State of Utah

GARY R. HERBERT
Governor

GREG BELL
Lieutenant Governor

Department of
Environmental Quality

Amanda Smith
Executive Director

DIVISION OF WATER QUALITY
Walter L. Baker, P.E.
Director

TECHNICAL MEMORANDUM

TO: Perry/Willard Spur Technical Workgroup

FR: Nicholas von Stackelberg, P.E.

DATE: September 30, 2010

SUBJECT: Estimated Nutrient Levels in Willard Spur with Perry-Willard POTW

The purpose of this technical memorandum is to summarize the methodology and results of a simplified mixing analysis that was conducted to estimate the nutrient concentration in Willard Spur resulting from the addition of effluent from the Perry/Willard POTW.

Methodology

A digital elevation model (DEM) of Willard Spur was created using a 6-inch contour bathymetric map of Bear River Bay created by BIO-WEST Consultants, Logan, UT. The Willard Spur was distinguished from the Bear River Bay by delineating a boundary along the higher ground between the Great Salt Lake Minerals evaporative basins and the Bear River Migratory Bird Refuge (Figure 1).

The water boundary in the northeastern portion of Willard Spur was mapped in August 2010 using a handheld GPS unit. The water boundary points were then overlayed on the bathymetric map to estimate the water elevation in the Spur (4,201.6 feet NGVD29 vertical datum). The DEM was then used to calculate the water volume in Willard Bay at the estimated water elevation (11.7 million cubic meters).

The effluent loading was estimated at selected discharge volumes and nutrient concentration levels. Three discharge volumes were evaluated based on projected operation rates provided by Perry and Willard Cities (Table 1). Four nutrients were included in the analysis: total phosphorus (TP); total nitrogen (TN); nitrate and nitrite (NO3); and ammonia (NH4). Three nutrient concentrations were evaluated; the levels were based on specifications for the STM-Aerotor™ and data from four wastewater facilities currently using the technology (Table 2) [Krauth Technical Memo, 9/6/2010].

Table 1: Perry-Willard POTW Discharge Rate

Discharge Level	Discharge Rate (MGD)	Projected Operation
Low	0.35	2010 – Perry Only
Medium	0.60	2011 – Perry and Willard
High	2.00	Max. Capacity (2030)

Table 2: Perry-Willard POTW Effluent Nutrient Concentration (mg/L)

Discharge Level	TP	TN	NO3	NH4	Probability
Low	2.5	10	8	0.1	Very low – manufacturer's specification
Medium	4.0	20	16	1.0	Most likely
High	5.0	30	24	3.0	Low - conservative

Three mixing scenarios were evaluated to estimate the impact of the addition of the Perry-Willard POTW effluent to Willard Spur.

1. Full Flush Scenario
   Willard Spur was assumed to completely flush with Bear River flows each spring. Therefore, effluent was assumed to only accumulate during the critical summer months of June-July-August and no change in year-over-year background concentration.

2. Partial Flush Scenario
   Willard Spur was assumed to partially flush each year. Therefore, background concentration in year n+1 was assumed to be the average of the final mixed and background concentration of year n. The analysis was carried out over five years.

3. No Flush Scenario
   No flushing of Willard Spur was assumed to occur. Therefore, initial concentration in year n+1 was assumed to be the final mixed concentration in year n. The analysis was carried out over five years.

The background concentration was based on the average of four samples collected from Willard Spur on August 4, 2010 (Figure 1 and Table 3). Full sampling results are attached in the Appendix.

Table 3: Willard Spur Background Nutrient Concentration (mg/L)

TP	TN[1]	NO3[2]	NH4[2]
0.126	3.64	0.05	0.04

1: Based on analysis for dissolved nitrogen.
2: Readings below detection limit assumed at half of detection limit
(NO3 = 0.10 mg/L; NH4 = 0.05 mg/L).

