Lake Champlain Phosphorus Removal

Technologies and Cost for Point Source Phosphorus Removal

Final Report

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Executive Summary

Approximately 100 wastewater treatment plants and facilities (WWTPs) in New York, Vermont, and the Province of Quebec have been identified as point sources of phosphorous loading which discharge (directly or indirectly) to Lake Champlain. Excess phosphorous in bodies of water is a major concern to regulatory agencies worldwide due to its propensity to cause eutrophication and degrade water quality. U.S. EPA is revising the Vermont portion of the Lake Champlain Total Maximum Daily Load (TMDL) and is considering adopting stricter TMDL based phosphorous limits for Vermont wastewater facilities whose discharges directly affect Lake Champlain. Meeting these new standards would require additional operational and capital improvement costs. The New York portion of the Lake Champlain TMDL is not currently being revised, but New York WWTFs are included in this report for efficiency purposes so that cost estimates will be available for future use when the New York TMDL is updated or to aid any interim WWTF upgrade considerations.

The purpose of this report is to develop generalized technology recommendations and cost estimates for phosphorus removal upgrades to bring 90 WWTFs in the Lake Champlain basin (60 in Vermont and an additional 30 in New York) into compliance with potential new Total Phosphorus (TP) discharge standards. Many of the subject facilities are currently configured to achieve effluent phosphorus concentrations of less than 1 mg/L TP. For those facilities we have established representative feasible technologies and costs to comply with new standards that would require effluent phosphorus concentrations of either 0.2 mg/L or 0.1 mg/L TP. For facilities that are currently producing effluents with phosphorus concentrations greater than 1 mg/L (which are typically the small plants with flows less than 0.2 MGD) we have established representative feasible technologies to achieve 1.0 mg/L TP. Note that the technologies and cost estimates for achieving 1.0 mg/L TP are very comparable to those needed to achieve 0.8 mg/L TP, so these costs are appropriate for use when evaluating TMDL scenarios that include TP targets of either 1.0 mg/L or 0.8 mg/L at small facilities. For WWTPs larger than 1 MGD we have considered the appropriateness of enhanced biological phosphorus removal (EBPR) among the alternatives. Due to the process complexity introduced by biological phosphorus removal, we have considered only physical/chemical alternatives for facilities smaller than 1 MGD.

The design criteria for biological and/or chemical P removal were developed based on the effluent TP objective for the full range of facility design capacities and were then used as the basis for estimates of capital cost, O&M cost, energy consumption, and footprint required for the P removal processes as well as changes in sludge production and disposal needs (for most plants) associated with each process. Although they must be considered in any decision related to the feasibility and cost of phosphorus removal and may be significant at some plants, costs related to potential increases in sludge dewatering and storage needs are outside the scope of this report. Additional costs for sludge disposal have been estimated based on typical rates for landfill disposal in Vermont. Similarly, site-specific costs for things such as road improvements to support additional chemical transport or the installation of pumping systems for filter feed when gravity feed is not an option are beyond the scope of this report as well. However, these additional costs will not be applicable for many phosphorus upgrades.

Section 2 of the report provides a summary of information on each WWTP including design and current flows, current effluent TP, facility description (if made available to the authors), and charts of flow and effluent TP for the last several years. Section 3 describes the process of phosphorus removal by chemical addition and develops estimates of the quantity of either alum or ferric chloride that would be required at each WWTP. Recommendations on chemical storage volume and estimates of chemical cost and capital cost for storage and feed equipment (in addition to any equipment already in use) are included. Section 4 provides information on options for the enhanced solids removal facilities that are necessary to meet low effluent TP requirements once the TP has been chemically treated. This includes processes such as moving bed filters, cloth disk filters, and enhanced sedimentation. Enhanced biological phosphorus removal is discussed in Section 5. Although inappropriate for WWTPs under 1.0 MGD ADF, EBPR was considered for the larger WWTPs because it can significantly decrease the quantity of chemical addition required. In Section 6 costs for full treatment upgrades are developed to include chemical addition and filtration as well as EBPR where appropriate. Capital costs are then converted to monthly bond payments (assuming state funding rates) and combined with estimated O&M costs to estimate the required monthly rate increase to fund the phosphorus removal improvements based on the number of rate payers for each WWTP.

Capital cost estimates have been based on upgrades with a capacity equal to the rated treatment capacity of the facility. O&M costs have been based on the average treated flow over the five year period 2007-2011. They may be adjusted proportionally to estimate the O&M cost at other flow rates using the formula:

New O&M cost = (2007 to 2011 O&M cost) x (New Flow Rate/2007 to 2011 Flow Rate)

Tables ES-1 through ES-4 show the estimated costs and monthly rate increases that would be necessary to achieve compliance with the following scenarios: 1) effluent TP limits of 1.0 mg/L for small plants (less than 200,000 mgd) and 0.2 mg/L for large plants, and 2) effluent TP limits of 1.0 mg/L for small plants and 0.1 mg/L for the large plants. The tables include the total capital and other costs for each scenario by state. State median monthly rate increases to fund the capital and O&M costs are also noted. Additional detail is included in Section 6 of the report. While it is recognized that other funding sources may be available for these types of upgrades (especially for capital costs), the monthly rate increases are provided to demonstrate the potential costs to rate payers if capital costs were funded through a 20 year bonding process and then added to monthly O&M costs.

Note that four Vermont municipal facilities are already achieving 0.2 mg/l without filters or other type of enhanced solids removal. If VTDEC required the installation of filters to increase the potential for consistent compliance with the 0.2 mg/L or 0.1 mg/L targets, the additional capital costs would be approximately $2.14 million for Barre, $0.78 million for Brandon, $0.74 million for Castleton and $0.74 million for Poultney, based on the filter cost curves developed in Section 4. These costs are not included in Tables ES-1 or ES-2.

Table ES-1 Vermont WWTFs – Summary of Costs for Phosphorus Removal to 1.0 or 0.2 mg/L TP

Vermont WWTPs	ADF	Target TP	Capital Cost	Total Monthly O&M Cost		Monthly Rate Increase	
	MGD	mg/L		Alum	Ferric	Alum	Ferric
Alburgh	0.082	No additional treatment required to achieve 0.1 mg/L				$ -	$ -
Barre City	2.879	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Benson	0.015	1.0 mg/L	$ 96,444	$ 253	$ 160	$ 11.22	$ 9.80
Brandon	0.422	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Brown Ledge Camp	Closed					- n/a -	- n/a -
Burlington East	0.614	0.2 mg/L	$ 1,095,000	$ 316	$ 308	$ 2.16	$ 2.16
Burlington Electric	0.139	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Burlington Main	4.451	0.2 mg/L	$ 2,921,000	$ 1,800	$ 1,434	$ 0.85	$ 0.83
Burlington North	1.213	0.2 mg/L	$ 217,000	$ 442	$ 433	$ 0.29	$ 0.29
Cabot	0.026	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Castleton	0.366	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Enosburg Falls	0.275	0.2 mg/L	$ 840,744	$ 162	$ 150	$ 3.64	$ 3.63
Essex Junction	1.969	0.2 mg/L	$ 153,000	$ 973	$ 747	$ 0.20	$ 0.18
Fair Haven	0.212	0.2 mg/L	$ 840,744	$ 202	$ 164	$ 4.77	$ 4.73
Fairfax	0.035	1.0 mg/L	$ 100,744	$ 524	$ 369	$ 6.70	$ 5.70
Hardwick	0.214	0.2 mg/L	$ 1,275,000	$ 345	$ 311	$ 7.21	$ 7.17
Hinesburg	0.158	0.2 mg/L	$ 850,744	$ 170	$ 146	$ 6.43	$ 6.39
IBM	2.999	0.2 mg/L	$ 4,110,000	$ 310	$ 396	- n/a -	- n/a -
Jeffersonville	0.036	1.0 mg/L	$ 100,744	$ 788	$ 433	$ 8.18	$ 5.94
Johnson	0.186	0.2 mg/L	$ 700,744	$ 193	$ 156	$ 4.56	$ 4.52
Marshfield	0.020	1.0 mg/L	$ 100,744	$ 313	$ 239	$ 9.34	$ 8.50
Middlebury	1.035	0.2 mg/L	$ 1,355,000	$ 352	$ 356	$ 1.58	$ 1.58
Milton	0.231	0.2 mg/L	$ 880,744	$ 379	$ 247	$ 4.75	$ 4.62
Montpelier	1.972	0.2 mg/L	$ 2,268,000	$ 734	$ 628	$ 1.41	$ 1.39
Morrisville	0.308	0.2 mg/L	$ 840,744	$ 275	$ 198	$ 3.34	$ 3.28
Newport Center	0.021	0.2 mg/L	$ 596,444	$ 154	$ 131	$ 34.28	$ 34.03
North Troy	0.078	0.2 mg/L	$ 600,744	$ 266	$ 239	$ 9.62	$ 9.54
Northfield	0.565	0.2 mg/L	$ 885,000	$ 315	$ 302	$ 1.93	$ 1.92
Northwest State Correctional	0.023	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Orwell	0.021	1.0 mg/L	$ 100,744	$ 234	$ 191	$ 8.04	$ 7.57
Otter Valley Union High School	0.002	1.0 mg/L	$ 96,444	$ 180	$ 138	- n/a -	- n/a -
Pittsford	0.066	1.0 mg/L	$ 100,744	$ 332	$ 252	$ 2.90	$ 2.62
Pittsford Fish Hatchery	1.745	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Plainfield	0.059	1.0 mg/L	$ 100,744	$ 410	$ 299	$ 3.54	$ 3.11
Poultney	0.265	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Proctor	0.258	0.2 mg/L	$ 1,298,000	$ 714	$ 513	$ 6.41	$ 6.23
Richford	0.246	0.2 mg/L	$ 1,270,744	$ 255	$ 188	$ 6.17	$ 6.11
Richmond	0.075	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Rock Tenn	0.231	0.2 mg/L	$ 1,350,744	$ 354	$ 259	$ 7.06	$ 6.97
Rutland City	5.313	0.2 mg/L	$ 3,913,000	$ 842	$ 852	$ 0.88	$ 0.88
Salisbury Fish Hatchery	0.908	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Shelburne 1	0.307	0.2 mg/L	$ 100,744	$ 169	$ 146	$ 0.50	$ 0.49
Shelburne 2	0.389	0.2 mg/L	$ 100,744	$ 244	$ 181	$ 0.44	$ 0.40
Sheldon Springs	0.018	1.0 mg/L	$ 96,444	$ 292	$ 171	$ 9.84	$ 8.31
Shoreham	0.01	1.0 mg/L	$ 100,744	$ 258	$ 206	$ 17.43	$ 16.24
South Burlington Airport Parkway	1.645	0.2 mg/L	$ 128,000	$ 635	$ 513	$ 0.18	$ 0.16
South Burlington Bartlett Bay	0.620	0.2 mg/L	$ 100,744	$ 199	$ 171	$ 0.26	$ 0.25
St. Albans City	2.690	0.2 mg/L	$ 115,000	$ 362	$ 315	$ 0.08	$ 0.08
Stowe	0.310	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Swanton	0.548	0.2 mg/L	$ 885,000	$ 339	$ 321	$ 1.99	$ 1.99

Table ES-1 continued

Vermont WWTPs	ADF	Target TP	Capital Cost	Total Monthly O&M Cost		Monthly Rate Increase	
	MGD	mg/L		Alum	Ferric	Alum	Ferric
Troy/Jay	0.045	0.2 mg/L	$ 876,444	$ 161	$ 137	$ 23.18	$ 23.06
Vergennes	0.401	0.2 mg/L	$ 100,744	$ 246	$ 182	$ 0.43	$ 0.39
Wallingford	0.071	1.0 mg/L	$ 100,744	$ 322	$ 242	$ 2.66	$ 2.40
Waterbury	0.255	2013 improvements anticipated to achieve 0.1 mg/L				$ -	$ -
Weed Fish Culture Station	4.642	No additional treatment required to achieve 0.1 mg/L				$ -	$ -
West Pawlet	0.015	1.0 mg/L	$ 100,744	$ 353	$ 264	$ 13.05	$ 11.71
West Rutland	0.202	0.2 mg/L	$ 840,744	$ 175	$ 153	$ 4.98	$ 4.95
Williamstown	0.070	1.0 mg/L	$ 100,744	$ 538	$ 378	$ 3.40	$ 2.88
Winooski	0.760	0.2 mg/L	$ 1,095,000	$ 477	$ 444	$ 1.80	$ 1.79
Wyeth (PBM Nutritionals)	0.123	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Total for all Vermont WWTPs			**$ 33,903,076**	**$ 17,355**	**$ 14,062**	**$2.41 median**	**$2.28 median**

Table ES-2 Vermont WWTFs – Summary of Costs for Phosphorus Removal to 1.0 or 0.1 mg/L TP

Vermont WWTPs	ADF	Target TP	Capital Cost	Total Monthly O&M Cost		Monthly Rate Increase	
	MGD	mg/L		Alum	Ferric	Alum	Ferric
Alburgh	0.082	No additional treatment required to achieve 0.1 mg/L				$ -	$ -
Barre City	2.879	0.1 mg/L	$ 100,744	$ 897	$ 641	$ 0.11	$ 0.09
Benson	0.015	1.0 mg/L	$ 96,444	$ 253	$ 160	$ 11.22	$ 9.80
Brandon	0.422	0.1 mg/L	$ 100,744	$ 367	$ 285	$ 0.47	$ 0.43
Brown Ledge Camp	Closed					- n/a -	- n/a -
Burlington East	0.614	0.1 mg/L	$ 1,095,000	$ 927	$ 543	$ 2.39	$ 2.25
Burlington Electric	0.139	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Burlington Main	4.451	0.1 mg/L	$ 2,921,000	$ 6,916	$ 3,627	$ 1.11	$ 0.94
Burlington North	1.213	0.1 mg/L	$ 217,000	$ 1,546	$ 862	$ 0.49	$ 0.37
Cabot	0.026	0.1 mg/L	$ 96,444	$ 149	$ 129	$ 5.56	$ 5.39
Castleton	0.366	0.1 mg/L	$ 100,744	$ 279	$ 228	$ 0.49	$ 0.46
Enosburg Falls	0.275	0.1 mg/L	$ 840,744	$ 303	$ 245	$ 3.76	$ 3.71
Essex Junction	1.969	0.1 mg/L	$ 153,000	$ 3,620	$ 1,884	$ 0.51	$ 0.31
Fair Haven	0.212	0.1 mg/L	$ 840,744	$ 339	$ 269	$ 4.92	$ 4.84
Fairfax	0.035	1.0 mg/L	$ 100,744	$ 524	$ 369	$ 6.70	$ 5.70
Hardwick	0.214	0.1 mg/L	$ 1,275,000	$ 897	$ 515	$ 7.79	$ 7.39
Hinesburg	0.158	0.1 mg/L	$ 850,744	$ 269	$ 219	$ 6.57	$ 6.50
IBM	2.999	0.1 mg/L	$ 4,110,000	$ 1,634	$ 958	- n/a -	- n/a -
Jeffersonville	0.036	1.0 mg/L	$ 100,744	$ 788	$ 433	$ 8.18	$ 5.94
Johnson	0.186	0.1 mg/L	$ 700,744	$ 317	$ 252	$ 4.71	$ 4.63
Marshfield	0.02	1.0 mg/L	$ 100,744	$ 313	$ 239	$ 9.34	$ 8.50
Middlebury	1.035	0.1 mg/L	$ 1,355,000	$ 1,164	$ 676	$ 1.76	$ 1.65
Milton	0.231	0.1 mg/L	$ 880,744	$ 621	$ 382	$ 4.99	$ 4.75
Montpelier	1.972	0.1 mg/L	$ 2,268,000	$ 22,249	$ 1,454	$ 3.88	$ 1.49
Morrisville	0.308	0.1 mg/L	$ 840,744	$ 496	$ 374	$ 3.50	$ 3.41
Newport Center	0.021	0.1 mg/L	$ 596,444	$ 271	$ 163	$ 35.55	$ 34.37
North Troy	0.078	0.1 mg/L	$ 600,744	$ 718	$ 402	$ 10.93	$ 10.01
Northfield	0.565	0.1 mg/L	$ 885,000	$ 929	$ 538	$ 2.17	$ 2.01
Northwest State Correctional	0.023	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Orwell	0.021	1.0 mg/L	$ 100,744	$ 234	$ 191	$ 8.04	$ 7.57
Otter Valley Union High School	0.002	1.0 mg/L	$ 96,444	$ 180	$ 138	- n/a -	- n/a -

Table ES-2 continued

Vermont WWTPs	ADF	Target TP	Capital Cost	Total Monthly O&M Cost		Monthly Rate Increase	
	MGD	mg/L		Alum	Ferric	Alum	Ferric
Pittsford	0.066	1.0 mg/L	$ 100,744	$ 332	$ 252	$ 2.90	$ 2.62
Pittsford Fish Hatchery	1.745	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Plainfield	0.059	1.0 mg/L	$ 100,744	$ 410	$ 299	$ 3.54	$ 3.11
Poultney	0.265	0.1 mg/L	$ 96,444	$ 200	$ 145	$ 0.59	$ 0.54
Proctor	0.258	0.1 mg/L	$ 1,298,000	$ 2,433	$ 953	$ 7.92	$ 6.62
Richford	0.246	0.1 mg/L	$ 1,270,744	$ 436	$ 334	$ 6.33	$ 6.24
Richmond	0.075	0.1 mg/L	$ 96,444	$ 152	$ 130	$ 1.94	$ 1.87
Rock Tenn	0.231	0.1 mg/L	$ 1,350,744	$ 558	$ 433	$ 7.26	$ 7.14
Rutland City	5.313	0.1 mg/L	$ 3,913,000	$ 4,255	$ 2,302	$ 1.03	$ 0.94
Salisbury Fish Hatchery	0.908	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Shelburne 1	0.307	0.1 mg/L	$ 100,744	$ 336	$ 262	$ 0.63	$ 0.57
Shelburne 2	0.389	0.1 mg/L	$ 100,744	$ 491	$ 365	$ 0.58	$ 0.51
Sheldon Springs	0.018	1.0 mg/L	$ 96,444	$ 292	$ 171	$ 9.84	$ 8.31
Shoreham	0.010	1.0 mg/L	$ 100,744	$ 258	$ 206	$ 17.43	$ 16.24
South Burlington Airport Parkway	1.645	0.1 mg/L	$ 128,000	$ 2,437	$ 1,286	$ 0.43	$ 0.27
South Burlington Bartlett Bay	0.62	0.1 mg/L	$ 100,744	$ 519	$ 384	$ 0.38	$ 0.33
St. Albans City	2.69	0.1 mg/L	$ 115,000	$ 1,674	$ 901	$ 0.19	$ 0.13
Stowe	0.31	0.1 mg/L	$ 100,744	$ 369	$ 288	$ 0.64	$ 0.58
Swanton	0.548	0.1 mg/L	$ 885,000	$ 995	$ 571	$ 2.27	$ 2.09
Troy/Jay	0.045	0.1 mg/L	$ 876,444	$ 304	$ 176	$ 23.90	$ 23.25
Vergennes	0.401	0.1 mg/L	$ 100,744	$ 497	$ 370	$ 0.57	$ 0.50
Wallingford	0.071	1.0 mg/L	$ 100,744	$ 322	$ 242	$ 2.66	$ 2.40
Waterbury	0.255	2013 improvements anticipated to achieve 0.1 mg/L				$ -	$ -
Weed Fish Culture Station	4.642	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
West Pawlet	0.015	1.0 mg/L	$ 100,744	$ 353	$ 264	$ 13.05	$ 11.71
West Rutland	0.202	0.1 mg/L	$ 840,744	$ 291	$ 236	$ 5.11	$ 5.05
Williamstown	0.070	1.0 mg/L	$ 100,744	$ 538	$ 378	$ 3.40	$ 2.88
Winooski	0.760	0.1 mg/L	$ 1,095,000	$ 1,455	$ 816	$ 2.09	$ 1.90
Wyeth (PBM Nutritionals)	0.123	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Total for all Vermont WWTPs			**$ 34,595,384**	**$ 67,109**	**$ 27,939**	**$3.40 median**	**$2.62 median**

Table ES-3 New York WWTFs – Summary of Costs for Phosphorus Removal to 1.0 or 0.2 mg/L TP

New York WWTPs	ADF	Target TP	Capital Cost	Total Monthly O&M Cost		Monthly Rate Increase	
	MGD	mg/L		Alum	Ferric	Alum	Ferric
Adirondak Fish Hatchery	2.921	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Altona Correctional	0.069	0.1 mg/L	$ 596,444	$ 366	$ 219	- n/a -	- n/a -
Au Sable Forks	0.059	1.0 mg/L	$ 100,744	$ 671	$ 379	$ 4.60	$ 3.47
Cadyville	0.003	1.0 mg/L	$ 96,444	$ 178	$ 155	$ 51.42	$ 49.70
Champlain	0.265	0.1 mg/L	$ 840,744	$ 696	$ 555	$ 4.34	$ 4.22
Champlain Park	Closed					- n/a -	- n/a -
Chazy	0.037	0.1 mg/L	$ 66,908	$ 273	$ 169	$ 3.81	$ 3.17
Crown Point	0.031	1.0 mg/L	$ 100,744	$ 741	$ 672	$ 9.26	$ 8.76
Dannemora	0.877	1.0 mg/L	$ 1,966,000	$ 12,399	$ 4,192	$ 5.86	$ 3.73
Essex	0.005	0.1 mg/L	$ 550,744	$ 283	$ 221	$ 142.93	$ 140.10
Fort Ann	0.067	0.1 mg/L	$ 550,744	$ 567	$ 335	$ 11.63	$ 10.84
Granville	0.75	0.1 mg/L	$ 1,050,744	$ 772	$ 445	$ 1.89	$ 1.79
Great Meadows Correctional	0.365	0.1 mg/L	$ 730,744	$ 562	$ 417	- n/a -	- n/a -
International Paper	15.148	0.1 mg/L	$ 112,300	$ 3,593	$ 1,877	- n/a -	- n/a -
Keeseville	0.359	0.1 mg/L	$ 66,908	$ 320	$ 184	$ 0.42	$ 0.34

Table ES-3 continued

New York WWTPs	ADF	Target TP	Capital Cost	Total Monthly O&M Cost		Monthly Rate Increase	
	MGD	mg/L		Alum	Ferric	Alum	Ferric
Lake Placid	1.114	0.1 mg/L	$ 1,454,000	$ 4,447	$ 2,308	$ 2.45	$ 2.01
Peru	0.238	0.1 mg/L	$ 752,000	$ 2,064	$ 817	$ 5.70	$ 4.51
Peru/Valcour	0.004	0.1 mg/L	$ 496,444	$ 451	$ 308	$ 172.18	$ 164.07
Plattsburgh	5.48	0.1 mg/L	$ 7,672,000	$ 42,074	$ 15,169	$ 3.40	$ 2.28
Port Henry	0.539	0.1 mg/L	$ 862,000	$ 2,156	$ 1,177	$ 2.80	$ 2.38
Rouses Point	0.78	0.1 mg/L	$ 1,341,000	$ 6,460	$ 2,405	$ 3.91	$ 2.73
Saranac Lake	1.87	0.1 mg/L	$ 1,515,000	$ 2,887	$ 1,565	$ 1.31	$ 1.15
St Armand	0.04	1.0 mg/L	$ 100,744	$ 1,081	$ 982	$ 9.11	$ 8.54
Ticonderoga	1.238	0.1 mg/L	$ 1,676,000	$ 4,758	$ 2,466	$ 2.47	$ 2.05
Wadhams	0.006	1.0 mg/L	$ 96,444	$ 300	$ 229	$ 30.32	$ 27.64
Washington Correctional	0.114	0.1 mg/L	$ 696,444	$ 303	$ 173	- n/a -	- n/a -
Westport	0.136	1.0 mg/L	$ 100,744	$ 799	$ 723	$ 2.21	$ 2.08
Whitehall	0.625	0.1 mg/L	$ 845,000	$ 1,170	$ 647	$ 2.02	$ 1.83
Willsboro	0.041	1.0 mg/L	$ 100,744	$ 739	$ 670	$ 6.99	$ 6.61
Wyeth Research	Closed					- n/a -	- n/a -
Total for all New York WWTPs			**$ 24,538,776**	**$ 91,110**	**$ 39,459**	**$4.34 median**	**$3.47 median**

Table ES-4 New York WWTFs – Summary of Costs for Phosphorus Removal to 1.0 or 0.1 mg/L TP

New York WWTPs	ADF	Target TP	Capital Cost	Total Monthly O&M Cost		Monthly Rate Increase	
	MGD	mg/L		Alum	Ferric	Alum	Ferric
Adirondak Fish Hatchery	2.921	No additional treatment required to achieve 0.1 mg/L				- n/a -	- n/a -
Altona Correctional	0.069	0.2 mg/L	$ 596,444	$ 244	$ 172	- n/a -	- n/a -
Au Sable Forks	0.059	1.0 mg/L	$ 100,744	$ 671	$ 379	$ 4.60	$ 3.47
Cadyville	0.003	1.0 mg/L	$ 96,444	$ 178	$ 155	$ 51.42	$ 49.70
Champlain	0.265	0.2 mg/L	$ 840,744	$ 462	$ 360	$ 4.14	$ 4.05
Champlain Park	Closed					- n/a -	- n/a -
Chazy	0.037	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Crown Point	0.031	1.0 mg/L	$ 100,744	$ 741	$ 672	$ 9.26	$ 8.76
Dannemora	0.877	1.0 mg/L	$ 1,966,000	$ 6,563	$ 1,948	$ 4.35	$ 3.15
Essex	0.005	0.2 mg/L	$ 550,744	$ 295	$ 190	$ 143.47	$ 138.71
Fort Ann	0.067	0.2 mg/L	$ 550,744	$ 336	$ 215	$ 10.84	$ 10.43
Granville	0.75	0.2 mg/L	$ 1,050,744	$ 320	$ 227	$ 1.75	$ 1.72
Great Meadows Correctional	0.365	0.2 mg/L	$ 730,744	$ 297	$ 211	- n/a -	- n/a -
International Paper	15.148	No additional treatment required to achieve 0.2 mg/L				- n/a -	- n/a -
Keeseville	0.359	No additional treatment required to achieve 0.2 mg/L				$ -	$ -
Lake Placid	1.114	0.2 mg/L	$ 1,454,000	$ 2,503	$ 980	$ 2.05	$ 1.74
Peru	0.238	0.2 mg/L	$ 752,000	$ 1,070	$ 445	$ 4.75	$ 4.16
Peru/Valcour	0.004	0.2 mg/L	$ 496,444	$ 362	$ 286	$ 167.09	$ 162.80
Plattsburgh	5.48	0.2 mg/L	$ 7,672,000	$ 20,501	$ 7,115	$ 2.50	$ 1.95
Port Henry	0.539	0.2 mg/L	$ 862,000	$ 1,258	$ 567	$ 2.42	$ 2.13
Rouses Point	0.78	0.2 mg/L	$ 1,341,000	$ 3,226	$ 1,196	$ 2.97	$ 2.38
Saranac Lake	1.87	0.2 mg/L	$ 1,515,000	$ 1,368	$ 680	$ 1.12	$ 1.04
St Armand	0.04	1.0 mg/L	$ 100,744	$ 1,081	$ 982	$ 9.11	$ 8.54
Ticonderoga	1.238	0.2 mg/L	$ 1,676,000	$ 2,662	$ 1,039	$ 2.09	$ 1.79
Wadhams	0.006	1.0 mg/L	$ 96,444	$ 300	$ 229	$ 30.32	$ 27.64
Washington Correctional	0.114	0.2 mg/L	$ 696,444	$ 166	$ 128	- n/a -	- n/a -
Westport	0.136	1.0 mg/L	$ 100,744	$ 799	$ 723	$ 2.21	$ 2.08
Whitehall	0.625	0.2 mg/L	$ 845,000	$ 600	$ 343	$ 1.81	$ 1.72
Willsboro	0.041	1.0 mg/L	$ 100,744	$ 739	$ 670	$ 6.99	$ 6.61
Wyeth Research	Closed					- n/a -	- n/a -
Total for all New York WWTPs			**$ 24,292,660**	**$ 46,741**	**$ 19,910**	**$4.14 median**	**$3.15 median**

1 Introduction

1.1 Purpose

Approximately 100 wastewater treatment plants and facilities (WWTPs) in New York, Vermont, and the Province of Quebec have been identified as point sources of phosphorous loading which discharge (directly or indirectly) to Lake Champlain. Excess phosphorous in bodies of water is a major concern to regulatory agencies worldwide due to its propensity to cause eutrophication and degrade water quality. U.S. EPA is revising the Vermont portion of the Lake Champlain Total Maximum Daily Load (TMDL) and is considering adopting stricter TMDL based phosphorous limits for Vermont wastewater facilities whose discharges affect Lake Champlain. Meeting these new standards would require additional operational and capital improvement costs. The New York portion of the Lake Champlain TMDL is not currently being revised, but the New York WWTFs are included in this report for efficiency purposes so that cost estimates will be available for future use when the New York TMDL is updated or to aid any interim WWTF upgrade considerations.

The purpose of this report is to develop generalized technology recommendations and cost estimates for phosphorus removal upgrades to bring 90 WWTFs in the Lake Champlain basin (60 in Vermont and an additional 30 in New York) into compliance with potential new Total Phosphorus (TP) discharge standards.

The design criteria for biological and/or chemical P removal will be developed based on the effluent TP objective for the full range of facility design capacities and will be used as the basis for feasibility evaluations considering capital cost, O&M cost, energy consumption, and footprint required for the P removal processes as well as changes in sludge production and disposal needs (for most plants) associated with each process. Although they must be considered in any decision related to the feasibility and cost of phosphorus removal, technologies and costs related to increases in sludge dewatering and storage needs are outside the scope of this report. Additional costs for sludge disposal have been estimated based on typical rates for landfill disposal in Vermont. Similarly, site-specific costs for things such as road improvements to support additional chemical transport or the installation of pumping systems for filter feed when gravity feed is not an option are beyond the scope of this report as well. However, these additional costs will not be applicable for many phosphorus upgrades.

This report includes sections addressing the treatment technologies considered, sections on the cost estimates and other factors associated with the treatment technologies, and separate sections addressing the needs of the Vermont and New York plants.

1.2 Potential Effluent Phosphorus Limits and Phosphorus Removal Technologies

The phosphorus concentration in municipal wastewater tends to be 5 to 10 mg/L unless it is particularly concentrated by low flow fixtures or diluted by infiltration/inflow. Using the biological treatment processes typical of municipal wastewater treatment plants, a portion of the phosphorus (depending on the BOD concentration of the wastewater) is taken up by the biomass and removed with the waste biosolids. Under normal conditions, phosphorus will comprise approximately 2% of the waste biosolids mass and the phosphorus remaining in the effluent without specific treatment for phosphorus removal will be between 1 and 6 mg/L. For industrial effluents or municipal facilities dominated by industrial contributors, the effluent phosphorus concentration may be greater or lesser depending on the industry.

Additional phosphorus is removed from wastewater by transforming it from a soluble (dissolved) form to a particulate (solid) form. There is no gas form that is practical for phosphorus removal from wastewater. The transformation from a dissolved to a solid form can be accomplished by chemical or biological (biochemical) means. The transformation efficiency depends on many factors but even in a highly optimized system there will exist a small quantity of soluble phosphorus that is unreactive and will not be transformed using either process. That unreactive portion is most commonly termed the "recalcitrant" dissolved organic phosphorus or rDOP. The rDOP concentration is commonly 0.01 to 0.04 mg/L. This is similar to the recalcitrant dissolved organic nitrogen (rDON) and COD that remain in well treated effluents and may be evidence of the presence of compounds that are non-biodegradable or very slowly degradable. Further, a portion of the solids that are formed in these processes may persist in un-flocculated "colloidal" form. Because colloidal solids are difficult to remove by sedimentation or filtration, the colloidal material may be inaccurately characterized as soluble in some systems. In order to achieve very low effluent phosphorus concentrations, effluent solids (including colloidal solids) must be very effectively removed. To achieve a 1 mg/L TP effluent concentration standard sedimentation is usually adequate. However, to achieve phosphorus concentrations of 0.2 mg/L or less, enhanced solids removal technologies (including filtration and ballasted clarification) are usually employed to provide the consistent solids removal necessary.

Many of the subject facilities are currently configured to achieve effluent phosphorus concentrations of less than 1 mg/L TP. For those facilities we have established representative feasible technologies and costs to comply with new standards that would require effluent phosphorus concentrations of either 0.2 mg/L or 0.1 mg/L TP. For facilities that are currently producing effluents with phosphorus concentrations greater than 1 mg/L (which are almost always the small plants with flows less than 0.2 MGD) we have established representative feasible technologies to achieve 1.0 mg/L TP. For WWTPs larger than 1 MGD we have considered the appropriateness of enhanced biological phosphorus removal (EBPR) among the alternatives. Due to the process complexity introduced by biological phosphorus removal, we have considered only physical/chemical alternatives for facilities smaller than 1 MGD.

2 WWTPs Background

Of the 90 treatment plants included in this evaluation, 60 are located in Vermont and 30 are in New York. This section presents background information on each plant including a description of the process and sludge production (if available), effluent TP limits, and flow and effluent TP history. Based on this information, target effluent TP goals for this evaluation were established for each WWTF. A summary of those goals is included at the end of this section.

2.1 Vermont WWTPs

Table 2.1 lists the Vermont WWTFs that were included in this study. Each is addressed in a separate section below to provide basic plant process information as well as historical performance relative to phosphorus removal.

Table 2.1 Vermont WWTFs

Section	WWTF	Section	WWTF
2.1.1	Alburgh	2.1.31	Otter Valley Union High School
2.1.2	Barre City	2.1.32	Pittsford
2.1.3	Benson	2.1.33	Pittsford Fish Hatchery
2.1.4	Brandon	2.1.34	Plainfield
2.1.5	Brown Ledge Camp	2.1.35	Poultney
2.1.6	Burlington East	2.1.36	Proctor
2.1.7	Burlington Electric	2.1.37	Richford
2.1.8	Burlington Main	2.1.38	Richmond
2.1.9	Burlington North	2.1.39	Rock Tenn
2.1.10	Cabot	2.1.40	Rutland City
2.1.11	Castleton	2.1.41	Salisbury Fish Hatchery
2.1.12	Enosburg Falls	2.1.42	Shelburne #1
2.1.13	Essex Junction	2.1.43	Shelburne #2
2.1.14	Fair Haven	2.1.44	Sheldon Springs
2.1.15	Fairfax	2.1.45	Shoreham
2.1.16	Hardwick	2.1.46	South Burlington Airport Parkway
2.1.17	Hinesburg	2.1.47	South Burlington Bartlett Bay
2.1.18	IBM	2.1.48	St. Albans City
2.1.19	Jeffersonville	2.1.49	Stowe
2.1.20	Johnson	2.1.50	Swanton
2.1.21	Marshfield	2.1.51	Troy/Jay
2.1.22	Middlebury	2.1.52	Vergennes
2.1.23	Milton	2.1.53	Wallingford
2.1.24	Montpelier	2.1.54	Waterbury
2.1.25	Morrisville	2.1.55	Weed Fish Culture Station
2.1.26	Newport Center	2.1.56	West Pawlet
2.1.27	North Troy	2.1.57	West Rutland
2.1.28	Northfield	2.1.58	Williamstown
2.1.29	Northwest State Correctional	2.1.59	Winooski
2.1.30	Orwell	2.1.60	Wyeth (PBM Nutritionals)

2.1.1 Alburgh

<u>Facility Description</u>

The Alburgh WWTF is an aerated lagoon that uses an aerated lagoon type process with spray disposal to a hay field that is designed to treat up to 0.13 MGD of average daily flow (ADF). The 2011 ADF was 0.183 MGD, exceeding the design rating of the facility. Treated effluent is land applied. Sludge is not regularly removed. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 1.0 mg/L daily maximum TP limit.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.1, the Alburgh WWTF has reported extremely low effluent phosphorus concentration over the entire period from 1995 to 2011. The reported effluent TP averaged 0.036 mg/L during that period. The effluent from the hay field underdrain is already in compliance with the most restrictive TP limit (0.1 mg/L) to be considered in this evaluation.

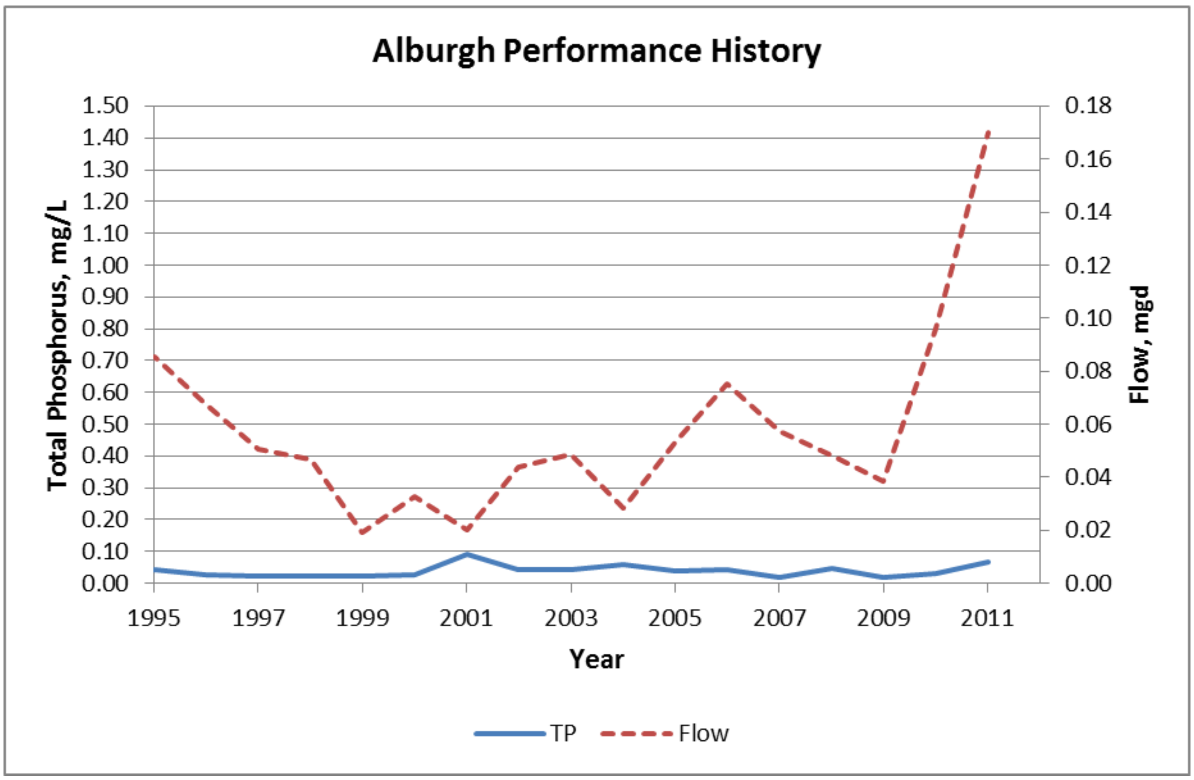


Figure 2.1.1 Alburgh WWTF Performance History

2.1.2 Barre City

Facility Description

The Barre City WWTF is an oxidation ditch activated sludge plant designed to treat up to 4.0 MGD ADF. The 2011 ADF was 3.23 MGD. Sludge is digested anaerobically before being mechanically dewatered and landfilled. Approximately 557 dry tons of sludge were disposed in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 7306 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.2, the Barre City WWTF has reported relatively low effluent phosphorus concentration since 1996 when the effluent TP first dropped to less than 0.5 mg/L. Since 1998, the reported effluent TP has remained between 0.1 mg/L and 0.2 mg/L and has averaged 0.138 mg/L. This is excellent phosphorus removal performance and produces an effluent well within the current limits for both concentration and annual loading. Only the 0.1 mg/L effluent TP goal remains to be considered for the Barre City WWTF in this evaluation.

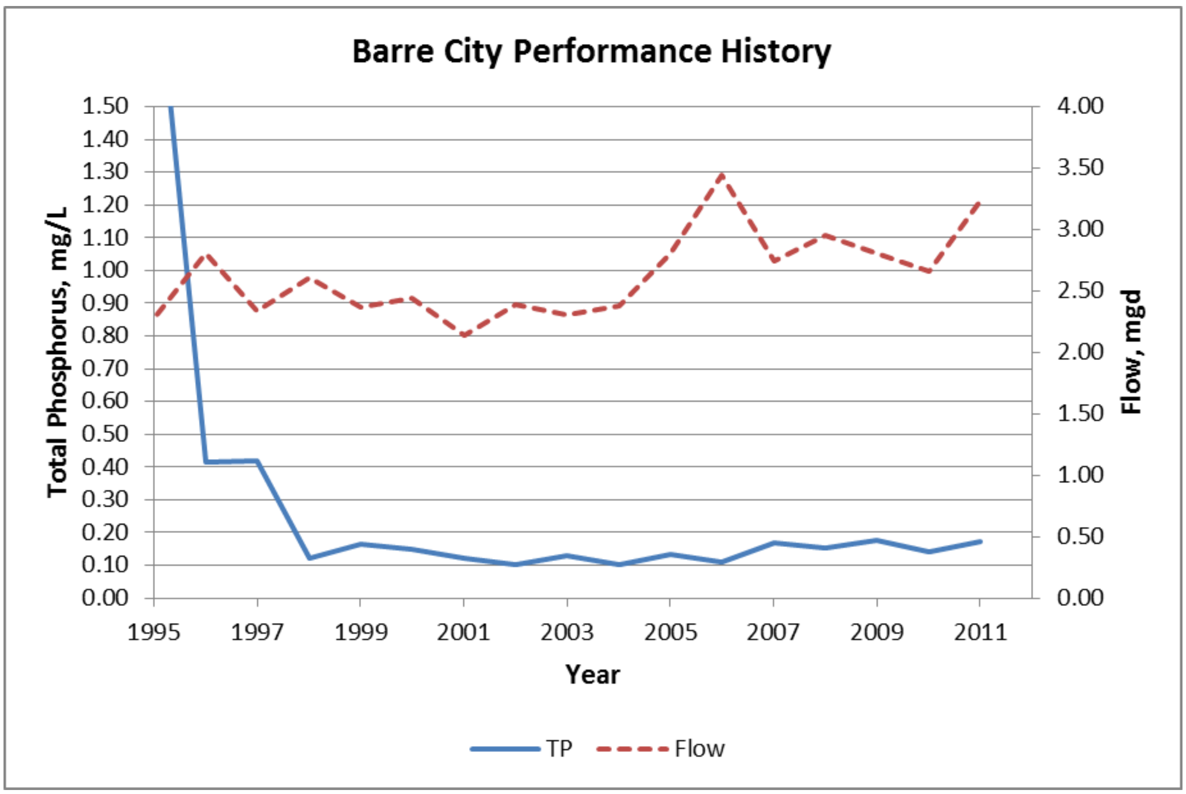


Figure 2.1.2 Barre City WWTF Performance History

2.1.3 Benson

Facility Description

The Benson WWTF is an aerated lagoon facility designed to treat up to 0.0177 MGD ADF. The 2011 ADF was 0.018 MGD slightly exceeding the design treatment capacity. Accumulated sludge is disposed of irregularly following lime stabilization. The effluent phosphorus concentration is sampled quarterly for annual load monitoring only. The allowable annual TP loading is currently 268 lb/yr which requires an annual average concentration of less than 4.97 mg/L at the design ADF and less than 4.89 mg/L at the 2011 ADF.

Effluent Phosphorus History

As shown in Figure 2.1.3, the Benson WWTF has reported moderate effluent phosphorus concentration since 2006 when the effluent TP first dropped to less than 3.0 mg/L. Since 2006, the reported effluent TP has remained between 1.5 mg/L and 3.0 mg/L and has averaged 2.34 mg/L. This phosphorus removal performance produces an effluent well within the current limit for annual loading. The additional treatment required to produce an effluent phosphorus at less than 1.0 mg/L will be considered in this evaluation.

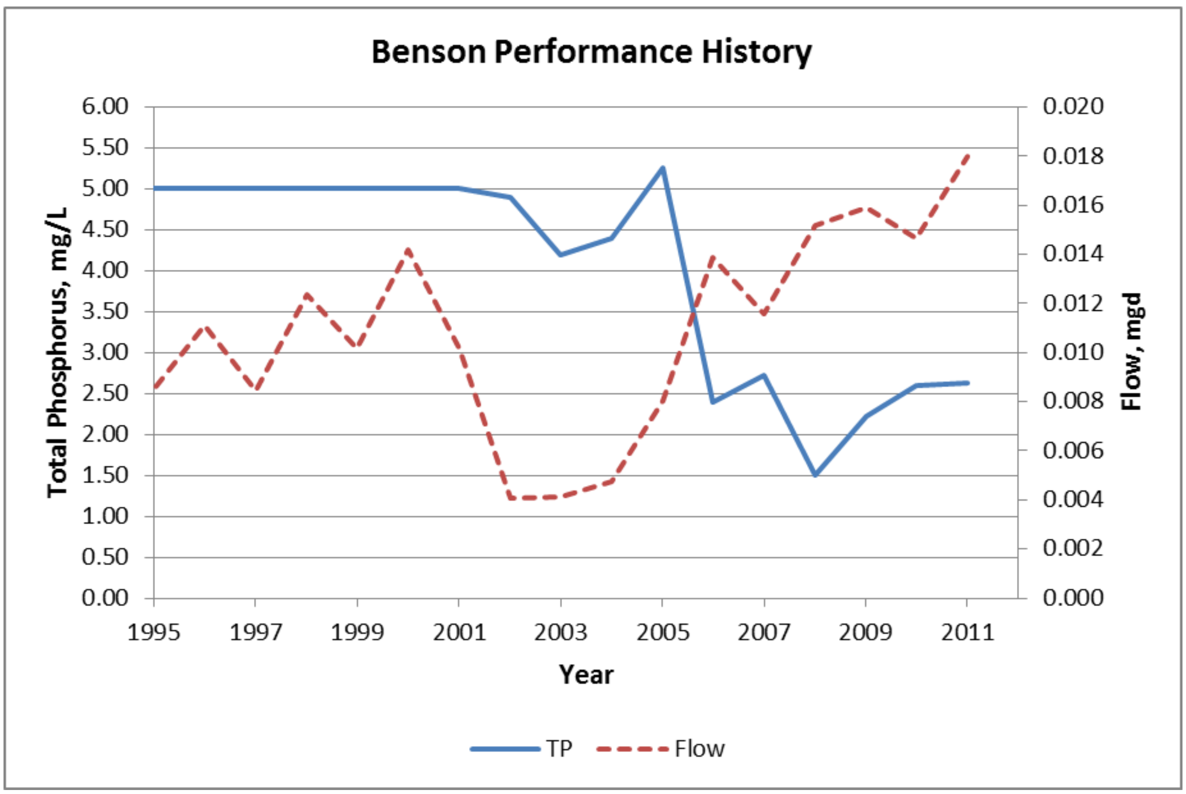


Figure 2.1.3 Benson WWTF Performance History

2.1.4 Brandon

Facility Description

The Brandon WWTF is an oxidation ditch facility designed to treat up to 0.70 MGD ADF. The 2011 ADF was 0.54 MGD. Sludge is disposed to the Rutland WWTF for further processing. Approximately 54 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled twice monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 1278 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.4, the Brandon WWTF has reported effluent phosphorus concentrations of less than 0.5 mg/L since 2001. In 2010 and 2011, the reported effluent TP was between 0.1 mg/L and 0.2 mg/L and averaged 0.132 mg/L. This is excellent phosphorus removal performance and produces an effluent well within the current limits for both concentration and annual loading. Only the 0.1 mg/L effluent TP goal remains to be considered for the Brandon WWTF in this evaluation.

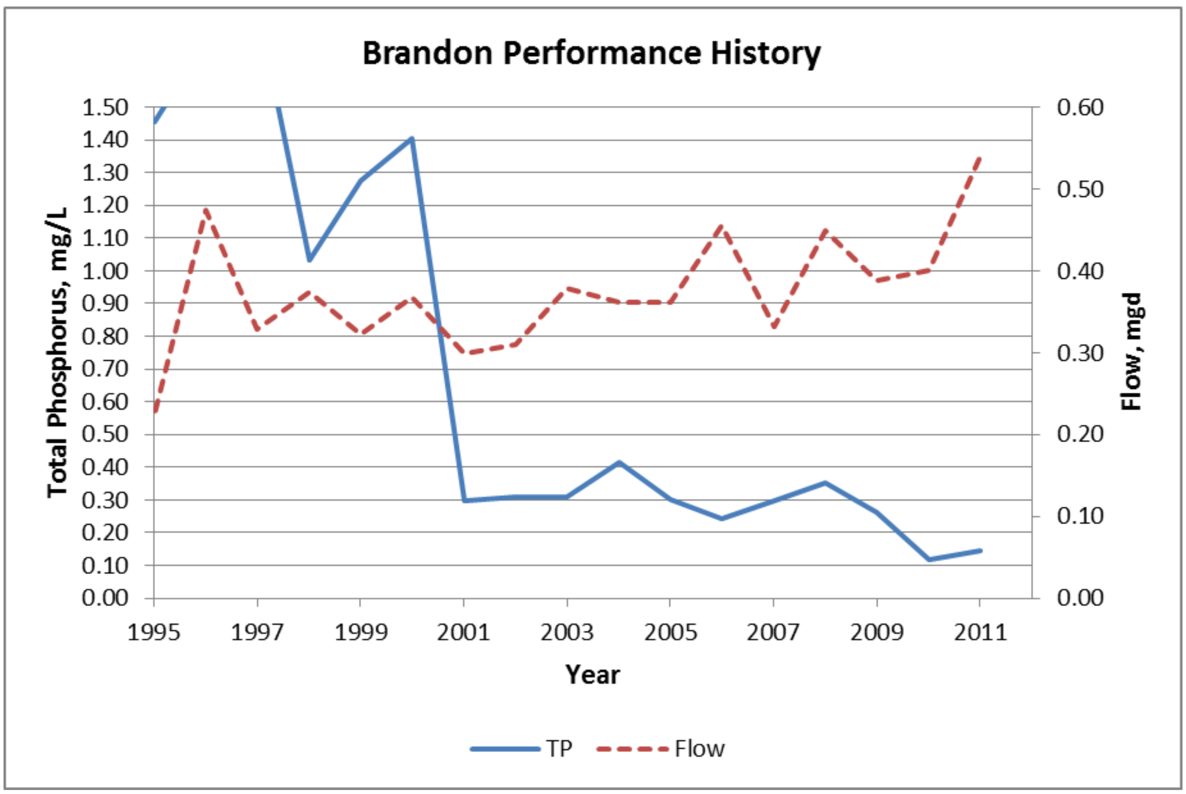


Figure 2.1.4 Brandon WWTF Performance History

2.1.5 Brown Ledge Camp

Facility Description

The Brown Ledge Camp WWTF ceased operating in 2010 and reported no discharge in 2011. When operating, the effluent flow was very low, averaging just 2000 gallons per day between 1991 and 2010.

Effluent Phosphorus History

As shown in Figure 2.1.2, the Brown Ledge WWTF reported effluent phosphorus concentration of between 2.0 and 3.5 mg/L TP since 2004. As it is no longer operating, improvements to increase phosphorus removal were not considered in this evaluation.

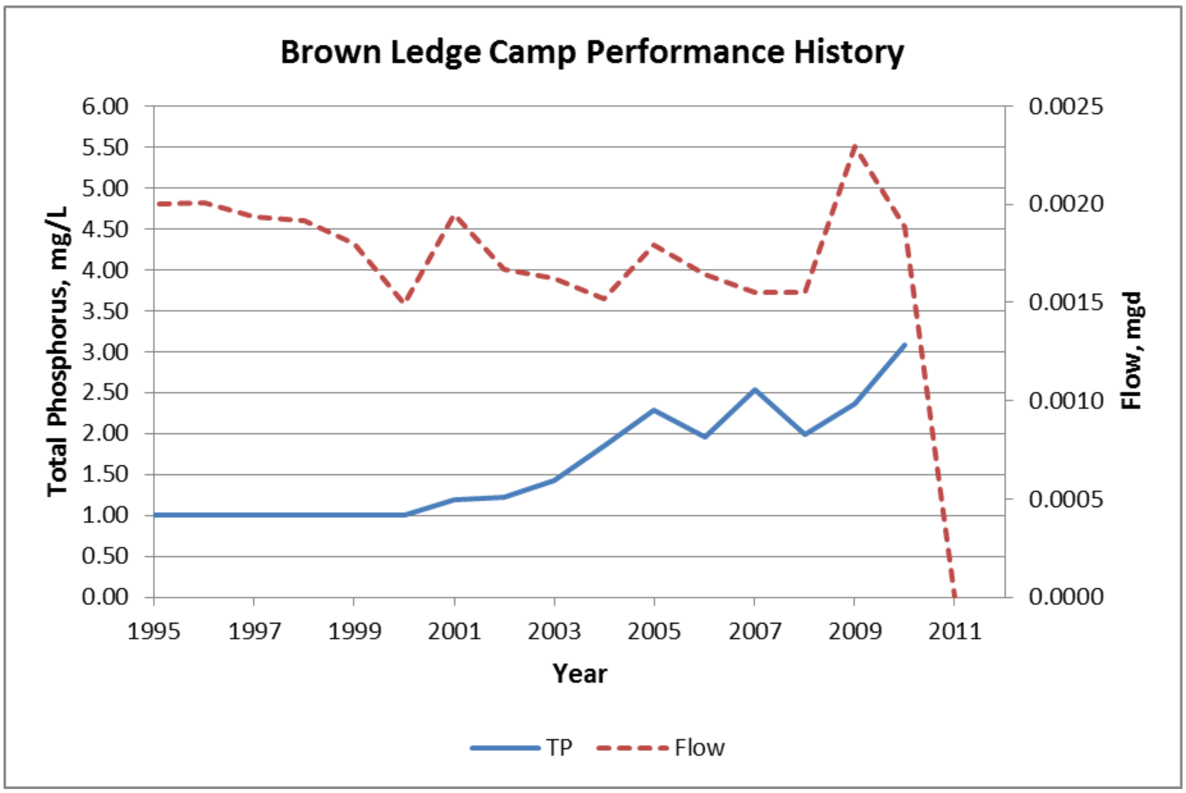


Figure 2.1.5 Brown Ledge Camp WWTF Performance History

2.1.6 Burlington East

Facility Description

The Burlington East WWTF (aka Burlington Riverside Avenue WWTF) is an activated sludge plant situated on a constricted site. It is designed to treat up to 1.2 MGD ADF. The 2011 ADF was 0.64 MGD. Sludge is transferred to the Burlington Main WWTF for additional processing and disposal. Approximately 131 dry tons of sludge were disposed in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 2191 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.6, the Burlington East WWTF has reported moderately low effluent phosphorus concentration since at least 1995 remaining between 0.3 mg/L and 0.6 mg/L and averaging 0.428 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Burlington East WWTF in this evaluation.

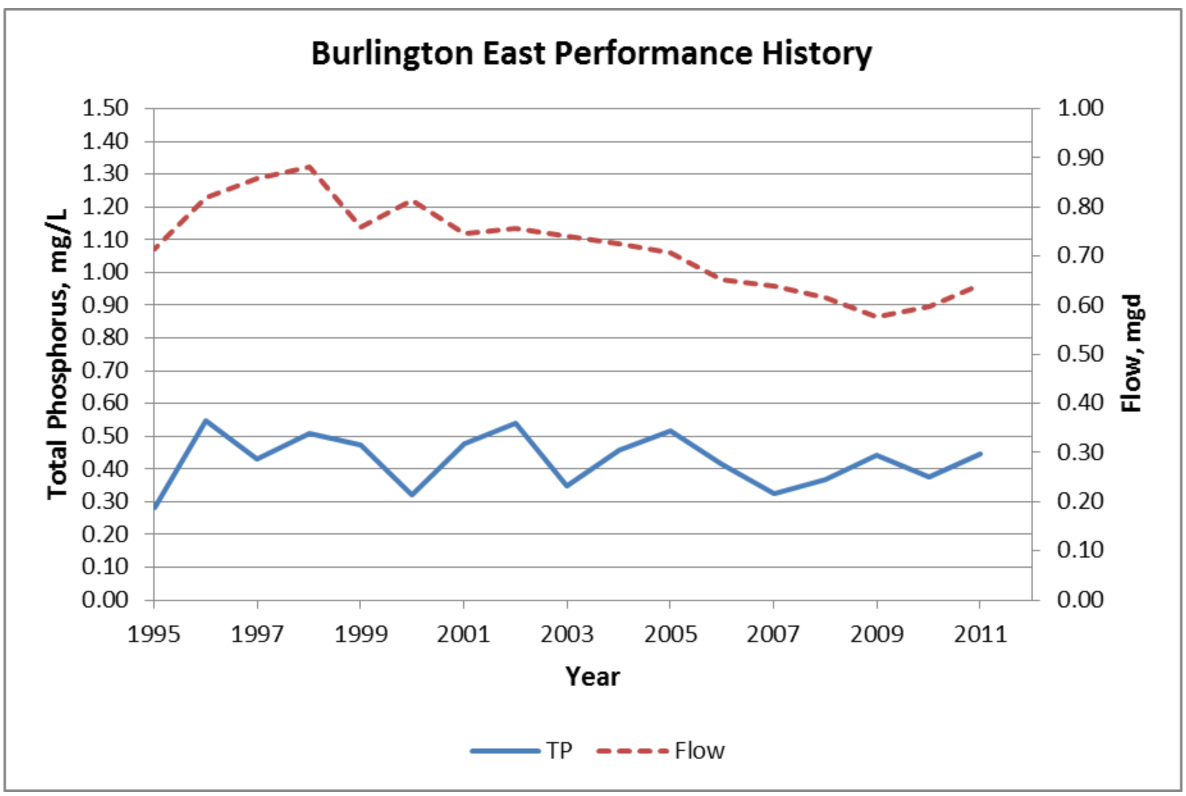


Figure 2.1.6 Burlington East WWTF Performance History

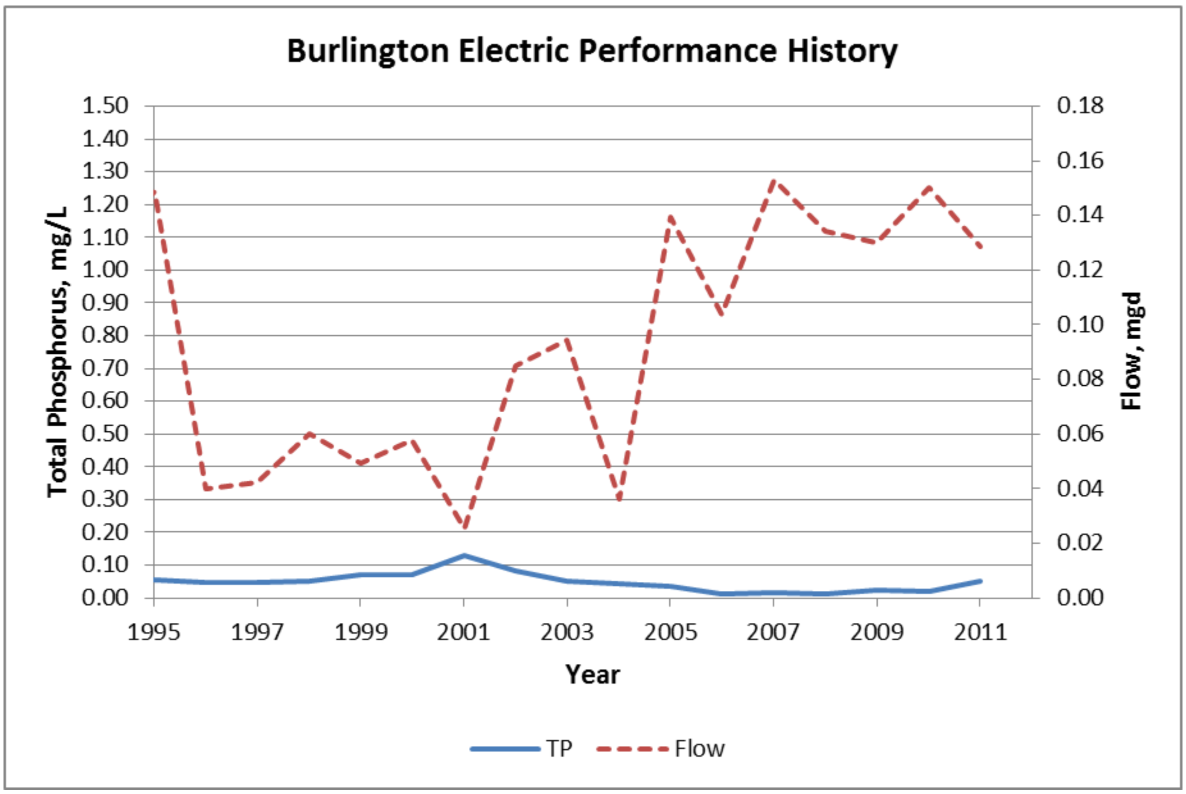
2.1.7 Burlington Electric

Facility Description

The Burlington Electric discharges non-contact cooling and boiler blowdown water. It is designed to treat up to 0.365 MGD ADF. The 2011 ADF was 0.129 MGD. The allowable annual TP loading is currently 37 lb/yr which requires an annual average concentration of less than 0.09 mg/L at current ADF and less than 0.033 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.7, the Burlington Electric WWTF has reported very low effluent phosphorus concentration averaging less than 0.048 mg/L TP since 1995. Effluent TP remained below 0.1 mg/L except for 2001 when it reached a high of 0.128 mg/L TP. This effluent quality is within the current limits for both TP and appears to already be in compliance with the most restrictive TP limit (0.1 mg/L) to be considered in this evaluation.



igure 2.1.7 Burlington Electric WWTF Performance History

2.1.8 Burlington Main

<u>Facility Description</u>

The Burlington Main WWTF is an activated sludge plant on a constricted site that is designed to treat up to 5.3 MGD ADF and is operated with an anoxic zone to achieve nitrogen removal. The 2011 ADF was 5.0 MGD. A combined sewer overflow operates at high flows. This WWTF receives sludge from the Burlington East WWTF and Burlington North WWTF to be dewatered along with the sludge generated at Burlington Main WWTF. The combined sludge is then disposed to landfill. Approximately 1724 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 9682 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.8, the Burlington Main WWTF has reported moderately low effluent phosphorus concentration since at least 1995 remaining between 0.3 mg/L and 0.6 mg/L and averaging 0.463 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Burlington Main WWTF in this evaluation.

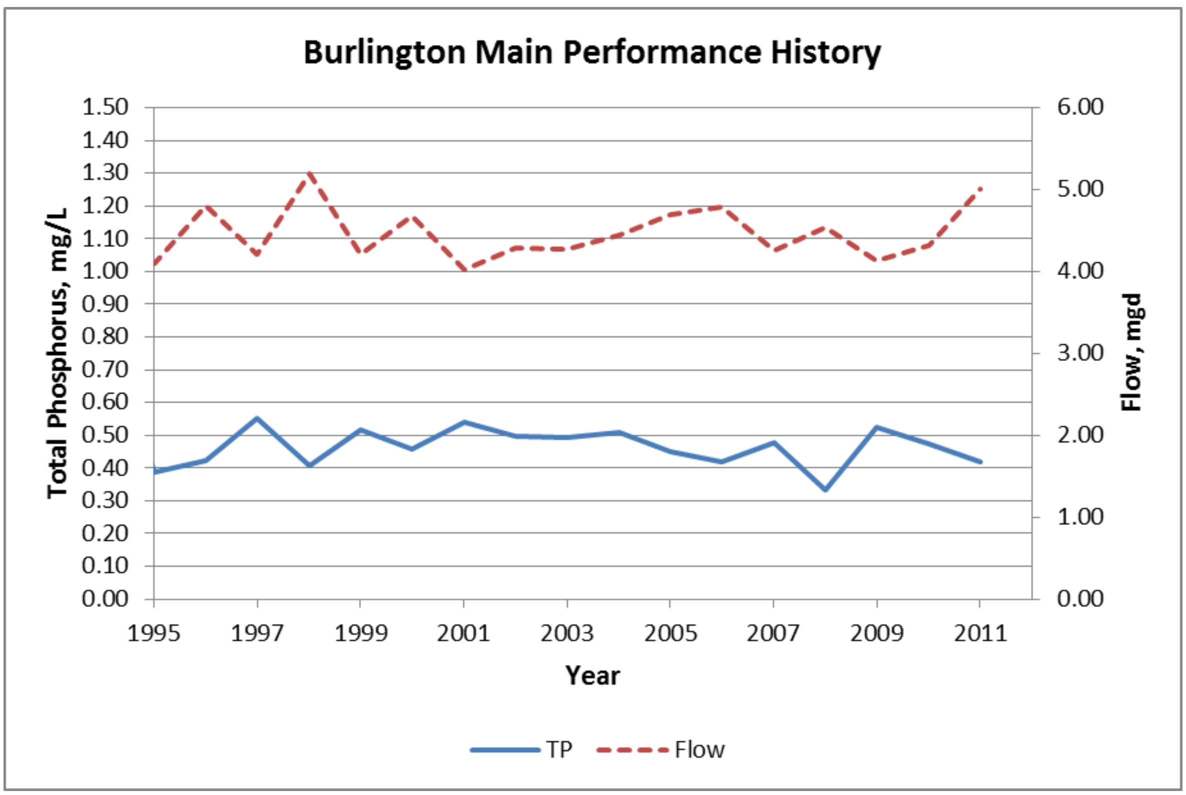


Figure 2.1.8 Burlington Main WWTF Performance

2.1.9 Burlington North

Facility Description

The Burlington North WWTF is an activated sludge plant that is designed to treat up to 2.0 MGD ADF. The 2011 ADF was 1.54 MGD. Sludge is disposed by transferring to the Burlington Main WWTF for further processing and disposal. Approximately 191 dry tons of sludge were disposed in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 3653 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.9, the Burlington North WWTF has reported moderately low effluent phosphorus concentration since at least 1995 remaining between 0.23 mg/L and 0.6 mg/L and averaging 0.403 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Burlington North WWTF in this evaluation.

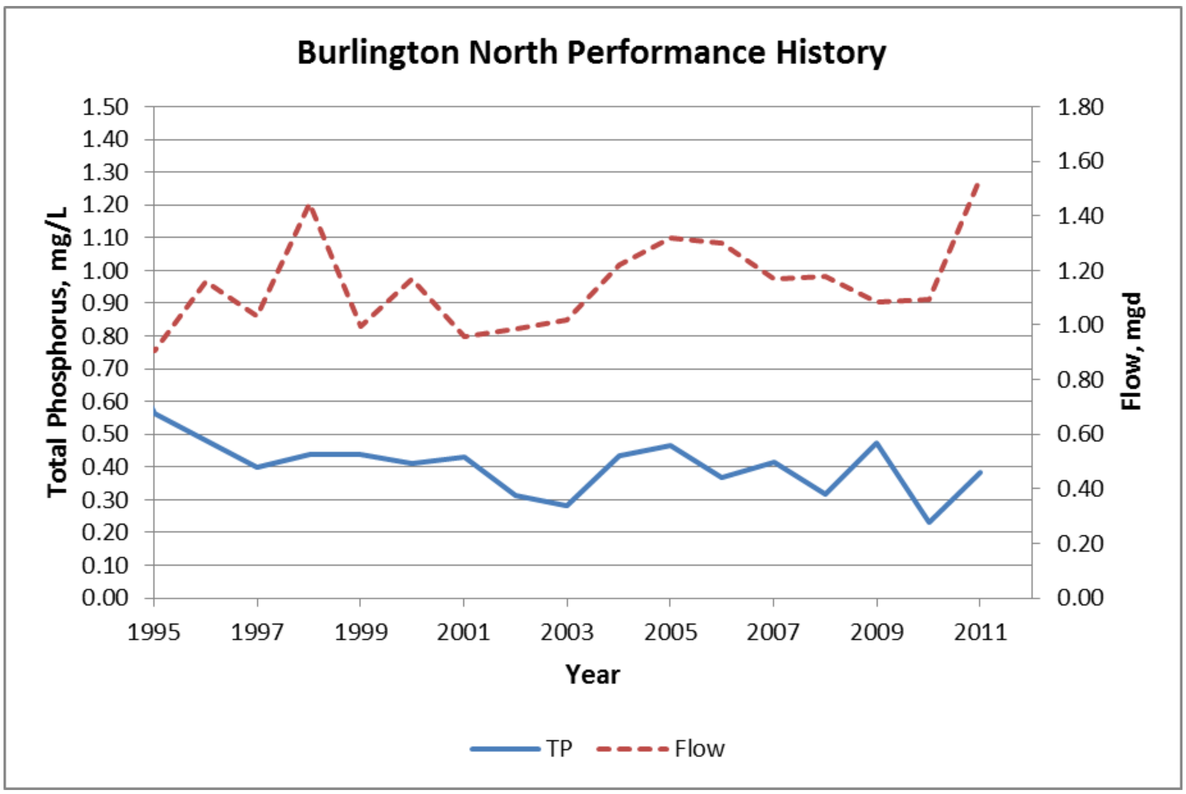


Figure 2.1.9 Burlington North WWTF Performance

2.1.10 Cabot

Facility Description

The Cabot WWTF is a membrane bioreactor (MBR) type activated sludge plant that is designed to treat up to 0.05 MGD ADF. The 2011 ADF was 0.027 MGD. Sludge is disposed by liquid hauling to St Johnsbury WWTF. Approximately 5.8 dry tons of sludge was produced in 2011. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 90 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.10, the Cabot WWTF has reported low effluent phosphorus concentration since 2004 remaining between 0.10 mg/L and 0.4 mg/L. The facility has achieved less than 0.2 mg/L TP in three different operating years and averaged 0.099 mg/L TP for 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading and demonstrates that improvements will not be needed to attain the 0.2 mg/L effluent phosphorus goal. However improvements to attain 0.1 mg/L effluent phosphorus goals remain to be considered for the Cabot WWTF in this evaluation.

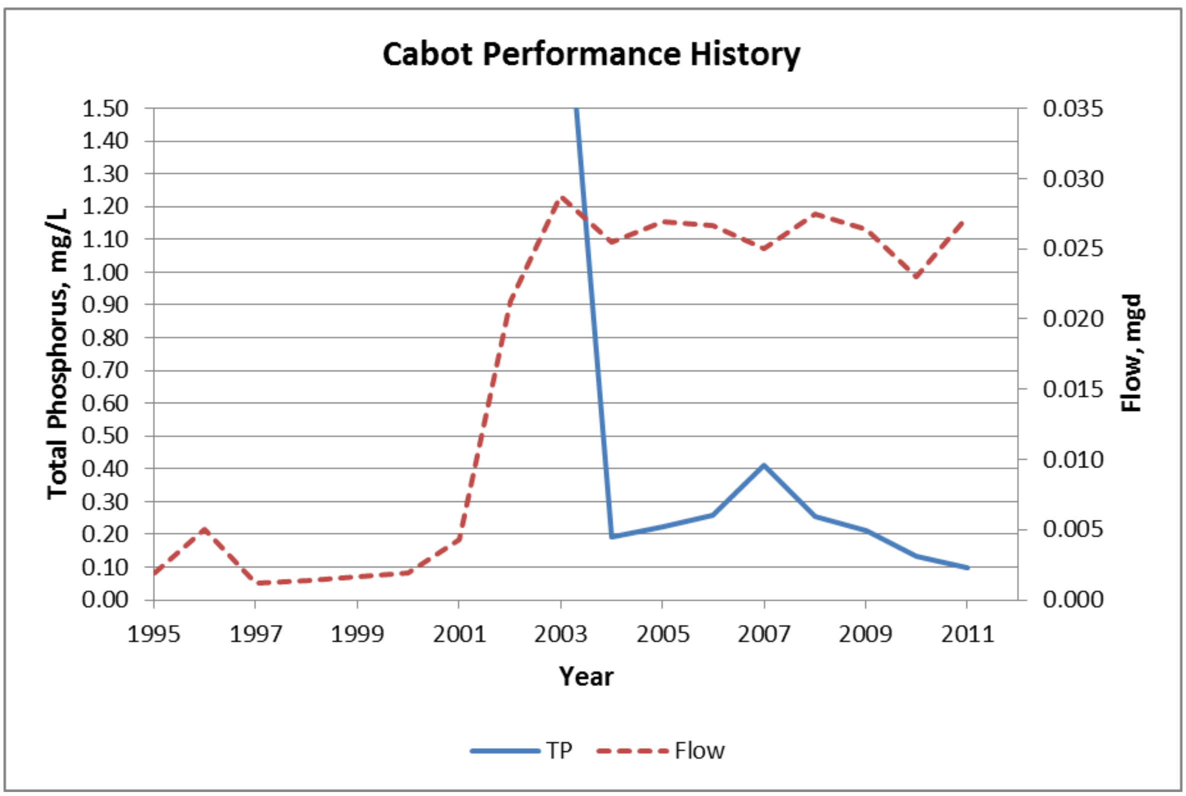


Figure 2.1.10 Cabot WWTF Performance

2.1.11 Castleton

<u>Facility Description</u>

The Castleton WWTF is a sequencing batch reactor (SBR) plant with chemical addition for phosphorus removal that is designed to treat up to 0.48 MGD ADF. The 2011 ADF was 0.33 MGD. Sludge is disposed by transferring to the Rutland WWTF for further processing and disposal. Approximately 67 dry tons of sludge was produced in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 875 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.11, the Castleton WWTF has reported very low effluent phosphorus concentration since at least 2000, remaining between 0.14 mg/L and 0.6 mg/L and averaging 0.147 mg/L over the period 2008 to 2010. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to reliably attain the 0.1 mg/L effluent phosphorus goals remain to be considered for the Castleton WWTF in this evaluation.

