Water Quality Benefit Calculation for the Lake City Sprayfield Conversion Project

Prepared for

Suwannee River Water Management District

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Section 1.0 Introduction

1.1 Background

The Ichetucknee Springshed Water Quality Improvement Project (ISWQIP; Lake City Sprayfield Conversion Project) is a first of its kind, conversion of an existing wastewater spray irrigation site to a groundwater recharge wetland. Treated effluent from the City of Lake City's St. Margaret's Water Reclamation Facility (WRF) meets current effluent quality limitations. However, the WRF was identified as a potential source of nutrient loading to the Santa Fe River and the Lake City Wetland was implemented under the Santa Fe River Basin Management Action Plan (BMAP) to reduce regional total nitrogen (TN) loads while providing beneficial recharge to the Upper Floridan Aquifer (UFA) and the Ichetucknee Springs System.

Figure 1 shows the City's wastewater spray irrigation site prior to the wetland conversion project. The site was divided into three sprayfield zones (A = 168 ac; B = 93 ac; C = 68 ac). The Lake City Wetland was constructed in 2015-2016 with normal operations beginning in 2017. The wetland was constructed within the footprint of Sprayfield A on approximately 140 acres with 9 wetland cells (Figure 3) and approximately 121 acres of marsh area.

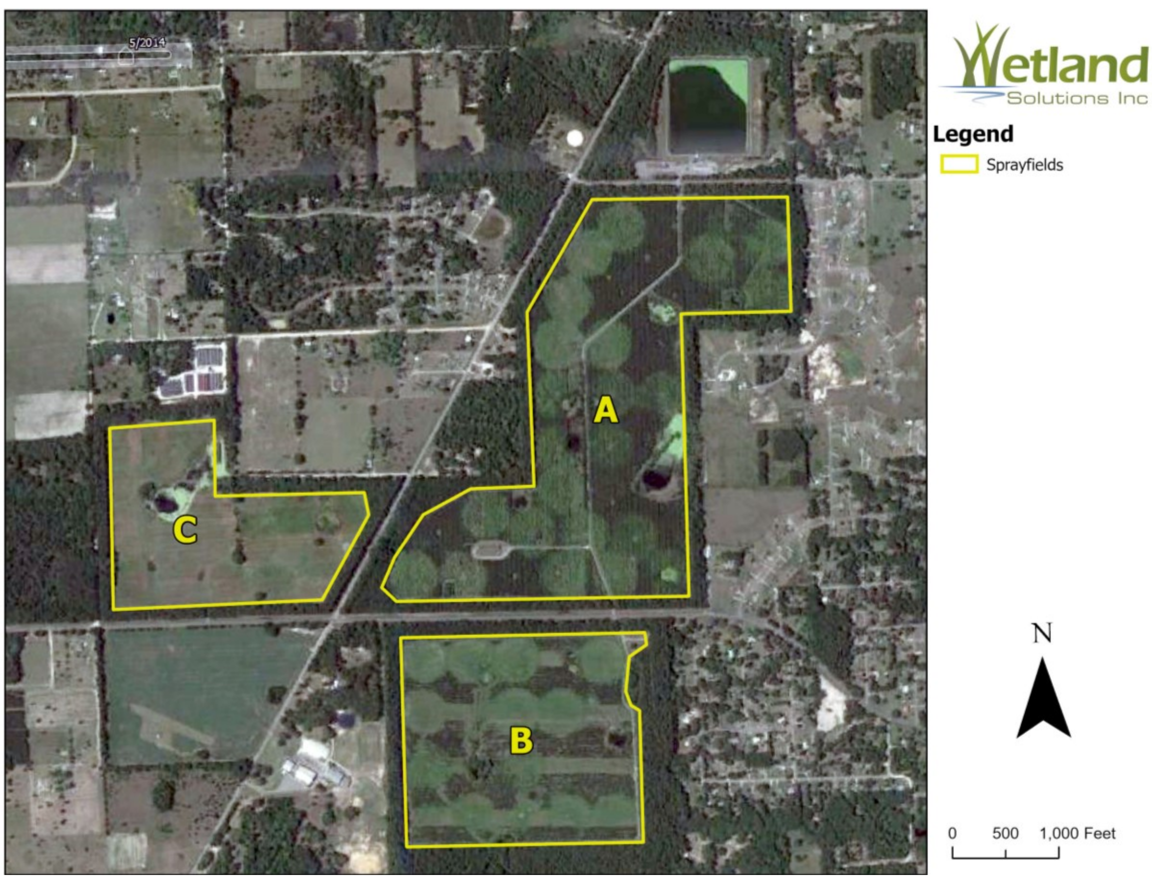


Figure 1. City of Lake City's Sprayfield (Pre-Project Sprayfields A, B, and C; Google Earth Imagery 2015)

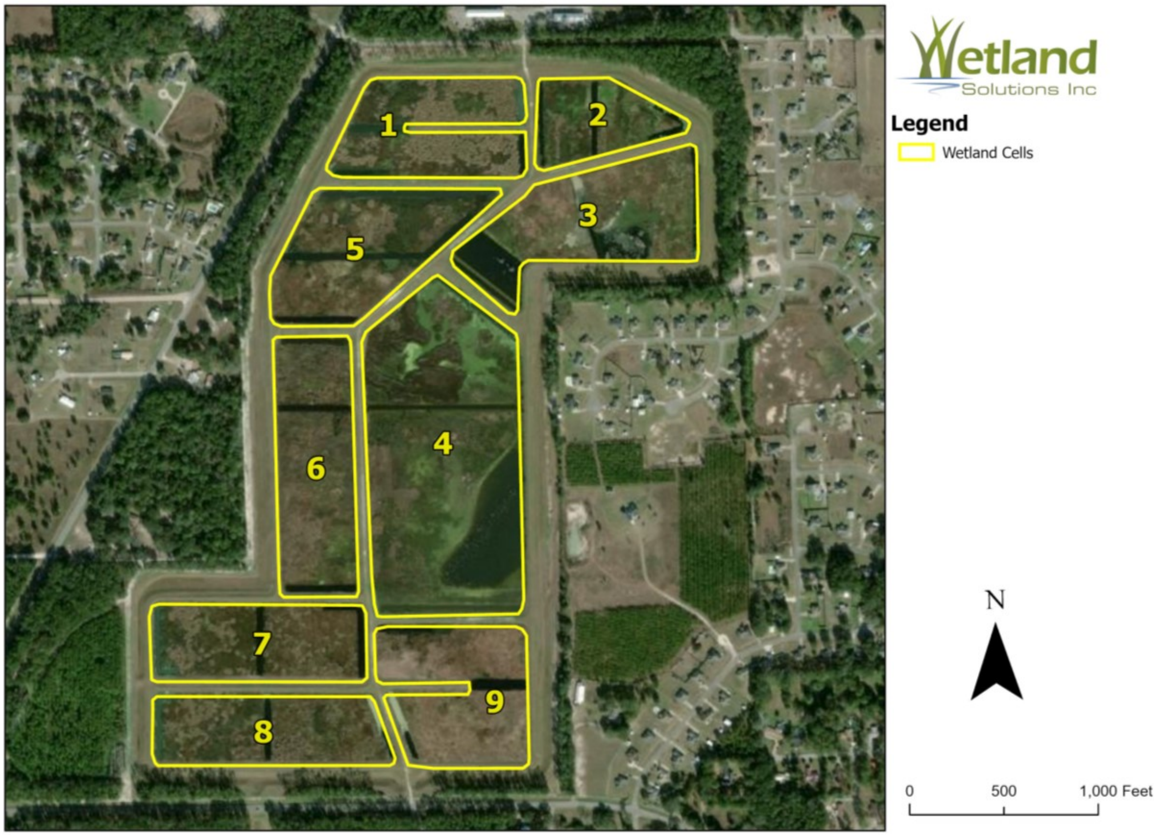


Figure 2. Lake City Wetland Site (Post-Project Converted Sprayfield A)

1.2 Purpose

The Suwannee River Water Management District (SRWMD) has completed Phase 1 of the project to convert a portion of the City's sprayfield to constructed treatment wetlands. The purpose of this report is to evaluate the City's operational data to determine estimates of pre- and post-project nutrient loading of both total nitrogen (TN) and total phosphorus (TP) and to calculate the net water quality benefit achieved by implementing this project. The pre- and post-project periods are identified below.