Two additional short-term operation scenarios were evaluated with 0.2 MGD discharge and TP of 3.0 mg/L and TN of 10.0 mg/L; one operation scenario assumed year-round discharge and the other assumed discharge only during the winter months (October through April). The 0.2 MGD discharge rate is for the plant operating with only Willard City connected and also is considered the minimum discharge to operate the plant (personal communication with Tyson Knudsen of Sunrise Engineering).

Modeling Assumptions

Following are the modeling assumptions for the analysis. The assumptions are considered to be conservative in an attempt to evaluate most limiting conditions.

- Full mixing of POTW effluent in Willard Spur.
- Initial water volume in Willard Spur for each year remains constant.
- No outflow from Willard Spur during year, except for spring flush assumption.
- No evapotranspiration of wastewater effluent during the year.
- No net increase in biological uptake of nutrients.
- The current background conditions in Willard Spur represent most limiting conditions, i.e. low water level and high nutrient background concentration.

Results

The results of the analysis are summarized in Table 4. The medium discharge volume (0.60 MGD) and nutrient concentration from the Perry-Willard wastewater treatment facility is considered the most probable scenario for the actual operation within the five-year period of the analysis. Figure 2 graphically presents the results of the most probable scenario.

The results of the short-term operation scenarios are summarized in Table 5.