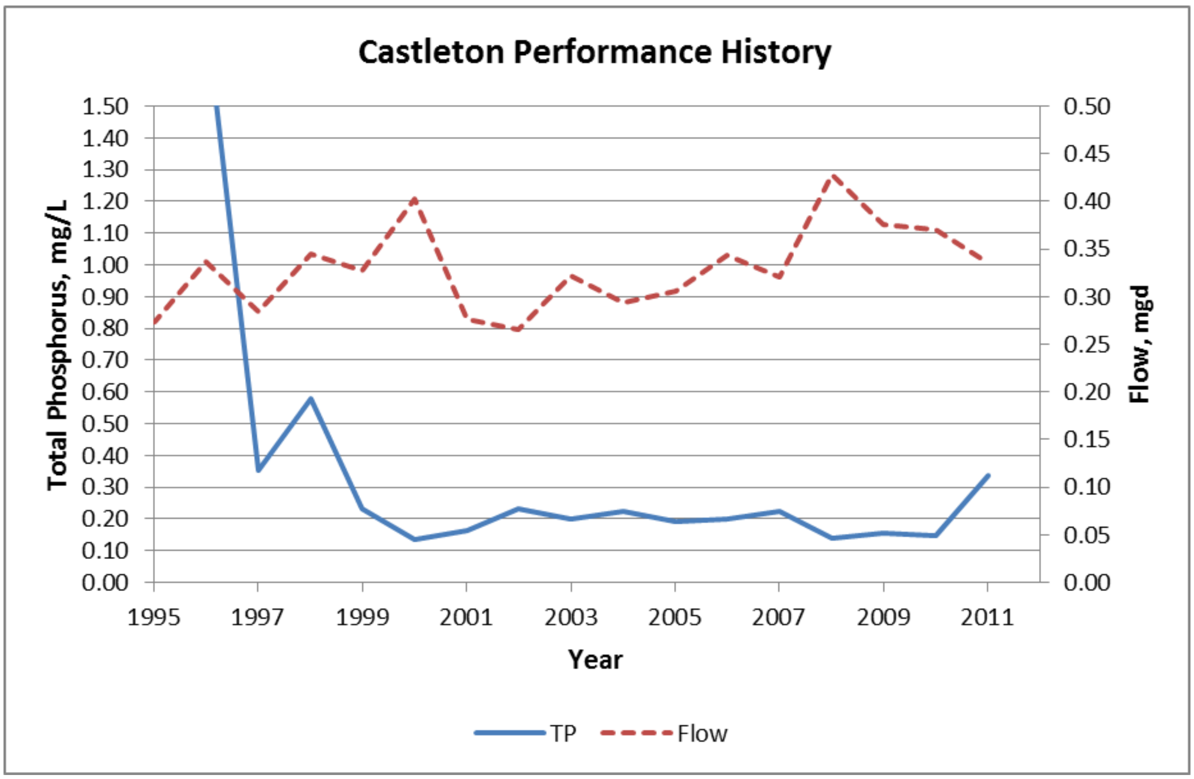


Figure 2.1.11 Castleton WWTF Performance

2.1.12 Enosburg Falls

<u>Facility Description</u>

The Enosburg Falls WWTF is an extended aeration facility with biological phosphous removal designed to treat up to 0.45 MGD ADF. The 2011 ADF was 0.29 MGD. Sludge is disposed by transferring to the Plattsburg WWTF and Burlington Main for further processing and disposal. Approximately 59 dry tons of sludge was disposed in 2011. The effluent phosphorus concentration is sampled twice monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 822 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.12, the Enosburg Falls WWTF has reported moderately low effluent phosphorus concentration since at least 1998 remaining between 0.16 mg/L and 0.5 mg/L and averaging 0.316 mg/L over the period 1998 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to reliably attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Enosburg Falls WWTF in this evaluation.

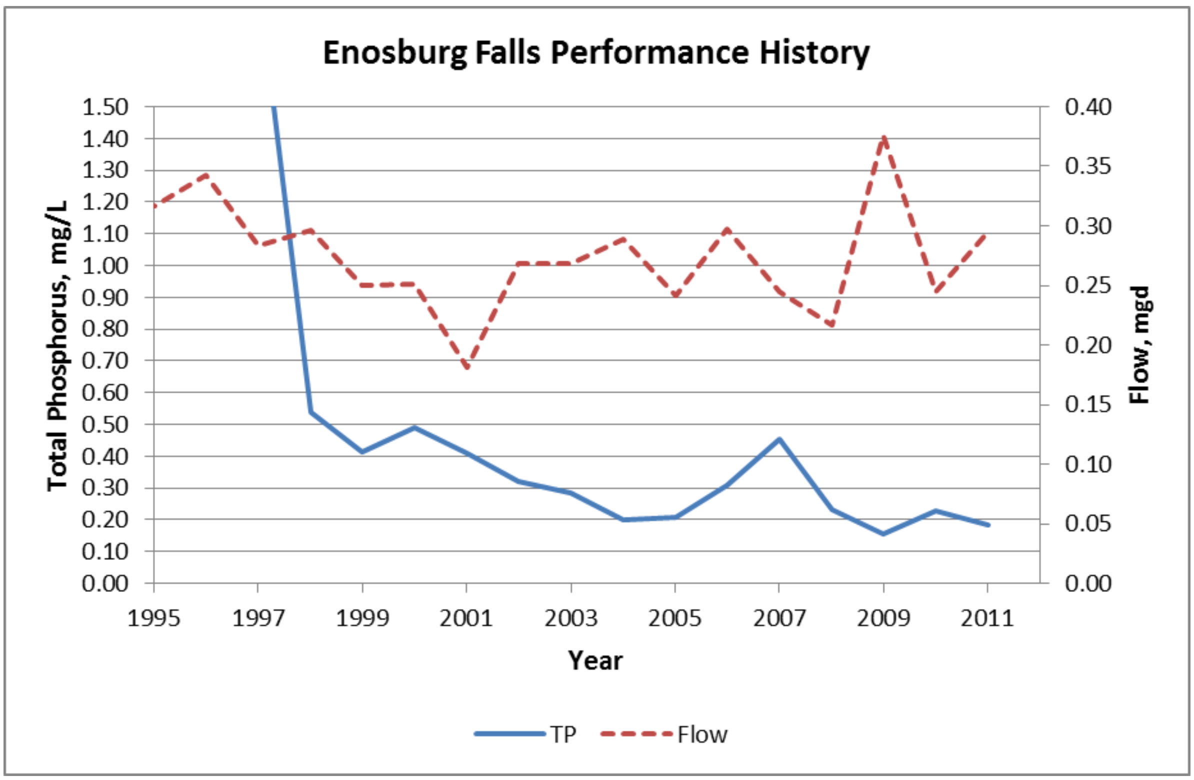


Figure 2.1.12 Enosburg Falls WWTF Performance

2.1.13 Essex Junction

Facility Description

The Essex Junction WWTF is an activated sludge plant with cloth disk filtration that is designed to treat up to 3.30 MGD ADF. An upgrade that is underway will add biological phosphorus removal. The 2011 ADF was 2.31 MGD. Sludge is digested anaerobically before being land applied as a liquid. Approximately 310 dry tons of sludge was disposed in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 5663 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.13, the Essex Junction WWTF has reported moderate effluent phosphorus concentration since at least 1995 remaining between 0.47 mg/L and 0.61 mg/L and averaging 0.546 mg/L over the period 2001 to 2011. This degree of phosphorus removal produces an effluent within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Essex Junction WWTF in this evaluation.

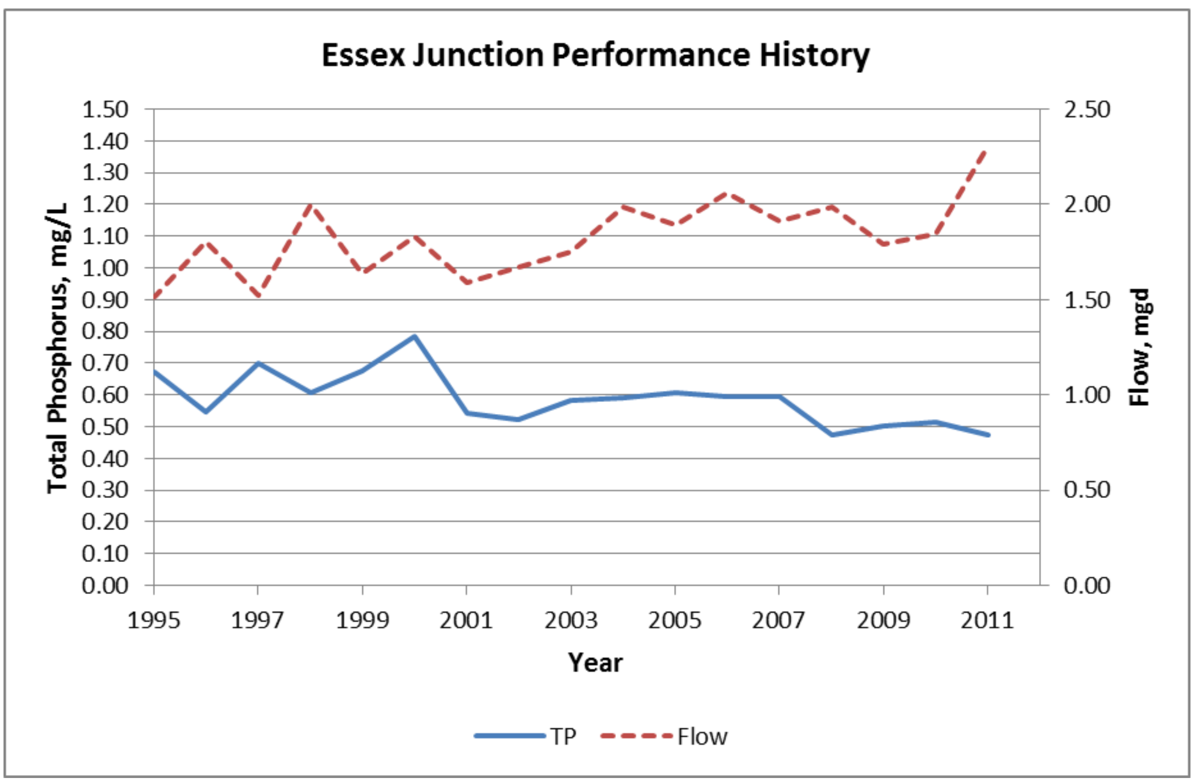


Figure 2.1.13 Essex Junction WWTF Performance

2.1.14 Fair Haven

Facility Description

The Fair Haven WWTF is an extended aeration facility with three selector zones two of which hmay be anoxic or anaerobic for nutrient removal and is designed to treat up to 0.5 MGD ADF. The 2011 ADF was 0.23 MGD. Sludge is disposed to the Rutland WWTF for further processing. Approximately 63 dry tons of sludge were disposed in 2011. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 912 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.14, the Fair Haven WWTF has reported moderately low effluent phosphorus concentration since at least 2002 and has remained between 0.31 mg/L and 0.34 mg/L and averaged 0.335 mg/L over the period 2008 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Fair Haven WWTF in this evaluation.

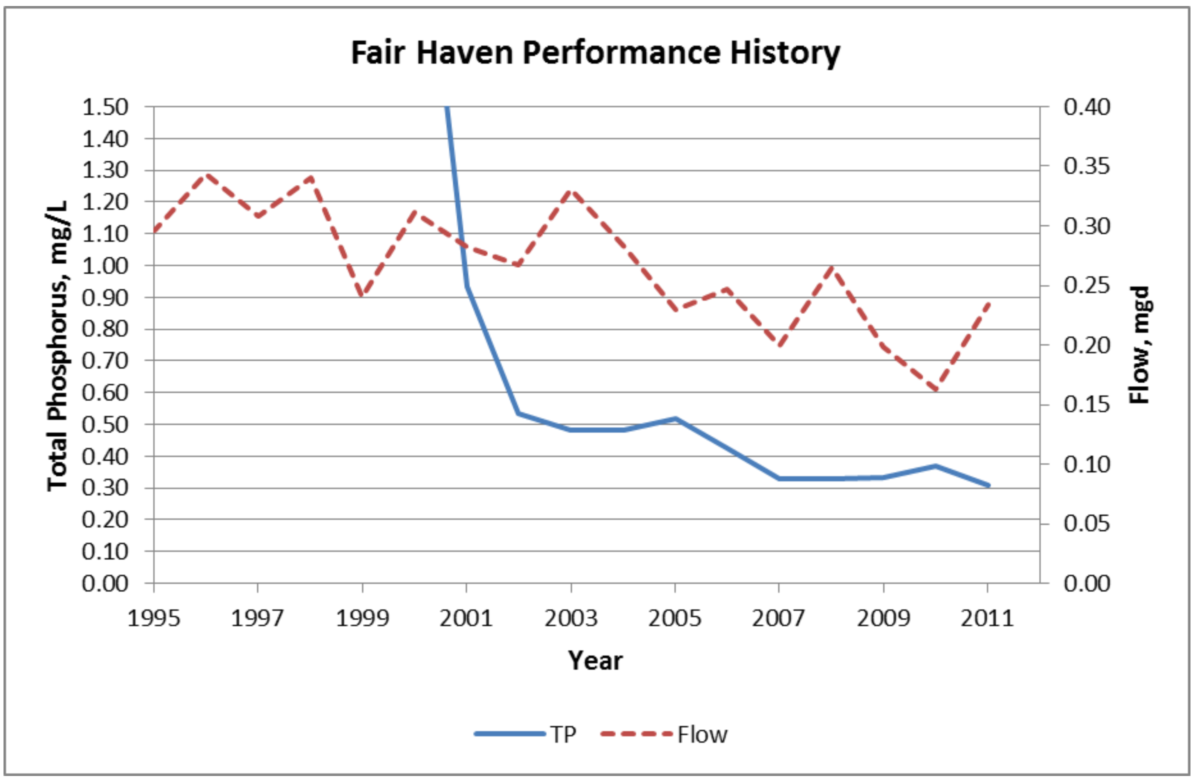


Figure 2.1.14 Fair Haven WWTF Performance

2.1.15 Fairfax

Facility Description

The Fairfax WWTF uses an aerated lagoon type process designed to treat up to 0.078 MGD of average daily flow (ADF). The 2011 ADF was 0.0463 MGD. Sludge is irregularly removed, stabilized by lime addition and is liquid land applied. The effluent phosphorus concentration is sampled monthly. The allowable annual TP loading is currently 1188 lb/yr which requires an annual average concentration of less than 5.00 mg/L at the design ADF and less than 8.42 mg/L at the 2011 ADF.

Effluent Phosphorus History

As shown in Figure 2.1.9, the Fairfax WWTF has reported high effluent phosphorus concentration since at least 2002 remaining between 3.85 mg/L and 5.50 mg/L and averaging 5.04 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent within the current limit for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Fairfax WWTF in this evaluation.

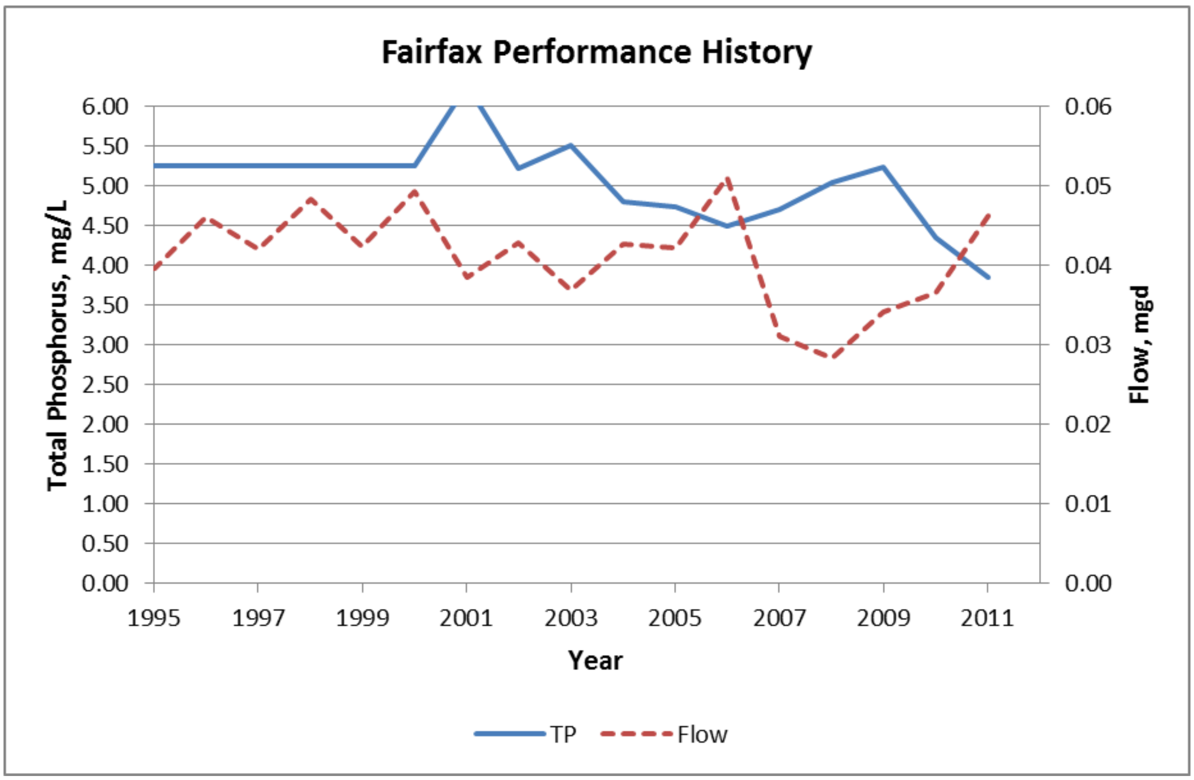


Figure 2.1.15 Fairfax WWTF Performance

2.1.16 Hardwick

<u>Facility Description</u>
The Hardwick WWTF uses an aerated lagoon type process with an anaerobic zone in the first lagoon and in-lagoon chemical addition that is designed to treat up to 0.371 MGD ADF. The 2011 ADF was 0.247 MGD. Sludge is irregularly removed, stabilized by lime addition and is liquid land applied. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 933 lb/yr which requires an annual average concentration of less than 1.24 mg/L at current ADF and less than 0.826 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>
As shown in Figure 2.1.16, the Hardwick WWTF has reported moderately low effluent phosphorus concentration since 2008 remaining between 0.427 mg/L and 0.488 mg/L and averaging 0.450 mg/L over the period 2008 to 2011. This degree of phosphorus removal produces an effluent well within the current limit for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Hardwick WWTF in this evaluation.

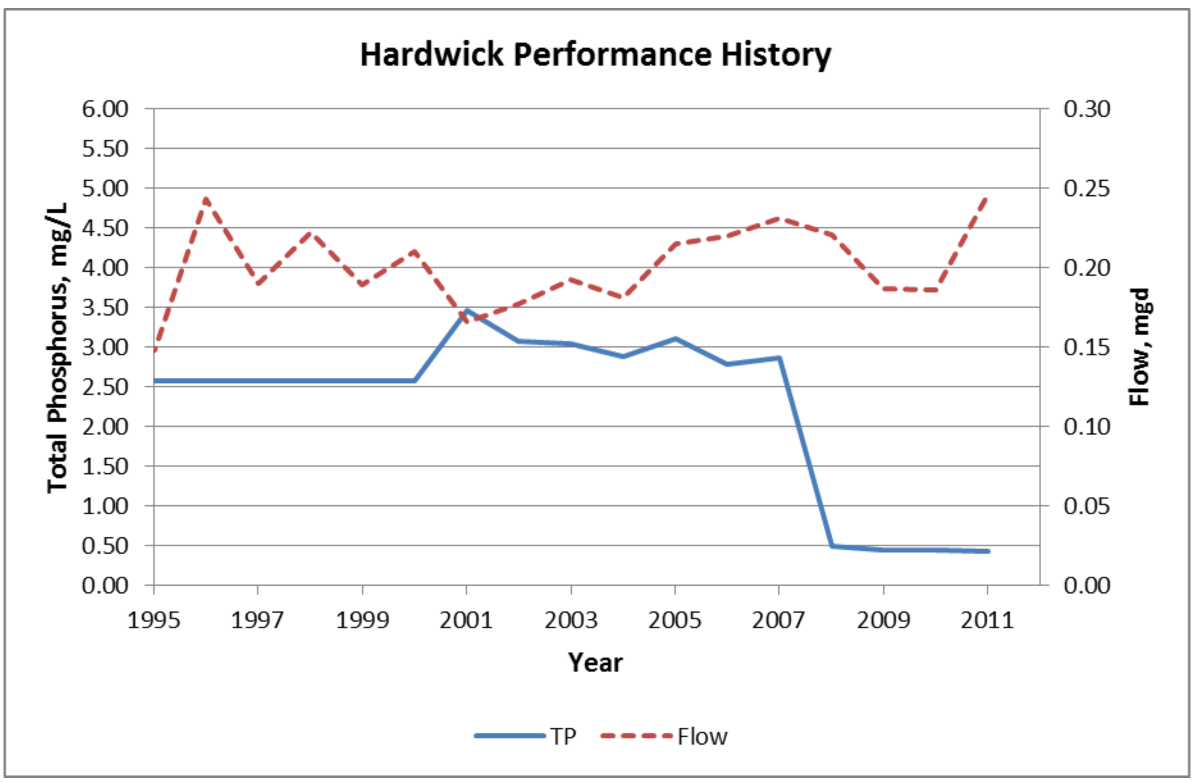


Figure 2.1.16 Hardwick WWTF Performance

2.1.17 Hinesburg

Facility Description

The Hinesburg WWTF uses an aerated lagoon type process with in-lagoon chemical addition that is designed to treat up to 0.25 MGD ADF. The 2011 ADF was 0.17 MGD. Sludge is irregularly removed, stabilized by lime addition and is liquid land applied. The effluent phosphorus concentration is sampled twice monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 608 lb/yr which requires an annual average concentration of less than 1.17 mg/L at current ADF and less than 0.8 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.17, the Hinesburg WWTF has reported low effluent phosphorus concentration since at least 1997 remaining between 0.217 mg/L and 0.455 mg/L and averaging 0.347 mg/L over the period 1997 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Hinesburg WWTF in this evaluation.

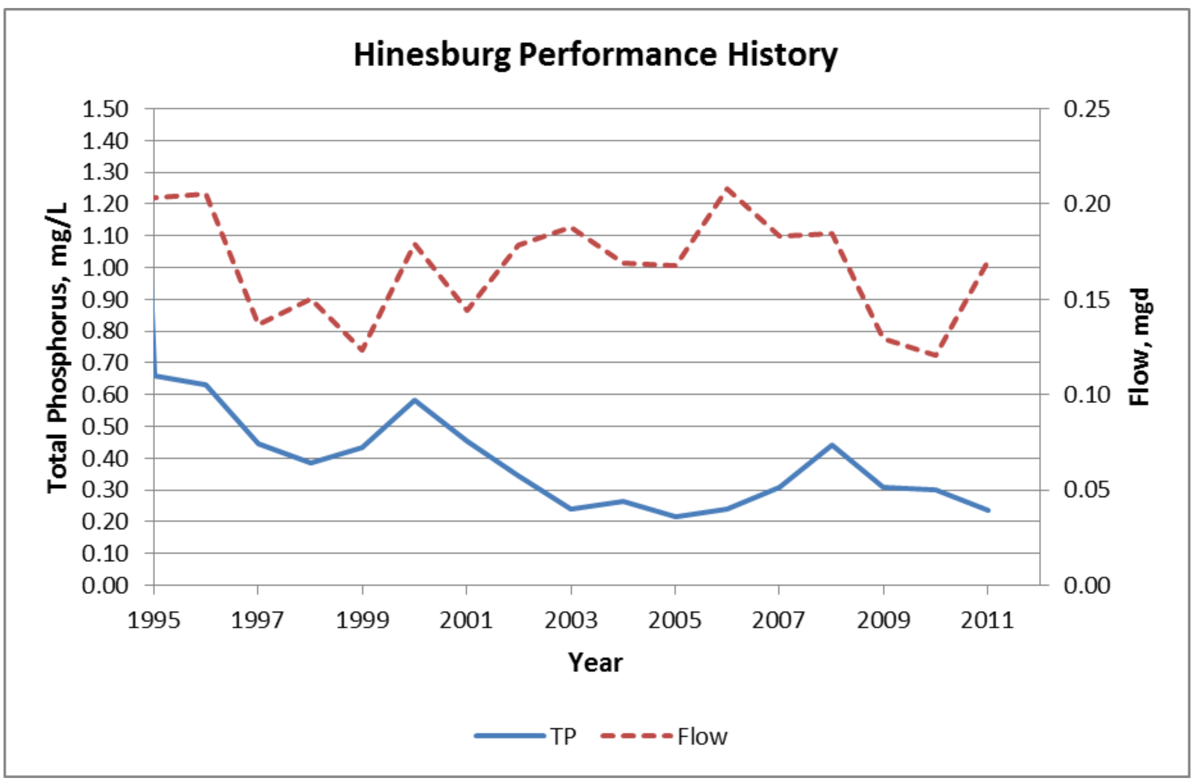


Figure 2.1.17 Hinesburg WWTF Performance

2.1.18 IBM

Facility Description

The IBM WWTF is designed to treat up to 8.0 MGD ADF. The 2011 ADF was 3.09 MGD. The allowable annual TP loading is currently 12194 lb/yr which requires an annual average concentration of less than 1.29 mg/L at current ADF and less than 0.5 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.18, the IBM WWTF has reported moderately very low effluent phosphorus concentration since at least 1995 remaining between 0.137 mg/L and 0.265 mg/L and averaging 0.205 mg/L over the period 2007 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to reliably attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the IBM WWTF in this evaluation.

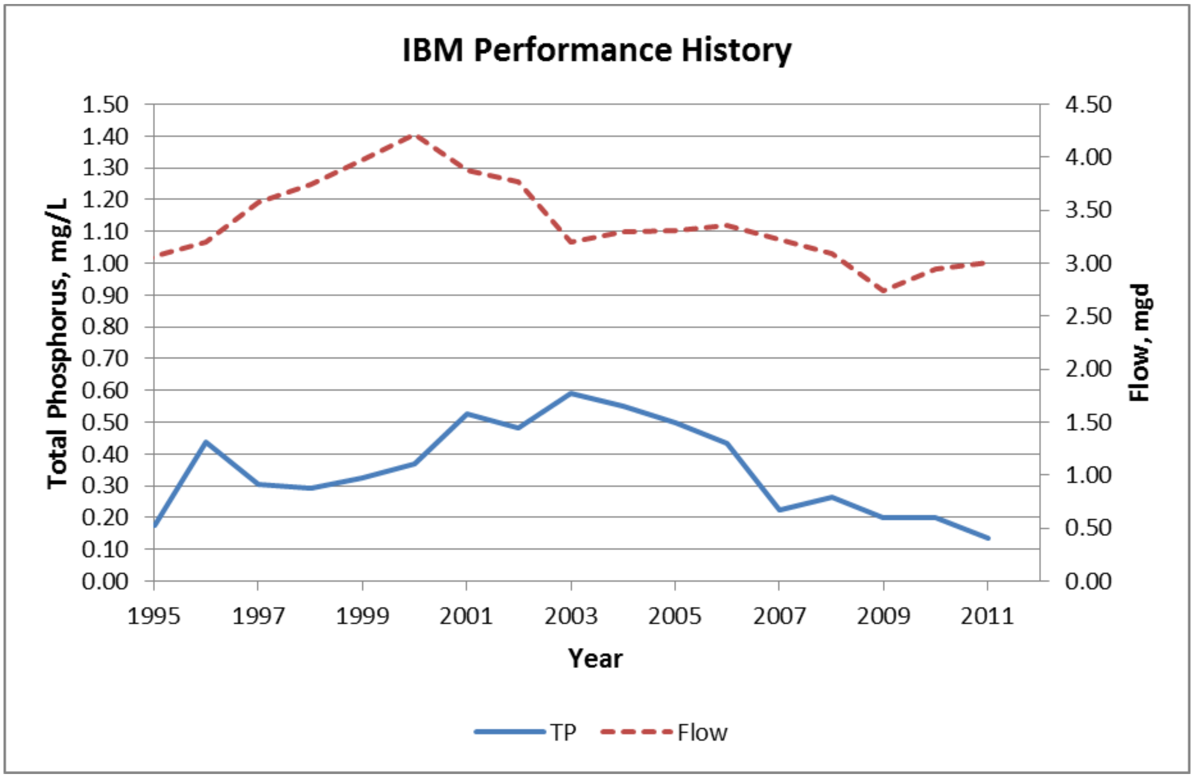


Figure 2.1.18 IBM WWTF Performance

2.1.19 Jeffersonville

Facility Description

The Jeffersonville WWTF is an aerated lagoon plant that is designed to treat up to 0.077 MGD ADF. The 2011 ADF was 0.0375 MGD. Sludge is irregularly disposed after mechanical dewatering. The effluent phosphorus concentration is sampled monthly. The allowable annual TP loading is currently 1172 lb/yr which requires an annual average concentration of less than 10.27 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.19, the Jeffersonville WWTF has reported moderately high effluent phosphorus concentration since at least 2001 remaining between 5.48 mg/L and 7.39 mg/L and averaging 6.50 mg/L over the period 2001 to 2011. This degree of phosphorus removal produces an effluent well within the current limit for annual loading but does not comply with the limit at design ADF. Improvements to attain the 1.0 mg/L effluent phosphorus goals remain to be considered for the Jeffersonville WWTF in this evaluation.

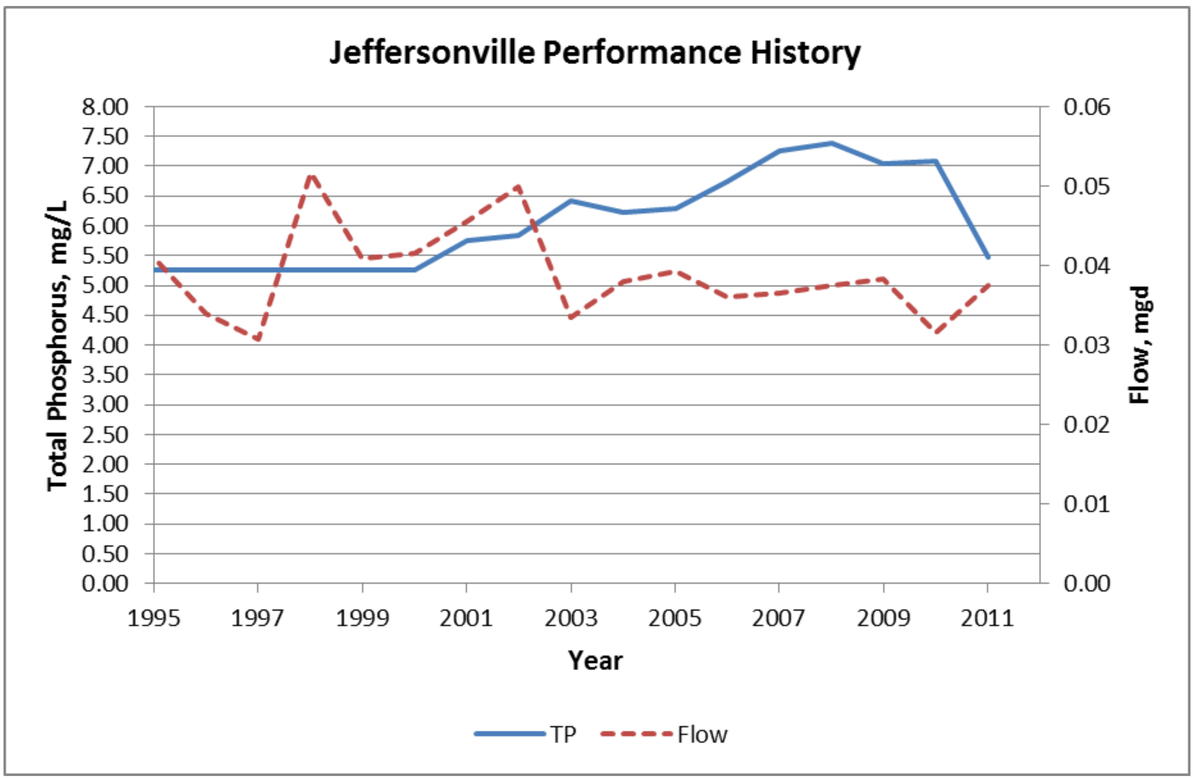


Figure 2.1.19 Jeffersonville WWTF Performance

2.1.20 Johnson

Facility Description

The Johnson WWTF is an SBR type activated sludge plant that is designed to treat up to 0.27 MGD ADF. The 2011 ADF was 0.214 MGD. Mechanically dewatered sludge is disposed by landfilling. Approximately 35 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 493 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.20, the Johnson WWTF has reported moderately low effluent phosphorus concentration since at least 1998 remaining between 0.267 mg/L and 0.485 mg/L and averaging 0.324 mg/L over the period 1998 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Johnson WWTF in this evaluation.

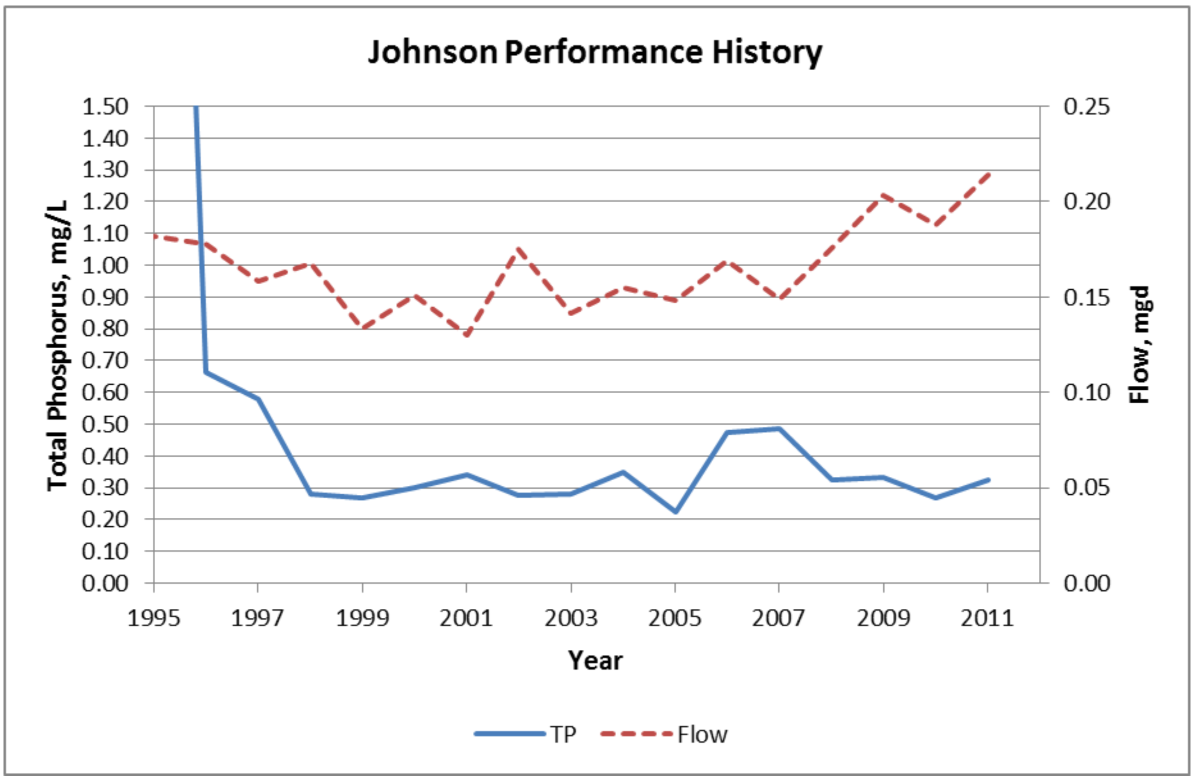


Figure 2.1.20 Johnson WWTF Performance

2.1.21 Marshfield

Facility Description

The Marshfield WWTF is an aerated lagoon plant that is designed to treat up to 0.045 MGD ADF. The 2011 ADF was 0.0219 MGD. Sludge is disposed of irregularly after mechanical dewatering. The effluent phosphorus concentration is sampled monthly. The allowable annual TP loading is currently 685 lb/yr which requires an annual average concentration of less than 10.28 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.21, the Marshfield WWTF has reported irregular effluent phosphorus concentration since 2005 ranging from 1.736 mg/L and 4.975 mg/L probably as a result of chemical addition trials. This degree of phosphorus removal produces an effluent well within the current limit for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Marshfield WWTF in this evaluation.

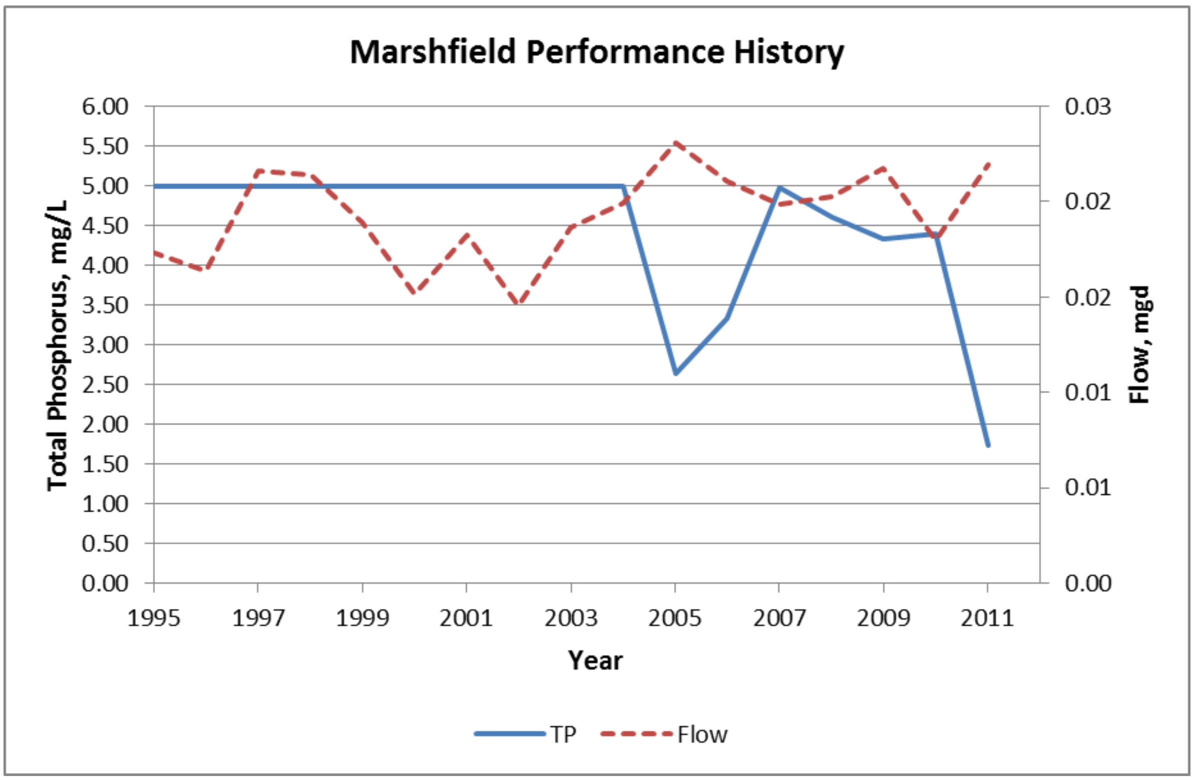


Figure 2.1.21 Marshfield WWTF Performance

2.1.22 Middlebury

Facility Description

The Middlebury WWTF is an SBR type activated sludge plant that is designed to treat up to 2.2 MGD ADF. The 2011 ADF was 1.07 MGD. Sludge is dewatered by pressing and disposed. Approximately 658 dry tons of sludge were disposed in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 4018 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.22, the Middlebury WWTF has reported progressively lower effluent phosphorus concentration since at least 2001 remaining at less than 0.5 mg/L and achieving 0.23 mg/L in 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Middlebury WWTF in this evaluation.

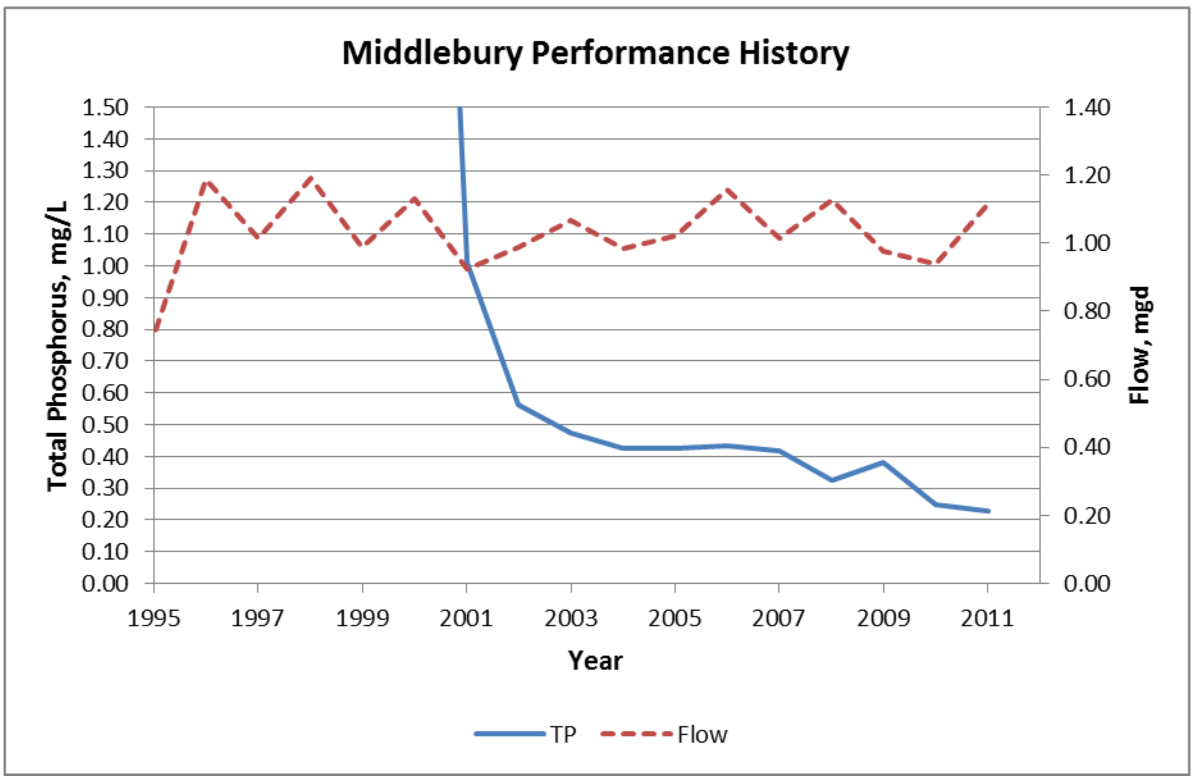


Figure 2.1.22 Middlebury WWTF Performance

2.1.23 Milton

<u>Facility Description</u>
The Milton WWTF is an SBR type activated sludge plant that is designed to treat up to 1.0 MGD ADF. The 2011 ADF was 0.30 MGD. Sludge is mechanically dewatered and disposed to a landfill. Approximately 63 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 1827 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

<u>Effluent Phosphorus History</u>
As shown in Figure 2.1.23, the Milton WWTF has reported progressively lower effluent phosphorus concentration since at least 2001 remaining at less than 1.0 mg/L since 2006 and achieving 0.538 mg/L in 2011. The effluent TP has averaged 0.55 mg/L since 2008. This degree of phosphorus removal produces an effluent within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Milton WWTF in this evaluation.

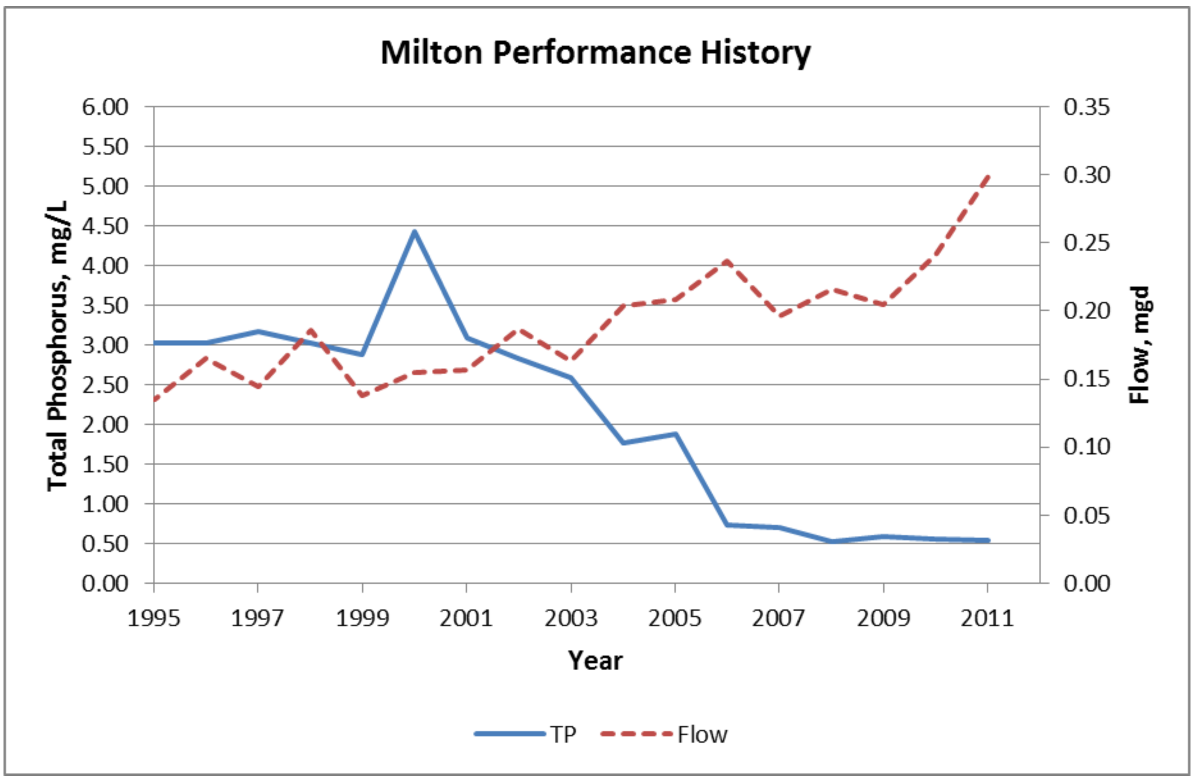


Figure 2.1.23 Milton WWTF Performance

2.1.24 Montpelier

<u>Facility Description</u>

The Montpelier WWTF is an activated sludge plant on a constricted site that is designed to treat up to 3.97 MGD ADF. The 2011 ADF was 2.178 MGD. After anaerobic digestion, sludge is mechanically dewatered and disposed by landfilling. Approximately 619 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 7253 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.24, the Montpelier WWTF has reported moderately low effluent phosphorus concentration since at least 2002 remaining between 0.197 mg/L and 0.525 mg/L and averaging 0.363 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to reliably attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Montpelier WWTF in this evaluation.

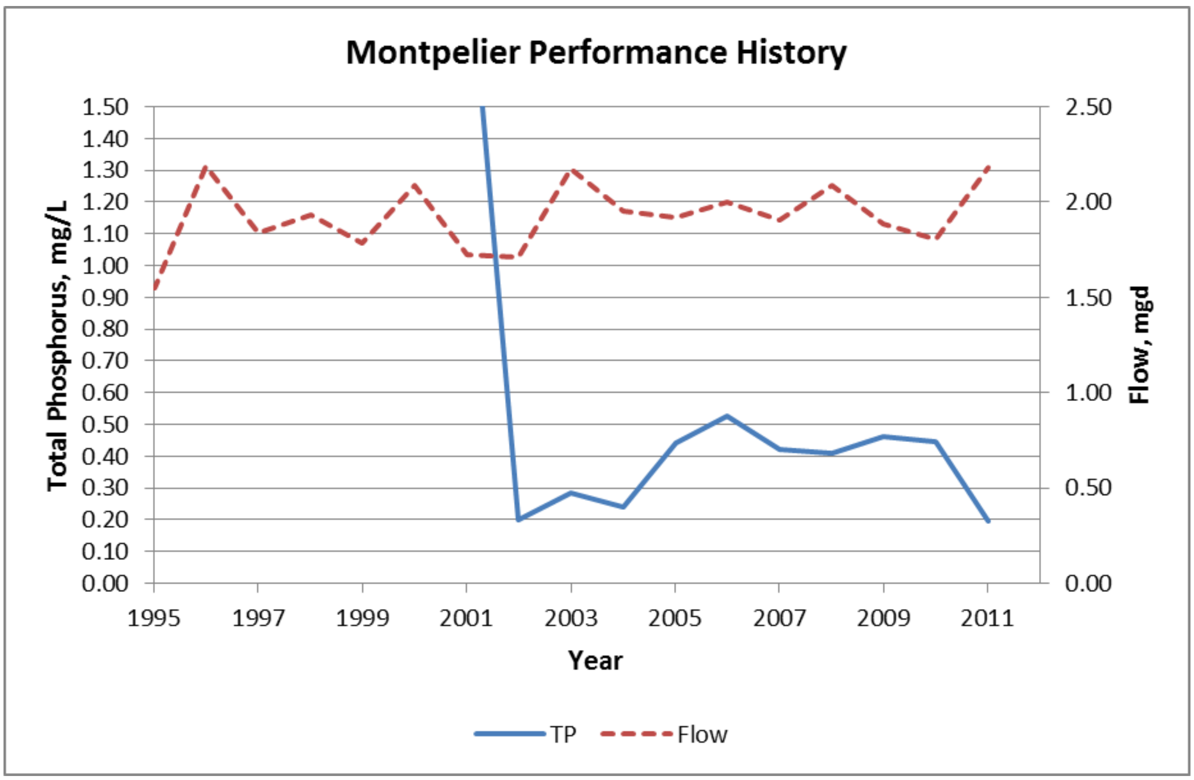


Figure 2.1.24 Montpelier WWTF Performance

2.1.25 Morrisville

Facility Description

The Morrisville WWTF is an SBR type activated sludge plant that is designed to treat up to 0.425 MGD ADF. The 2011 ADF was 0.312 MGD. Sludge is mechanically dewatered and disposed to a landfill. Approximately 77 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 776 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.25, the Morrisville WWTF has reported progressively lower effluent phosphorus concentration since 2004 remaining at less than 0.5 mg/L since 2007 and achieving 0.206 mg/L in 2011. This degree of phosphorus removal produces an effluent within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Morrisville WWTF in this evaluation.

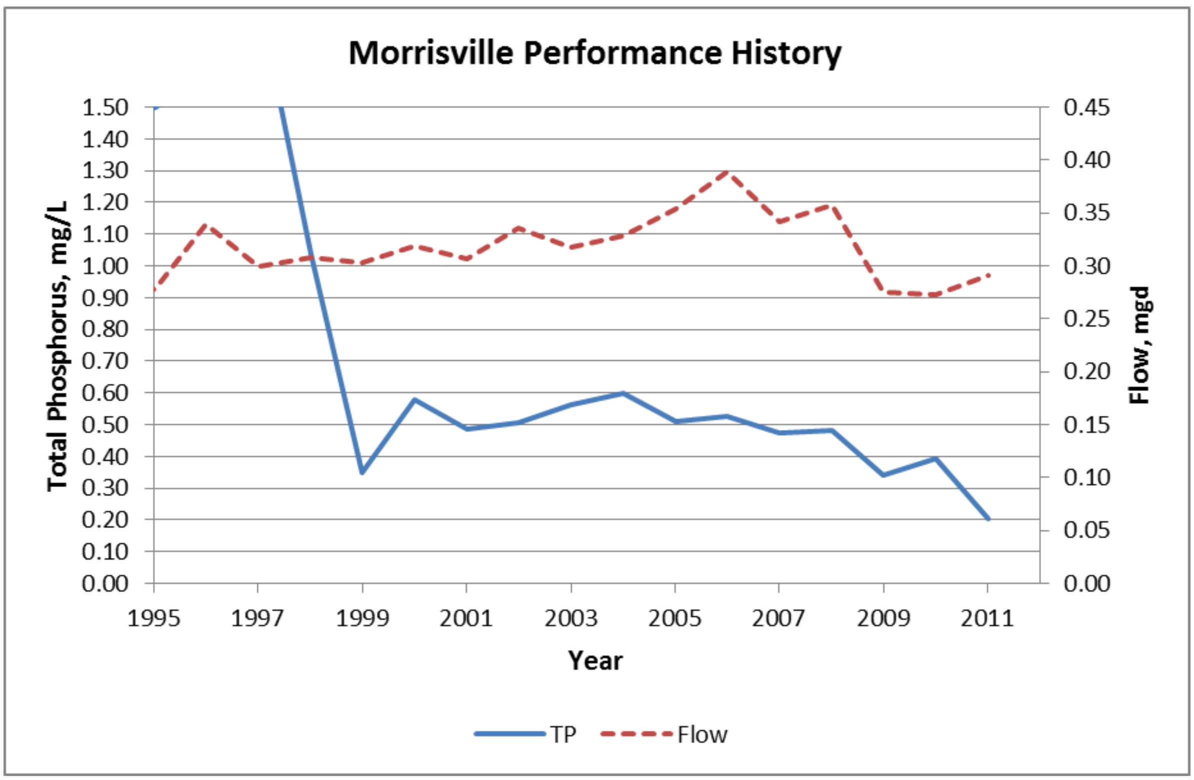


Figure 2.1.25 Morrisville WWTF Performance

2.1.26 Newport Center

Facility Description

The Newport Center WWTF is a subsurface treatment plant that is designed to treat up to 0.0415 MGD ADF. The 2011 ADF was 0.0340 MGD. The effluent phosphorus concentration is sampled monthly from May through October for monitoring purposes. The allowable annual TP loading is currently 13.2 lb/yr which requires an annual average concentration of less than 0.12 mg/L at current ADF and less than 0.10 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.26 the Newport Center WWTF has reported erratic effluent phosphorus concentration. Apparently at non-detect levels prior to 2003 (possibly as a function of the influent phosphorus concentration), since 2008 it has ranged between 0.63 mg/L and 1.52 mg/L. The current degree of phosphorus removal is inadequate to produce an effluent within the current limit for annual loading. Improvements to attain reliable performance at less than 1.0 mg/L and at both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Newport Center WWTF in this evaluation.

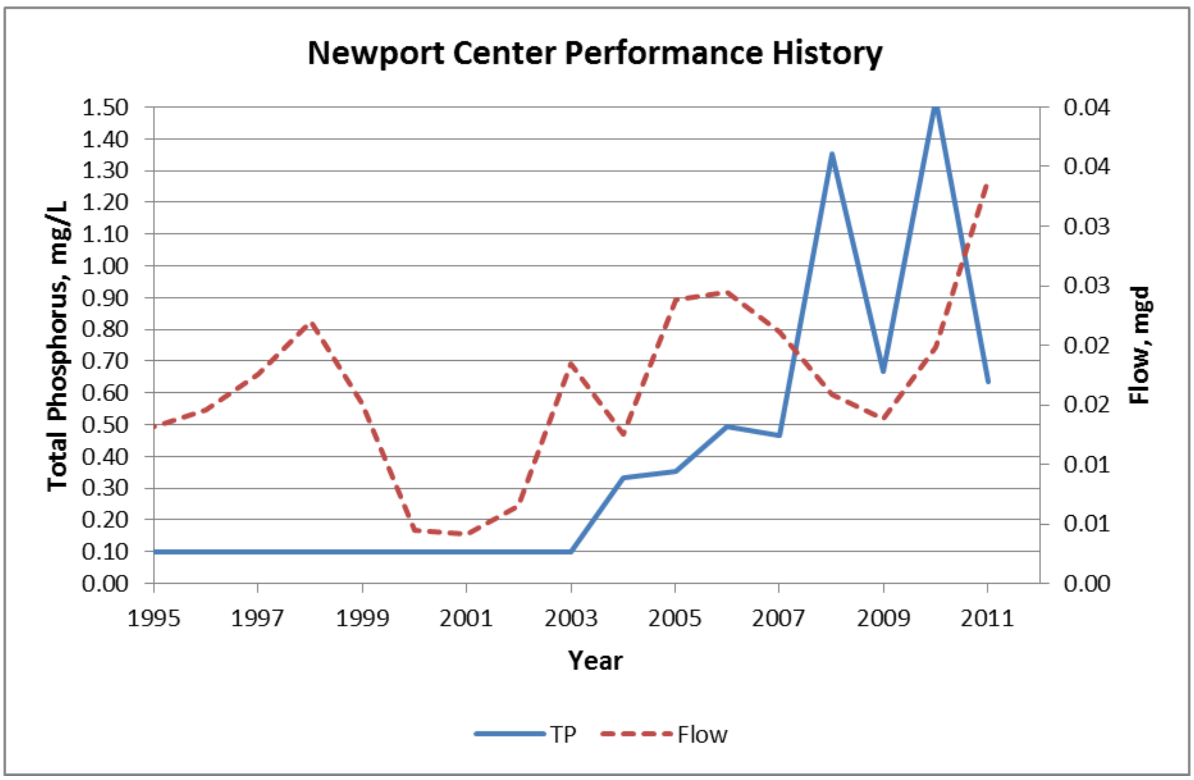


Figure 2.1.26 Newport Center WWTF Performance

2.1.27 North Troy

Facility Description

The North Troy WWTF is an extended aeration activated sludge plant that is designed to treat up to 0.11 MGD ADF. The 2011 ADF was 0.066 MGD. Sludge is dewatered on sand drying beds before being disposed to a landfill. Approximately 24.5 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled monthly for monitoring. The allowable annual TP loading is currently 1675 lb/yr which requires an annual average concentration of less than 8.30 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.27, the North Troy WWTF has reported moderate but erratic effluent phosphorus concentration since at least 2000 remaining between 0.37 mg/L and 1.71 mg/L and averaging less than 0.5 mg/L two of those years. This degree of phosphorus removal produces an effluent well within the current limit for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the North Troy WWTF in this evaluation.

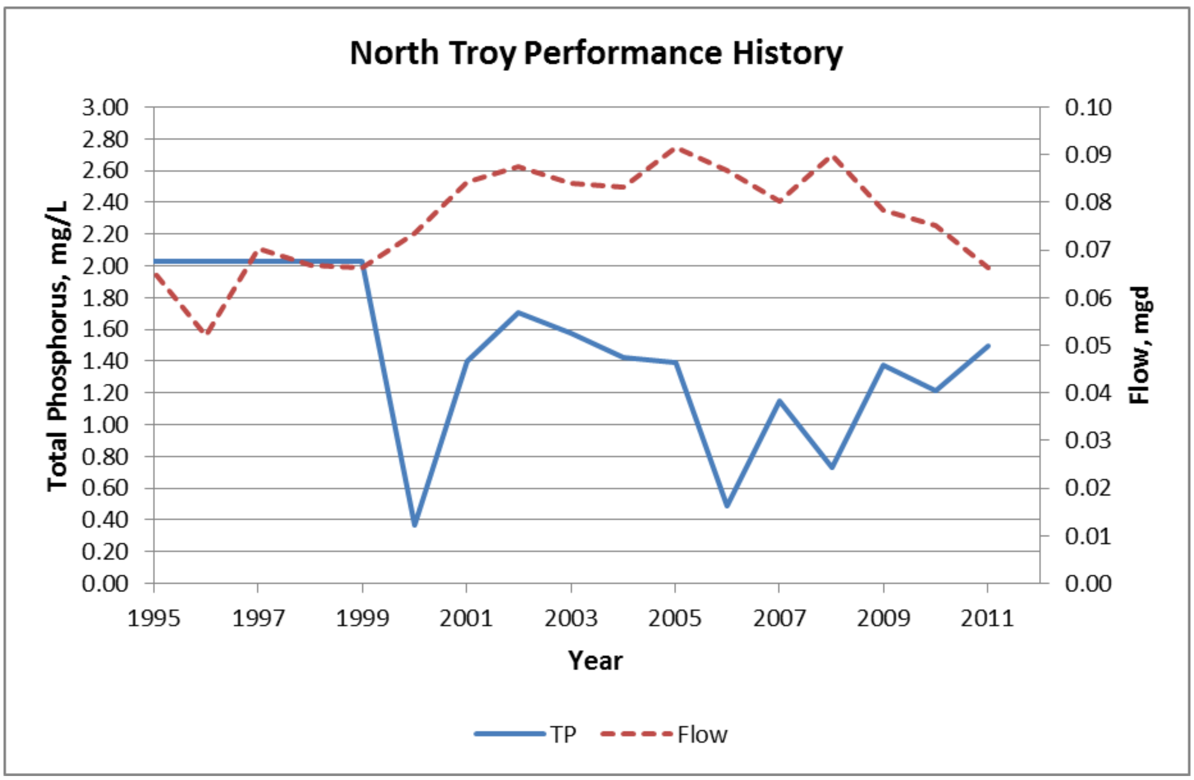


Figure 2.1.27 North Troy WWTF Performance

2.1.28 Northfield

2.1.28.1

The Northfield WWTF is an SBR type activated sludge plant that is designed to treat up to 1.0 MGD ADF. The 2011 ADF was 0.66 MGD. Sludge is dewatered mechanically and disposed by landfilling. Approximately 111 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 1827 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.28, the Northfield WWTF has reported very low effluent phosphorus concentration since 2005 remaining between 0.336 mg/L and 0.592 mg/L and averaging 0.403 mg/L over the period 2005 to 2011. This degree of phosphorus removal produces an effluent within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Northfield WWTF in this evaluation.

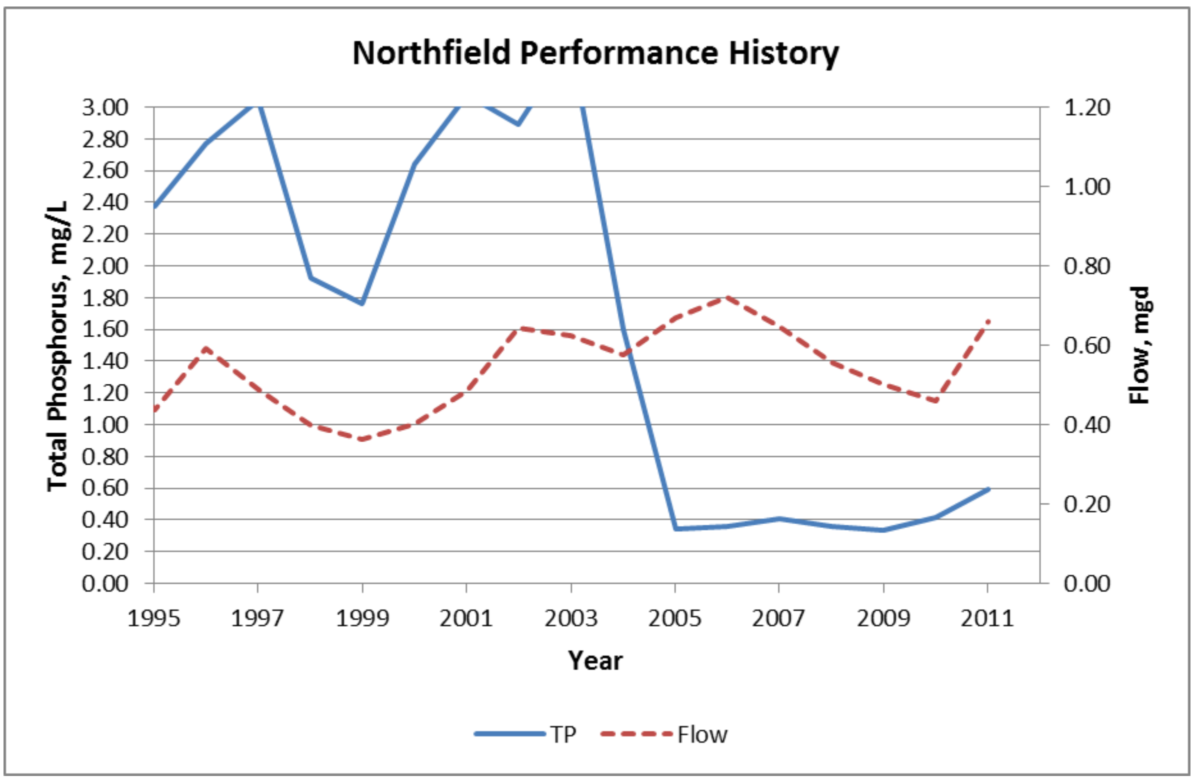


Figure 2.1.28 Northfield WWTF Performance

2.1.29 Northwest State Correctional

Facility Description

The Northwest State Correctional WWTF is a tertiary treatment facility with chemical flocculation, tube settlers, and mixed media gravity filters designed to treat up to 0.040 MGD ADF. The 2011 ADF was 0.029 MGD. Sludge is disposed of intermittently by liquid hauling. The allowable annual TP loading is currently 61 lb/yr which was calculated by assuming a 0.5 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.29, the Northwest State Correctional WWTF has reported extremely low effluent phosphorus concentration since at least 1995 with only one year averaging greater than 0.25 mg/L TP including two years averaging less than 0.1 mg/L TP. For 2011 the facility achieved an effluent TP of 0.056 mg/L. This degree of phosphorus removal produces an effluent well within the current limit for annual loading. No improvements to phosphorus removal need be considered for the Northwest State Correctional WWTF in this evaluation.

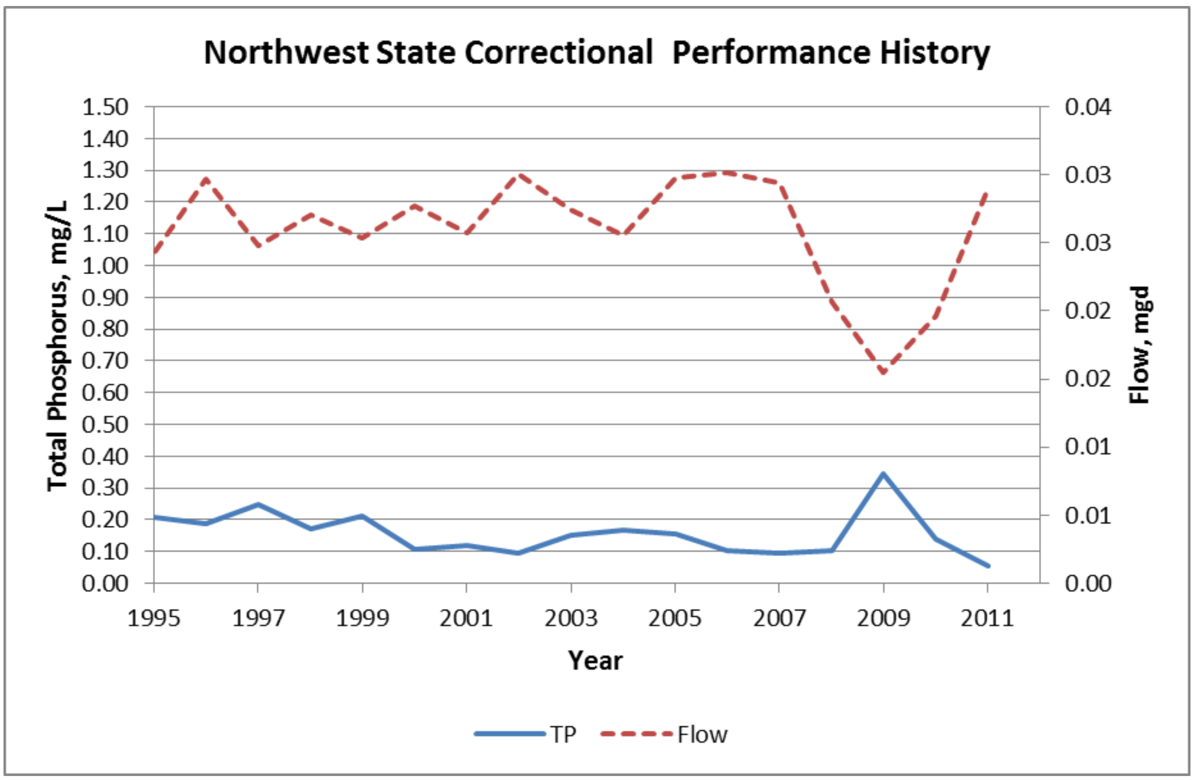


Figure 2.1.29 Northwest State Correctional WWTF Performance

2.1.30 Orwell

Facility Description

The Orwell WWTF is an aerated lagoon plant that is designed to treat up to 0.033 MGD ADF. The 2011 ADF was 0.0281 MGD. Sludge is disposed of intermittently by liquid hauling. The effluent phosphorus concentration is sampled quarterly for monitoring purposes. The allowable annual TP loading is currently 502 lb/yr which requires an annual average concentration of less than 5.87 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.30, the Orwell WWTF has reported moderate effluent phosphorus concentration since at least 1995 remaining between 1.5 mg/L and 3.55 mg/L except for a single year and averaging 3.00 mg/L over that period. This degree of phosphorus removal produces an effluent well within the current limit for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Orwell WWTF in this evaluation.

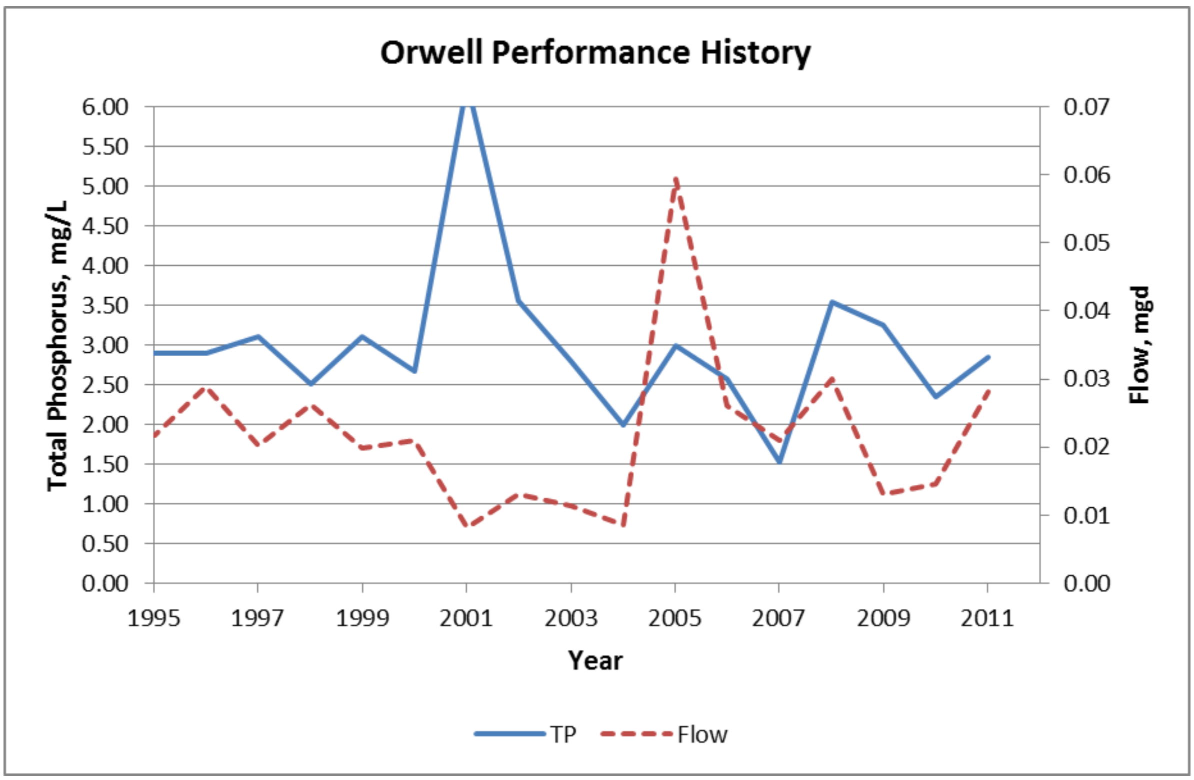


Figure 2.1.30 Orwell WWTF Performance

2.1.31 Otter Valley Union High School

Facility Description

The Otter Valley Union High School WWTF is a small package facility consisting of two concrete lagoons, a clarifier, and a sand filter designed to treat up to 0.025 MGD ADF. The 2011 ADF was 0.002 MGD. The allowable annual TP loading is currently 381 lb/yr which requires an annual average concentration of less than 62.58 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.31, the Otter Valley Union High School WWTF has reported effluent phosphorus concentration between 3.4 mg/L and 7.0 mg/L and averaged 5.18 mg/L over the period 1995 to 2011. This degree of phosphorus removal can produce an effluent within the current limit for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Otter Valley Union High School WWTF in this evaluation.

