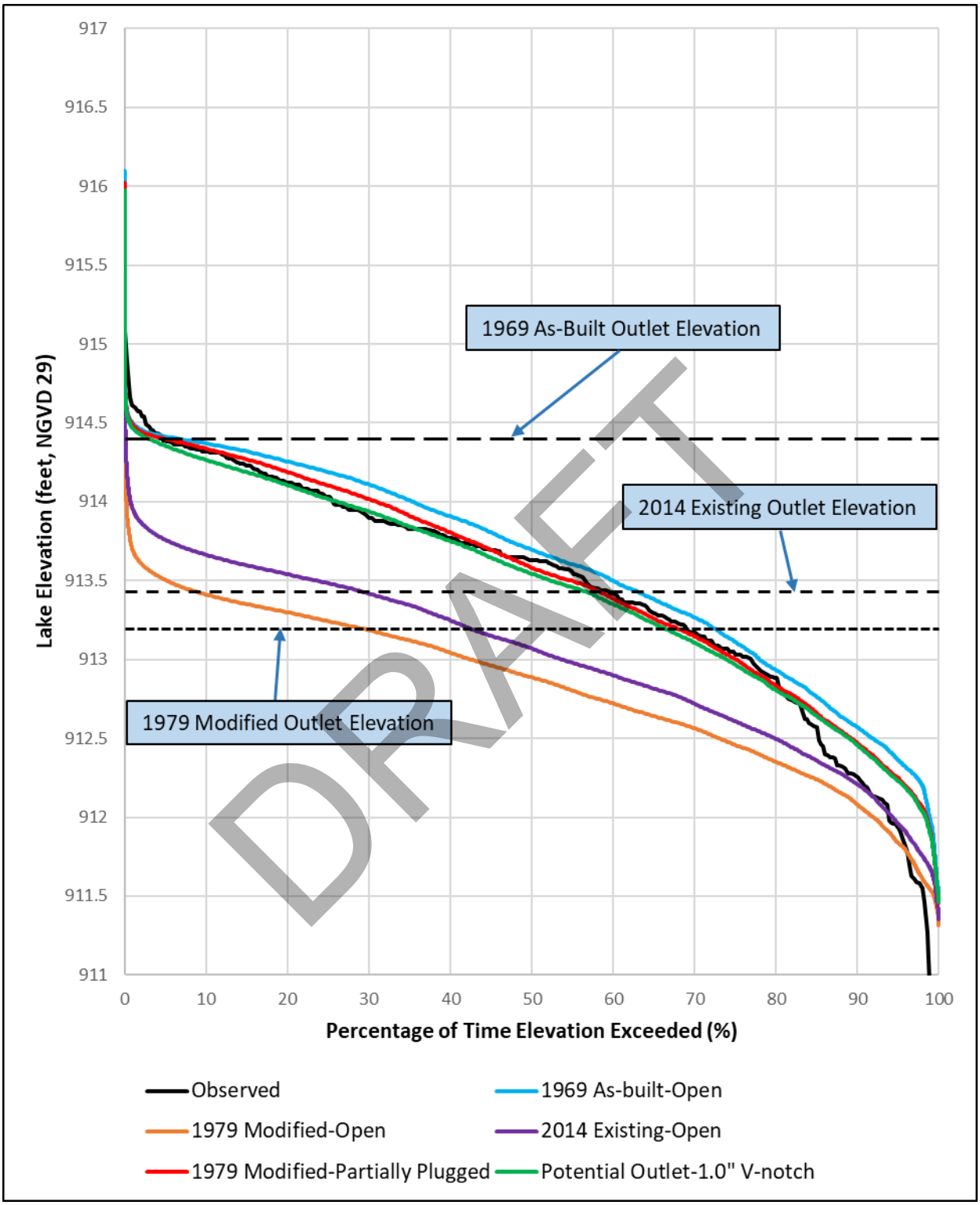


Figure 4: Elevation-Duration Curves for the modeled Duck Lake outlet scenarios and observed water surface elevations.