- Pre-Project 2013 – 2015
- Post-Project 2017 – 2019

Additionally, a Phase 2 project is currently being implemented to increase flow to the treatment wetlands and enhance recharge to the UFA. This report also estimates project water quality improvements expected for Phase 2 of this project at both current and at permitted flow rates.

Section 2.0 Methods

2.1 Data Sources

This section presents data sources and calculations used to determine the net water quality benefit associated with implementing the sprayfield to groundwater recharge wetland conversion project.

2.1.1 Effluent Discharge

Monthly pumping estimates to the sprayfields/wetland were calculated from daily totalizer readings logged by the City. Daily flows were divided between each sprayfield (A, B, and C) with flows estimated by proportionally distributing logged daily total flows across the irrigation laterals used by the City each day.

2.1.2 Effluent Water Quality

Monthly average TN and TP concentration data from St. Margaret's WRF (FLA113956) were obtained from the Florida Department of Environmental Protection (FDEP). Monitoring site number EFA-2, effluent from the onsite 45-million gallon (MG) lined reservoir prior to discharge to sprayfield, was used to estimate project inflow concentrations. Monthly TN and TP pumped mass loading estimates to each sprayfield were calculated using the following formula.

$$M_P = C \text{ x } V_P \text{ x } 8.345$$

where:

M_P = monthly TN and TP pumped mass loading (lbs)
C = monthly average EFA-2 TN and TP concentrations (mg/L)
V_P = monthly pumped totals (MG)

2.1.3 Weather Data

Daily rainfall data were obtained from the SRWMD Station 02322600[1]: Alligator Lake North (30.17694, -82.63167) approximately 4.6 miles northeast of the project site. Monthly rainfall additions to each sprayfield were calculated using the following formula.

$$V_{RF} = RF \text{ x } A \text{ x } 0.0272$$

where:

V_{RF} = monthly rainfall additions to each sprayfield (MG)
RF = monthly totals measured at the Alligator Lake North station (in)
A = sprayfield area (ac)

TN atmospheric deposition (wet and dry) was estimated from annual deposition maps developed by the National Atmospheric Deposition Program (NADP)[2] from 2013 to 2018. No 2019 deposition maps were published at the time of this report; therefore 2019 deposition was

[1] http://www.mysuwanneeriver.org/realtime/rain-levels.php
[2] http://nadp.slh.wisc.edu/committees/tdep/tdepmaps/

estimated using a linear regression between annual rainfall and deposition from 2013 to 2018 (r^2 = 0.734). Annual deposition to the project site was calculated using the following formula.

$$M_{ATN} = D_{TN} \text{ x A x } 0.8922$$

where:

M_{ATN} = TN atmospheric deposition to the project site (lbs)
D_{TN} = TN deposition to the project site estimated from the NADP (kg/ha)
A = site area (ac)

TN atmospheric deposition to each sprayfield was estimated by proportionally distributing annual totals by the sprayfield rainfall volumes calculated above.

TP atmospheric deposition to the site was estimated from wet and dry deposition data collected in Gainesville, Florida (Brezonik et al., 1983). Annual deposition to the project site was calculated using the following formula.

$$M_{ATP} = D_{TP} \ x \text{ A } x \ 0.0089$$

where:

M_{ATP} = TP atmospheric deposition to the project site (lbs)
D_{TP} = TP deposition to the project site estimate from the Gainesville station (mg/m^2)
A = site area (ac)

As with TN deposition, TP atmospheric deposition to each sprayfield was estimated by proportionally distributing annual totals by the sprayfield rainfall volumes calculated above.

Daily evapotranspiration (ET) data were obtained from the University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) Florida Automated Weather Network (FAWN) Suwanee Valley Agricultural Extension Center Live Oak Station[3] approximately 18 miles northwest of the project site. Monthly ET losses from each sprayfield were calculated using the following formula.

$$V_{ET} = \text{ET x A x } 0.0272$$

where:

V_{ET} = monthly ET losses from each sprayfield (MG)
ET = monthly ET totals measured at the Live Oak station (in)
A = sprayfield area (ac)

2.1.4 Nitrogen Source Inventory Loading Tool

Nutrient loading to the UFA was estimated based on the treatment assumptions applied as part of the Nitrogen Source Inventory Loading Tool (NSILT). NSILT is a GIS and spreadsheet-based tool, developed by FDEP, used to identify and quantify the major contributing nitrogen sources to groundwater. The Santa Fe River BMAP documents nitrogen attenuation estimates for different nitrogen source categories (FDEP, 2018). NSILT nitrogen attenuation estimates from this report were used in this study to estimate loading to the UFA and include the following:

- Atmospheric Deposition – 90% (range reported 85 – 95%)

[3] https://fawn.ifas.ufl.edu/data/reports/

- WWTF Sprayfield - 60% (range reported 50 – 75%)

The WWTF Sprayfield attenuation rate (60%) was also used on post wetland treatment mass outflows to estimate loading to the UFA.

NSILT was developed to assess nitrogen sources and no equivalent tool is available for phosphorus. TP attenuation for this report was estimated to be zero. This is based on recent research in North Florida characterizing phosphorus soil changes associated with sites that have received more than 25 years of waste water irrigation, which included the Lake City Sprayfields (Weinkam, 2015). This research concluded that long-term loading influenced phosphorus lability and three of the four fields studied observed leached P concentrations higher than the effluent applied.

2.1.5 Wetland Water Quality

For the post-project period, operational water quality monitoring data collected by WSI from each wetland outflow control structure, were used to calculate TN and TP mass removals from each wetland cell. Monthly TN and TP concentration data were available from February 2017 to September 2018; and quarterly from November 2018 to November 2019. Missing monthly data during the quarterly monitoring period were estimated using linear interpolation.

Monthly TN and TP mass outflows from each wetland cell were calculated using the following formula.

$$M_W = C \text{ x } V_I \text{ x } 8.345$$

where:

M_W = monthly TN and TP mass outflows from each wetland cell (lbs)
C = monthly TN and TP concentrations (mg/L)
V_I = monthly infiltration estimates discussed below (MG)

2.1.6 Infiltration Estimates

Monthly infiltration estimates to the UFA by sprayfield/wetland were calculated as the difference between inputs (pumped inflows and rainfall) and ET, using the following formula.

$$V_I = [V_P + V_{RF}] - V_{ET}$$

where:

V_I = infiltration (MG)
V_P = pumped inflows (MG)
V_{RF} = rainfall (MG)
V_{ET} = ET (MG)

Monthly infiltration from each wetland cell was estimated by proportionally distributing the wetland infiltration total, as calculated above, by the wetland cell area.

On occasion, there were months with limited or no pumped inflows to a sprayfield, resulting in a negative infiltration estimate. For these occurrences, the monthly infiltration was forced to zero.

2.2 Modeling Scenarios

A number of modeling scenarios were conducted to calculate the net water quality benefit achieved from implementing this sprayfield conversion project. Analyses were conducted for both the pre-project and post-project periods, under actual flow and projected permitted flow conditions. A summary of each modeling scenario is discussed below.

2.2.1 Pre-Project (2013 – 2015) Scenario – Sprayfields A, B, and C

An estimate of pre-project nutrient treatment was calculated for the individual sprayfields (A, B, and C) and for the entire site using 2013 to 2015 water quality and flow conditions.

2.2.2 Post-Project (2017 – 2019) Scenario 1A & 1B – Wetland / Sprayfields B and C

The post-project performance was conducted from 2017 to 2019 following Sprayfield A conversion to the Lake City Wetland. Nutrient treatment was summarized for the wetland, individual sprayfields (B and C), and overall site for the following flow conditions:

1A. actual flows – using actual pumped flows to the wetland and sprayfields (B and C)

1B. total permitted flows – total permitted flow conditions were assigned by using actual pumped flows to the wetland and proportionally increasing pumped flows to the sprayfields (B and C) to reach a three-year annual average of 3 MGD

2.2.3 Post-Project (2017 – 2019) Scenario 2 – Sprayfields A, B, and C

Water quality and flow conditions varied considerably between the pre-project and post-project periods. In order to evaluate treatment performance equally between the sprayfields and wetland, the post-project conditions were used to assess the performance of the original sprayfields, without the wetland conversion. To estimate pumped flows to each sprayfield, the average pre-project pumped flow proportions (A – 44%, B – 39%, and C – 17%) were used to adjust post-project monthly pumped flows in this scenario.

