resourceful. naturally.
engineering and environmental consultants
BARR

Technical Memorandum

To: Valley Branch Watershed District Landlocked Basin Comprehensive Planning Study Project Stakeholders
From: Katie Kramarczuk, Tyler Olsen, Jay Hawley, Jennifer Koehler
Subject: VBWD Landlocked Basin Flood Mitigation Comprehensive Planning Study – Basin Water Quality Modeling
Date: October 2023
Project: 23821268.00
c: John Hanson, Nicholas Vottero, Jeremiah Jazdzewski

1 Background

This Valley Branch Watershed District (VBWD) Landlocked Basin Comprehensive Planning Study identified management alternatives for ten landlocked basins within VBWD. To fully understand the consequences of the management alternatives, the VBWD Board of Managers wanted to understand the impact of proposed high water outlets on the water quality (with a focus on eutrophication and nutrients) in downstream receiving waters. This includes the St. Croix River (Lake St. Croix), which is currently listed as impaired for excess nutrients and has an approved total maximum daily load (TMDL).

This memo summarizes the water quality assessment conducted with the VBWD Landlocked Basin Comprehensive Planning Study. The goals of this water quality assessment included the following:

- Understanding current water quality conditions
- Estimating potential water quality impacts with the addition of pumped/gravity outlets on the various landlocked basins
- Identifying and evaluating potential water quality mitigation strategies that may be needed to improve water quality or reduce downstream water quality impacts
- Estimating the potential increase in pollutant loading to the St. Croix River and determining if the VBWD will continue to meet the requirements of its Municipal Separate Storm Sewer System (MS4) permit with the Minnesota Pollution Control Agency (MPCA)
- Recommending a water quality management approach for each basin that is included in the proposed high water management alternative

Based on the flood risk and damage assessments, the high water level management alternatives identified and evaluated in the comprehensive planning study included pumping water, constructing gravity outlets on select landlocked basins (with mitigation measures), and acquiring flood-prone dwellings. Alternative 1 of the study includes pumped or gravity outlets from the following landlocked basins:

- Downs Lake (gravity outlet)
- Eden Park Pond (pumped outlet)
- Klawitter Pond (pumped outlet)
- Legion Pond (pumped outlet)
- Reid Park Ponds (pumped outlet)

Although Alternative 1 does not include creating an outlet from McDonald Lake, the lake has historically had poor water quality and is listed as impaired for excessive nutrients by the MPCA. The lake was included in the scope of the basin water-quality-modeling effort to help understand what will be needed for McDonald Lake to meet the state water quality standards.

2 Basin Water Quality Data

Barr Engineering Co. (Barr) evaluated the existing water quality of the landlocked basins using monitoring data from the Metropolitan Council's Environmental Information Management System (EIMS) database, including data collected as part of the VBWD water quality monitoring program.

Barr summarized the three eutrophication parameters for each landlocked basin: total phosphorous (TP), chlorophyll-*a* (Chl-a), and Secchi depth (SD). The amount of available data varied by year and waterbody:

- Eden Park Pond does not have any available water quality data.
- Reid Park Ponds had one testing location in its east basin, with 1 year of data collected in 2021.
- Downs Lake, Klawitter Pond, Legion Pond, and McDonald Lake are typically part of the VBWD routine water quality monitoring program and have multiple years of data.

Summer average (June–September) water quality measurements per MPCA guidance are summarized in Table 2-1. This table also includes state water quality standards (if applicable) for each basin and the MPCA impairment status.

Table 2-1 Basin Water Quality Data

Basin	Available Data	Summer Average TP (µg/L)	Summer Average Chl-a (µg/L)	Summer Average Secchi Depth (m)	MPCA Eutrophication Standards	Listed as Impaired (Year and Impairment)
Downs	1998–2022	164	65	0.5	TP: 60 µg/L Chl-a: 20 µg/L SD: 1.0 m	Yes (2012 Nutrients)
Eden Park	None	N/A	N/A	N/A	N/A	No
Klawitter	2002–2022	121	40	0.7	N/A	No
Legion	2005–2006 2008–2009 2017 2020–2021	80	25	1.2	N/A	No
Reid Park Ponds	2021 (East) None (West)	40	9	0.91	N/A	No
McDonald	1999 2001–2022	57	34	1.6	TP: 60 µg/L Chl-a: 20 µg/L SD: 1.0 m	Yes (2022 Nutrients)

Downs and McDonald Lakes do not meet the state of Minnesota's north central forest ecoregion water quality standards for TP. They do not meet the standards for chlorophyll-*a*, and Downs Lake does not meet the standard for Secchi disc depth. Legion, Klawitter, Reid Park, and Eden Park Ponds are considered wetlands, and the MPCA eutrophication standards do not apply. However, creating outlets for them, especially Klawitter and Legion ponds, could negatively impact receiving waterbodies because they have high concentrations of both TP and chlorophyll-*a*.

