BRUCE A. ANDERSON RECREATION AREA RECHARGE LAKE

WATER QUALITY IMPROVEMENT STUDY

7 JUNE 2024

PREPARED FOR:

UPPER BIG BLUE
Natural Resources District

PREPARED BY:

THE FLATWATER GROUP INC.

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To: Jack Wergin, UBBNRD
Marie Krausnick, UBBNRD

From: The Flatwater Group, Inc. (TFG)

Date: 7 June 2024

Re: Recharge Lake Water Quality Improvement Study

Introduction/Overview

In January 2024, TFG contracted with the Upper Big Blue NRD (UBBNRD) to conduct a water quality improvement study for the Bruce A. Anderson Recreation Area (Recharge Lake) near York, Nebraska. The major components of TFG's Scope of Work included project management, data collection and site assessment, nutrient loading assessment and fisheries evaluation, Best Management Practices (BMP) alternatives evaluation and report documentation and concept map preparation.

Recharge Lake was constructed in 1990 as part of a 5-year groundwater recharge study. The lake is 44 acres in surface area and is open to the public for passive and active recreational use. The proximity to the City of York enables widespread public use.

Study Purpose

The purpose of this study is to further evaluate BMPs identified in the UBBNRD's 2020 Water Quality Management Plan (WQMP) and provide a concept level construction cost opinion for implementation. Due to a lack of landowner participation in watershed BMP alternatives, in-lake treatment options outlined in the WQMP were evaluated in greater detail to address nutrient loading and sedimentation impairments. The in-lake treatments identified in the WQMP include:

- Near-Lake Wet Detention Pond
- In-Lake Wetlands
- Reservoir Deepening
- Island Stabilization

Additional in-lake BMPs were identified by TFG upon consultation with UBBNRD staff. These BMPs were considered to help replace the watershed BMPs and to enhance aquatic habitat, the fishery and angler access.

- Floating Treatment Wetlands
- Jetties and Shoreline Stabilization
- Underwater Aquatic Habitat Structures
- North Tributary Sediment Basin

Background Data

TFG coordinated with UBBNRD staff to collect, compile, and evaluate existing data sets to determine supplemental information needs. Available documents included:

- UBBNRD Water Quality Management Plan (WQMP) and associated GIS data
- 2018 NRCS Bathymetric Survey
- As-built construction plans for Recharge Lake

Past studies completed for Recharge Lake are summarized in the WQMP, which includes a baseline for existing water quality conditions and nutrient loading into Recharge Lake. The key WQMP data included water quality sampling data and average annual loading estimates developed for phosphorus, nitrogen, and sediment.

To work toward required pollutant load reductions, the WQMP outlined a “Treatment Train” approach that would implement multiple complimentary BMPs in series to treat various non-point pollutants with increased efficiency. The UBBNRD engaged stakeholders and discussed various non-structural and avoidance practices as well as in-field, near field and riparian practices as part of the “Treatment Train” approach. However, stakeholders did not choose to participate in the proposed voluntary implementation strategy.

Field Data Collection

On 12 March 2024, TFG team members conducted a bathymetric survey of Recharge Lake using a boat with attached sonar capable bathymetric equipment to map the lake bottom. Survey equipment was also used to measure soft sediment depth from the boat. Additionally, a canoe was used to collect bathymetric data in the sediment basin west of Road K. The water level was 3.4ft below the dam overflow at the time of survey. Secchi disk measurements ranged from 3 to 6-inches. These low readings are likely related to shallow water levels and to seasonal and wind driven lake turnover.

TFG staff also performed drone flights to inventory lake shoreline conditions to complement observations made by team members in the boat (Figure 1). This data was used to develop a shoreline inventory map of the entire lake. See attached Exhibits 1 and 2.

Figure 1.
Digital Elevation Model (DEM) 3D topographical surface generated from TFG LiDAR drone flight over Recharge Lake.

Sediment and Nutrient Loading Assessment

The ability of BMP alternatives to enhance water quality in Recharge Lake was evaluated through a sediment and nutrient loading assessment. This assessment took watershed based average annual loading rates reported in the WQMP study and applied them on a daily time interval. By routing daily estimates of sediment and nutrient laden runoff through individual BMP structures, a better understanding of site-specific trapping capabilities can be gained. Factors such as BMP size, hydraulic loading rates, detention and retention times, and sediment particle size can have a major impact on BMP effectiveness.