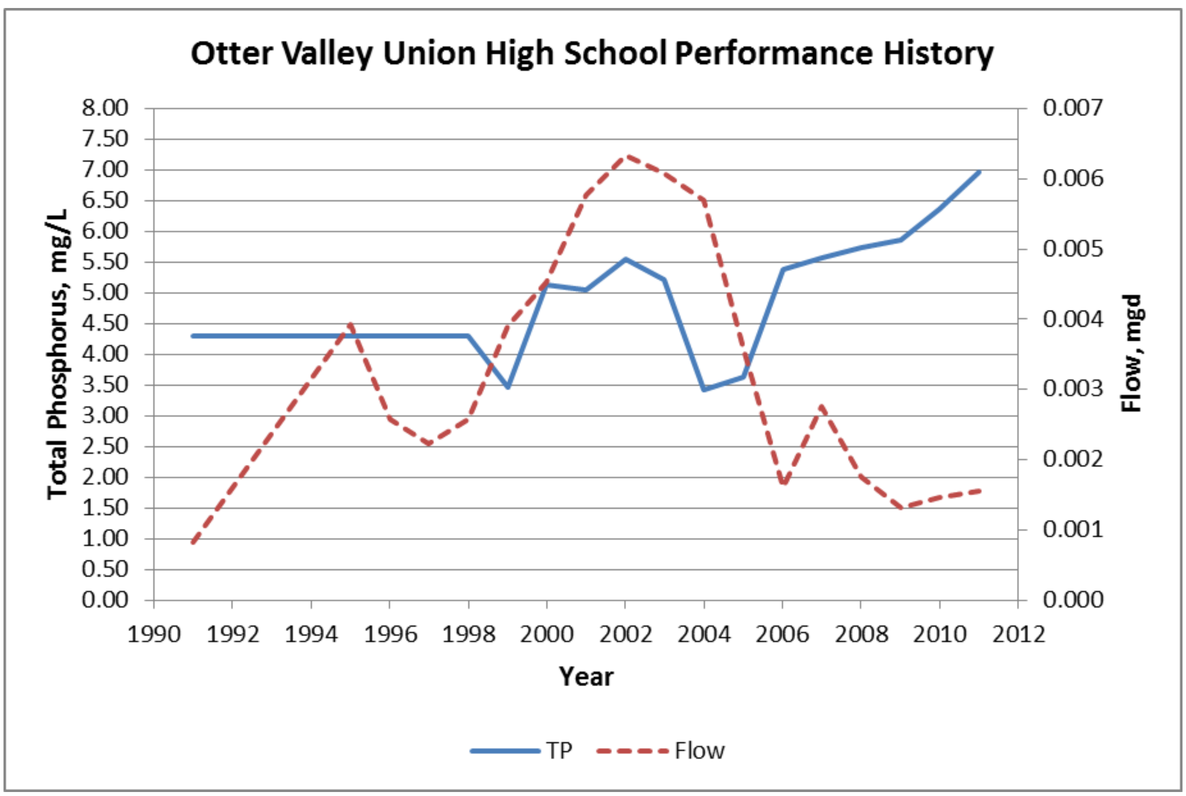


Figure 2.1.31 Otter Valley Union High School WWTF Performance

2.1.32 Pittsford

Facility Description

The Pittsford WWTF is a Sequox activated sludge plant that is designed to treat up to 0.085 MGD ADF. The 2011 ADF was 0.0613 MGD. Sludge is stored aerobically before liquid hauled for disposal; 14.6 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled monthly for monitoring purposes. The allowable annual TP loading is currently 1064 lb/yr which requires an annual average concentration of less than 5.70 mg/L at current ADF and less than 4.11 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.32, the Pittsford WWTF has reported moderate effluent phosphorus concentration since 2001 remaining between 1.50 mg/L and 2.63 mg/L and averaging 2.09 mg/L over the period 2001 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Pittsford WWTF in this evaluation.

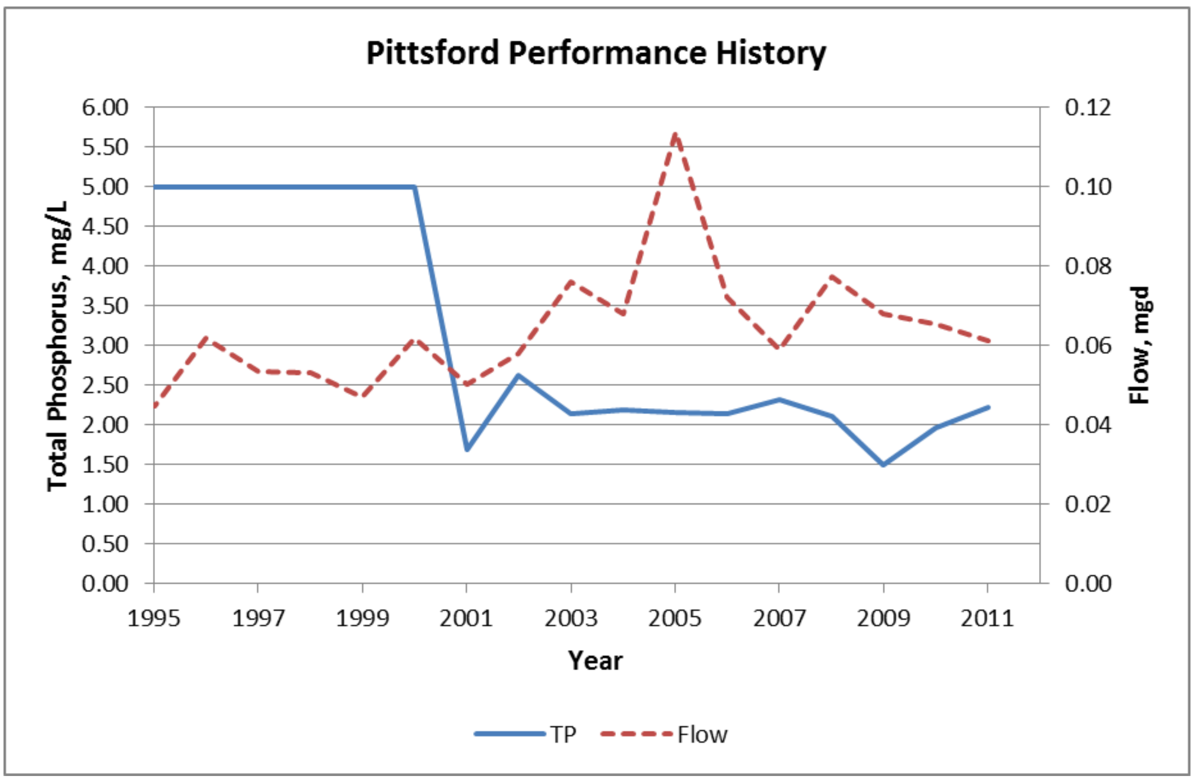


Figure 2.1.32 Pittsford WWTF Performance

2.1.33 Pittsford Fish Hatchery

<u>Facility Description</u>

The Pittsford Fish Hatchery WWTF is designed to treat up to 2.60 MGD ADF. The 2011 ADF was 1.82 MGD. The allowable annual TP loading is currently 1522 lb/yr which requires an annual average concentration of less than 0.27 mg/L at current ADF and less than 0.19 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.33, the Pittsford Fish Hatchery WWTF has reported very low effluent phosphorus concentration since at least 2001 remaining between 0.010 mg/L and 0.133 mg/L and averaging 0.055 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limit for annual loading. No phosphorus removal improvements need be considered for the Pittsford Fish Hatchery WWTF in this evaluation.

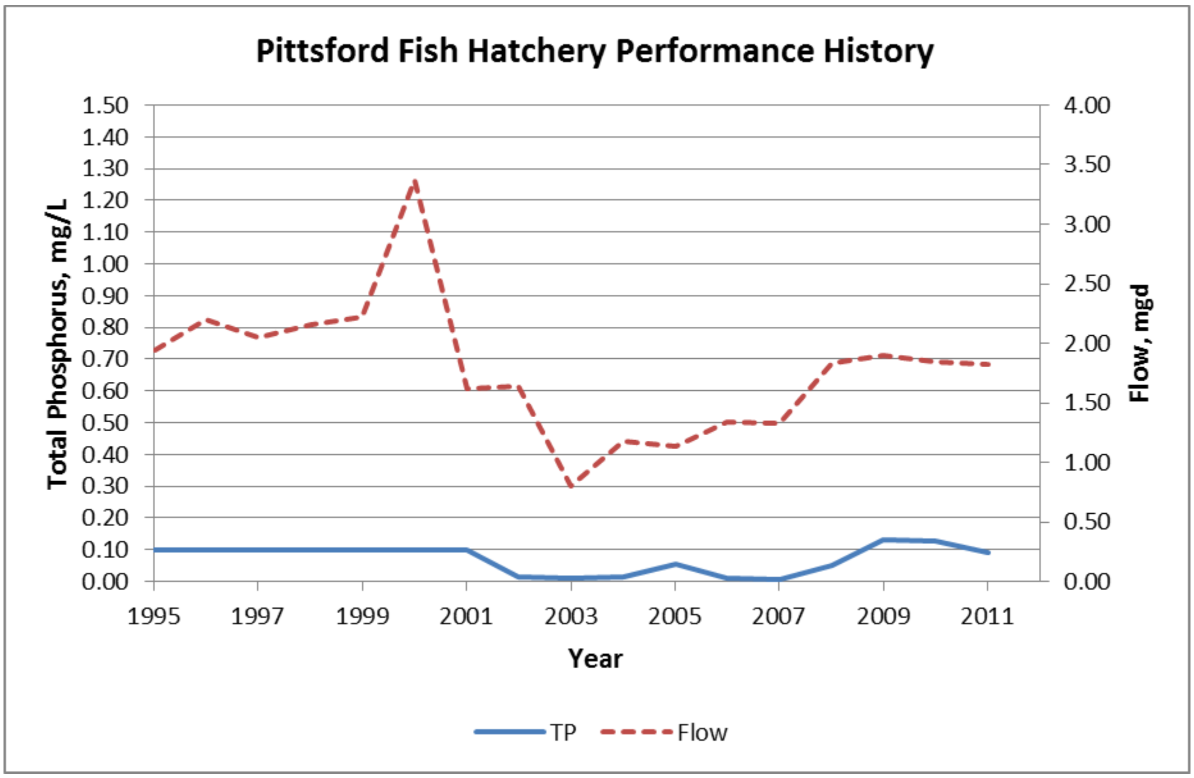


Figure 2.1.33 Pittsford Fish Hatchery WWTF Performance

2.1.34 Plainfield

Facility Description

The Plainfield WWTF is an SBR type activated sludge plant that is designed to treat up to 0.125 MGD ADF. The 2011 ADF was 0.0655 MGD. Sludge is disposed by transferring to the Barre WWTF for further processing and disposal. Approximately 13 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled monthly for monitoring. The allowable annual TP loading is currently 1523 lb/yr which requires an annual average concentration of less than 7.63 mg/L at current ADF and less than 4.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.34, the Plainfield WWTF has reported moderate effluent phosphorus concentration since at least 1996 remaining between 1.22 mg/L and 3.325 mg/L and averaging 2.31 mg/L over the period 1996 to 2011. This degree of phosphorus removal produces an effluent well within the current limit for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Plainfield WWTF in this evaluation.

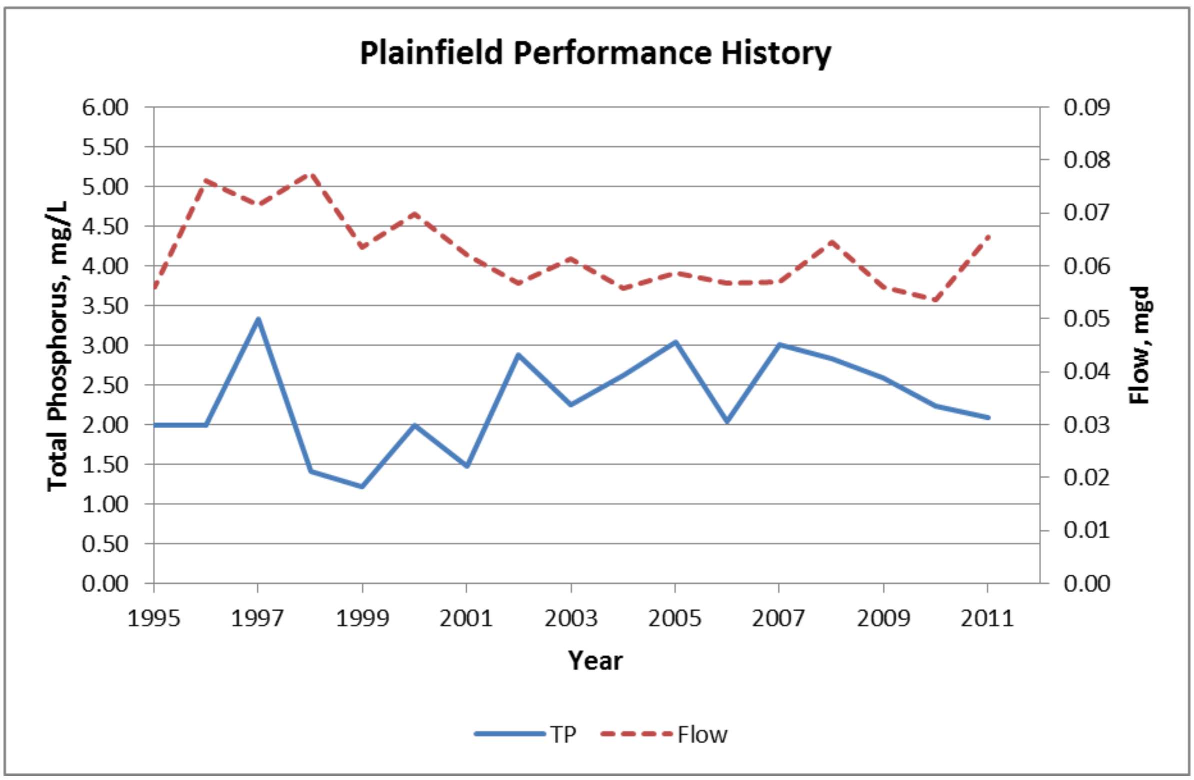


Figure 2.1.34 Plainfield WWTF Performance

2.1.35 Poultney

Facility Description

The Poultney WWTF is an SBR type activated sludge plant that is designed to treat up to 0.5 MGD ADF. The 2011 ADF was 0.287 MGD. Sludge is dewatered on sand drying beds before being disposed by landfilling. Approximately 38 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled twice monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 912 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.35, the Poultney WWTF has reported very low effluent phosphorus concentration since 2003 remaining between 0.10 mg/L and 0.186 mg/L and averaging 0.137 mg/L over the period 2003 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to consistently attain the 0.1 mg/L effluent phosphorus goal remain to be considered for the Poultney WWTF in this evaluation.

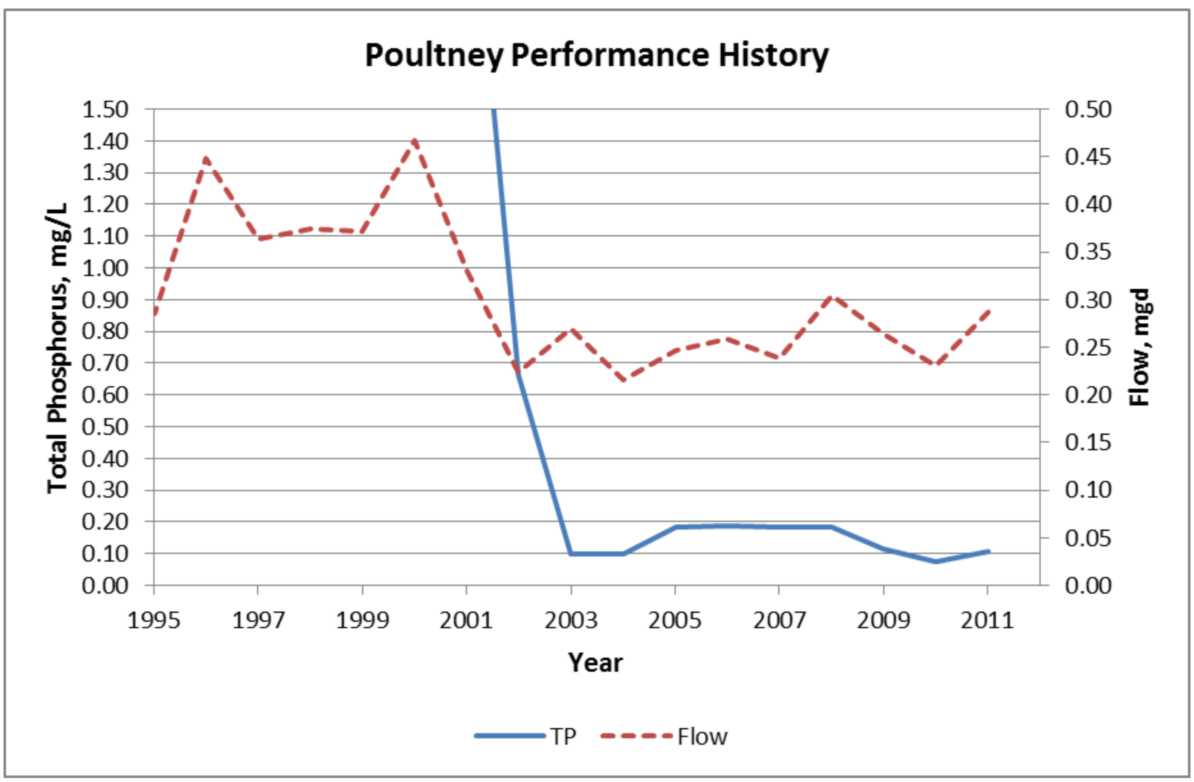


Figure 2.1.35 Poultney WWTF Performance

2.1.36 Proctor

Facility Description

The Proctor WWTF is an aerated lagoon plant with in-lagoon chemical addition that is designed to treat up to 0.325 MGD ADF. The 2011 ADF was 0.275 MGD. Sludge is disposed periodically by liquid hauling. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 791 lb/yr which requires an annual average concentration of less than 0.95 mg/L at current ADF and less than 0.8 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.36, the Proctor WWTF has reported moderately low and declining effluent phosphorus concentration since 2002 remaining below 2.50 mg/L since then. In 2010 and 2011 the effluent TP averaged 0.48 mg/L and 0.38 mg/L respectively. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Proctor WWTF in this evaluation.

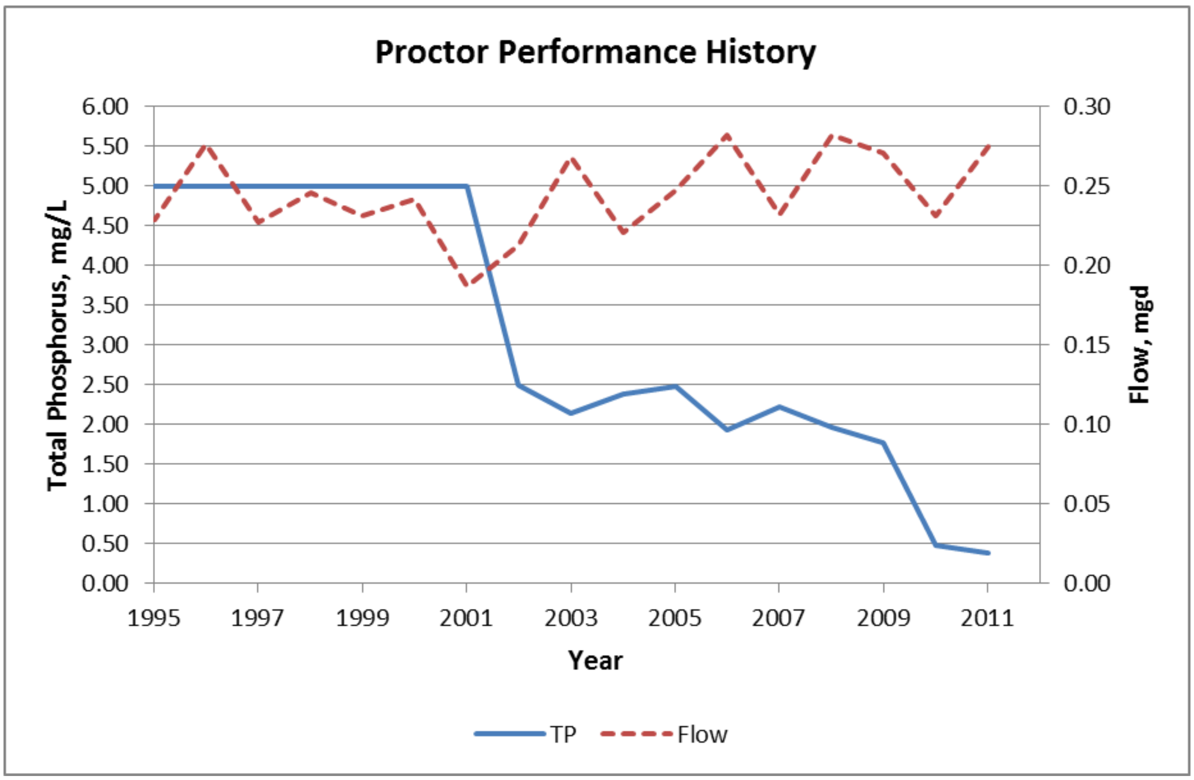


Figure 2.1.36 Proctor WWTF Performance

2.1.37 Richford

<u>Facility Description</u>

The Richford WWTF is an aerated lagoon plant with in-lagoon chemical addition that is designed to treat up to 0.380 MGD ADF. The 2011 ADF was 0.2465 MGD. Sludge is disposed periodically by liquid hauling. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 925 lb/yr which requires an annual average concentration of less than 1.23 mg/L at current ADF and less than 0.8 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.37, the Richford WWTF has reported moderate to low and declining effluent phosphorus concentration since 1999 remaining below 0.48 mg/L since 2007. Between 2007 and 2011 the effluent TP averaged 0.39 mg/L. This degree of phosphorus removal produces an effluent well within the current limits for both conc. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Richford WWTF in this evaluation.

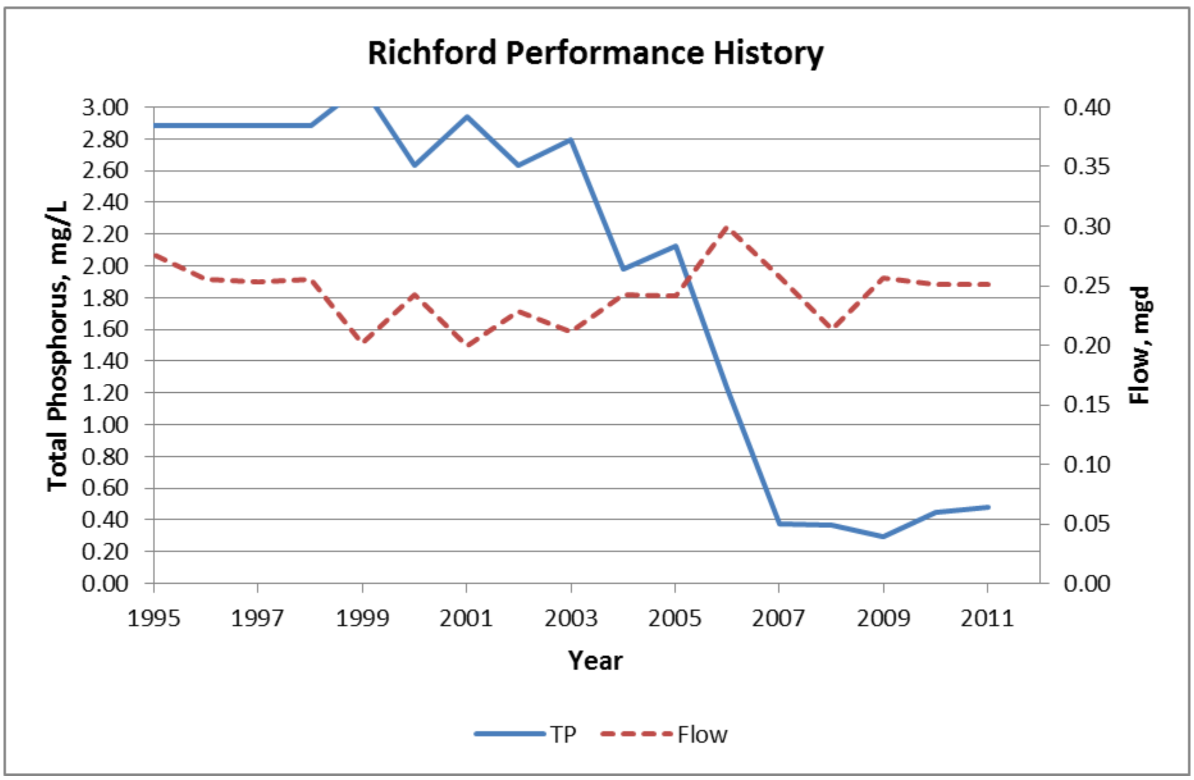


Figure 2.1.37 Richford WWTF Performance

2.1.38 Richmond

Facility Description

The Richmond WWTF is an extended aeration activated sludge plant with anoxic selectors and cloth disk filtration that is designed to treat up to 0.222 MGD ADF. The 2011 ADF was 0.078 MGD. Sludge is disposed by landfilling after mechanical dewatering. Approximately 210 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 405 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.38, the Richmond WWTF has reported very low effluent phosphorus concentration since 2005 remaining between 0.283 mg/L and 0.098 mg/L and averaging 0.173 mg/L over the period 2005 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to consistently attain the 0.1 mg/L effluent phosphorus goal remain to be considered for the Richmond WWTF in this evaluation.

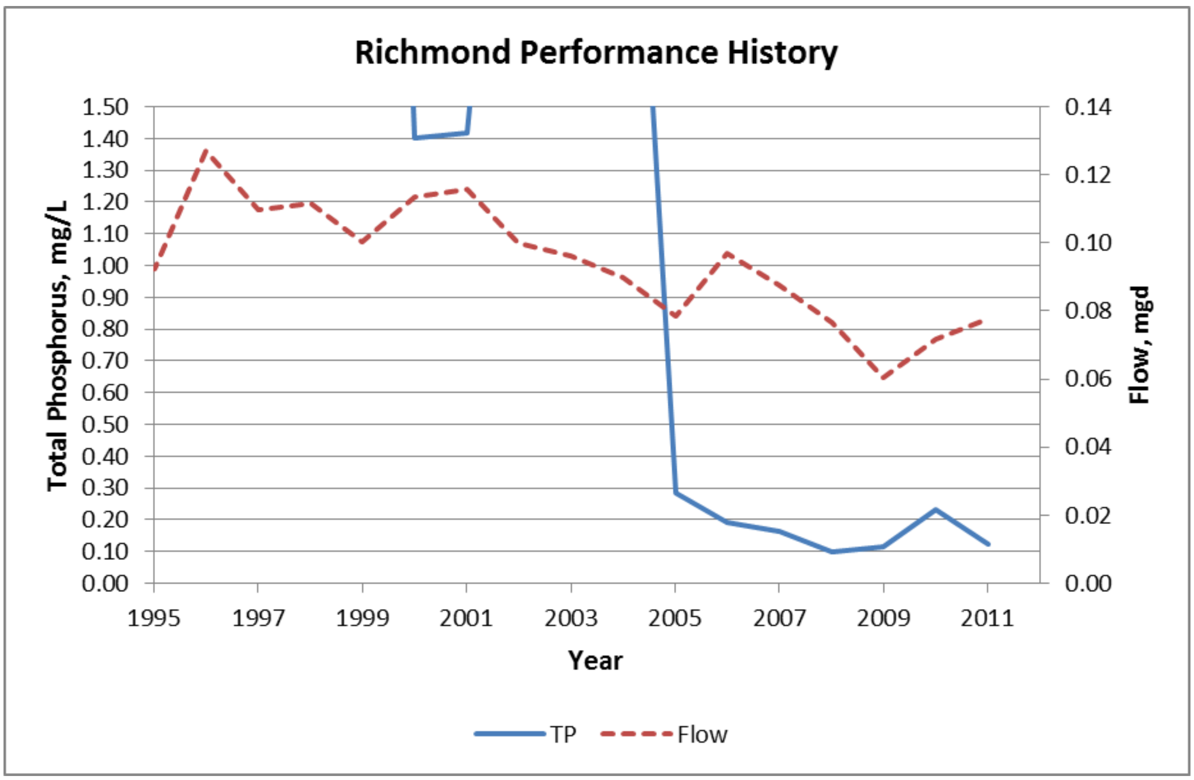


Figure 2.1.38 Richmond WWTF Performance

2.1.39 Rock Tenn

Facility Description

The Rock Tenn WWTF is a combination of a historical aerated lagoon system and a new activated sludge system. The activated sludge system is designed to treat up to 0.4 MGD. The permitted system flow is 2.5 MGD ADF. The 2011 ADF was 0.219 MGD and has been less than 0.33 MGD since at least 1995. The allowable annual TP loading is currently 2778 lb/yr which requires an annual average concentration of less than 0.91 mg/L at current ADF and less than 0.365 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.39, the Rock Tenn WWTF has reported moderately low effluent phosphorus concentration since 2002 remaining between 0.366 mg/L and 0.576 mg/L and averaging 0.48 mg/L over the period 2002 to 2011. This degree of phosphorus removal produces an effluent within the current annual loading limit but would not be sufficient at flows exceeding 1.90 MGD. Improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Rock Tenn WWTF in this evaluation.

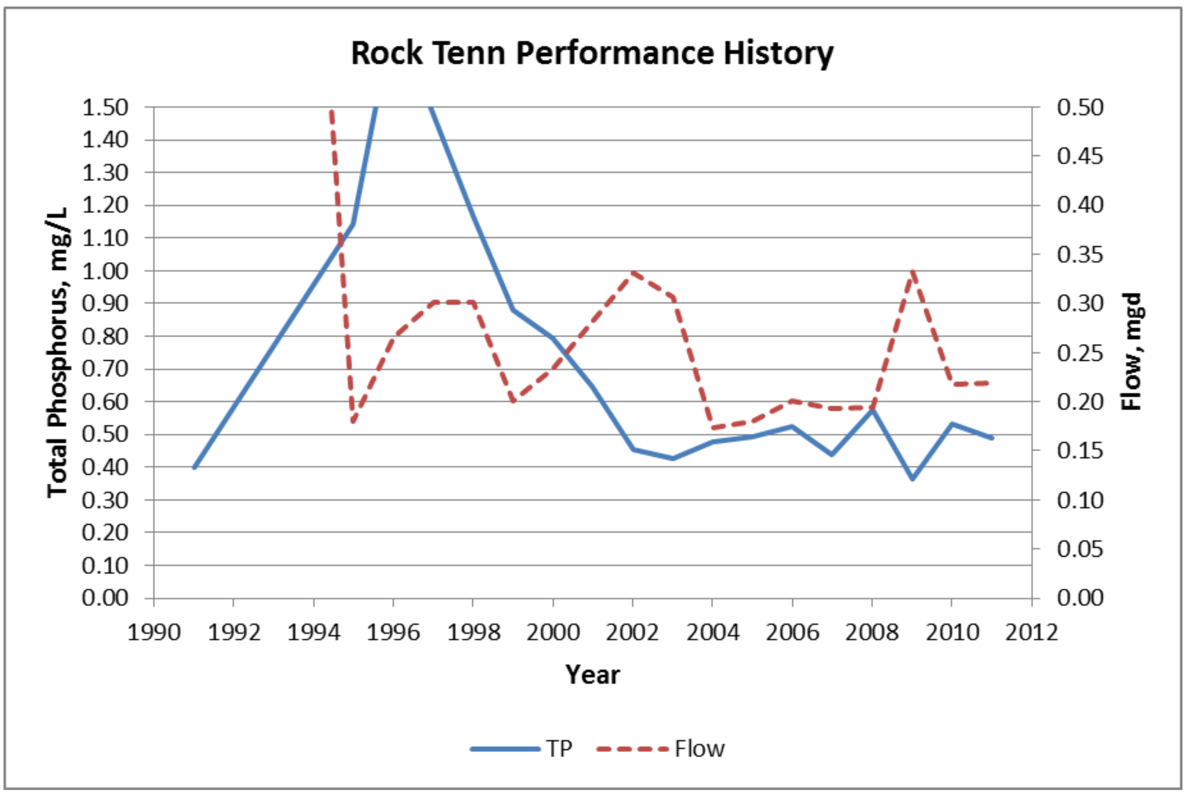


Figure 2.1.39 Rock Tenn WWTF Performance

2.1.40 Rutland City

Facility Description
The Rutland City WWTF is an extended aeration activated sludge plant on a constricted site that is designed to treat up to 8.1 MGD ADF. The 2011 ADF was 5.80 MGD. Sludge is anaerobically digested, mechanically dewatered and then landfilled for disposal. Approximately 852 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled weekly from June 15 through September 30 and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 12,422 lb/yr which was calculated by assuming a 0.5 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History
As shown in Figure 2.1.40, the Rutland City WWTF has reported very low effluent phosphorus concentration since at least 1995 remaining between 0.225 mg/L and 0.40 mg/L and averaging 0.285 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Rutland City WWTF in this evaluation.

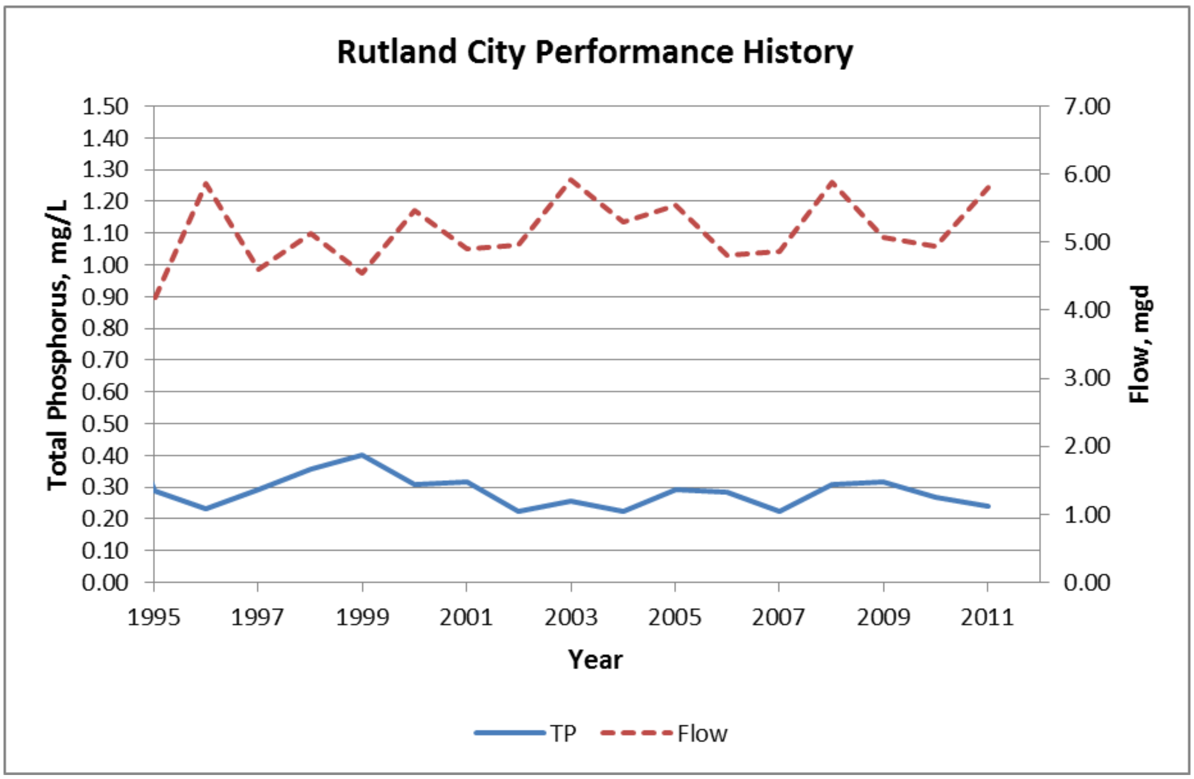


Figure 2.1.40 Rutland City WWTF Performance

2.1.41 Salisbury Fish Hatchery

Facility Description

The Salisbury Fish Hatchery WWTF designed to treat up to 1.31 MGD ADF. The 2011 ADF was 0.846 MGD. The allowable annual TP loading is currently 399 lb/yr which requires an annual average concentration of less than 0.15 mg/L at current ADF and less than 0.1 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.41, the Salisbury Fish Hatchery WWTF has reported very low effluent phosphorus concentration since at least 1995 remaining between 0.122 mg/L and 0.042 mg/L and averaging 0.060 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. No improvements to effluent phosphorus removal need be considered for the Salisbury Fish Hatchery WWTF in this evaluation.

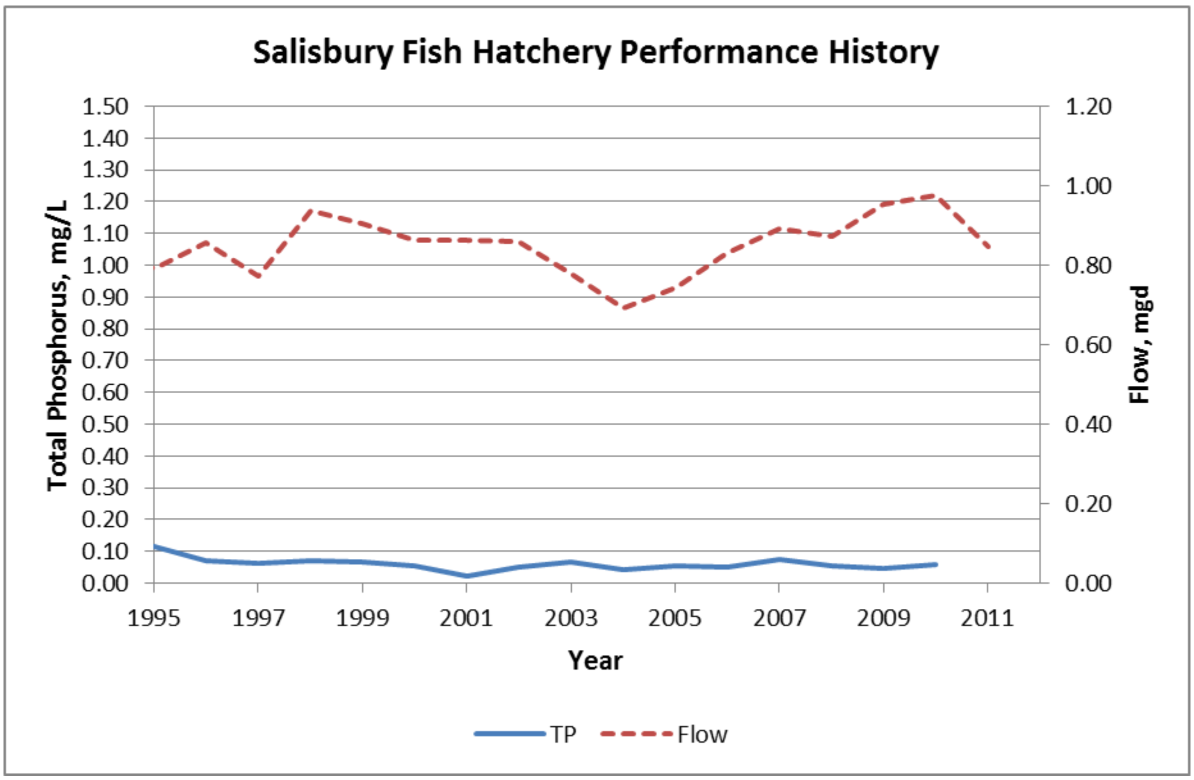


Figure 2.1.41 Salisbury Fish Hatchery WWTF Performance

2.1.42 Shelburne #1

Facility Description

The Shelburne #1 WWTF is an SBR type activated sludge plant with cloth disk filtration on a constricted site that is designed to treat up to 0.44 MGD ADF. The 2011 ADF was 0.356 MGD. Sludge is disposed by transferring as liquid to the Shelburne #2 WWTF for further processing and disposal. Approximately 56 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 767 lb/yr which requires an annual average concentration of less than 0.71 mg/L at current ADF and less than 0.57 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.42, the Shelburne #1 WWTF has reported very low effluent phosphorus concentration since 2005 remaining between 0.242 mg/L and 0.311 mg/L and averaging 0.277 mg/L over the period 2005 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Shelburne #1 WWTF in this evaluation.

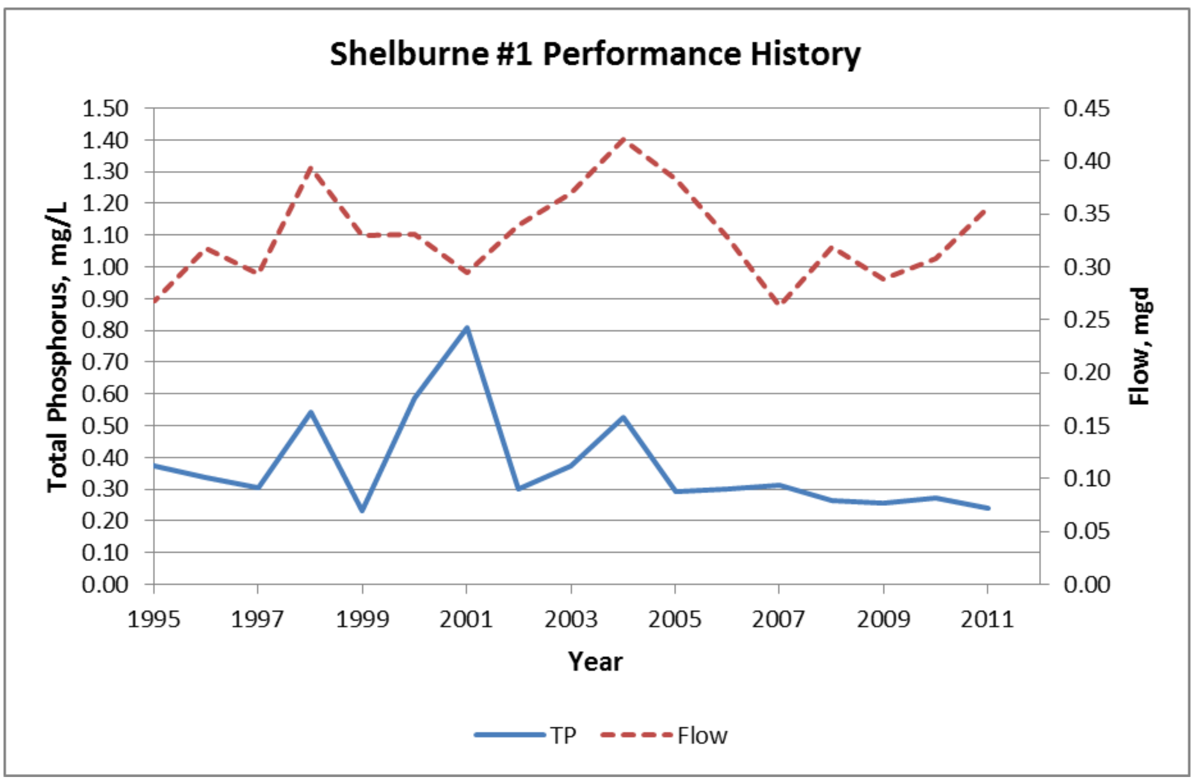


Figure 2.1.42 Shelburne #1 WWTF Performance

2.1.43 Shelburne #2

Facility Description

The Shelburne #2 WWTF is an SBR type activated sludge plant with cloth disk filtration on a constricted site that is designed to treat up to 0.66 MGD ADF. The 2011 ADF was 0.484 MGD. Sludge generated at this plant and at the Shelburne #1 WWTF is mechanically dewatered and disposed by landfilling. Approximately 239 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 1095 lb/yr which requires an annual average concentration of less than 0.74 mg/L at current ADF and less than 0.545 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.43, the Shelburne #2 WWTF has reported very low effluent phosphorus concentration since 2003 remaining between 0.242 mg/L and 0.483 mg/L and averaging 0.340 mg/L over the period 2003 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Shelburne #1 WWTF in this evaluation.

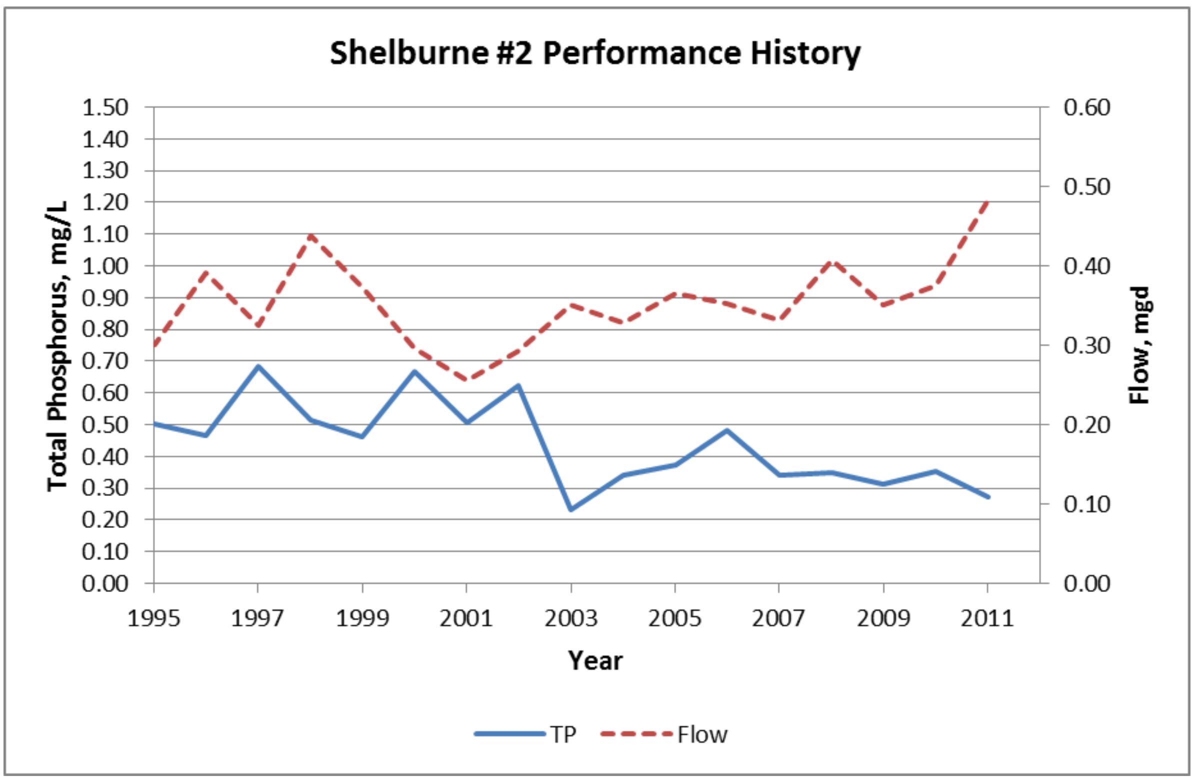


Figure 2.1.43 Shelburne #2 WWTF Performance

2.1.44 Sheldon Springs

Facility Description

The Sheldon Springs WWTF is an extended aeration activated sludge plant that is designed to treat up to 0.054 MGD ADF. The 2011 ADF was 0.0203 MGD. Sludge is removed intermittently and dewatered in sand drying beds before landfill disposal. The effluent phosphorus concentration is sampled monthly for monitoring. The allowable annual TP loading is currently 822 lb/yr which requires an annual average concentration of less than 13.3 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.44, the Sheldon Springs WWTF has reported moderate effluent phosphorus concentration since at least 1999 remaining between 1.57 mg/L and 2.89 mg/L and averaging 2.19 mg/L over the period 1999 to 2011. This degree of phosphorus removal produces an effluent well within the current limit for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Sheldon Springs WWTF in this evaluation.

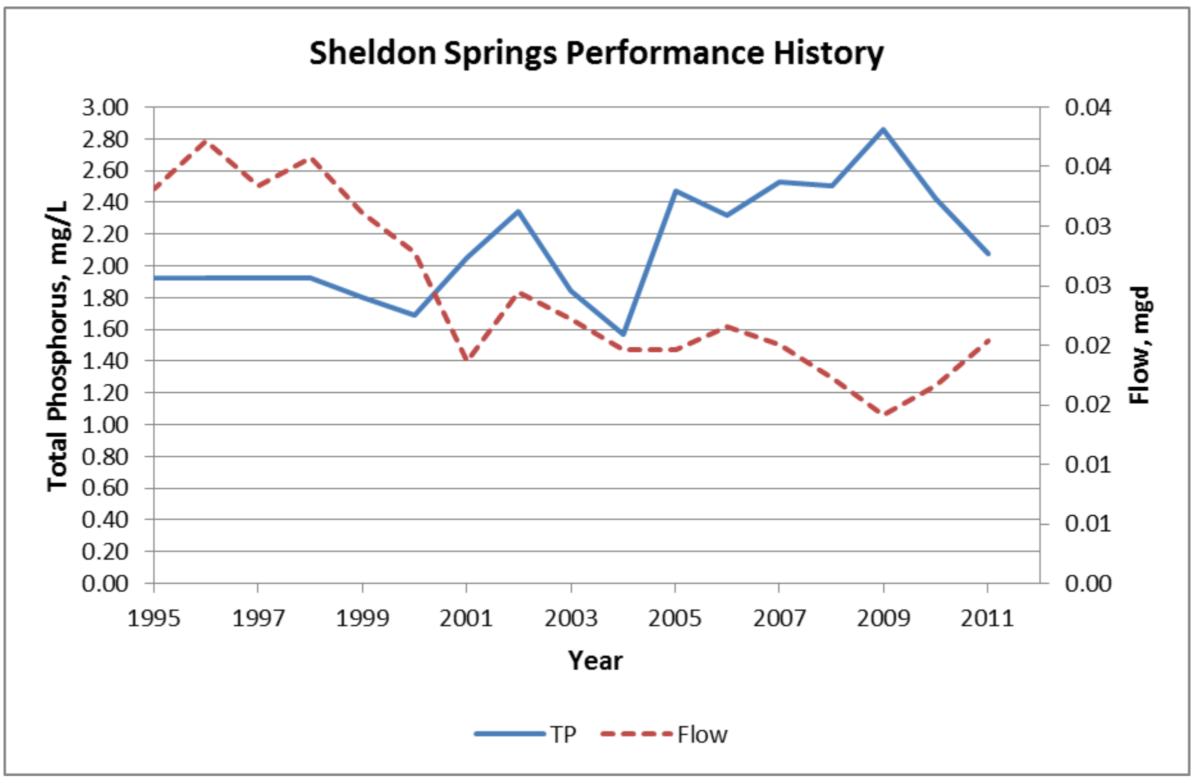


Figure 2.1.44 Sheldon Springs WWTF Performance

2.1.45 Shoreham

<u>Facility Description</u>

The Shoreham WWTF is a sand filtration plant that is designed to treat up to 0.035 MGD ADF. The 2011 ADF was 0.0096 MGD. Sludge is disposed as liquid. The effluent phosphorus concentration is sampled monthly for monitoring. The allowable annual TP loading is currently 533 lb/yr which requires an annual average concentration of less than 18.23 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.45, since 2001 the Shoreham WWTF has reported effluent phosphorus concentration remaining between 3.95 mg/L and 6.20 mg/L and averaging 4.97 mg/L over the period 2001 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Shoreham WWTF in this evaluation.

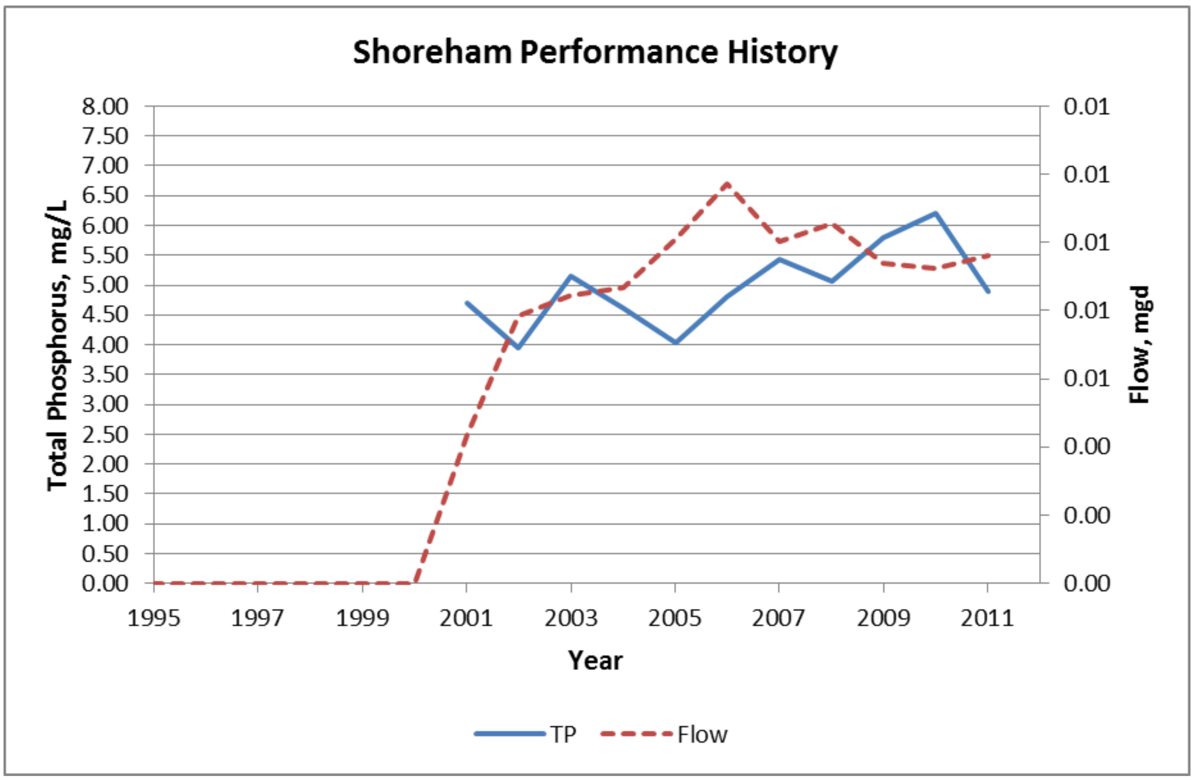


Figure 2.1.45 Shoreham WWTF Performance

2.1.46 South Burlington Airport Parkway

Facility Description

The South Burlington Airport Parkway WWTF is an activated sludge plant with cloth disk filtration that is designed to treat up to 3.3 MGD ADF. The 2011 ADF was 2.01 MGD. Sludge is digested and disposed by landfilling. Approximately 475 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 4201 lb/yr which requires an annual average concentration of less than 0.69 mg/L at current ADF and less than 0.42 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.46, the South Burlington Airport Parkway WWTF has reported moderately low effluent phosphorus concentration since at least 1995 remaining between 0.33 mg/L and 0.642 mg/L and averaging 0.499 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the South Burlington Airport Parkway WWTF in this evaluation.

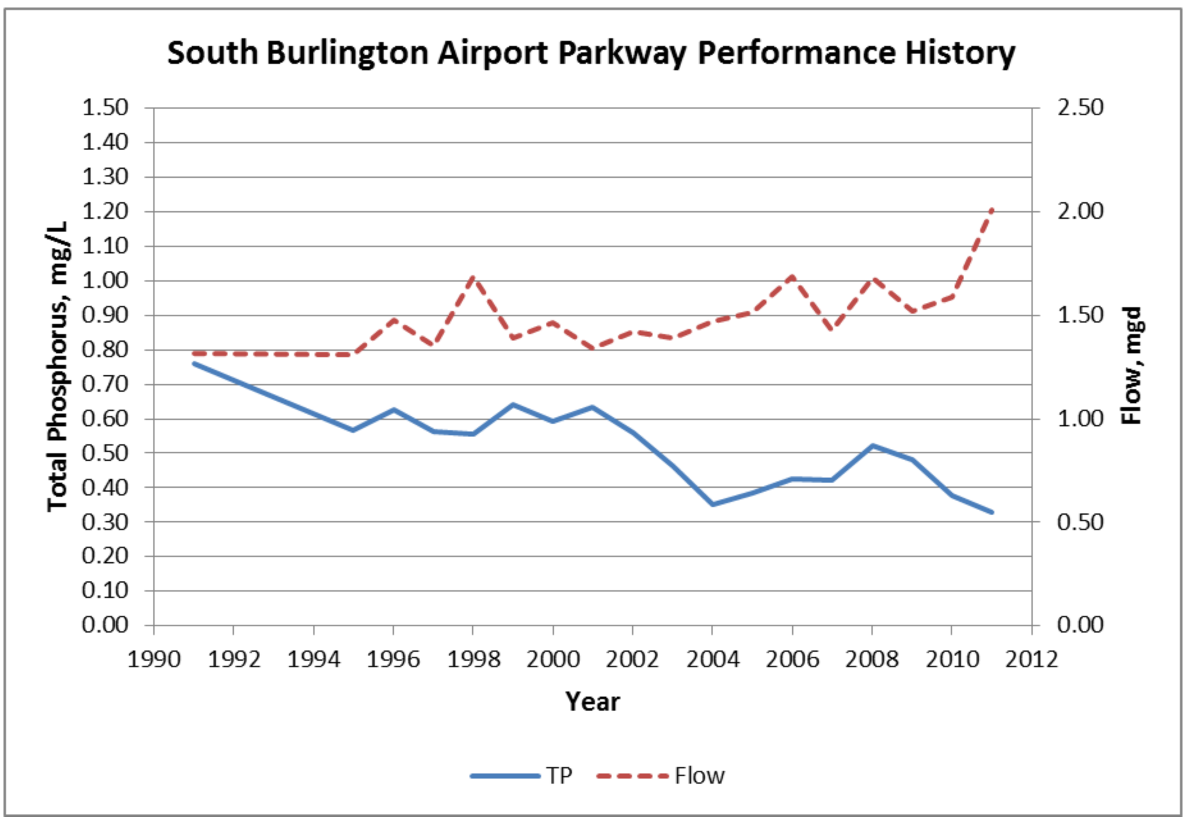


Figure 2.1.46 South Burlington Airport Parkway WWTF Performance

2.1.47 South Burlington Bartlett Bay

Facility Description

The South Burlington Bartlett Bay WWTF is an extended aeration activated sludge plant with cloth disk filtration that is designed to treat up to 1.25 MGD ADF. The 2011 ADF was 0.85 MGD. Sludge is disposed as liquid by transferring to several other WWTFs for further processing and disposal. Approximately 188 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 1935 lb/yr which requires an annual average concentration of less than 0.75 mg/L at current ADF and less than 0.508 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.47, the South Burlington Bartlett Bay WWTF has reported very low effluent phosphorus concentration since at least 1995 remaining between 0.364 mg/L and 0.168 mg/L and averaging 0.233 mg/L over the period 2002 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the South Burlington Bartlett Bay WWTF in this evaluation.

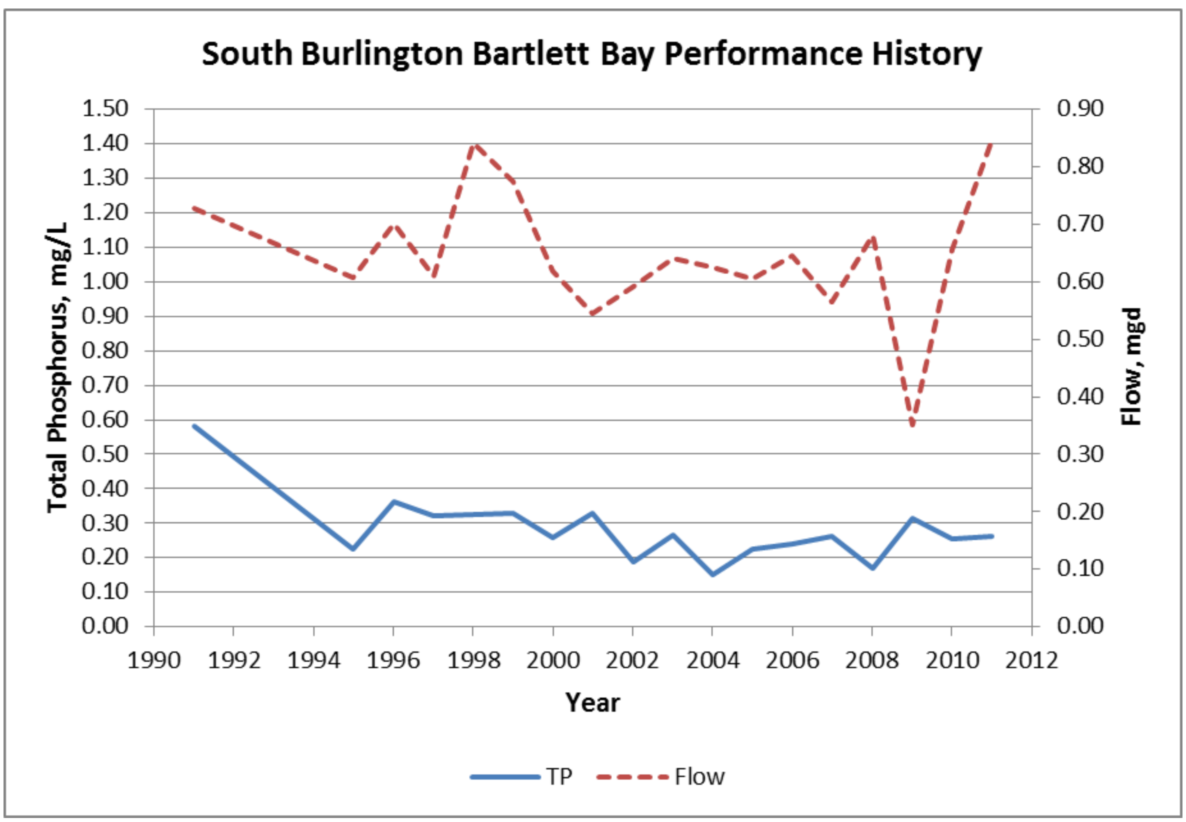


Figure 2.1.47 South Burlington Bartlett Bay WWTF Performance

2.1.48 St Albans City

Facility Description

The St Albans City WWTF is a trickling filter/rotating biological contactor (RBC) plant with granular filtration on a constricted site. It is designed to treat up to 4.0 MGD ADF. The 2011 ADF was 3.1 MGD. Sludge is anaerobically digested, mechanically dewatered, and disposed to a landfill. Approximately 363 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.5 mg/L monthly average TP limit. The allowable annual TP loading is currently 6089 lb/yr which was calculated by assuming a 0.5 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.48, the St Albans City WWTF has reported very low effluent phosphorus concentration since at least 1996 remaining between 0.145 mg/L and 0.367 mg/L and averaging 0.248 mg/L over the period 1996 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the St Albans City WWTF in this evaluation.

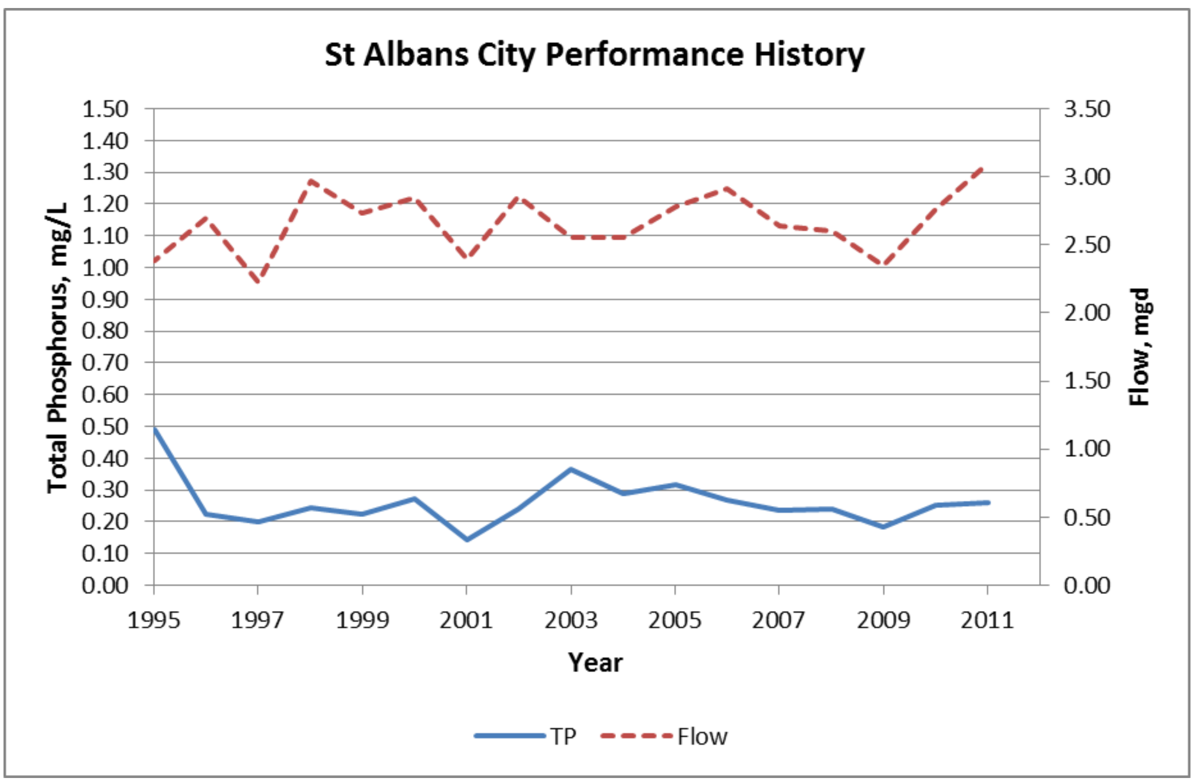


Figure 2.1.48 St Albans City WWTF Performance

2.1.49 Stowe

Facility Description

The Stowe WWTF is an SBR activated sludge plant with post-SBR solids contact clarifiers and cloth disk filtration on a constricted site that is designed to treat up to 1.0 MGD ADF. The 2011 ADF was 0.32 MGD. Sludge is treated using autothermal aerobic digestion (ATAD) to exceptional quality (EQ) standards, mechanically dewatered, and distributed for public use. Approximately 82 dry tons of sludge were disposed in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 621 lb/yr which requires an annual average concentration of less than 0.64 mg/L at current ADF and less than 0.2 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.49, the Stowe WWTF has reported sporadically very low effluent phosphorus concentration since at least 1995 remaining between 0.115 mg/L and 0.6 mg/L and averaging 0.34 mg/L over the period 1995 to 2011. Effluent TP averaged 0.151 for 2010 and 2011. This degree of phosphorus removal produces an effluent within the current limits for both concentration and annual loading but with increased annual loading. However improvements to attain the 0.1 mg/L effluent phosphorus goals remain to be considered in this evaluation.

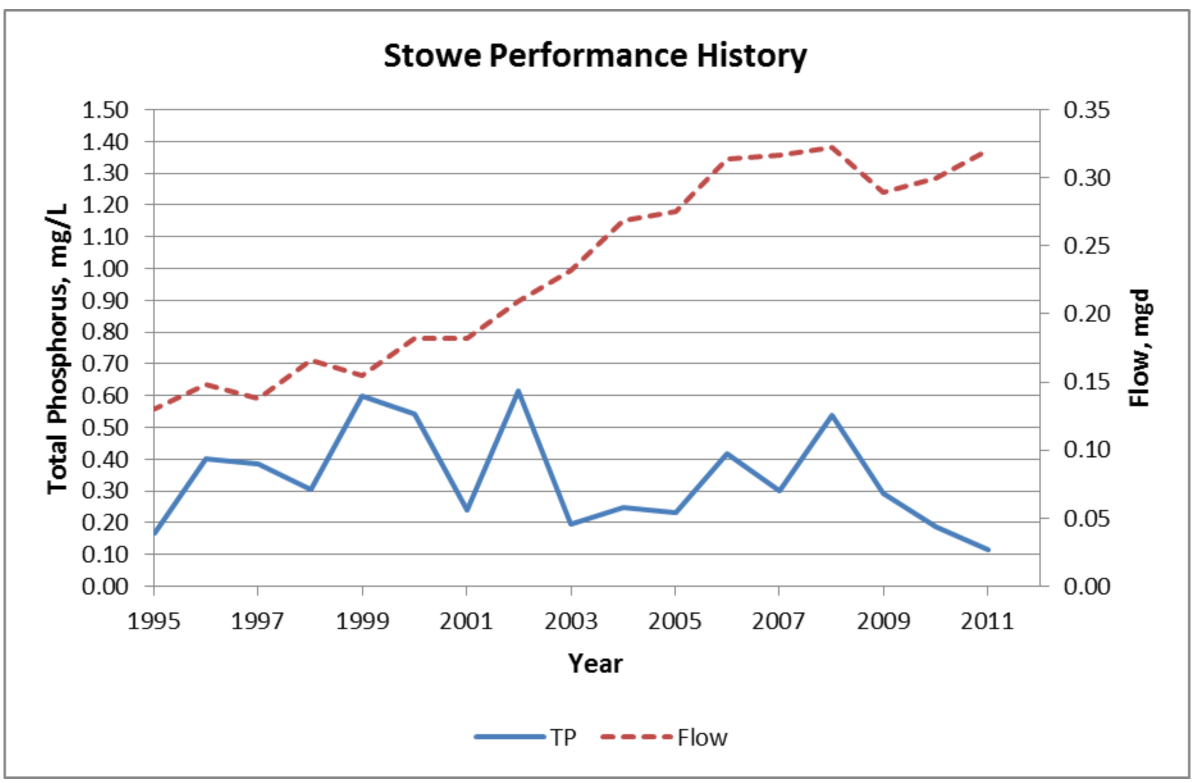


Figure 2.1.49 Stowe WWTF Performance

2.1.50 Swanton

Facility Description

The Swanton WWTF is a facultative lagoon plant with post lagoon clarifiers that is designed to treat up to 0.9 MGD ADF. The 2011 ADF was 0.60 MGD. Sludge is intermittently disposed by lime stabilization, mechanical dewatering, and land application. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 1.0 mg/L monthly average TP limit. The allowable annual TP loading is currently 1644 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.50, the Swanton WWTF has reported moderately low effluent phosphorus concentration since 2001 remaining between 0.3085 mg/L and 0.633 mg/L and averaging 0.484 mg/L over the period 2001 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Swanton WWTF in this evaluation.

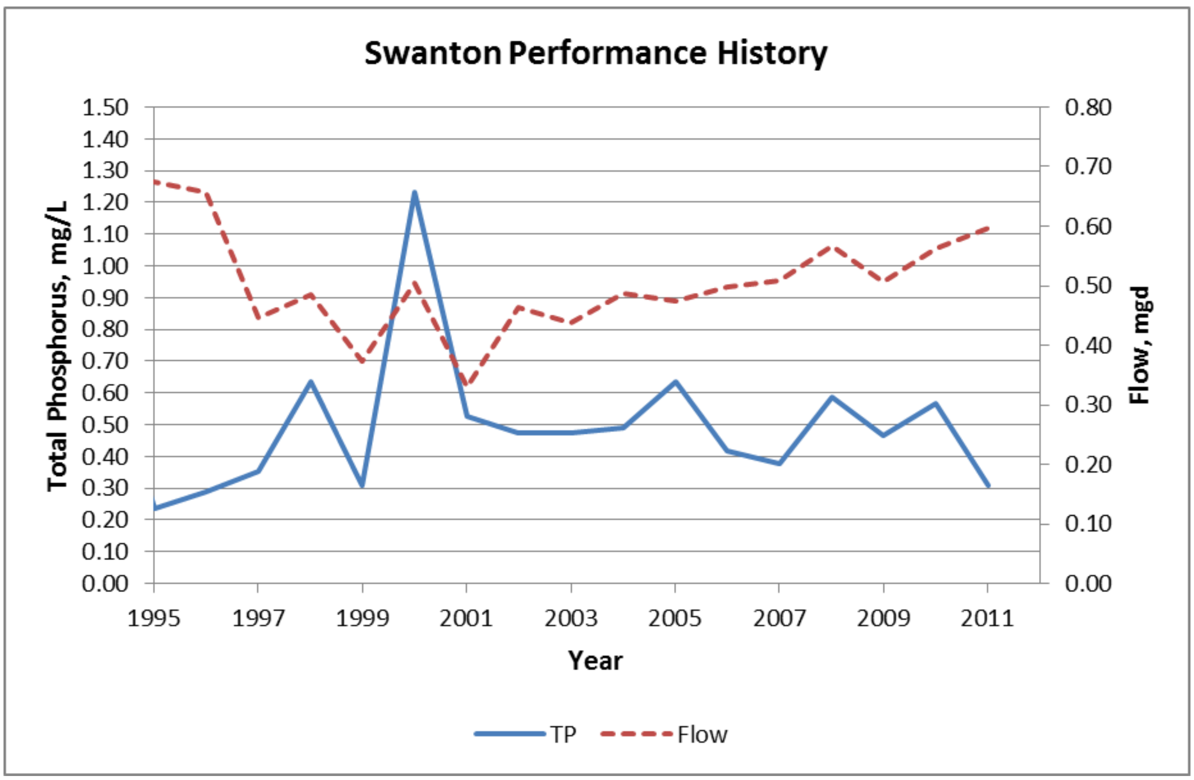


Figure 2.1.50 Swanton WWTF Performance

2.1.51 Troy/Jay

Facility Description

The Troy/Jay WWTF is an SBR type activated sludge plant with filters (recently converted from lagoons) that is designed to treat up to 0.8 MGD ADF. The 2011 ADF was 0.45 MGD. Sludge is stored in two lagoons prior to centrifuge dewatering and then further solar dried before disposal. The effluent phosphorus concentration is sampled monthly for monitoring and is required to meet a 0.8 mg/L monthly average TP limit. Currently, the plant is require to meet a monthly average max of 1.33 lb/day TP and an annual loading limit of 487 lb/yr which both require an annual average concentration of less than 0.2 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.51, the Troy/Jay WWTF has reported moderately low effluent phosphorus concentration since 2007 remaining between 0.527 mg/L and 0.628 mg/L. This degree of phosphorus removal produced an effluent exceeding the current limits for annual loading. However, this performance history is not predictive of future performance as the process has been upgraded from lagoons to SBRs. Performance history for other Vermont SBR facilities without filters in this evaluation indicates that effluent phosphorus of 0.2 mg/L to 0.5 mg/L is typical. This degree of phosphorus removal may produce an effluent within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Troy/Jay WWTF in this evaluation.