3 Basin Response Modeling Inputs

Barr completed in-lake (in-basin) modeling using the Canfield Bachman mass balance method within an Excel-based lake response model. The mass balance uses inputs such as watershed runoff load and other phosphorus sources such as internal and atmospheric load to predict the annual average in-lake phosphorus concentrations.

Barr ran the lake response model for the average annual conditions for each basin for all years that water quality data was available. For basins that only had one year of monitoring data, Barr only ran the lake model for that year. Barr then compared the final lake model predictions to the monitored data to determine how well the model fit the system of each lake.

The following sections describe how Barr developed various inputs, including runoff and pollutant loads, for the lake response modeling of each landlocked basin.

3.1 Watershed Loading Modeling

Barr created a program for predicting polluting particle passage through pits, puddles, and ponds (P8) water quality model for the Downs Lake and Eden Park Pond drainage areas to evaluate existing watershed loading to both basins. P8 is a water quality model used to predict the generation and transport of sediment and associated pollutants (such as total phosphorus) mobilized by stormwater runoff in developed watersheds. The assessment used P8 model version 3.5.

3.1.1 Existing Conditions P8 Model Development

Barr created a P8 model for the Downs Lake subwatershed (which includes the Eden Park Pond subwatershed) to estimate detailed watershed runoff and pollutant inflows to the basins. The P8 model includes best management practices (BMPs) constructed within the watershed, including infiltration and filtration basins and stormwater ponds.

Barr constructed the Downs Lake P8 model using hydrologic inputs generated for the Downs Lake XPSWMM model and the following assumptions:

- *Watershed Areas:* Barr used the watershed delineations from the XPSWMM model for the P8 model. However, because P8 generates pollutants for all impervious areas in the model and open water area is treated as impervious, Barr removed any open water area from watersheds with waterbodies.
- *Pervious Curve Number (CN):* Pervious CN values were calculated based on underlying soil types.
- *Impervious Area:* P8 calculates runoff and associated pollutant loading from directly and indirectly connected impervious surfaces separately from pervious surfaces. Barr used a total impervious raster and directly connected impervious raster for 2016 development conditions throughout the watershed to develop these inputs. We originally developed these rasters for the XPSWMM modeling. Open water surfaces were not included in these calculations for the P8 modeling.
- Barr assumed no street sweeping in the P8 model.

- All model parameters related to snowfall, snowpack, snowmelt, and particle characteristics were left at default values.

The hydrologic conditions in the P8 model reflect 2016 land-use conditions in the watershed. We used the default particle file, NURP50, which was developed from National Urban Runoff Program (NURP) studies (USEPA, 1986) and reflected the median (50th percentile) sediment characteristics of all monitored sites.

Because P8 is limited in the number of devices and watersheds that can be included in the model, Barr did not include landlocked subwatersheds within the Downs Lake drainage area; these areas would likely not overtop and drain to Downs Lake even during extreme rainfall events.

Barr created the hydraulic inputs for the modeled P8 devices (BMPs), including storage volumes, infiltration/filtration rates, outlet configurations, and routing, by exporting this data from the XPSWMM model. P8 devices used to reflect the existing system in the Downs Lake watershed primarily included detention ponds, general devices, and pipes (to summarize loads at key points in the watershed). Barr used typical filtration efficiencies published by the Minnesota Pollution Control Agency (MPCA Stormwater Manual) for sand filters.

To simulate annual pollutant loading to Downs Lake and Eden Park Pond through a continuous model run, Barr created hourly climate data (hourly precipitation and daily average temperatures) from the Minneapolis/St. Paul Airport (MSP) weather station. The model was run from 1998–2021 to simulate existing conditions. The annual precipitation for 1998 through 2021 is summarized in Table 3-1.