WQMP Data Summary

Annual watershed estimates for precipitation-based runoff, sediment yield, and nutrient loading were calculated in the WQMP. A district wide evaluation of runoff potential based on land cover, soil type and slope class estimated an average annual yield of 1.61-inches for the Recharge Lake watershed. Average annual runoff loads of sediment, phosphorus and nitrogen were estimated using the EPA's Spreadsheet Tool for Estimating Pollutant Loads (STEPL). The 8,540 acre watershed is comprised of 88% cropland, 6% urban, 5% grassland, and 1% forested. As a result, cropland drives the sediment and nutrient loading characteristics for the watershed. Average annual loadings were estimated at 6,050 tons of sediment, 18,635 lbs of phosphorus, and 53,682 lbs of nitrogen. Internal phosphorus loads from waterfowl, resuspension, and bottom sediment release was estimated at 13,600lbs, for a total annual load of 32,235lbs.

Water quality was sampled by the Nebraska Department of Environment and Energy (NDEE) over the period of 2002 to 2010. Both total phosphorus and nitrogen were found to exceed water quality standards for all samples collected. Average total phosphorus samples measured 495 ug/L, which is 10 times the standard of 50ug/L. Average total nitrogen samples measured 2,180ug/L, which is over 2 times the standard of 1,000 ug/L. Conversely, algae production as indicated by chlorophyll-a samples were below the water quality standard 10 mg/m^3. This is likely due to high turbidity as indicated by Secchi disk measurements that averaged 14-inches, with many readings of less than 10-inches.

Sediment Depth Analysis

The NRCS performed a bathymetric survey of Recharge Lake in 2018. The WQMP recommended the collection of additional bathymetric data to facilitate the evaluation of sediment loading. As described in the Field Data Collection section, TFG performed a bathymetric and sediment depth survey in March of 2024. Sediment depths of 0.2 to 2.3 ft were measured in the upper limits of the reservoir and in the sediment basin upstream of Road K. Comparisons of the 2024 and 2018 surveys estimated roughly 21,400 cy of accumulation over 6 years, which equates to 4,200 tons/yr of sediment loading.

To estimate the volume of sediment accumulated in the reservoir since construction in 1990, as-built plans were consulted for pre-project topography data. The reservoir site plan (as-built sheet 3) included 4-ft interval contour data. These contours were digitized and georeferenced using fence locations. Surface comparison between this map and current bathymetry found that roughly

134,000cy of sediment has accumulated over 34 years. This equates to approximately 4,650 tons/yr. See attached Exhibit 3 for locations of sediment accumulation.

It should be noted that annual loading estimates are approximate, and the accuracy of the sediment depth analysis is limited due to resolution of as-built contours and differences in collection methods used between the NRCS and TFG bathymetric surveys. TFG's estimated annual load of 4,650 tons/yr is within 25% of the WQMP estimate of 6,040 tons/yr, which indicates that these values are reasonably appropriate for planning purposes.

Daily Sediment and Nutrient Loading Analysis

To evaluate BMP alternative sediment and nutrient trapping efficiency at Recharge Lake, TFG estimated daily loading rates from historic rainfall data. This spreadsheet-based analysis applied daily watershed curve number and Universal Soil Loss Equation (USLE) erosion estimation procedures to estimate storm-based runoff and sediment yield, respectively. Rainfall data was acquired for the period of 1990 to 2023. Watershed input parameters were calibrated to match average annual values reported in the WQMP described above. Total phosphorus and nitrogen loading rates were distributed based on daily sediment and excess precipitation yield, respectively. The ten-year period from 1999 to 2008 was considered for BMP evaluation as it reflects a range of rainfall conditions over a typical span of time between potential maintenance operations. Annual summaries are provided to demonstrate the variability in daily rainfall from year to year, and its impact on sediment and nutrient runoff (Table 1).