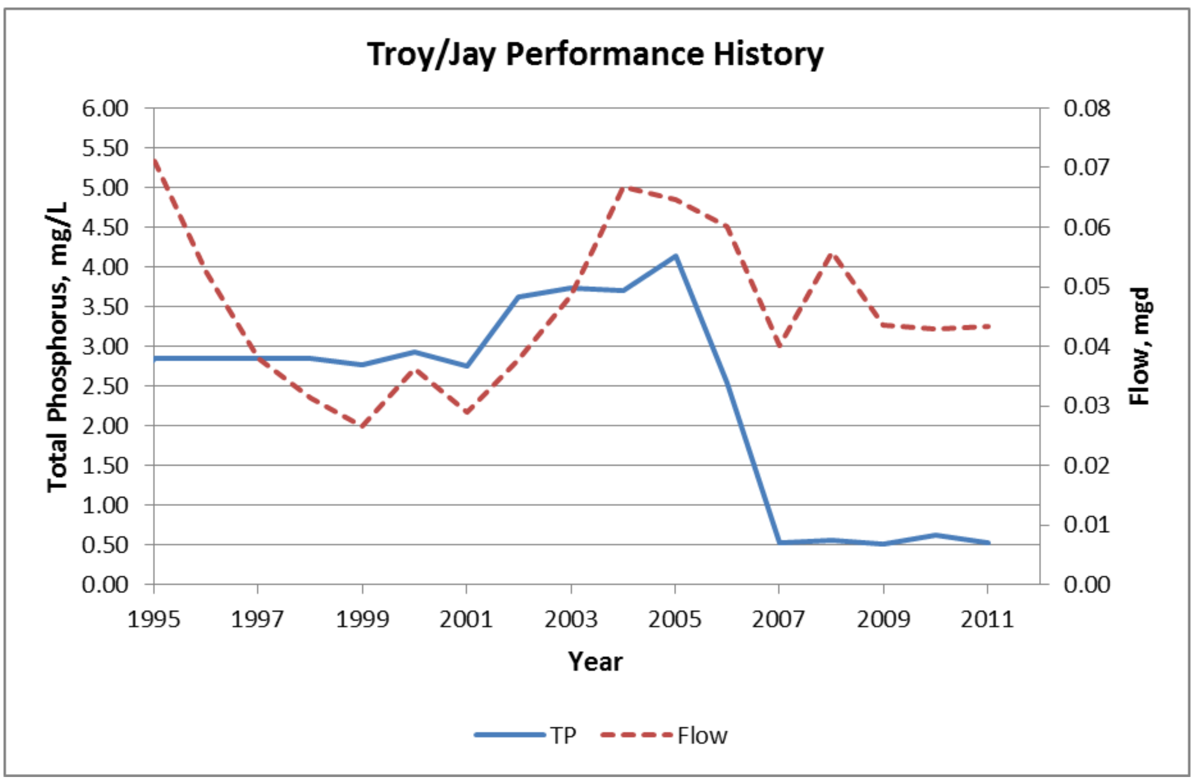


Figure 2.1.51 Troy/Jay WWTF Performance

2.1.52 Vergennes

<u>Facility Description</u>

The Vergennes WWTF is an aerated lagoon plant with cloth disk filtration that is designed to treat up to 0.75 MGD ADF. The 2011 ADF was 0.472 MGD. Sludge is intermittently disposed by lime stabilization and liquid land application. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 1369 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.1.52 the Vergennes WWTF has reported moderately low effluent phosphorus concentration since at least 1995 remaining between 0.153 mg/L and 0.493 mg/L and averaging 0.312 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to consistently attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Vergennes WWTF in this evaluation.

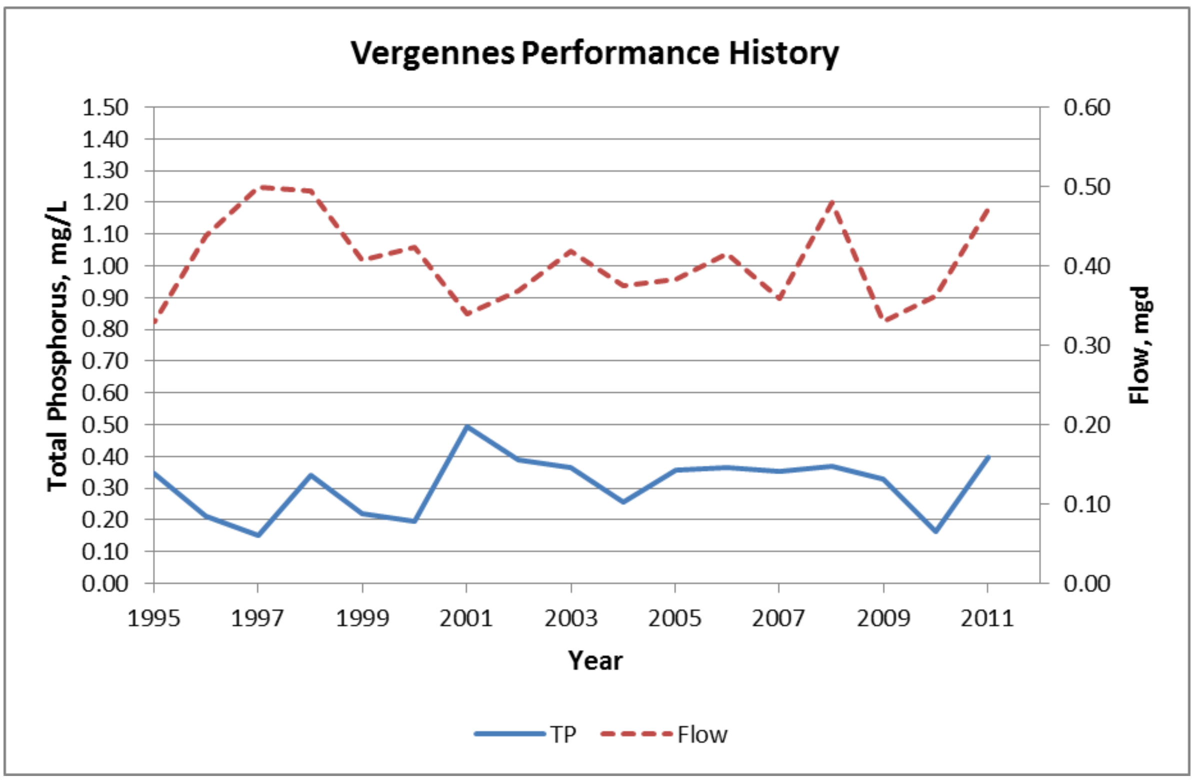


Figure 2.1.52 Vergennes WWTF Performance

2.1.53 Wallingford

Facility Description

The Wallingford WWTF is an oxidation ditch extended aeration activated sludge plant that is designed to treat up to 0.12 MGD ADF. The 2011 ADF was 0.0645 MGD. Sludge is disposed by dewatering on sand drying beds and then transferring to the Rutland WWTF. Approximately 12.9 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled monthly for monitoring. The allowable annual TP loading is currently 1827 lb/yr which requires an annual average concentration of less than 9.3 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.53, the Wallingford WWTF has reported effluent phosphorus concentration less than 3.0 mg/L since 2001 which has declined to less than 0.5 mg/L for 2011. However, given the short time period of compliance and lack of chemical addition currently, improvements need be considered to achieve a 1.0 mg/L effluent TP for the Wallingford WWTF in this evaluation.

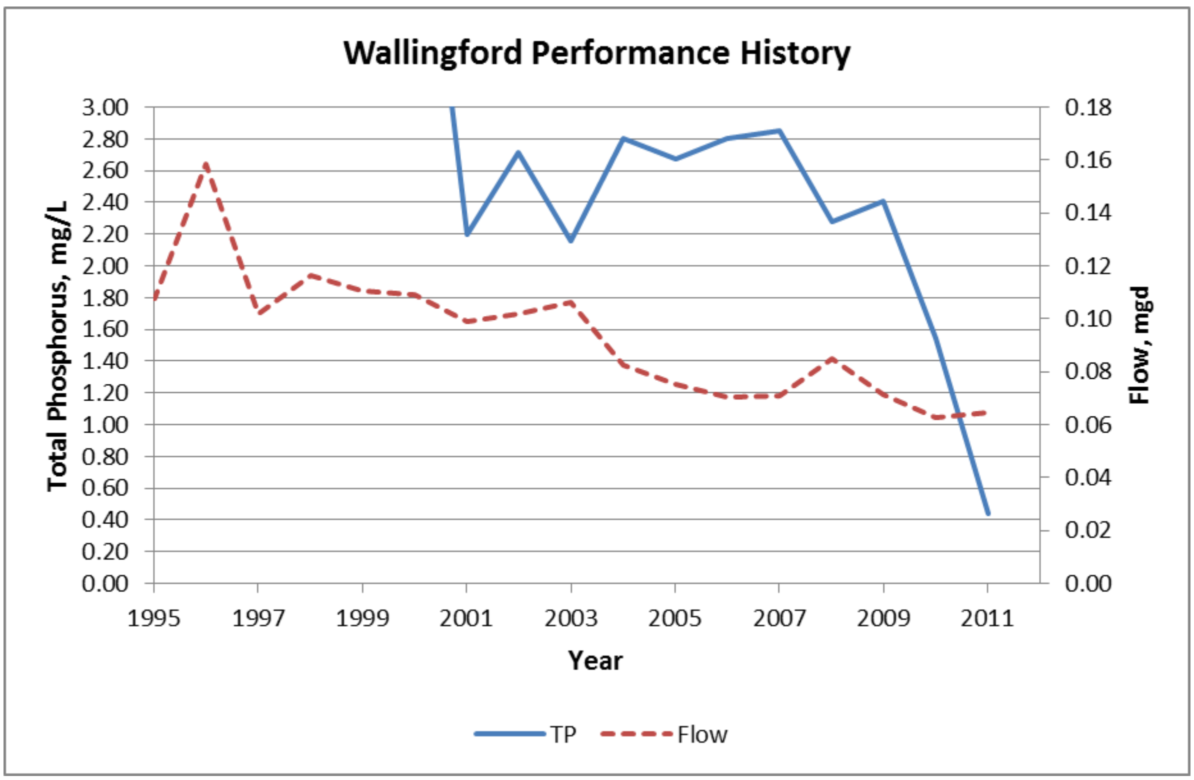


Figure 2.1.53 Wallingford WWTF Performance

2.1.54 Waterbury

Facility Description

The Waterbury WWTF is an aerated lagoon plant that is designed to treat up to 0.51 MGD ADF. The 2011 ADF was 0.27 MGD. Sludge is disposed by lime stabilization and land application. After n-going improvements to add chemical feed and ballasted sedimentation (CoMag) are complete, the CoMag sludge will be applied to drying beds before landfilling. Approximately 101 dry tons of sludge was disposed of in 2011. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 1241 lb/yr which requires an annual average concentration of less than 1.51 mg/L at current ADF and less than 0.8 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.54, the Waterbury WWTF has reported declining effluent phosphorus concentration since at least 2002 decreasing from 5.7 mg/L to 3.2 mg/L. This degree of phosphorus removal does not produce an effluent within the current limits for either concentration or annual loading. However the CoMag process is expected to achieve the required effluent TP concentration. Those improvements are also expected to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals so no further improvements need be considered for the Waterbury WWTF in this evaluation.

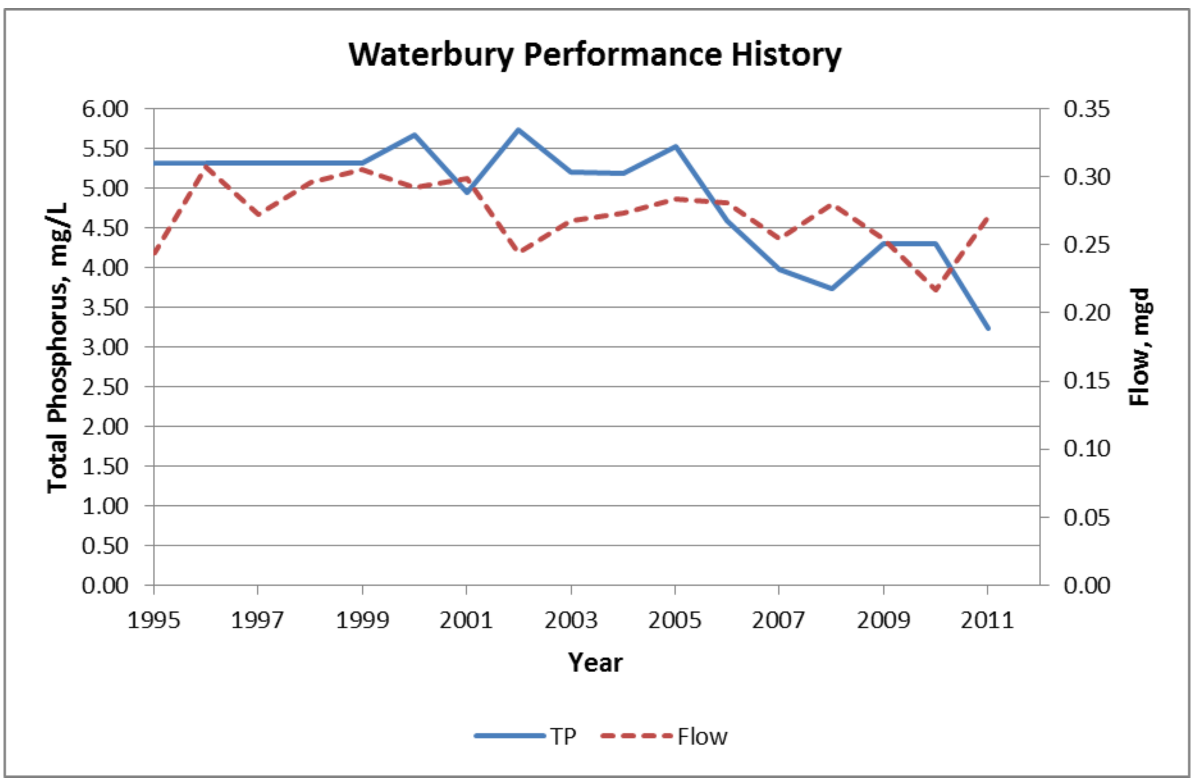


Figure 2.1.54 Waterbury WWTF Performance

2.1.55 Weed Fish Culture Station

Facility Description

The Weed Fish Culture Station WWTF is designed to treat up to 11.5 MGD ADF. The 2011 ADF was 2.97 MGD. The allowable annual TP loading is currently 1242 lb/yr which requires an annual average concentration of less than 1.51 mg/L at current ADF and less than 0.8 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.55, the Weed Fish Culture Station WWTF has reported very low effluent phosphorus concentration since at least 1995 remaining between 0.018mg/L and 0.090 mg/L and averaging 0.058 mg/L over the period 1995 to 2011. This effluent is well within the current limits for both concentration and annual loading. No improvements in effluent phosphorus removal need be considered for the Weed Fish Culture Station WWTF in this evaluation.

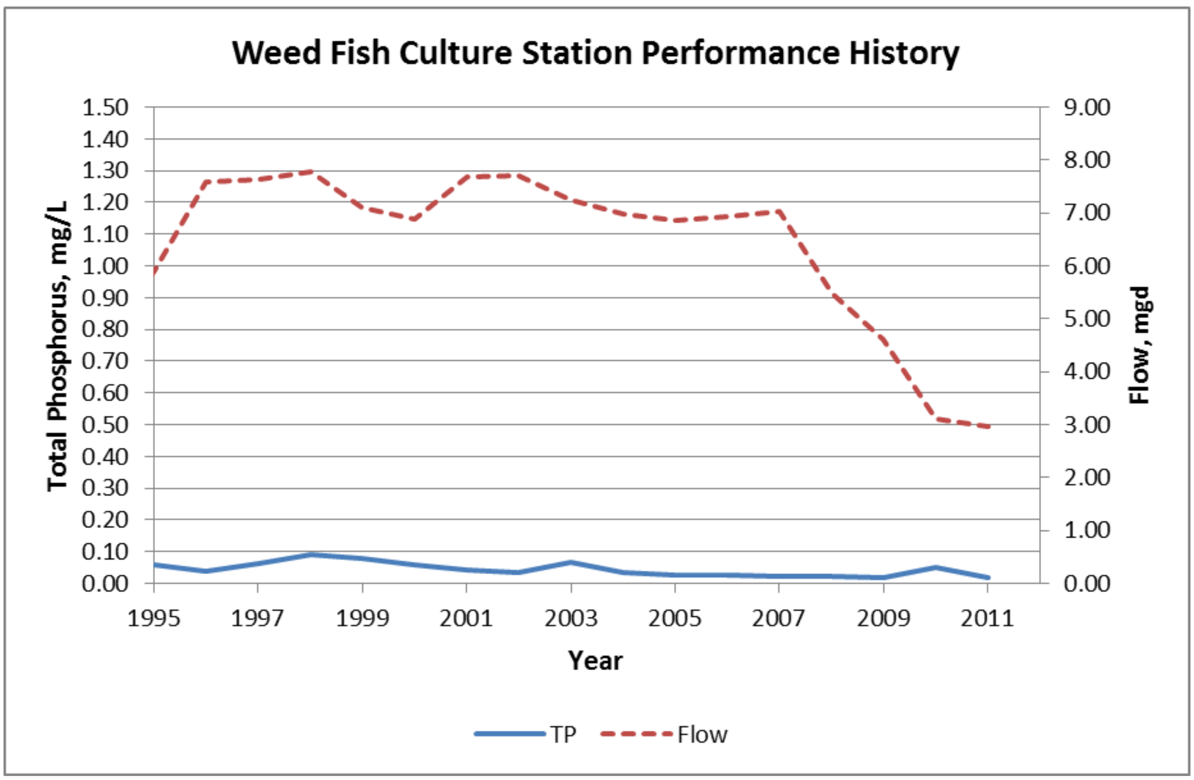


Figure 2.1.55 Weed Fish Culture Station WWTF Performance

2.1.56 West Pawlet

Facility Description

The West Pawlet WWTF is a rotating biological contactor (RBC) plant that is designed to treat up to 0.04 MGD ADF. The 2011 ADF was 0.0174 MGD. Sludge is transported as liquid to an incineration site. Approximately 9.93 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled monthly. The allowable annual TP loading is currently 608 lb/yr which requires an annual average concentration of less than 11.48 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.56, the West Pawlet WWTF has reported effluent phosphorus concentration since at least 2003 remaining between 4.8 mg/L and 7.4 mg/L and averaging 6.0 mg/L over the period 2003 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the West Pawlet WWTF in this evaluation.

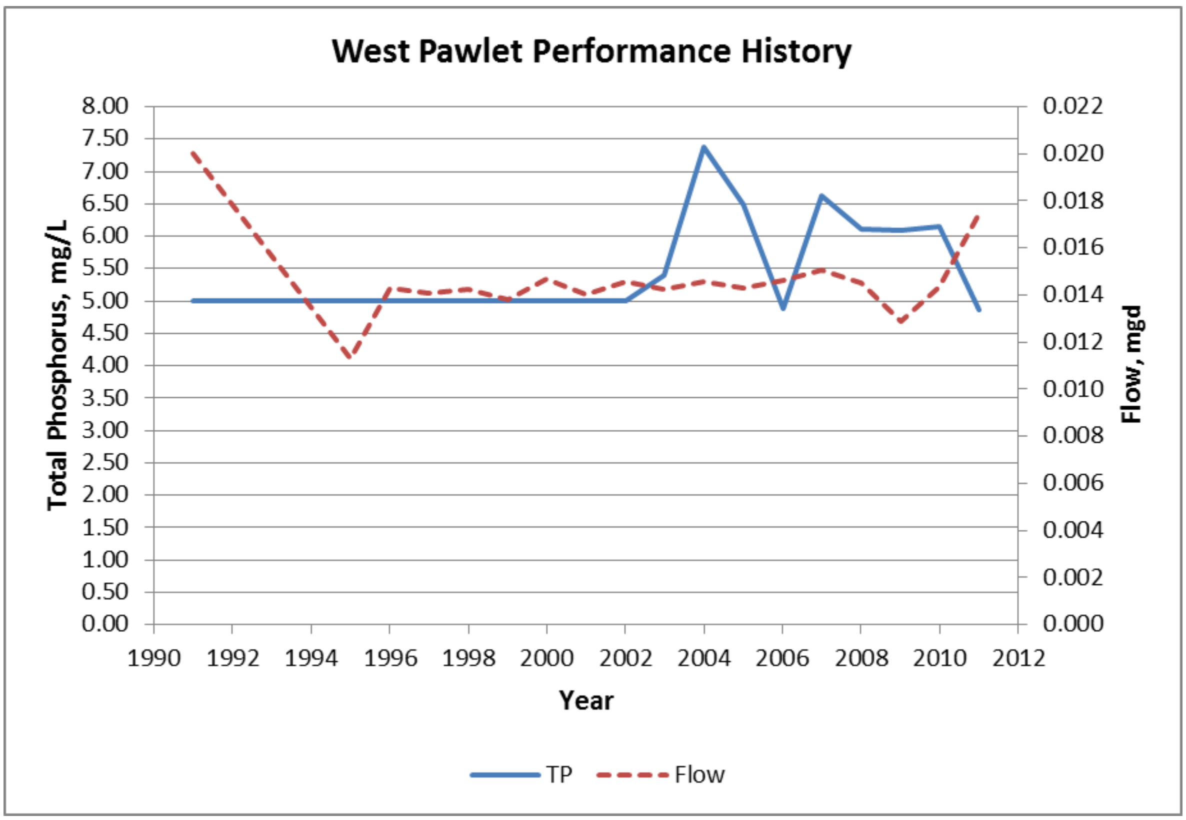


Figure 2.1.56 West Pawlet WWTF Performance

2.1.57 West Rutland

Facility Description

The West Rutland WWTF is an SBR type activated sludge plant that is designed to treat up to 0.45 MGD ADF. The 2011 ADF was 0.219 MGD. Sludge is disposed by transferring as liquid to the Rutland WWTF for further processing and disposal. Approximately 29.3 dry tons of sludge were disposed in 2011. The effluent phosphorus concentration is sampled monthly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 802 lb/yr which requires an annual average concentration of less than 1.2 mg/L at current ADF and less than 0.586 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.57, the West Rutland WWTF has reported moderately low effluent phosphorus concentration since at least 2001 remaining between 0.106 mg/L and 0.408 mg/L and averaging 0.277 mg/L over the period 2001 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to consistently attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the West Rutland WWTF in this evaluation.

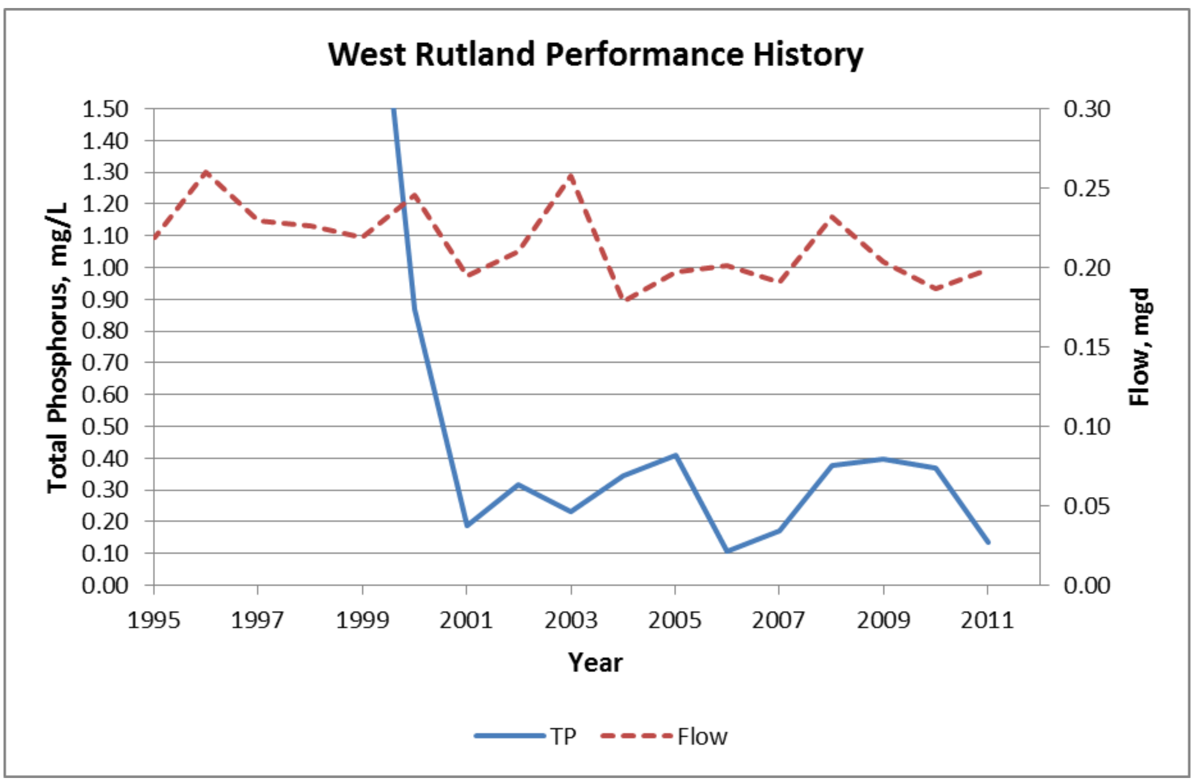


Figure 2.1.57 West Rutland WWTF Performance

2.1.58 Williamstown

Facility Description

The Williamstown WWTF is an aerated lagoon plant that is designed to treat up to 0.15 MGD ADF. The 2011 ADF was 0.0721 MGD. Sludge is irregularly disposed as liquid. The effluent phosphorus concentration is sampled monthly for monitoring. The allowable annual TP loading is currently 2283 lb/yr which requires an annual average concentration of less than 10.40 mg/L at current ADF and less than 5.0 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.58, the Williamstown WWTF has reported moderate effluent phosphorus concentration between 2 mg/L and 5 mg/L over the period 1999 to 2011. The TP has declined steadily since 2005. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain 1.0 mg/L effluent phosphorus goals remain to be considered for the Williamstown WWTF in this evaluation.

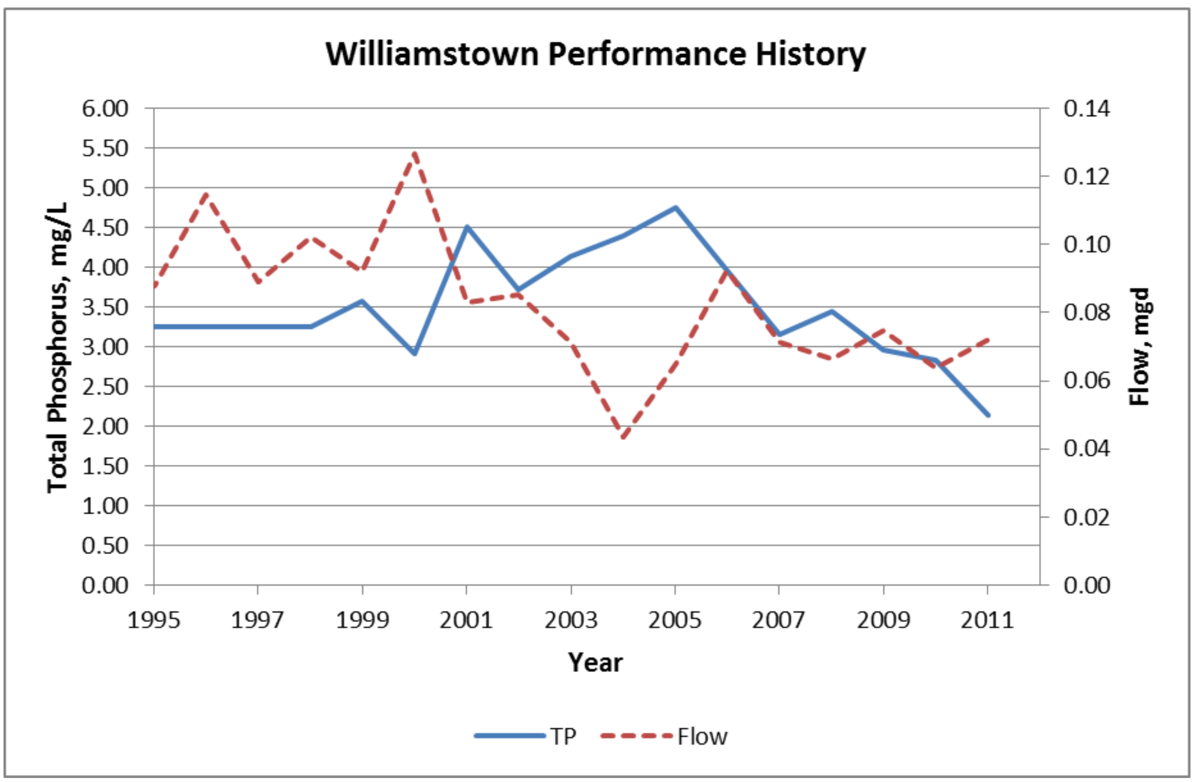


Figure 2.1.58 Williamstown WWTF Performance

2.1.59 Winooski

Facility Description

The Winooski WWTF is an extended aeration activated sludge plant that is designed to treat up to 1.4 MGD ADF. The 2011 ADF was 0.92 MGD. Sludge is disposed by transferring as liquid to the Burlington Main WWTF for further processing and disposal. Approximately 130 dry tons of sludge was generated in 2011. The effluent phosphorus concentration is sampled weekly and is currently required to meet a 0.8 mg/L monthly average TP limit. The allowable annual TP loading is currently 2557 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.59, the Winooski WWTF has reported moderately low effluent phosphorus concentration since at least 1998 remaining between 0.275 mg/L and 0.518 mg/L and averaging 0.46 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Winooski WWTF in this evaluation.

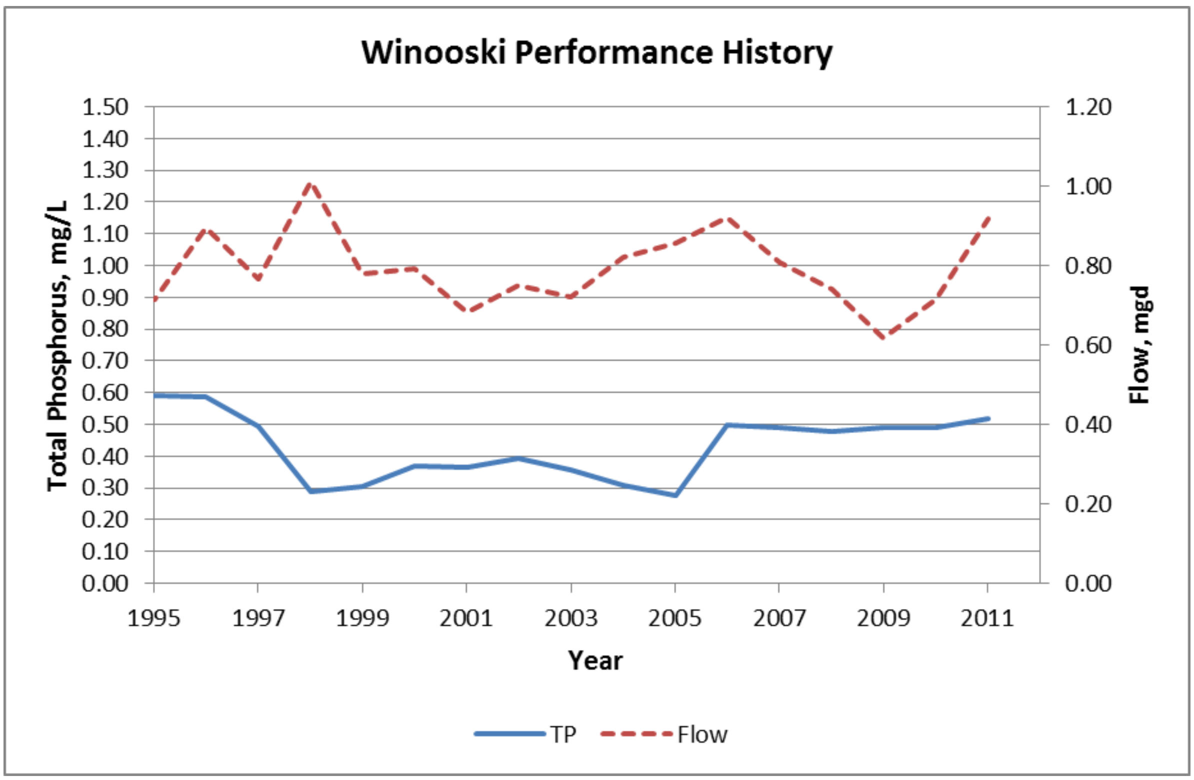


Figure 2.1.59 Winooski WWTF Performance

2.1.60 Wyeth (PBM Nutritionals)

Facility Description

The Wyeth WWTF is an activated sludge plant with chemical addition and filtration that is designed to treat up to 0.425 MGD ADF. The 2011 ADF was 0.121 MGD. The allowable annual TP loading is currently 776 lb/yr which was calculated by assuming a 0.6 mg/L concentration (as an annual average) at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.1.60 the Wyeth WWTF has reported very low effluent phosphorus concentration since 1997 remaining between 0.033 mg/L and 0.212 mg/L and averaging 0.076 mg/L over the period 1999 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. No improvements to effluent phosphorus need be considered for the Wyeth WWTF in this evaluation.

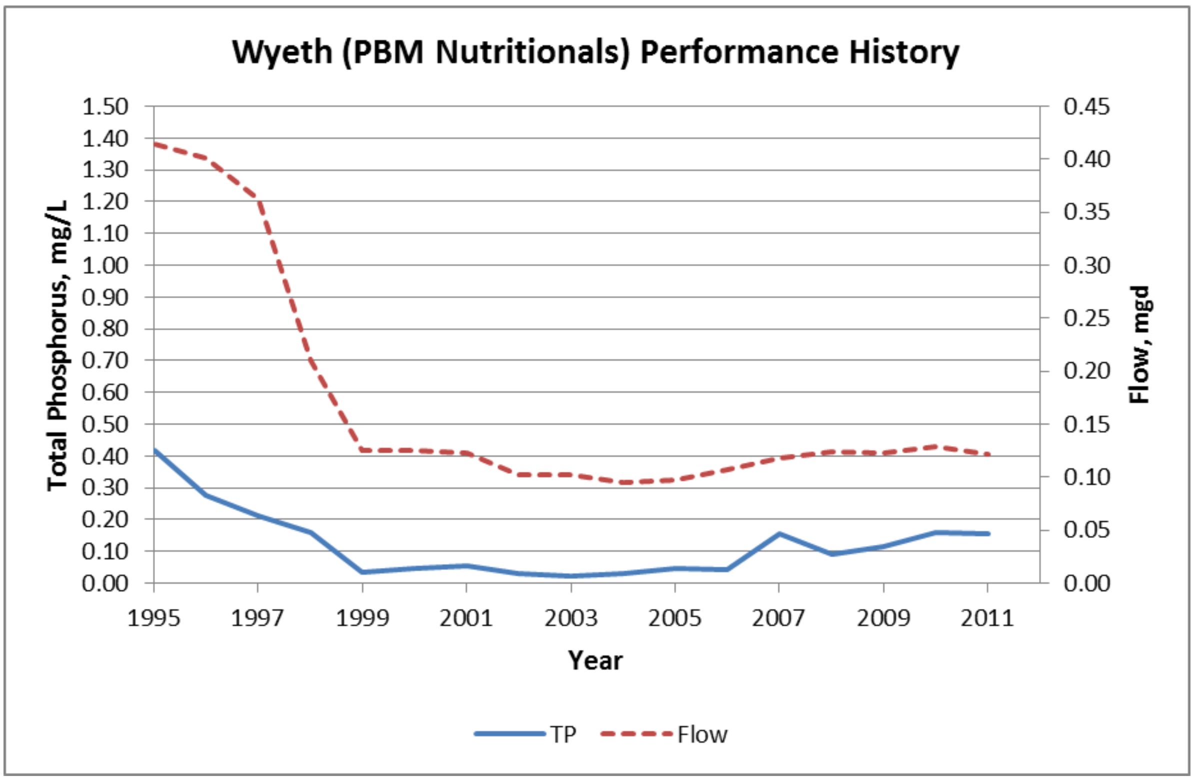


Figure 2.1.60 Wyeth (PBM Nutritionals) WWTF Performance

2.2 New York WWTPs

Table 2.2 lists the New York WWTFs that were included in this study. Each is addressed in a separate sub-section below to provide basic plant process information as well as historical performance relative to phosphorus removal.

Table 2.2 New York WWTF

Section	WWTF	Section	WWTF
2.2.1	Adirondack Fish Hatchery	2.2.16	Lake Placid
2.2.2	Altona Correctional	2.2.17	Peru
2.2.3	Au Sable Forks	2.2.18	Peru/Valcour
2.2.4	Cadyville	2.2.19	Plattsburgh
2.2.5	Champlain	2.2.20	Port Henry
2.2.6	Champlain Park	2.2.21	Rouses Point
2.2.7	Chazy	2.2.22	Saranac Lake
2.2.8	Crown Point	2.2.23	St Armand
2.2.9	Dannemora	2.2.24	Ticonderoga
2.2.10	Essex	2.2.25	Wadhams
2.2.11	Fort Ann	2.2.26	Washington Correctional
2.2.12	Granville	2.2.27	Westport
2.2.13	Great Meadows Correctional	2.2.28	Whitehall
2.2.14	International Paper	2.2.29	Willsboro
2.2.15	Keeseville	2.2.30	Wyeth Research

2.2.1 Adirondack Fish Hatchery

Facility Description

The Adirondack Fish Hatchery WWTF is designed to treat up to 3.6 MGD ADF. The 2011 ADF was 2.98 MGD. The effluent phosphorus concentration is sampled weekly. The allowable 12 month rolling average TP loading is currently 176 lb/yr which requires an annual average concentration of less than 0.019 mg/L at current ADF and less than 0.016 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.1, the Adirondack Fish Hatchery WWTF has reported very low effluent phosphorus concentration since 1999 remaining between 0.0.004 mg/L and 0.0.009 mg/L and averaging 0.006 mg/L over the period 1999 to 2011. This degree of phosphorus removal produces an effluent well within the current limits annual loading. No improvements in effluent phosphorus need be considered for the Adirondack Fish Hatchery WWTF in this evaluation.

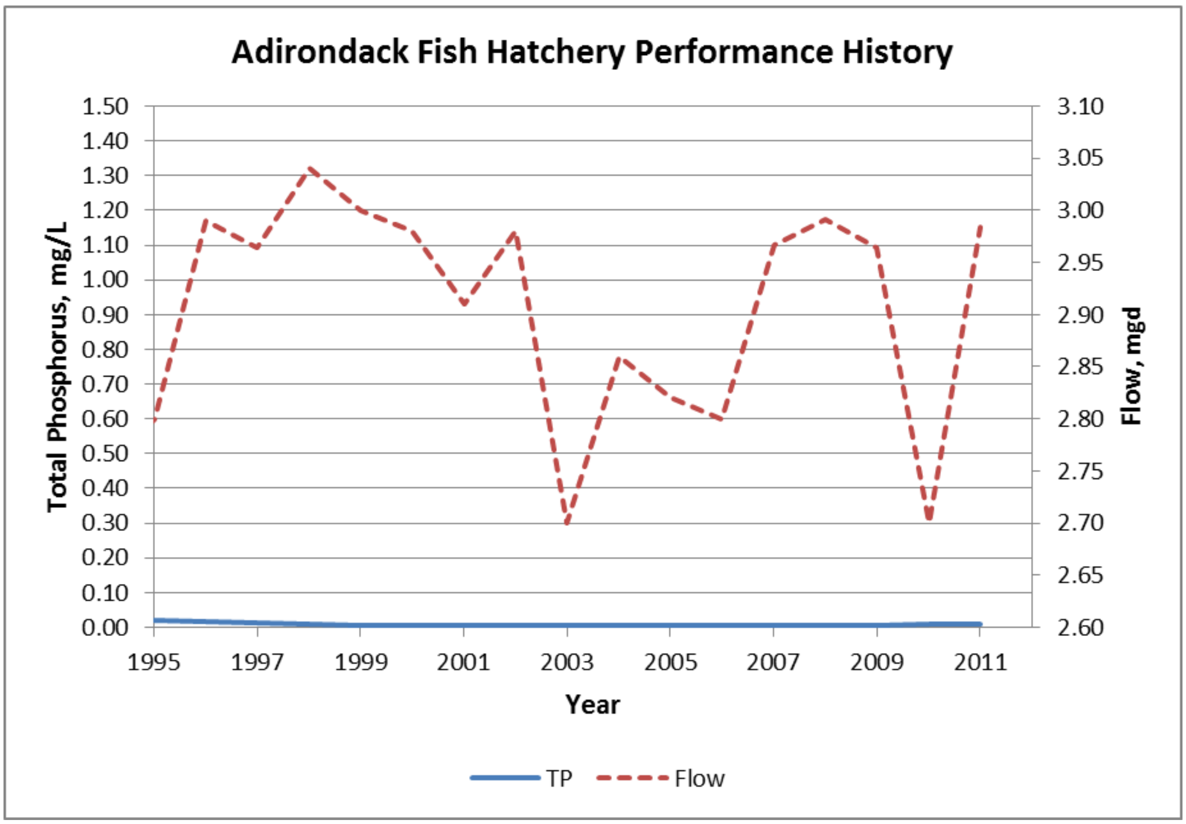


Figure 2.2.1 Adirondack Fish Hatchery WWTF Performance

2.2.2 Altona Correctional

<u>Facility Description</u>

The Altona Correctional WWTF is designed to treat up to 0.12 MGD ADF. The 2011 ADF was 0.059 MGD. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 176 lb/yr which requires an annual average concentration of less than 0.98 mg/L at current ADF and less than 0.48 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.2.2, the Altona Correctional WWTF has reported low effluent phosphorus concentration since 2004 remaining between 0.22 mg/L and 0.60 mg/L with the exception of one year and averaging 0.257 mg/L over the period 2009 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Altona Correctional WWTF in this evaluation.

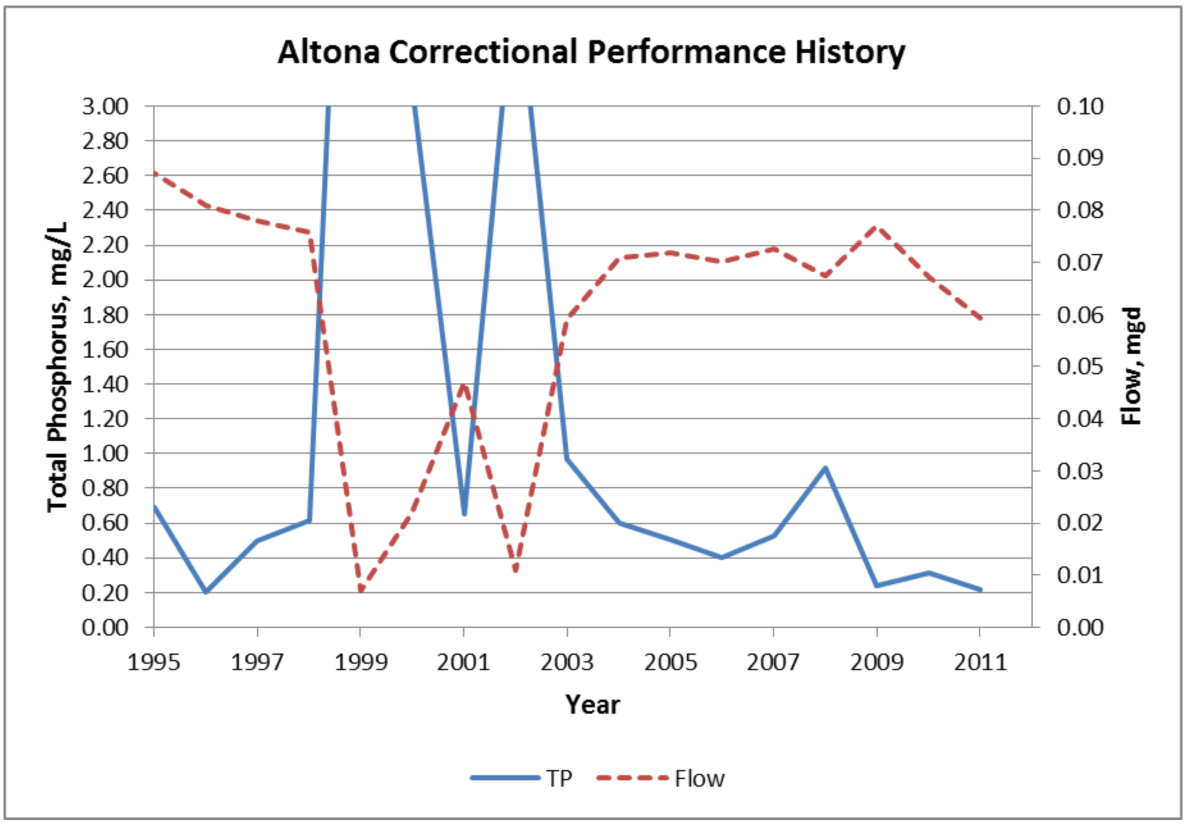


Figure 2.2.2 Altona Correctional WWTF Performance

2.2.3 Au Sable Forks

Facility Description

The Au Sable Forks WWTF is an aerated lagoon plant designed to treat up to 0.147 MGD ADF. The 2011 ADF was 0.063 MGD. The effluent phosphorus concentration is sampled monthly. Sludge is either transferred to another WWTP or disposed of in a landfill. The allowable 12 month rolling average TP loading is currently 1631 lb/yr which requires an annual average concentration of less than 8.5 mg/L at current ADF and less than 3.64 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.3, the Au Sable Forks WWTF has reported effluent phosphorus concentration since at least 1995 remaining between 2.99 mg/L and 4.85 mg/L and averaging 4.186 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the Au Sable Forks WWTF in this evaluation.

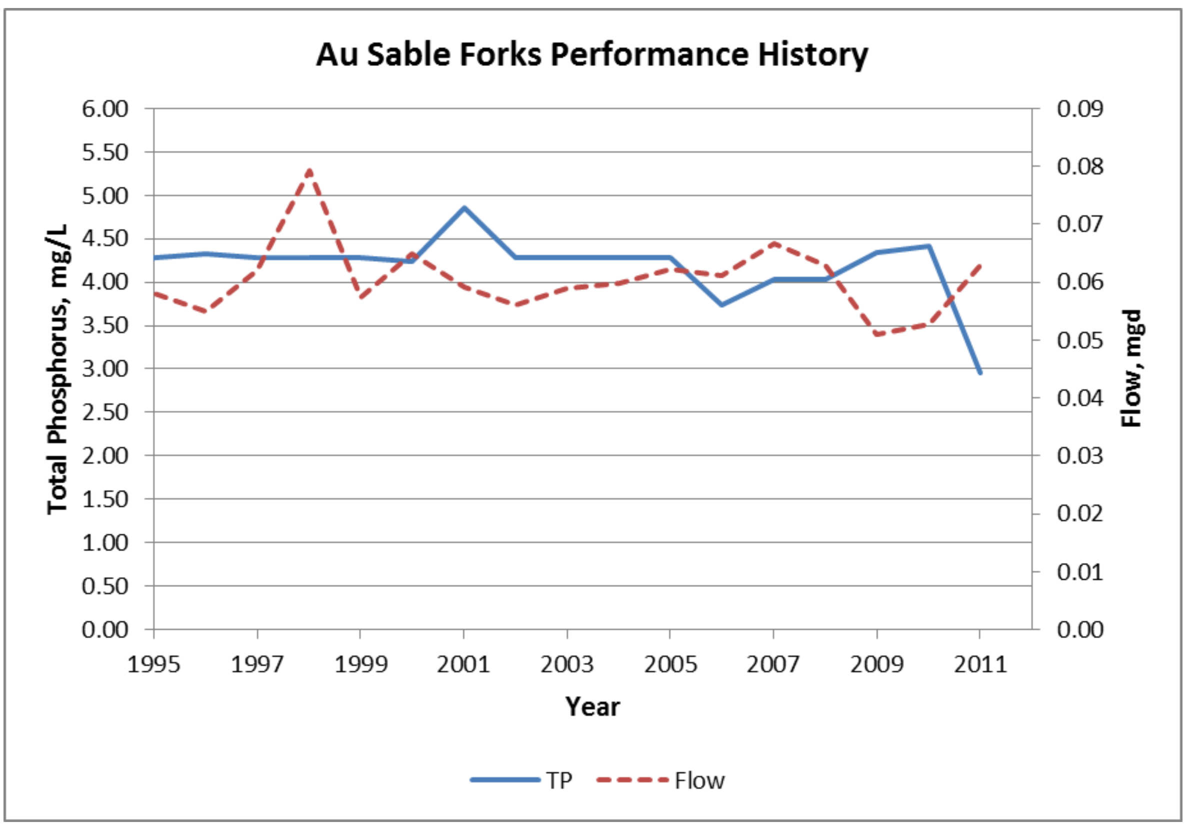


Figure 2.2.3 Au Sable Forks WWTF Performance

2.2.4 Cadyville

Facility Description

The Cadyville WWTF is an extended aeration activated sludge plant designed to treat up to 0.006 MGD ADF. The 2011 ADF was 0.004 MGD. Sludge is digested aerobically, dewatered on drying beds, and sent to a landfill for disposal. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 88 lb/yr which requires an annual average concentration of less than 7.23 mg/L at current ADF and less than 4.83 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.4, the Cadyville WWTF has reported generally declining effluent phosphorus concentration since 2004 averaging 1.44 mg/L over the period 2009 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goals remain to be considered for the Cadyville WWTF in this evaluation.

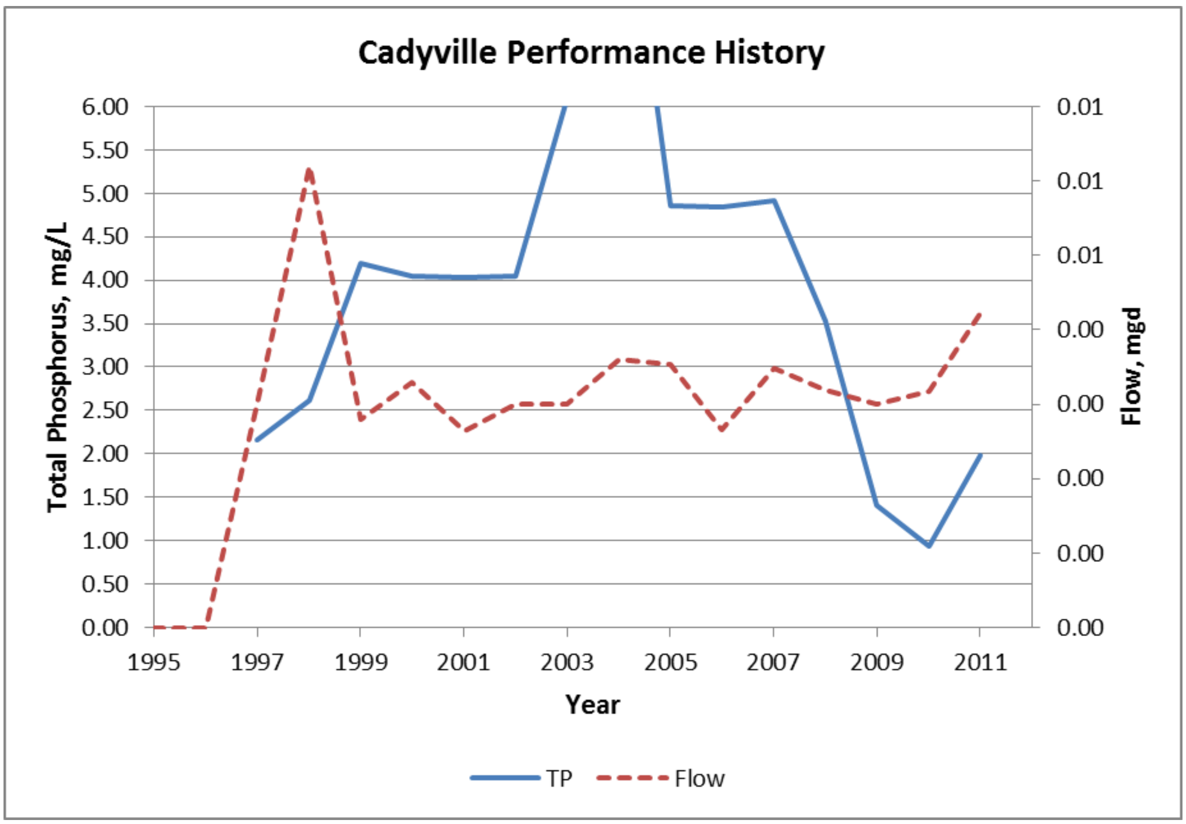


Figure 2.2.4 Cadyville WWTF Performance

2.2.5 Champlain

Facility Description

The Champlain WWTF is an extended aeration activated sludge plant with process controls for chemical and biological phosphorus removal; it is designed to treat up to 0.65 MGD ADF. The 2011 ADF was 0.247 MGD. Sludge is aerobically digested and dewatered in geotextile bags on sand drying beds before landfilling at the Franklin County landfill. The effluent phosphorus concentration is sampled twice monthly. The allowable 12 month rolling average TP loading is currently 1257 lb/yr which requires an annual average concentration of less than 1.67 mg/L at current ADF and less than 0.635 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.5, the Champlain WWTF has reported declining effluent phosphorus concentration since 2000. It has remained between 0.406 mg/L and 0.649 mg/L and averaged 0.491 mg/L over the period 2004 to 2011. This degree of phosphorus removal produces an effluent within the current limits for both concentration and annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Champlain WWTF in this evaluation.

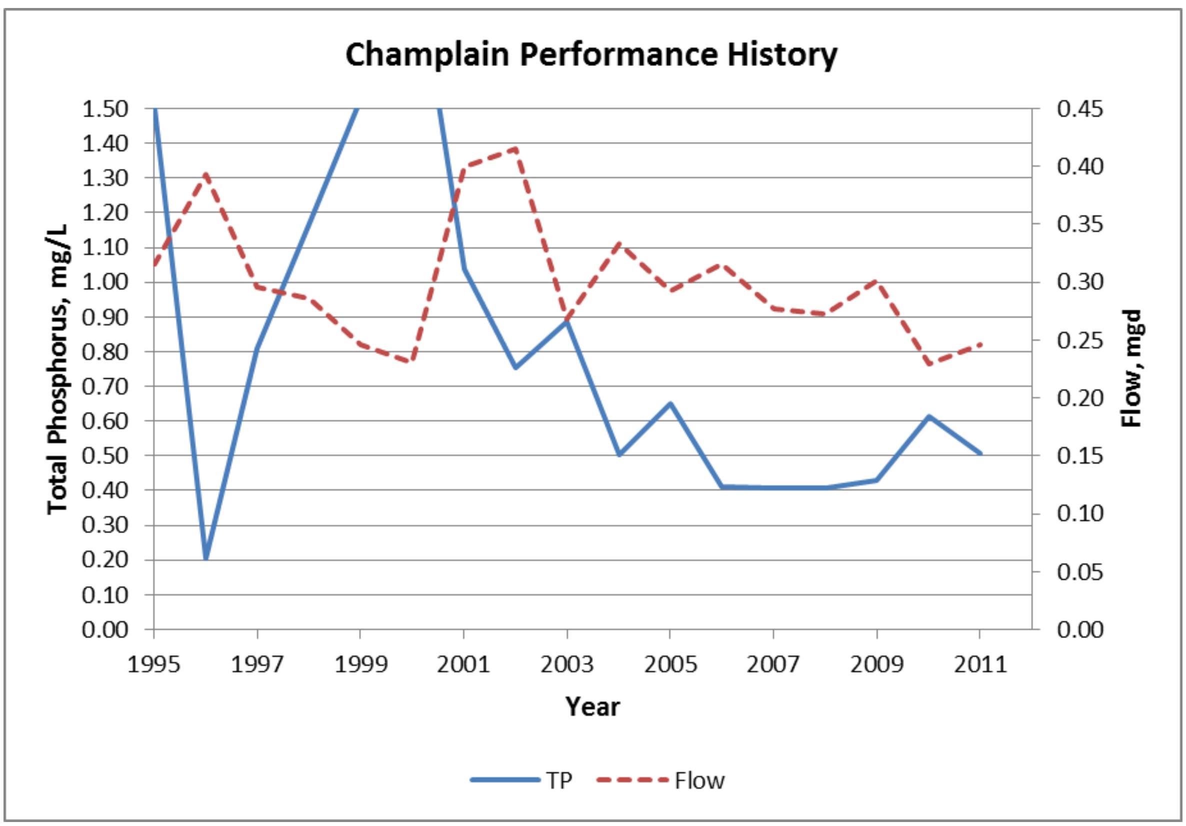


Figure 2.2.5 Champlain WWTF Performance

2.2.6 Champlain Park

Facility Description

The Champlain Park WWTF was a trickling filter plant designed to treat up to 0.162 MGD ADF but has not discharged since 2009. Sludge stabilized via aerobic digestion, dewatered on drying beds, and then sent to a landfill for disposal. The allowable 12 month rolling average TP loading was 639 lb/yr which requires an annual average concentration of less than 1.30 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.6, the Champlain Park WWTF reported moderate effluent phosphorus concentration since at least 1995 remaining between 1.62 mg/L and 4.16 mg/L over the period 1995 to 2011. This degree of phosphorus removal produced an effluent inadequate to meet the current limits for annual loading.

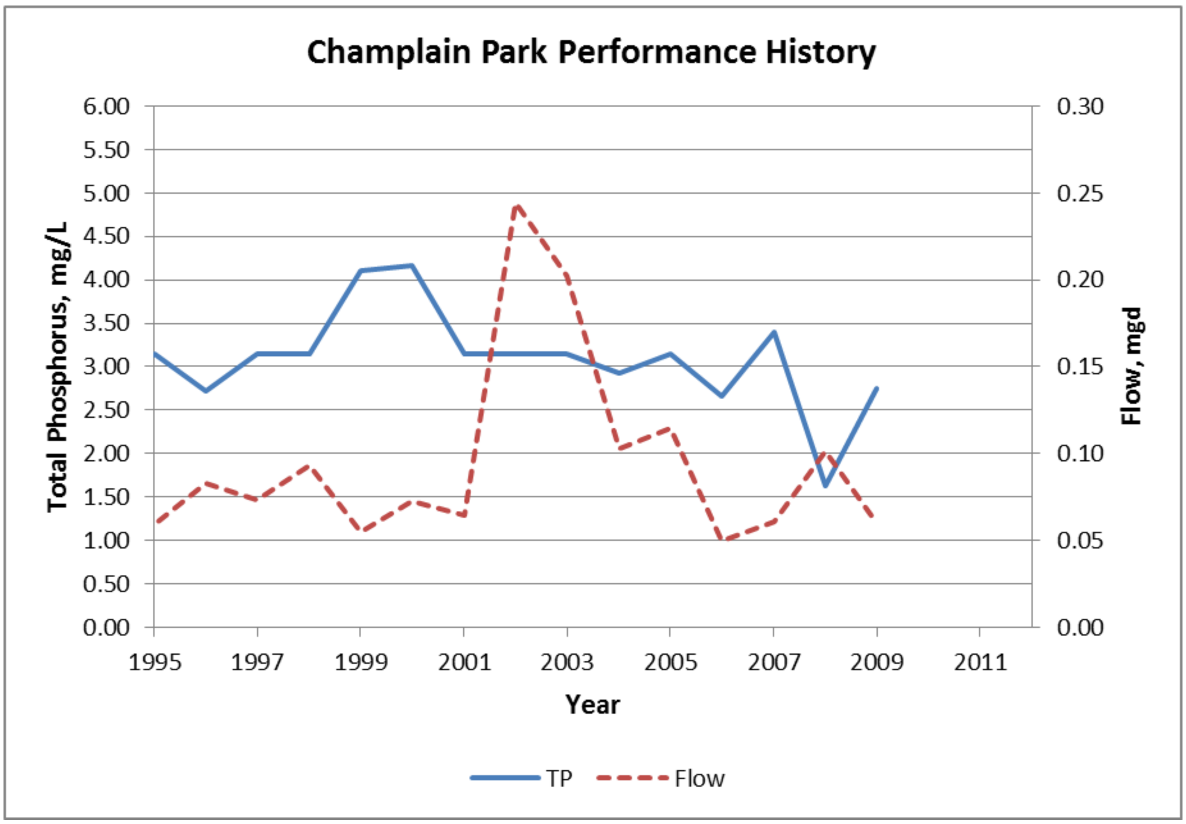


Figure 2.2.6 Champlain Park WWTF Performance

2.2.7 Chazy

Facility Description

The Chazy WWTF is an SBR type plant designed to treat up to 0.085 MGD ADF. The 2011 ADF was 0.042 MGD. Sludge is aerobically digested and dried on reed beds. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 220 lb/yr which requires an annual average concentration of less than 1.72 mg/L at current ADF and less than 0.85 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.7, the Chazy WWTF has reported declining effluent phosphorus concentration since 2007 achieving 0.108 mg/L and 0.111 mg/L in 2010 and 2011 respectively. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading. However improvements to attain the 0.1 mg/L effluent phosphorus goals remain to be considered for the Chazy WWTF in this evaluation.

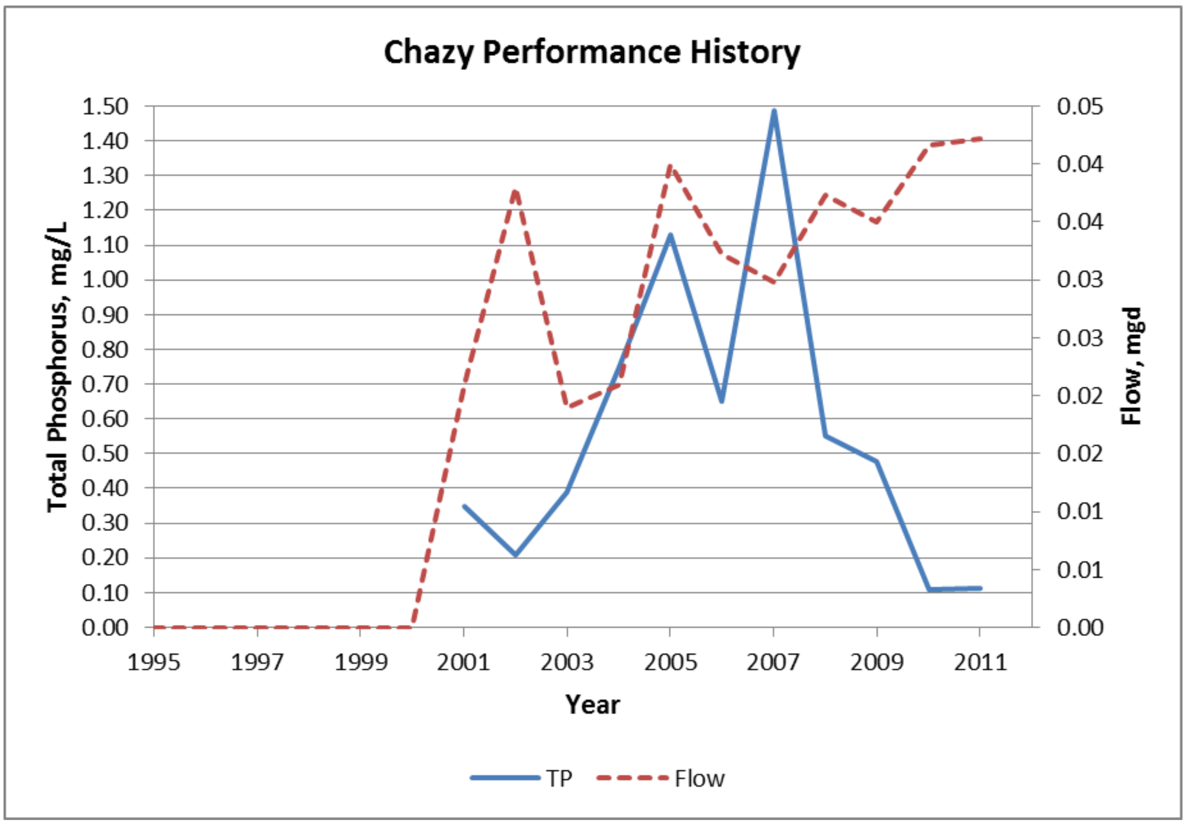


Figure 2.2.7 Chazy WWTF Performance

2.2.8 Crown Point

Facility Description

The Crown Point WWTF is a rotating biological contactor (RBC) plant designed to treat up to 0.060 MGD ADF. The 2011 ADF was 0.036 MGD. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 377 lb/yr which requires an annual average concentration of less than 3.44 mg/L at current ADF and less than 2.06 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.8, the Crown Point WWTF has operated at several effluent phosphorus concentration since at least 1995 remaining between 0.81 mg/L and 4.55 mg/L and averaging 2.98 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goals remain to be considered for the Crown Point WWTF in this evaluation.

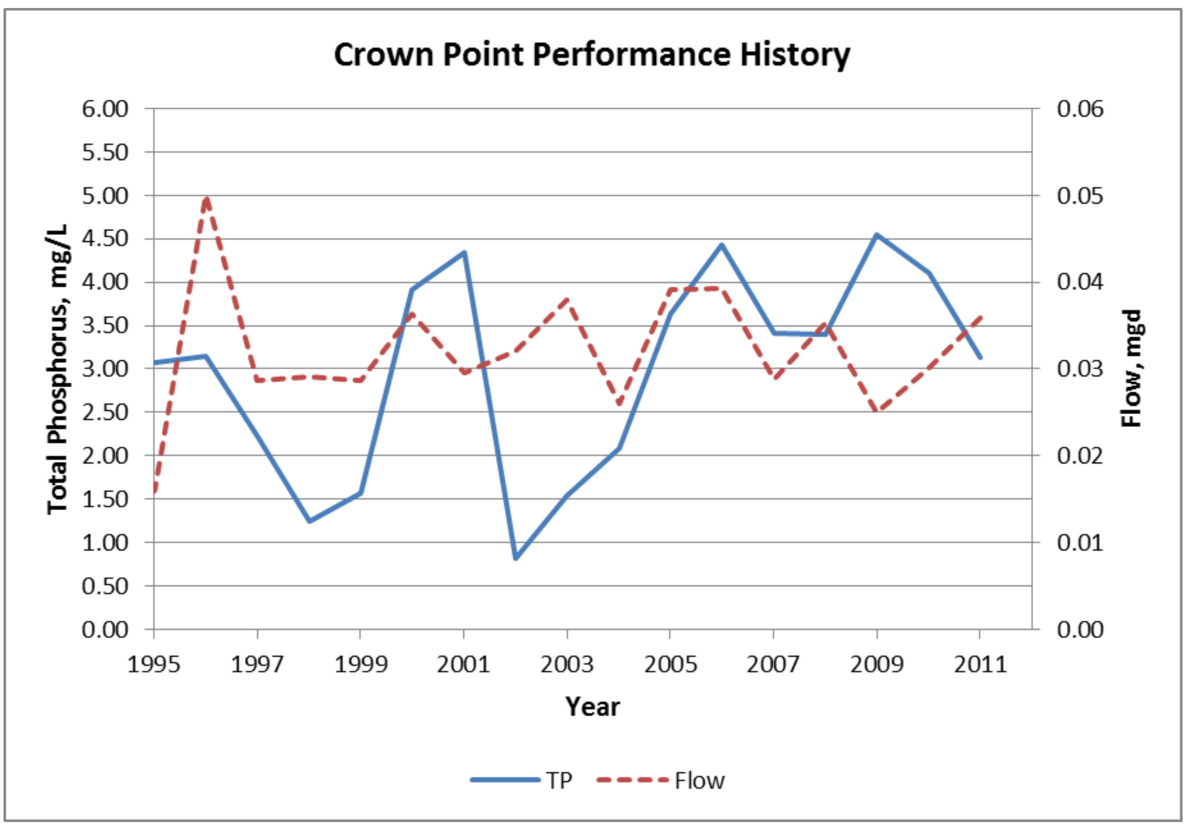


Figure 2.2.8 Crown Point WWTF Performance

2.2.9 Dannemora

Facility Description

The Dannemora WWTF is an aerated lagoon facility designed to treat up to 1.5 MGD ADF. The 2011 ADF was 1.004 MGD. The facility has influent screening and disinfects with hypochlorite on a seasonal basis. The effluent phosphorus concentration is sampled weekly. The allowable 12 month rolling average TP loading is currently 7407 lb/yr which requires an annual average concentration of less than 2.42 mg/L at current ADF and less than 1.622 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.9, the Dannemora WWTF has reported moderate effluent phosphorus concentration since at least 1995 remaining between 1.74 mg/L and 3.07 mg/L and averaging 1.99 mg/L over the period 2009 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for both concentration and annual loading but effluent TP must be further decreased as flow approaches design ADF. Because Dannemora is in the large plant category, improvements to attain 0.2 mg P/L and 0.1 mg P/L should be considered in addition to the 1.0 mg/L effluent phosphorus goal for this evaluation.

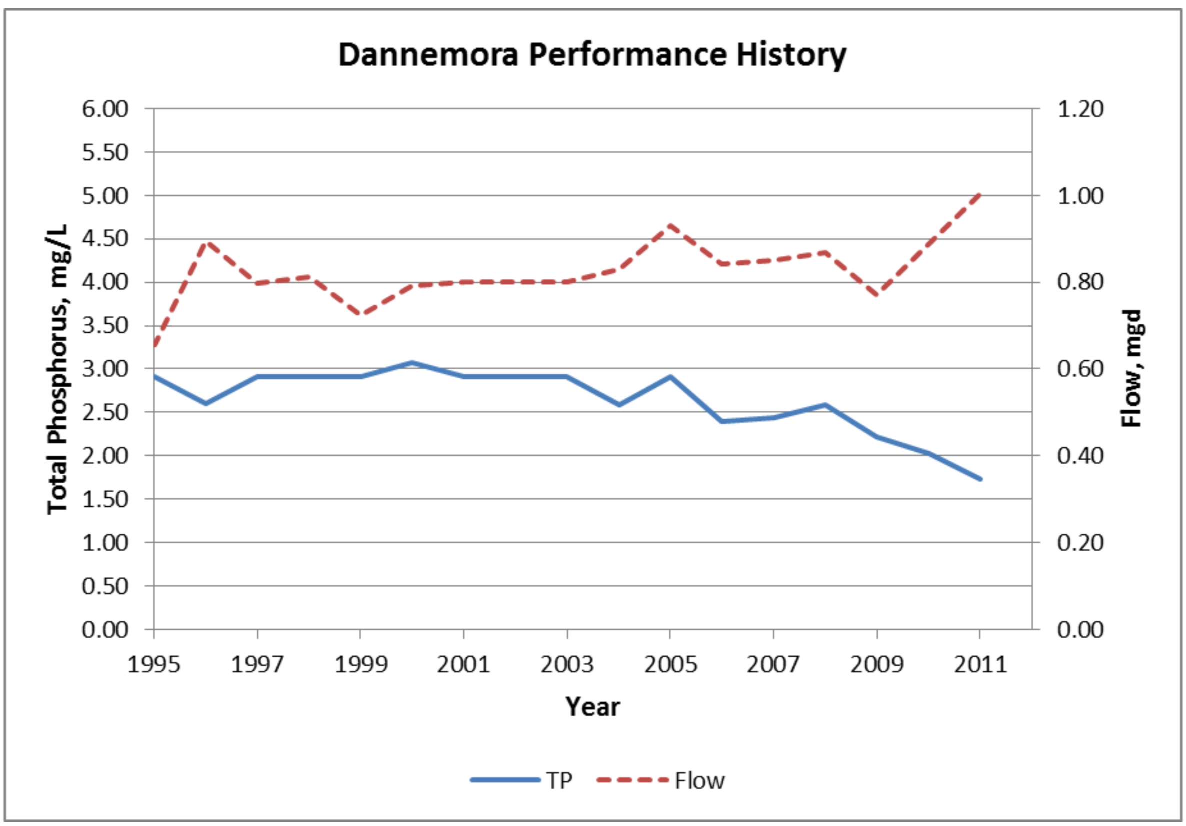


Figure 2.2.9 Dannemora WWTF Performance

2.2.10 Essex

<u>Facility Description</u>

The Essex WWTF is designed to treat up to 0.065 MGD ADF. The 2011 ADF was 0.005 MGD. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 99 lb/yr which requires an annual average concentration of less than 6.8 mg/L at current ADF and less than 0.5 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>

The Essex WWTF began operating in 2001. As shown in Figure 2.2.10, the plant reported a 2011 effluent phosphorus concentration of 3.63 mg/L for 2011. This degree of phosphorus removal produces an effluent within the current limit for annual loading. However improvements will be needed to attain the 0.5 mg/L limit at design ADF. Both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Essex WWTF in this evaluation.