Table 3-1 Total Annual Precipitation at MSP

Year	Precipitation (in)
1998	33.4
1999	30.5
2000	30.5
2001	34.2
2002	38.4
2003	22.7
2004	27.4
2005	33.4
2006	27.6
2007	34.3
2008	22.4
2009	24.8
2010	32.9
2011	26.9
2012	29.6
2013	32.8
2014	35.4

Year	Precipitation (in)
2015	36.1
2016	40.3
2017	32.4
2018	33.6
2019	43.2
2020	29.8
2021	26.0
Average	***31.6***

3.1.2 Existing Conditions P8 Model Results

Barr summarized the total annual runoff volume and pollutant loading to Downs Lake and Eden Park Pond from the existing conditions P8 model. These results are included in Table 3-2, which Barr incorporated into the Downs Lake and Eden Park Pond response models (see Section 4).

Table 3-2 Downs Lake and Eden Park Pond Watershed Runoff and Pollutant Loading

Year	Downs Lake		Eden Park Pond	
	Net Discharge (Runoff Volume) to Lake (ac-ft/year)	TP Load (pounds/year)	Net Discharge (Runoff Volume) to Pond (ac-ft/year)	TP Load (pounds/year)
1998	363.6	117.7	25.4	18.8
1999	314.2	107.5	23.1	17.7
2000	270.5	101.9	20.3	16.1
2001	609.9	129.8	49.6	19.5
2002	505.9	136.2	37.5	19.9
2003	171.7	76.3	14.3	13.2
2004	181.3	98.0	16.4	17.2
2005	295.1	119.5	21.9	18.4
2006	348.5	103.7	24.0	15.9
2007	558.8	127.8	42.1	18.8
2008	166.5	78.5	14.7	14.2
2009	204.1	86.1	16.0	14.3
2010	368.8	120.1	25.4	18.8
2011	489.4	102.8	40.7	15.5
2012	298.2	103.9	20.9	16.8
2013	393.0	108.9	26.7	16.9
2014	827.0	139.1	68.8	19.4
2015	301.6	124.6	24.2	20.6
2016	336.7	144.7	26.8	23.6

Year	Downs Lake		Eden Park Pond	
	Net Discharge (Runoff Volume) to Lake (ac-ft/year)	TP Load (pounds/year)	Net Discharge (Runoff Volume) to Pond (ac-ft/year)	TP Load (pounds/year)
2017	297.8	114.1	22.5	18.4
2018	391.7	120.6	26.3	17.9
2019	571.6	147.7	43.1	22.7
2020	241.9	98.7	19.0	16.5
2021	217.3	96.1	17.5	15.8
Average	***363.5***	***112.7***	***27.8***	***17.8***

3.1.3 Estimated Watershed Inflows for Other Landlocked Basins

For the other landlocked basins that do not have an existing-conditions P8 model, Barr estimated annual watershed inflows to each basin based on daily precipitation and an estimated watershed runoff coefficient generated from continuous simulation surface water models (XPSWMM/PCSWMM).

Barr estimated the watershed pollutant loading using published land-use-based event mean concentration (EMC) values for TP from the Minnesota Pollution Control Agency (MPCA Stormwater Manual), land use based runoff coefficients (USDOT, 2009), and the watershed land-use data developed for the surface water models (XPSWMM/PCSWMM). The land use TP EMC values and runoff coefficients used are shown in Table 3-3.

The total areas of each type of land use within the total basin watershed, and their respective runoff coefficients, were used to estimate a runoff volume from each land use type within the basin watershed. The runoff volumes by land use were then multiplied by their respective EMC values to estimate a TP loading from each land use within the basin subwatershed. The TP loads were summed for all the land uses within the basin watershed to estimate total TP load within the basin. The total TP load within the basin was divided by the total runoff volume within the basin to estimate an "effective" TP EMC for the watershed runoff for each basin. These effective TP EMC values are shown in Table 3-4.

Table 3-3 Land-Use-Based TP Runoff Concentrations

Land Use	TP Event Mean Runoff Concentration (ug/L)	Land Use Runoff Coefficient
Commercial	200	0.6
Industrial	235	0.7
Residential	325	0.3
Freeways/Transportation	280	0.9
Mixed	290	0.5
Open space	190	0.3
Conventional roof	30	0.9

Land Use	TP Event Mean Runoff Concentration (ug/L)	Land Use Runoff Coefficient
Agriculture	533	0.15

Table 3-4 Basin Effective TP EMC Values

Basin Drainage Area	Effective TP EMC (ug/L)
Klawitter Pond	302
East Reid Park Pond	228
West Reid Park Pond	228
Legion Pond	199
McDonald Lake	265

To estimate the total annual runoff volume to each basin, Barr used the estimated total annual runoff and precipitation volume as estimated for the groundwater model development. Because the estimates from the groundwater modeling included both runoff generated on the watershed and direct precipitation on the basin surface, Barr removed the direct precipitation volume on the water surface area from the runoff volume to the basin.