2.2.4 Post-Project (2017 – 2019) Scenario 3– Wetland

An additional scenario was developed to estimate nutrient loading to the UFA if all of the permitted flow capacity went through the wetland, at the current performance (the Phase 2 expansion). Permitted flow conditions were estimated by scaling up wetland monthly flows to meet a three-year annual average of 3 MGD.

Section 3.0 Results

3.1 Pre-Project/Post-Project Nutrient Treatment

Pre-project (Sprayfields A, B, and C) and post-project (Wetland/Sprayfield B and C - Scenario 1A) annual average water budget and nutrient treatment results for actual pumped inflows to the project site are provided in Table 1, Table 2, and Table 3.

Annual average total inflows to the project site were similar between the study periods, with 1,312 MG during pre-project and 1,257 MG during post-project periods (Table 1). Pumped inflows accounted for about 66% of the total site inflows and rainfall contributing about 34%. Average site infiltration was also similar with 953 MG and 932 MG (or 73% of average total outflow) during the pre- and post-project periods, respectively.

Table 1. Pre-Project (2013–2015) and Post-Project (2017–2019) Annual Average Water Budget

Parameter		Units	Pre-Project (2013-2015)		Post-Project (2017-2019)	
			Average (SE)		Average (SE)	
Inflow	Pump	MG	853	(± 35)	836	(± 18)
	Rainfall	in	51.4	(± 3.3)	51.5	(± 6.5)
		MG	459	(± 30)	420	(± 53)
	Total	MG	1,312	(± 64)	1,257	(± 71)
Outflow	ET	in	40.4	(± 0.2)	42.6	(± 0.3)
		MG	361	(± 1.5)	348	(± 2.6)
	Infiltration	MG	953	(± 63)	932	(± 59)
	Total	MG	1,313	(± 64)	1,280	(± 56)

Annual average nutrient (TN and TP) mass loading to the site (via EFA-2, reservoir) was substantially greater during the post-project period for both TN and TP (Table 2 and Table 3). Post-project TN mass loading was 38% higher than the pre-project period (difference 14,913 lbs/yr), while post-project TP mass loading was 26% higher (difference 3,713 lbs/yr). However, even though loadings were greater during the post-project period, post-project TN and TP mass removals were greater (TN – 78%; TP – 31%) with lower mass loading to the UFA (TN difference 3,497 lbs/yr; TP – difference 1,975 lbs/yr).

Table 2. Pre-Project (2013–2015) and Post-Project (2017–2019) Annual Average Total Nitrogen Treatment

Parameter		Units	Pre-Project (2013-2015) Average (SE)		Post-Project (2017-2019) Average (SE)	
Mass Inflow	EFA-2	mg/L	5.50	(± 1.16)	7.75	(± 1.62)
		lbs	39,166	(± 7,073)	54,080	(± 12,395)
	Atm. Deposition	lbs	2,223	(± 72)	1,962	(± 84)
	Total	lbs	41,390	(± 7,025)	56,042	(± 12,476)
		lbs/ac	126	(± 21)	186	(± 41)
Mass Outflow	Loading to UFA	lbs	15,889	(± 2,824)	12,392	(± 4,192)
		lbs/ac	48.3	(± 8.6)	41.2	(± 13.9)
	% of Input	%	38%	(± 0.3%)	22%	(± 2.9%)
Outflow	Conc. to UFA	mg/L	2.00	(± 0.45)	1.59	(± 0.45)
Mass Removal		lbs	25,501	(± 4,201)	43,650	(± 8,307)
		%	62%	(± 0.3%)	78%	(± 2.9%)

Table 3. Pre-Project (2013–2015) and Post-Project (2017–2019) Annual Average Total Phosphorus Treatment

Parameter		Units	Pre-Project (2013-2015) Average (SE)		Post-Project (2017-2019) Average (SE)	
Mass Inflow	EFA-2	mg/L	2.03	(± 0.32)	2.60	(± 0.28)
		lbs	14,460	(± 1,859)	18,173	(± 1,730)
	Atm. Deposition	lbs	170	(± 0)	156	(± 0)
	Total	lbs	14,630	(± 1,859)	18,328	(± 1,730)
		lbs/ac	44.5	(± 5.6)	61.0	(± 5.8)
Mass Outflow	Loading to UFA	lbs	14,630	(± 1,859)	12,655	(± 828)
		lbs/ac	44.5	(± 5.6)	42.1	(± 2.8)
	% of Input	%	100%	(± 0.0%)	69%	(± 4.7%)
Outflow	Conc. to UFA	mg/L	1.84	(± 0.32)	1.63	(± 0.13)
Mass Removal		lbs	0	(± 0)	5,673	(± 1,234)
		%	0%	(± 0%)	31%	(± 4.7%)

3.1.1 Pre-Project/Post-Project Nutrient Treatment – Sprayfield A / Wetland

The Lake City Wetland was only constructed within the footprint of Sprayfield A. To better understand the water quality benefit achieved with the sprayfield conversion, a comparison was conducted between only pre-project sprayfield A and the post-project wetland (Scenario 1A). Annual average water budget and nutrient treatment results for actual pumped inflows are provided in Table 4, Table 5, and Table 6.

Annual average total inflows to Sprayfield A / Wetland were substantially different between the study periods, with 608 MG during pre-project and 756 MG during post-project periods (Table

4). Pumped inflows were 61% of pre-project inflow totals and 74% of post-project totals. Average site infiltration was also greater during the post-project period with 423 MG (70% of total outflow) and 594 MG (79% of total outflow) during the pre- and post-project periods, respectively.

Table 4. Pre-Project (2013–2015) and Post-Project (2017–2019) Annual Average Water Budget for Sprayfield A / Wetland

Parameter		Units	Pre-Project (2013-2015) Average (SE)		Post-Project (2017-2019) Average (SE)	
Inflow	Pump	MG	373	(± 18)	561	(± 87)
	Rainfall	in	51.4	(± 3.3)	51.5	(± 6.5)
		MG	234	(± 15)	195	(± 25)
	Total	MG	608	(± 33)	756	(± 64)
Outflow	ET	in	40.4	(± 0.2)	42.6	(± 0.3)
		MG	184	(± 0.8)	162	(± 1.2)
	Infiltration	MG	423	(± 33)	594	(± 63)
	Total	MG	608	(± 33)	756	(± 64)

Annual average nutrient (TN and TP) mass loading to the site (via EFA-2, reservoir) was substantially greater during the post-project period for both TN and TP (Table 5 and Table 6). Post-project TN mass loading was 102% higher than the pre-project period (difference 17,268 lbs/yr), while post-project TP mass loading was 100% higher (difference 6,231 lbs/yr). However, even though loadings were greater during the post-project period, post-project TN and TP mass removals were greater (TN – 88%; TP – 45%) with lower mass loading to the UFA (TN difference 2,552 lbs/yr; TP – difference 543 lbs/yr).

Table 5. Pre-Project (2013–2015) and Post-Project (2017–2019) Annual Average Total Nitrogen Treatment for Sprayfield A / Wetland

Parameter		Units	Pre-Project (2013-2015) Average (SE)		Post-Project (2017-2019) Average (SE)	
Mass Inflow	EFA-2	mg/L	5.50	(± 1.16)	7.75	(± 1.62)
		lbs	16,868	(± 2,942)	34,136	(± 3,332)
	Atm. Deposition	lbs	1,135	(± 37)	911	(± 39)
	Total	lbs	18,003	(± 2,918)	35,047	(± 3,371)
		lbs/ac	107	(± 17)	251	(± 24)
Mass Outflow	Loading to UFA	lbs	6,861	(± 1,174)	4,309	(± 472)
		lbs/ac	40.8	(± 7.0)	30.9	(± 3.4)
	% of Input	%	38%	(± 0.3%)	12%	(± 0.2%)
Outflow	Conc. to UFA	mg/L	1.94	(± 0.44)	0.87	(± 0.19)
Mass Removal		lbs	11,143	(± 1,744)	30,738	(± 2,900)
		%	62%	(± 0.3%)	88%	(± 0.2%)