Table 1. Annual Results of Daily Sediment and Nutrient Loading Analysis

Year	Precip	Runoff	Avg Inflow	Peak Daily Inflow	Sediment Inflow	Sediment Inflow	Nitrogen Inflow	Phos Inflow
-	in	in	cfs	cfs	tons	cy	(lbs)	(lbs)
Period Average	26.5	1.54	51	268	5,824	4,936	51,780	30,183
1999	27.9	1.92	44	248	7,253	6,147	64,661	37,592
2000	20.3	0.58	33	142	2,034	1,724	19,370	10,540
2001	24.9	1.49	52	251	5,555	4,708	50,128	28,792
2002	22.8	0.58	29	84	1,935	1,640	19,462	10,028
2003	22.7	0.81	47	160	2,899	2,457	27,224	15,025
2004	22.9	0.54	62	155	1,962	1,663	18,104	10,167
2005	26.5	2.16	75	543	8,815	7,471	72,677	45,687
2006	27.6	1.67	64	399	6,526	5,531	56,068	33,824
2007	33.6	2.71	55	381	10,284	8,716	91,021	53,302
2008	35.5	2.95	54	314	10,974	9,301	99,087	56,878

Procedures used in this analysis are generally limited to ephemeral streams. This allows for conservatively high estimates of event-based sediment and nutrient loading. Nutrient loading derived from intermittent baseflow conditions are not considered.

BMP Alternatives Evaluation

The BMPs identified by the WQMP and through this study were evaluated for their effectiveness to improve water quality in Recharge Lake. Two Alternatives were considered for this analysis. Alternative 1 utilizes the general BMPs and areas from the WQMP, as shown in Figure 2. Alternative 2, as shown in attached Exhibit 4, was developed for this study to meet water quality goals stated in the WQMP and through this study.