Finally, to estimate the annual watershed TP load to each basin over a period of time, Barr multiplied the annual runoff volume reaching the basin by the basin specific TP EMC value to estimate the annual watershed TP loads to each basin. These results are summarized in Table 3-5.

This methodology for estimating TP loading to the basin makes several assumptions:

- The methodology for calculating a basin-specific EMC value assumes that all runoff (and therefore TP loading) from each land use reaches the basin waterbody, regardless of contributing position within the basin. As a result, basins with higher TP EMC values concentrated in non-contributing areas will overestimate TP loads to the basin; basins with lower TP EMC values concentrated in non-contributing areas will underestimate TP loads to the basin.
- Barr did not adjust the basin TP EMCs to account for BMP treatment in the upstream watershed by various ponds, wetlands, or other BMPs to be conservative in nutrient loading for this planning level assessment.

Table 3-5 Estimated Annual Runoff and TP Loading to Other Landlocked Basins

Year	Klawitter Pond		East Reid Park Pond		West Reid Park Pond		Legion Pond		McDonald Lake	
	Net Runoff Volume to Pond (ac-ft/yr)	TP Load (lbs/yr)	Net Runoff Volume to Pond (ac-ft/yr)	TP Load (lbs/yr)	Net Runoff Volume to Pond (ac-ft/yr)	TP Load (lbs/yr)	Net Runoff Volume to Pond (ac-ft/yr)	TP Load (lbs/yr)	Net Runoff Volume to Lake (ac-ft/yr)	TP Load (lbs/yr)
1998	46.6	38.3	26.8	16.6	3.2	2.0	23.2	12.5	125.0	90.1
1999	42.6	35.0	24.9	15.4	3.1	1.9	21.2	11.5	114.5	82.6
2000	43.8	36.0	26.7	16.5	4.1	2.5	24.1	13.0	118.2	85.3
2001	49.3	40.5	30.5	18.9	4.8	3.0	29.1	15.7	133.7	96.4
2002	55.1	45.3	33.6	20.8	5.3	3.3	32.2	17.4	149.9	108.1
2003	32.3	26.6	19.0	11.8	2.8	1.7	17.3	9.3	87.8	63.3
2004	40.5	33.3	24.6	15.3	4.0	2.5	24.9	13.4	110.6	79.7
2005	50.0	41.1	31.0	19.2	5.2	3.2	33.5	18.1	138.3	99.7
2006	38.9	32.0	23.9	14.8	3.6	2.2	23.4	12.6	110.2	79.5
2007	48.6	39.9	30.5	18.9	4.8	3.0	29.9	16.2	137.8	99.4
2008	31.9	26.2	19.9	12.3	3.2	2.0	20.1	10.9	90.2	65.1
2009	36.6	30.1	23.5	14.6	4.2	2.6	26.3	14.2	104.1	75.0
2010	48.3	39.7	31.4	19.4	5.6	3.5	35.4	19.1	137.2	98.9
2011	38.1	31.3	24.2	15.0	3.8	2.4	24.6	13.3	107.3	77.4
2012	41.6	34.2	26.5	16.4	4.2	2.6	26.2	14.2	117.0	84.4
2013	46.3	38.1	29.2	18.1	4.6	2.8	31.0	16.7	131.4	94.7
2014	48.7	40.1	28.9	17.9	3.7	2.3	27.9	15.1	136.9	98.7
2015	49.4	40.7	29.2	18.1	3.6	2.2	25.8	13.9	137.0	98.8
2016	52.1	42.8	30.0	18.5	3.0	1.9	22.0	11.9	141.4	102.0
2017	39.9	32.8	24.1	14.9	2.4	1.5	14.3	7.7	106.6	76.9
2018	44.0	36.2	26.6	16.5	3.1	1.9	16.0	8.7	112.3	81.0
2019	53.1	43.6	32.2	20.0	3.3	2.0	18.0	9.7	139.0	100.3
2020	35.2	29.0	21.7	13.4	2.0	1.3	8.7	4.7	90.7	65.4
2021	34.0	28.0	19.7	12.2	2.1	1.3	8.0	4.3	79.8	57.5
Average	**43.6**	35.9	**26.6**	16.5	**3.7**	2.3	**23.5**	12.7	**119.0**	85.8