Table 6. Pre-Project (2013–2015) and Post-Project (2017–2019) Annual Average Total Phosphorus Treatment for Sprayfield A / Wetland

Parameter		Units	Pre-Project (2013-2015) Average (SE)		Post-Project (2017-2019) Average (SE)	
Mass Inflow	EFA-2	mg/L	2.03	(± 0.32)	2.60	(± 0.28)
		lbs	6,241	(± 784)	12,473	(± 2,699)
	Atm. Deposition	lbs	87	(± 0)	72	(± 0)
	Total	lbs	6,328	(± 784)	12,545	(± 2,699)
		lbs/ac	37.7	(± 4.7)	89.8	(± 19.3)
Mass Outflow	Loading to UFA	lbs	6,328	(± 784)	6,872	(± 1,471)
		lbs/ac	37.7	(± 4.7)	49.2	(± 10.5)
	% of Input	%	100%	(± 0.0%)	55%	(± 0.7%)
Outflow	Conc. to UFA	mg/L	1.79	(± 0.31)	1.39	(± 0.16)
Mass Removal		lbs	0	(± 0)	5,673	(± 1,234)
		%	0%	(± 0.0%)	45%	(± 0.7%)

A water quality benefit was observed following the sprayfield conversion project. However, the large differences between pre- and post-project inflows and water quality make direct comparisons difficult. In order to evaluate treatment performance equally additional assessments were conducted below (Section 3.2).

3.2 Sprayfield Nutrient Treatment during Post-Project Conditions

Due to the water quality and flow variability between the pre-project (2013–2015) and post-project (2017–2019) periods, the post-project conditions were used to assess nutrient treatment using only the original sprayfields (A, B, and C), without the wetland conversion (Scenario 2). Annual average water budget and nutrient treatment performance for the sprayfields during post-project conditions are provided in Table 7 and Table 8.

As expected, the sprayfield water budget under post-project conditions (Table 7) is very similar to the post-project water budget presented in Table 1. The slight variations in rainfall, ET, and infiltration are due to the project area differences between Sprayfield A (168 ac) and the wetland footprint (140 ac). Annual average total inflows to the project site were 1,296 MG (pumped inflows 65% and rainfall 35% of total inflow) with an average site infiltration of 916 MG (71% of total outflow).

Table 7. Annual Average Water Budget for Sprayfields with Post-Project (2017-2019) Conditions

Parameter		Units	Post-Project (Sprayfields)	
			Average (SE)	
Inflow	Pump	MG	836	(± 18)
	Rainfall	in	51.5	(± 6.5)
		MG	460	(± 58)
	Total	MG	1,296	(± 76)
Outflow	ET	in	42.6	(± 0.3)
		MG	381	(± 2.8)
	Infiltration	MG	916	(± 78)
	Total	MG	1,296	(± 76)

Table 8. Annual Average Nutrient Treatment for Sprayfields with Post-Project (2017-2019) Conditions

Parameter		Units	TN		TP	
			Average (SE)		Average (SE)	
Mass Inflow	EFA-2	mg/L	7.75	(± 1.62)	2.60	(± 0.28)
		lbs	54,080	(± 12,395)	18,173	(± 1,730)
	Atm. Deposition	lbs	2,147	(± 92)	170	(± 0)
	Total	lbs	56,227	(± 12,483)	18,343	(± 1,730)
		lbs/ac	171	(± 38)	55.8	(± 5.3)
Mass Outflow	Loading to UFA	lbs	21,847	(± 4,967)	18,343	(± 1,730)
		lbs/ac	66.4	(± 15.1)	55.8	(± 5.3)
	% of Input	%	39%	(± 0.3%)	100%	(± 0.0%)
Outflow	Conc. to UFA	mg/L	2.86	(± 0.43)	2.40	(± 0.37)
Mass Removal		lbs	34,380	(± 7,517)	0	(± 0%)
		%	61%	(± 0.3%)	0%	(± 0%)

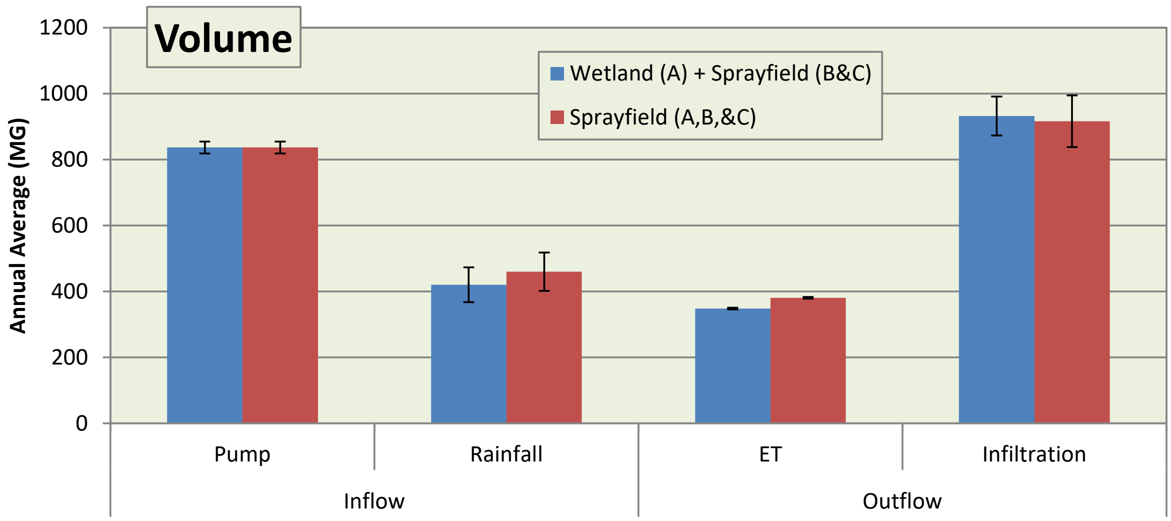
Figure 3 provides a summary of the site nutrient treatment performance with and without sprayfield conversion, during post-project water quality and flow conditions. The difference between mass loadings to the UFA defines the net water quality benefit achieved from implementing this project and are summarized below.

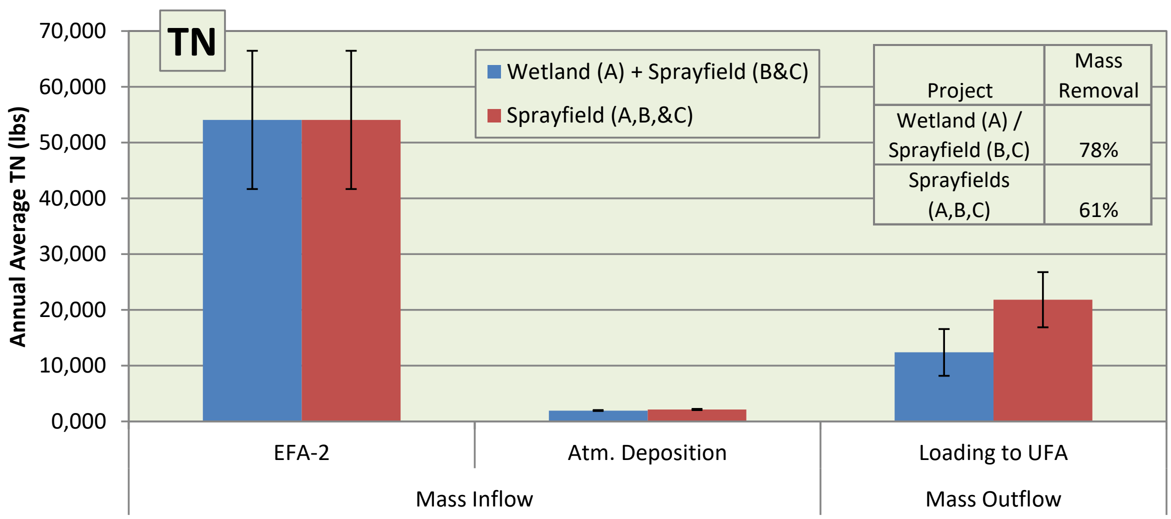
<u>Average TN Mass Loading to UFA</u>

- Sprayfield (A, B, C) = 21,847 lbs/yr (61% mass removal)
- Wetland (A) + Sprayfield (B, C) = 12,392 lbs/yr (78% mass removal)
- Water Quality Benefit = 9,455 lbs/yr