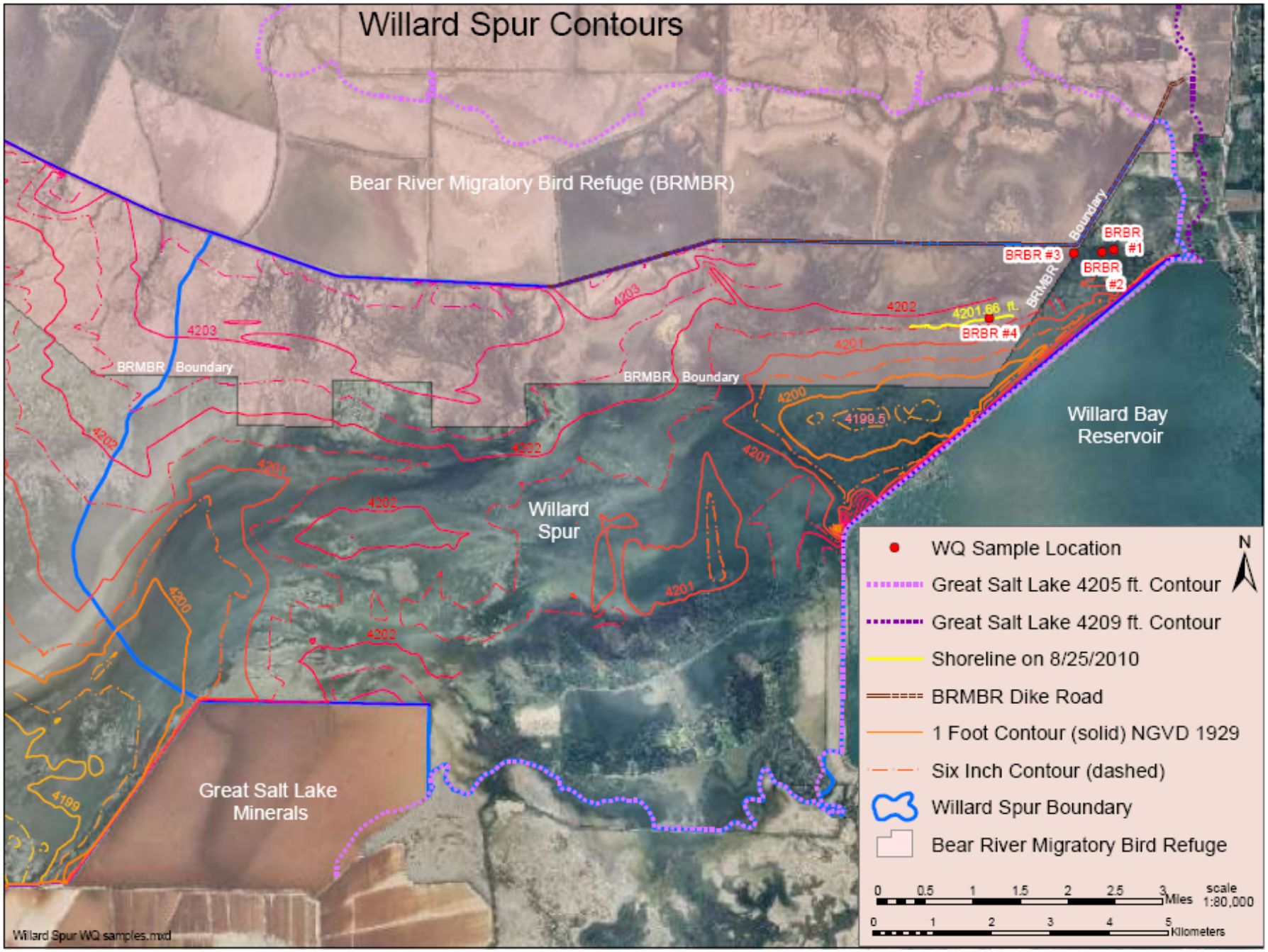

Figure 1: Bathymetric Map of Willard Spur

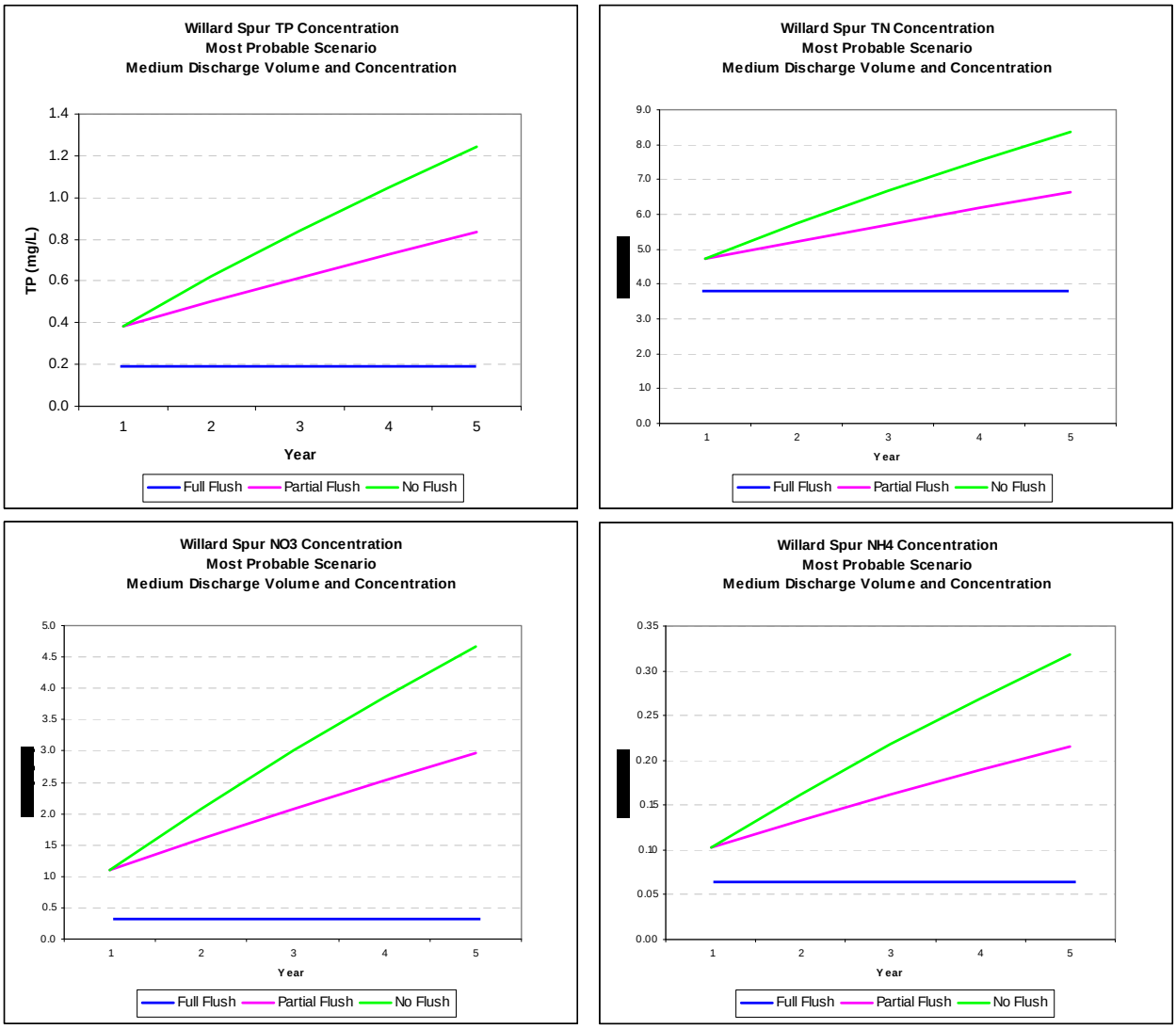

Figure 2 Most Probable Scenario Mixing Analysis Results

Table 4: Nutrient Concentration in Willard Spur with Perry/Willard WWTP Discharge - Long-Term Operation Scenarios

Scenario					Spur	WWTP Discharge				TP (mg/L)			Total N (mg/L)			Nitrate N (mg/L)			Ammonia N (mg/L)		
#	Discharge[3]	Nutrient Conc.[2]	Flush[1]	Year	Volume (m^3)	Rate (MGD)	Duration (years)	Volume (m^3)	Total Volume	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed
Low Nutrient Concentration - Full Flush																					
1	Low	Low	Full	1	11,741,416	0.35	0.25	120,897	11,862,313	0.126	2.5	0.150	3.64	10	3.70	0.05	8	0.13	0.04	0.1	0.041
2	Medium	Low	Full	1	11,741,416	0.60	0.25	207,251	11,948,668	0.126	2.5	0.167	3.64	10	3.75	0.05	8	0.19	0.04	0.1	0.041
3	High	Low	Full	1	11,741,416	2.00	0.25	690,838	12,432,254	0.126	2.5	0.258	3.64	10	3.99	0.05	8	0.49	0.04	0.1	0.043
Low Nutrient Concentration - Partial Flush																					