Table 2. Percentage of Time Water Level in Duck Lake Exceeds the Outlet Elevation

Scenario	Percent of Time Water Level is Higher than Elevation		
	914.4 ft	913.2 ft	913.45 ft
Observed (entire record)	5%	70%	59%
1969 As-built-Open	7%	72%	62%
1979 Modified-Open	0.05%	29%	8%
2014 Existing-Open	0.1%	42%	28%
1979 Modified-Partially Plugged	5%	68%	57%
Potential 1.0-inch V-notch	3%	66%	55%

Based on the analysis of the observed lake levels and the modeled outlet scenarios, we have a better understanding of how the lake might respond under different outlet conditions. Some key takeaways from this analysis include:

- Regardless of the outlet control elevation, the water surface elevation of Duck Lake drops below its outlet elevation for a significant amount of time. For example, Figure 2 shows the lake would have been below the 2014 Existing Outlet elevation for all of 2023 even if the outlet had not been replaced.
- The Free-flowing (i.e., Open) outlet scenarios:
    - Only the "1969 As-built-Open" scenario closely matched the observed water surface elevations.
    - The "1979 Modified-Open" and "2014 Existing-Open" results trended below the observed data most of the time as can be seen in the Figures 2 and 4 as well as the results summaries in Table 2 and Table 3.
    - This indicates that the lake outlet was frequently plugged by debris or ice, keeping water levels artificially higher than the constructed control elevation.
    - If the outlet in place prior to 2014 had been well maintained and kept free from debris, the average lake level could have been approximately 0.5 feet lower than what was observed. A well-maintained outlet in the pre-2014 configuration would have resulted in water levels above elevation 913.45 feet only 8% of the time and negligible amount of time above elevation 914.4 feet.
- Potential Outlet Revision:
    - In order to match the observed water surface elevations, any potential outlet will need to greatly restrict outflows below 914.4. The "Potential 1.0-inch V-notch" design, while constructable, will still be prone to plugging due to how narrow it is and will require frequent maintenance.
    - Revising the outlet to mimic conditions before 2014 would have a negligible impact on the minimum lake elevation (~0.1 feet)
    - Future water surface elevations might average 0.5 feet higher than if the outlet is modified to match the "Potential 1.0-inch V-notch" design ***and*** is kept free from debris However, the lake elevations are also impacted by climate conditions (precipitation, temperature, humidity, etc.) as well as variable groundwater seepage rates so this 0.5-foot average increase is not guaranteed.
    - The frequencies of time the water level would be above the control elevation (913.45 ft) would increase from about 28% to 55% when comparing the 2014 existing outlet to a potential v-notch design. This would closely mimic the observed duration curve.

- If the v-notch were to plug, then the outlet would function similar to the original 1969 As-built outlet and the control elevation of the lake could increase by up to approximately 1-foot to the control structure's rim elevation of 914.4. The increased control elevation resulting from a plugged v-notch would reduce the available floodplain detention storage which in turn could increase the potential for flooding during extreme events for property and infrastructure around the lake.
- Revising the outlet presents permitting challenges with the DNR and requires property owner (Twin Cities & Western Railroad) permission.

Next Steps

The following step are suggested to further consider an outlet modification:

- Discuss findings with the city of Eden Prairie and MN DNR to assess the probability of regulatory approval of the potential revised outlet configuration.
- Further investigate the potential ecological benefits of the increase in the elevation-duration curve by roughly 0.5 feet with DNR fisheries, aquatic vegetation, and lake experts.
- Discuss the potential for construction access with Twin Cities & Western Railroad.

REFERENCES

Barr Engineering Company. 2021. *Technical Memorandum: Duck Lake Outlet Environmental Impact Review*. December 3, 2021. Prepared for the Riley-Purgatory-Bluff Creek Watershed District.

University of Minnesota: TCMA 1-Meter Land Cover Classification dataset, 2015. ESRI files downloaded on 8/9/2017 from https://gisdata.mn.gov/dataset/base-landcover-twincities.