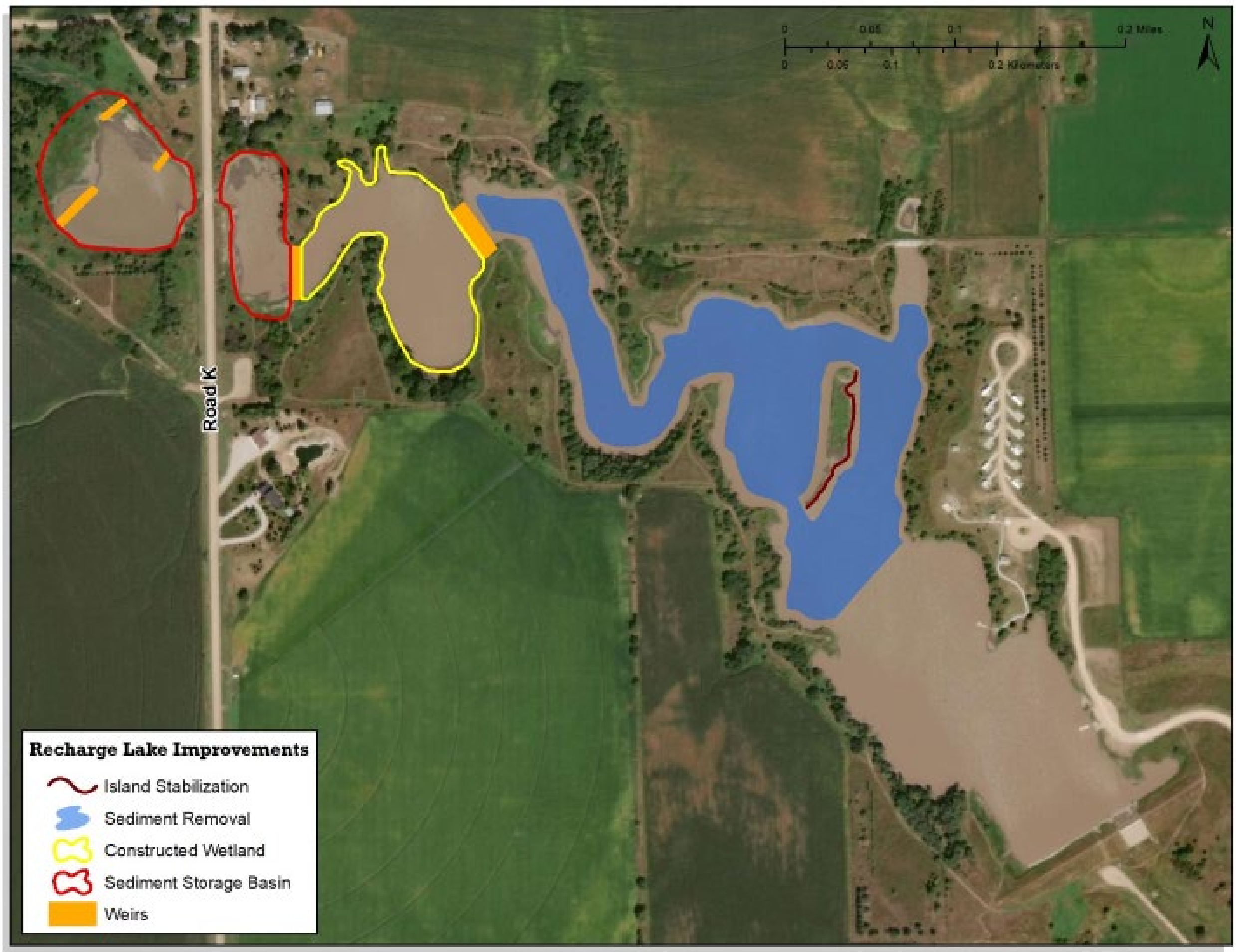

Figure 2. Conceptual In-Lake BMPs (Source: UBBNRD 2020 WQMP)

<u>Near-Lake Wet Detention Pond – Step 1 of the Water Quality "Treatment Train"</u>

- A wet pond removes sediment and nutrients through particle settling, and nutrient uptake can occur through biological activity (Figure 3). The WQMP BMPs propose the construction of a wet pond in the upper limits of Recharge Lake, upstream and downstream of Road K. The basic footprint already exists but would need to be enhanced to provide water quality benefits.
- The WQMP, Alternative 1, identified a constructed wet pond basin with 6 acres dedicated for primary sediment storage. Alternative 2 increased this complex to 8 acres based on site conditions, optimal placement of the overflow weir, and water quality improvement goals.

- BMP includes targeted excavation areas (4ft deep) to facilitate future maintenance. This excavation increases the operating depth to 0 to 8 ft.
- Earthen baffle structures force water to flow over a long distance, which improves sediment and nutrient trapping performance.
- Flow through the BMP is controlled by a weir overflow structure constructed of rock riprap and/or articulated concrete block matting.

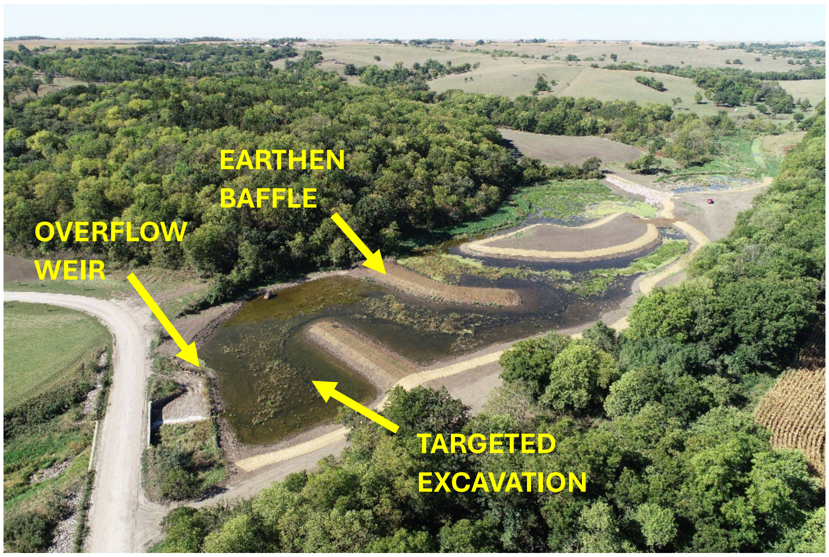

Figure 3.
Near-Lake Wet Detention Pond at Summit Lake near Tekamah NE

<u>Floating Treatment Wetlands – Step 2 of the Water Quality Treatment Train</u>

- Floating treatment wetlands (FTW) could be implemented as an intermediate strategy to reduce nutrient loading and provide aquatic habitat for fish and insects.
- This BMP was not identified in the WQMP. Alternative 2 shows FTWs with a combined area of 13,000 sq-ft.
- FTWs could be employed immediately after the restoration project to establish emergent wetland vegetation, and then discontinued as the In-Lake Wetlands BMP (described below) becomes established.
- FTWs are typically 400 to 1,000 sq-ft in area and consist of a frame, matting material to hold plants, and about 1,000 plants (Figure 4). Plant roots are suspended in the water column below the FTW and absorb nutrients from the water body. The suspension allows FTWs to adapt to fluctuating water body depths.