4	Low	Low	Partial	1	11,741,416	0.35	1	483,586	12,225,003	0.126	2.5	0.220	3.64	10	3.89	0.05	8	0.36	0.04	0.1	0.042
				2						0.173		0.265	3.77		4.01	0.21		0.52	0.04		0.044
				3						0.219		0.309	3.89		4.13	0.36		0.66	0.04		0.045
				4						0.264		0.353	4.01		4.25	0.51		0.81	0.04		0.046
				5						0.308		0.395	4.13		4.36	0.66		0.95	0.04		0.047
5	Medium	Low	Partial	1	11,741,416	0.60	1	829,005	12,570,422	0.126	2.5	0.283	3.64	10	4.06	0.05	8	0.57	0.04	0.1	0.044
				2						0.204		0.356	3.85		4.26	0.31		0.82	0.04		0.046
				3						0.280		0.426	4.05		4.44	0.57		1.06	0.04		0.048
				4						0.353		0.495	4.25		4.63	0.81		1.28	0.05		0.049
				5						0.424		0.561	4.44		4.81	1.05		1.51	0.05		0.051
6	High	Low	Partial	1	11,741,416	2.00	1	2,763,351	14,504,768	0.126	2.5	0.578	3.64	10	4.85	0.05	8	1.56	0.04	0.1	0.051
				2						0.352		0.761	4.25		5.34	0.81		2.18	0.05		0.056
				3						0.557		0.927	4.79		5.79	1.49		2.73	0.05		0.060
				4						0.742		1.077	5.29		6.19	2.11		3.23	0.06		0.064
				5						0.909		1.212	5.74		6.55	2.67		3.69	0.06		0.067
Low Nutrient Concentration - No Flush																					