3.2 Internal Sediment Phosphorus Loading

Often, a significant source of phosphorus in shallow lakes is the internal release of phosphorus from anoxic bottom sediments. Barr calculated each basin's internal sediment phosphorus load from collected sediment cores and in-situ laboratory release rate experiments (Barr, 2023). The measured anoxic release rate for each basin is included in Table 3-6. Additionally, Barr calculated an anoxic factor using the Nurnberg equation and the phosphorus data for each water body. The equation is as follows:

$$\mathrm{AFshallow} = -35.4 + 44.2 \log (TP) + 0.95\ z/A0.5$$

Where TP is the average phosphorus concentration in the basin, z is the basin's mean depth (m), and A is the surface area (km^2). The anoxic factor represents the number of days in a growing season when the basin would be anoxic. Typically, the higher the anoxic factor, the higher the anoxic internal load of TP.

Table 3-6 Anoxic Release Rates for Basins

Basin	Average Anoxic Factor (Days)	Anoxic Release Rate ($mg/m^2/day$)	Average Internal Load (lbs/yr)
Downs Lake[1]	69.9	4.37–11.0	114.9
Eden Park Pond	N/A	3.64	10
Klawitter Pond	100.8	4.23	22.7
Legion Pond	64.2	4.23	49.8
McDonald Lake[1]	58.8	1.63–3.1	56.9
Reid Park Pond (West)	N/A	34	20.2
Reid Park Pond (East)	54.6	N/A	N/A

[1] The range of anoxic release rates represents two different methods of calculation. The first method uses the mobile phosphorus sediment fraction and the relationship from Pilgrim et al. (2007) to calculate a release rate. The second method uses measured release rates in a sediment column experiment that Barr performed in the laboratory. Results from the sediment column experiment were used in the lake water quality modeling when available.

3.3 Other Potential Sources of Phosphorus Loading

While this planning-level assessment primarily focused on internal sediment and watershed loads to the receiving waterbodies, there are several other potential sources of phosphorus loading that could be contributing to the internal loads. These have not been quantified in this assessment and further evaluation would be recommended for each basin if developing a water quality management plan in the future.

In addition to the internal loading of phosphorus from sediment, there are other potential in-lake phosphorus loading sources, including curly-leaf pondweed, rough fish, and wind and boat activity. Curlyleaf pondweed can contribute to interal loading due to its unusual growth cycle with die back typically occurring in early to mid summer. Rough fish, wind, and boat activity causing sediment resuspension that can bring high phosphorus concentration into the water column. Almost all the basins have had recent aquatic plant surveys identifying invasive plants. As part of aquatic plant point intercept surveys completed in 2013–2014, curly-leaf pondweed was found in McDonald Lake, Friedrich’s Pond, and Sunfish Lake. Common carp, also considered invasive, are found in the VBWD. There is limited motor boat activity on most of these basins.

Another potential source would be failing septic systems in the watershed tributary to the basins. According to the MPCA, approximately 21% of septic systems are failing. Additionally, data from Washington County reviewed as part of recent TMDL studies in the VBWD (MPCA, 2016) and follow-up studies (Barr, 2018) suggest that noncompliant systems could be more significant, estimating 25-30% and 56% of systems are noncompliant, respectively.

3.4 Groundwater Fluxes

Because the groundwater modeling showed that many of the landlocked basins are influenced by groundwater, especially in the recent wet period, Barr used the net groundwater flux results from the groundwater models to estimate annual groundwater load into or discharge from the basin. The annual volume of water in or out of each basin was incorporated into the lake response modeling. Barr assumed groundwater inflows had a TP concentration of 25 ug/L (USGS, 2005). The model uses the groundwater flux volume and concentration in the water mass balance for each basin, which impacts the calculation of the in-lake TP concentration.

Groundwater interaction varies from year to year. Although many of the basins experienced some groundwater inflow during the recent wet period (2014–2020), on an average annual basis, the net groundwater flux for all basins was estimated to be a discharge from the basin to the groundwater. Therefore, on an average annual basis, groundwater TP contribution was 0 lbs/yr for all basins.

3.5 Atmospheric Deposition

Atmospheric deposition of phosphorus directly to the basin surface was based on the estimated basin surface area throughout the year, which was determined by the water balance model using an average deposition rate of 0.24 pounds per acre per year. This rate was established in the Detailed Assessment of Phosphorus Sources to Minnesota Watersheds (Barr, 2004).

3.6 Sedimentation Rate

In the Canfield Bachman model, a coefficient representing the sedimentation rate of particulate pollutants is used in calculating the in-basin TP concentration. Barr adjusted this coefficient for each basin to match the modeled in-basin TP concentrations to the monitored TP concentrations. This value can range from 0.5 to 1.5.