<u>Average TP Mass Loading to UFA</u>

- Sprayfield (A, B, C) = 18,343 lbs/yr (0% mass removal)
- Wetland (A) + Sprayfield (B, C) = 12,655 lbs/yr (31% mass removal)
- Water Quality Benefit = 5,688 lbs/yr





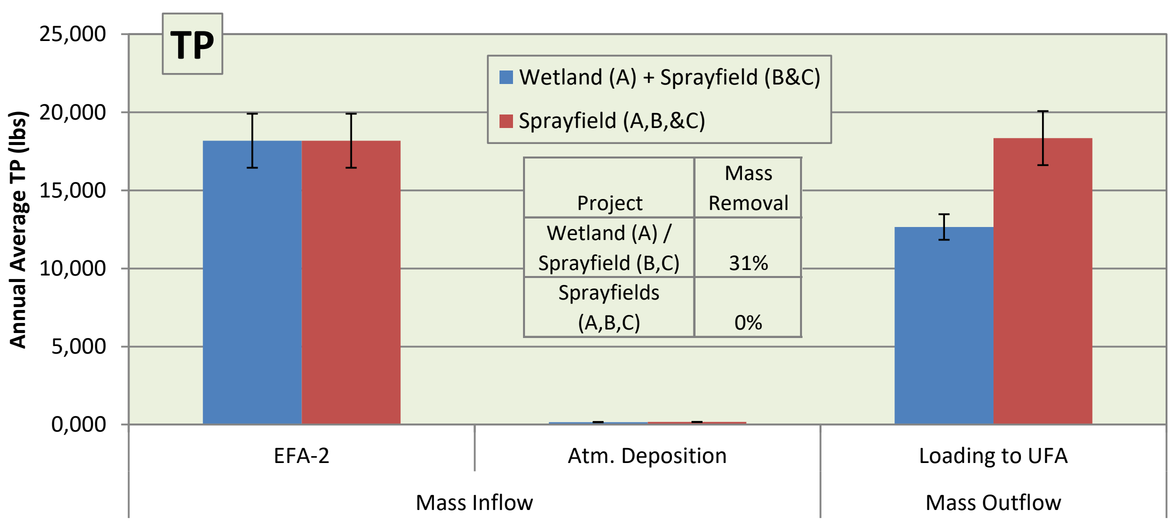


Figure 3. Post-Project (2017-2019) Annual Average Water Budget and Nutrient Treatment with and without Sprayfield Conversion Project

3.3 Post-Project Nutrient Treatment at Permitted Flow

Post-project (Wetland/Sprayfield B and C - Scenario 1B) annual average water budget and nutrient treatment results for permitted pumped inflows are provided in Table 9 and Table 10. Total permitted flow conditions were estimated by using 2017-2019 actual pumped flows to the wetland and proportionally increasing pumped flows to sprayfields (B and C) to reach a three-year annual average of 3 MGD.

Annual average total inflows to the project site were 1,515 MG (pumped inflows 72% and rainfall 28% of total inflow) with an average site infiltration of 1,188 MG (77% of total outflow).

Table 9. Post-Project (Permitted Flow) Annual Average Water Budget

Parameter		Units	Post-Project (Permitted Flow) Average (SE)	
Inflow	Pump	MG	1,095	(± 115)
	Rainfall	in	51.5	(± 6.5)
		MG	420	(± 53)
	Total	MG	1,515	(± 166)
Outflow	ET	in	42.6	(± 0.3)
		MG	348	(± 2.6)
	Infiltration	MG	1,188	(± 157)
	Total	MG	1,536	(± 154)

Table 10. Post-Project (Permitted Flow) Annual Average Nutrient Treatment

Parameter		Units	TN Average (SE)		TP Average (SE)	
Mass Inflow	EFA-2	mg/L	7.97	(± 1.55)	2.57	(± 0.30)
		lbs	72,793	(± 21,170)	23,521	(± 1,741)
	Atm. Deposition	lbs	1,962	(± 84)	156	(± 0)
	Total	lbs	74,755	(± 21,250)	23,677	(± 1,741)
		lbs/ac	249	(± 71)	78.8	(± 5.8)
Mass Outflow	Loading to UFA	lbs	19,877	(± 7,719)	18,003	(± 1834)
		lbs/ac	66.1	(± 25.7)	59.9	(± 6.1)
	% of Input	%	27%	(± 3.5%)	76%	(± 5.4%)
Outflow	Conc. to UFA	mg/L	2.01	(± 0.54)	1.82	(± 0.16)
Mass Removal		lbs	54,878	(± 13,548)	5,673	(± 1,234)
		%	73%	(± 3.5%)	24%	(± 5.4%)

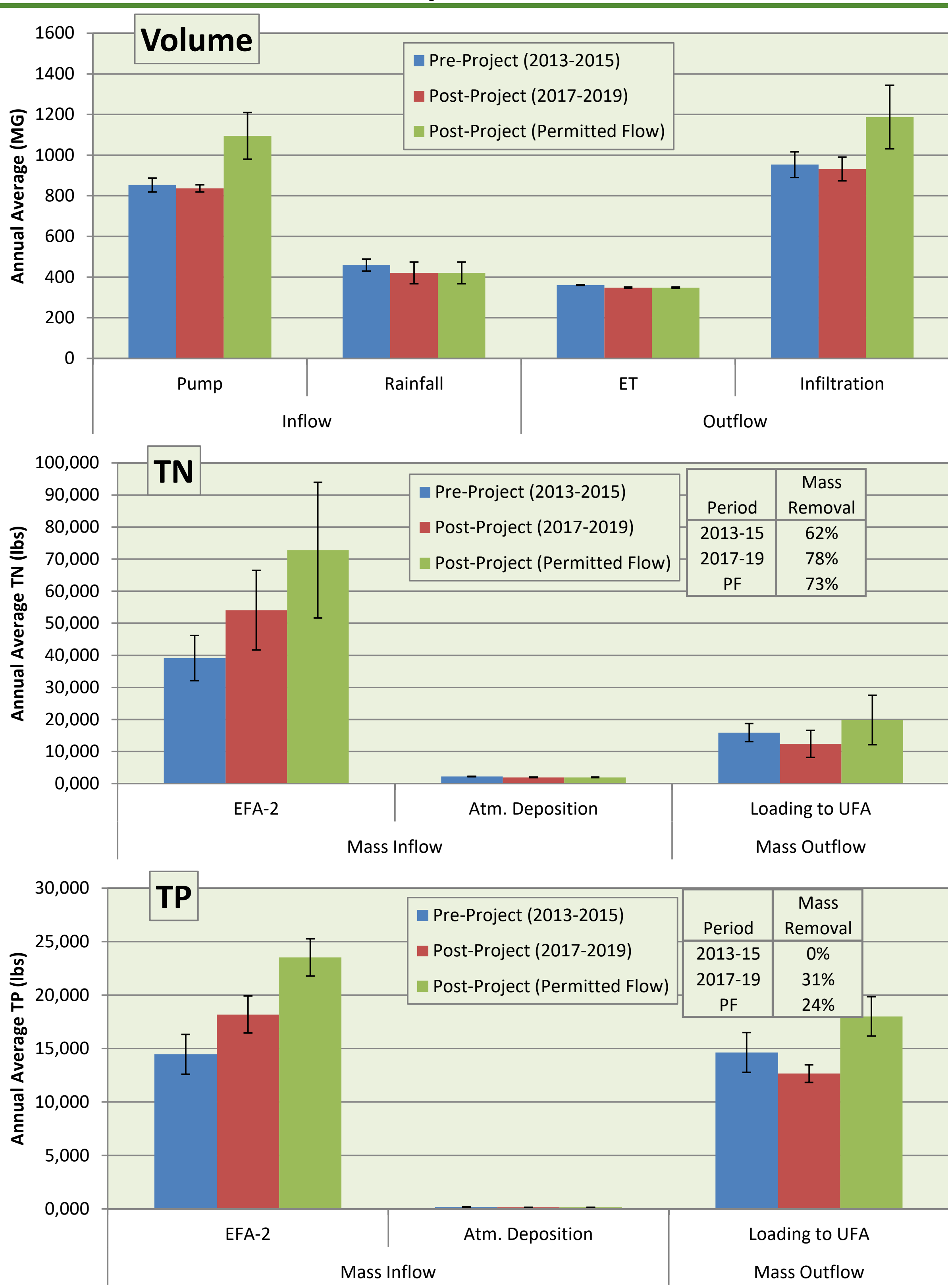


Figure 4. Pre-Project (2013-2015) and Post-Project (2017-2019 and Permitted Flow) Annual Average Water Budget and Nutrient Treatment

Figure 4 provides a comparison of the site annual average water budget and nutrient treatment performance between the Pre-Project and the Post-Project periods, both at current and at permitted flows. At permitted flow conditions, average pumped site inflows increased about 259 MG (31%) relative to current post-project conditions, resulting in a 27% (256 MG) increase in infiltration. Post-project pumped nutrient loadings increased by 35% (18,713 lbs/yr) and 29% (5,348 lbs/yr) for TN and TP, respectively. Post-project TN and TP loading to the UFA also increased by 60% (7,485 lbs/yr) and 42% (5,348 lbs/yr), between current and permitted flow conditions.