7	Low	Low	None	1	11,741,416	0.35	1	483,586	12,225,003	0.126	2.5	0.220	3.64	10	3.89	0.05	8	0.36	0.04	0.1	0.042
				2						0.220		0.310	3.89		4.13	0.36		0.67	0.04		0.045
				3						0.310		0.397	4.13		4.37	0.67		0.96	0.04		0.047
				4						0.397		0.480	4.37		4.59	0.96		1.24	0.05		0.049
				5						0.480		0.560	4.59		4.80	1.24		1.50	0.05		0.051
8	Medium	Low	None	1	11,741,416	0.60	1	829,005	12,570,422	0.126	2.5	0.283	3.64	10	4.06	0.05	8	0.57	0.04	0.1	0.044
				2						0.283		0.429	4.06		4.45	0.57		1.06	0.04		0.048
				3						0.429		0.565	4.45		4.82	1.06		1.52	0.05		0.051
				4						0.565		0.693	4.82		5.16	1.52		1.95	0.05		0.054
				5						0.693		0.812	5.16		5.48	1.95		2.35	0.05		0.057
9	High	Low	None	1	11,741,416	2.00	1	2,763,351	14,504,768	0.126	2.5	0.578	3.64	10	4.85	0.05	8	1.56	0.04	0.1	0.051
				2						0.578		0.944	4.85		5.83	1.56		2.79	0.05		0.061
				3						0.944		1.241	5.83		6.63	2.79		3.78	0.06		0.068
				4						1.241		1.481	6.63		7.27	3.78		4.59	0.07		0.074
				5						1.481		1.675	7.27		7.79	4.59		5.24	0.07		0.079