Figure 4.
UNL Students assembling a floating treatment wetland at Cooper YMCA in Lincoln NE

<u>In-Lake Treatment Wetlands – Step 3 of the Water Quality "Treatment Train"</u>

- The proposed In-Lake Wetland would be created downstream of the Near-Lake Detention Wet Pond. Emergent wetland vegetation would provide aquatic habitat and filter sediment and nutrient runoff (Figure 5).
- The WQMP, Alternative 1 identified an In-Lake Wetland complex of 4.5 acres. Alternative 2 increased this complex to 8 acres based on site conditions, optimal placement of the overflow weir, and water quality improvement goals.
- Flow through the BMP is controlled by a weir overflow structure constructed of rock riprap and/or articulated concrete block matting.
- Designed to trap sediment becoming shallower over time to promote establishment of emergent wetland vegetation - no excavation is planned for this area. Operating depths are 0 to 4 ft.
- Underwater baffles with native wetland vegetation plantings increase hydraulic retention times and promote recruitment of desired species to other areas as conditions allow.

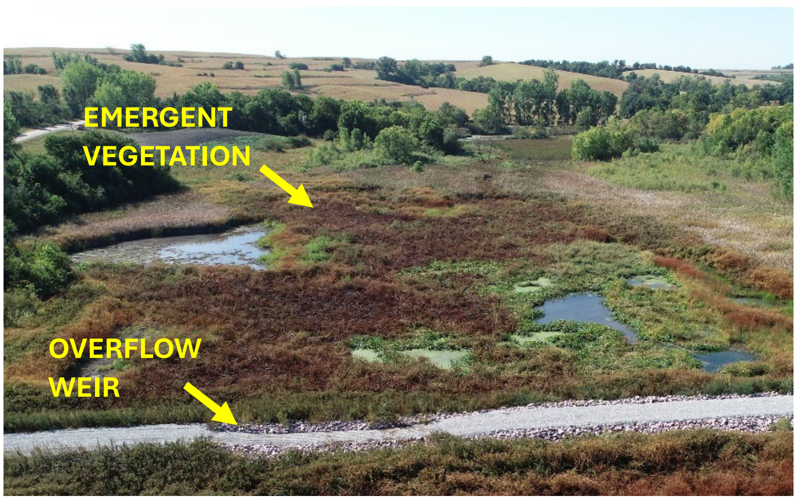

Figure 5.
In-Lake Treatment Wetland
at Summit Lake near Tekamah NE

<u>Reservoir Deepening – Step 4 of the Water Quality "Treatment Train"</u>

- As stated in the WQMP, sediment removal from Recharge Lake will reduce re-suspension, revive the lake's capacity to attenuate nutrients, and reduce in-lake phosphorus that is attached to sediment particles. Excavation to increase the storage capacity by 20%. This goal was identified in UBBNRDs 2018 plan for the recreation area.
- The WQMP, Alternative 1 identified an excavation volume of 62 ac-ft to achieve the 20% goal. Alternative 2 meets the 20% goal with a reduced volume of 55 ac-ft. The upstream BMPs in Alternative 2 reduce the open water surface area by 5.5 acres, which has the added benefit of increasing the average depth in Recharge Lake with less excavation.
- The BMP includes excavation to achieve a depth of >12ft in 25% of the reservoir, which improves the fishery through better over-winter survivability and water quality.
- Deep water excavation areas (6ft) are targeted in areas with highest sediment thickness.
- Shallow water excavation areas (4ft) target sediment accumulation in the upper reservoir.

- Draining of the reservoir to allow "dry-land" excavation, as compared to dredging, is recommended for cost considerations. This approach provides the added benefit of removing undesirable fish species such as carp, which are known to increase turbidity, resuspend phosphorous, and decrease native submerged aquatic vegetation while increasing algae. Additionally, the approach facilitates removal of invasive plant species.