3.4 Wetland Nutrient Treatment at Permitted Flow

An analysis was conducted to estimate nutrient loading to the UFA if all of the permitted flow capacity went through the wetland (Scenario 3), at the current post-project performance (2017-2019). Permitted flow conditions were estimated by scaling up wetland monthly flows to meet a three-year annual average of 3 MGD. The annual average water budget and nutrient treatment results are provided in Table 11 and Table 12.

Annual average total inflows to the project site were 1,290 MG (pumped inflows 85% and rainfall 15% of total inflow) with an average site infiltration of 1,129 MG (87% of total outflow).

Table 11. Wetland (Permitted Flow) Annual Average Water Budget

Parameter		Units	Wetland (Permitted Flow)	
			Average (SE)	
Inflow	Pump	MG	1,095	(± 169)
	Rainfall	in	51.5	(± 6.5)
		MG	195	(± 25)
	Total	MG	1,290	(± 146)
Outflow	ET	in	42.6	(± 0.3)
		MG	162	(± 1.2)
	Infiltration	MG	1,129	(± 145)
	Total	MG	1,290	(± 146)

Table 12. Wetland (Permitted Flow) Annual Average Nutrient Treatment

Parameter		Units	TN		TP	
			Average (SE)		Average (SE)	
Mass Inflow	EFA-2	mg/L	7.29	(± 1.91)	2.67	(± 0.22)
		lbs	66,660	(± 6,507)	24,357	(± 5,271)
	Atm. Deposition	lbs	911	(± 39)	72	(± 0)
	Total	lbs	67,571	(± 6,546)	24,429	(± 5,271)
		lbs/ac	484	(± 47)	175	(± 38)
Mass Outflow	Loading to UFA	lbs	8,115	(± 713)	13,140	(± 3,038)
		lbs/ac	58.1	(± 5.1)	94.1	(± 21.8)
	% of Input	%	12%	(± 0.1%)	54%	(± 1.5%)
Outflow	Conc. to UFA	mg/L	0.86	(± 0.19)	1.39	(± 0.16)
Mass Removal		lbs	59,456	(± 5,833)	11,289	(± 2,292)
		%	88%	(± 0.1%)	46%	(± 1.5%)

Figure 5 provides a comparison of the annual average water budget and nutrient treatment performance between the pre-project (sprayfield A) and the post-project (wetland) periods, both at current and at permitted flows. At permitted flow conditions, average pumped site inflows increased about 534 MG (95%) relative to current post-project conditions, resulting in a 90% (534 MG) increase in infiltration. Post-project pumped nutrient loadings also increased by 95% (32,524 lbs/yr) and 95% (11,884 lbs/yr) for TN and TP, respectively. Post-project TN and TP loading to the UFA increased by 88% (3,806 lbs/yr) and 91% (6,268 lbs/yr), between current and permitted flow conditions.

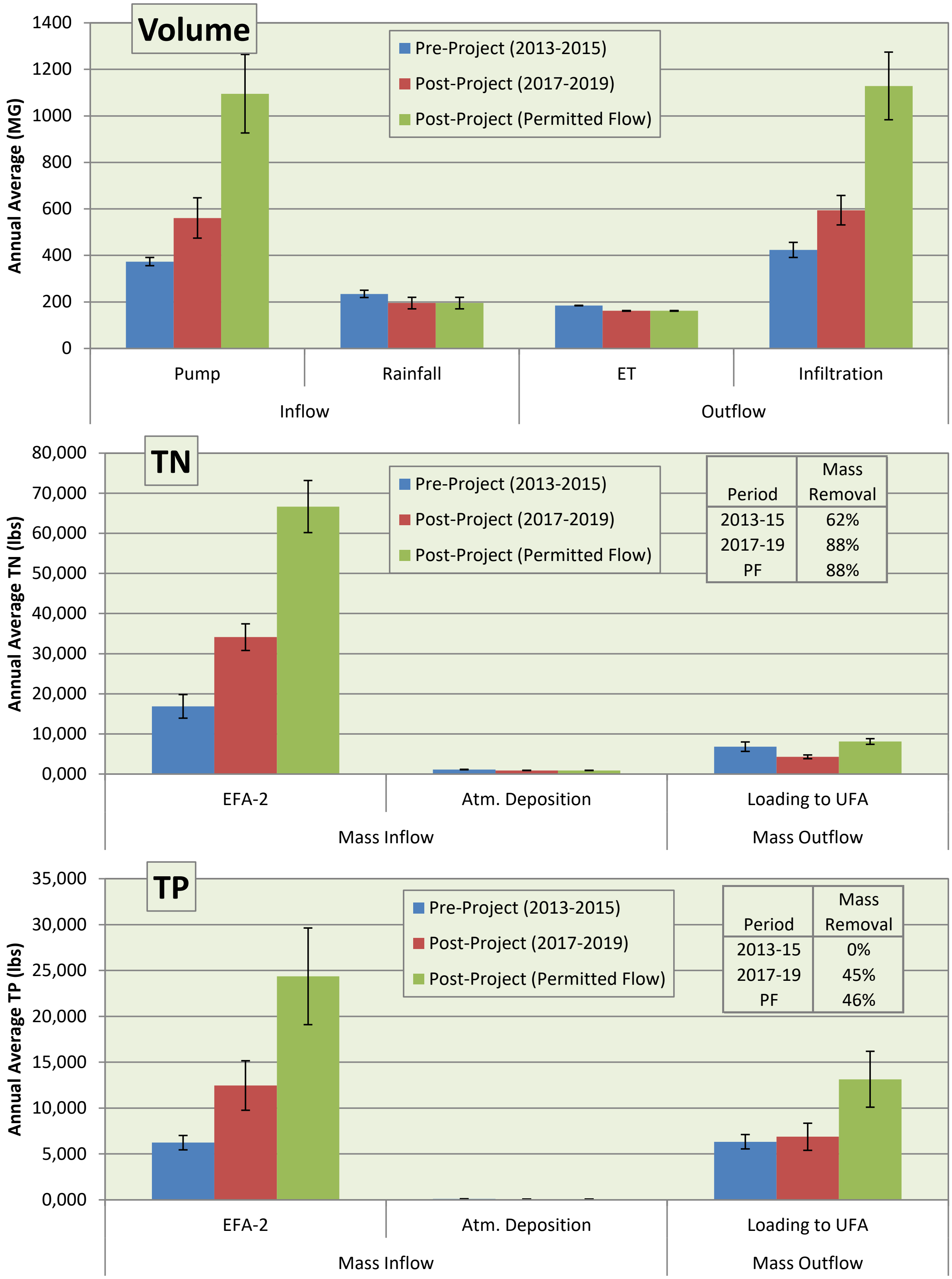


Figure 5. Pre-Project (2013-2015) Sprayfield A and Post-Project (2017-2019 and Permitted Flow) Wetland Annual Average Water Budget and Nutrient Treatment

Section 4.0 Summary and Conclusions

This analysis evaluated the water quality improvement resulting from conversion of one of the City of Lake City's sprayfields to a groundwater recharge wetland. The evaluation specifically compares the sprayfield performance to the wetland performance based on a variety of scenarios. Each of the evaluated scenarios consistently shows that the wetland provides more nutrient removal than the sprayfield it replaced. However, the magnitude of the removal is difficult to quantify in the pre- versus post-project period because of multiple changing variables including both flow and water quality. Because this evaluation relied on an assumed nutrient removal for total nitrogen for the sprayfield of 60% from the NSILT model, the treatment efficiency of the sprayfield cannot change in response to variable surface mass loading rates or chemical forms, which is contrary to the way that both active and passive water quality treatment systems function. For this study, this limitation was used to make a simplification for comparison of the pre- to post-project period by using the pre-project operations and treatment performance from NSILT with the post-project water quality, flow, and weather conditions to estimate a without project condition for the 2017-19 data.