1: Full - complete turnover of water in Spur duing spring flush. Assumed three months of accumulation June - Sept.
Partial - partial turnover of water in Spur. Background concentration year n+1 equals average of background and final mixed concerntration in year n.
None - no turnover of water in Spur. Background concentration year n+1 equals final mixed concentration year n.
2: Concentration of nutrients in eflluent.
3: Volume of effluent.

Table 4: Nutrient Concentration in Willard Spur with Perry/Willard WWTP Discharge - Long-Term Operation Scenarios

Scenario					Spur	WWTP Discharge				TP (mg/L)			Total N (mg/L)			Nitrate N (mg/L)			Ammonia N (mg/L)		
#	Discharge[3]	Nutrient Conc.[2]	Flush[1]	Year	Volume (m^3)	Rate (MGD)	Duration (years)	Volume (m^3)	Total Volume	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed
Medium Nutrient Concentration - Full Flush																					
10	Low	Medium	Full	1	11,741,416	0.35	0.25	120,897	11,862,313	0.126	4.0	0.165	3.64	20	3.81	0.05	16	0.21	0.04	1	0.050
11	Medium	Medium	Full	1	11,741,416	0.60	0.25	207,251	11,948,668	0.126	4.0	0.193	3.64	20	3.92	0.05	16	0.33	0.04	1	0.057
12	High	Medium	Full	1	11,741,416	2.00	0.25	690,838	12,432,254	0.126	4.0	0.341	3.64	20	4.55	0.05	16	0.94	0.04	1	0.093
Medium Nutrient Concentration - Partial Flush																					
13	Low	Medium	Partial	1	11,741,416	0.35	1	483,586	12,225,003	0.126	4.0	0.279	3.64	20	4.29	0.05	16	0.68	0.04	1	0.078
				2						0.203		0.353	3.96		4.60	0.37		0.98	0.06		0.096
				3						0.278		0.425	4.28		4.90	0.67		1.28	0.08		0.114
				4						0.351		0.496	4.59		5.20	0.98		1.57	0.10		0.132
				5						0.424		0.565	4.90		5.49	1.27		1.86	0.11		0.149
14	Medium	Medium	Partial	1	11,741,416	0.60	1	829,005	12,570,422	0.126	4.0	0.381	3.64	20	4.72	0.05	16	1.10	0.04	1	0.103
				2						0.254		0.501	4.18		5.22	0.58		1.59	0.07		0.133
				3						0.377		0.616	4.70		5.71	1.08		2.07	0.10		0.161
				4						0.497		0.728	5.21		6.18	1.58		2.53	0.13		0.189
				5						0.612		0.836	5.69		6.64	2.05		2.97	0.16		0.216
15	High	Medium	Partial	1	11,741,416	2.00	1	2,763,351	14,504,768	0.126	4.0	0.864	3.64	20	6.76	0.05	16	3.09	0.04	1	0.223
				2						0.495		1.163	5.20		8.02	1.57		4.32	0.13		0.297
				3						0.829		1.433	6.61		9.16	2.94		5.43	0.21		0.364
				4						1.131		1.678	7.88		10.19	4.19		6.44	0.29		0.424
				5						1.404		1.899	9.04		11.13	5.31		7.35	0.36		0.479
Medium Nutrient Concentration - No Flush																					
16	Low	Medium	None	1	11,741,416	0.35	1	483,586	12,225,003	0.126	4.0	0.279	3.64	20	4.29	0.05	16	0.68	0.04	1	0.078
				2						0.279		0.426	4.29		4.91	0.68		1.29	0.08		0.114
				3						0.426		0.568	4.91		5.51	1.29		1.87	0.11		0.149
				4						0.568		0.704	5.51		6.08	1.87		2.43	0.15		0.183
				5						0.704		0.834	6.08		6.63	2.43		2.96	0.18		0.215
17	Medium	Medium	None	1	11,741,416	0.60	1	829,005	12,570,422	0.126	4.0	0.381	3.64	20	4.72	0.05	16	1.10	0.04	1	0.103
				2						0.381		0.620	4.72		5.73	1.10		2.08	0.10		0.162
				3						0.620		0.843	5.73		6.67	2.08		3.00	0.16		0.218
				4						0.843		1.051	6.67		7.55	3.00		3.86	0.22		0.269
				5						1.051		1.246	7.55		8.37	3.86		4.66	0.27		0.317
18	High	Medium	None	1	11,741,416	2.00	1	2,763,351	14,504,768	0.126	4.0	0.864	3.64	20	6.76	0.05	16	3.09	0.04	1	0.223
				2						0.864		1.461	6.76		9.28	3.09		5.55	0.22		0.371
				3						1.461		1.945	9.28		11.32	5.55		7.54	0.37		0.491
				4						1.945		2.337	11.32		12.98	7.54		9.15	0.49		0.588
				5						2.337		2.653	12.98		14.31	9.15		10.46	0.59		0.666

1: Full - complete turnover of water in Spur duing spring flush. Assumed three months of accumulation June - Sept.
Partial - partial turnover of water in Spur. Background concentration year n+1 equals average of background and final mixed concerntration in year n.
None - no turnover of water in Spur. Background concentration year n+1 equals final mixed concentration year n.
2: Concentration of nutrients in eflluent.
3: Volume of effluent.

Table 4: Nutrient Concentration in Willard Spur with Perry/Willard WWTP Discharge - Long-Term Operation Scenarios