Island Restoration

- Over time, the primary island within Recharge Lake has eroded away. The WQMP estimated that 60% of the island surface area has been lost to erosion. Shoreline protection measures associated with this BMP are described further below.
- The WQMP, Alternative 1 identified shoreline protection along the east side of the Island to protect against prevailing southeast summer and fall winds. Alternative 2 extends this protection around the island to facilitate placement of spoil material from the Reservoir Deepening BMP to reclaim the lost surface area.
- While this BMP was not evaluated for nutrient load reductions, it does provide a sediment reduction benefit.

Shoreline Protection Measures

- Using a combination of drone flight imagery and in-lake boat reconnaissance, TFG developed a shoreline inventory map (Exhibit 1). Shoreline was categorized as having either active erosion, marginal erosion with some vegetation, shallow vegetated stable slope or existing rock riprap protection.
- Alternative 2 shows recommended locations for shoreline protection measures. A wind rose analysis (Figure 6) was performed by TFG to calculate prevailing wind direction and identify locations for shoreline armoring and jetties (Figure 7). Jetties can be employed to reduce the lake fetch and wind-driven waves, thereby reducing shoreline erosion.

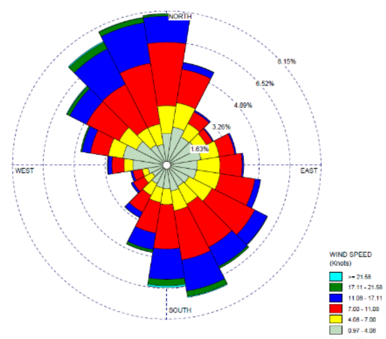

Figure 6. Wind Rose diagram for York AWDN Station (March to May)

- Protection measures include hard armoring with rock, block retaining wall and sheet-pile seawall. Softer measures include bio-stabilization through native planting revetments, which create living shorelines for aquatic habitat.
- Shoreline protection offers the opportunity to improve angler access to the lake. In many cases, these angler access improvements were located in proximity to selective reservoir deepening.

Figure 7. Shoreline Protection Measures at Conestoga Reservoir near Denton NE

<u>Aquatic Habitat Structures</u>

- Potential underwater aquatic habitat structures include rock piles, gravel spawning beds (Figure 8), log cribs / root pile (Figure 9), and mussel filtration beds water quality and fishery.
- Alternative 2 shows potential locations for aquatic habitat structures.

Figure 8. Gravel Spawning Bed. A combination of small riprap (Class A) and crushed limestone are placed in lake footprint adjacent to shoreline to block aquatic vegetation and provide fish habitat (photo from Summit Lake during lake drawdown).

Figure 9. Log Crib / Root Pile. Underwater "islands" were left in place as sediment was removed from around them. The photo also shows trees anchored with weights and cables to provide fish habitat features (photo above from Conestoga Reservoir during lake drawdown).

BMP Alternative Effectiveness

Effectiveness of BMP alternatives for trapping sediment and nutrients was considered in the WQMP. Trapping efficiency was based on EPA guidance for sediment basins and treatment wetlands, which is summarized in Table 2 below. These efficiencies are intended for watershed planning purposes on an average annual basis and do not account for site specific considerations such as BMP surface area, treatment volume, hydraulic length, etc.

Table 2. General BMP Trapping Efficiencies for Watershed Planning

BMP	Sediment	Total Phosphorus	Total Nitrogen
Sediment Basin	86%	69%	55%
Treatment Wetland	78%	44%	20%

Source: EPA STEPL

Two methods were employed to evaluate BMP trapping efficiency. Both methods utilize engineering procedures particle settling structure design. The first method evaluates the surface area and hydraulic length relative to depth to estimate hydraulic loading rate through the BMPs. The second method evaluates the storage volume and associated detention / retention times. Nitrogen is very mobile in surface water, while Phosphorus is held tightly to suspended clay and organic matter particles. Therefore, Nitrogen reductions were estimated based on the hydraulic loading rate and retention time through the BMPs, while Phosphorus reductions were estimated relative to sediment trapping. This evaluation results in a high to low range of trapping efficiency estimates, as shown in tables 3 and 4. For planning purposes, TFG recommends using the average result from the two methods.

The WQMP takes a "Treatment Train" approach to estimating the effectiveness of BMPs to improving water quality. Tables 3 and 4 replicate this approach for this study to evaluate the two alternatives. The first column provides the values estimated in the WQMP report for reference purposes. TFG deviated slightly from this approach to 1) account for the lack of Watershed BMPs that are not being adopted and 2) account for internal Phosphorus loads estimated for release from bottom sediments that occur downstream of the treatment train.