A key recommendation of this study would be that for future water quality evaluations, when possible, post-project input data (weather, water quality, and flow) and pre-project operations and performance data (flow splits and removal efficiencies) should be used to calculate a without project performance estimate for comparison, rather than a pre- versus post-project comparison. This approach results in a more relevant comparison of treatment with a fewer number of variables.

For this study, a comparison of the sprayfield performance based on post-project conditions and the measured wetland performance resulted in a 9,455 pound per year increase in TN removal and a 5,688 pound per year increase in TP removal. Additionally, there was an estimated recharge increase of 188 million gallons per year on the area converted to wetland. With a project cost of approximately $5.3 million, this results in a cost-effectiveness over 20 years of $28 per pound for TN, $47 for TP, and $1.40 per 1,000 gallons of recharge.

By applying a combination of the methods discussed here, with a robust post-project sampling protocol, performance estimates can be developed for funded water quality and water quantity projects. These estimates provide the District with an improved understanding of actual project and technology performance and can be used to ensure that the most beneficial projects are preferentially funded. These estimates can also be used to more accurately define the benefits of these projects to the natural systems they are implemented to support.

Section 5.0 References

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Appendix A

Annual Nutrient Treatment Summaries

LAKE CITY SPRAYFIELD NUTRIENT TREATMENT SUMMARY – PROJECT SITE

Pre-Project Scenario / Post-Project Sprayfield Conversion (Scenario 1A) / Post-Project Sprayfield Conversion at Permitted Flow Capacity (Scenario 1B)

Parameter			Units	Pre-Project					Post-Project					Post-Project (Permitted Flow)				
				2013 - 2015		Annual			2017 - 2019		Annual			2017 - 2019 [a]		Annual [a]		
				Total	Average	2013	2014	2015	Total	Average	2017	2018	2019	Total	Average	2017	2018	2019
Water Budget	Inflow	Pump	MG	2,560	853	819	922	819	2,509	836	865	841	804	3,285	1,095	1,300	1,080	904
		Rainfall	in	154	51.4	48.4	58.1	47.7	154	51.5	60.8	54.7	39.0	154	51.5	60.8	54.7	39.0
			MG	1,377	459	432	519	426	1,261	420	497	446	318	1,261	420	497	446	318
		Total	MG	3,937	1,312	1,251	1,441	1,245	3,770	1,257	1,361	1,287	1,122	4,546	1,515	1,797	1,526	1,223
	Outflow	ET	in	121	40.4	40.4	40.6	40.0	128	42.6	42.3	42.3	43.3	128	42.6	42.3	42.3	43.3
			MG	1,082	361	361	363	358	1,044	348	345	346	353	1,044	348	345	346	353
		Infiltration	MG	2,859	953	890	1,078	891	2,795	932	1,024	949	822	3,563	1,188	1,458	1,189	0,916
		Total	MG	3,940	1,313	1,251	1,441	1,248	3,839	1,280	1,369	1,295	1,175	4,607	1,536	1,803	1,534	1,269
Total Nitrogen	Mass Inflow	EFA-2	mg/L	5.50	5.50	7.73	3.77	5.22	7.75	7.75	10.4	7.92	4.76	7.97	7.97	10.1	8.09	4.78
			lbs	117,499	39,166	52,790	29,058	35,651	162,239	54,080	74,764	55,570	31,905	218,380	72,793	109,386	72,943	36,051
		Atm. Deposition	lbs	6,670	2,223	2,160	2,366	2,144	5,885	1,962	2,075	2,013	1,798	5,885	1,962	2,075	2,013	1,798
		Total	lbs	124,169	41,390	54,950	31,424	37,795	168,125	56,042	76,838	57,583	33,704	224,265	74,755	111,460	74,956	37,849
			lbs/ac	377	126	167	95.5	115	559	186	256	192	112	746	249	371	249	126
	Mass Outflow	Loading to UFA	lbs	47,667	15,889	21,332	11,860	14,475	37,175	12,392	19,755	12,182	5,238	59,631	19,877	33,604	19,131	6,896
			lbs/ac	145	48.3	64.8	36.0	44.0	124	41.2	65.7	40.5	17.4	198	66.1	111.8	63.6	22.9
		% of Input	%	38%	38%	39%	38%	38%	22%	22%	26%	21%	16%	27%	27%	30%	26%	18%
	Outflow	Conc. to UFA	mg/L	2.00	2.00	2.87	1.32	1.95	1.59	1.59	2.31	1.54	0.76	2.01	2.01	2.76	1.93	0.90
	Mass Removal		lbs	76,502	25,501	33,618	19,564	23,320	130,950	43,650	57,084	45,401	28,466	164,634	54,878	77,857	55,824	30,953
			%	62%	62%	61%	62%	62%	78%	78%	74%	79%	84%	73%	73%	70%	74%	82%
Total Phosphorus	Mass Inflow	EFA-2	mg/L	2.03	2.03	2.66	1.61	1.88	2.60	2.60	2.06	2.95	2.83	2.57	2.57	2.02	2.99	2.86
			lbs	43,379	14,460	18,166	12,361	12,852	54,518	18,173	14,845	20,658	19,015	70,563	23,521	21,972	26,997	21,595
		Atm. Deposition	lbs	511	170	170	170	170	467	156	156	156	156	467	156	156	156	156
		Total	lbs	43,890	14,630	18,337	12,531	13,022	54,985	18,328	15,001	20,814	19,171	71,030	23,677	22,127	27,152	21,750
			lbs/ac	133	44.5	55.7	38.1	39.6	183	61.0	49.9	69.2	63.8	236	78.8	73.6	90.3	72.3
	Mass Outflow	Loading to UFA	lbs	43,890	14,630	18,337	12,531	13,022	37,965	12,655	11,756	14,308	11,901	54,010	18,003	18,883	20,647	14,480
			lbs/ac	133	44.5	55.7	38.1	39.6	126	42.1	39.1	47.6	39.6	180	59.9	62.8	68.7	48.2
		% of Input	%	100%	100%	100%	100%	100%	69%	69%	78%	69%	62%	76%	76%	85%	76%	67%
	Outflow	Conc. to UFA	mg/L	1.84	1.84	2.47	1.39	1.75	1.63	1.63	1.38	1.81	1.73	1.82	1.82	1.55	2.08	1.89
	Mass Removal		lbs	0	0	0	0	0	17,020	5,673	3,244	6,506	7,270	17,020	5,673	3,244	6,506	7,270
			%	0%	0%	0%	0%	0%	31%	31%	22%	31%	38%	24%	24%	15%	24%	33%

[a] Permitted flow conditions estimated by scaling up sprayfield (Field B & C) monthly flows to meet an annual average of 3 MGD

LAKE CITY SPRAYFIELD NUTRIENT TREATMENT SUMMARY – SPRAYFIELD A / WETLAND

Pre-Project Scenario / Post-Project Sprayfield Conversion (Scenario 1A) / Post-Project Sprayfield Conversion at Permitted Flow Capacity (Scenario 3)