4 Existing Conditions Basin Response Modeling Results

Using the inputs generated following the methodology outlined in Section 3, Barr ran the lake (basin) response models for each landlocked basin for the average annual loading condition. The results from the lake response spreadsheet model using the Canfield Bachman method are summarized in the table below. This includes a comparison of the monitored in-basin TP concentration to the modeled in-basin TP concentration, as well as the average annual TP load to each basin by source.

Table 4-1 Existing Conditions Average Annual Basin Response Modeling Results and Mass Balance Summary

Basin	Average Annual In-Basin TP Concentration (ug/L)		Source-Based Average Annual TP Load to Basin				Total Annual TP Load to Basin (lbs/yr)
	Monitored Data	Existing Conditions Model	Watershed TP Load (lbs/yr) (% of total load)	Groundwater TP Load (lbs/yr) (% of total load)	Internal TP Load (lbs/yr) (% of total load)	Atmospheric TP Load (lbs/yr) (% of total load)	
Downs Lake	159.3	155.3	112.7 (29%)	0.0 (0%)	271.1 (69%)	9.0 (2%)	392.8
Eden Park Pond	N/A	114.5	17.8 (62%)	0.0 (0%)	9.8 (34%)	1.2 (4%)	28.8
Klawitter Pond	116.3	116.3	35.9 (60%)	0.0 (0%)	22.7 (38%)	1.2 (2%)	59.7
Legion Pond	71.3	85.2	12.7 (19%)	0.0 (0%)	49.8 (75%)	4.1 (6%)	66.6
McDonald Lake	59.2	67.2	85.8 (44%)	0.0 (0%)	96.1 (50%)	11.3 (6%)	193.3
Reid Park Pond (West)	N/A	146.7	1.3 (6%)	0.0 (0%)	20.2 (92%)	0.5 (2%)	22.0
Reid Park Pond (East)	30.0	53.1	12.2 (90%)	0.0 (0%)	0.0 (0%)	1.4 (10%)	13.6

5 Proposed Conditions Basin Response Modeling

In the lake (basin) response models, Barr evaluated the proposed high water level management alternatives that included pumping of landlocked basins (Reid Park Ponds, Legion Pond, and Eden Park Pond) and installing a permanent gravity outlet for Downs Lake to evaluate the water quality impacts of the alternatives on water quality in the receiving basins. Barr also evaluated water quality improvement through an alum treatment for Klawitter Pond to be pumped to Goetschel Pond. Additionally, Barr calculated the increase in load from Downs Lake with its new gravity outlet, as related to the St. Croix River TMDL and VBWD's MS4 permit.

The following sections describe the modeling of the proposed alternatives in the lake response models and the results of those model runs.

5.1 Alum Treatments

For each basin with a new pumped outlet to manage high water levels, Barr evaluated the impact of an alum treatment on the in-lake water quality. Based on recent studies of alum effectiveness, Barr assumed that an alum treatment would achieve an 80% reduction in the internal phosphorus load in the basins. The in-lake water quality response to an alum treatment for each waterbody is shown in Table 5-1 below.

Table 5-1 Basin Response Model Results for Alum Treatment

Basin	Monitored Data	Existing Conditions Model	Proposed Conditions Model with Alum Treatments for Each Basin[1]	
	Average Annual In-Basin TP Concentration (µg/L)	Average Annual In-Basin TP Concentration (µg/L)	Average Annual In-Basin TP Concentration (µg/L)	% Reduction from Modeled Existing Concentration
Downs Lake	159.3	155.3	89.5	42%
Eden Park Pond	N/A	114.5	95.0	17%
Klawitter Pond	116.3	116.3	94.7	19%
Legion Pond	71.3	85.2	54.8	36%
McDonald Lake	59.2	67.2	52.4	22%
Reid Park Pond (West)	N/A	146.7	82.2	44%
Reid Park Pond (East)[2]	30	53.1	N/A	N/A

[1] Proposed model reflects an 80% reduction in internal phosphorus load.

[2] East Reid Park Pond would not require an alum treatment due to its high-quality water.

5.2 Downs Lake Response to Proposed Conditions

Using the proposed conditions long-term simulation XPSWMM model results, Barr updated the Downs Lake response model to reflect the proposed conditions, which include pumping water from Legion Pond, Reid Park Ponds, and Eden Park Pond into Downs Lake to reduce flood levels upstream. This scenario also assumes that Downs Lake would have a gravity outlet system installed to manage water levels on the lake.