Reductions in Total Phosphorus (TP) were not able to achieve the WQMP water quality standard of 50ug/L using the recommended design-based estimates for either Alternative 1 or 2 (Table 3). Alternative 2 reduced TP concentration reductions to 129 ug/L, as compared to 173 ug/L under Alternative 1. The water quality standard is still not met under Alternative 1 when considering the potential TP concentration range of 96 to 250 ug/L. Alternative 2, however, is able to achieve the water quality standard within the potential TP concentration range of 46 to 212 ug/L.

Findings for Total Nitrogen (TN) reductions were similar to TP. Alternative 1 achieved an expected TN concentration of 1,419 ug/L (range 1,011 to 1,688 ug/L), which did not meet the WQMP water quality standard of 1,000 ug/L. Alternative 2 further reduced TN concentrations to 1,080 ug/L (range of 787 to 1,282 ug/L), which does include the water quality standard.

Table 3. Total Phosphorus (TP) Treatment Train Loading Assessment

Parameter	Units	WQMP	Alternative 1 WQMP Concept			Alternative 2 TFG Concept		
		Report	Low	Design	High	Low	Design	High
Total Watershed Load (External)	lbs/yr	32,235	31,335	31,335	31,335	31,335	31,335	31,335
Measured TP Concentration	ug/L	495						
Watershed BMPs								
Reduction in TP	lbs/yr	(11,449)						
Post BMP Load	lbs/yr	20,786						
Near Lake Detention Ponds								
Capture Rate	%	69%	35%	49%	64%	40%	56%	72%
Reduction in TP	lbs/yr	(14,342)	(10,985)	(15,491)	(19,996)	(12,404)	(17,549)	(22,695)
Post BMP Load	lbs/yr	6,444	20,350	15,844	11,339	18,931	13,786	8,640
Floating Treatment Wetlands								
Capture Rate	lb/sf					0.010	0.045	0.080
Area of FTW	sf					13,000	13,000	13,000
Reduction in TP	lbs/yr					(130)	(585)	(1,040)
Post BMP Load	lbs/yr					18,801	13,201	7,600
In-Lake Wetlands								
Capture Rate	%	44%	15%	26%	44%	22%	32%	55%
Reduction in TP	lbs/yr	(2,835)	(3,112)	(4,042)	(4,973)	(4,188)	(4,468)	(4,749)
Post BMP Load	lbs/yr	3,608	17,238	11,802	6,366	14,613	8,732	2,851
Reservoir Deepening								
Reduction in TP	lbs/yr	(3,248)	(3,248)	(3,248)	(3,248)	(3,248)	(3,248)	(3,248)
Internal TP Load	lbs/yr	-	900	900	900	900	900	900
Post BMP Load	lbs/yr	360	14,890	9,454	4,018	12,265	6,384	503
Expected TP Concentration	ug/L	44	250	173	96	212	129	46

Table 4. Total Nitrogen (TN) Treatment Train Loading Assessment

Parameter	Units	WQMP	Alternative 1 WQMP Concept			Alternative 2 TFG Concept		
		Report	Low	Design	High	Low	Design	High
Total Watershed Load (External)	lbs/yr	53,682	53,682	53,682	53,682	53,682	53,682	53,682
Measured TN Concentration	ug/L	2,180						
Watershed BMPs								
Reduction in TN	lbs/yr	(30,530)						
Post BMP Load	lbs/yr	23,152						
Near Lake Detention Ponds								
Capture Rate	%	55%	7%	19%	37%	11%	24%	42%
Reduction in TN	lbs/yr	(12,734)	(3,545)	(10,062)	(19,996)	(5,804)	(13,128)	(22,695)
Post BMP Load	lbs/yr	10,418	50,137	43,620	33,686	47,878	40,554	30,987
Floating Treatment Wetlands								
Capture Rate	lb/sf					0.05	0.15	0.25
Area of FTW	sf					13,000	13,000	13,000
Reduction in TN	lbs/yr					(650)	(1,950)	(3,250)
Post BMP Load	lbs/yr					47,228	38,604	27,737
In-Lake Wetlands								
Capture Rate	%	20%	17%	20%	26%	34%	35%	38%
Reduction in TN	lbs/yr	(2,084)	(8,603)	(8,748)	(8,893)	(16,392)	(14,055)	(11,719)
Post BMP Load	lbs/yr	8,335	41,534	34,872	24,793	31,486	26,498	19,269
Expected TN Concentration	ug/L	345	1,688	1,419	1,011	1,282	1,080	787

Note: The potential range in nutrient reductions (Low to High) are shown for each alternative. The average of this range is recommended for design purposes.