Parameter			Units	Pre-Project					Post-Project					Post-Project (Permitted Flow)				
				2013 - 2015		Annual			2017 - 2019		Annual			2017 - 2019 [a]		Annual [a]		
				Total	Average	2013	2014	2015	Total	Average	2017	2018	2019	Total	Average	2017	2018	2019
Water Budget	Inflow	Pump	MG	1,119	373	354	409	356	1,682	561	400	585	697	3,285	1,095	782	1,143	1,361
		Rainfall	in	154	51.4	48.4	58.1	47.7	154	51.5	60.8	54.7	39.0	154	51.5	60.8	54.7	39.0
			MG	703	234	221	265	218	586	195	231	207	148	586	195	231	207	148
		Total	MG	1,823	608	575	674	574	2,268	756	631	792	845	3,871	1,290	1,012	1,350	1,509
	Outflow	ET	in	121	40.4	40.4	40.6	40.0	128	42.6	42.3	42.3	43.3	128	42.6	42.3	42.3	43.3
			MG	552	184	185	185	183	485	162	160	160	164	485	162	160	160	164
		Infiltration	MG	1,270	423	390	489	391	1,783	594	471	632	681	3,386	1,129	852	1,189	1,345
		Total	MG	1,823	608	575	674	574	2,268	756	631	792	845	3,871	1,290	1,012	1,350	1,509
Total Nitrogen	Mass Inflow	EFA-2	mg/L	5.50	5.50	7.73	3.77	5.22	7.75	7.75	10.4	7.92	4.76	7.29	7.29	11.3	7.59	4.73
			lbs	50,604	16,868	22,573	12,770	15,261	102,408	34,136	37,866	37,055	27,488	199,979	66,660	73,943	72,360	53,677
		Atm. Deposition	lbs	3,406	1,135	1,103	1,208	1,095	2,734	911	964	935	835	2,734	911	964	935	835
		Total	lbs	54,010	18,003	23,676	13,978	16,356	105,142	35,047	38,829	37,990	28,323	202,713	67,571	74,906	73,294	54,512
			lbs/ac	321	107	141	83.2	97.4	753	251	278	272	203	1,452	484	536	525	390
	Mass Outflow	Loading to UFA	lbs	20,582	6,861	9,139	5,229	6,214	12,927	4,309	4,884	4,668	3,374	24,346	8,115	8,886	8,769	6,691
			lbs/ac	123	40.8	54.4	31.1	37.0	92.6	30.9	35.0	33.4	24.2	174	58.1	63.6	62.8	47.9
		% of Input	%	38%	38%	39%	37%	38%	12%	12%	13%	12%	12%	12%	12%	12%	12%	12%
	Outflow	Conc. to UFA	mg/L	1.94	1.94	2.81	1.28	1.90	0.87	0.87	1.24	0.89	0.59	0.86	0.86	1.25	0.88	0.60
	Mass Removal		lbs	33,428	11,143	14,536	8,749	10,142	92,215	30,738	33,945	33,321	24,949	178,367	59,456	66,020	64,526	47,822
			%	62%	62%	61%	63%	62%	88%	88%	87%	88%	88%	88%	88%	88%	88%	88%
Total Phosphorus	Mass Inflow	EFA-2	mg/L	2.03	2.03	2.66	1.61	1.88	2.60	2.60	2.06	2.95	2.83	2.67	2.67	2.17	2.85	2.80
			lbs	18,724	6,241	7,810	5,483	5,431	37,419	12,473	7,250	13,903	16,266	73,070	24,357	14,157	27,149	31,764
		Atm. Deposition	lbs	261	86.9	86.9	86.9	86.9	217	72.3	72.3	72.3	72.3	217	72.3	72.3	72.3	72.3
		Total	lbs	18,985	6,328	7,897	5,570	5,518	37,635	12,545	7,322	13,975	16,338	73,287	24,429	14,229	27,221	31,836
			lbs/ac	113	37.7	47.0	33.2	32.8	270	89.8	52.4	100	117	525	175	102	195	228
	Mass Outflow	Loading to UFA	lbs	18,985	6,328	7,897	5,570	5,518	20,615	6,872	4,078	7,469	9,068	39,419	13,140	7,509	13,980	17,931
			lbs/ac	113	37.7	47.0	33.2	32.8	148	49.2	29.2	53.5	64.9	282	94.1	53.8	100	128
		% of Input	%	100%	100%	100%	100%	100%	55%	55%	56%	53%	56%	54%	54%	53%	51%	56%
	Outflow	Conc. to UFA	mg/L	1.79	1.79	2.42	1.37	1.69	1.39	1.39	1.04	1.42	1.60	1.39	1.39	1.06	1.41	1.60
	Mass Removal		lbs	0	0	0	0	0	17,020	5,673	3,244	6,506	7,270	33,868	11,289	6,721	13,241	13,906
			%	0%	0%	0%	0%	0%	45%	45%	44%	47%	44%	46%	46%	47%	49%	44%

[a] Permitted flow conditions estimated by scaling up wetland monthly flows to meet an annual average of 3 MGD

LAKE CITY SPRAYFIELD NUTRIENT TREATMENT SUMMARY – PROJECT SITE

Post-Project Sprayfield Conversion (Scenario 1A) / Post-Project Sprayfield (Scenario 2)

				Wetland (A) + Sprayfield (B&C)					Sprayfield (A,B,&C)				
				2017 - 2019		Annual			2017 - 2019 [a]		Annual [a]		
Parameter			Units	Total	Average	2013	2014	2015	Total	Average	2017	2018	2019
Water Budget	Inflow	Pump	MG	2,509	836	865	841	804	2,509	836	865	841	804
		Rainfall	in	154	51.5	60.8	54.7	39.0	154	51.5	60.8	54.7	39.0
			MG	1,261	420	497	446	318	1,380	460	544	488	348
		Total	MG	3,770	1,257	1,361	1,287	1,122	3,889	1,296	1,408	1,329	1,152
	Outflow	ET	in	128	42.6	42.3	42.3	43.3	128	42.6	42.3	42.3	43.3
			MG	1,044	348	345	346	353	1,142	381	378	378	386
		Infiltration	MG	2,795	932	1,024	949	822	2,747	916	1,031	951	766
		Total	MG	3,839	1,280	1,369	1,295	1,175	3,889	1,296	1,408	1,329	1,152
Total Nitrogen	Mass Inflow	EFA-2	mg/L	7.75	7.75	10.4	7.92	4.76	7.75	7.75	10.4	7.92	4.76
			lbs	162,239	54,080	74,764	55,570	31,905	162,239	54,080	74,764	55,570	31,905
		Atm. Deposition	lbs	5,885	1,962	2,075	2,013	1,798	6,441	2,147	2,270	2,202	1,968
		Total	lbs	168,125	56,042	76,838	57,583	33,704	168,680	56,227	77,034	57,773	33,873
			lbs/ac	559	186	256	192	112	513	171	234	176	103
	Mass Outflow	Loading to UFA	lbs	37,175	12,392	19,755	12,182	5,238	65,540	21,847	30,133	22,448	12,959
			lbs/ac	124	41.2	65.7	40.5	17.4	199	66.4	91.6	68.2	39.4
		% of Input	%	22%	22%	26%	21%	16%	39%	39%	39%	39%	38%
	Outflow	Conc. to UFA	mg/L	1.59	1.59	2.31	1.54	0.763	2.86	2.86	3.50	2.83	2.027
	Mass Removal		lbs	130,950	43,650	57,084	45,401	28,466	103,140	34,380	46,902	35,324	20,914
			%	78%	78%	74%	79%	84%	61%	61%	61%	61%	62%
Total Phosphorus	Mass Inflow	EFA-2	mg/L	2.60	2.60	2.06	2.95	2.83	2.60	2.60	2.06	2.95	2.83
			lbs	54,518	18,173	14,845	20,658	19,015	54,518	18,173	14,845	20,658	19,015
		Atm. Deposition	lbs	467	156	156	156	156	511	170	170	170	170
		Total	lbs	54,985	18,328	15,001	20,814	19,171	55,029	18,343	15,015	20,828	19,185
			lbs/ac	183	61.0	49.9	69.2	63.8	167	55.8	45.6	63.3	58.3
	Mass Outflow	Loading to UFA	lbs	37,965	12,655	11,756	14,308	11,901	55,029	18,343	15,015	20,828	19,185
			lbs/ac	126	42.1	39.1	47.6	39.6	167	55.8	45.6	63.3	58.3
		% of Input	%	69%	69%	78%	69%	62%	100%	100%	100%	100%	100%
	Outflow	Conc. to UFA	mg/L	1.63	1.63	1.38	1.81	1.73	2.40	2.40	1.75	2.63	3.00
	Mass Removal		lbs	17,020	5,673	3,244	6,506	7,270	0	0	0	0	0
			%	31%	31%	22%	31%	38%	0%	0%	0%	0%	0%

[a] Inflow pumping to each sprayfield estimated by fractionating 2017 - 2019 monthly pumped totals by 2013 - 2015 sprayfield flow fractions