Under these conditions, Barr analyzed scenarios where these upstream waterbodies either received an alum treatment or did not receive an alum treatment before being pumped. Due to its consistently poor water quality, all scenarios assume Downs Lake receives an alum treatment to help manage TP concentrations.

The response in Downs Lake water quality is summarized in Table 5-2. Overall, Downs Lake water quality is estimated to improve compared to existing conditions. However, despite the estimated improvement in water quality, Downs Lake will still not meet MPCA shallow lake standards and will remain impaired unless further load reductions can be made in the watershed.

Table 5-2 Downs Lake Response—Proposed Model Results

Scenario	Average Annual In-Basin TP Concentration (µg/L)	Average Annual TP Export Load (lbs/yr)
Existing Conditions	140.5	0
Alternative 1, Option 1 with upstream alum treatments	95.6	46.4

Scenario	Average Annual In-Basin TP Concentration (µg/L)	Average Annual TP Export Load (lbs/yr)
Alternative 1, Option 1 without upstream alum treatments	96.6	46.9
Alternative 1, Option 2 with upstream alum treatments	95.7	46.3
Alternative 1, Option 2 without upstream alum treatments	96.5	46.7

[1] Proposed model includes pumped inflows from Legion, Reid Park Ponds, and Eden Park Pond. All proposed options assume Downs Lake will receive an alum treatment.

5.3 Estimated Impact of the New Discharges on Loads to the St. Croix River

The VBWD has an MS4 permit from the MPCA. As part of the most recent MS4 permit renewal, the VBWD estimated annual TP loads to the St. Croix River (Lake St. Croix) for all years with flow and water quality data available, including discharges from the following:

- "Project 1007" storm sewer system
- Valley Creek
- Kelle's Creek

We used these loading estimates to demonstrate compliance with the Lake St. Croix TMDL wasteload allocation (WLA) assigned to the VBWD of 0.193 lbs TP/acre/year.

Using the continuous simulations from the XPSWMM modeling for the proposed conditions from Downs Lake and the proposed in-lake phosphorus concentration from the lake response model simulations, Barr calculated the proposed additional TP load from Downs Lake to the St. Croix River. Table 5-3 below summarizes the total TP load per year for each drainage area within the St. Croix River watershed and the average annual TP load.

Table 5-3 Summary of TP Loading for VBWD MS4

Year	Rest Area Pond TP Load	Valley Creek TP Load	Kelle's Creek TP Load	Additional TP Load from Proposed Downs Lake System
	(lbs/yr)	(lbs/yr)	(lbs/yr)	(lbs/yr)
1999	-	2,107	-	-
2000	-	1,947	-	-
2001	-	2,056	-	-
2002	-	2,038	-	-
2003	-	2,382	-	-
2004	-	1,296	-	-
2005	-	1,762	-	-

Year	Rest Area Pond TP Load	Valley Creek TP Load	Kelle's Creek TP Load	Additional TP Load from Proposed Downs Lake System
	(lbs/yr)	(lbs/yr)	(lbs/yr)	(lbs/yr)
2006	-	1,604	-	-
2007	-	2,558	-	-
2008	-	879	-	-
2009	-	1,158	-	-
2010	-	996	-	-
2011	-	1,532	-	-
2012	-	1,008	350	-
2013	58	1,295	183	12
2014	569	1,315	1,066	73
2015	0	1,080	317	60
2016	1,105	1,204	-	121
2017	630	-	-	28
2018	634	-	877	72
2019	-	-	1,268	-
2020	1,483	-	494	116
Average Annual	***640***	***1,568***	***651***	***69***

The average annual TP load used for the TMDL calculations, shown in Table 5-4. The calculated value represents the aerial loading of pounds of phosphorus per acre of the VBWD per year. Overall, Downs Lake exports an additional 0.002 pounds/ac/yr of TP to the St. Croix, remaining below VBWD's WLA of 0.193 lbs/ac/yr.

Table 5-4 Aerial Loading Calculation for VBWD MS4

TMDL Scenario	Total Average Annual TP Load (lbs/yr)	Watershed Area (ac)[1]	Aerial TP Load (lbs/ac/yr)
Existing Conditions	2,859	43,755	0.065
Proposed Conditions with Downs Lake	2,927	43,755	0.067
Difference	68	0	0.002

[1] Calculation uses watershed area from the TMDL (for the entire VBWD)

6 Summary and Conclusions

To reduce downstream water quality impacts from the flood mitigation alternatives involving outlets, water quality improvements are needed to offset the additional TP load from Downs Lake; however, water quality mitigation might not be necessary at other basins.