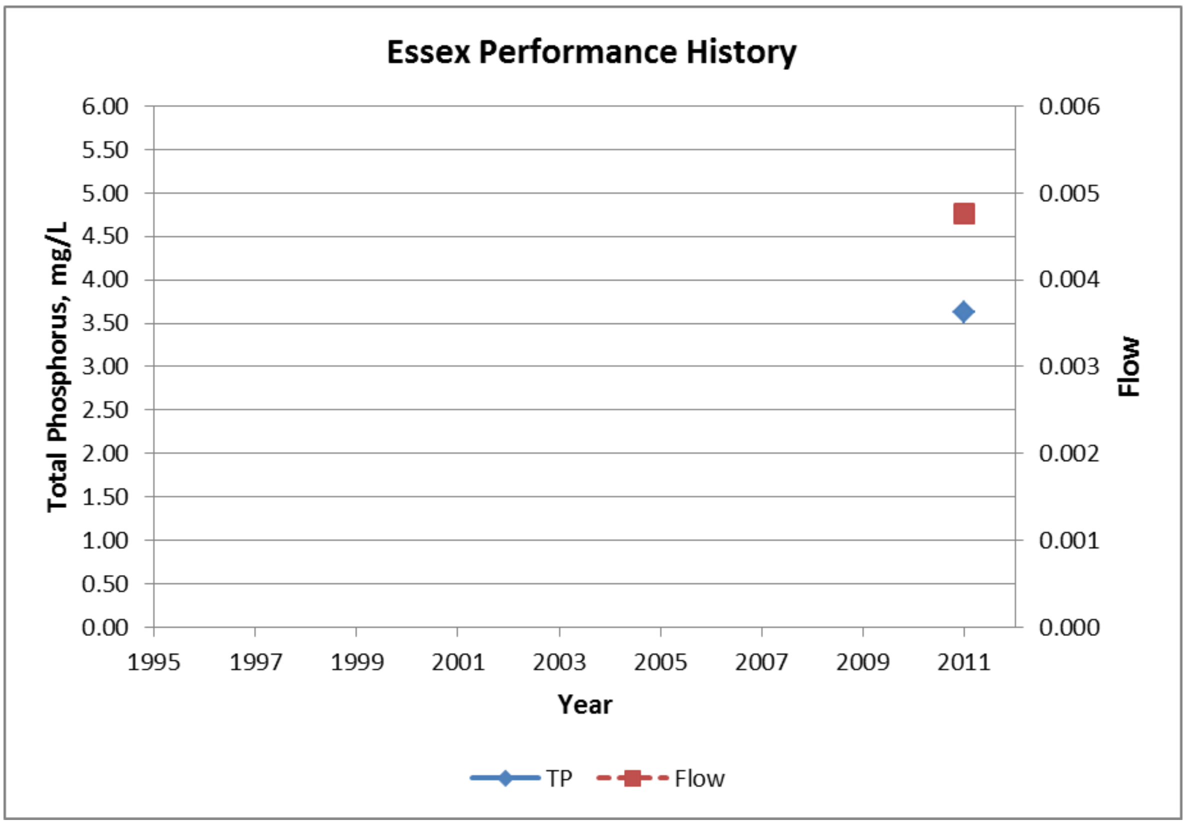


Figure 2.2.10 Essex WWTF Performance

2.2.11 Fort Ann

Facility Description

The Fort Ann WWTF is an activated sludge plant designed to treat up to 0.11 MGD ADF. The 2011 ADF was 0.069 MGD. The effluent phosphorus concentration is sampled monthly. Sludge is dewatered via covered drying beds and transferred to another plant for landfill disposal. The allowable 12 month rolling average TP loading is currently 485 lb/yr which requires an annual average concentration of less than 2.31 mg/L at current ADF and less than 1.45 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.11, the Fort Ann WWTF has reported moderately low effluent phosphorus concentration since at least 2008 remaining between 0.545 mg/L and 0.713 mg/L and averaging 0.610 mg/L over the period 2008 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Fort Ann WWTF in this evaluation.

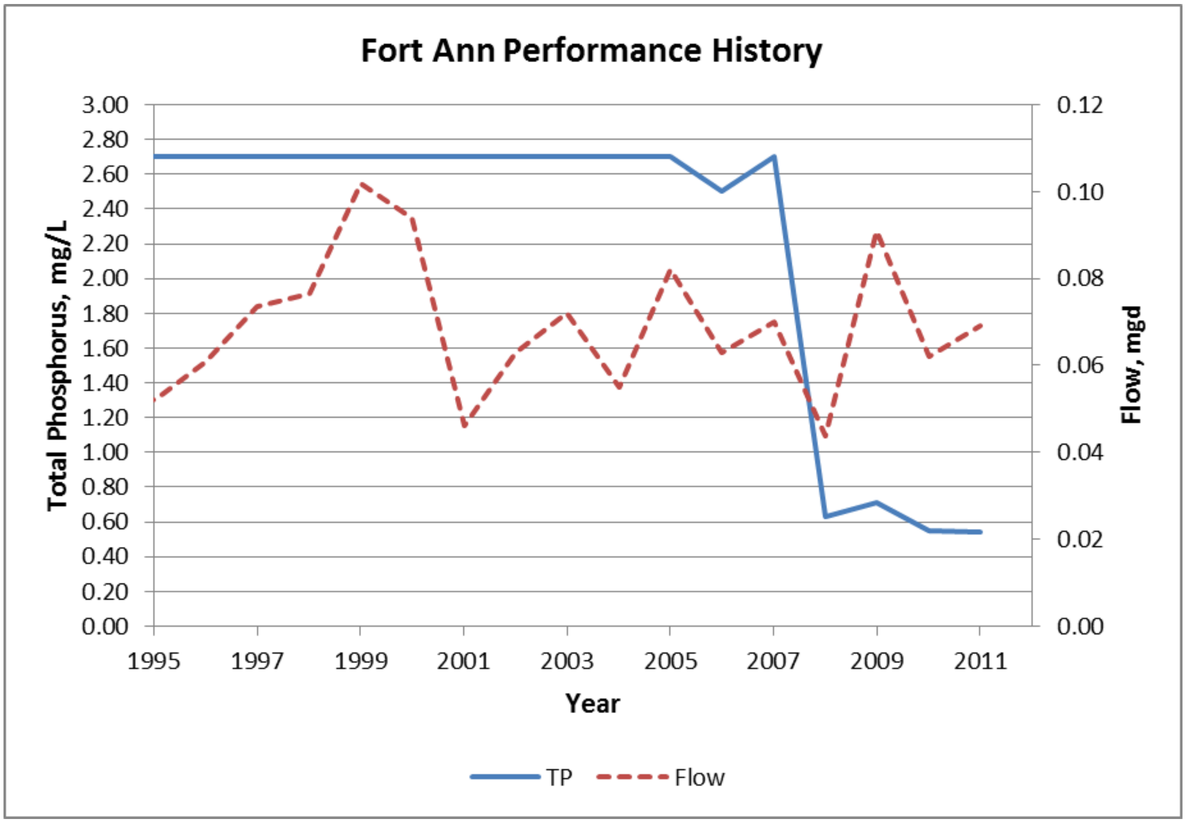


Figure 2.2.11 Fort Ann WWTF Performance

2.2.12 Granville

Facility Description

The Granville WWTF is a trickling filter plant designed to treat up to 1.3 MGD ADF. The 2011 ADF was 0.827 MGD. Sludge is anaerobically digested in the Imhoff tank before being dewatered on sand drying beds and transported to the Town of Easton for disposal. The effluent phosphorus concentration is sampled weekly. The allowable 12 month rolling average TP loading is currently 1587 lb/yr which requires an annual average concentration of less than 0.63 mg/L at current ADF and less than 0.40 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.12 the Granville WWTF has reported very low effluent phosphorus concentration since 2007 remaining between 0.253 mg/L and 0.413 mg/L and averaging 0.304 mg/L over the period 2007 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Granville WWTF in this evaluation.

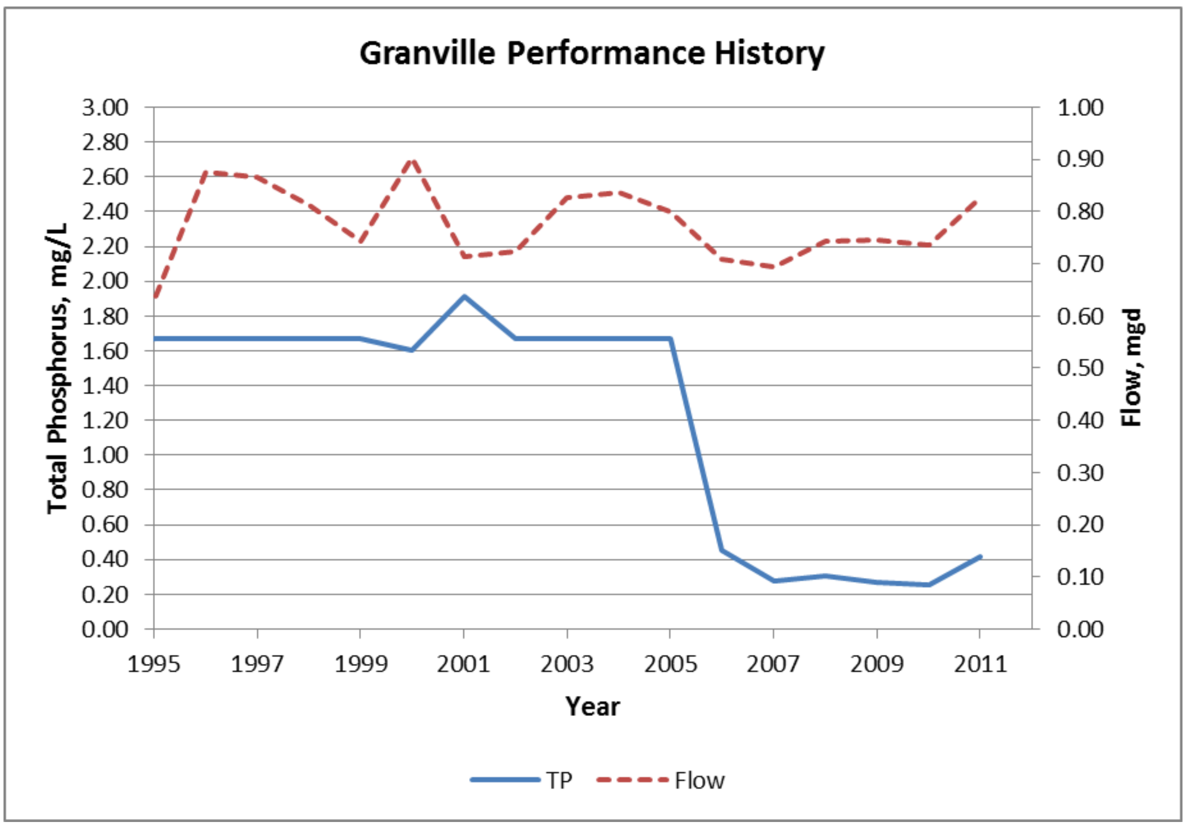


Figure 2.2.12 Granville WWTF Performance

2.2.13 Great Meadows Correctional

Facility Description

The Great Meadows Correctional WWTF is designed to treat up to 0.4 MGD ADF. The 2011 ADF was 0.352 MGD. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 617 lb/yr which requires an annual average concentration of less than 0.58 mg/L at current ADF and less than 0.51 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.13, the Great Meadows Correctional WWTF has reported low effluent phosphorus concentration since 1996 remaining between 0.14 mg/L and 0.58 mg/L and averaging 0.294 mg/L over the period 1996 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Great Meadows Correctional WWTF in this evaluation.

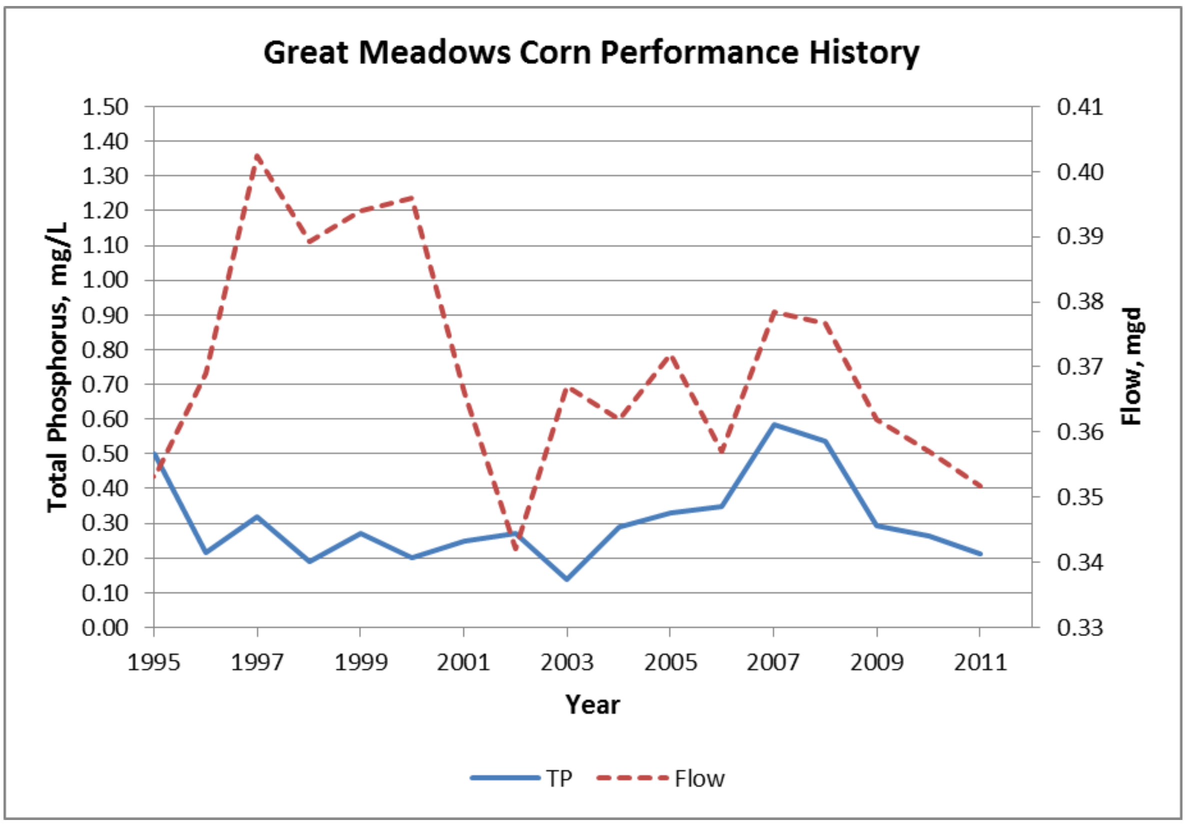


Figure 2.2.13 Great Meadows Corn WWTF Performance

2.2.14 International Paper

Facility Description

The International Paper WWTF is designed to treat up to 17.5 MGD ADF. The 2011 ADF was 14.325 MGD. The effluent phosphorus concentration is sampled three times per week. The allowable 12 month rolling average TP loading is currently 13805 lb/yr which requires an annual average concentration of less than 0.32 mg/L at current ADF and less than 0.26 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.14, the International Paper WWTF has reported very low effluent phosphorus concentration since at least 1995 remaining between 0.106 mg/L and 0.30 mg/L and averaging 0.220 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain 0.1 mg/L effluent phosphorus goals remain to be considered for the International Paper WWTF in this evaluation.

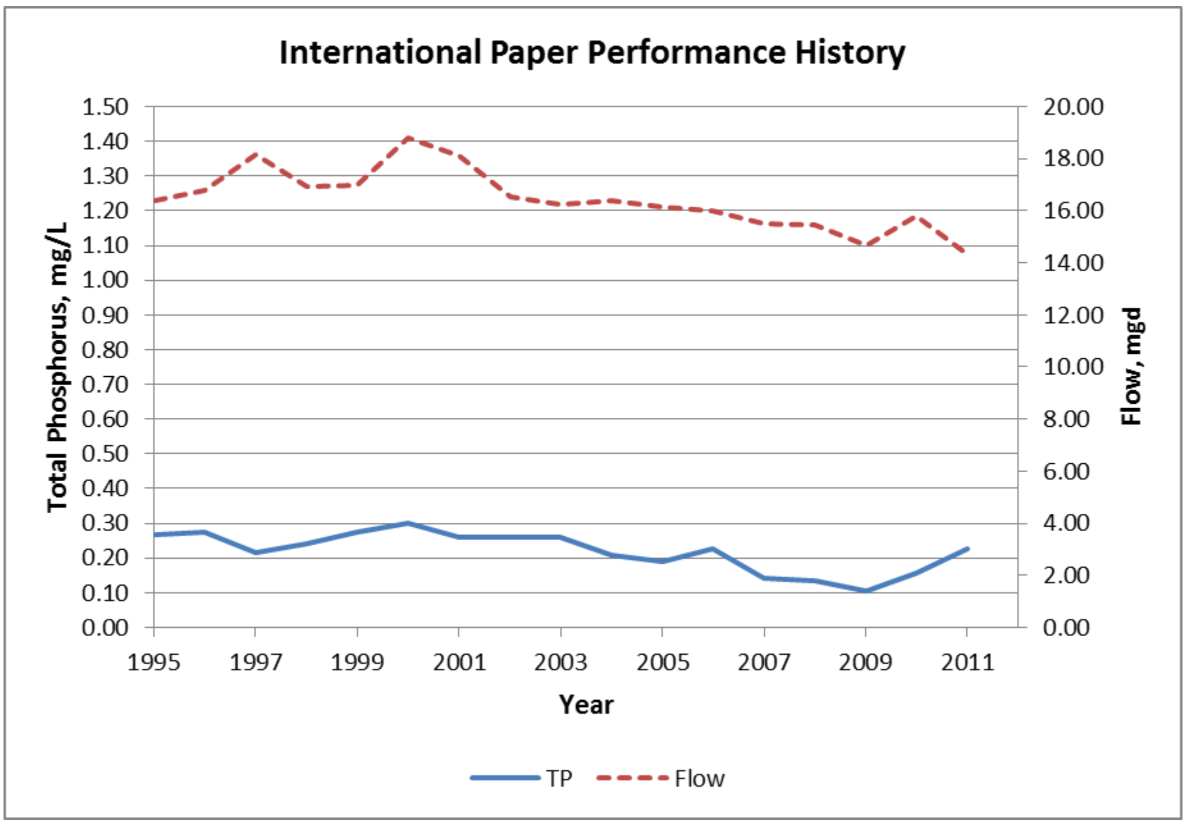


Figure 2.2.14 International Paper WWTF Performance

2.2.15 Keeseville

Facility Description

The Keeseville WWTF is a trickling filter plant and is designed to treat up to 0.70 MGD ADF. The 2011 ADF was 0.42 MGD. Sludge is digested and dewatered on sand drying beds. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 728 lb/yr which requires an annual average concentration of less than 0.57 mg/L at current ADF and less than 0.60 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.15, the Keeseville WWTF has reported very low effluent phosphorus concentration since 2008 remaining between 0.091 mg/L and 0.164 mg/L and averaging 0.134 mg/L over the period 2008 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain 0.1 mg/L effluent phosphorus goals remain to be considered for the Keeseville WWTF in this evaluation.

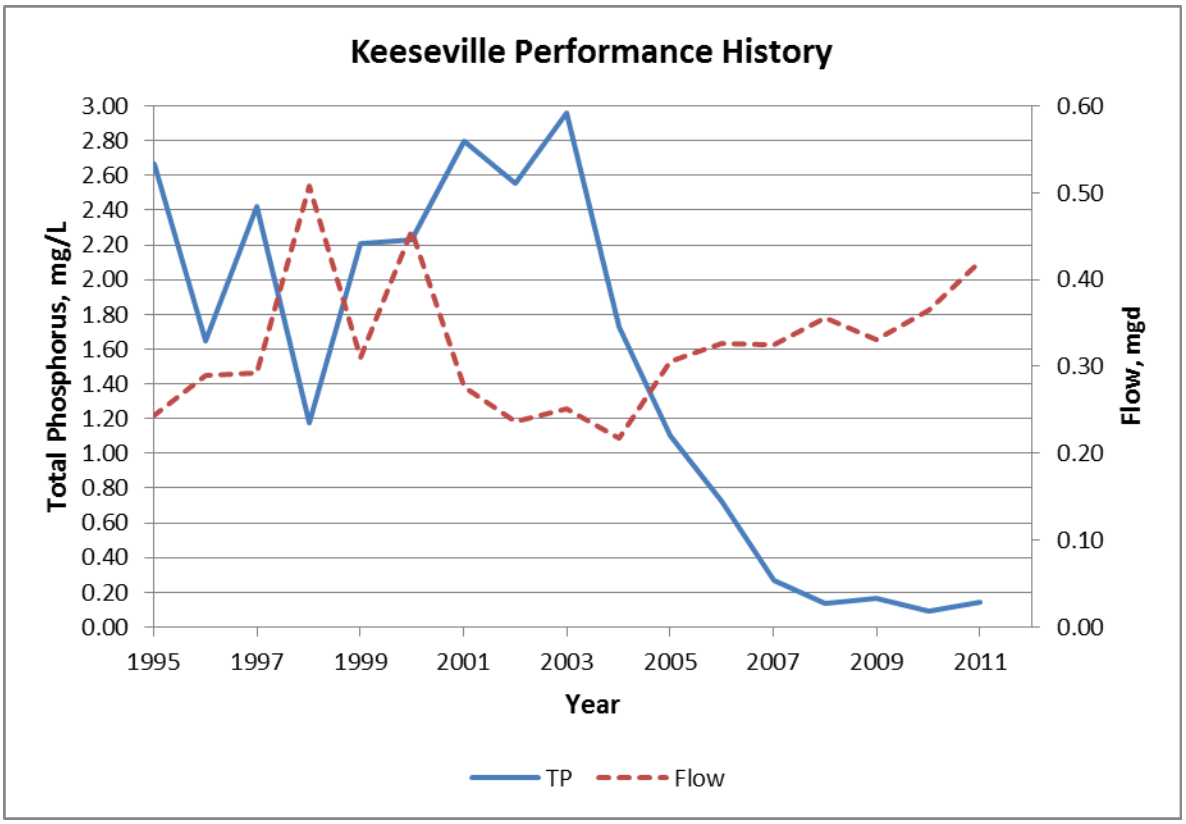


Figure 2.2.15 Keeseville WWTF Performance

2.2.16 Lake Placid

Facility Description

The Lake Placid WWTF is an activated sludge plant and is designed to treat up to 2.5 MGD ADF. The 2011 ADF was 1.61 MGD. An anaerobically digested sludge is dewatered on asphalt drying beds and then transported to the Saranac Lake Landfill for use as cover material. The effluent phosphorus concentration is sampled weekly. The allowable 12 month rolling average TP loading is currently 4762 lb/yr which requires an annual average concentration of less than 1.35 mg/L at current ADF and less than 0.63 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.16, the Lake Placid WWTF has reported moderate effluent phosphorus concentration since 2006 remaining between 0.78 mg/L and 1.12 mg/L and averaging 0.96 mg/L over the period 2006 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements will be needed to comply at design flow and to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Lake Placid WWTF in this evaluation.

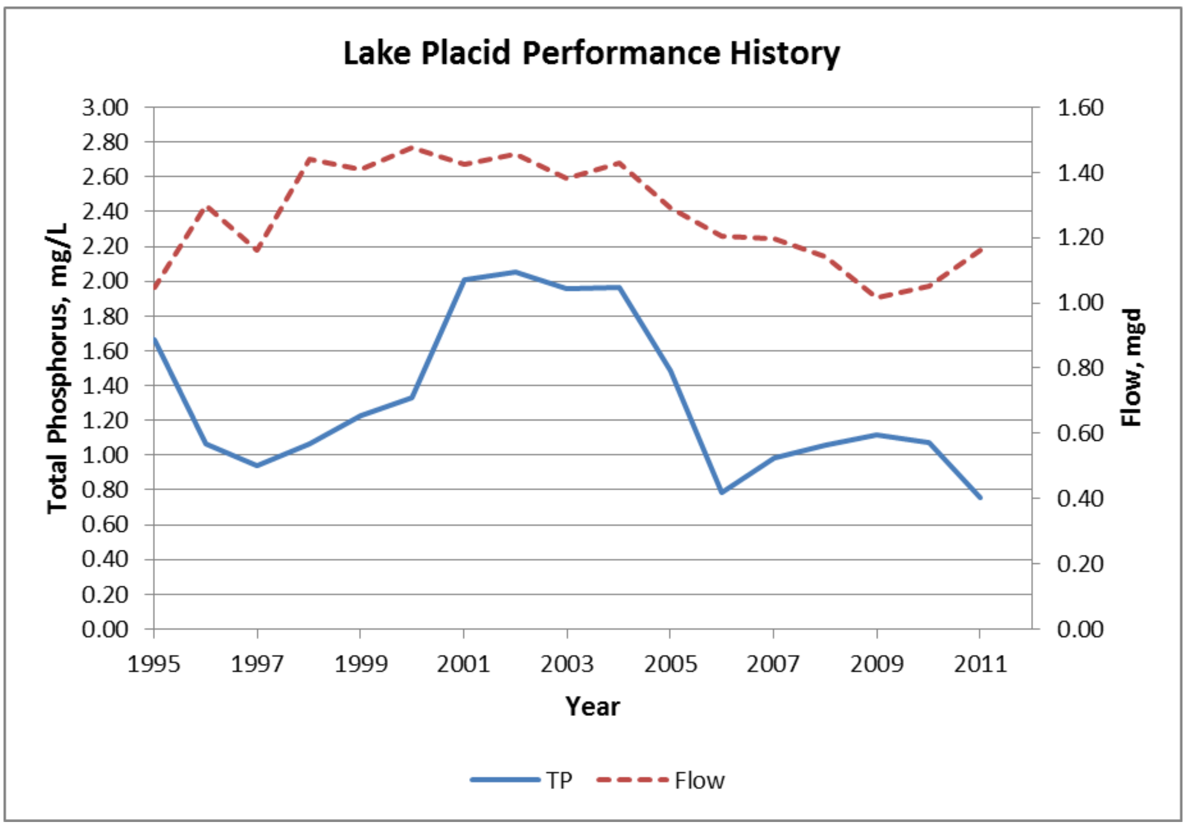


Figure 2.2.16 Lake Placid WWTF Performance

2.2.17 Peru

Facility Description

The Peru WWTF is a nitrifying activated sludge plant with a chemical feed system and is designed to treat up to 0.5 MGD ADF. The 2011 ADF was 0.31 MGD. Sludge is dewatered and transported to the Clinton County composting facility for disposal. The effluent phosphorus concentration is sampled twice monthly. The allowable 12 month rolling average TP loading is currently 1345 lb/yr which requires an annual average concentration of less than 1.43 mg/L at current ADF and less than 0.88 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.17, the Peru WWTF has reported moderately low effluent phosphorus concentration since 2009 remaining between 0.725 mg/L and 1.46 mg/L and averaging 1.13 mg/L over the period 2009 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Peru WWTF in this evaluation.

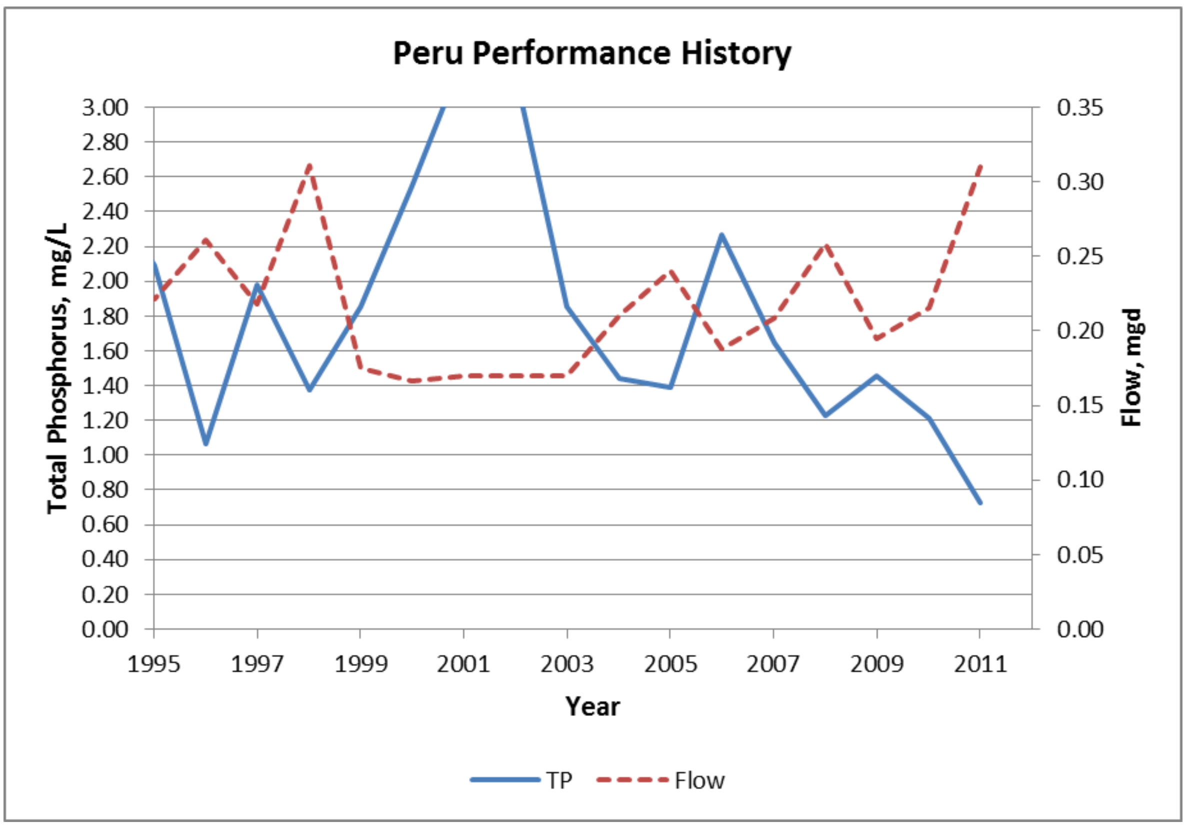


Figure 2.2.17 Peru WWTF Performance

2.2.18 Peru/Valcour

<u>Facility Description</u>

The Peru/Valcour WWTF is solids separation facility designed to treat up to 0.048 MGD ADF. The 2011 ADF was 0.006 MGD. The effluent phosphorus concentration is sampled monthly. Grit removal, sand filtration, and hypochlorite disinfection are the only treatment processes. The allowable 12 month rolling average TP loading is currently 22 lb/yr which requires an annual average concentration of less than 1.20 mg/L at current ADF and less than 0.15 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.2.18, the Peru/Valcour WWTF has reported effluent phosphorus concentration greater than currently required since 2000 remaining between 1.78 mg/L and 3.65 mg/L and averaging 2.66 mg/L over the period 2000 to 2011. Improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Peru/Valcour WWTF in this evaluation.

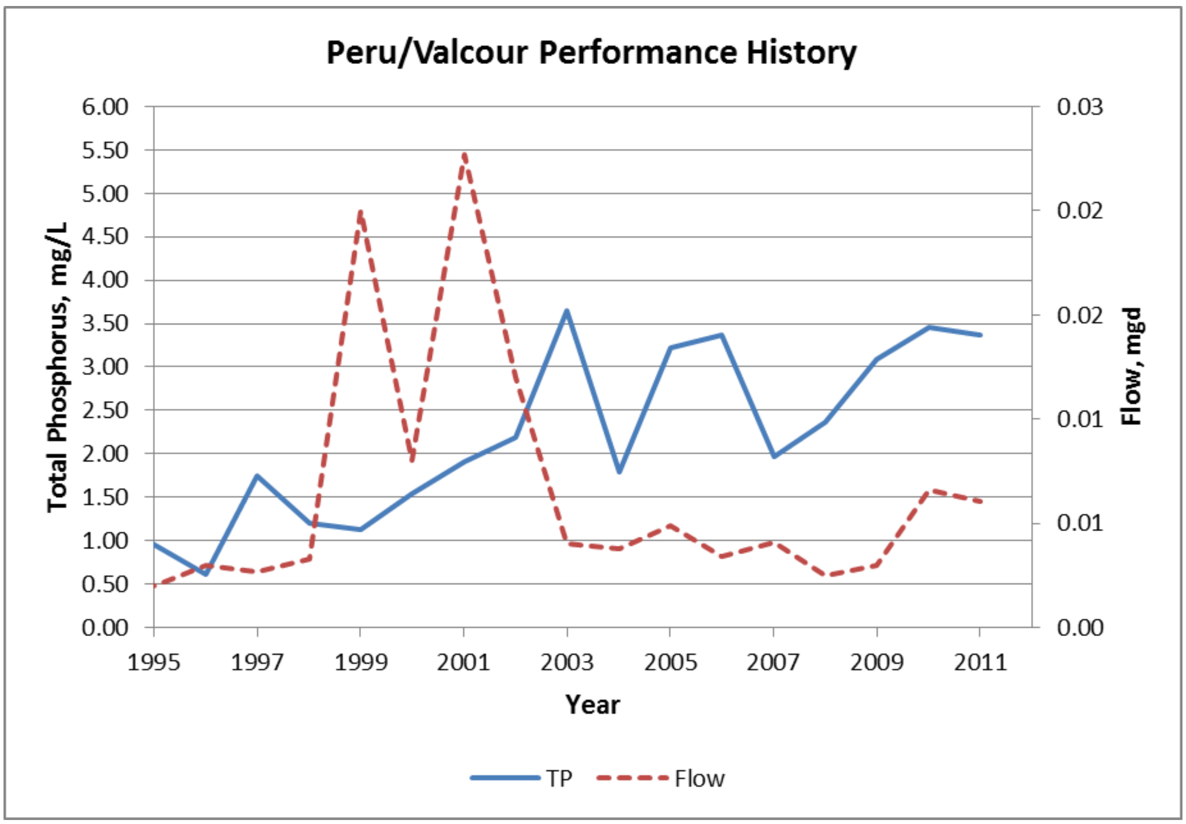


Figure 2.2.18 Peru/Valcour WWTF Performance

2.2.19 Plattsburgh

<u>Facility Description</u>

The Plattsburgh WWTF is a conventional activated sludge plant with a chemical feed system and is designed to treat up to 16 MGD ADF. The 2011 ADF was 6.21 MGD. The effluent phosphorus concentration is sampled twice weekly. Thickened sludge is stabilized with lime, as well as other chemicals, and land applied. The allowable 12 month rolling average TP loading is currently 23920 lb/yr which requires an annual average concentration of less than 1.27 mg/L at current ADF and less than 0.49 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.2.19, the Plattsburgh WWTF has reported moderately low effluent phosphorus concentration since at least 1995 remaining between 0.59 mg/L and 1.3 mg/L and averaging 1.15 mg/L over the period 2003 to 2011. This degree of phosphorus removal produces an effluent within the current limits annual loading but will not comply at design flow. Improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Plattsburgh WWTF in this evaluation.

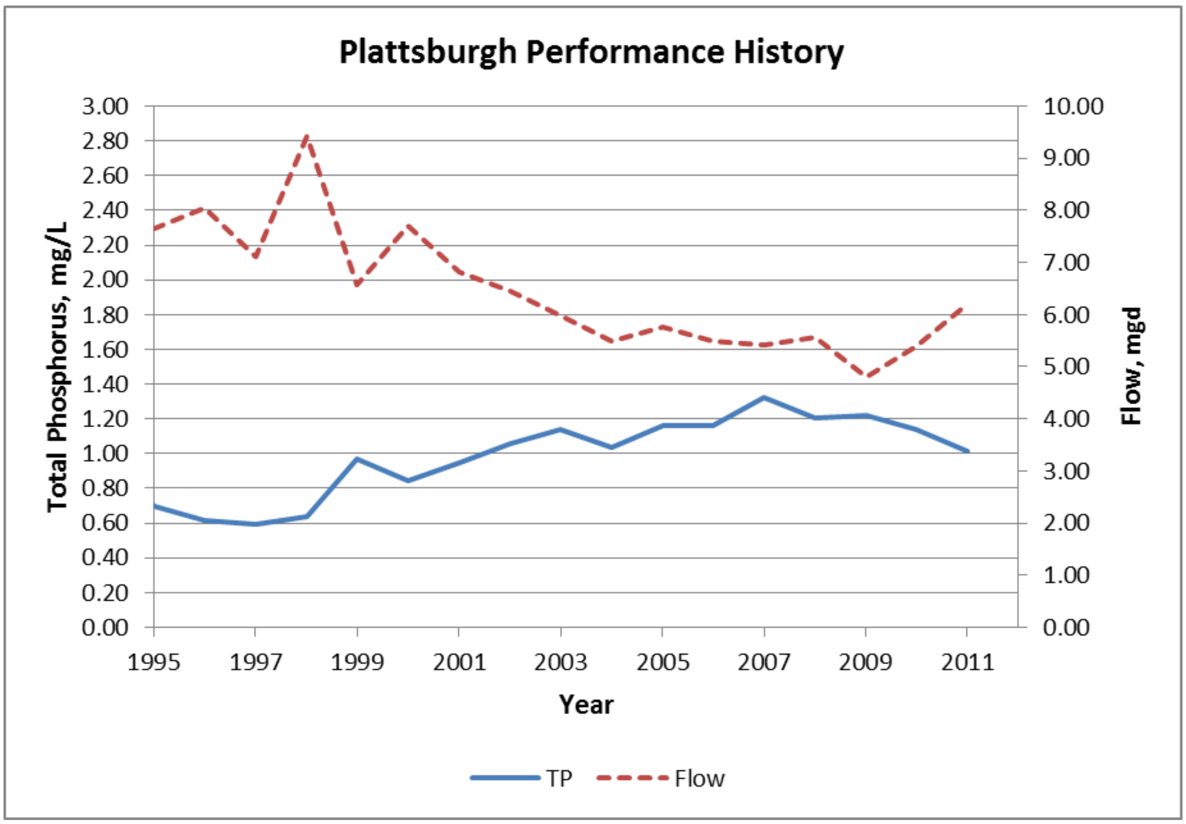


Figure 2.2.19 Plattsburgh WWTF Performance

2.2.20 Port Henry

Facility Description

The Port Henry WWTF is a trickling filter plant with a chemical feed system and is designed to treat up to 0.60 MGD ADF. The 2011 ADF of 0.625 MGD exceeded design. The sludge is anaerobically digested in Imhoff tanks and dewatered on sand filter beds. The effluent phosphorus concentration is sampled twice per month. The allowable 12 month rolling average TP loading is currently 1080 lb/yr which requires an annual average concentration of less than 0.57 mg/L at current ADF and less than 0.59 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.20, the Port Henry WWTF has reported declining effluent phosphorus concentration since 2004. Effluent TP remained between 0.473 mg/L and 0.615 mg/L and averaging 0.549 mg/L over the period 2009 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Port Henry WWTF in this evaluation.

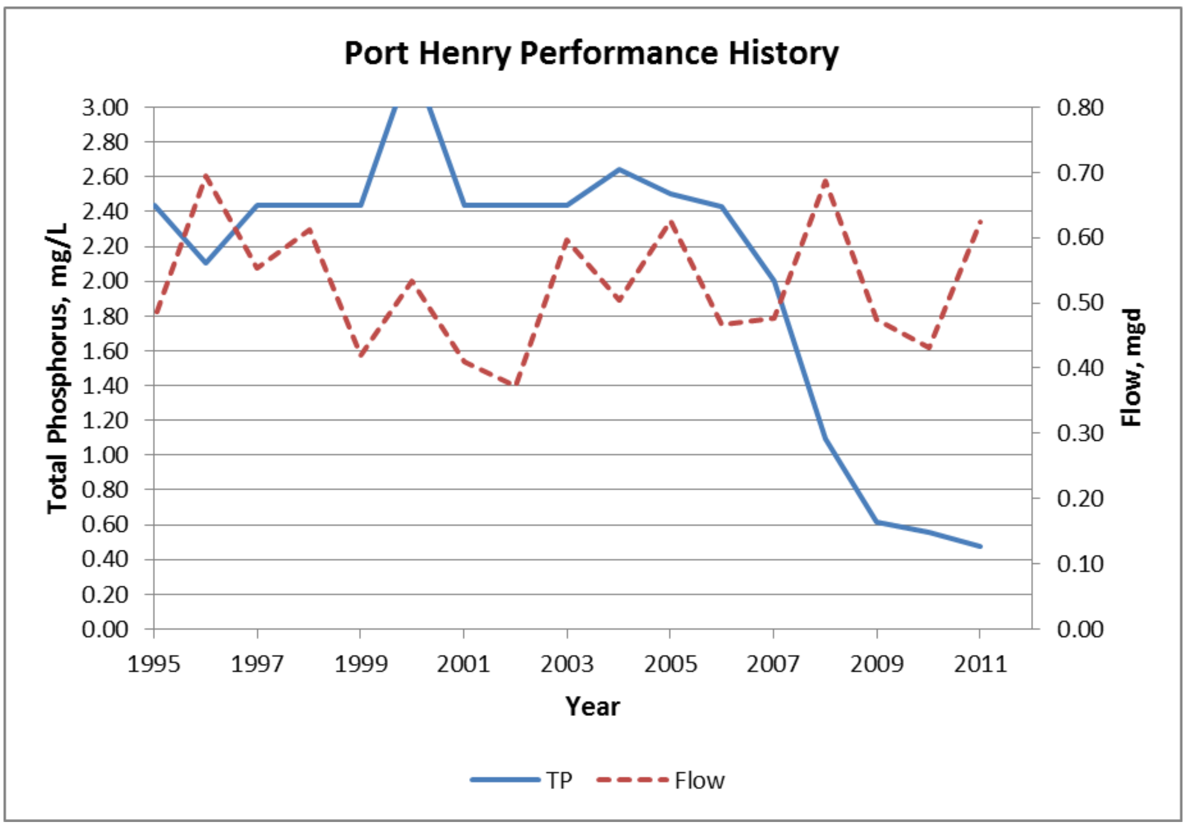


Figure 2.2.20 Port Henry WWTF Performance

2.2.21 Rouses Point

Facility Description

The Rouses Point WWTF is an oxidation ditch type activated sludge plant designed to treat up to 2.0 MGD ADF. The 2011 ADF was 0.99 MGD. Sludge is dewatered by belt filter press and composted on-site. The effluent phosphorus concentration is sampled weekly. The allowable 12 month rolling average TP loading is currently 5754 lb/yr which requires an annual average concentration of less than 1.91 mg/L at current ADF and less than 0.95 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.21 the Rouses Point WWTF has reported declining effluent phosphorus concentration since 2007. Averaging 0.9713 mg/L over the period 2009 to 2011 and 0.735 for 2001 alone. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Rouses Point WWTF in this evaluation.

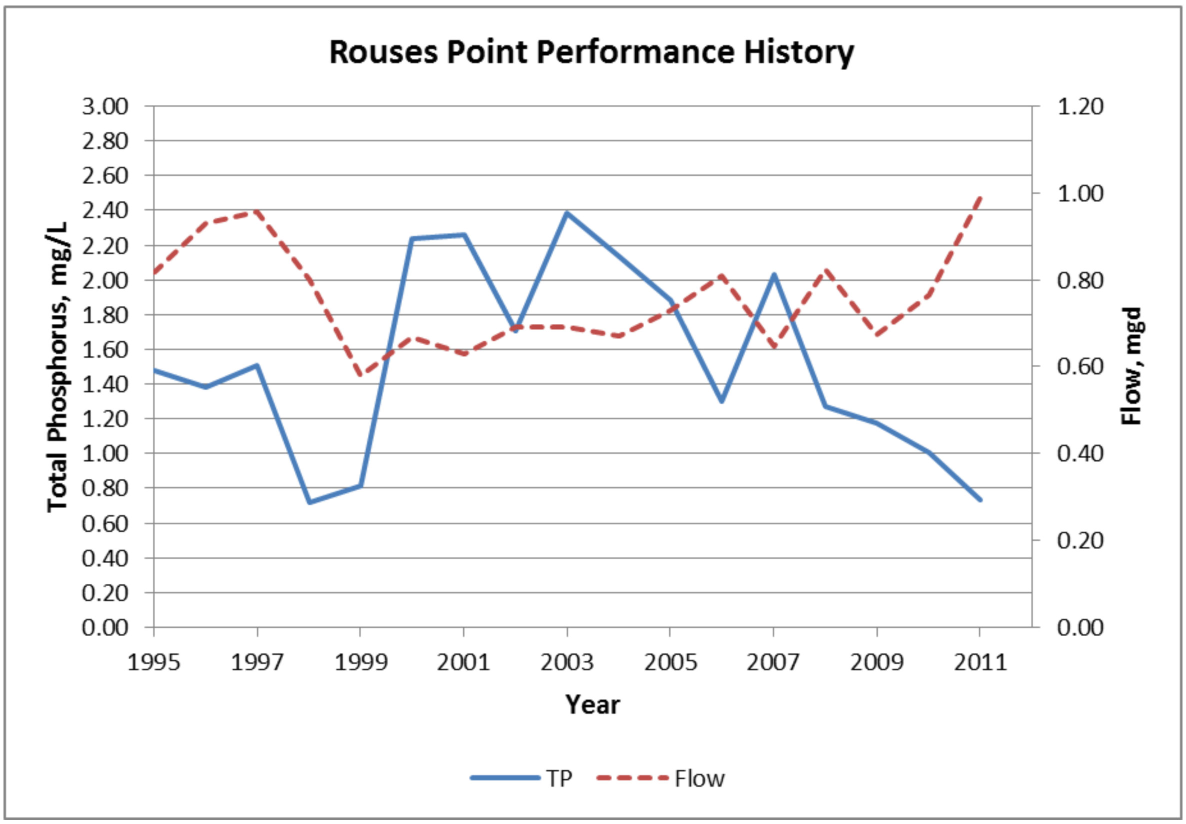


Figure 2.2.21 Rouses Point WWTF Performance

2.2.22 Saranac Lake

Facility Description

The Saranac Lake WWTF is an activated sludge plant with chemical feed facilities and is designed to treat up to 2.62 MGD ADF. The 2011 ADF was 2.083 MGD. Sludge is anaerobically digested, thickened on a belt filter press and then dewatered on sand drying beds before being transported off-site for disposal. The effluent phosphorus concentration is sampled weekly. The allowable 12 month rolling average TP loading is currently 4938 lb/yr which requires an annual average concentration of less than 0.78 mg/L at current ADF and less than 0.62 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.22, the Saranac Lake WWTF has reported declining effluent phosphorus concentration since 2002 remaining between 0.351 mg/L and 0.483mg/L and averaging 0.405 mg/L over the period 2008 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Saranac Lake WWTF in this evaluation.

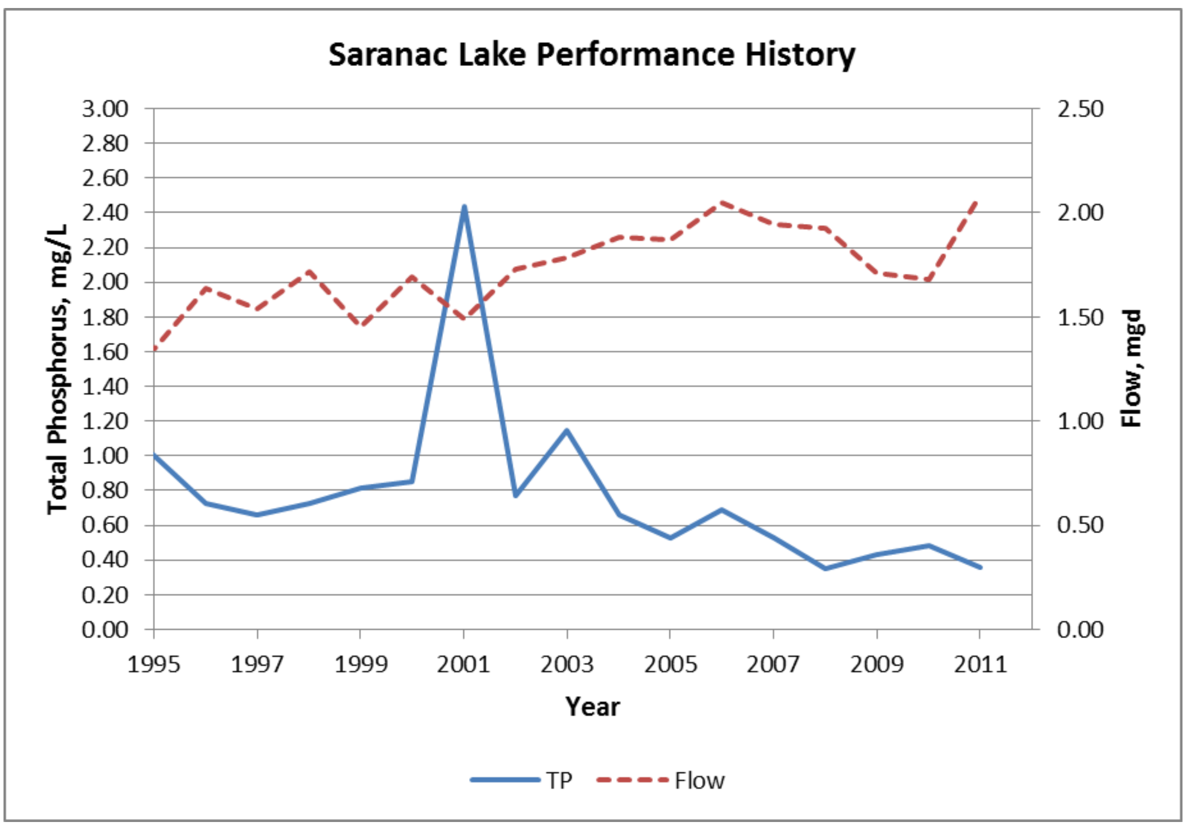


Figure 2.2.22 Saranac Lake WWTF Performance

2.2.23 St Armand

Facility Description

The St Armand WWTF is a facultative/aerated lagoon system designed to treat up to 0.06 MGD ADF. The 2011 ADF was 0.038 MGD. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 617 lb/yr which requires an annual average concentration of less than 5.29 mg/L at current ADF and less than 3.38 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.23, the St Armand WWTF has reported effluent phosphorus concentration since at least 1995 remaining between 3.58 mg/L and 5.25 mg/L and averaging 4.426 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading but will need t obe reduced as flow increases. Improvements to attain the 1.0 mg/L effluent phosphorus goal remain to be considered for the St Armand WWTF in this evaluation.

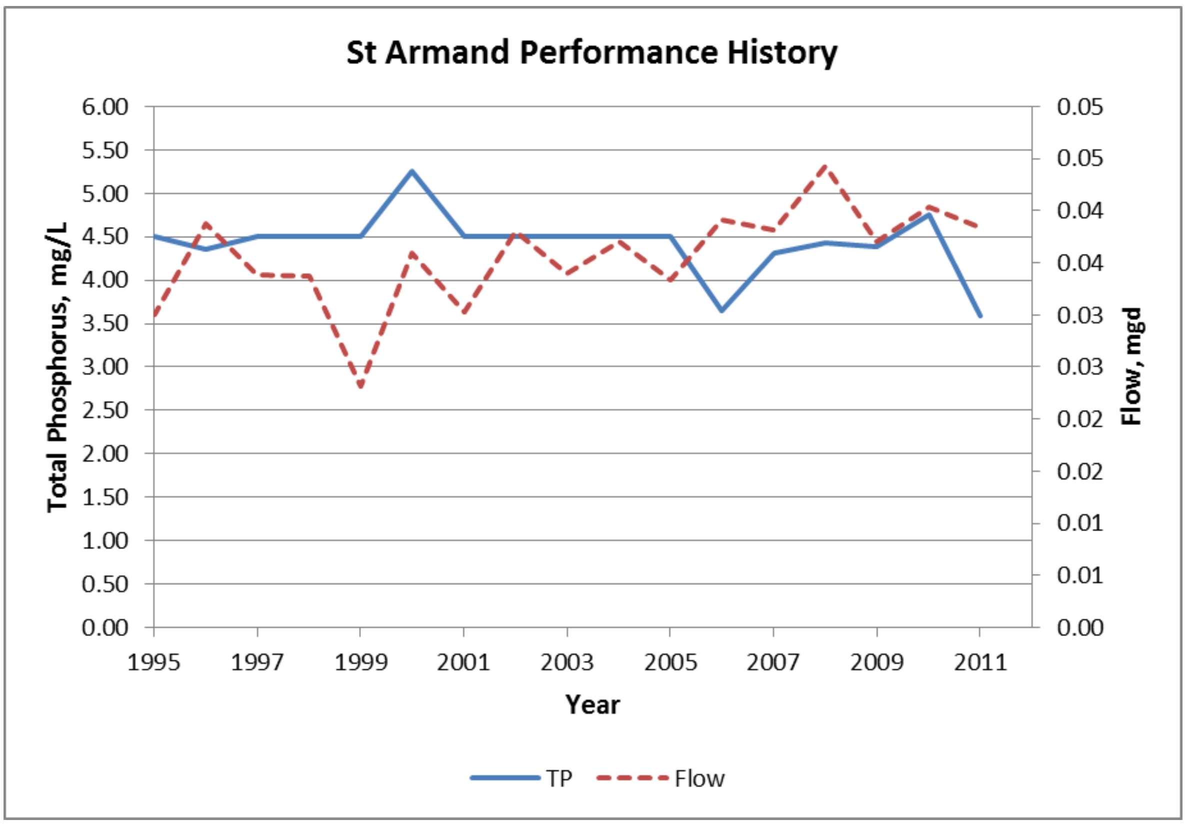


Figure 2.2.23 St Armand WWTF Performance

2.2.24 Ticonderoga

Facility Description

The Ticonderoga WWTF is an extended aeration activated sludge plant on a constricted site and operates combined sewer overflow under some wet weather conditions. It is designed to treat up to 1.7 MGD ADF. The 2011 ADF was 1.51 MGD. The effluent phosphorus concentration is sampled weekly. Lime-stabilized sludge is thickened and land applied. The allowable 12 month rolling average TP loading is currently 3241 lb/yr which requires an annual average concentration of less than 0.70 mg/L at current ADF and less than 0.63 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.24, the Ticonderoga WWTF has reported moderately low effluent phosphorus concentration since 2009 remaining between 0.490 mg/L and 0.798 mg/L and averaging 0.52 mg/L over the period 2010 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Ticonderoga WWTF in this evaluation.

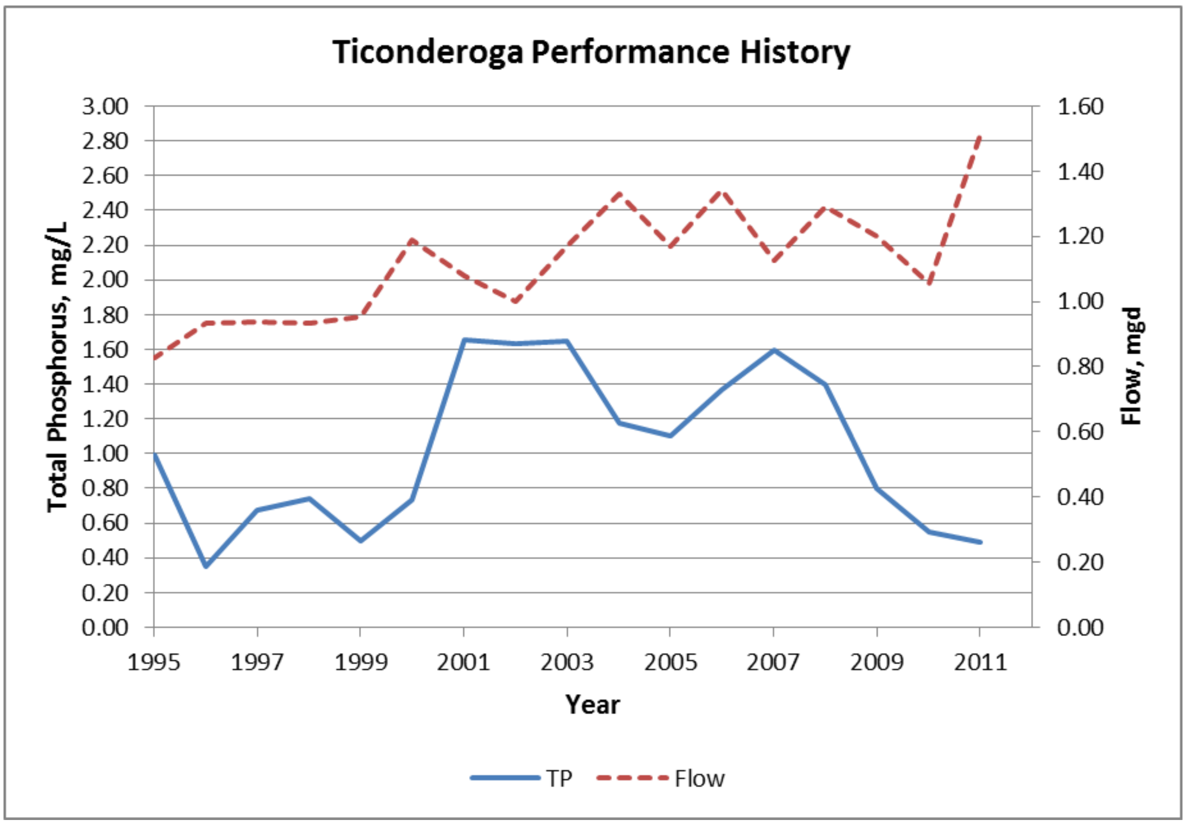


Figure 2.2.24 Ticonderoga WWTF Performance

2.2.25 Wadhams

Facility Description

The Wadhams WWTF is a sand filtration facility designed to treat up to 0.015 MGD ADF. The 2011 ADF was 0.005 MGD. The effluent phosphorus concentration is sampled quarterly. Sludge from the sand filters is sent to another plant for disposal. The allowable 12 month rolling average TP loading is currently 88 lb/yr which requires an annual average concentration of less than 5.52 mg/L at current ADF and less than 1.93 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.25 the Wadhams WWTF has reported effluent phosphorus concentration since at least 1995 remaining between 2.57 mg/L and 4.1 mg/L and averaging 3.66 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading but will not comply at increased flow. Improvements to attain the 1.0 mg/L effluent phosphorus goals remain to be considered for the Wadhams WWTF in this evaluation.

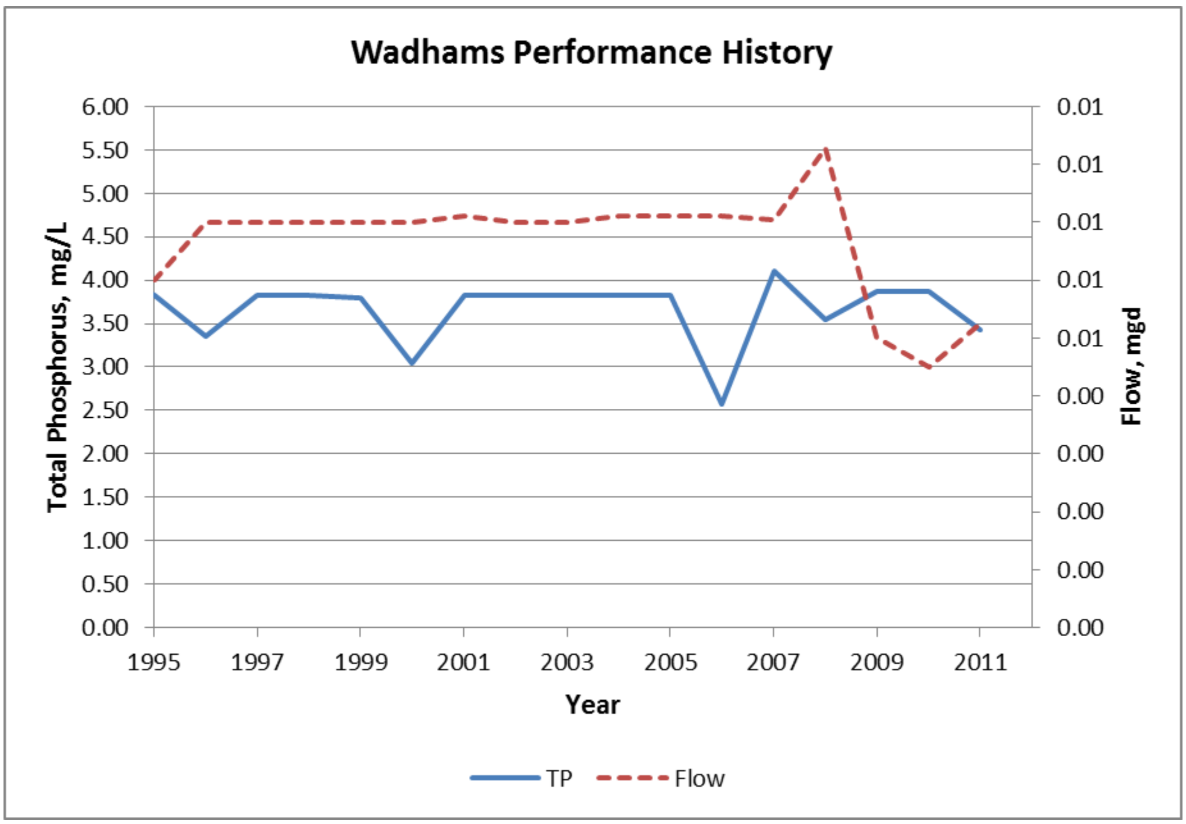


Figure 2.2.25 Wadhams WWTF Performance

2.2.26 Washington Correctional

Facility Description

The Washington Correctional WWTF is designed to treat up to 0.25 MGD ADF. The 2011 ADF was 0.107 MGD. The effluent phosphorus concentration is sampled monthly. The allowable 12 month rolling average TP loading is currently 265 lb/yr which requires an annual average concentration of less than 0.81 mg/L at current ADF and less than 0.35 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.26 the Washington Correctional WWTF has reported moderately low effluent phosphorus concentration since at least 1996 remaining between 0.15 mg/L and 0.36 mg/L and averaging 0.258 mg/L over the period 1995 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to consistently attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Washington Correctional WWTF in this evaluation.

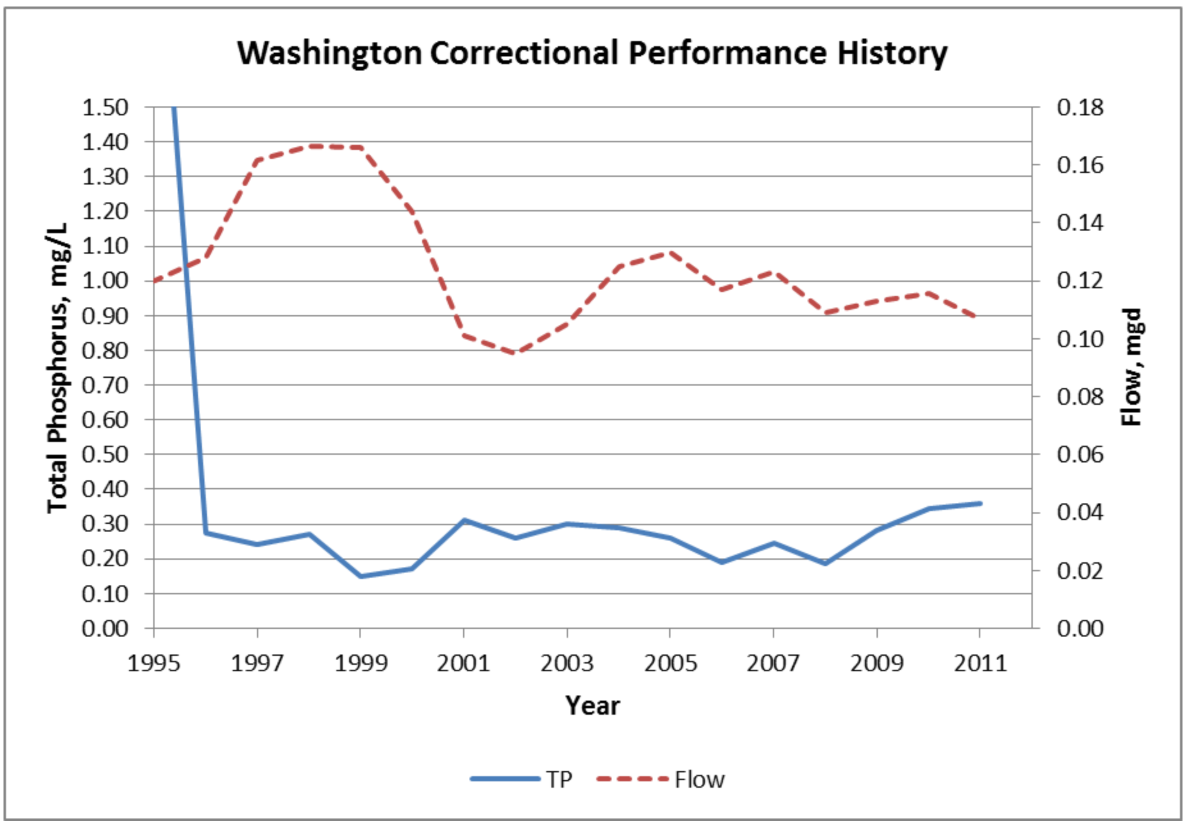


Figure 2.2.26 Washington Correctional WWTF Performance

2.2.27 Westport

Facility Description

The Westport WWTF is an extended aeration activated sludge facility designed to treat up to 0.12 MGD ADF. The 2011 ADF 0.148 MGD exceeded the design flow. The effluent phosphorus concentration is sampled monthly. Aerobically digested sludge is dewatered via reed beds. The allowable 12 month rolling average TP loading is currently 882 lb/yr which requires an annual average concentration of less than 1.96 mg/L at current ADF and less than 2.41 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.27, the Westport WWTF has reported moderately low effluent phosphorus concentration since 2008 remaining between 1.34 mg/L and 1.75 mg/L and averaging 1.497 mg/L over the period 2008 to 2011. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goals remain to be considered for the Westport WWTF in this evaluation.

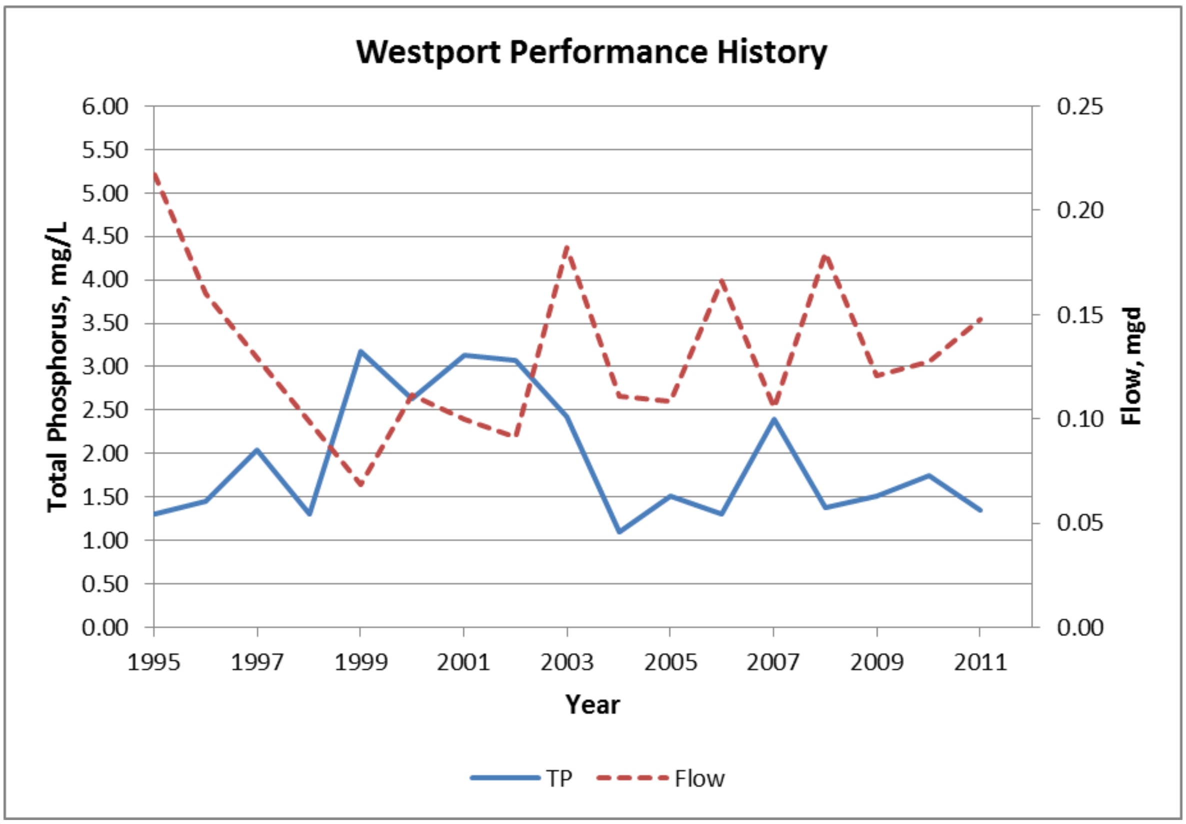


Figure 2.2.27 Westport WWTF Performance

2.2.28 Whitehall

Facility Description

The Whitehall WWTF is an extended aeration activated sludge plant designed to treat up to 0.8 MGD ADF. The 2011 ADF was 0.753 MGD. Sludge is dewatered on sand drying beds and transported to the Town of Easton for disposal and composting. The effluent phosphorus concentration is sampled weekly. The allowable 12 month rolling average TP loading is currently 1323 lb/yr which requires an annual average concentration of less than 0.58 mg/L at current ADF and less than 0.54 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.28, the Whitehall WWTF has reported very low effluent phosphorus concentration since 2009 remaining between 0.281 mg/L and 0.376 mg/L and averaging 0.334 mg/L over the period 2009 to 2011. This degree of phosphorus removal produces an effluent well within the current limits for annual loading. However improvements to attain both the 0.2 mg/L and 0.1 mg/L effluent phosphorus goals remain to be considered for the Whitehall WWTF in this evaluation.

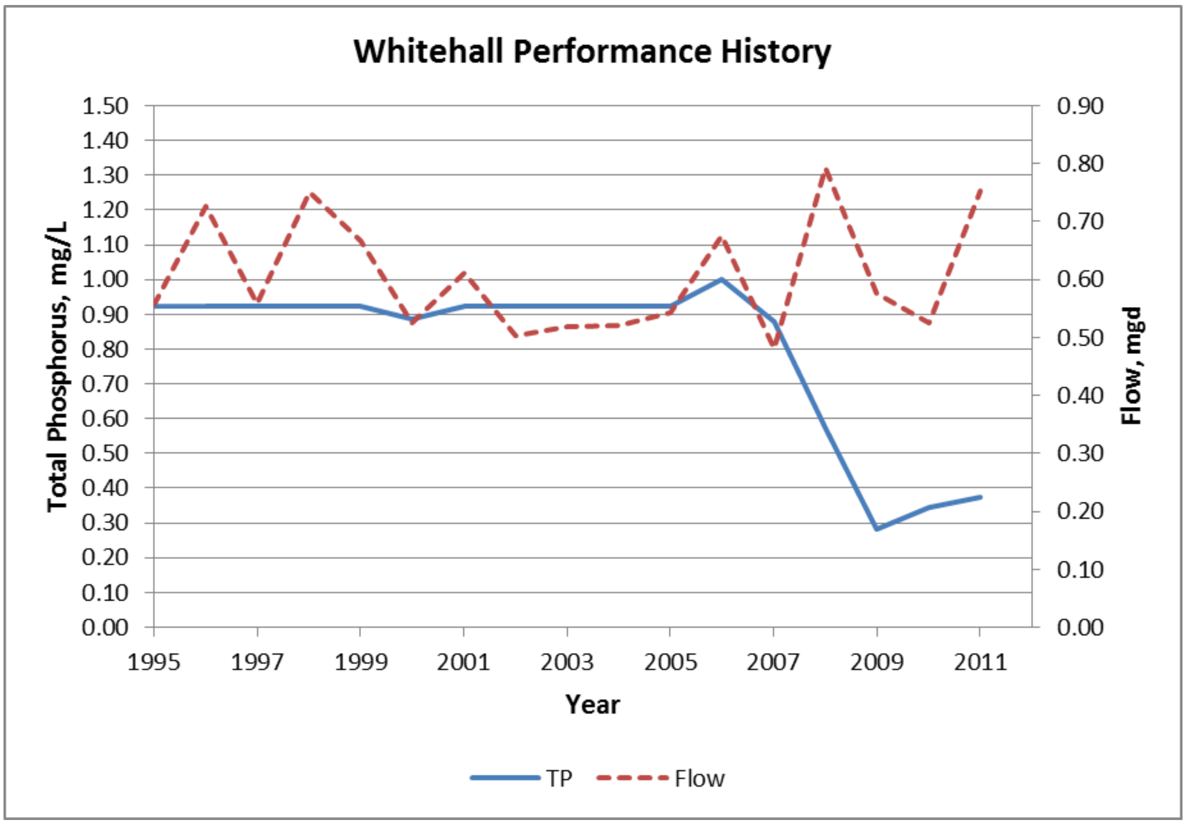


Figure 2.2.28 Whitehall WWTF Performance

2.2.29 Willsboro

<u>Facility Description</u>

The Willsboro WWTF is a rotating biological contactor facility designed to treat up to 0.075 MGD ADF. The 2011 ADF was 0.043 MGD. The effluent phosphorus concentration is sampled monthly. Sludge is aerobically digested and dewatered via drying beds. The allowable 12 month rolling average TP loading is currently 633 lb/yr which requires an annual average concentration of less than 4.89 mg/L at current ADF and less than 2.77 mg/L at the design ADF.