Scenario					Spur	WWTP Discharge				TP (mg/L)			Total N (mg/L)			Nitrate N (mg/L)			Ammonia N (mg/L)		
#	Discharge[3]	Nutrient Conc.[2]	Flush[1]	Year	Volume (m^3)	Rate (MGD)	Duration (years)	Volume (m^3)	Total Volume	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed
High Nutrient Concentration - Full Flush																					
19	Low	High	Full	1	11,741,416	0.35	0.25	120,897	11,862,313	0.126	5.0	0.176	3.64	30	3.91	0.05	24	0.29	0.04	3	0.070
20	Medium	High	Full	1	11,741,416	0.60	0.25	207,251	11,948,668	0.126	5.0	0.211	3.64	30	4.10	0.05	24	0.47	0.04	3	0.091
21	High	High	Full	1	11,741,416	2.00	0.25	690,838	12,432,254	0.126	5.0	0.397	3.64	30	5.10	0.05	24	1.38	0.04	3	0.204
High Nutrient Concentration - Partial Flush																					
22	Low	High	Partial	1	11,741,416	0.35	1	483,586	12,225,003	0.126	5.0	0.319	3.64	30	4.68	0.05	24	1.00	0.04	3	0.157
				2						0.222		0.411	4.16		5.18	0.52		1.45	0.10		0.213
				3						0.317		0.502	4.67		5.67	0.99		1.90	0.16		0.268
				4						0.410		0.591	5.17		6.16	1.44		2.34	0.21		0.322
				5						0.500		0.678	5.66		6.63	1.89		2.76	0.27		0.375
23	Medium	High	Partial	1	11,741,416	0.60	1	829,005	12,570,422	0.126	5.0	0.447	3.64	30	5.38	0.05	24	1.63	0.04	3	0.235
				2						0.287		0.598	4.51		6.19	0.84		2.37	0.14		0.326
				3						0.442		0.743	5.35		6.98	1.60		3.08	0.23		0.415
				4						0.592		0.883	6.16		7.73	2.34		3.77	0.32		0.500
				5						0.738		1.019	6.95		8.47	3.06		4.44	0.41		0.582
24	High	High	Partial	1	11,741,416	2.00	1	2,763,351	14,504,768	0.126	5.0	1.055	3.64	30	8.66	0.05	24	4.61	0.04	3	0.604
				2						0.590		1.430	6.15		10.69	2.33		6.46	0.32		0.832
				3						1.010		1.770	8.42		12.53	4.40		8.13	0.58		1.039
				4						1.390		2.078	10.48		14.20	6.26		9.64	0.81		1.225
				5						1.734		2.356	12.34		15.70	7.95		11.01	1.02		1.395
High Nutrient Concentration - No Flush																					
25	Low	High	None	1	11,741,416	0.35	1	483,586	12,225,003	0.126	5.0	0.319	3.64	30	4.68	0.05	24	1.00	0.04	3	0.157
				2						0.319		0.504	4.68		5.68	1.00		1.91	0.16		0.270
				3						0.504		0.682	5.68		6.65	1.91		2.78	0.27		0.378
				4						0.682		0.853	6.65		7.57	2.78		3.62	0.38		0.481
				5						0.853		1.017	7.57		8.46	3.62		4.43	0.48		0.581
26	Medium	High	None	1	11,741,416	0.60	1	829,005	12,570,422	0.126	5.0	0.447	3.64	30	5.38	0.05	24	1.63	0.04	3	0.235
				2						0.447		0.748	5.38		7.00	1.63		3.10	0.24		0.418
				3						0.748		1.028	7.00		8.52	3.10		4.48	0.42		0.588
				4						1.028		1.290	8.52		9.94	4.48		5.77	0.59		0.747
				5						1.290		1.535	9.94		11.26	5.77		6.97	0.75		0.896
27	High	High	None	1	11,741,416	2.00	1	2,763,351	14,504,768	0.126	5.0	1.055	3.64	30	8.66	0.05	24	4.61	0.04	3	0.604
				2						1.055		1.806	8.66		12.73	4.61		8.31	0.60		1.060
				3						1.806		2.415	12.73		16.02	8.31		11.30	1.06		1.430
				4						2.415		2.907	16.02		18.68	11.30		13.72	1.43		1.729
				5						2.907		3.306	18.68		20.84	13.72		15.68	1.73		1.971

1: Full - complete turnover of water in Spur duing spring flush. Assumed three months of accumulation June - Sept.
Partial - partial turnover of water in Spur. Background concentration year n+1 equals average of background and final mixed concerntration in year n.
None - no turnover of water in Spur. Background concentration year n+1 equals final mixed concentration year n.
2: Concentration of nutrients in eflluent.
3: Volume of effluent.