Planning Level Cost Estimates

Opinions of construction cost were developed for Alternatives 1 and 2 for planning purposes. Table 5 provides a summary of the costs for each BMP component. For comparison, the total phosphorus, nitrogen and sediment reductions are included to evaluate the potential benefits of each BMP.

Table 5. Relative Cost Comparison of BMP implementation for Alternatives 1 and 2. Total phosphorus (TP), nitrogen (TN), and sediment treatment reductions for BMPs are included.

BMP Component	Alternative 1 WQMP Concept				Alternative 2 TFG Concept			
	Cost	TP	TN	Sediment	Cost	TP	TN	Sediment
		lbs/yr	lbs/yr	tons/yr		lbs/yr	lbs/yr	tons/yr
Near Lake Detention Ponds	$869,000	(15,491)	(10,062)	(3,321)	$1,079,000	(17,549)	(13,128)	(3,762)
Floating Treatment Wetlands	-	-	-	-	$244,000	(585)	(1,950)	-
In-Lake Wetlands	$309,000	(4,042)	(8,748)	(656)	$309,000	(4,468)	(14,055)	(584)
Reservoir Deepening	$2,053,000	(3,248)	-	-	$1,821,000	(3,248)	-	-
Island Restoration[1]	$149,000				$149,000			
Shore-line Protection[2]	-				$648,000			
Aquatic Habitat Structures[3]	-				$65,000			
General Costs[4]	$338,000				$432,000			
Construction Cost Total 30% Contingency Total + Contingency[5]	$3,718,000 $1,115,000 $4,833,000	(22,781)	(18,810)	(88,746)	$4,747,000 $1,424,000 $6,171,000	(25,266)	(27,184)	(79,544)

1) *Island Restoration line-item cost is limited to shore-line protection only. Earthwork and seeding costs are accounted for under near lake detention ponds and reservoir deepening line items.*
2) *Shore-line Protection line item includes jetties and rock riprap shore-line armoring with a chip trail for angler access.*
3) *Aquatic Habitat Structure line item based on gravel / rock beds. Log structures and rubble piles generally use waste materials and have lower associated costs.*
4) *General Construction Costs include mobilization, erosion and sediment control, general site work, and haul road construction.*
5) *Typical engineering design cost is 10-12% and construction administration/observation is 5-7%.*

Alternative 2 represents the high-end cost estimate to achieve water quality goals, improve aquatic habitat, and enhance angler access. To meet project budgets based on available funding, this alternative can be scaled back. Table 5 is intended to help guide project budget planning by showing each BMPs impact on nutrient reductions. Below are additional planning considerations:

- Cost for reservoir deepening is scalable based on volume of sediment removed.
  - Excavation volume is 62 ac-ft for Alternative 1 and 55 ac-ft for Alternative 2.
- The design life of the near lake detention ponds before maintenance was estimated based on sediment accumulation versus available capacity.
  - Available capacity is 12 ac-ft for Alternative 1 and 16 ac-ft for Alternative 2.

  - The amount of time anticipated before first maintenance was estimated as 10 years for Alternative 1 and 18 years for Alternative 2, which accounts for accumulation in both the detention ponds and in-lake wetlands.
  - Subsequent maintenance periods are every 7 years for Alternative 1 and 12 years for Alternative 2.
  - Sediment accumulation amounts will fluctuate from year to year. Years with more precipitation will accumulate more sediment, while dry years will have less.

Water Level Management Recommendation

In discussions with UBBNRD staff, a higher quality fishery and better water clarity were observed when the reservoir conservation pool was managed at a higher elevation. Below are some potential benefits associated with groundwater pumping to maintain a higher conservation pool:

- Potential to reduce TSS and turbidity
- Added depth results in less turnover from wind
- Better aquatic habitat with deeper water