<u>Effluent Phosphorus History</u>

As shown in Figure 2.2.29 the Willsboro WWTF has reported declining effluent phosphorus concentration since at least 1995 attaining 2.772 mg/L and 2.600 mg/L in 2010 and 2011 respectively. This degree of phosphorus removal produces an effluent within the current limits for annual loading. However improvements to attain the 1.0 mg/L effluent phosphorus goals remain to be considered for the Willsboro WWTF in this evaluation.

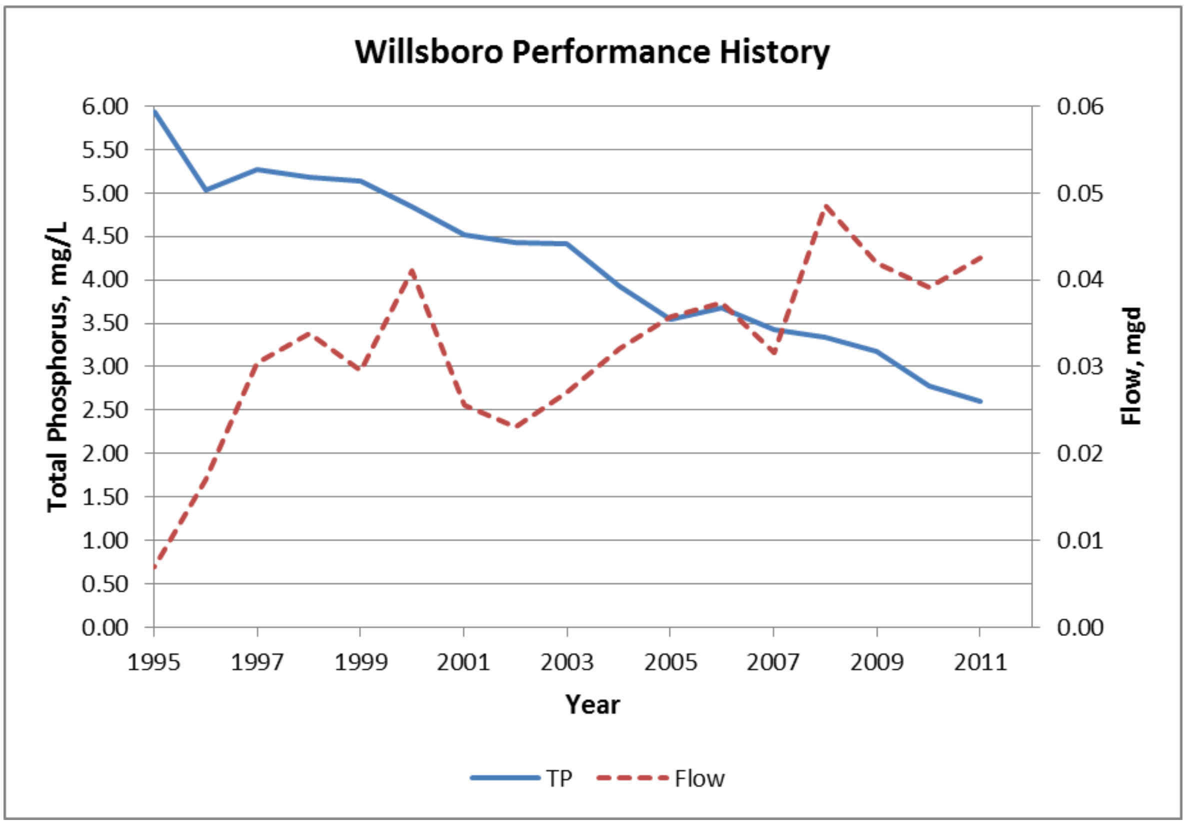


Figure 2.2.29 Willsboro WWTF Performance

2.2.30 Wyeth Research

Facility Description

The Wyeth Research WWTF was designed to treat up to 0.78 MGD ADF. This facility has been closed and reported no flow in 2011. The allowable 12 month rolling average TP loading was currently 154 lb/yr which required an annual average concentration of less than 0.65 mg/L at the design ADF.

Effluent Phosphorus History

As shown in Figure 2.2.30, the Wyeth Research WWTF reported declining effluent phosphorus concentration since 2005 attaining 0.213 mg/L in 2010.remaining 0.677 mg/L and 0.718 mg/L in 2008 and 2009 respectively before closure in 2010.

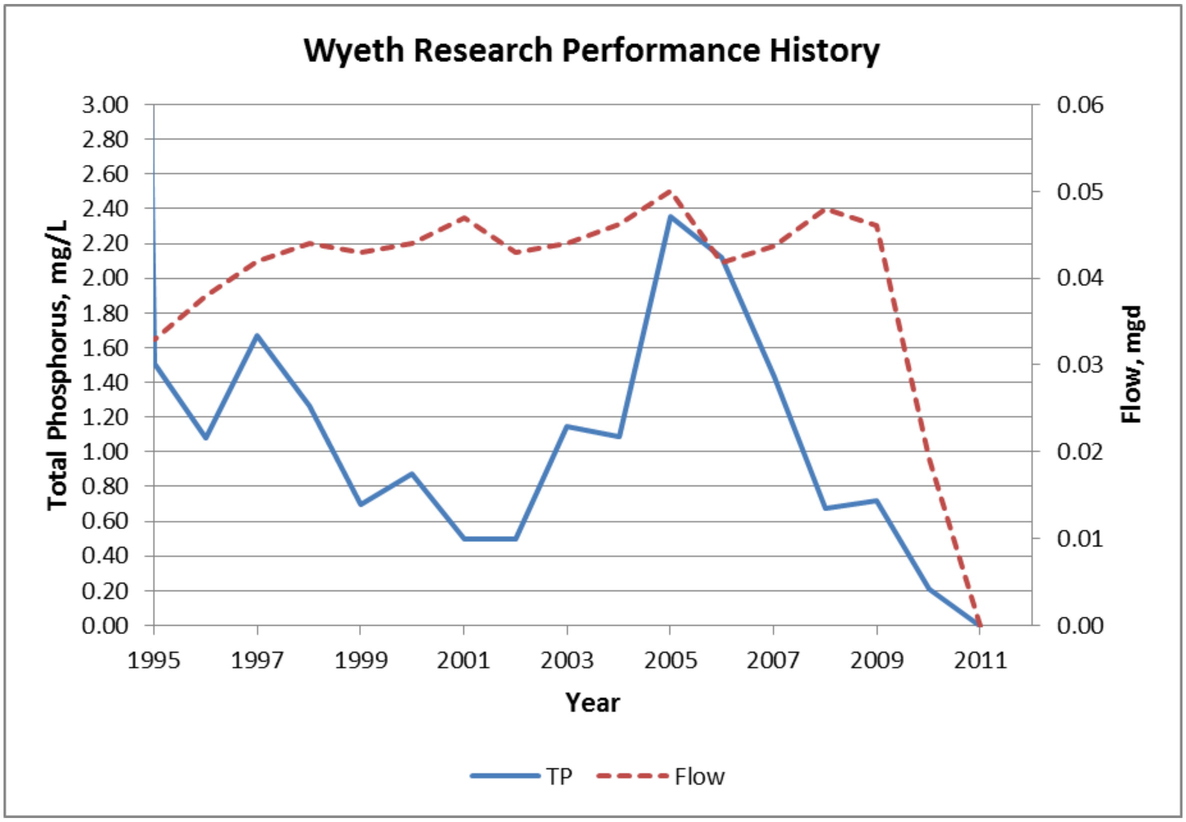


Figure 2.2.30 Wyeth Research WWTF Performance

2.3 WWTFs Phosphorus Discharge Levels to be Assessed

For facilities that are currently producing effluents with phosphorus concentrations greater than 1 mg/L we are to establish representative feasible technologies and costs to achieve 1.0 mg/L TP. Many of the subject facilities are currently configured to achieve effluent phosphorus concentrations of less than 1 mg/L TP. For those facilities we ate to establish representative feasible technologies and costs to comply with new standards that would require effluent phosphorus concentrations of either 0.2 mg/L or 0.1 mg/L TP.

As described above, several of the WWTPs considered in this evaluation are already achieving effluent phosphorus concentrations less than the 0.1 mg/L TP level and need no improvements. For others, improvements will be considered to bring them to compliance with limits of 0.2 and/or 0.1 mg/L TP annual average. Several of the WWTPs under consideration are not currently achieving the 1.0 mg/L effluent TP level and will be evaluated for the needs to achieve it. Because Vermont's Newport Center WWTP is not consistently achieving 1.0 mg/L effluent TP but the current TMDL would require 0.1 mg/L TP at design flow, that facility will be evaluated for needs to achieve each level of phosphorus removal. Similarly, New York's Dannemora WWTP will be evaluated for needs to achieve 1.0 mg P/L but because ti is a large facility, imp[rovements to achieve 0.2 mg/L and 0.1 mg/L effluent phosphorus will also be considered.

Tables 2.3.1 and 2.3.2 summarize the Vermont and New York WWTFs under consideration and the effluent phosphorus levels to be assessed for each. N/A indicates those facilities that are already achieving the effluent phosphorus level goal.

Table 2.3.1 Vermont WWTF Effluent Phosphorus Levels to be Assessed

WWTF	TP Levels to be Assessed, mg/L	WWTF	TP Levels to be Assessed, mg/L
Alburgh	N/A	Otter Valley Union High School	1.0
Barre City	0.1	Pittsford	1.0
Benson	1.0	Pittsford Fish Hatchery	N/A
Brandon	0.1	Plainfield	1.0
Brown Ledge Camp	Closed	Poultney	0.1
Burlington East	0.1/0.2	Proctor	0.2/0.1
Burlington Electric	N/A	Richford	0.2/0.1
Burlington Main	0.1/0.2	Richmond	0.1
Burlington North	0.1/0.2	Rock Tenn	0.2/0.1
Cabot	0.1	Rutland City	0.2/0.1
Castleton	0.1	Salisbury Fish Hatchery	N/A
Enosburg Falls	0.2/0.1	Shelburne #1	0.2/0.1
Essex Junction	0.2/0.1	Shelburne #2	0.2/0.1
Fair Haven	0.20/0.1	Sheldon Springs	1.0
Fairfax	1.0	Shoreham	1.0
Hardwick	0.2/0.1	South Burlington Airport Parkway	0.2/0.1
Hinesburg	0.2/0.1	South Burlington Bartlett Bay	0.2/0.1
IBM	0.2/0.1	St. Albans City	0.2/0.1
Jeffersonville	1.0	Stowe	0.1
Johnson	0.2/0.1	Swanton	0.2/0.1
Marshfield	1.0	Troy/Jay	0.2/0.1
Middlebury	0.2/0.1	Vergennes	0.2/0.1
Milton	0.2/0.1	Wallingford	1.0
Montpelier	0.2/0.1	Waterbury	N/A
Morrisville	0.2/0.1	Weed Fish Culture Station	N/A
Newport Center	1.0/0.2/0.1	West Pawlet	1.0
North Troy	0.2/0.1	West Rutland	0.2/0.1
Northfield	0.2/0.1	Williamstown	1.0
Northwest State Correctional	N/A	Winooski	0.2/0.1
Orwell	1.0	Wyeth (PBM Nutritionals)	N/A

Table 2.3.2 New York WWTF Effluent Phosphorus Levels to be Assessed

WWTF	TP Levels to be Assessed, mg/L	WWTF	TP Levels to be Assessed, mg/L
Adirondack Fish Hatchery	NA	Lake Placid	0.2/0.1
Altona Correctional	0.2/0.1	Peru	0.2/0.1
Au Sable Forks	1.0	Peru/Valcour	0.2/0.1
Cadyville	1.0	Plattsburgh	0.2/0.1
Champlain	0.2/0.1	Port Henry	0.2/0.1
Champlain Park	Closed	Rouses Point	0.2/0.1
Chazy	0.1	Saranac Lake	0.2/0.1
Crown Point	1.0	St Armand	1.0
Dannemora	1.0/0.2/0.1	Ticonderoga	0.2/0.1
Essex	0.2/0.1	Wadhams	1.0
Fort Ann	0.2/0.1	Washington Correctional	0.2/0.1
Granville	0.2/0.1	Westport	1.0
Great Meadows Correctional	0.2/0.1	Whitehall	0.2/0.1
International Paper	0.1	Willsboro	1.0
Keeseville	0.1	Wyeth Research	Closed

3 Chemical Phosphorus Removal

3.1 Process Description and Fundamentals

Total phosphorous is a combination of ortho-, poly-, and organophosphates both in dissolved and precipitated form. Most of the insoluble phosphorous is removed through adsorption and agglomeration with settleable solids at facilities equipped with primary clarifiers. The remaining phosphorous species are consumed at different rates with orthophosphates (e.g. PO_4^{3-}) being the most bioavailable. The more complex poly- and organophosphates are also hydrolyzed into orthophosphates throughout a typical aerobic treatment process. As a result, typical secondary clarifier effluent phosphorous is predominantly present as orthophosphate.

Addition of trivalent iron and aluminum are the two most common methods of removing phosphate through chemical means. Iron is typically dosed as a ferric chloride solution at 38-42% strength (w/w). Aluminum is most commonly added as “alum” or aluminum sulfate ($Al_2(SO_4)_3$-$18H_2O$) in a 45-49% (w/w) solution, but other forms like poly-aluminum chloride ($Al_n(OH)_mCl_{3n-m}$) are also becoming popular for treatment applications. Contrary to popular belief, addition of any of these inorganic metal salts does not directly lead to chemical precipitation of phosphorous as $FePO_4$ or $AlPO_4$ as a result of pure chemical reaction because free ions of iron and aluminum only exist in appreciable quantities far below the typical pH of most wastewaters (approx. 6.5-7.5). Instead, ferric and aluminum salts react upon contact with water to form hydroxide complexes which generally have low solubility and quickly begin to precipitate, forming inorganic flocs. The overall negative charge of ferric or aluminum flocs not only provides coulombic attraction for positively charged orthophosphates, they also serve as a nucleation point for greater floc formation and increased adsorption of complex phosphates and suspended solids.

Although other chemicals like ferric sulfate and pre-polymerized alum species have also been shown to be effective, analyses of dose and phosphorous removal performance are nowhere as numerous or extensive as that for ferric chloride and aluminum sulfate (alum). Additionally, some literature sources indicate that pre-polymerized aluminum may actually be less effective than un-polymerized species at binding and removing phosphorus. The remainder of this report deals with only the two most common and well-documented inorganic salts, ferric chloride and alum. Various formulations of iron and aluminum are capable of reducing phosphorus to acceptable target concentrations so dosage information contained herein should be used only as a general guideline of chemical treatment performance. The wide variation in wastewater composition between different treatment plants makes it difficult to ascertain dosing rate and consequent sludge production from purely empirical data. Whenever possible, bench scale testing should be performed directly on samples of the wastewater treatment stream at the dosing location.

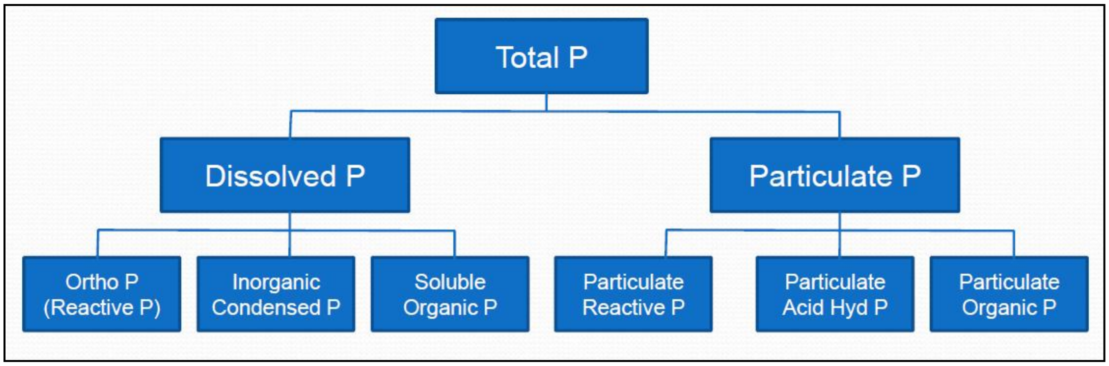


Fig 3.1-1 Fractionation of total phosphorus in wastewater

The regulatory discharge standard of measuring phosphorus as total phosphorus (TP) is simple to measure, even with on-site WWTP laboratory equipment, but it does not address the complexity of phosphorus fractionation in various wastewater streams. Figure 3.1-1 illustrates the breakdown of total phosphorus into its constituent components. As mentioned previously, most wastewater influent phosphorus is present in both dissolved and particulate form. Some of the particulate phosphorus is converted into dissolved species and then utilized by mixed liquor bacteria, which have a clear preference for dissolved constituents. Throughout the treatment process of a conventional activated sludge system, the fractions of dissolved/particulate and reactive/non-reactive species change and therefore, addition of metal salt at different steps in the process will provide different results. To date, most research has focused on chemical precipitation of secondary effluent and subsequent filtration because the presence of particulate solids in any significant amounts tends to increase the variability of the dose response curve.

In the classic sense, chemical treatment is preferential for dissolved phosphorus species. In the presence of colloidal solids, however, dissolved phosphates tend to be less available and phosphorus removal becomes more dependent on general solids removal, rather than specific ferric or alum-to-phosphate interactions. Therefore, addition of an inorganic salt to mixed liquor effluent (or influent) increases hydroxide floc formation, which attracts not only dissolved but also other suspended colloidal particles, some of which may carry particulate phosphorus that is neither chemically or biologically available. Settling in secondary clarifiers does not remove all suspended solids, however, so even if an operator were to dose enough metal salt to remove all dissolved phosphorus species, particulate phosphorus would still remain within the suspended solids, thereby leaving a residual TP. These colloidal particulate forms of phosphorus are generally not reactive and do not undergo degradation at anaerobic conditions, unlike solids formed through the bio-P process.

3.2 Alternative Approaches

Figure 3.2-1 illustrates a typical activated sludge or aerated lagoon system with some common dosing points for chemical phosphorus treatment. Adding chemicals to the head of the activated sludge process or treatment lagoon (point 1) is often the easiest dosing method and insures maximal contact time between the hydroxide flocs formed and any phosphorus species present. There are two main disadvantages to this approach, however. Ferric and alum hydroxides attract other chemical constituents aside from phosphorus and this competitive effect is most present at the start of the mixed liquor basin where concentrations of all constituents are high while dissolved phosphates are relatively low. However, there have also been some reports of ferric addition having a deleterious effect on microbial populations, presumably due to an overly strong binding of dissolved phosphorus, thus making it unavailable for cellular growth. The practical limit of this dosing method in reducing total phosphorus is approximately 1 mg/L, or greater, so it is typically only utilized when a facility has relatively lax discharge standards or when step-wise addition is the objective.

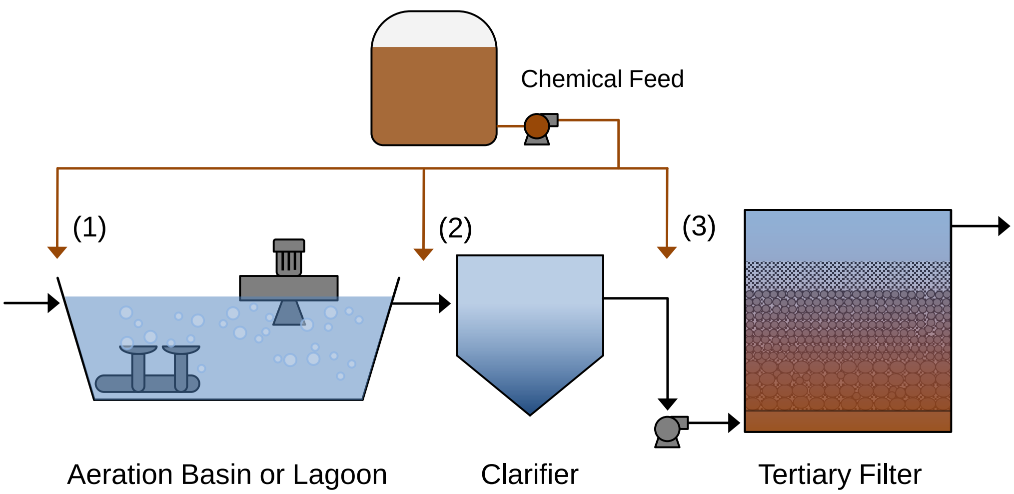


Fig3.2-1– Common dosing points for chemical addition

A much more common dosing point is the effluent channel of the aeration basin, or the influent pipe of the secondary clarifier in a conventional activated sludge plant (point 2). For lagoon systems, this dosing point is located at the head of a final unaerated zone or at the start of a final settling pond. SBR systems can be dosed anywhere between the start and finish of the aeration cycle, as long as mixing time and energy are sufficient. Smaller facilities that need to reach a limit of 1 mg/L TP or slightly lower may opt to use this dosing method if bench scale testing of their mixed liquor indicates that this can be accomplished with a reasonable chemical dose. Unlike the previous dosing point, the overall mixing time here is reduced significantly which enables operators to see a more rapid system response to dosing changes. Mixing energy and total mixing time are both important components of successful coprecipitation and adsorption by chemical addition (Szabo et al. 2008). The phosphorus removal process is believed to be governed by both fast and slow kinetic reactions so maximizing the probability of phosphorus contact with hydroxide flocs should be a primary design criterion at any dosing point.

Wastewater microbes will always absorb some dissolved phosphorus for cellular growth during aerobic respiration. Reductions of up to 50% have been observed at conventional WWTPs as a result of this natural process, so dosing at the end of the aerobic treatment zone can lead to significant chemical cost savings at larger facilities that currently dose at the influent stream. Lastly, it is important to remember that both the first and the second dosing points still rely on a good settling sludge to make sure that phosphorus-carrying suspended solids are not accidentally discharged over the effluent weir.

One distinct disadvantage of all chemical treatment options is the production of excess sludge. The quantity is primarily affected by chemical dose, but sludge properties and temperature also play a role. For ferric chloride addition, the sludge mass can be estimated as a combination of $Fe_{1.6}(H_2PO_4)(OH)_{3.8}$ and $Fe(OH)_3$. The former is stoichiometric sludge equivalent and the latter is the excess hydroxide floc formed as a result of dosing above the stoichiometric value. The respective sludge species for alum are $Al_{0.8}(H_2PO_4)(OH)_{1.4}$ and $Al(OH)_3$. These chemical formulas are more representative of phosphate speciation at typical wastewater pH and clearly show that phosphorus removal is not governed by a simple stoichiometric unity like for $FePO_4$ or $AlPO_4$, as was previously thought. Molar ratio dose response curves for this reaction are logarithmic in nature, especially when the target residual TP concentration is less than 1 mg/L. Therefore, the required dose often exceeds the apparent stoichiometry of the phosphoric acid complexes and hydroxides shown above and is best estimated from laboratory testing.

When chemical sludge is not segregated from biological solids streams (dosing points 1 and 2), it can have a noticeable effect on plant operation. If the chemical sludge is mixed with the recycled biomass (as in a conventional activated sludge process or lagoon), the nonvolatile portion of the mixed liquor solids will increase and the plant will need to operate at a higher MLSS concentration in order to maintain the same quantity of biomass under aeration or risk decreasing its solids retention time. The degree to which MLSS, MCRT, and wasting rate are affected by these chemical solids is difficult to approximate due to the sheer variety of operational parameters at each individual facility. When normalized for BOD load and cell growth yield, however, the principal factor in determining the ratio of chemical sludge versus biological sludge production is the amount of phosphorus that needs to be removed from the system. For example: for a conventional activated sludge plant that has an SRT or MCRT of 12 days (yield or Y_{OBS} of 0.83 lbs/lb BOD), influent BOD of 190 mg/L, and a flow rate of 0.5 MGD, the amount of solids that need to be wasted per day to maintain this sludge age becomes:

$$BOD \times Q \times Y_{OBS} = (190)(0.5)(0.83) \times 8.34 = 658 \text{ lbs/day}$$

If the effluent TP was 1.0 mg/L while the target concentration was 0.1 mg/L, approximately 54 lbs/day of additional ferric sludge would be generated due to the additional chemical treatment and would need to be wasted from the system. An increase of the target concentration to 0.2 mg/L would yield 45 lbs/day additional sludge. This constitutes an 8.2 and 6.8% respective increase in overall sludge production. Assuming the same influent BOD concentration and SRT for all Lake Champlain wastewater facilities of interest, plants that currently achieve an effluent TP of about 1.0 mg/L would experience a 10% increase in sludge production.

Lagoon systems do not really operate on the same SRT principle as conventional WWTPs do but the amount of sludge produced can be approximated by using the above equation with a yield ratio of around 0.4 lbs organic matter/lb BOD. It should come as no surprise that lagoon systems not only generate less cells and cell debris, but also that chemical addition would have much more pronounced effect on their overall sludge production. A lagoon with the same influent characteristics as the previous example would require the same amount of chemical to be dosed but the resulting sludge would constitute a 13-17% increase in sludge production.

Excess sludge can pose two main challenges for any wastewater treatment facility. First, it constitutes an increased operational expenditure in the form of additional solids disposal. The financial burden of inert or biological solids disposal varies considerably between facilities and is beyond the scope of this report. A simple estimate of the financial effect of additional sludge disposal will be included in Section 6. The second issue, and one that affects plant operations and capacity, is the increase in solids loading rate (SLR) of the clarifier or settling pond/basin. SLR is a key determining factor in clarifier design and if it is reached or surpassed, poor settling performance will frequently result. Beyond a certain point, an increase in recycled chemical sludge concentration will eventually require additional settling equipment for the facility.

Dosing point 3 still remains the most efficient single location for chemical phosphorus treatment. With nearly all suspended solids removed from the process stream, the amount of competing reactions with hydroxide flocs is greatly reduced and co-precipitation of dissolved phosphorus species becomes the primary removal mechanism. The absence of competing reactions allows this method to achieve the lowest total phosphorus limits relative to any other dosing point. A majority of the research conducted on dose response and phosphorus removal has been focused on chemical addition to either real or simulated secondary effluent. In most studies, the precipitated solids were filtered out to determine the final residual phosphorus concentration. This illustrates a key limitation of any chemical treatment technology; progressively lower concentrations of phosphorus are directly proportional to the settleability of the co-precipitant flocs they create. At some point, the phosphorus-rich flocs become so small and dispersed that they reach the limits of the utilized separation technology, thereby creating a small residual total phosphorus concentration.

The dosing rate or molar dosing ratio can be increased to counteract this effect but only until the point of diminishing return. Very high molar ratios have been used to reach 0.1 mg/L TP but in most cases, this may not be a cost-effective solution. The only other alternative is to increase the separation process through the use of a filter. Many kinds of filtration systems can be employed with good to excellent results. Conventional sand or dual-media filters have been used successfully in the past but new technologies such as upflow beds filters and microfiltration skids have been gaining in popularity. Currently available technology alternatives for filtration and settling are discussed further in Section 5.

The trade-off between dosing rate and filtration efficiency can only be estimated at best because treatment requirements, process limitations, funding, and other factors all play into this decision. Our general recommendation, based on literature review and previous experience, is as follows:

1.0 mg/L – Can be reached through addition to MLSS effluent or influent
0.5 mg/L – Can be reached through secondary effluent treatment and tertiary settling or through high dosing of the MLSS effluent, in some situations
0.2 mg/L – Can be attained by tertiary chemical addition and enhanced solids removal such as filtration or ballasted clarification.
0.1 mg/L – Some type of filtration technology is recommended here for year-round compliance
<100 μg/L – Advanced filtration technologies recommended for continuous compliance; a filter of some kind is required to reach these concentrations

There is some evidence to suggest that multi-point dosing may be the most efficient method of chemical addition to remove phosphorus. This is especially true for plants that currently use inorganic salts for phosphorus treatment but do not yet have a phosphorus limit that cannot be met through settling alone. In these cases, dosing at both the mixed liquor and the secondary effluent (followed by tertiary settling or filtration) may actually reduce the overall quantity of chemical to be added. This method also provides some level of redundancy such that if one of the chemical feed systems goes down, the addition at the second dosing point can temporarily be increased to help meet discharge criteria.

An alternate multi-point dosing approach is to recycle the settled and/or backwashed solids of the tertiary solids separation step back to the end of the aeration zone (dose point 2). This allows the chemical feed at dose point 2 to be augmented by recycled hydroxide flocs which are typically still capable of removing phosphorus, albeit at a lower efficiency. The overall effect becomes similar to a solids contact clarifier where flocs that have not yet reached their reactive or adsorptive capacity are reintroduced to fresh, incoming substrates in hopes of maximizing overall efficiency and minimizing the chemical dose.

Calculations presented in this report focus solely on secondary clarifier effluent chemical addition and filtration because this represents a “best case” scenario where influence from suspended solids and competing reactions is minimized. However, it is recommended that the efficacy of chemical addition to mixed liquor should be investigated at a laboratory bench scale by facilities that want to optimize their chemical dosing plan prior to committing to capital improvement projects.

3.3 Chemical Feed System Sizing and Capital Cost

Estimation of chemical dosing required for phosphorous removal at each facility identified in this study was based on criteria laid out in WEF Manual of Practice No. 34 – Nutrient Removal (Water Environment Federation, 2010). Figures 7.9 and 7.12 of this reference resource (p.252-255) were used to estimate the metal-to-phosphorous molar ratio necessary to reduce total phosphorous to the desired residual level of either 0.2 or 0.1 mg/L. The original authors of this dosage data (Szabo et al., 2008) performed laboratory testing of simulated and actual secondary clarifier effluent, followed by chemical addition (ferric chloride or alum), a small allowance for reaction time, and final filtration through a 0.45 μm filter. Estimated stoichiometric ratios are likely to be higher if the chemical is to be injected into either the inlet or outlet of the mixed liquor zone.

Data for average flow and total effluent phosphorous were available for 1991 and 1995-2011 for all facilities discharging directly or indirectly into Lake Champlain. However, since many of the facilities selected for this study appear to have already implemented some means of phosphorous removal, only data from the last 5 years was analyzed in order to better represent the current state of effluent TP loading at each facility.

Chemical pricing information was gathered through personal communication and email correspondence with several industrial chemical suppliers who currently service the upstate New York and Vermont area. Prices reflect bulk chemical cost as well as whole, repackaged 250-300 gallon totes and 55-gallon drums. There appears to be a wide discrepancy between chemical manufacturer pricing, largely due to delivery costs, shipping quantities, and market price volatility.

Cost tables listed in Section 3.5 are estimates of the average cost of chemical consumption for each WWTF. Capital facilities needed for chemical phosphorus removal may include feeding equipment, transfer lines, secondary containment, electrical connection, SCADA integration, personal protective equipment (PPE), and additional employee training.

Plants that currently use chemical addition for phosphorus treatment will already have some if not all of the equipment required for upgrading to a lower phosphorus discharge standard. The following is a brief and estimated capital improvement pricing guide for plants that seek to install a brand new chemical feed system, or just upgrade components of their old one.

Pumps

A variety of standard dosing pumps can be used for chemical feed of both ferric and alum solutions. The most common types include solenoid-diaphragm, mechanical-diaphragm, and peristaltic. Of the three broad categories, solenoid-driven diaphragm pumps are generally reserved for light and/or intermediate duty as their internal components do not last very long under continuous duty operations, although the same could be said of lower-end peristaltic pumps as well. For reliable, long-term performance, most municipalities and industries prefer to use mechanical-solenoid-type or heavy-duty peristaltic dosing pumps.

Most facilities that discharge to Lake Champlain are rated at 1 MGD hydraulic capacity or less, so chemical feed rates usually can be covered by a dosing pump with a maximum flow rate of only 20-30 gallons per day. Chemical pumps in this range typically start around $1,000 and go all the way up to $3,500 depending on features and component durability. When estimating the size of a pump needed for operation, it is advisable to design around a flow rate span that can include both ferric and alum chemicals, in case market pricing or availability one day makes switching to a different chemical more cost effective. Connecting the feed pump(s) to a flow meter to enable flow-based control via a PID loop is highly recommended for all facilities wherever possible. An estimated cost for this installation and PID loop wiring is about $500 per pump.

Storage

Many of the treatment facilities of interest in this report show evidence of current and ongoing implementation of phosphorus treatment measures. In these cases, and if they employ chemical addition, their current chemical storage vessels may be able to accommodate an increase in their dosing rate, and hence, contained storage volume.

For those facilities that have to, or choose to install new chemical storage tanks, there are five typical classes available. Standard/linear HDPE, Heavy Duty HDPE (thicker wall dimensions), Cross-linked HDPE, Double-walled HDPE, and FRP. Of these five, the latter choice is often more expensive than the rest but can be molded accurately to the client's desired specifications. Due to this "custom" nature of FRP tanks, their pricing information was unavailable for this report. All remaining HDPE tank types are presented in order of increasing durability, safety, and cost. Table 3.3-1 lists approximate pricing for each HDPE category in several common sizes of bulk storage containers.

Table 3.3-1 Estimated Cost of Bulk Chemical Storage Tanks

Volume (gallons)	Sec. Containment Int. and Ext. Volumes (ft^3)		Linear HDPE	Heavy Duty HDPE	Cross-linked HDPE	Double-wall HDPE
1,000	147	76	$700	$1,200	$1,200	$3,000
1,500	221	96	$900	$1,500	$2,100	$4,000
2,000	294	114	$1,300	$1,900	$2,400	$6,000
2,500	368	130	$1,400	$2,100	$3,000	$7,000
3,000	441	145	$1,700	$2,400	$4,000	$8,000
4,000	588	174	$2,600	$4,000	$6,000	$11,000
5,000	735	200	$3,000	$5,500	$8,000	$13,000
10,000	1,471	312	$8,000	$11,000	$16,000	$27,000

Plastic tanks are the most common on-site storage solution, especially if the monthly chemical consumption volume dictates the use of bulk delivery versus totes or drums. Smaller plants may see some benefit from drums and totes, especially in the short term or if chemical dosing is only required on a seasonal basis. Additionally, some chemical suppliers may charge a fee if a bulk delivery is less than the full holding capacity of the delivery truck, negating some of the pricing benefits of buying in bulk. However, bulk delivery cost will typically still be cheaper than either pre-packaged container option over the course of time, after all capital improvement costs associated with storage tank installation are paid off.

Secondary Containment

Secondary containment of plastic tanks is usually best managed with small, shallow concrete basins. For each of the standard tank sizes listed above in Table 3.3-1, the second and third columns show an estimated internal and external volume, respectively, for a secondary containment basin. This estimate is based off the following assumptions:

- Tank height to width ratio of 1:1, cylindrical shape
- 2 feet of clearance on each side of the tank
- Secondary containment internal volume is 110% of the total tank volume
- Uniform concrete thickness of 6”

Secondary containment for totes (250-300 gal) can be done in this fashion as well, typically placing them on an elevated grating for easier removal by forklift. Drums (55 gal) can usually be stacked 4 to a pallet, for forklift transport, and several plastic secondary containment solutions are available for them commercially.

3.4 Operations and Maintenance Costs

Chemicals

Regardless of type, chemicals constitute the bulk of the operational cost of any chemical phosphorus treatment system. Any capital costs associated with system installation will always be eclipsed by routine chemical costs, sometimes in just a short while. Please see Section 3.4 below for a more in depth analysis of chemical cost data.

Increased sludge production

An analysis of solids disposal fees for each facility is not covered in the scope of this report, but instead, the estimates of additional sludge produced for each dosing chemical and target phosphorus concentration have been included.

Power

Power requirements are almost negligible for chemical feed systems, especially when compared to other process equipment like blowers or mixers. Most chemical feed pumps are 120V and do not typically go above 0.25 horsepower in rating. It is estimated that daily operation of one such chemical feed pump at an electrical cost of $0.08 per kWh would equal approximately $0.36 per day, or $131.40 over the course of an entire year. Energy for lighting and heating of building spaces related to chemical storage and feed should also be considered and has been included in the cost estimates developed for each scenario in Section 6.

Labor

Initial training in chemical handling would be needed for those facilities not now using chemical phosphorus removal. Cost should be estimated specific to the facility. On-going operation of chemical phosphorus removal systems is relatively simple and additional labor required should not necessitate additional staffing.

Lab Supplies

There will be some minor costs for additional reagents during increased monitoring when a chemical feed system is first being installed and adjusted. Yet this cost is temporary and relatively insignificant.

Mechanical Equipment Maintenance

Industrial, continuous duty feed equipment needs to be maintained well for proper operation but modern design features like automatic leak detection, hose wear cycle counters, and anti-siphon valves have greatly facilitated operability and the ease with which high-wear components can be replaced. Peristaltic hose tubing is the most routinely replaced component of these systems so extra tubing should always remain on hand. Once the system is adjusted for correct flow rates, however, choosing a good tubing/RPM can greatly prolong the longevity of the tubing before replacement.

3.5 Chemical Costs

Table 3.5-1 lists the general price points used for calculations as well as the physical properties of each chemical dosed. Molar ratios used for chemical dose calculations and sludge production were discussed previously in Section 3.3.

Table 3.5-1 Physical Properties of Phosphorus Removal Chemicals

Parameter	Ferric chloride, $FeCl_3$	Alum, $Al_2(SO_4)^3 \cdot 18H_2O$
Solution strength (w/w)	40%	48.50%
Specific Gravity (at 20°C)	1.415	1.332
Density (lbs/gal)	11.81	11.12
Delivery Type	*Price per gallon solution*	
Drums	$3.00	$2.85
Totes	$2.89	$2.70
Bulk	$2.00	$1.20

Tables 3.5-2 and 3.5-3 summarize the chemical dosing requirements and associated costs, at both 0.2 and 0.1 mg/L TP effluent discharge limits, for all New York and Vermont facilities, respectively.

Costs are segregated by delivery method as denoted by their respective abbreviations:

- B- Bulk
- D – Drums
- T – Totes

For most facilities, more than one method of chemical delivery and storage could be utilized successfully, though capital and operating costs may vary significantly between the options available. The following criteria were used to determine which chemical feed methods were most appropriate:

Drums and totes were only considered at plants where one unit of storage surpasses the estimated peak day chemical dosing rate over a 72-hour period. This is a “long weekend rule” that provides allowance for a lack of facility staffing over a typical weekend or an extended 3-day weekend with careful operator pre-planning. For drums, this equates to a maximum allowable daily flow rate of 15 gallons per day: 45 (gallons per drum) divided by 3 (days of unsupervised operation). Any chemical/target phosphorus limit combination that is believed to require a peak day flow rate in excess of this value is not deemed to be safely operational using a drum container for storage and feed. For totes, which typically contain about 300 gallons of nominal capacity, this dosing rate value is 91.67 gallons per day. Few treatment facilities have chemical consumption needs that surpass this flow rate so totes are a viable storage container option for most plants.

Table 3.5-2 Estimated Chemical Dosing and Cost for New York WWTFs

New York Facilities	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	0.2 mg/L TP limit									0.1 mg/L TP limit								
			Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)							Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)					
Facility Name	*MGD*	*mg/L*	*mg/L* Fe	*mg/L* Al	*D* Fe	*T* Fe	*B* Fe	*D* Al	*T* Al	*B* Al	*mg/L* Fe	*mg/L* Al	*D* Fe	*T* Fe	*B* Fe	*D* Al	*T* Al	*B* Al
Adirondack Fish Hatchery	2.921	0.007																
Altona Correctional	0.069	0.444	0.86	0.41	$12	$12	-	$93	$88	-	1.80	0.96	$57	$55	-	$216	$204	-
Au Sable Forks	0.059	3.955	18.96	9.16	$236	$227	-	-	-	$747	23.63	17.80	-	$623	$432	-	-	$1,454
Cadyville	0.003	2.554	11.88	5.74	$9	$8	-	$64	$61	-	15.04	11.33	$24	$23	-	$127	$120	-
Champlain	0.265	0.473	0.96	0.46	$53	$51	-	-	$381	$169	1.95	1.04	$239	$230	-	-	$855	$380
Champlain Park	0.074	2.592	12.08	5.83	$187	$180	-	-	$1,336	$594	15.28	11.50	-	$502	$348	-	-	$1,173
Chazy	0.037	0.547	1.22	0.59	$10	$9	-	$72	$68	-	2.34	1.25	$40	$39	-	$152	$144	-
Crown Point	0.031	3.719	17.77	8.58	$116	$111	-	-	$825	$367	22.19	16.71	-	$306	$212	-	-	$715
Dannemora	0.877	2.201	10.10	4.88	-	$1,789	$1,240	-	-	$5,892	12.88	9.70	-	-	$3,484	-	-	$11,728
Essex	0.005	3.633	17.33	8.37	$17	$17	-	$130	$124	-	21.66	16.31	$48	$46	-	-	$241	$107
Fort Ann	0.067	1.028	4.18	2.02	$59	$57	-	-	$420	$187	5.69	4.28	$177	$170	-	-	$892	$397
Granville	0.750	0.304	0.37	0.18	$57	$55	-	$432	$410	$182	1.07	0.57	$370	$355	$246	-	$1,321	$587
Great Meadows Correctional	0.365	0.377	0.62	0.30	$48	$46	-	$359	$340	$151	1.45	0.77	$245	$235	-	-	$875	$389
International Paper	15.148	0.153									0.28	0.15	-	$1,863	$1,291	-	-	$3,078
Keeseville	0.359	0.161									0.32	0.17	$53	$51	-	$200	$189	-
Lake Placid	1.114	0.997	2.80	1.35	-	$630	$437	-	-	$2,075	4.69	2.50	-	$2,323	$1,610	-	-	$3,838
Peru	0.238	1.255	5.33	2.57	$266	$255	$177	-	$1,893	$841	7.08	5.33	-	$748	$519	-	-	$1,746
Peru/Valcour	0.004	2.851	13.38	6.47	$12	$12	-	$94	$89	-	16.87	12.70	$35	$33	-	-	$175	-
Plattsburgh	5.480	1.180	4.95	2.39	-	-	$3,793	-	-	$18,021	6.62	4.98	-	-	$11,184	-	-	$37,653
Port Henry	0.539	0.949	2.63	1.27	$298	$286	$198	-	$2,122	$943	4.44	2.37	-	$1,064	$737	-	-	$1,757
Rouses Point	0.780	1.243	5.27	2.54	-	$829	$575	-	-	$2,731	7.01	5.28	-	$2,431	$1,685	-	-	$5,674
Saranac Lake	1.870	0.430	0.81	0.39	$317	$305	$212	-	$2,262	$1,005	1.73	0.92	-	$1,435	$995	-	-	$2,371
St Armand	0.040	4.297	20.68	9.99	$172	$165	-	-	$1,226	$545	25.73	19.38	-	$453	$314	-	-	$1,058
Ticonderoga	1.238	0.965	2.69	1.30	-	$672	$466	-	-	$2,214	4.52	2.41	-	$2,490	$1,726	-	-	$4,114
Wadhams	0.006	3.765	18.00	8.70	$23	$22	-	-	$162	-	22.47	16.92	$63	$60	-	-	$316	$140
Washington Correctional	0.114	0.283	0.29	0.14	$7	$7	-	$53	$50	-	0.96	0.51	$50	$48	-	$190	$180	-
Westport	0.136	1.677	7.46	3.60	$213	$205	-	-	$1,520	$675	9.67	7.28	-	$586	$406	-	-	$1,367
Whitehall	0.625	0.490	1.02	0.49	$134	$129	-	-	$953	$424	2.04	1.09	-	$567	$393	-	$2,107	$937
Willsboro	0.041	3.066	14.47	6.99	$124	$119	-	-	$882	$392	18.18	13.69	-	$330	$228	-	-	$769
Wyeth Research	0.031	0.609	1.44	0.69	$9	$9	-	$71	$68	-	2.66	1.42	$39	$37	-	$146	$138	-

Table 3.5-3 Estimated Chemical Dosing and Cost for Vermont WWTFs

Vermont Facilities	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	0.2 mg/L TP limit									0.1 mg/L TP limit								
			Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)							Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)						
	MGD	*mg/L*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*		*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*	
Agrimark	n/a	n/a									*- facility closed -*									
Alburg	0.082	0.036																		
Barre City	2.879	0.162										0.33	0.17	$434	$417	$289	-	$1,551	$689	
Benson	0.015	2.334	10.77	5.21	$34	$33	-	$117	$110	-		13.70	10.31	$95	$92	-	-	$482	$214	
Brandon	0.422	0.235	0.12	0.06	$11	$10	-	$37	$35	-		0.71	0.38	$138	$132	-	-	$492	$219	
Brown Ledge Camp	0.001	2.490	11.56	5.59	$4	$3	-	$12	$11	-		14.65	11.04	$10	$9	-	$53	$50	-	
Burlington East	0.614	0.392	0.68	0.33	$87	$84	-	$298	$282	$125		1.53	0.81	$434	$417	$289	-	$1,551	$689	
Burlington Electric	0.139	0.024																		
Burlington Main	4.451	0.445	0.86	0.42	-	$774	$537	-	$2,608	$1,159		1.80	0.96	-	$3,572	$2,476	-	-	$5,902	
Burlington North	1.213	0.363	0.57	0.28	$146	$140	-	$499	$473	$210		1.38	0.73	-	$743	$515	-	$2,760	$1,227	
Cabot	0.026	0.223	0.08	0.04	$0	$0	-	$1	$1	-		0.64	0.34	$8	$7	-	$29	$27	-	
Castleton	0.366	0.201	0.00	0.00	$0	$0	-	$1	$0	-		0.53	0.28	$89	$86	-	$336	$318	$141	
Enosburg Falls	0.275	0.251	0.18	0.09	$10	$10	-	$35	$33	-		0.79	0.42	$100	$97	-	-	$359	$159	
Essex Junction	1.969	0.512	1.10	0.53	$453	$436	$302	-	$1,468	$652		2.15	1.15	-	$1,886	$1,307	-	-	$3,115	
Fair Haven	0.212	0.334	0.47	0.23	$21	$20	-	$72	$68	-		1.22	0.65	$120	$116	-	-	$429	$191	
Fairfax	0.035	4.633	22.38	10.81	$166	$159	-	-	$537	$239		27.79	20.93	-	$436	$302	-	-	$1,018	
Hardwick	0.214	0.934	2.58	1.25	$116	$112	-	-	$376	$167		4.36	2.32	-	$415	$288	-	$1,544	$686	
Hinesburg	0.158	0.319	0.42	0.20	$14	$13	-	$47	$45	-		1.15	0.61	$84	$80	-	$315	$299	$133	
IBM	2.999	0.205	0.02	0.01	$12	$11	-	$39	$37	-		0.55	0.29	-	$734	$509	-	$2,729	$1,213	
Jeffersonville	0.036	6.850	33.57	16.22	-	$246	$170	-	$828	$368		41.38	31.17	-	$667	$463	-	-	$1,558	
Johnson	0.186	0.347	0.52	0.25	$20	$19	-	$69	$65	-		1.29	0.69	$111	$107	-	-	$397	$176	
Marshfield	0.020	4.009	19.23	9.29	$82	$79	-	-	$266	$118		23.97	18.05	-	$217	-	-	$1,139	$506	
Middlebury	1.035	0.320	0.42	0.20	$92	$88	-	$314	$298	$132		1.15	0.61	-	$530	$368	-	$1,972	$876	
Milton	0.231	0.582	1.34	0.65	$65	$63	-	$223	$211	-		2.52	1.34	$270	$259	$180	-	$965	$429	
Montpelier	1.972	0.387	0.66	0.32	$272	$262	$182	-	$882	$392		1.50	0.80	-	$1,317	$913	-	-	$2,175	
Morrisville	0.308	0.379	0.63	0.30	$41	$39	-	$139	$132	-		1.46	0.78	$208	$200	-	-	$742	$330	
Newport Center	0.021	0.928	2.56	1.24	$11	$11	-	$38	$36	-		4.33	2.31	$42	$40	-	$158	$150	-	
North Troy	0.078	1.192	5.01	2.42	$82	$79	-	-	$266	$118		6.70	5.04	$242	$232	-	-	$1,220	$542	
Northfield	0.565	0.424	0.79	0.38	$93	$90	-	$319	$302	$134		1.69	0.90	$443	$426	$295	-	$1,582	$703	
Northwest State Correctional	0.023	0.148										0.25	0.13	$3	$3	-	$10	$9	-	

Table 3.5-3 Estimated Chemical Dosing and Cost for Vermont WWTFs (continued)

Vermont Facilities (Continued)	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	**0.2** mg/L TP limit								**0.1** mg/L TP limit							
			Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)						Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)					
	MGD	*mg/L*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*
Orwell	0.021	2.703	12.63	6.10	$57	$54	-	$194	$183	-	15.96	12.02	$158	$152	-	-	$796	$354
Otter Valley Union High School	0.002	6.095	29.76	14.38	$11	$11	-	$38	$36	-	36.75	27.68	$30	$29	-	-	$152	-
Pittsford	0.066	2.019	9.18	4.44	$127	$123	-	-	$413	$183	11.77	8.86	-	$346	$240	-	-	$807
Pittsford Fish Hatchery	1.745	0.081																
Plainfield	0.059	2.550	11.87	5.73	$148	$142	-	-	$479	$213	15.02	11.31	-	$397	$275	-	-	$926
Poultney	0.265	0.133									0.17	0.09	$21	$20	-	$79	$75	-
Proctor	0.258	1.363	5.87	2.84	$318	$306	$212	-	$1,029	$458	7.74	5.83	-	$888	$616	-	-	$2,072
Richford	0.246	0.393	0.68	0.33	$35	$34	-	$120	$114	-	1.53	0.82	$174	$168	-	-	$624	$277
Richmond	0.075	0.146									0.24	0.13	$8	$8	-	$32	$30	-
Rock Tenn	0.231	0.481	0.99	0.48	$48	$46	-	$164	$155	-	1.99	1.06	$213	$205	-	-	$761	$338
Rutland City	5.313	0.272	0.25	0.12	$281	$270	$187	-	$910	$405	0.90	0.48	-	$2,121	$1,471	-	-	$3,505
Salisbury Fish Hatchery	0.908	0.060																
Shelburne #1	0.307	0.270	0.24	0.12	$16	$15	-	$54	$51	-	0.89	0.47	$126	$121	-	-	$450	$200
Shelburne #2	0.389	0.325	0.44	0.21	$36	$35	-	$123	$116	-	1.18	0.63	$212	$204	-	-	$758	$337
Sheldon Springs	0.018	2.477	11.50	5.56	$43	$41	-	$146	$138	-	14.58	10.98	$119	$115	-	-	$602	$268
Shoreham	0.010	5.480	26.66	12.88	$55	$53	-	-	$177	-	32.98	24.84	$149	$143	-	-	$753	$335
South Burlington Airport Parkway	1.645	0.427	0.80	0.38	$275	$265	$183	-	$891	$396	1.71	0.91	-	$1,250	$866	-	-	$2,065
South Burlington Bartlett Bay	0.620	0.252	0.18	0.09	$24	$23	-	$81	$77	-	0.79	0.42	$228	$219	-	-	$814	$362
St. Albans City	2.690	0.234	0.12	0.06	$68	$65	-	$232	$220	-	0.70	0.37	-	$840	$582	-	$3,122	$1,388
Stowe	0.310	0.286	0.30	0.15	$20	$19	-	$67	$64	-	0.97	0.52	$139	$134	-	-	$498	$221
Swanton	0.548	0.461	0.92	0.44	$106	$102	-	$362	$343	$152	1.89	1.01	-	$461	$320	-	$1,713	$761
Troy/Jay	0.045	0.552	1.24	0.60	$12	$11	-	$40	$38	-	2.37	1.26	$49	$47	-	$186	$177	-
Vergennes	0.401	0.323	0.43	0.21	$36	$35	-	$124	$118	-	1.17	0.62	$216	$208	-	-	$772	$343
Wallingford	0.071	1.903	8.60	4.15	$128	$123	-	-	$415	$184	11.06	8.33	-	$349	$242	-	-	$814
Waterbury	0.255	3.903	18.70	9.03	-	$964	$668	-	-	$1,443	23.32	17.56	-	-	$1,836	-	-	$6,181
Weed Fish Culture Station	4.642	0.026																
West Pawlet	0.015	5.968	29.12	14.07	$91	$87	-	-	$294	$131	35.98	27.10	-	$238	-	-	-	$555
West Rutland	0.202	0.290	0.32	0.15	$14	$13	-	$46	$44	-	1.00	0.53	$93	$90	-	-	$333	$148
Williamstown	0.070	2.905	13.66	6.60	$200	$192	-	-	$648	$288	17.20	12.95	-	$533	$370	-	-	$1,245
Winooski	0.760	0.493	1.03	0.50	$164	$158	-	-	$532	$237	2.06	1.10	-	$695	$481	-	$2,582	$1,147
Wyeth (PBM Nutritionals)	0.123	0.135									0.18	0.10	$10	$10	-	$39	$37	-

Tables 3.5-4 and 3.5-5 present more detailed information on chemical storage options and recommended volumes as well as estimated additional chemical sludge production. Bulk storage and delivery can be used in many circumstances because ferric chloride and alum solutions tend to have a relatively long shelf life, when compared to other common municipal treatment chemicals, like sodium hypochlorite. A conservative criterion for shelf life of each chemical was set to 12 months and the minimum reasonable chemical storage tank volume was determined to be 1,000 gallons. If the total annual chemical consumption was determined to be less than 1,000 gallons, bulk storage was ruled out as a possible storage option.

Additional estimation for storage container swapping by operators was assumed to be 4 times per month for drums, and 2 times per month for totes. Delivery limits were assumed to be limited to one pallet of drums (4 drums or approximately 200 gallons total) or one to two full totes (600 gallons). Abbreviations “D” and “T” in tables 3.5-4 and 3.5-5 denote these two total storage volumes. Wherever applicable, bulk storage was assumed to constitute either 1,000 gallons or two full months of storage (at average dosing rate) plus an additional 10% for headspace, whichever is greater.

Table 3.5-4 Chemical Storage Volumes and Sludge Production New York Facilities

New York Facilities	0.2 mg/L TP limit						0.1 mg/L TP limit					
	Increase in Sludge Mass (Fe/Al)		Recommended Storage Type & Bulk Storage Volume (where applicable) (D/T/B = Drum/Tote/Bulk) (Fe/Al)				Increase in Sludge Mass (Fe/Al)		Recommended Storage Type & Bulk Storage Volume (where applicable) (D/T/B = Drum/Tote/Bulk) (Fe/Al)			
Facility Name	*lbs/day*		*gal*		*gal*		*lbs/day*		*gal*		*gal*	
Adirondack Fish Hatchery	n/a	n/a					n/a	n/a				
Altona Correctional	1.8	1.0	D/T/-	-	D/T/-	-	2.5	2.1	D/T/-	-	D/T/-	-
Au Sable Forks	23.1	17.9	D/T/-	-	-/-/B	1,245	27.3	30.4	-/T/B	1,000	-/-/B	2,424
Cadyville	0.8	0.6	D/T/-	-	D/T/-	-	1.0	1.1	D/T/-	-	D/T/-	-
Champlain	7.4	4.5	D/T/-	-	-/T/B	1,000	10.4	8.8	D/T/-	-	-/T/B	1,000
Champlain Park	18.6	14.2	D/T/-	-	-/T/B	1,000	22.0	24.5	-/T/B	1,000	-/-/B	1,954
Chazy	1.3	0.8	D/T/-	-	D/T/-	-	1.7	1.5	D/T/-	-	D/T/-	-
Crown Point	11.4	8.8	D/T/-	-	-/T/B	1,000	13.4	14.9	-/T/B	1,000	-/-/B	1,191
Dannemora	185.1	141.0	-/T/B	1,240	-/-/B	9,820	219.9	244.8	-/-/B	3,484	-/-/B	19,547
Essex	1.7	1.3	D/T/-	-	D/T/-	-	2.0	2.2	D/T/-	-	-/T/B	1,000
Fort Ann	6.1	4.5	D/T/-	-	-/T/B	1,000	7.4	8.3	D/T/-	-	-/T/B	1,000
Granville	11.1	4.9	D/T/-	-	D/T/B	1,000	16.0	13.6	D/T/B	1,000	-/T/B	1,000
Great Meadows Correctional	7.5	4.0	D/T/-	-	D/T/B	1,000	10.6	9.0	D/T/-	-	-/T/B	1,000
International Paper	n/a	n/a	-/-/-	-	-/-/-	-	84.1	71.1	-/T/B	1,291	-/-/B	5,129
Keeseville	n/a	n/a	-/-/-	-	-/-/-	-	2.3	1.9	D/T/-	-	D/T/-	-
Lake Placid	76.4	55.5	-/T/B	1,000	-/-/B	3,458	104.8	88.6	-/T/B	1,610	-/-/B	6,396
Peru	27.2	20.1	D/T/B	1,000	-/T/B	1,402	32.7	36.4	-/T/B	1,000	-/-/B	2,911
Peru/Valcour	1.2	0.9	D/T/-	-	D/T/-	-	1.5	1.6	D/T/-	-	-/T/-	-
Plattsburgh	585.1	431.3	-/-/B	3,793	-/-/B	30,036	706.1	785.9	-/-/B	11,184	-/-/B	62,755
Port Henry	35.0	25.2	D/T/B	1,000	-/T/B	1,572	48.0	40.6	-/T/B	1,000	-/-/B	2,929
Rouses Point	88.3	65.4	-/T/B	1,000	-/-/B	4,552	106.4	118.4	-/T/B	1,685	-/-/B	9,457
Saranac Lake	46.0	26.9	D/T/B	1,000	-/T/B	1,676	64.8	54.8	-/T/B	1,000	-/-/B	3,952
St Armand	16.8	13.0	D/T/-	-	-/T/B	1,000	19.8	22.1	-/T/B	1,000	-/-/B	1,764
Ticonderoga	81.9	59.2	-/T/B	1,000	-/-/B	3,690	112.4	95.0	-/T/B	1,726	-/-/B	6,857
Wadhams	2.2	1.7	D/T/-	-	-/T/-	-	2.6	2.9	D/T/-	-	-/T/B	1,000
Washington Correctional	1.5	0.6	D/T/-	-	D/T/-	-	2.2	1.8	D/T/-	-	D/T/-	-
Westport	21.5	16.2	D/T/-	-	-/T/B	1,126	25.6	28.5	-/T/B	1,000	-/-/B	2,279
Whitehall	18.3	11.3	D/T/-	-	-/T/B	1,000	25.6	21.6	-/T/B	1,000	-/T/B	1,561
Willsboro	12.2	9.4	D/T/-	-	-/T/B	1,000	14.4	16.1	-/T/B	1,000	-/-/B	1,282
Wyeth Research	1.2	0.8	D/T/-	-	D/T/-	-	1.7	1.4	D/T/-	-	D/T/-	-

Table 3.5-5 Chemical Storage Volumes and Sludge Production Vermont Facilities

Vermont Facilities	0.2 mg/L TP limit						0.1 mg/L TP limit					
	Increase in Sludge Mass (Fe/Al)		Recommended Storage Type & Bulk Storage Volume (where applicable) (D/T/B = Drum/Tote/Bulk) (Fe/Al)				Increase in Sludge Mass (Fe/Al)		Recommended Storage Type & Bulk Storage Volume (where applicable) (D/T/B = Drum/Tote/Bulk) (Fe/Al)			
	lbs/day		*gal*		*gal*		*lbs/day*		*gal*		*gal*	
Agrimark			- *facility closed* -									
Alburg	n/a	n/a										
Barre City	11.0	n/a	n/a	-	n/a	-	18.8	15.9	D/T/B	1,000	-/T/B	1,149
Benson	3.4	2.6	D/T/-	-	D/T/-	-	4.0	4.5	D/T/-	-	-/T/B	1,000
Brandon	4.0	0.9	D/T/-	-	D/T/-	-	6.0	5.0	D/T/-	-	-/T/B	1,000
Brown Ledge Camp	0.4	0.3	D/T/-	-	D/T/-	-	0.4	0.5	D/T/-	-	D/T/-	-
Burlington East	13.3	7.4	D/T/-	-	D/T/B	1,000	18.8	15.9	D/T/B	1,000	-/T/B	1,149
Burlington Electric	n/a	n/a	n/a	-	n/a	-	n/a	n/a	n/a	-	n/a	-
Burlington Main	114.8	68.2	-/T/B	1,000	-/T/B	1,932	161.2	136.3	-/T/B	2,476	-/-/B	9,837
Burlington North	23.6	12.4	D/T/-	-	D/T/B	1,000	33.5	28.3	-/T/B	1,000	-/T/B	2,045
Cabot	0.2	0.0	D/T/-	-	D/T/-	-	0.3	0.3	D/T/-	-	D/T/-	-
Castleton	2.5	0.0	D/T/-	-	D/T/-	-	3.9	3.3	D/T/-	-	D/T/B	1,000
Enosburg Falls	2.9	0.9	D/T/-	-	D/T/-	-	4.4	3.7	D/T/-	-	-/T/B	1,000
Essex Junction	61.0	38.4	D/T/B	1,000	-/T/B	1,087	85.1	71.9	-/T/B	1,307	-/-/B	5,192

Table 3.5-5 Chemical Storage Volumes and Sludge Production Vermont Facilities (continued)

Vermont Facilities	**0.2** mg/L TP limit						**0.1** mg/L TP limit					
	Increase in Sludge Mass (Fe/Al)		Recommended Storage Type & Bulk Storage Volume (where applicable) (D/T/B = Drum/Tote/Bulk) (Fe/Al)				Increase in Sludge Mass (Fe/Al)		Recommended Storage Type & Bulk Storage Volume (where applicable) (D/T/B = Drum/Tote/Bulk) (Fe/Al)			
	lbs/day		*gal*		*gal*		*lbs/day*		*gal*		*gal*	
Fair Haven	3.6	1.8	D/T/-	-	D/T/-	-	5.2	4.4	D/T/-	-	-/T/B	1,000
Fairfax	16.2	12.6	D/T/-	-	-/T/B	1,000	19.1	21.2	-/T/B	1,000	-/-/B	1,696
Hardwick	13.7	9.8	D/T/-	-	-/T/B	1,000	18.7	15.8	-/T/B	1,000	-/T/B	1,144
Hinesburg	2.5	1.2	D/T/-	-	D/T/-	-	3.6	3.1	D/T/-	-	D/T/B	1,000
IBM	21.5	1.0	D/T/-	-	D/T/-	-	33.1	28.0	-/T/B	1,000	-/T/B	2,021
Jeffersonville	24.9	19.4	-/T/B	1,000	-/T/B	1,000	29.2	32.5	-/T/B	1,000	-/-/B	2,596
Johnson	3.4	1.7	D/T/-	-	D/T/-	-	4.8	4.1	D/T/-	-	-/T/B	1,000
Marshfield	8.1	6.2	D/T/-	-	-/T/B	1,000	9.5	10.6	-/T/-	-	-/T/B	1,000
Middlebury	16.7	7.8	D/T/-	-	D/T/B	1,000	23.9	20.2	-/T/B	1,000	-/T/B	1,461
Milton	8.4	5.5	D/T/-	-	D/T/-	-	11.7	9.9	D/T/B	1,000	-/T/B	1,000
Montpelier	42.0	23.1	D/T/B	1,000	-/T/B	1,000	59.4	50.2	-/T/B	1,000	-/-/B	3,626
Morrisville	6.4	3.4	D/T/-	-	D/T/-	-	9.0	7.6	D/T/-	-	-/T/B	1,000
Newport Center	1.3	1.0	D/T/-	-	D/T/-	-	1.8	1.5	D/T/-	-	D/T/-	-
North Troy	8.4	6.2	D/T/-	-	-/T/B	1,000	10.2	11.3	D/T/-	-	-/T/B	1,000
Northfield	13.6	7.9	D/T/-	-	D/T/B	1,000	19.2	16.2	D/T/B	1,000	-/T/B	1,172
Northwest State Correctional	n/a	n/a	n/a	-	n/a	-	0.1	0.1	D/T/-	-	D/T/-	-
Orwell	5.6	4.3	D/T/-	-	D/T/-	-	6.6	7.4	D/T/-	-	-/T/B	1,000
Otter Valley Union High School	1.1	0.8	D/T/-	-	D/T/-	-	1.3	1.4	D/T/-	-	-/T/-	-
Pittsford	12.7	9.7	D/T/-	-	-/T/B	1,000	15.1	16.9	-/T/B	1,000	-/-/B	1,346
Pittsford Fish Hatchery	n/a	n/a	n/a	-	n/a	-	n/a	n/a	n/a	-	n/a	-
Plainfield	14.6	11.2	D/T/-	-	-/T/B	1,000	17.4	19.3	-/T/B	1,000	-/-/B	1,543
Poultney	0.4	n/a	n/a	-	n/a	-	0.9	0.8	D/T/-	-	D/T/-	-
Proctor	32.4	24.1	D/T/B	1,000	-/T/B	1,000	38.9	43.3	-/T/B	1,000	-/-/B	3,454
Richford	5.4	3.0	D/T/-	-	D/T/-	-	7.6	6.4	D/T/-	-	-/T/B	1,000
Richmond	0.2	n/a	n/a	-	n/a	-	0.4	0.3	D/T/-	-	D/T/-	-
Rock Tenn	6.6	4.1	D/T/-	-	D/T/-	-	9.2	7.8	D/T/-	-	-/T/B	1,000
Rutland City	65.5	23.8	D/T/B	1,000	-/T/B	1,000	95.7	80.9	-/T/B	1,471	-/-/B	5,842
Salisbury Fish Hatchery	n/a	n/a	n/a	-	n/a	-	n/a	n/a	n/a	-	n/a	-
Shelburne #1	3.7	1.3	D/T/-	-	D/T/-	-	5.5	4.6	D/T/-	-	-/T/B	1,000
Shelburne #2	6.4	3.0	D/T/-	-	D/T/-	-	9.2	7.8	D/T/-	-	-/T/B	1,000
Sheldon Springs	4.2	3.2	D/T/-	-	D/T/-	-	5.0	5.6	D/T/-	-	-/T/B	1,000
Shoreham	5.3	4.1	D/T/-	-	-/T/-	-	6.3	7.0	D/T/-	-	-/T/B	1,000
South Burlington Airport Parkway	40.1	23.3	D/T/B	1,000	-/T/B	1,000	56.4	47.7	-/T/B	1,000	-/-/B	3,442
South Burlington Bartlett Bay	6.7	2.0	D/T/-	-	D/T/-	-	9.9	8.4	D/T/-	-	-/T/B	1,000
St. Albans City	25.3	5.8	D/T/-	-	D/T/-	-	37.9	32.0	-/T/B	1,000	-/T/B	2,313
Stowe	4.2	1.7	D/T/-	-	D/T/-	-	6.0	5.1	D/T/-	-	-/T/B	1,000
Swanton	14.8	9.0	D/T/-	-	D/T/B	1,000	20.8	17.6	-/T/B	1,000	-/T/B	1,269
Troy/Jay	1.5	1.0	D/T/-	-	D/T/-	-	2.1	1.8	D/T/-	-	D/T/-	-
Vergennes	6.5	3.1	D/T/-	-	D/T/-	-	9.4	7.9	D/T/-	-	-/T/B	1,000
Wallingford	12.8	9.7	D/T/-	-	-/T/B	1,000	15.3	17.0	-/T/B	1,000	-/-/B	1,357
Waterbury	98.3	76.0	-/T/B	1,000	-/-/B	2,405	115.9	129.0	-/-/B	1,836	-/-/B	10,302
Weed Fish Culture Station	n/a	n/a	n/a	-	n/a	-	n/a	n/a	n/a	-	n/a	-
West Pawlet	8.9	6.9	D/T/-	-	-/T/B	1,000	10.4	11.6	-/T/-	-	-/-/B	1,000
West Rutland	2.8	1.1	D/T/-	-	D/T/-	-	4.0	3.4	D/T/-	-	-/T/B	1,000
Williamstown	19.7	15.2	D/T/-	-	-/T/B	1,000	23.3	26.0	-/T/B	1,000	-/-/B	2,074
Winooski	22.4	13.9	D/T/-	-	-/T/B	1,000	31.3	26.5	-/T/B	1,000	-/T/B	1,912
Wyeth (PBM Nutritionals)	0.2	n/a	n/a	-	n/a	-	0.4	0.4	D/T/-	-	D/T/-	-

3.6 References

Water Environment Federation, 2010. *WEF Manual of Practice No. 34 – Nutrient Removal* McGraw Hill, New York, NY

Szabo, A., Takacs, I., Murthy, S., Daigger, G.T., Licsko, I., Smith, S., 2008. Significance of design and operational variables in chemical phosphorus removal. *Water Environment Research* 80, 407-416.

4 Enhanced Biological Phosphorus Removal

4.1 Process Description and Fundamentals

Introduction to Biological Phosphorus Removal

Phosphorus will be removed to some extent by any biological process. Typical excess biomass contains approximately 2% phosphorus by mass. When the excess sludge is wasted from the process, the phosphorus is wasted along with the sludge. Certain configurations of the activated sludge process promote the growth of microorganisms that tend to store additional phosphorus (to between 4% and 12% of the biomass composition) thereby providing enhanced biological phosphorus removal (EBPR) when that sludge is wasted. However, during sludge processing a significant portion of the phosphorus is often released from the waste biomass and returned to the process with the sludge liquor from thickening, decanting, and dewatering processes. Because operation of an activated sludge WWTF to promote reliable EBPR and to minimize phosphorus release and return from sludge processing is complex, it tends to be less successful for small WWTFs with leaner staffing. Consequently, we have considered EBPR as an appropriate technology only for facilities that are treating ADFs of 1.0 MGD or greater.

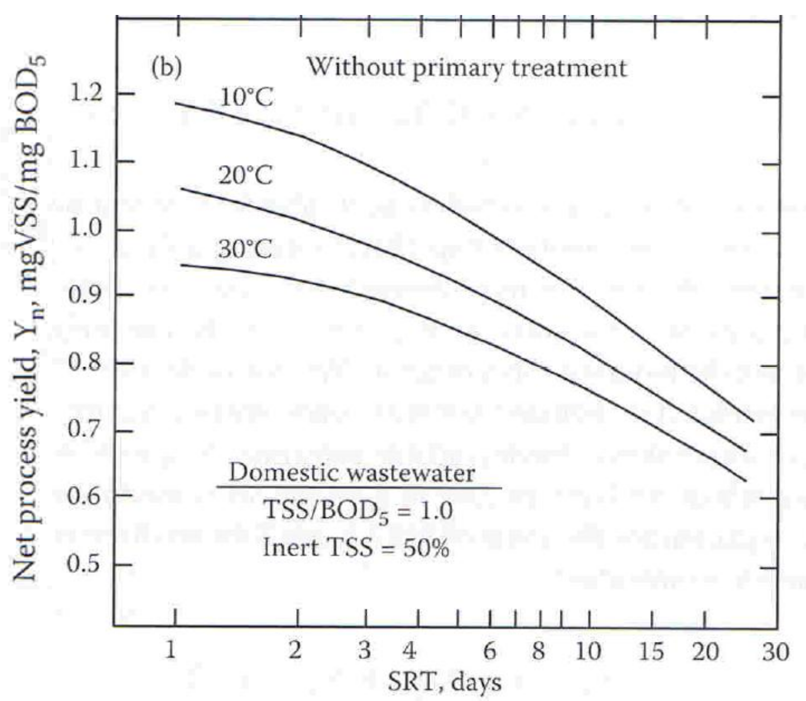
Incidental Biological Phosphorus Removal

Biological processes function by promoting the growth of a biomass that is mainly bacterial. The biomass itself is composed of carbon, the nutrients nitrogen and phosphorus, and other trace elements. Typical bacterial biomass composition can be approximated by the formula $C_5H_7O_2NP_{0.08}$ having a molecular weight of approximately 115.5 g/mol (Grady et al., 2011). With a molecular weight of 14 g/mol, nitrogen comprises approximately 12% of the biomass. With a molecular weight of 31 g/mol, phosphorus comprises approximately 2% of the biomass. Consequently, when 100 lbs of excess biomass are removed from a WWTF, approximately 12 lb nitrogen and 2 lb phosphorus are removed along with it.