The results from the two proposed lake response models (with and without alum treatment of the pumped basins) indicate that alum treatments at Legion Pond, Reid Park Ponds, and Eden Park Pond will not significantly affect the in-lake TP concentration in Downs Lake if water from these basins is pumped into Downs Lake. Therefore, it may not be necessary to treat Legion Pond, Reid Park Ponds, and Eden Park Pond should the pumping alternative be pursued. The model results in Table 5-2 display a very minimal difference between the average Downs Lake TP concentration and the average in-basin TP concentration if the upstream waterbodies are treated with alum.

For Klawitter Pond, the results from the basin response model indicate that an alum treatment alone will not improve water quality to achieve an in-basin TP concentration similar to Goetschel Pond (summer average TP concentration of 35 µg/L from 2011 to 2020). Therefore, if Klawitter Pond's water were to be routed to Goetschel Pond, additional mitigation, such as enhanced filtration, would be needed to further reduce (approximately 69%) the effluent concentration to match Goetschel Pond.

An alum treatment should be considered for Downs Lake to improve overall water quality, even though it is expected that the lake would remain impaired with a worse in-lake TP concentration than the MPCA's standard for shallow lakes. The internal loading within Downs Lake contributes less to the estimated TP concentration than the direct watershed load. Additional reductions in watershed loads should be considered to achieve state water quality standards. Using the lake response model, Barr estimated that the watershed TP load would need to be reduced by approximately 40% (in addition to the reduction in internal loading) to meet the shallow lake standard.

Additionally, an alum treatment should be considered for Lake McDonald to improve its water quality. Lake McDonald's average TP concentration is 59.2 µg/L, slightly below the MPCA's standard for shallow lakes. With an alum treatment, the internal concentration would be reduced further to approximately 37 µg/L, improving water quality and protecting the lake from being impaired.

Ultimately, the planning-level assessment has demonstrated that even with the alternative that includes numerous pumped outlets and the gravity outlet from Downs Lake, the VBWD will continue to meet the requirements of the Lake St. Croix TMDL wasteload allocations assuming that the basins evaluated will receive alum treatments.

Should the high-water level management alternative (including pumped and gravity outlets) be selected for future implementation, Barr recommends continued detailed water quality monitoring and evaluation in all basins to better understand the nutrient dynamics in these systems. This evaluation should include an examination of vegetation (invasive species), rough fish activity, wind and/or boat activity as additional internal source of phosphorus to the basins as well as evaluation of adjacent septic systems. This planning-level assessment has not accounted for the potential loading from these other sources.

As part of further water quality assessment required by the TMDL process, the watershed should conduct point intercept plant surveys to better quantify the coverage and density of curly-leaf pondweed in waterbodies and account for vegetation as a source of phosphorus in the TMDL. Additionally, with regards to Downs Lake, which is listed by the MPCA as impaired for excess nutrients, we would recommend a future study that includes a more detailed in-lake model to further evaluate the impact of in-lake water quality management (e.g., alum or other shallow lake management options) and an evaluation of watershed load reduction practices needed for Downs Lake to meet state water quality standards.

7 References

Barr. 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds. Completed for the MPCA.

Barr. 2018. State of Minnesota Clean Water Fund (CWF) grant (C15-2471), VBWD Kelle's Creek Septic System Inspection Program. Completed for BWSR.

MPCA. 2014. The Minnesota Nutrient Reduction Strategy Report.

MPCA. 2016. Valley Branch Watershed District Total Maximum Daily Load Study Report.

MPCA. 2022 (Draft) 303(d) List of Impaired Waters.

MPCA. 2023. MPCA Stormwater Manual.

USEPA. 1986. National Urban Runoff Program (NURP) studies.

United States Geological Survey (USGS). 2005. Water-Quality Assessment of Part of the Upper Mississippi River Basin, Minnesota and Wisconsin – Groundwater Quality along a Flow System in the Twin Cities Metropolitan Area, 1997-1998. Scientific Investigations Report 2005-5120

United States Department of Transportation (USDOT). 2009. Urban Drainage Design Manual: Hydraulic Engineering Circular No. 22. 3rd ed. FHWA-NHI-10-009. Washington, DC. Table 3-1, p. 3-6.

VBWD. 2022. MS4 Permit Submittal to the MPCA.