Table 5: Nutrient Concentration in Willard Spur with Perry/Willard POTW Discharge - Short-Term Operation Scenarios

Scenario			Spur	WWTP Discharge				TP (mg/L)			Total N (mg/L)			Nitrate N (mg/L)			Ammonia N (mg/L)		
#	Flush[1]	Year	Volume (m^3)	Rate (MGD)	Duration (years)	Volume (m^3)	Total Volume	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed	Back-ground	WWTP Effluent	Total Mixed
Low Nutrient Concentration - Willard City Discharge Year-Round (0.2 MGD)																			
W-1	Full	1	11,741,416	0.20	0.25	69,084	11,810,500	0.126	3	0.143	3.64	10	3.68	0.05	8	0.10	0.04	0.1	0.040
W-2	Partial	1	11,741,416	0.20	1	276,335	12,017,752	0.126	3	0.192	3.64	10	3.79	0.05	8	0.23	0.04	0.1	0.041
		2						0.159		0.224	3.71		3.86	0.14		0.32	0.04		0.042
		3						0.192		0.256	3.79		3.93	0.23		0.41	0.04		0.043
		4						0.224		0.288	3.86		4.00	0.32		0.50	0.04		0.043
		5						0.256		0.319	3.93		4.07	0.41		0.58	0.04		0.044
W-3	None	1	11,741,416	0.20	1	276,335	12,017,752	0.126	3	0.192	3.64	10	3.79	0.05	8	0.23	0.04	0.1	0.041
		2						0.192		0.257	3.79		3.93	0.23		0.41	0.04		0.043
		3						0.257		0.320	3.93		4.07	0.41		0.59	0.04		0.044
		4						0.320		0.381	4.07		4.21	0.59		0.76	0.04		0.045
		5						0.381		0.442	4.21		4.34	0.76		0.92	0.05		0.047
Low Nutrient Concentration - Willard City Discharge Winter Only (October - April)																			
W-4	Full	1	11,741,416	0.20	0	0	11,741,416	0.126	3	0.126	3.64	10	3.64	0.05	8	0.05	0.04	0.1	0.040
W-5	Partial	1	11,741,416	0.20	0.58	161,195	11,902,612	0.126	3	0.165	3.64	10	3.73	0.05	8	0.16	0.04	0.1	0.041
		2						0.145		0.184	3.68		3.77	0.10		0.21	0.04		0.041
		3						0.165		0.203	3.73		3.81	0.16		0.26	0.04		0.042
		4						0.184		0.222	3.77		3.85	0.21		0.32	0.04		0.042
		5						0.203		0.241	3.81		3.89	0.26		0.37	0.04		0.042
W-6	None	1	11,741,416	0.20	0.58	161,195	11,902,612	0.126	3	0.165	3.64	10	3.73	0.05	8	0.16	0.04	0.1	0.041
		2						0.165		0.203	3.73		3.81	0.16		0.26	0.04		0.042
		3						0.203		0.241	3.81		3.89	0.26		0.37	0.04		0.042
		4						0.241		0.279	3.89		3.98	0.37		0.47	0.04		0.043
		5						0.279		0.315	3.98		4.06	0.47		0.57	0.04		0.044

1: Full - complete turnover of water in Spur duing spring flush. Assumed three months of accumulation June - Sept.
Partial - partial turnover of water in Spur. Background concentration year n+1 equals average of background and final mixed concerntration in year n.
None - no turnover of water in Spur. Background concentration year n+1 equals final mixed concentration year n.

APPENDIX

Willard Spur Water Quality Sampling
8/2/2010

	1	2	3	4	
Parameter	201003837	201003838	201003839	201003840	Average
Total Phosphorus (mg/L)	0.182	0.08	0.163	0.08	0.126
Nitrogen - Dissolved (mg/L)	5.22	3.39	2.97	2.97	3.638
Ammonia N (mg/L)	0.025	0.025	0.058	0.06	0.042
Nitrite + Nitrate N (mg/L)	0.05	0.05	0.05	0.05	0.050
Chlorophyl A (ug/L)	25.1	3.8	5.2	11.6	11.425
TSS (mg/L)	104*	55.2	52.8	81	63.000
Non-detects assumed to be 50% of detection limit (NH4 = 0.05 mg/L; NO3/NO2 = 0.10 mg/L)					