All biological processes produce excess biomass. Most (if not all) of the WWTFs considered in this study use aerobic biological processes including conventional activated sludge, extended aeration activated sludge, sequencing batch reactor activated sludge, membrane bioreactor activated sludge, trickling filters, and aerated lagoons. The quantity of excess biomass generated by any of these processes is based on the same fundamentals of bacterial growth. Key is the balance between bacterial true yield and bacterial decay. The true yield (quantity of biomass which is generated by bacterial growth resulting from metabolism of one gram of BOD_5) depends mainly on the composition of the wastewater. Difficult to degrade compounds tend to have lower true yields than compounds that require less energy to degrade. Most municipal wastewaters contain a similar blend of compounds to be degraded so provide similar true yields. However, at the same time that new biomass is being generated, other biomass is decaying. AS it decays, biomass releases its carbon, nitrogen, and phosphorus back into the wastewater. The excess (net) biomass to be wasted from the system is the biomass generated as a result of BOD_5 metabolism via true yield minus the biomass that has decayed during the same period of time. The result is termed the net yield.

Like yield, the decay rate is similar in most aerobic activated sludge processes. However, the period of time over which the biomass is subject to decay within the process will vary with process operation and will affect the extent of decay. For example, if decay is 2% per day (2 d^{-1}), a biomass that has a solids retention time (SRT) of 10 days will exhibit 20% decay while a biomass that is operated at a 5 day SRT will experience only 10% decay. Therefore processes operated with longer SRTs will exhibit lower net yields (less excess biomass for the same BOD_5 removal than processes operated with shorter SRTs. As with most other chemical or biochemical reactions, decay rate increases with wastewater temperature so both SRT and temperature affect net yield. The combined effects of SRT and wastewater temperature are shown in Figure 4.1-1.

Figure 4.1-1 Net Yield, lb VSS/lb BOD Removed (from Grady et al, 2011)



For example, a conventional activated sludge process operated with an SRT of 8 days at a wastewater temperature of 15 degrees C is estimated to net approximately 0.9 lb VSS/ lb BOD_5 removed. An extended aeration process operated with an SRT of 20 days at the same 15 degree C wastewater temperature is estimated to net approximately 0.78 lb VSS/lb BOD_5 removed. The conventional system with the shorter SRT generates approximately 15% more excess biomass to be wasted from the process. Therefore in this example the shorter SRT conventional process also wastes approximately 15% more phosphorus from the system. This is a fundamental principle of biological phosphorus removal: **processes operated at longer SRTs generate less excess biomass and therefore remove less phosphorus than processes operated at shorter SRTs**. Although SRT is not used as a control parameter for trickling filter or aerated lagoon processes, both produce little waste biomass because they naturally operate at long SRTs. With little waste biomass there is little opportunity for biological phosphorus removal.

Although short SRT processes provide greater potential for phosphorus removal, the greater mass of sludge wasted at a short SRT also results in increased sludge handling requirements for thickening, dewatering and disposal. Further, stable nitrification (the biological process to convert ammonia to nitrate) requires a moderately long SRT particularly at cold wastewater temperatures. To minimize sludge production and assure stable nitrification, wastewater processes design and wastewater operator training have often focused on operation at the long SRTs that minimize phosphorus removal.

Enhanced Biological Phosphorus Removal

<u>EBPR Performance Capabilities and Limitations</u>
As shown in Figure 4.1.1, even at very short SRTs and cold wastewater temperatures net yield would peak at approximately 1.2 lb VSS/lb BOD_5 removed. At 2% phosphorus in the VSS, this limits incidental biological phosphorus removal to approximately 0.024 lb TP/lb BOD_5 removed. At a typical municipal influent BOD_5 of 190 mg/L (Metcalf and Eddy, 2003), a maximum of approximately 4.56 mg/L TP could be removed using this approach. Because typical influent TP is approximately 7 mg/L (Metcalf and Eddy, 2003), an effluent soluble phosphorus concentration of over 2 mg/L would remain without additional treatment. At more practical SRTs and wastewater temperatures, incidental phosphorus removal would be even less.

Enhanced biological phosphorus removal (EBPR) processes are used to increase the phosphorus content of the biomass thereby removing more soluble phosphorus at the same SRT and net yield. Using EBPR, the phosphorus content of the biomass can be increased from the typical 2% to between 4% and 12% TP. Table 4.1-1 shows the phosphorus uptake estimated for biomass VSS phosphorus contents of 2%, 4% and 6% from activated sludge processes operated at 15 degrees C with SRTs from 5 days to 30 days.

Table 4.1-1 P Uptake for Municipal Influent at 190 mg/L BOD_5 and 15 degrees C

SRT	Net Yield	TP in VSS		
days	lb VSS/lb BOD_5	2%	4%	6%
		P Uptake, mg/L		
5	0.98	3.72	7.45	11.17
8	0.90	3.42	6.84	10.26
12	0.83	3.15	6.31	9.46
16	0.78	2.96	5.93	8.89
30	0.63	2.39	4.79	7.18

Without EBPR (at 2% TP in the waste VSS), the phosphorus uptake is estimated at between 2 and 4 mg/L with greater removal at shorter SRT. With moderate EBPR (4% TP in the waste VSS), the phosphorus uptake is estimated at between 4 and 8 mg/L. For a typical municipal influent at 7 mg/L TP, essentially all of the influent phosphorus would be removed before attaining 6% TP in the waste VSS. This assumes that the bacteria can scavenge essentially all of the soluble phosphorus from the water and that phosphorus is effectively sequestered in the biomass once taken up. Both of those assumptions are invalid.

As with all biochemical reactions, compound uptake rate decreases as the available compound concentration decreases. So theoretically as soluble phosphorus is taken up and its concentration in the water declines, the rate of phosphorus uptake decreases until it essentially ceases even though there would still be a small amount of soluble phosphorus present. That is theoretical because as phosphorus is being scavenged from the water by some bacteria, other bacteria are decaying which releases phosphorus along with nitrogen, carbon and other cellular compounds. Consequently no biological process can achieve extremely low soluble reactive phosphorous concentrations in practice.

Another factor affecting the effluent soluble phosphorus concentration is the unreactive soluble phosphorus. Even in a highly optimized EBPR process there will exist a small quantity of soluble phosphorus that is unreactive and will not be incorporated into or stored by the biomass nor can it be removed chemically. That unreactive portion is most commonly termed the “recalcitrant” dissolved organic phosphorus or rDOP. This is similar to the recalcitrant dissolved organic nitrogen (rDON) and COD that remain in well treated effluents and may be evidence of the presence of compounds that are non-biodegradable or very slowly degradable. The rDOP concentration is commonly 0.01 to 0.04 mg/L.

Taken together the rDOP and the remaining soluble reactive phosphorus are typically 0.2 mg/L or greater in any EBPR process. Effluents of EBPR processes using membranes for highly effective solids removal can achieve TP concentrations of 0.2 mg/L or less. However, without perfect solids separation, the effluent TP is supplemented by the phosphorous content of any solids that remain the effluent. If for example an EBPR process has developed a biomass that has 4% TP in the VSS, 10 mg/L of VSS in the effluent would contribute 0.4 mg/L of particulate phosphorous. Consequently EBPR processes using only standard sedimentation can rarely achieve reliable performance to less than 1 mg/L TP. With enhanced solids removal such as ballasted clarification or filtration, effluent TP between 0.5 mg/L and 0.2 mg/L is possible. To reliably achieve effluent TP less than 0.2 mg/L usually requires tertiary chemical addition to supplement the EBPR.

Phosphorus Uptake and Release During EBPR

All EBPR processes include the essential element of alternating anaerobic and aerobic environments. Phosphorus is released from the biomass in the anaerobic zone but taken up in greater quantity in the aerobic zone. The phosphorus that exceeds the 2% required for cell synthesis is stored as polyphosphate chains inside the biomass and is removed from the system when the excess biomass is wasted.

Anaerobic Zone

In the anaerobic environment (simply a mixed unaerated tank usually open at the surface) the influent (or primary effluent) wastewater is blended with recycled biomass. Some fraction of that biomass will be composed of naturally occurring phosphorus accumulating organisms (PAOs). Under anaerobic conditions the PAOs are able to take up BOD in the form of volatile fatty acids (VFAs, i.e. acetic acid). VFAs are generated by fermentation of other forms of BOD in the sewer system, in the primary clarifier if used, and to some extent in the anaerobic zone itself. Under anaerobic conditions, the PAOs cannot metabolize VFAs but are able to convert and store it as poly-β-hydroxy alkanoate (PHA) to be metabolized under aerobic conditions. To generate the energy required to transport the VFA into the cell and to convert it to PHA, the PAOs cleave phosphate ions from an internally stored polyphosphate chain thereby accessing the energy contained in each polyphosphate bond. The phosphate ions cleaved from the chain are released from the cell as potassium phosphate or magnesium phosphate thereby increasing the soluble phosphorus concentration in the anaerobic zone. Figure 4.1.3 is a generalized depiction of the changes to BOD and P concentration within an EBPR process.

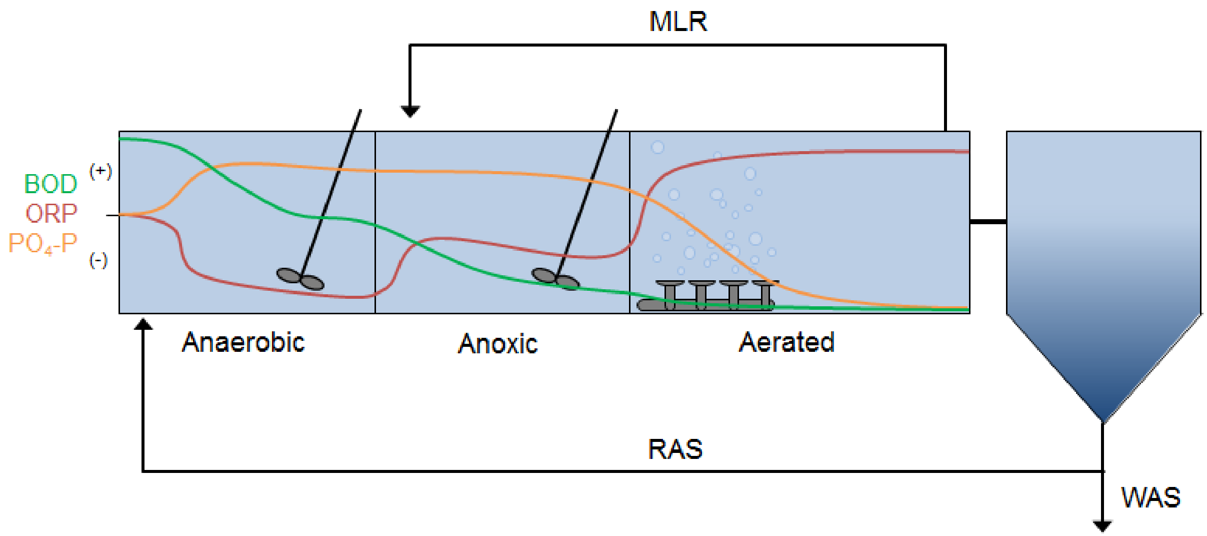


Figure 4.1-2 EBPR Configuration Schematic

For each mg of P to be removed, approximately 10 mg VFA COD is required at the anaerobic tank (Grady et al., 2011). For most systems, some VFAs are present but other soluble BOD must be fermented to VFA in the anaerobic zone. Based on the efficiency of fermentation, approximately 2 mg/L of soluble COD is estimated to be required for each 1 mg/L VFA to be generated fermentatively. Grady et. al, (2011) recommend an anaerobic SRT of between 0.5 and 1.5 days at 20 degrees C to allow for the necessary fermentation. For this evaluation we will assume an anaerobic SRT of 1.5 days will be adequate year round.

Aerobic Zone

The aerobic zone is the site of stored PHA oxidation and phosphorus uptake by the PAOs. Other remaining BOD will also be oxidized and if the SRT is long enough, ammonia will be converted to nitrate via nitrification. At 15 degrees C the minimum aerobic SRT for PAOs is approximately 2.1 days. At that same temperature, the minimum SRT for nitrification is approximately 2.9 days. It is very difficult to consistently operate to within 0.7 day of the SRT target so would be impractical to attempt to operate to maintain EBPR without nitrification. That goal would be even more difficult to attain at warmer wastewater temperatures when the minimum aerobic SRTs for nitrification and EBPR are even more similar. Consequently, nitrification, and the resultant nitrate, are likely in any EBPR process operating at 15 degrees C or higher.

Anoxic Zone

Anoxic conditions (presence of nitrate in absence of oxygen) are necessary for denitrification (conversion of nitrate to nitrogen gas) but an anoxic zone is not a requirement for EBPR. Most PAOs are strict aerobes and must have oxygen in order to metabolize the VFA COD that they stored as PHA while in the anaerobic zone. However, an anoxic zone is often included in EBPR systems. One reason to include an anoxic zone is because the WWTF must remove nitrogen to meet discharge requirements. A second reason to include an anoxic zone is because any nitrate present in the RAS stream when it enters the anaerobic zone will be used as an electron acceptor for oxidation of BOD (including VFAs). As long as nitrate is available, PAOs will use it as an electron acceptor to oxidize VFAs and other BOD rather than storing VFAs as PHA. Further, the facultative organisms present will oxidize BOD using nitrate rather than fermenting it to VFA. Approximately 6 mg soluble COD will be oxidized for each mg nitrate-N introduced into the anaerobic zone with the RAS. Consequently, it is important that the nitrate concentration of the RAS be low so that sufficient soluble COD remains to supply the VFA needed in the EBPR anaerobic zone. Including an anoxic zone for denitrification of nitrate generated by nitrification of ammonia in the aerobic zone is a common and practical way to minimize nitrate in the anaerobic zone. Another alternative is to operate the process to avoid the generation of nitrate by maintaining a short aerobic SRT and/or low aerobic zone dissolved oxygen (DO) concentration. Finally, the influent COD may be supplemented by external sources of VFA or COD as necessary to provide the quantity needed by the PAOs.

4.2 EBPR Sizing and Capital Costs

EBPR Sizing

Based on the above discussion it is clear that to incorporate EBPR into an activated sludge process an anaerobic tank is needed. For this evaluation, the necessary volume will be determined by assuming the parameters discussed above and summarized in Table 4.2-1.

Table 4.2-1 EBPR Sizing Parameter Assumptions

Assumed Parameter	Value	Units
Anaerobic SRT	1.5	days
Mixed Liquor Suspend Solids Concentration	3000	mg TSS/L
Net yield	0.90	lb VSS/lb BOD5 removed
BOD removed in bioreactor	190	mg BOD/L
MLSS volatile fraction	75%	VSS/TSS

Together these parameters provide a reasonable basis for preliminary sizing of the anaerobic tankage for EBPR. At a 1.0 MGD ADF, these assumptions lead to the calculated results shown in Table 4.2-2.

Table 4.2-2 EBPR Sizing for 1.0 MGD ADF

Calculated Parameter	Value	Units
BOD Loading	1585	lb BOD/day
WAS	1426	lb VSS/day
Anaerobic Biomass	2139	lb VSS/day
MLVSS	2250	mg VSS/L
Anaerobic Volume	0.11	MG
Anaerobic HRT	2.7	hr

EBPR Capital Cost

Although existing excess aeration basin volume may be converted to function anaerobically, for purposes of this evaluation it will be assumed that all EBPR anaerobic volume would be constructed as new tankage. Concrete required for anaerobic tankage was estimated based on constructing two rectangular tanks with a common wall, a combined operating volume of 0.11 MG per MGD of WWTF design ADF, a 14 foot operating depth, and 3 feet of freeboard. Mixer sizing is based on 35 hp/MG. It is also assumed that the anaerobic tank would be constructed near the existing tankage so that no additional pumping would be required. Basis of costs is as shown in Table 4.2-3.

Table 4.2-3 Budget Items to Add EBPR to Existing Activated Sludge WWTF

Expense Type	Units	Value
In Place Concrete	$/CY	850
Excavation and Backfill	$/CY	20
Floating Mixers, installed, incl electrical	$/hp	31,250
Civil/Piping	% of tank cost	20
Contractor Mobilization, Overhead, Profit	% of Construction cost	20
Design Engineering	Per Vermont ANR fee curves used by CWSRF program	
Construction Phase Engineering		
Contingency	% Project cost	25

Based on the sizing criteria and unit budget costs in Tables 4.2-2 and 4.2-3, the estimated budget required to add EBPR to an existing activated sludge WWTF is shown in Figure 4.2-1 as a function of ADF from 1.0 MGD to 20 MGD.

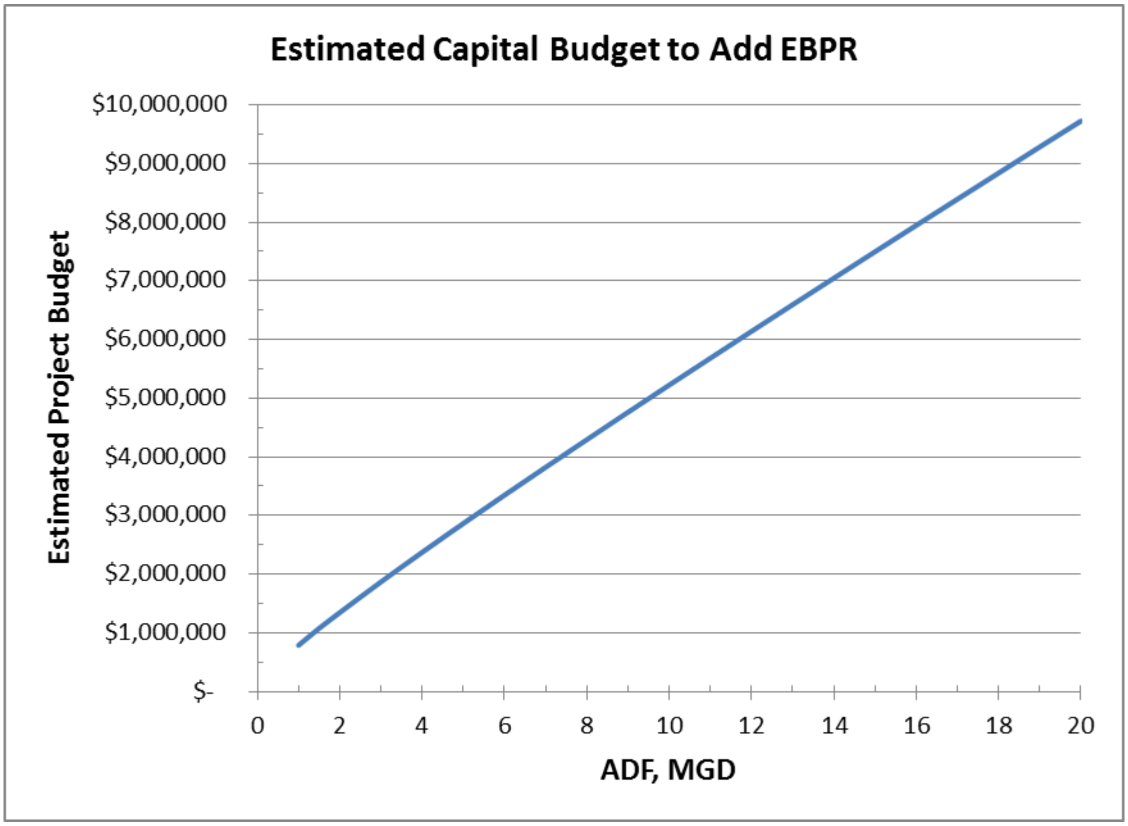


Figure 4.2-1 Estimated Capital Budget Needed to Add EBPR to Existing Activated Sludge WWTF

EBPR Operation and Maintenance

Operation and Maintenance of EBPR is mainly for the mixers that are used to keep the solids suspended in the anaerobic zone. Either submersible or surface mixers may be used but maintenance for the submersible mixers is typically more costly as the submersible motors are more expensive and more susceptible to seal failure. Vertical shaft surface mount mixers may be installed on fixed walkways or float mounted. The less costly and more flexible float mount type has been assumed for this evaluation. Maintenance of top mounted mixers is primarily for lubrication and replacement of wear components and is anticipated at approximately $150/hp annually. Electrical cost to operate the mixers is estimated at $0.10/KWHr for constant operation at rated horsepower. Total annual cost for EBPR O&M is the sum of the mixer maintenance cost and the mixer electricity cost and is shown as cost curves in Figure 4.2-2 and in detail in Table 4.2-4.

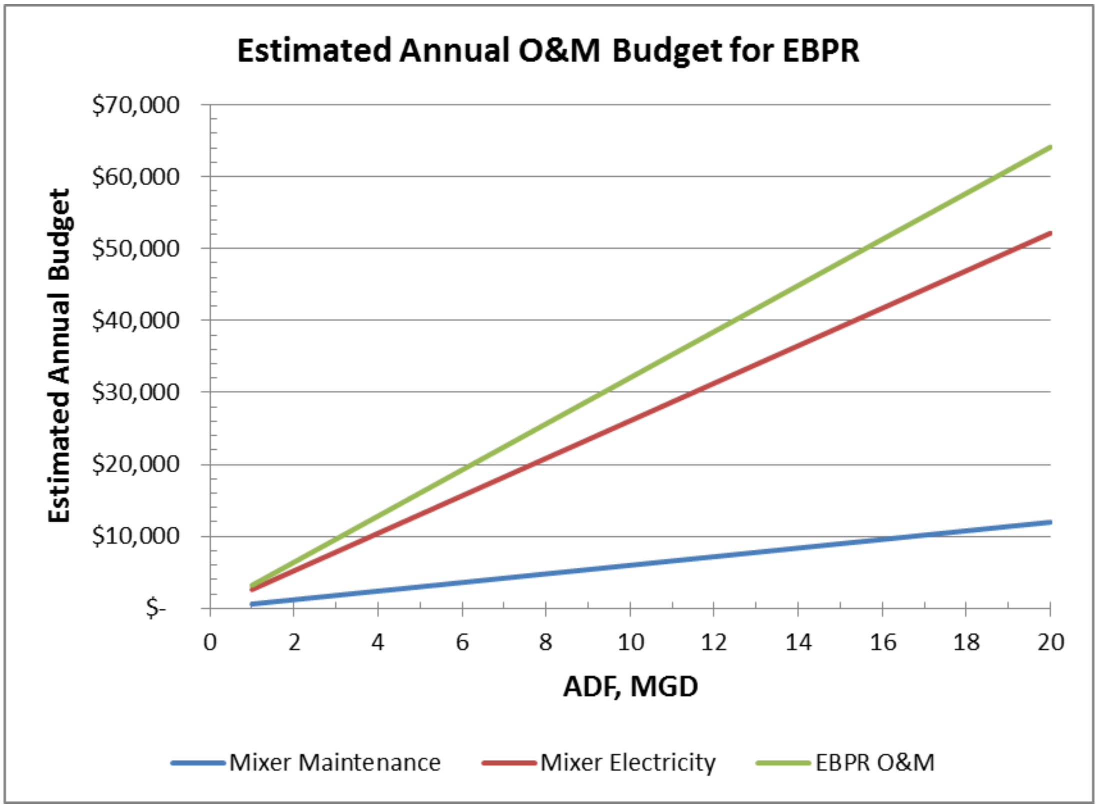


Figure 4.2-2 Estimated Annual O&M Cost for EBPR

Table 4.2-4 Estimated Annual O&M Cost for EBPR

MGD	HP	Annual $	Annual KWHr	Annual $	Annual $
ADF	Mixing	Mixer Maintenance	Mixer Energy	Mixer Electricity	EBPR O&M
1	4	$ 599	26074	$ 2,607	$ 3,206
1.5	6	$ 898	39112	$ 3,911	$ 4,809
2	8	$ 1,197	52149	$ 5,215	$ 6,412
2.5	10	$ 1,496	65186	$ 6,519	$ 8,015
3	12	$ 1,796	78223	$ 7,822	$ 9,618
3.5	14	$ 2,095	91261	$ 9,126	$ 11,221
4	16	$ 2,394	104298	$ 10,430	$ 12,824
4.5	18	$ 2,693	117335	$ 11,734	$ 14,427
5	20	$ 2,993	130372	$ 13,037	$ 16,030
6	24	$ 3,591	156447	$ 15,645	$ 19,236
7	28	$ 4,190	182521	$ 18,252	$ 22,442
8	32	$ 4,788	208596	$ 20,860	$ 25,648
9	36	$ 5,387	234670	$ 23,467	$ 28,854
10	40	$ 5,985	260745	$ 26,074	$ 32,059
11	44	$ 6,584	286819	$ 28,682	$ 35,265
12	48	$ 7,182	312894	$ 31,289	$ 38,471
13	52	$ 7,781	338968	$ 33,897	$ 41,677
14	56	$ 8,379	365043	$ 36,504	$ 44,883
15	60	$ 8,978	391117	$ 39,112	$ 48,089
16	64	$ 9,576	417192	$ 41,719	$ 51,295
17	68	$ 10,175	443266	$ 44,327	$ 54,501
18	72	$ 10,773	469341	$ 46,934	$ 57,707
19	76	$ 11,372	495415	$ 49,542	$ 60,913
20	80	$ 11,970	521490	$ 52,149	$ 64,119

4.3 EBPR Energy, Footprint, and Sludge Production

Energy

As described above, the energy required for EBPR is the electricity for mixing and is shown in Table 4.2-4 and in Figure 4.2-3. Additional energy would be required if pumping is necessary between the anaerobic tank and the existing process tankage.

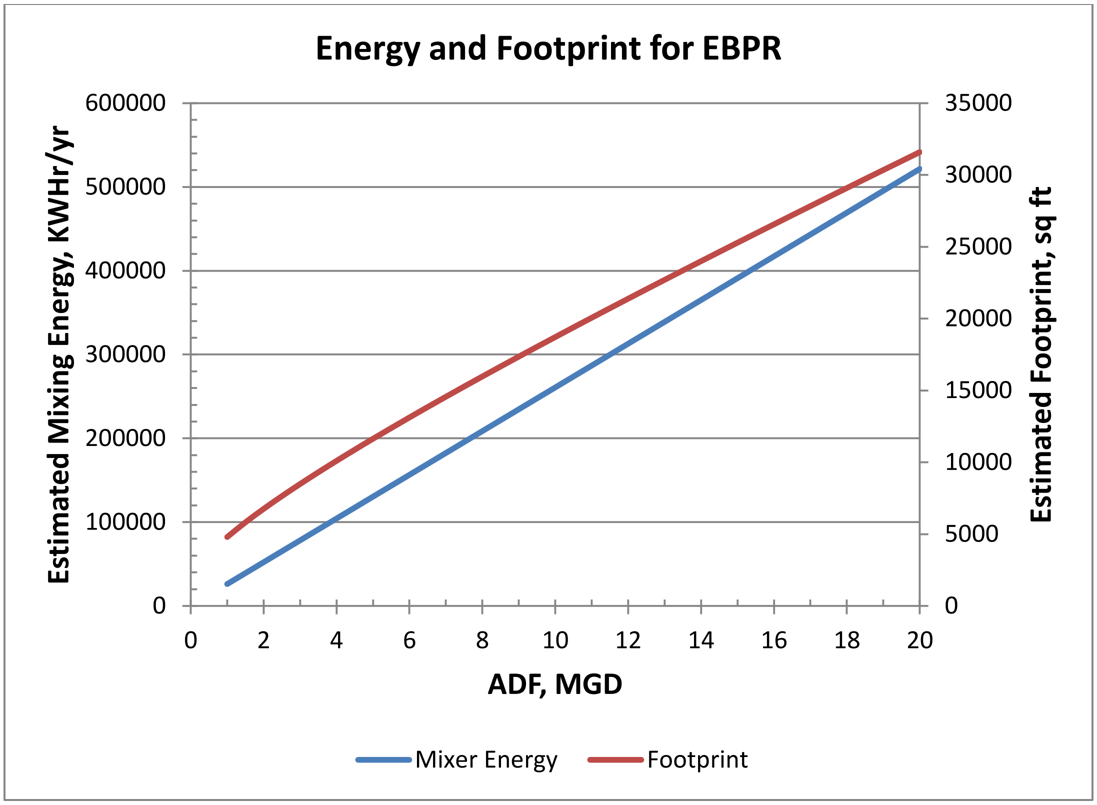


Figure 4.2-3 Estimated Annual Energy and Footprint Requirements for EBPR

Footprint

Additional treatment facility area will be required for the footprint of the anaerobic tankage. The required area has been estimated based on the footprint of the anaerobic tankage plus a 15 foot buffer zone on all sides of the tank. More or less area may be required at specific facilities depending on the layout of existing tankage and other facilities. The estimated area required to implement EBPR is shown in Figure 4.2.-3.

Sludge Production

Sludge production will not increase as a consequence of EBPR unless the operating SRT of the WWTF is decreased to fully optimize EBPR or external carbon source is used to supplement the VFA content of the wastewater. Approximately 20 mg/L BOD must be fermented to volatile acids for each mg P/L to be removed. If supplemental carbon is needed, the solids production will increase according to the net yield for the WWTF. For this evaluation, it is assumed that supplemental carbon is not required. Individual facility needs should be assessed through an influent sampling and analysis program as a part of any preliminary study for EBPR implementation.

4.4 References

Grady, Daigger, Love and Filipe, 2011. *Biological Wastewater Treatment, Third Edition*, CRC Press, Boca Raton, FL

Metcalf and Eddy, revised by Tchbanoglous, Burton, and Stensel, 2003. *Wastewater Engineering, Treatment and Reuse, Fourth Edition,* McGraw Hill, New York, NY

5 Enhanced Solids Removal

5.1 Importance of Enhanced Solids Removal

Both chemical and enhanced biological phosphorus removal (EBPR) are focused on converting soluble phosphorus into a particulate form. When very effectively applied, chemical phosphorus removal is capable of reducing the soluble phosphorus concentration to approximately the rDOP concentration of 0.02 to 0.04 mg/L. Very effective EBPR will typically result in a soluble phosphorus concentration of 0.2 to 0.5 mg/L that is a combination of the rDOP and the phosphorus resulting from the constant process of biomass decay. To achieve lower effluent soluble phosphorus concentration from an EBPR system, application of chemical phosphorus removal would be needed to remove the soluble phosphorus down to the rDOP level downstream of the secondary clarifier effluent. However even very effective chemical phosphorus removal or EBPR combined with tertiary chemical phosphorus removal must also include very effective solids removal to assure that the phosphorus that has been incorporated into the solids does not remain in the effluent where it would be included in the measure of total phosphorus (TP). Due to the solids that escape over the weir, typical secondary clarifiers are rarely sufficient to achieve 0.2 or 0.1 mg/L TP.

To meet a 0.1 mg/L TP limit, and reserving 0.04 mg/L for rDOP, the effluent particulate phosphorus concentration must be less than 0.06 mg/L. Similarly, to meet 0.2 mg/L and 1.0 mg/L TP limits the effluent particulate phosphorus concentrations must be less than, 0.16 mg/L and 0.96 mg/L respectively. In well operating EBPR processes the biomass will contain 4% or more phosphorus in the VSS (about 3% P on a TSS basis). For chemical phosphorus removal systems or EBPR that also uses chemical phosphorus removal, the chemical sludge produced increases the non-volatile fraction so that the combined mixed liquor (both EBPR biomass and chemical sludge) will contain P at approximately 2.5% of TSS. For tertiary systems where the solids are mainly due to chemical precipitation, the phosphorus content of the chemical sludge may be 6 % - 10% of the chemical sludge TSS. The greater the phosphorus concentration in the TSS, the more important it is that those solids be prevented for escaping into the effluent.

Figure 5.1-1 shows the effluent particulate phosphorus concentration that would result from TSS in the effluent at a range of solids phosphorous contents from 2% (non-EBPR biomass) to 12% (tertiary chemical P removal). Even at the lowest P content of 2%, the 0.1 mg/L TP standard cannot be achieved if effluent TSS exceeds 4 mg/L. Standard sedimentation is the easiest and least costly method of solids separation in a wastewater process but the solids that are too small or diffuse cannot be removed through standard sedimentation alone. Enhanced solids removal technologies such as filtration or enhanced clarification are needed to obtain the low effluent solids concentrations required.

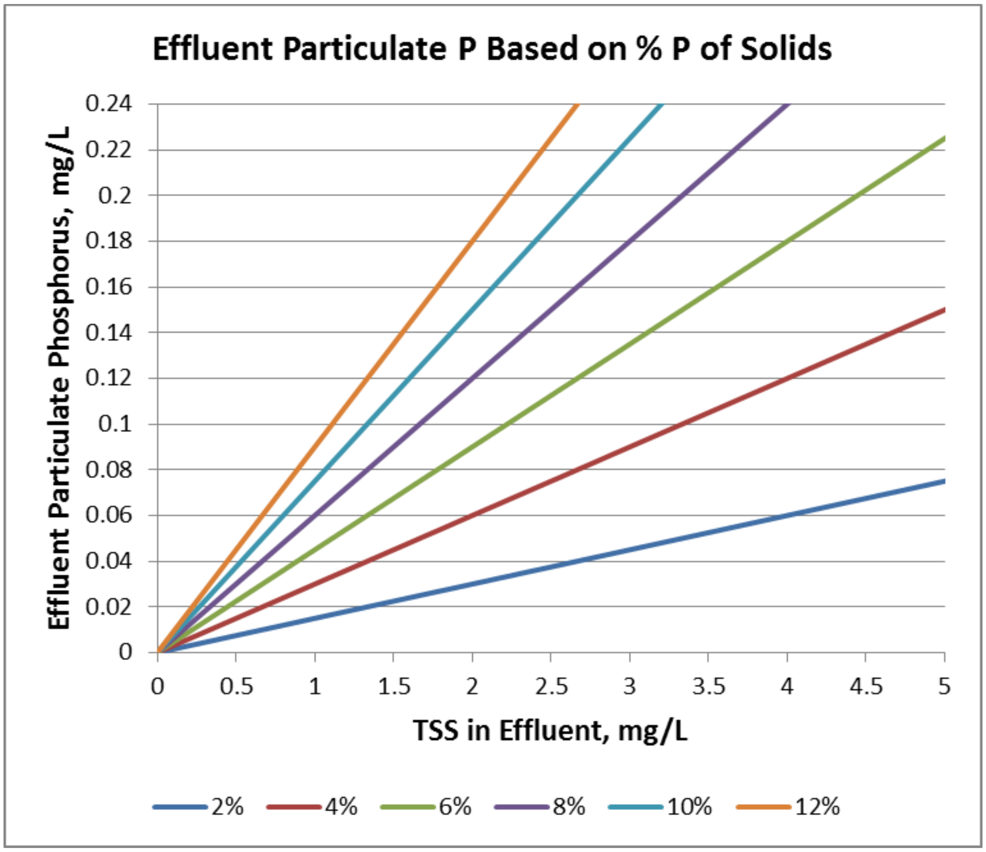


Figure 5.1-1 Effluent Particulate Phosphorus

5.2 Enhanced Solids Removal Technology Descriptions

Filtration

Many different types of filters have been used successfully to assist with phosphorus removal, including traditional gravity filters, travelling bridge filters, moving bed filters, cloth-disk filters, and microfiltration membranes. Each is a solids removal technology and will only remove the phosphorus that has been reacted with chemical or taken up by the biomass. Any phosphorus remaining in soluble form will pass through the filter into the effluent. The proprietary enhanced filtration technology known as BluePro (Blue Water) is an exception in that soluble phosphorus reacts with chemical at the filter media surface.

Depth Filtration

Gravity Filters

Wastewater is applied to the top of the media bed, allowing the water to flow downward by gravity. The wastewater is then collected in underdrains that allow the wastewater to enter but retain the filter media. Once a set amount of time passes or a predetermined head loss is measured in the filter, a backwash cycle is initiated. The filter is backwashed by either water or an air/water combination that removes the trapped solids from the media. The solids are directed to the head of the plant, while the filter media are retained. After the backwash cycle is complete, the filter is placed back into service. (Usually, the entire filter must be taken out of service to be backwashed.) A supply of filtered effluent (stored in a clear well) to backwash the filter might be required. If the production rate of the filters that remain in service is greater than the required backwash rate, the clear well might not be needed. Alternatively, some filters are divided into two to four cells, which allows only one cell to be taken out of service at a time while the remaining cells continue to produce water that can be used to backwash the out-of-service cell.

If the sand or alternate medium contains a variety of particle sizes, the smaller grains might accumulate at the top of the filter. The smaller grains have smaller pore sizes, which might be filled or blinded by the wastewater at a faster rate than the larger grains. This accumulation might lead to more frequent backwashing of the filters. Using an air/water backwash system, rather than water alone, might minimize this problem by not fully fluidizing the bed.

Traveling Bridge/Automatic Backwash Filter

The automatic backwash filter or traveling bridge filter has a relatively shallow sand depth of 12 inches. The width of the unit is typically fixed at approximately 16 feet. The length of the traveling bridge filter is determined by the amount of surface area required for a given application. Wastewater is applied to the top of the sand and filters downward through the filter. The head loss across the filter is relatively low at less than 4.9 feet (WEF and ASCE 1998, pp. 16–19). A traveling bridge and backwash hood move along the filter to backwash one cell of the filter at a time. This allows the remaining filter cells to stay in operation while a portion of the filter is backwashed. The rate of backwash water generated is less because of the shallow sand bed and smaller area backwashed when compared to a conventional sand filter. In a conventional filter, the backwash might need to be stored to allow the solids to be fed slowly back to the head of the process to avoid slug loads. In contrast, a traveling bridge filter produces a relatively constant amount of backwash when the filter is in operation so backwash equalization is not necessary.

Moving-Bed Filter

A moving-bed filter cleans a portion of the granular media continuously so that operation does not need to stop to perform a backwash cycle. The filter can operate in a downflow or upflow mode. In the downflow mode, wastewater enters the top of the filter and flows downward through the media. The solids filtered from the wastewater are drawn downward with the sand. An airlift pump transfers the solids and sand to the top of the filter, where a filter washbox is located. The sand is separated from the solids by gravity. The cleaned sand is returned to the top of the filter, and the solids are returned to the plant headworks or directed to disposal.

In an upflow moving-bed filter, the wastewater enters through the bottom of the filter and is pumped upward through the sand. Solids captured in the sand move downward and are airlifted to a reject compartment through the center of the filter. The turbulence created by the air lift pumps separates the solids from the sand. The clean sand is separated from the solids by gravity. The solids are directed to the headworks of the plant, and the clean sand is deposited on top of the filter. The advantage of an upflow filter is that the wastewater encounters the sand containing the most solids first and passes through the cleanest sand before it exits the filter over a weir. Single stage upflow moving bed filters are typically guaranteed to achieve an effluent of 0.3 mg/L or less with adequate chemical addition. Backwash water generation is typically 15% of the treated water volume.

Moving Bed Filters In Series

To achieve very low effluent phosphorus concentrations, moving bed filters may be combined in a series configuration. For example, the Dynasand D2 system consists of deep bed and standard bed upflow moving bed filters in series. The deep bed filter contains coarse sand and uses a proprietary process called continuous contact filtration, which allows coagulation, flocculation, and separation to occur in the filter. The standard bed filter is filled with a finer sand mix. Both filters are continuously backwashed. The backwash water from the filters is treated in a lamella gravity settler, a high-rate gravity plate settler, to remove solids before being returned to the head of the plant. With adequate of alum upstream of each filter, the D2 process is guaranteed to achieve annual average effluent concentration of 0.03 mg/L. Figure 5.2-1 shows the process.

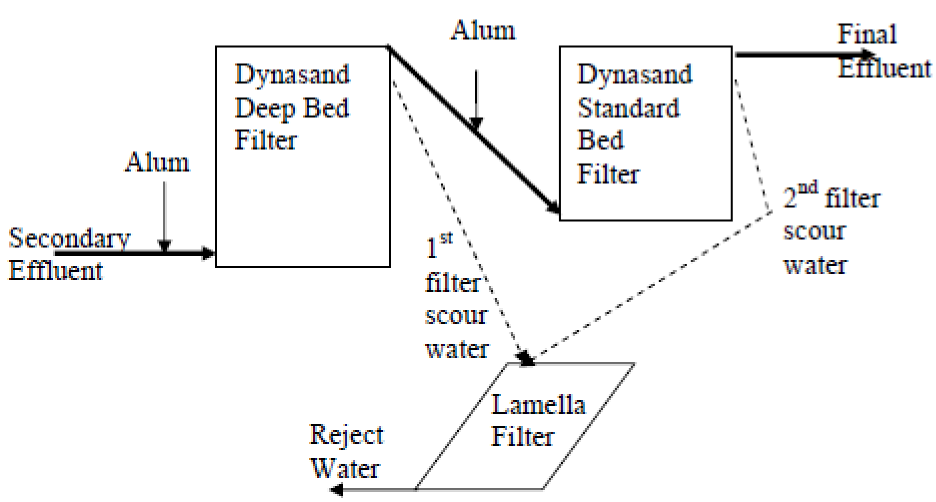


Figure 5.2-1 Schematic of Moving Bed Filters in Series

Moving Bed Filters with Ferric Oxide Coating

Another approach to moving bed filters specifically includes the feed of ferric chloride to form and maintain a hydrous ferric oxide-coated media. The BluePRO adsorption filter system uses a ferric chloride feed step followed by a proprietary pre-reactor zone and moving-bed filter. The abrasion of the sand particles against one another in the moving bed filter exposes new adsorption sites on the media. The process can be operated in a dual-stage mode with two Blue PRO filtration systems in series. The process is illustrated in Figure 5.2-2.

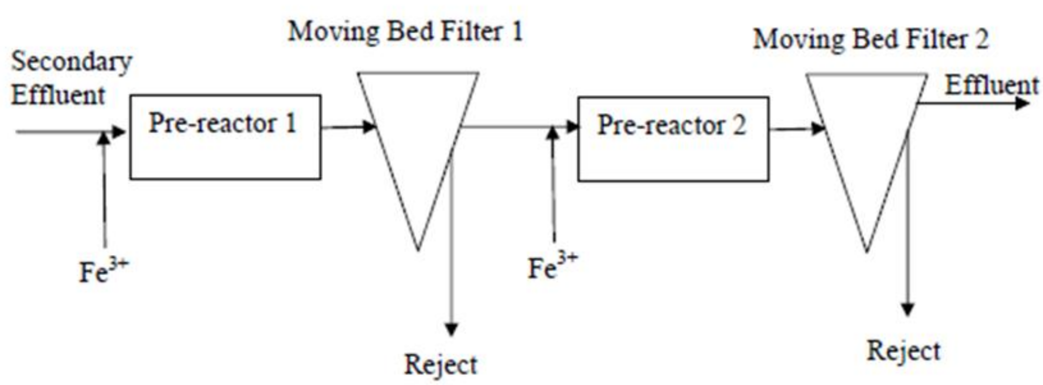


Figure 5.2-2 Schematic of Moving Bed Filters in Series with Ferric Oxide Coating

<u>Surface Filtration</u>

Cloth Disk Filters

As the name implies, cloth disk filters use specially designed cloth to filter the wastewater, rather than sand or other granular media. The cloth panels are installed vertically inside a steel or concrete tank. The wastewater submerges the cloth panels and travels horizontally through them. Solids accumulate on the outside of the cloth panels, while filtered water is collected on the inside of the panels and directed to the effluent chamber. The solids on the outside of the cloth form a mat, and the water level in the filter rises. When the water reaches a preset level, the filter is backwashed by liquid suction. The cloth filters are rotated during the backwash process. Two cloth filter panels are backwashed at a time, allowing the other panels to continue filtering water, thereby eliminating the need to have a tank to store flows for backwashing the filter. The backwashed solids are directed to the headworks of the plant. Larger solids settle to the bottom of the basin, from which they are periodically pumped out and directed to the headworks of the plant or the solids-handling process.

Cloth filters can operate at a higher hydraulic loading rate than granular media filters, resulting in a smaller footprint. The backwash rate is also reduced because there is no need to fluidize the bed as required with granular media filters. Typical backwash generation rate is between 4% and

6% of the treated flow. Cloth filters are usually installed in small plants (average flows less than 5 to 10 MGD); however, significantly larger installations have also been constructed.

Cloth disk filters, have already been installed at several of the WWTFs considered in this study including conventional activated sludge plants, SBR plants, extended aeration plants and at least one aerated lagoon. At the Richmond WWTF, an annual average effluent TP of 0.098 mg/L has been achieved with an extended aeration activated sludge plant using cloth disk filters. At the Stowe WWTF, an annual average effluent TP of 0.115 has been achieved with an SBR activated sludge plant effluent and cloth disk filters. Other Vermont WWTFs have achieved annual effluent TPs of less than 0.2 mg/L. Other WWTFs (outside the Lake Champlain basin, ex. Pickens County WWTP in Easely SC and Keowee Key WWTP in Salem SC) have achieved effluent annual average TP < 0.1 mg/L using cloth disk filters on chemically treated activated sludge process effluent. Backwash water generation is typically 5% of the treated water volume.

Membrane Filtration

Membrane filters can be used externally to remove suspended solids or can be incorporated into the activated-sludge process as a membrane bioreactor (MBR). MBR systems employ a suspended-growth biological reactor, from which effluent is passed through a membrane filter rather than using a secondary clarifier. By so doing, suspended solids and the phosphorus associated with them are effectively removed from the effluent. Membranes will retain essentially all solids including colloidals. MBRs can achieve 0.2 mg/L or less while systems using secondary clarifiers and tertiary membranes can achieve 0.04 mg/L or lower with chemical addition to the tertiary stage. Membrane life is approximately 7 to 10 years before replacement is required.

Enhanced Clarification Processes

Enhanced clarification systems include solids contact clarifiers (ex. Infilco's DensaDeg), ballasted clarifiers (ex. Veolia's Actiflo, Siemens CoMag and BioMag) and combined tertiary clarifier/filtration systems (ex. Westech's Trident HS). Each of these technologies aims to improve phosphorus removal by improving flocculation of colloidal particulates and increasing the settleability of produced solids.

Solids Contact Clarifiers

Solids contact clarifiers mix the secondary effluent with coagulants and previously settled solids, forming larger floc. After mixing in the center of the clarifier, the wastewater moves outward to the settling zone, where the solids move downward to the bottom and the treated water exits the unit over a weir. Periodically, solids are removed from the clarifier for treatment and disposal. A filter then removes solids that pass through the tertiary clarifier. The upflow buoyant-media clarifier mixes the coagulant and polymer with the secondary effluent, allows flocculation to occur, and provides clarification. A tube clarifier has inclined tubes in a portion of the clarifier. The water flows up through the tubes, and solids flow downward to the bottom of the clarifier, from which they are pumped out. Similarly, a plate clarifier has inclined plates installed in a portion of the clarifier. The water flows upward between the plates, and solids settle onto the plates and slide down to the bottom of the clarifier. For the tertiary clarification process to be successful, the velocity through the unit must be low enough to allow the solids in the secondary effluent to settle.

DensaDeg is a high-rate solids contact clarification process that consists of a reactor zone, a pre-settling/thickening zone, and a clarification zone. Metal salts are mixed with the influent to the process, and the pH is adjusted to optimize phosphorus removal based on the wastewater characteristics at the specific site. The wastewater then enters the base of the reactor and is mixed with sludge returned from the solids contact clarifier. The reactor tank contains a turbine and draft tube that promote floc formation and separate the solids. Polymer is added to increase the sludge density. In the pre-settling/thickening zone, the sludge settles to the bottom because of the increased density and continues to thicken. Sludge is returned to the reactor zone or removed from the process for further treatment. In the clarification zone, the supernatant flows up through the settling tubes as the effluent from the process. Additional phosphorus can be removed by following the process with filtration.

<u>Ballasted Clarification</u>

Sand Ballast

Actiflo is a sand-ballasted flocculation process. Metal salt and polymer are added upstream of the coagulation tank. The pH is adjusted to optimize phosphorus removal on the basis of the wastewater characteristics at the specific site and the type of polymer used. The wastewater is then mixed with fine sand and polymer. The fine sand, referred to as microsand, provides a large surface area to which the formed floc can attach; it also increases the sedimentation rate by acting as ballast. The solids are settled in a clarifier equipped with lamellar tubes. The microsand is recovered in a cyclonic separator and returned to the process.

Magnetite Ballast

The CoMag process is a magnetite ballasted clarification process. A flocculation tank with three compartments is the initial stage. In the first compartment, wastewater is mixed with a metal salt and the pH is adjusted to optimize phosphorus removal on the basis of the wastewater characteristics at the specific site. Then fine particles of magnetite are added to increase the density of the floc. In the third compartment, polymer is added to increase flocculation.

Magnetite is an inert form of iron (Fe_3O_4) that has a high density (SG > 5), about twice that of sand. Magnetite is fed into the system as a 10-20% slurry. The high density of the material makes it less useful as a nucleation agent for floc formation but appears to help build and settle flocs that have already been formed as a result of inorganic salt addition in the previous reaction step. It is estimated that the specific gravity of chemical and biological flocs is increased from 1.02-1.03 to about 1.2-1.3, leading to considerably faster settling velocities.

After ballasting, the wastewater enters a clarifier. The settled solids are returned to the flocculation tank except for a small amount of waste solids. The remaining solids are wasted from the system. An optional magnetic separator can be applied to capture any solids that passed through the clarifier. Few WWTFs need the magnetic separator.

Magnetite is recovered from the sludge waste stream (including backwash from the magnetic separator if used) by passing the sludge through a high speed shear mill and drum separator. The magnets on the drum ensure recovery rates of 95-98%. It is indicated from the manufacturer's previous experience with full-scale installations that approximately 5 pounds of magnetite is lost per 1 million gallons of water treated, or an operational cost of about $6,000 per year per MGD. The first full-scale CoMag system was installed in Concord, Massachusetts, at a 1.2 MGD municipal facility with an ultimate treatment goal of 0.2 mg/L TP. The facility has reported a consistent effluent phosphorus concentration of approximately 0.05 mg/L. The plant's reported average daily power consumption was 150 kWh. According to the EPA report "Advanced Wastewater Treatment to Achieve Low Effluent Phosphorus" (EPA 910-R-07-002) the full capital cost of the installed CoMag facility was approximately $3 million in 2007. Similarly, CoMag costs for an upgrade at the 0.51 MGD ADF Waterbury VT WWTP were estimated at $1.52 million (of an overall project cost of $6.1 million, "Village of Waterbury Vermont WWTP Upgrade Phosphorus Removal to 0.2 mg/L", Stantec, 2012).

The CoMag process is illustrated in Figure 5.2-3 and is configured as a tertiary clarifier. Using the same basic technology, the BioMag process adds the magnetic ballast and polymer upstream of the activated sludge process so that the ballast becomes incorporated into the activated sludge flocs of the mixed liquor thereby improving their settleability in the secondary clarifier.

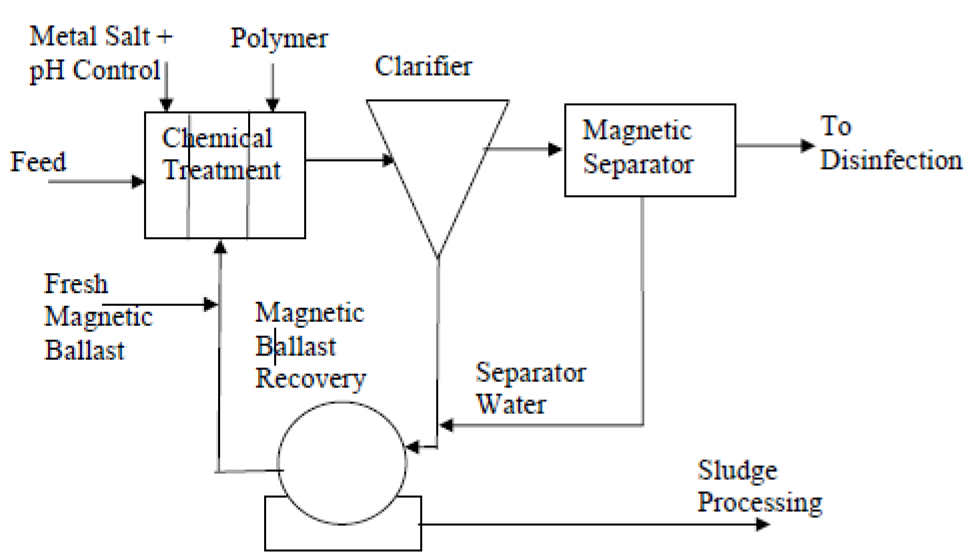


Figure 5.2-3 Schematic of Magnetite Ballasted Clarifier System

Combined Clarification and Filtration Processes

Tertiary Clarification with Filtration

The practice of adding tertiary clarifiers upstream of filters can further achieve low solids concentrations and thus low phosphorus effluent levels. Tertiary clarifiers that could be used include solids contact clarifiers, upflow buoyant-media clarifiers, tube clarifiers, plate clarifiers, and a second set of secondary clarifiers. To improve performance through the tertiary clarifiers, a coagulant, such as alum or ferric chloride, and a polymer can be added upstream of the unit.

For example, the Trident HS system consists of two clarification processes followed by filtration. Metal salts and polymer are added upstream of the tube clarifier, which contains a recycle flow of precipitated solids to decrease the variation of the influent quality entering the unit. From the tube clarifier, additional polymer is added before the wastewater enters an adsorption clarifier. The adsorption clarifier consists of a buoyant-media bed to remove additional solids before filtration. The media in the clarifier do not have any adsorption properties but rather is an upflow filter containing coarse media. The accumulated solids are flushed from the clarifier using air and water from the tube clarifier. A mixed-media gravity filter follows the two-stage clarification process for applications designed to meet phosphorus concentrations of less than 0.1 mg/L. The filter is backwashed using air and water simultaneously. The process is depicted in Figure 5.2-4.

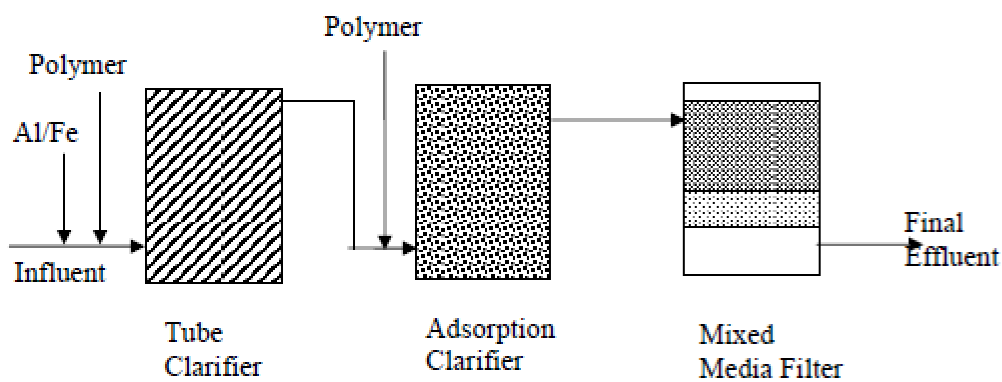


Figure 5.2-4 Schematic of Tertiary Clarification with Filtration

5.3 Enhanced Solids Removal Costs

Because of the number of treatment facilities addressed, this evaluation is not intended to identify the optimal technology for any specific WWTF. Instead, specific technologies that are representative of the filtration and enhanced sedimentation systems have been included to present a range of capital and O&M costs that would be incurred to add an enhanced solids removal step to achieve low effluent phosphorus concentrations. Basis of costs for all enhanced solids removal technologies is shown in Table 5.3-1. Engineering costs are calculated according to the Vermont ANR fee curves used by the CWSRF program (http://www.anr.state.vt.us/dec/ fed/financial/docs/FED%20Engineering%20Fee%20Allowance%20-%20Effective%209-1-11.pdf). A large contingency (25%) is used because of the generalized nature of the estimates.

Table 5.3-1 Budget Items to Add Enhanced Solids Removal to Existing WWTFs

Expense Type	Units	Value
In Place Concrete	$/CY	850
Building (w/mechanical)	$/sq ft	250
Equipment Installation	% of equipment cost	15
Electrical and Controls	% of equipment cost	15
Civil/Piping	% of equipment cost	10
Contractor Mobilization, Overhead, Profit	% of Construction cost	20
Design Engineering (prelim + final)	Per Vermont ANR fee curves used by CWSRF program	
Construction Phase Engineering		
Contingency	% Project cost	25
Electricity (avg. including demand charge)	$/KWHr	0.10

Moving Bed Filter

Moving bed filters may be installed as package units (typically in fiberglass tanks) or with the equipment installed in site constructed concrete tanks. Parkson Dynasand filters provide 50sq ft of filtration area per unit and use a design loading rate of 3.5 gpm/sq ft at ADF. Cost assumes fiberglass filters up to 4 units (1.0 MGD ADF) and concrete filters with common wall construction for larger installations. Although typical upflow filters used constant backwash generating about 15% backwash volume, with the Ecowash backwash system the Dynasand filters operate in 5 hour cycles with just 30 minutes of backwash per cycle at 10 gpm/sq ft while backwashing. This decreases both backwash volume and compressor energy for airlift pumping to backwash. All filters were assumed to be installed in a building for protection from the weather. Capital cost estimates for both package and site built moving bed filter systems are shown in Figure 5.3-1 as a function of system ADF capacity.

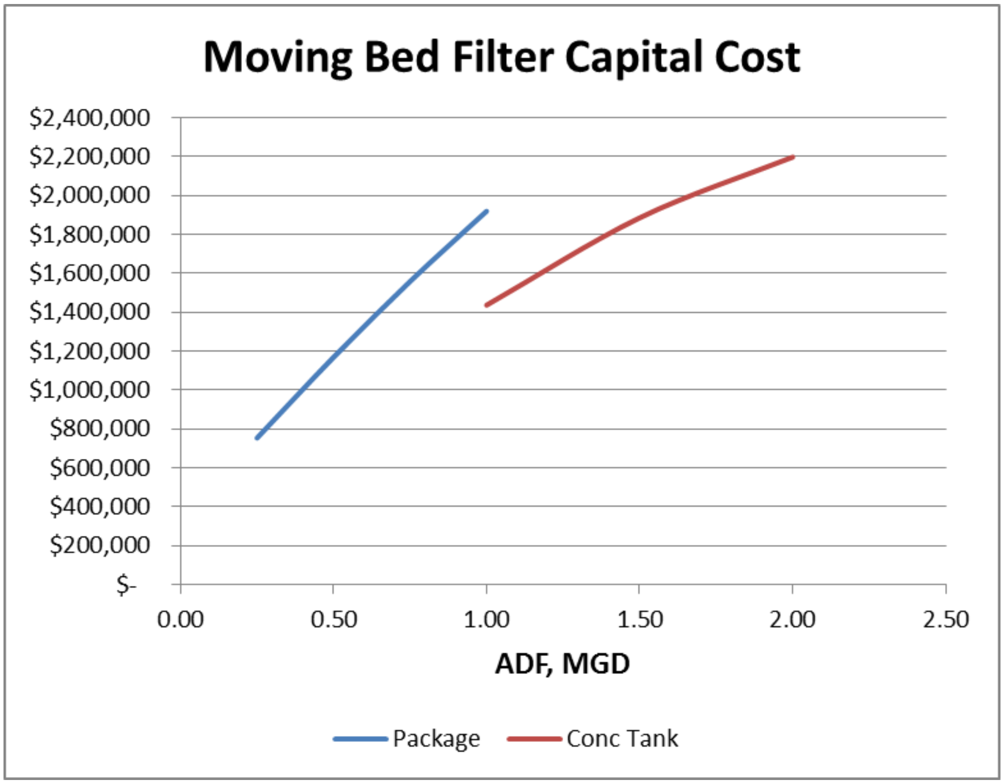


Figure 5.3-1 Capital Cost Budget for Moving Bed Filter

<u>Operation and Maintenance Costs</u>

Operation and maintenance costs for moving bed filters are based mainly on the cost to lift the flow to the filter elevation and to operate the air compressor during backwash. Required lift was assumed to be 8 feet. Pump operating head was assumed at 10 feet. Each filter uses a 5 hp compressor motor for airlift pumping during backwashing. The backwashing process is timer operated at 30 minutes out of every 5 hour cycle. A single Dynasand filter generates backwash waste at a rate of 12 gpm during backwash so approximately 360 gallons per filter per cycle or 1728 gallons per filter per day. At a capacity of 0.25 mgd per filter, this is equivalent to approximately 0.7% backwash generation. The cost for heating the filter building was estimated based on 0.25 air changes per hour and an annual average heating requirement of 24 degrees F plus a safety factor of 50%. The average cost for electricity was assumed as $0.10 per KWHr. Operating energy cost for the moving bed filter is shown in Figure 5.3-2.

<u>Footprint, and Sludge Production</u>

Footprint estimates for the moving bed filters assume 4 feet clear around each individual package filter unit. Concrete tank units are assumed to share common wall construction with 4 feet clear around the outer perimeter of the filter gang. Figure 5.3-2 shows moving bed filter system footprint.

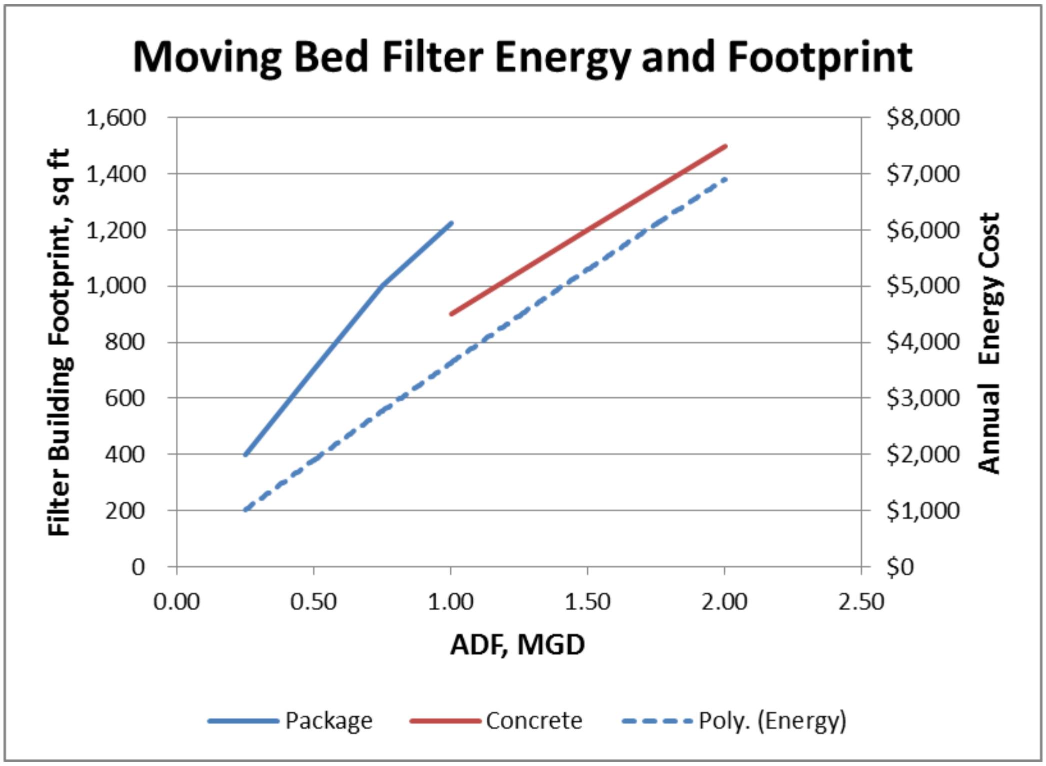


Figure 5.3-2 Annual Energy Cost and Footprint for Moving Bed Filter

Cloth Disk Filter

<u>Sizing and Capital Cost</u>

Aqua Aerobic provides its cloth disk filter technology in two unit sizes: the MiniDisk Filter which provides 12 sq ft of filter area per disk and the AquaDisk filter which provides 53.8 sq ft of filter area per disk. The MiniDisk is sold only as a package unit including a stainless steel tank. The AquaDisk is available with a painted carbon steel tank, a stainless steel tank or for installation in a site constructed concrete tank. Concrete tanks were assumed for this evaluation. All filters were assumed to be installed in a building for protection from the weather. Each MiniDisk unit can include up to six disks. Each AquaDisk unit can include up to 12 disks which are provided in pairs. Capital cost estimates for several configurations of disk filter systems are shown in Figure 5.3-3 as a function of system ADF capacity at the recommended loading rate of 3.25 gpm/sq ft ADF.

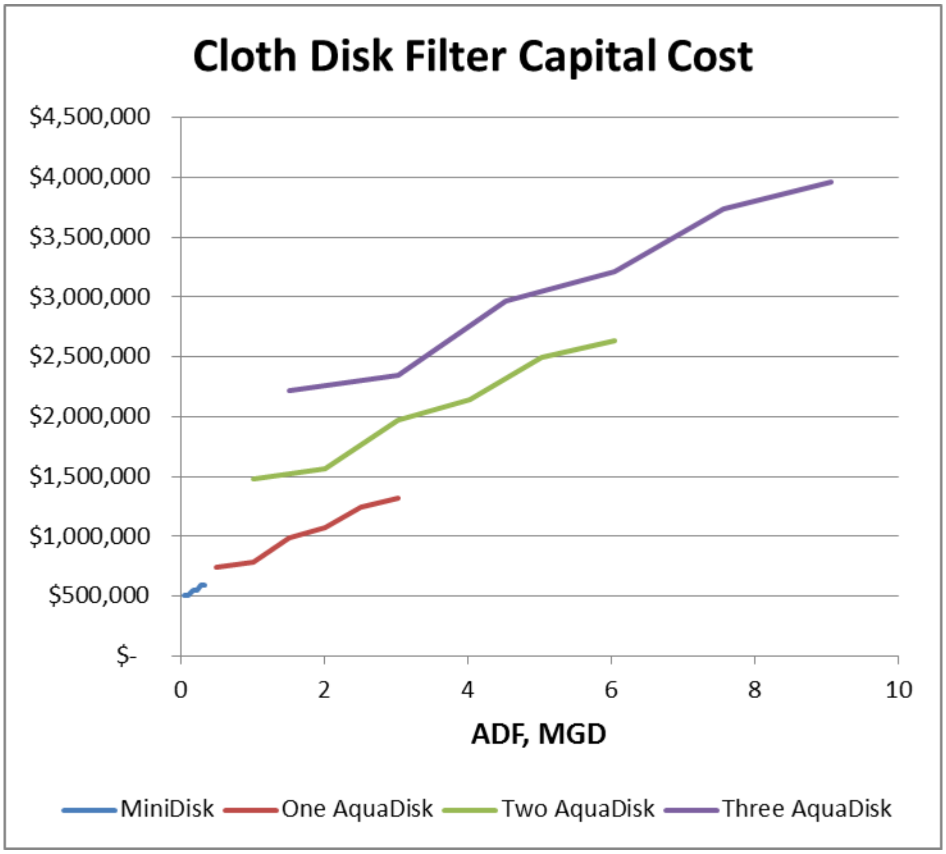


Figure 5.3-3 Capital Cost Budget for Cloth Disk Filter

The Minidisk filter option is available for ADF capacities up to 0.337 mgd. Although the MiniDisk is included in data presented in Figure 5.3-3, a capital cost curve specific to the installation of the MiniDisk and at a scale more appropriate to flows less than 0.4 mgd is included as Figure 5.3-4.

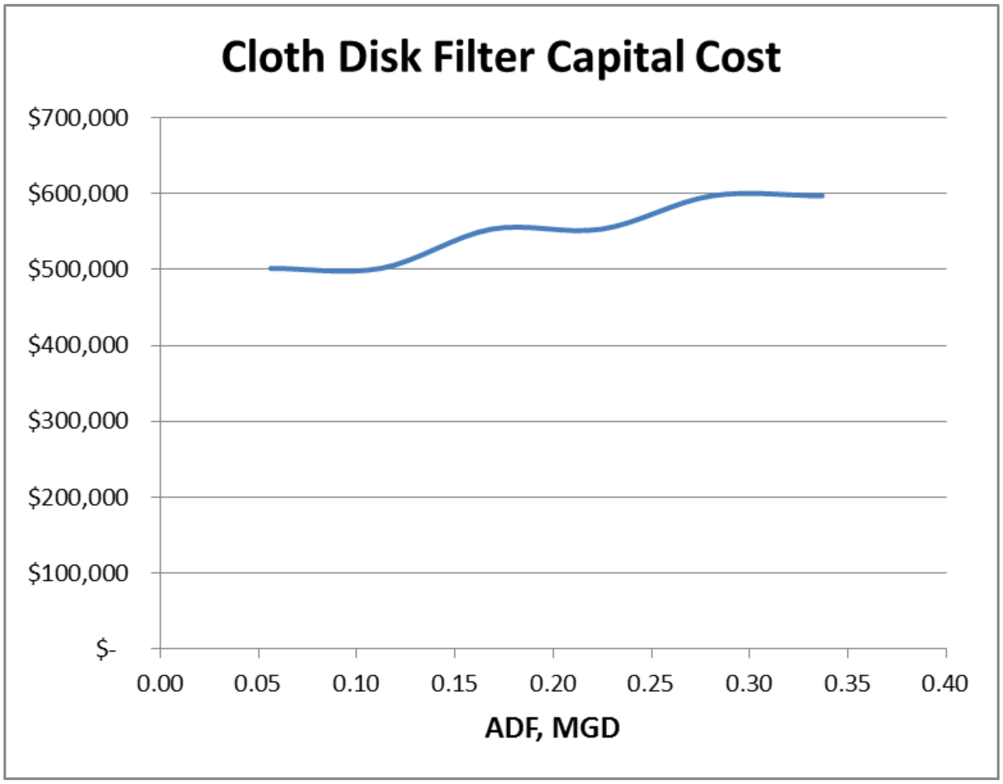


Figure 5.3-4 Capital Cost Budget Estimate for Small Cloth Disk Filter

Operation and Maintenance Costs

Operation and maintenance costs for cloth disk filters are minimal. Each filter uses a fractional hp motor to turn the disks during backwashing. For energy cost estimates 0.25 hp was assumed. The backwashing process typically occurs daily for no more than 15 minutes per pair of disks. The disk filter generates backwash waste at a rate of between 4% and 6% of the treated flow. Backwash pump head is determined by the elevation and length of pipe to the backwash return point (usually the headworks) rather than headloss at the filter. For energy estimates, pump operating head was assumed as 25 feet, backwash waste was assumed at 5% of treated flow. The cost for heating the filter building was estimated based on 0.25 air changes per hour and an annual average heating requirement of 24 degrees F plus a safety factor of 50%. The average cost for electricity was assumed as $0.10 per KWHr. Operating energy cost for the cloth disk filter is shown in Figure 5.3-5.

Footprint and Sludge Production

Due to the vertical configuration of the disks, footprint is also relatively small. Footprint estimates assume 4 feet clear around each single filter units. Multiple units are assumed to share common wall construction with 4 feet clear around the outer perimeter of the filter gang. Figure 5.3-5 shows cloth disk filter footprint.

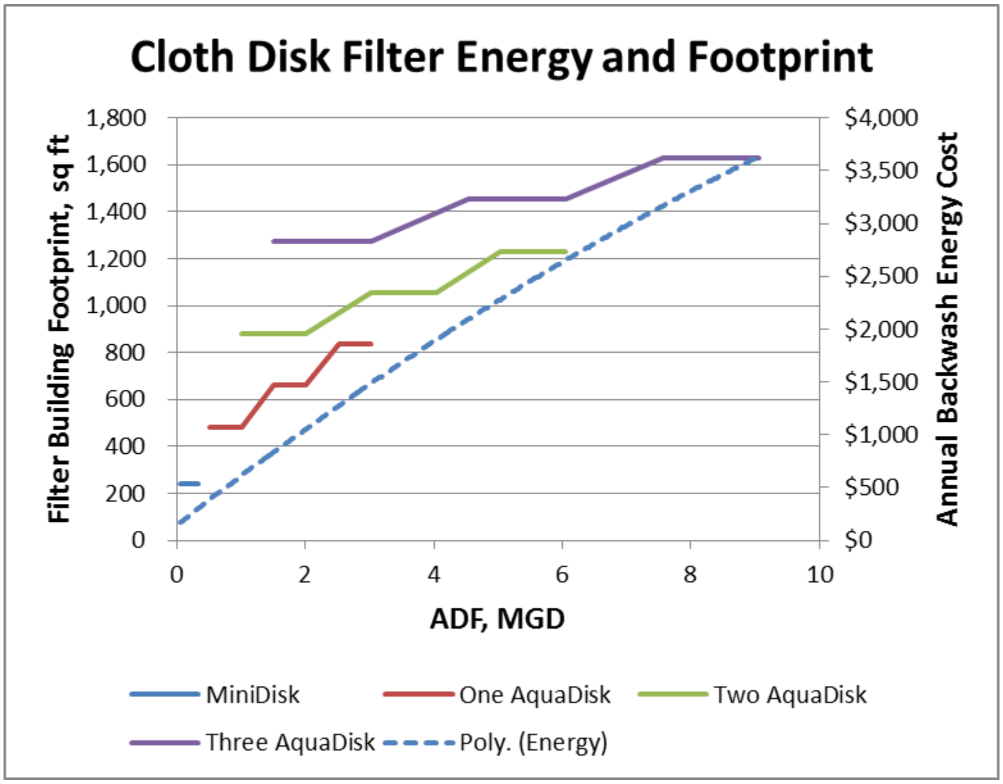


Figure 5.3-5 Annual Energy Cost and Footprint for Cloth Disk Filter

Ballasted Clarification

Ballasted clarification systems may be installed with site built or package clarifiers. Kruger's Actiflo system is one of the most widely installed and was used as the basis for this evaluation. The Actiflo system is provided as a package to be installed on a concrete pad. The smallest unit is capable of up to 0.5 mgd. All ballasted clarifiers were assumed to be installed in a building for protection from the weather. Capital cost estimates for ballasted clarifier systems are shown in Figure 5.3-6 as a function of system ADF capacity.

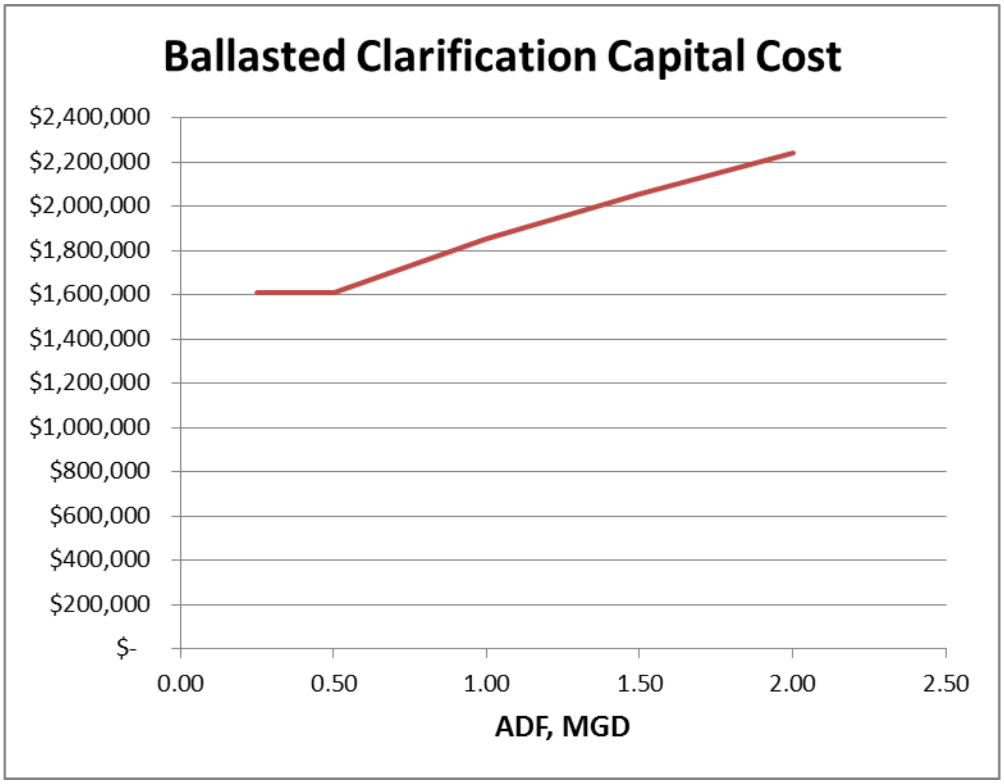


Figure 5.3-6 Capital Cost Budget for Ballasted Clarification

<u>Operation and Maintenance Costs</u>
Operation and maintenance costs for the Actiflo ballasted clarifier system include the power to operate the motors including:

- Pre-Coagulation Tank Mixer
- Coagulation Tank Mixer
- Maturation Tank Mixer
- Scraper Motor
- Sand Recirculation Pump

A 5.0 hp motor is used for sand circulation and 0.5 hp for the scraper motor. Mixer motor sizes vary depending on the design capacity. The cost for heating the clarification building was estimated based on 0.25 air changes per hour and an annual average heating requirement of 24 degrees F plus a safety factor of 50%. The average cost for electricity was assumed as $0.10 per KWHr. Operating energy cost for Actiflo systems is shown in Figure 5.3-7.

In addition to power, the ballasted clarifier would require polymer at approximately 0.3 mg/L dosage rate and makeup microsand at a rate of approximately 1 mg/L treated. Cost for these commodities is assumed at $5100 per ton and $200 per ton respectively. These costs are shown in Table 5.3-1.

Table 5.3-1 Annual Cost for Polymer and Sand for Ballasted Clarification

ADF MGD	Polymer $/year	Sand $/year
0.25	$ 582	$ 76
0.5	$ 1,164	$ 152
1	$ 2,329	$ 304
1.5	$ 3,493	$ 457
2	$ 4,657	$ 609

Footprint and Sludge Production

Footprint estimates for the ballasted clarifiers assume 4 feet clear around each individual package clarifier unit. Figure 5.3-7 shows ballasted clarifier system footprint.

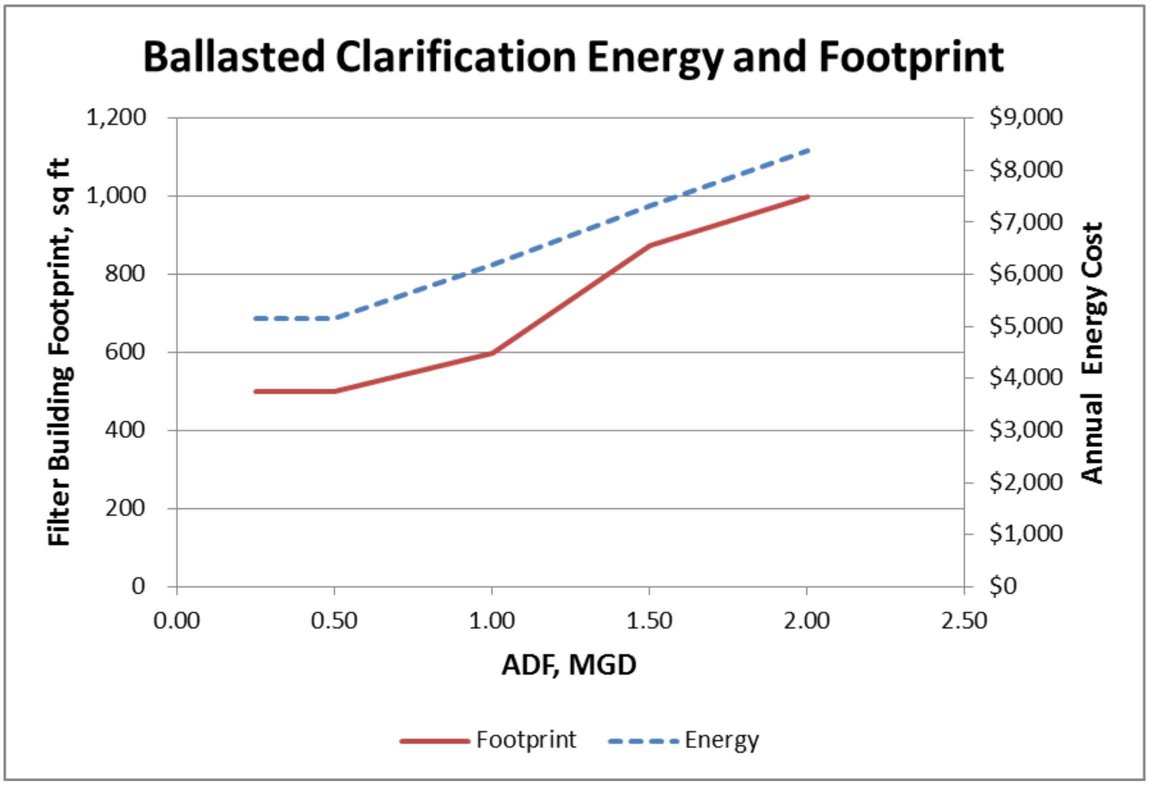


Figure 5.3-7 Annual Energy Cost and Footprint for Ballasted Clarification

6 Phosphorus Removal Improvements and Costs

6.1 Basis for Process Recommendations

As described in Sections 1 and 2, this evaluation is to consider three effluent phosphorus concentration goals:

1.0 mg/L TP
0.2 mg/L TP
0.1 mg/L TP

Many of the facilities under consideration are already achieving one or more of these performance goals. For facilities not yet achieving one or more of the effluent TP goals, this evaluation will consider only chemical treatment (combined with enhanced solids removal where applicable) if the design ADF is less than 1.0 MGD. For facilities with design flow greater than 1.0 MGD, this evaluation will consider a combination of EBPR and chemical phosphorus removal (again, combined with enhanced solids removal where applicable).

6.2 Cost to Achieve 1.0 mg/L TP

Vermont WWTPs

In Section 2, historical performance of each of the 60 Vermont WWTPs was charted and described. One of the Vermont WWTFs is no longer in service. Six of the WWTFs are already able to achieve the most stringent standard of 0.1 mg/L TP. The remaining 52 Vermont WWTFs have been evaluated for the improvements that would allow them to meet the phosphorus standards that they have not already demonstrated.

As shown in Table 6.2-1, thirteen of the WWTFs require additional treatment to achieve the 1.0 mg/L TP effluent standard. Several of these (six) are aerated lagoon facilities, two are extended aeration plants, one is an SBR, one is an RBC plant, one is a Sequox activated sludge facility, and one uses sand filtration.

Table 6.2-1 Vermont WWTFs – Evaluate Chemical P Removal to Achieve 1.0 mg/L TP

Facility Name	Process Type
Benson	Aerated Lagoon
Fairfax	Aerated Lagoon
Jeffersonville	Aerated Lagoon
Marshfield	Aerated Lagoon
Orwell	Aerated Lagoon
Otter Valley Union High School	Lagoons w/ clarifier and filter
Pittsford	Sequox activated sludge
Plainfield	SBR

Facility Name	Process Type
Sheldon Springs	Extended Aeration
Shoreham	Sand Filtration
Wallingford	Extended Aeration
West Pawlet	RBC
Williamstown	Aerated Lagoon

New York WWTPs

In Section 2, historical performance of each of the 30 New York WWTPs was charted and described. Two of the New York WWTFs are no longer in service. One of the WWTFs is already able to achieve the most stringent standard of 0.1 mg/L TP. The remaining 27 New York WWTFs have been evaluated for the improvements that would allow them to meet the phosphorus standards that they have not already demonstrated.

As shown in Table 6.2-2, eight of the WWTFs require additional treatment to achieve the 1.0 mg/L TP effluent standard. All but one of these is designed to treat less than 1 MGD ADF so chemical phosphorus removal will be the sole process considered for those evaluations. However, the Dannemora WWTF is designed to treat up to 1.5 MGD and treated just over 1.0 MGD in 2011. If that facility is a type of activated sludge process (conventional, extended aeration, or SBR) modification of the process to incorporate EBPR should also be considered.

Table 6.2-2 New York WWTFs – Evaluate Chemical P removal to Achieve 1.0 mg/L TP

Facility Name	Facility Name
Au Sable Forks	St Armand
Cadyville	Wadhams
Crown Point	Westport
Dannemora	Willsboro

Capital Cost

To achieve 1.0 mg/L TP in the effluent of these facilities, either alum or ferric would be fed directly to the lagoon (as is being done at Hardwick, Hinesburg, Proctor, and Richford lagoons that are all achieving less than 0.5 mg/L TP), fed just upstream of the clarifier (for those facilities with clarifiers), or fed at the end of the aeration cycle just before settling for the SBR plants.

Based on equipment costs presented in Section 3, chemical feed would require a pair of chemical metering pumps with flow pacing at an equipment expense of approximately $6000. Other costs would include the equipment installation, electrical and controls, and piping. The metering pumps should be installed in a building with space provided for storage of the chemical (either drums, totes, or bulk tank) and spill containment. For configurations of drums, totes, or a single 1000 gallon bulk tank (all but Dannemora), a building of approximately 12 ft x 12 ft ($36,000 @

$250/sq ft) would be appropriate. As described in Section 2, the expense for a single 1000 gallon bulk tank would be approximately $2000 delivered. Because the cost for pumps and storage building would not change appreciably but chemical cost would be lower, the bulk tank should be considered for all but the smallest facilities. With the bulk tank, the cost for a small chemical feed system with building is shown in Table 6.2-3. Without the bulk tank, the cost would be approximately $4300 less. These estimates are for a "typical" facility. Site specific costs may be significantly higher or lower. For instance, some facilities may need significant improvements to roads in order to receive chemical deliveries. Other facilities may have existing chemical storage and feed systems with sufficient capacity to provide the increased dose without additional capital expense.

Table 6.2-3 Estimated Capital Cost for Chemical Feed to Achieve 1.0 mg/L TP

Item	Number or Size	Rate	Estimated Cost
Metering Pumps	2	$3000	$6000
Bulk Tank	1 @ 1000 gal	$2000	$2000
Installation	LS		$1500
Electrical/I&C	LS		$1500
Containment	1.5 CY	$800/CY	$1200
Civil/Piping	LS		$2000
Building	144 sq ft	$250/sq ft	$36,000
Construction total			$50,200
Contractor's OH&P		20%	$10,040
Contractor total			$60,240
Design Engineering	Per Vermont ANR fee curves used by CWSRF program		$4128
Construction Engineering			$6192
Project			$80,595
Contingency		25%	$20,149
Budget			$100,744

Without EBPR for the Dannemora WWTF, chemical storage of up to 5000 gallons would be appropriate due to the greater treated flow and chemical consumption. That storage volume would require a more costly tank ($10,000) and building dimensions of approximately 14 ft x 16 ft (224 sq ft) bringing the total capital budget for a chemical feed system at Dannemora to approximately $153,142.

O&M Cost

Chemicals

As described in Section 3, chemicals constitute the bulk of the operational cost of any chemical phosphorus treatment system. Tables 6.2-4 and 6.2-5 provide estimates of the cost for chemical to remove phosphorus to 1.0 mg/L TP at the current ADF for each WWTF.

Table 6.2-4 Vermont WWTFs – Estimated Monthly Chemical Cost to Achieve 1.0 mg/L TP

Vermont Facilities	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	**1.0** mg/L TP limit							
			Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)					
	MGD	*mg/L*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*
Benson	0.015	2.334	4.57	2.67	$32	$31	-	$132	$125	-
Fairfax	0.035	4.633	12.45	7.28	$203	$195	-	-	$796	$354
Jeffersonville	0.036	6.850	20.04	11.72	-	$323	$224	-	-	$586
Marshfield	0.020	4.009	10.31	6.03	$97	$93	-	-	$381	$169
Orwell	0.021	2.703	5.83	3.41	$58	$55	-	-	$226	$100
Otter Valley Union High School	0.002	6.095	17.46	10.21	$14	$14	-	$59	$56	-
Pittsford	0.066	2.019	3.49	2.04	$107	$103	-	-	$419	$186
Plainfield	0.059	2.550	5.31	3.11	$146	$140	-	-	$572	$254
Sheldon Springs	0.018	2.477	5.06	2.96	$41	$40	-	$171	$162	-
Shoreham	0.010	5.480	15.35	8.98	$69	$67	-	-	$272	$121
West Pawlet	0.015	5.968	17.02	9.95	$117	$113	-	-	$459	$204
Wallingford	0.071	1.903	3.09	1.81	$102	$98	-	-	$398	$177
Williamstown	0.070	2.905	6.53	3.82	$210	$202	-	-	$825	$367

Table 6.2-5 New York WWTFs – Estimated Monthly Chemical Cost to Achieve 1.0 mg/L TP

New York Facilities	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	**1.0** mg/L TP limit							
			Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)					
Facility Name	*MGD*	*mg/L*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*
Au Sable Forks	0.059	3.955	10.12	5.92	-	$267	$185	-	$1,088	$484
Cadyville	0.003	2.554	5.32	3.11	$8	$8	-	$35	$33	-
Crown Point	0.031	3.719	9.32	5.45	$134	$129	-	-	$524	$233
Dannemora	0.877	2.201	4.12	2.41	-	$1,605	$1,113	-	-	$2,910
St Armand	0.040	4.297	11.29	6.61	$207	$199	-	-	$812	$361
Wadhams	0.006	3.765	9.47	5.54	$26	$25	-	$109	$103	-
Westport	0.136	1.677	2.32	1.36	$146	$141	-	-	$573	$255
Willsboro	0.041	3.066	7.08	4.14	$133	$128	-	-	$523	$232

<u>Power</u>

Cost for constant operation of a small chemical feed pump was estimated in Section 3 at approximately $11 per month or $132 annually. The cost for heating the chemical building is estimated based on 0.25 air changes per hour and an annual average heating requirement of 24 degrees F plus a safety factor of 50%. At $0.10/KWhr heating a 12' x 12' building is estimated at $114/yr. Heating for the larger building needed for Dannemora is estimated at $177/yr.

<u>Lab Supplies and Mechanical Equipment Maintenance</u>

Costs for lab supplies and maintenance materials for the chemical feed systems should be relatively minor for a properly designed system. A total of $100 per month is estimated.

Alkalinity Consumption and Increased Sludge Production

Chemical addition for phosphorus removal will consume alkalinity and increase the quantity of sludge generated at each facility in proportion to the quantity of chemical added as shown in Table 6.2-6 and 6.2-7.

Table 6.2-6 Vermont WWTFs – Estimated Alkalinity Consumed and Sludge Produced to Achieve 1.0 mg/L TP

Vermont Facilities	1.0 mg/L TP limit			
	Alkalinity Consumed (Fe/Al)		Increase in Sludge Mass (Fe/Al)	
	mg/L		lbs/day	
Benson	1.9	9.7	1.5	1.4
Fairfax	5.3	26.4	9.8	8.9
Jeffersonville	8.5	42.5	16.2	14.8
Marshfield	4.4	21.9	4.7	4.3
Orwell	2.5	12.4	2.8	2.5
Otter Valley Union High School	7.4	37.0	0.7	0.6
Pittsford	1.5	7.4	5.1	4.7
Plainfield	2.3	11.3	7.0	6.4
Sheldon Springs	2.1	10.7	2.0	1.8
Shoreham	6.5	32.5	3.3	3.1
West Pawlet	7.2	36.1	5.6	5.2
Wallingford	1.3	6.6	4.3	4.5
Williamstown	2.8	13.8	10.1	9.3

Table 6.2-7 New York WWTFs – Estimated Alkalinity Consumed and Sludge Produced to Achieve 1.0 mg/L TP

New York Facilities	1.0 mg/L TP limit			
	Alkalinity Consumed (Fe/Al)		Increase in Sludge Mass (Fe/Al)	
Facility Name	*mg/L*		*lbs/day*	
Au Sable Forks	4.3	21.5	13.3	12.2
Cadyville	2.3	11.3	0.4	0.4
Crown Point	4.0	19.8	6.4	5.9
Dannemora	1.7	8.7	80.3	73.6
St Armand	4.8	24.0	10.0	9.1
Wadhams	4.0	20.1	1.3	1.2
Westport	1.0	4.9	7.0	6.4
Willsboro	3.0	15.0	6.4	5.9

For lagoon facilities, the increase in sludge production will accelerate the frequency with which solids must be removed from the system and the cost of transporting and disposing of those solids. For the activated sludge systems (including EA and SBR) the chemical sludge will become a part of the mixed liquor as a result of solids recycle and retention. The mixed liquor suspended solids (MLSS) concentration may need to be increased to maintain the mass of volatile solids necessary to provide the biological treatment. If the facility is already operating at an MLSS that approaches the design solids loading limit for the clarifiers, additional clarifiers or aeration basin volume may be required. For RBC systems, the chemically generated sludge will increase the solids loading to the clarifiers. If the RBC system clarifiers are inadequate to the increase, additional clarifiers may be needed.

6.3 Cost to Achieve 0.1 mg/L TP

Vermont WWTPs

As shown in Tables 6.3-1, seven Vermont WWTPs are already achieving less than 0.2 mg/L TP but need additional treatment to achieve 0.1 mg/L TP.

Table 6.3-1 Vermont WWTFs – Evaluate Chemical P Removal to Achieve 0.1 mg/L TP

Facility Name	Process Type
Barre City	Activated Sludge
Brandon	Oxidation Ditches
Cabot	MBR
Castleton	SBR
Poultney	SBR
Richmond	Extended Aeration w cloth disk filters
Stowe	SBR w cloth disk filters

Filters are used at Richmond, Stowe, and Cabot to achieve the low effluent suspended solids needed for very low TP compliance. However, Barre, Brandon, Castleton and Poultney are also achieving very low effluent suspended solids without the use of polymers, filters, or any other type of enhanced solids removal. Although they are using different processes, each of these facilities is producing clarified effluent near 3 mg/L TSS consistently without filtration. Excellent clarification requires that the chemical solids generated by chemical addition must be well flocculated with the highly settleable biological solids. Two of these facilities are SBRs with the associated settling benefits but not all SBRs achieve the consistent settleability exhibited by the Castleton and Poultney facilities. Barre and Brandon use traditional clarifiers that appear to perform extremely well. The settleability at these plants tend to range from 70 to 105 ml/L as SVI. Clarifier overflow rates at these facilities average 320 gpd/sq ft and 220 gpd/sq ft respectively at 2011 flows and would be 402 gpd/sq ft and 363 gpd/sq ft at design flows.

These overflow rates are at or less than the common design guideline of 400 gpd/sq ft but are relatively common in practice so do not fully explain the excellent clarifier performance. Without more information, there is no lesson to be drawn from these facilities that can be replicated at others to assure excellent TS removal.

If VTDEC required the facilities at Barre, Brandon, Castleton, and Poultney to install filters to increase the potential for consistent compliance at increased flows, additional cost would be incurred. Based on the filter cost curves developed in Section 4, the additional capital cost is estimated at \$2.14 million, \$0.78 million, \$0.74 million, and \$0.74 million respectively.

New York WWTPs

As shown in Table 6.3-2, three New York WWTPs are already achieving less than 0.2 mg/L TP but need additional treatment to achieve 0.1 mg/L TP. Although not reported, it is assumed that these facilities include effluent filtration or will otherwise continue to achieve the excellent effluent solids removal necessary for very low TP compliance.

Table 6.3-2 New York WWTFs – Evaluate Chemical P Removal to Achieve 0.1 mg/L TP

Facility Name
Chazy
International Paper
Keeseville

Capital Cost

The WWTFs that are currently achieving less than 0.2 mg/L TP are assumed to be using chemical addition for phosphorus removal. To achieve lower levels of effluent phosphorus at these facilities would require increased chemical dosage and possibly additional bulk chemical storage.

If sufficient storage space is not currently available, chemical feed system upgrades to handle additional drums, totes, or a single 1000 gallon bulk tank would require a building of approximately 12 ft x 12 ft (\$36,000 @ \$250/sq ft). If a new building is needed, an additional pair of chemical metering pumps with flow pacing would be needed at the new chemical storage at an equipment expense of approximately \$6000. Other costs would include the equipment installation, electrical and controls, and piping. As described in Section 2, the expense for a single 1000 gallon bulk tank would be approximately \$2000 delivered. Because the cost for pumps and storage building would not change appreciably but chemical cost would be lower, the bulk tank should be considered for all but the smallest facilities. With the bulk tank, the cost for a supplemental chemical feed system and building (to augment the existing chemical storage and feed system) is shown in Table 6.3-3. Without the bulk tank, the cost would be approximately $4300 less.

Table 6.3-3 Estimated Capital Cost for Chemical Feed to Achieve 0.1 mg/L TP

<table>
<tr><th>Item</th><th>Number or Size</th><th>Rate</th><th>Estimated Cost</th></tr>
<tr><td>Metering Pumps</td><td>2</td><td>$3000</td><td>$6000</td></tr>
<tr><td>Bulk Tank</td><td>1 @ 1000 gal</td><td>$2000</td><td>$2000</td></tr>
<tr><td>Installation</td><td>LS</td><td></td><td>$1500</td></tr>
<tr><td>Electrical/I&C</td><td>LS</td><td></td><td>$1500</td></tr>
<tr><td>Containment</td><td>1.5 CY</td><td>$800/CY</td><td>$1200</td></tr>
<tr><td>Civil/Piping</td><td>LS</td><td></td><td>$2000</td></tr>
<tr><td>Building</td><td>144 sq ft</td><td>$250/sq ft</td><td>$36,000</td></tr>
<tr><td>Construction total</td><td></td><td></td><td>$50,200</td></tr>
<tr><td>Contractor’s OH&P</td><td></td><td>20%</td><td>$10,040</td></tr>
<tr><td>Contractor total</td><td></td><td></td><td>$60,240</td></tr>
<tr><td>Design Engineering</td><td colspan="2" rowspan="2">Per Vermont ANR fee curves used by CWSRF program</td><td>$4128</td></tr>
<tr><td>Construction Engineering</td><td>$6192</td></tr>
<tr><td>Project</td><td></td><td></td><td>$80,595</td></tr>
<tr><td>Contingency</td><td></td><td>25%</td><td>$20,149</td></tr>
<tr><td>Budget</td><td></td><td></td><td>$100,744</td></tr>
</table>

Without EBPR for the International Paper WWTF, chemical storage of up to 5000 gallons would be appropriate due to the greater treated flow and chemical consumption. That storage volume would require a more costly tank ($10,000) and building dimensions of approximately 14 ft x 16 ft (224 sq ft) bringing the total capital budget for a chemical feed system at International Paper to approximately $153,142.

O&M Cost

Chemicals

As described in Section 3, chemicals constitute the bulk of the operational cost of any chemical phosphorus treatment system. Tables 6.3-4 and 6.3-5 provide estimates of the cost for chemical to remove phosphorus to 0.1 mg/L TP at the current ADF for each WWTF.

Table 6.3-4 Vermont WWTFs – Estimated Monthly Chemical Cost to Achieve 0.1 mg/L TP

Vermont Facilities	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	0.1 mg/L TP limit							
			Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)					
	MGD	mg/L	mg/L		D	T	B	D	T	B
Barre City	2.879	0.162	0.33	0.17	$434	$417	$289	-	$1,551	$689
Brandon	0.422	0.235	0.71	0.38	$138	$132	-	-	$492	$219
Cabot	0.026	0.223	0.64	0.34	$8	$7	-	$29	$27	-
Castleton	0.366	0.201	0.53	0.28	$89	$86	-	$336	$318	$141
Poultney	0.265	0.133	0.17	0.09	$21	$20	-	$79	$75	-
Richmond	0.075	0.146	0.24	0.13	$8	$8	-	$32	$30	-
Stowe	0.310	0.286	0.97	0.52	$139	$134	-	-	$498	$221

Table 6.3-5 New York WWTFs – Estimated Monthly Chemical Cost to Achieve 0.1 mg/L TP

New York Facilities	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	0.1 mg/L TP limit							
			Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)					
Facility Name	MGD	mg/L	mg/L		D	T	B	D	T	B
Chazy	0.037	0.547	2.34	1.25	$40	$39	-	$152	$144	-
International Paper	15.148	0.153	0.28	0.15	-	$1,863	$1,291	-	-	$3,078
Keeseville	0.359	0.161	0.32	0.17	$53	$51	-	$200	$189	-

<u>Power</u>

Cost for constant operation of a small chemical feed pump was estimated in Section 3 at approximately $11 per month or $132 annually. The cost for heating the chemical building is estimated based on 0.25 air changes per hour and an annual average heating requirement of 24 degrees F plus a safety factor of 50%. At $0.10/KWhr heating a 12' x 12' building is estimated at $114/yr. Heating for the larger building needed for International Paper is estimated at $177/yr.

<u>Lab Supplies and Mechanical Equipment Maintenance</u>

Costs for lab supplies and maintenance materials for the chemical feed systems should be relatively minor for a properly designed system. A total of $100 per month is estimated.

<u>Alkalinity Consumption and Increased Sludge Production</u>

Chemical addition for phosphorus removal will consume alkalinity and increase the quantity of sludge generated at each facility in proportion to the quantity of chemical added as shown in Tables 6.3-6 and 6.3-7.

Table 6.3-6 Vermont WWTFs – Estimated Alkalinity Consumed and Sludge Produced to Achieve 0.1 mg/L TP

Vermont Facilities	0.1 mg/L TP limit			
	Alkalinity Consumed (Fe/Al)		Increase in Sludge Mass (Fe/Al)	
	mg/L		*lbs/day*	
Barre City	0.4	0.7	18.8	15.9
Brandon	0.8	1.6	6.0	5.0
Cabot	0.8	1.4	0.3	0.3
Castleton	0.6	1.2	3.9	3.3
Poultney	0.2	0.4	0.9	0.8
Richmond	0.3	0.5	0.4	0.3
Stowe	1.2	2.2	6.0	5.1

Table 6.3-7 New York WWTFs – Estimated Alkalinity Consumed and Sludge Produced to Achieve 0.1 mg/L TP

New York Facilities	0.1 mg/L TP limit			
	Alkalinity Consumed (Fe/Al)		Increase in Sludge Mass (Fe/Al)	
Facility Name	*mg/L*		*lbs/day*	
Chazy	2.8	5.2	1.7	1.5
International Paper	0.3	0.6	84.1	71.1
Keeseville	0.4	0.7	2.3	1.9

For activated sludge systems (including EA and SBR) the chemical sludge will become a part of the mixed liquor as a result of solids recycle and retention. The mixed liquor suspended solids (MLSS) concentration may need to be increased to maintain the mass of volatile solids necessary to provide the biological treatment. If the facility is already operating at an MLSS that approaches the design solids loading limit for the clarifiers, additional clarifiers or aeration basin volume may be required.

6.4 Cost to Achieve 0.2 mg/L and 0.1 mg/L TP

Vermont WWTPs

Tables 6.4-1 shows the 31 Vermont WWTPs that are achieving at least 1.0 mg/L effluent TP but are not achieving less than 0.2 mg/L TP. These WWTPs have been evaluated to determine the needs to bring them to compliance with both the 0.2mg/L TP limit and a more stringent 0.1 mg/L TP limit.

Table 6.4-1 Vermont WWTFs – Evaluate Chemical P Removal to Achieve 0.2 mg/L TP and 0.1 mg/L TP

Facility Name	Process Type
Burlington East	Activated Sludge
Burlington Main	Activated Sludge
Burlington North	Activated Sludge
Enosburg Falls	Extended Aeration w Bio-P
Essex Junction	Extended Aeration w cloth disk filtration
Fair Haven	Extended Aeration w selector zones
Hardwick	Aerated Lagoon w anaerobic zone and chemical addition
Hinesburg	Aerated Lagoon w chemical addition
IBM	Not Reported
Johnson	SBR
Middlebury	SBR
lton	SBR
Montpelier	Activated Sludge
Morrisville	SBR
Newport Center	Subsurface
North Troy	Extended Aeration
Northfield	SBR
Proctor	Aerated Lagoon w chemical addition
Richford	Aerated Lagoon w chemical addition
Rock Tenn	Aerated lagoon/activated sludge
Rutland City	Extended Aeration
Shelburne #1	SBR w cloth disk filters
Shelburne #2	SBR w cloth disk filters
South Burlington Airport Parkway	Activated Sludge w cloth disk filters
South Burlington Bartlett Bay	Extended Aeration w cloth disk filters
St. Albans City	Trickling Filter/RBC w granular filters
Swanton	Aerated Lagoon w clarifiers
Troy/Jay	SBR
Vergennes	Aerated Lagoon w cloth disk filters
West Rutland	SBR
Winooski	Extended Aeration

New York WWTPs

As shown in Table 6.4-2, 16 New York WWTPs have been evaluated for the improvements needed to bring them to compliance with both the 0.2mg/L TP limit and a more stringent 0.1 mg/L TP limit.

Table 6.4-2 New York WWTFs – Evaluate Chemical P Removal to Achieve 0.2 mg/L TP and 0.1 mg/L TP

Facility Name	Facility Name
Altona Correctional	Peru/Valcour
Champlain	Plattsburgh
Dannemora	Port Henry
Essex	Rouses Point
Fort Ann	Saranac Lake
Granville	Ticonderoga
Great Meadows Correctional	Washington Correctional
Lake Placid	Whitehall
Peru	

Capital Cost

WWTFs that are currently achieving less than 1.0 mg/L TP but not less than 0.2 mg/L are assumed to be using chemical addition for phosphorus removal and would require increased chemical dosage and possibly additional bulk chemical storage to achieve the lower TP level. Enhanced solids removal would also be needed to reliably comply with either the 0.2 mg/L or the 0.1 mg/L limits.

Chemical Feed System

If sufficient storage space is not currently available, chemical feed system upgrades to handle additional drums, totes, or a single 1000 gallon bulk tank would require a building of approximately 12 ft x 12 ft ($36,000 @ $250/sq ft). If a new building is needed, an additional pair of chemical metering pumps with flow pacing would be needed at the new chemical storage at an equipment expense of approximately $6000. Other costs would include the equipment installation, electrical and controls, and piping. As described in Section 3, the expense for a single 1000 gallon bulk tank would be approximately $2000 delivered. Because the cost for pumps and storage building would not change appreciably but chemical cost would be lower, the bulk tank should be considered for all but the smallest facilities. With the bulk tank, the cost for a supplemental chemical feed system and building (to augment the existing chemical storage and feed system) up to a 1000 gallon storage requirement is shown in Table 6.4-3. Without the bulk tank, the cost would be approximately $4300 less.

Table 6.4-3 Estimated Capital Cost for Chemical Feed to Achieve 0.2 mg/L and 0.1 mg/L TP at Facilities Storing ≤ 1000 gallons

Item	Number or Size	Rate	Estimated Cost
Metering Pumps	2	$3000	$6000
Bulk Tank	1 @ 1000 gal	$2000	$2000
Installation	LS		$1500
Electrical/I&C	LS		$1500
Containment	1.5 CY	$800/CY	$1200
Civil/Piping	LS		$2000
Building	144 sq ft	$250/sq ft	$36,000
Construction total			$50,200
Contractor's OH&P		20%	$10,040
Contractor total			$60,240
Design Engineering	Per Vermont ANR fee curves used by CWSRF program		$4128
Construction Engineering			$6192
Project			$80,595
Contingency		25%	$20,149
Budget			$100,744

For the larger facilities, chemical storage of over 1000 gallons would be needed due to the greater treated flow and chemical consumption. That storage volume would require more costly tankage and larger building dimensions bringing the total capital budget for a supplementary chemical feed system at those facilities to approximately the values shown in Table 6.4-4 (for Vermont WWTFs) and Table 6.4-5 (for New York WWTFs).

Table 6.4-4 Vermont WWTFs – Estimated Costs for Chemical Feed to Achieve 0.2 mg/L and 0.1 mg/L TP at Facilities Storing > 1000 gallons

Facility Name	Additional Storage Volume	Estimated Capital Budget	Annual Building Heating
Burlington Main	10,000 gal	$281 K	$336
Burlington North	2000 gal	$110 K	$122
Essex Junction	5000 gal	$153 K	$172
IBM	2000 gal	$110 K	$122
Middlebury	1500 gal	$105 K	$117
Montpelier	3500 gal	$128 K	$143
Rutland City	6000 gal	$173 K	$197
South Burlington Airport Parkway	3500 gal	$128 K	$143
St. Albans City	2500 gal	$115 K	$128
Swanton	1500 gal	$105 K	$117
Winooski	1500 gal	$105 K	$117

Table 6.4-5 New York WWTFs – Estimated Capital Cost for Chemical Feed to Achieve 0.2 mg/L and 0.1 mg/L TP at Facilities Storing > 1000 gallons

Facility Name	Additional Storage Volume	Estimated Capital Budget	Annual Building Heating
Dannomora	20,000 gal	$486 K	$963
Lake Placid	6500 gal	$184 K	$211
Peru	3000 gal	$122 K	$135
Port Henry	3000 gal	$122 K	$135
Plattsburgh	60,000 gal	$1302 K	$7471
Rouses Point	10,000 gal	$281 K	$336
Saranac Lake	4000 gal	$135K	$151
Ticonderoga	7000 gal	$196 K	$226
Whitehall	1500 gal	$105K	$117

If not using EBPR, the Plattsburgh WWTF would require significantly more chemical addition than any of the other facilities (approximately 60,000 gallons). With EBPR, the chemical storage can be reduced to a quantity suited to the post EBPR phosphorus removal task only.

Enhanced Solids Removal

Several of the WWTFs that are achieving effluents below 1.0 mg/L TP but not yet below 0.2 mg/L already have enhanced solids removal processes. The others either do not have enhanced solids removal processes or have not provided the information for this evaluation. All of them have the potential to require the addition of enhanced solids removal to meet the 0.2 mg/L and 0.1 mg/L effluent TP goals.

As described in Section 5, enhanced solids removal may involve a variety of filter and clarifier technologies. Based on the cost estimates developed in that section, the cloth filter option appears to be relatively economical on both a capital basis and for O&M. The cloth disk filter has also been regionally demonstrated (at Lake Champlain WWTFs and others) to provide sufficient phosphorus solids removal to meet the 0.2 mg/L and 0.1 mg/L effluent TP limits and appears to be an economical approach to solids removal. Therefore, cloth disk filter costs will be used as representative estimates of the cost of enhanced solids removal for most of these facilities. For the higher solids lagoon facility effluents, moving bed filters may be preferred and will be used as the cost basis for the Vermont lagoon facilities at Hardwick, Hinesburg, Proctor, and Richford. The lagoons at Swanton are operated with clarifiers so have a lower solids effluent and the lagoons at Vergennes already have cloth disk filters. The authors have not been provided with information on the process types at the New York facilities so will assume cloth filter addition in all cases.

Filter costs should be included along with chemical system costs in the overall evaluation for those WWTFs that do not already have filters or another enhanced solids removal process. Capital and annual energy costs for filters (based on cost curves presented in Section 5) are shown in Tables 6.4-6 and 6.4-7 for Vermont and New York WWTFs respectively. Capital costs are based on a filter for design capacity. Energy costs are based on operation of that facility at the average flow of the last five years. Note that should future limits require effluent TP even less than 0.1 mg/L, other solids removal technologies such as membranes may be required as extremely low levels of TP can only be attained by also removing the colloidal solids that can pass through filters and other non-membrane enhanced solids removal processes.

Table 6.4-6 Vermont WWTFs – Estimated Costs for Filters

Facility Name	Design ADF, MGD	Average Flow (Past 5 Years), MGD	Filter Type	Capital Cost	Annual Energy Cost
Burlington East	1.2	0.614	Cloth Disk	$ 0.99 M	$547
Burlington Main	5.3	4.451	Cloth Disk	$2.64 M	$2041
Burlington North	2.0	1.213	Cloth Disk	$1.07 M	$735
Enosburg Falls	0.45	0.275	Cloth Disk	$0.74 M	$343
Fair Haven	0.5	0.212	Cloth Disk	$0.74 M	$323
Hardwick	0.371	0.214	Moving Bed	$1.17 M	$1399
Hinesburg	0.25	0.158	Moving Bed	$0.75 M	$816
IBM	8.0	2.999	Cloth Disk	$4.00 M	$1799
Johnson	0.27	0.186	Cloth Disk	$0.60 M	$193
Middlebury	2.2	1.035	Cloth Disk	$1.25 M	$776
Milton	1.0	0.231	Cloth Disk	$0.78 M	$332
Montpelier	3.97	1.972	Cloth Disk	$2.14 M	$1177
Morrisville	0.425	0.308	Cloth Disk	$0.74 M	$353
Newport Center	0.042	0.021	Cloth Disk	$0.50 M	$142
North Troy	0.11	0.078	Cloth Disk	$0.50 M	$153
Northfield	1.0	0.565	Cloth Disk	$0.78 M	$436
Proctor	0.325	0.258	Moving Bed	$1.17 M	$1476
Richford	0.38	0.246	Moving Bed	$1.17 M	$1455
Rock Tenn	2.5	0.231	Cloth Disk	$1.25 M	$528
Rutland City	6.8	5.313	Cloth Disk	$3.74 M	$2512
Swanton	0.9	0.548	Cloth Disk	$0.78 M	$430
Troy/Jay	0.8	0.045	Cloth Disk	$0.78 M	$275
West Rutland	0.45	0.202	Cloth Disk	$0.74 M	$320
Winooski	1.4	0.760	Cloth Disk	$0.99 M	$592

Table 6.4-7 New York WWTFs – Estimated Costs for Cloth Disk Filters

Facility Name	Design ADF, MGD	Average Flow (Past 5 Years), MGD	Capital Cost	Annual Energy Cost
Altona Correctional	0.12	0.069	$0.55 M	$154
Champlain	0.65	0.265	$0.78 M	$343
Essex	0.065	0.005	$0.50 M	$131
Dannemora	1.5	0.877	$0.99 M	$628
Fort Ann	0.11	0.067	$0.50 M	$150
Granville	1.3	0.750	$0.99 M	$589
Great Meadows Correctional	0.4	0.365	$0.74 M	$370
Lake Placid	2.5	1.114	$1.25 M	$800
Peru	0.5	0.238	$0.74 M	$331
Peru/Valcour	0.048	0.004	$0.50 M	$130
Plattsburgh	16	5.48	$7.92 M	$2567
Port Henry	0.6	0.539	$0.78 M	$428
Rouses Point	2.0	0.780	$1.07 M	$601
Saranac Lake	2.62	1.870	$1.32 M	$1037
Ticonderoga	1.7	1.238	$1.07 M	$742
Washington Correctional	0.25	0.114	$0.60 M	$171
Whitehall	0.80	0.625	$0.78 M	$454

O&M Cost

<u>Chemicals</u>

As described in Section 3, chemicals constitute the bulk of the operational cost of any chemical phosphorus treatment system. Tables 6.4-8 and 6.4-9 provide estimates of the cost for chemical to remove phosphorus to 0.2 mg/L TP and 0.1 mg/L TP at the current ADF for each WWTF.

Table 6.4-8 Vermont WWTFs – Estimated Monthly Chemical Cost to Achieve 0.2 mg/L and 0.1 mg/L TP

Vermont Facilities	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	**0.2** mg/L TP limit: Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)						**0.1** mg/L TP limit: Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)					
	MGD	*mg/L*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*
Burlington East	0.614	0.392	0.68	0.33	$87	$84	-	$298	$282	$125	1.53	0.81	$434	$417	$289	-	$1,551	$689
Burlington Main	4.451	0.445	0.86	0.42	-	$774	$537	-	$2,608	$1,159	1.80	0.96	-	$3,572	$2,476	-	-	$5,902
Burlington North	1.213	0.363	0.57	0.28	$146	$140	-	$499	$473	$210	1.38	0.73	-	$743	$515	-	$2,760	$1,227
Enosburg Falls	0.275	0.251	0.18	0.09	$10	$10	-	$35	$33	-	0.79	0.42	$100	$97	-	-	$359	$159
Essex Junction	1.969	0.512	1.10	0.53	$453	$436	$302	-	$1,468	$652	2.15	1.15	-	$1,886	$1,307	-	-	$3,115
Fair Haven	0.212	0.334	0.47	0.23	$21	$20	-	$72	$68	-	1.22	0.65	$120	$116	-	-	$429	$191
Hardwick	0.214	0.934	2.58	1.25	$116	$112	-	-	$376	$167	4.36	2.32	-	$415	$288	-	$1,544	$686
Hinesburg	0.158	0.319	0.42	0.20	$14	$13	-	$47	$45	-	1.15	0.61	$84	$80	-	$315	$299	$133
IBM	2.999	0.205	0.02	0.01	$12	$11	-	$39	$37	-	0.55	0.29	-	$734	$509	-	$2,729	$1,213
Johnson	0.186	0.347	0.52	0.25	$20	$19	-	$69	$65	-	1.29	0.69	$111	$107	-	-	$397	$176
Middlebury	1.035	0.320	0.42	0.20	$92	$88	-	$314	$298	$132	1.15	0.61	-	$530	$368	-	$1,972	$876
Milton	0.231	0.582	1.34	0.65	$65	$63	-	$223	$211	-	2.52	1.34	$270	$259	$180	-	$965	$429
Montpelier	1.972	0.387	0.66	0.32	$272	$262	$182	-	$882	$392	1.50	0.80	-	$1,317	$913	-	-	$2,175
Morrisville	0.308	0.379	0.63	0.30	$41	$39	-	$139	$132	-	1.46	0.78	$208	$200	-	-	$742	$330
Newport Center	0.021	0.928	2.56	1.24	$11	$11	-	$38	$36	-	4.33	2.31	$42	$40	-	$158	$150	-
North Troy	0.078	1.192	5.01	2.42	$82	$79	-	-	$266	$118	6.70	5.04	$242	$232	-	-	$1,220	$542
Northfield	0.565	0.424	0.79	0.38	$93	$90	-	$319	$302	$134	1.69	0.90	$443	$426	$295	-	$1,582	$703
Proctor	0.258	1.363	5.87	2.84	$318	$306	$212	-	$1,029	$458	7.74	5.83	-	$888	$616	-	-	$2,072
Richford	0.246	0.393	0.68	0.33	$35	$34	-	$120	$114	-	1.53	0.82	$174	$168	-	-	$624	$277
Rock Tenn	0.231	0.481	0.99	0.48	$48	$46	-	$164	$155	-	1.99	1.06	$213	$205	-	-	$761	$338
Rutland City	5.313	0.272	0.25	0.12	$281	$270	$187	-	$910	$405	0.90	0.48	-	$2,121	$1,471	-	-	$3,505
Shelburne #1	0.307	0.270	0.24	0.12	$16	$15	-	$54	$51	-	0.89	0.47	$126	$121	-	-	$450	$200
Shelburne #2	0.389	0.325	0.44	0.21	$36	$35	-	$123	$116	-	1.18	0.63	$212	$204	-	-	$758	$337
South Burlington Airport Parkway	1.645	0.427	0.80	0.38	$275	$265	$183	-	$891	$396	1.71	0.91	-	$1,250	$866	-	-	$2,065
South Burlington Bartlett Bay	0.620	0.252	0.18	0.09	$24	$23	-	$81	$77	-	0.79	0.42	$228	$219	-	-	$814	$362
St. Albans City	2.690	0.234	0.12	0.06	$68	$65	-	$232	$220	-	0.70	0.37	-	$840	$582	-	$3,122	$1,388
Swanton	0.548	0.461	0.92	0.44	$106	$102	-	$362	$343	$152	1.89	1.01	-	$461	$320	-	$1,713	$761
Troy/Jay	0.045	0.552	1.24	0.60	$12	$11	-	$40	$38	-	2.37	1.26	$49	$47	-	$186	$177	-
Vergennes	0.401	0.323	0.43	0.21	$36	$35	-	$124	$118	-	1.17	0.62	$216	$208	-	-	$772	$343
West Rutland	0.202	0.290	0.32	0.15	$14	$13	-	$46	$44	-	1.00	0.53	$93	$90	-	-	$333	$148
Winooski	0.760	0.493	1.03	0.50	$164	$158	-	-	$532	$237	2.06	1.10	-	$695	$481	-	$2,582	$1,147

Table 6.4-9 New York WWTFs – Estimated Monthly Chemical Cost to Achieve 0.2 mg/L and 0.1 mg/L TP

New York Facilities	Average Flow (Past 5 Years)	Average Effluent TP (Past 5 Years)	**0.2** mg/L TP limit										**0.1** mg/L TP limit									
			Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)						Chemical Dose (Fe/Al)		Monthly Chemical Cost (Fe/Al) For Drums (D), Totes (T), and Bulk Delivery (B)					
Facility Name	*MGD*	*mg/L*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*	*mg/L*		*D*	*T*	*B*	*D*	*T*	*B*
Altona Correctional	0.069	0.444	0.86	0.41	$12	$12	-	$93	$88	-	1.80	0.96	$57	$55	-	$216	$204	-
Champlain	0.265	0.473	0.96	0.46	$53	$51	-	-	$381	$169	1.95	1.04	$239	$230	-	-	$855	$380
Dannemora	0.877	2.201	10.10	4.88	-	$1,789	$1,240	-	-	$5,892	12.88	9.70	-	-	$3,484	-	-	$11,728
Essex	0.005	3.633	17.33	8.37	$17	$17	-	$130	$124	-	21.66	16.31	$48	$46	-	-	$241	$107
Fort Ann	0.067	1.028	4.18	2.02	$59	$57	-	-	$420	$187	5.69	4.28	$177	$170	-	-	$892	$397
Granville	0.750	0.304	0.37	0.18	$57	$55	-	$432	$410	$182	1.07	0.57	$370	$355	$246	-	$1,321	$587
Great Meadows Correctional	0.365	0.377	0.62	0.30	$48	$46	-	$359	$340	$151	1.45	0.77	$245	$235	-	-	$875	$389
Lake Placid	1.114	0.997	2.80	1.35	-	$630	$437	-	-	$2,075	4.69	2.50	-	$2,323	$1,610	-	-	$3,838
Peru	0.238	1.255	5.33	2.57	$266	$255	$177	-	$1,893	$841	7.08	5.33	-	$748	$519	-	-	$1,746
Peru/Valcour	0.004	2.851	13.38	6.47	$12	$12	-	$94	$89	-	16.87	12.70	$35	$33	-	-	$175	-
Plattsburgh	5.480	1.180	4.95	2.39	-	-	$3,793	-	-	$18,021	6.62	4.98	-	-	$11,184	-	-	$37,653
Port Henry	0.539	0.949	2.63	1.27	$298	$286	$198	-	$2,122	$943	4.44	2.37	-	$1,064	$737	-	-	$1,757
Rouses Point	0.780	1.243	5.27	2.54	-	$829	$575	-	-	$2,731	7.01	5.28	-	$2,431	$1,685	-	-	$5,674
Saranac Lake	1.870	0.430	0.81	0.39	$317	$305	$212	-	$2,262	$1,005	1.73	0.92	-	$1,435	$995	-	-	$2,371
Ticonderoga	1.238	0.965	2.69	1.30	-	$672	$466	-	-	$2,214	4.52	2.41	-	$2,490	$1,726	-	-	$4,114
Washington Correctional	0.114	0.283	0.29	0.14	$7	$7	-	$53	$50	-	0.96	0.51	$50	$48	-	$190	$180	-
Whitehall	0.625	0.490	1.02	0.49	$134	$129	-	-	$953	$424	2.04	1.09	-	$567	$393	-	$2,107	$937

Power

Power for filter backwashing and building heating is included in Tables 6.4-6 and 6.4-7 above. Cost for constant operation of an additional small chemical feed pump was estimated in Section 3 at approximately \$11 per month or \$132 annually. The cost for heating the chemical building is estimated based on 0.25 air changes per hour and an annual average heating requirement of 24 degrees F plus a safety factor of 50%. At \$0.10/KWhr heating a 12' x 12' building is estimated at \$114/yr. Annual cost for heating for larger chemical storage and feed buildings is shown in Tables 6.4-4 and 6.4-5 above.

Lab Supplies and Mechanical Equipment Maintenance

Costs for lab supplies and maintenance materials for the chemical feed systems should be relatively minor for a properly designed system. A total of \$100 per month is estimated.

Alkalinity Consumption and Increased Sludge Production

Chemical addition for phosphorus removal will consume alkalinity and increase the quantity of sludge generated at each facility in proportion to the quantity of chemical added as shown in Tables 6.4-10 and 6.4-11.

Table 6.4-10 Vermont WWTFs – Estimated Alkalinity Consumed and Sludge Produced to Achieve 0.2 mg/L and 0.1 mg/L TP

Vermont Facilities	0.2 mg/L TP limit				0.1 mg/L TP limit			
	Alkalinity Consumed (Fe/Al)		Increase in Sludge Mass (Fe/Al)		Alkalinity Consumed (Fe/Al)		Increase in Sludge Mass (Fe/Al)	
	mg/L		lbs/day		mg/L		lbs/day	
Burlington East	0.3	1.1	13.3	7.4	1.8	3.4	18.8	15.9
Burlington Main	0.4	1.4	114.8	68.2	2.2	4.0	161.2	136.3
Burlington North	0.3	0.9	23.6	12.4	1.7	3.1	33.5	28.3
Cabot	0.0	0.1	0.2	0.0	0.8	1.4	0.3	0.3
Enosburg Falls	0.1	0.3	2.9	0.9	0.9	1.8	4.4	3.7
Essex Junction	0.5	1.7	61.0	38.4	2.6	4.8	85.1	71.9
Fair Haven	0.2	0.7	3.6	1.8	1.5	2.7	5.2	4.4
Hardwick	1.2	4.1	13.7	9.8	5.2	9.7	18.7	15.8
Hinesburg	0.2	0.7	2.5	1.2	1.4	2.5	3.6	3.1
IBM	0.0	0.0	21.5	1.0	0.7	1.2	33.1	28.0
Johnson	0.2	0.8	3.4	1.7	1.6	2.9	4.8	4.1
Middlebury	0.2	0.7	16.7	7.8	1.4	2.6	23.9	20.2
Milton	0.6	2.1	8.4	5.5	3.0	5.6	11.7	9.9
Montpelier	0.3	1.0	42.0	23.1	1.8	3.3	59.4	50.2
Newport Center	1.2	4.1	1.3	1.0	5.2	9.6	1.8	1.5
North Troy	5.8	9.6	8.4	6.2	9.5	23.8	10.2	11.3
Northfield	0.4	1.2	13.6	7.9	2.0	3.8	19.2	16.2
Proctor	6.8	11.3	32.4	24.1	11.0	27.5	38.9	43.3
Richford	0.3	1.1	5.4	3.0	1.8	3.4	7.6	6.4
Rock Tenn	0.5	1.6	6.6	4.1	2.4	4.4	9.2	7.8
Rutland City	0.1	0.4	65.5	23.8	1.1	2.0	95.7	80.9
Shelburne #1	0.1	0.4	3.7	1.3	1.1	2.0	5.5	4.6
Shelburne #2	0.2	0.7	6.4	3.0	1.4	2.6	9.2	7.8
South Burlington Airport Parkway	0.4	1.3	40.1	23.3	2.1	3.8	56.4	47.7
South Burlington Bartlett Bay	0.1	0.3	6.7	2.0	1.0	1.8	9.9	8.4
St. Albans City	0.1	0.2	25.3	5.8	0.8	1.6	37.9	32.0
Swanton	0.4	1.5	14.8	9.0	2.3	4.2	20.8	17.6
Troy/Jay	0.6	2.0	1.5	1.0	2.8	5.3	2.1	1.8
Vergennes	0.2	0.7	6.5	3.1	1.4	2.6	9.4	7.9
West Rutland	0.2	0.5	2.8	1.1	1.2	2.2	4.0	3.4
Winooski	0.5	1.6	22.4	13.9	2.5	4.6	31.3	26.5

Table 6.4-11 New York WWTFs – Estimated Alkalinity Consumed and Sludge Produced to Achieve 0.2 mg/L and 0.1 mg/L mg/L TP

New York Facilities	0.2 mg/L TP limit				0.1 mg/L TP limit			
	Alkalinity Consumed (Fe/Al)		Increase in Sludge Mass (Fe/Al)		Alkalinity Consumed (Fe/Al)		Increase in Sludge Mass (Fe/Al)	
Facility Name	*mg/L*		*lbs/day*		*mg/L*		*lbs/day*	
Altona Correctional	0.4	1.4	1.8	1.0	2.2	4.0	2.5	2.1
Champlain	0.5	1.5	7.4	4.5	2.3	4.3	10.4	8.8
Dannemora	11.6	19.4	185.1	141.0	18.3	45.8	219.9	244.8
Essex	20.0	33.3	1.7	1.3	30.8	77.0	2.0	2.2
Fort Ann	4.8	8.0	6.1	4.5	8.1	20.2	7.4	8.3
Granville	0.2	0.6	11.1	4.9	1.3	2.4	16.0	13.6
Great Meadows Correctional	0.3	1.0	7.5	4.0	1.7	3.2	10.6	9.0
Lake Placid	1.4	4.4	76.4	55.5	5.6	10.4	104.8	88.6
Peru	6.1	10.2	27.2	20.1	10.1	25.2	32.7	36.4
Peru/Valcour	15.4	25.7	1.2	0.9	24.0	60.0	1.5	1.6
Plattsburgh	5.7	9.5	585.1	431.3	9.4	23.5	706.1	785.9
Port Henry	1.3	4.2	35.0	25.2	5.3	9.9	48.0	40.6
Rouses Point	6.1	10.1	88.3	65.4	10.0	24.9	106.4	118.4
Saranac Lake	0.4	1.3	46.0	26.9	2.1	3.8	64.8	54.8
Ticonderoga	1.3	4.3	81.9	59.2	5.4	10.1	112.4	95.0
Washington Correctional	0.1	0.5	1.5	0.6	1.2	2.1	2.2	1.8
Whitehall	0.5	1.6	18.3	11.3	2.5	4.5	25.6	21.6

For lagoon facilities, the increase in sludge production will accelerate the frequency with which solids must be removed from the system and the cost of transporting and disposing of those solids. For the activated sludge systems (including EA and SBR) the chemical sludge will become a part of the mixed liquor as a result of solids recycle and retention. The mixed liquor suspended solids (MLSS) concentration may need to be increased to maintain the mass of volatile solids necessary to provide the biological treatment. If the facility is already operating at an MLSS that approaches the design solids loading limit for the clarifiers, additional clarifiers or aeration basin volume may be required. For the trickling filter/RBC system at St Albans City, the chemically generated sludge will increase the solids loading to the clarifiers. If the TF/RBC system clarifiers are inadequate to the increase, additional clarifiers may be needed. Additional information will be required to assess the effect of chemical addition on the subsurface system at Newport Center.

Cost Due to Increased Sludge Production

Chemical phosphorus removal generates chemical sludge proportional to the quantity of chemical required. Any increase in chemical addition to improve phosphorus removal will result in an increase in the quantity of sludge to be disposed by the WWTP. The costs for sludge handling and management (to thicken, digest, dewater, haul, and landfill or land apply) are specific to a particular sludge operation. Assessment of sludge handling and management were outside the scope of this evaluation but are important to evaluating the overall cost of improved phosphorus removal. The quantity of additional sludge produced at each plant using either alum or ferric as required to achieve target effluent TP limits was shown in Tables 6.2-6 and 6.2-7 for plants operating to achieve 1.0 mg/L TP, in Tables 6.3-6 and 6.3-7 for WWTPs operating to achieve 0.1 mg/L TP, and in Tables 6.4-10 and 6.4-11 for WWTPs operating to achieve either 0.2 mg/L or 0.1 mg/L.

For many of the Vermont WWTPs the annual sludge production was provided and can serve as a basis for comparison with the increased sludge production estimated for increased phosphorus removal. Where provided, each Vermont WWTPs estimated sludge production from those tables is compared with the 2011 sludge production in Table 6.4-12 (for plants treating to 1.0 or 0.2 mg/L TP) and Table 6.4-13 (for plants treating to 1.0 or 0.1 mg/L TP) to provide guidance as to the scale of potential sludge increase due to increased phosphorus removal. Note that Tables 6.4-14 and 6.4-15, for sludge increase at New York WWTPs treating to 1.0 and 0.2 mg/L TP and 1.0 or 0.1 mg/L TP respectively, does not include 2011 sludge production for which historical annual sludge production was not provided. Although sludge disposal costs are very site specific, and should be evaluated on an individual basis for each facility, a general sense of the financial impact is also shown in Table 6.6-11 by evaluating the tipping fee for landfilling the additional sludge at 25% TS and a rate of $90/wet ton.

Table 6.4-12 Vermont WWTFs – Potential Sludge Increase Due to Chemical Phosphorus Removal for Phosphorus Removal to 1.0 or 0.2 mg/L TP

Vermont WWTPs	Sludge Increase with Additional Chemical P Removal, lb/d		Sludge Increase with Additional Chemical P Removal, dry US tons/yr		Sludge Increase with Additional Chemical P Removal, wet US tons/yr (at 25% TS)		Added Disposal Cost, $/year (assumes landfilled at $90/wet ton)	
	Alum	Ferric	Alum	Ferric	Alum	Ferric	Alum	Ferric
Alburgh	No additional treatment required to achieve 0.1 mg/L							
Barre	No additional treatment required to achieve 0.2 mg/L							
Benson	1.4	1.5	0.3	0.3	1.0	1.1	$ 92	$ 101
Brandon	0.9	4.0	0.2	0.7	0.7	2.9	$ 60	$ 262
Brown Ledge Camp	0.3	0.4	0.0	0.1	0.2	0.3	$ 18	$ 23
Burlington East	7.4	13.3	1.3	2.4	5.4	9.7	$ 484	$ 874
Burlington Electric	No additional treatment required to achieve 0.1 mg/L							
Burlington Main	68.2	114.8	12.4	20.9	49.8	83.8	$ 4,478	$ 7,541
Burlington North	12.4	23.6	2.3	4.3	9.0	17.2	$ 812	$ 1,548
Cabot	0.0	0.2	0.0	0.0	0.0	0.2	$ 2	$ 14
Castleton	0.0	2.5	0.0	0.5	0.0	1.8	$ 1	$ 164
Enosburg Falls	0.9	2.9	0.2	0.5	0.6	2.2	$ 57	$ 194
Essex Junction	38.4	61.0	7.0	11.1	28.0	44.5	$ 2,520	$ 4,006

Table 6.4-12 continued

Vermont WWTPs	Sludge Increase with Additional Chemical P Removal, lb/d		Sludge Increase with Additional Chemical P Removal, dry US tons/yr		Sludge Increase with Additional Chemical P Removal, wet US tons/yr (at 25% TS)		Added Disposal Cost, $/year (assumes landfilled at $90/wet ton)	
	Alum	Ferric	Alum	Ferric	Alum	Ferric	Alum	Ferric
Fair Haven	1.8	3.6	0.3	0.7	1.3	2.7	$ 117	$ 239
Fairfax	8.9	9.8	1.6	1.8	6.5	7.1	$ 588	$ 642
Hardwick	9.8	13.7	1.8	2.5	7.2	10.0	$ 645	$ 897
Hinesburg	1.2	2.5	0.2	0.5	0.9	1.8	$ 77	$ 166
IBM	1.0	21.5	0.2	3.9	0.7	15.7	$ 64	$ 1,412
Jeffersonville	14.8	16.2	2.7	3.0	10.8	11.8	$ 973	$ 1,062
Johnson	1.7	3.4	0.3	0.6	1.2	2.5	$ 112	$ 222
Marshfield	4.3	4.7	0.8	0.9	3.1	3.4	$ 281	$ 307
Middlebury	7.8	16.7	1.4	3.0	5.7	12.2	$ 511	$ 1,095
Milton	5.5	8.4	1.0	1.5	4.0	6.2	$ 363	$ 554
Montpelier	23.1	42.0	4.2	7.7	16.8	30.6	$ 1,514	$ 2,758
Morrisville	3.4	6.4	0.6	1.2	2.5	4.6	$ 226	$ 418
Newport Center	1.0	1.3	0.2	0.2	0.7	1.0	$ 63	$ 87
North Troy	6.2	8.4	1.1	1.5	4.5	6.2	$ 409	$ 554
Northfield	7.9	13.6	1.4	2.5	5.8	10.0	$ 519	$ 896
Northwest State Correctional	No additional treatment required to achieve 0.2 mg/L							
Orwell	2.5	2.8	0.5	0.5	1.9	2.0	$ 167	$ 182
Otter Valley Union High School	0.6	0.7	0.1	0.1	0.5	0.5	$ 41	$ 45
Pittsford	4.7	5.1	0.9	0.9	3.4	3.7	$ 309	$ 337
Pittsford Fish Hatchery	No additional treatment required to achieve 0.1 mg/L							
Plainfield	6.4	7.0	1.2	1.3	4.7	5.1	$ 422	$ 461
Poultney	No additional treatment required to achieve 0.2 mg/L							
Proctor	24.1	32.4	4.4	5.9	17.6	23.6	$ 1,583	$ 2,126
Richford	3.0	5.4	0.5	1.0	2.2	3.9	$ 195	$ 352
Richmond	No additional treatment required to achieve 0.2 mg/L							
Rock Tenn	4.1	6.6	0.7	1.2	3.0	4.8	$ 266	$ 434
Rutland City	23.8	65.5	4.3	11.9	17.4	47.8	$ 1,563	$ 4,302
Salisbury Fish Hatchery	No additional treatment required to achieve 0.1 mg/L							
Shelburne 1	1.3	3.7	0.2	0.7	1.0	2.7	$ 88	$ 245
Shelburne 2	3.0	6.4	0.6	1.2	2.2	4.7	$ 200	$ 421
Sheldon Springs	1.8	2.0	0.3	0.4	1.3	1.5	$ 120	$ 131
Shoreham	3.1	3.3	0.6	0.6	2.2	2.4	$ 201	$ 219
South Burlington AP	23.3	40.1	4.3	7.3	17.0	29.3	$ 1,531	$ 2,633
South Burlington BB	2.0	6.7	0.4	1.2	1.5	4.9	$ 132	$ 439
St. Albans City	5.8	25.3	1.0	4.6	4.2	18.5	$ 378	$ 1,664
Stowe	1.7	4.2	0.3	0.8	1.2	3.0	$ 109	$ 273
Swanton	9.0	14.8	1.6	2.7	6.5	10.8	$ 588	$ 975

Table 6.4-12 continued

Vermont WWTPs	Sludge Increase with Additional Chemical P Removal, lb/d		Sludge Increase with Additional Chemical P Removal, dry US tons/yr		Sludge Increase with Additional Chemical P Removal, wet US tons/yr (at 25% TS)		Added Disposal Cost, $/year (assumes landfilled at $90/wet ton)	
	Alum	Ferric	Alum	Ferric	Alum	Ferric	Alum	Ferric
Troy/Jay	1.0	1.5	0.2	0.3	0.7	1.1	$ 65	$ 101
Vergennes	3.1	6.5	0.6	1.2	2.2	4.8	$ 202	$ 429
Wallingford	4.5	4.3	0.8	0.8	3.3	3.2	$ 294	$ 285
Waterbury	2013 improvements anticipated to achieve 0.1 mg/L							
Weed Fish Culture Station	No additional treatment required to achieve 0.1 mg/L							
West Pawlet	5.2	5.6	0.9	1.0	3.8	4.1	$ 339	$ 370
West Rutland	1.1	2.8	0.2	0.5	0.8	2.0	$ 75	$ 183
Williamstown	9.3	10.1	1.7	1.8	6.8	7.4	$ 609	$ 665
Winooski	13.9	22.4	2.5	4.1	10.2	16.4	$ 914	$ 1,473
Wyeth (PBM Nutritionals)	No additional treatment required to achieve 0.2 mg/L							

Table 6.4-13 Vermont WWTFs – Potential Sludge Increase Due to Chemical Phosphorus Removal for Phosphorus Removal to 1.0 or 0.1 mg/L TP

Vermont WWTPs	Sludge Increase with Additional Chemical P Removal, lb/d		Sludge Increase with Additional Chemical P Removal, dry US tons/yr		Sludge Increase with Additional Chemical P Removal, wet US tons/yr (at 25% TS)		Added Disposal Cost, $/year (assumes landfilled at $90/wet ton)	
	Alum	Ferric	Alum	Ferric	Alum	Ferric	Alum	Ferric
Alburgh	No additional treatment required to achieve 0.1 mg/L							
Barre City	15.9	18.8	2.9	3.4	11.6	13.7	$ 1,046	$ 1,237
Benson	1.4	1.5	0.3	0.3	1.0	1.1	$ 92	$ 101
Brandon	5.0	6.0	0.9	1.1	3.7	4.4	$ 332	$ 392
Brown Ledge Camp	0.5	0.4	0.1	0.1	0.3	0.3	$ 30	$ 27
Burlington East	15.9	18.8	2.9	3.4	11.6	13.7	$ 1,046	$ 1,237
Burlington Electric	No additional treatment required to achieve 0.1 mg/L							
Burlington Main	136.3	161.2	24.9	29.4	99.5	117.7	$ 8,954	$ 10,592
Burlington North	28.3	33.5	5.2	6.1	20.7	24.5	$ 1,861	$ 2,202
Cabot	0.3	0.3	0.1	0.1	0.2	0.2	$ 18	$ 22
Castleton	3.3	3.9	0.6	0.7	2.4	2.8	$ 215	$ 254
Enosburg Falls	3.7	4.4	0.7	0.8	2.7	3.2	$ 242	$ 286
Essex Junction	71.9	85.1	13.1	15.5	52.5	62.1	$ 4,727	$ 5,591
Fair Haven	4.4	5.2	0.8	1.0	3.2	3.8	$ 290	$ 343
Fairfax	8.9	9.8	1.6	1.8	6.5	7.1	$ 588	$ 642
Hardwick	15.8	18.7	2.9	3.4	11.6	13.7	$ 1,041	$ 1,232
Hinesburg	3.1	3.6	0.6	0.7	2.2	2.6	$ 201	$ 238
IBM	28.0	33.1	5.1	6.0	20.4	24.2	$ 1,840	$ 2,177
Jeffersonville	14.8	16.2	2.7	3.0	10.8	11.8	$ 973	$ 1,062
Johnson	4.1	4.8	0.7	0.9	3.0	3.5	$ 268	$ 317

Table 6.4-13 continued

Vermont WWTPs	Sludge Increase with Additional Chemical P Removal, lb/d		Sludge Increase with Additional Chemical P Removal, dry US tons/yr		Sludge Increase with Additional Chemical P Removal, wet US tons/yr (at 25% TS)		Added Disposal Cost, $/year (assumes landfilled at $90/wet ton)	
	Alum	Ferric	Alum	Ferric	Alum	Ferric	Alum	Ferric
Marshfield	4.3	4.7	0.8	0.9	3.1	3.4	$ 281	$ 307
Middlebury	20.2	23.9	3.7	4.4	14.8	17.5	$ 1,330	$ 1,573
Milton	9.9	11.7	1.8	2.1	7.2	8.5	$ 650	$ 769
Montpelier	50.2	59.4	9.2	10.8	36.7	43.4	$ 3,300	$ 3,904
Morrisville	7.6	9.0	1.4	1.6	5.6	6.6	$ 500	$ 592
Newport Center	1.5	1.8	0.3	0.3	1.1	1.3	$ 101	$ 119
North Troy	11.3	10.2	2.1	1.9	8.3	7.4	$ 744	$ 668
Northfield	16.2	19.2	3.0	3.5	11.9	14.0	$ 1,067	$ 1,262
Northwest State Correctional	0.1	0.1	0.0	0.0	0.1	0.1	$ 6	$ 8
Orwell	2.5	2.8	0.5	0.5	1.9	2.0	$ 167	$ 182
Otter Valley Union High School	0.6	0.7	0.1	0.1	0.5	0.5	$ 41	$ 45
Pittsford	4.7	5.1	0.9	0.9	3.4	3.7	$ 309	$ 337
Pittsford Fish Hatchery	No additional treatment required to achieve 0.1 mg/L							
Plainfield	6.4	7.0	1.2	1.3	4.7	5.1	$ 422	$ 461
Poultney	0.8	0.9	0.1	0.2	0.6	0.7	$ 50	$ 60
Proctor	43.3	38.9	7.9	7.1	31.6	28.4	$ 2,842	$ 2,553
Richford	6.4	7.6	1.2	1.4	4.7	5.5	$ 420	$ 497
Richmond	0.3	0.4	0.1	0.1	0.2	0.3	$ 20	$ 24
Rock Tenn	7.8	9.2	1.4	1.7	5.7	6.7	$ 513	$ 607
Rutland City	80.9	95.7	14.8	17.5	59.1	69.9	$ 5,318	$ 6,290
Salisbury Fish Hatchery	No additional treatment required to achieve 0.1 mg/L							
Shelburne 1	4.6	5.5	0.8	1.0	3.4	4.0	$ 303	$ 359
Shelburne 2	7.8	9.2	1.4	1.7	5.7	6.7	$ 511	$ 604
Sheldon Springs	1.8	2.0	0.3	0.4	1.3	1.5	$ 120	$ 131
Shoreham	3.1	3.3	0.6	0.6	2.2	2.4	$ 201	$ 219
South Burlington AP	47.7	56.4	8.7	10.3	34.8	41.2	$ 3,133	$ 3,706
South Burlington BB	8.4	9.9	1.5	1.8	6.1	7.2	$ 549	$ 649
St. Albans City	32.0	37.9	5.8	6.9	23.4	27.7	$ 2,105	$ 2,490
Stowe	5.1	6.0	0.9	1.1	3.7	4.4	$ 336	$ 397
Swanton	17.6	20.8	3.2	3.8	12.8	15.2	$ 1,155	$ 1,367
Troy/Jay	1.8	2.1	0.3	0.4	1.3	1.6	$ 119	$ 141
Vergennes	7.9	9.4	1.4	1.7	5.8	6.8	$ 521	$ 616
Wallingford	4.5	4.3	0.8	0.8	3.3	3.2	$ 294	$ 285
Waterbury	2013 improvements anticipated to achieve 0.1 mg/L							
Weed Fish Culture Station	No additional treatment required to achieve 0.1 mg/L							
West Pawlet	5.2	5.6	0.9	1.0	3.8	4.1	$ 339	$ 370
West Rutland	3.4	4.0	0.6	0.7	2.5	3.0	$ 225	$ 266
Williamstown	9.3	10.1	1.7	1.8	6.8	7.4	$ 609	$ 665
Winooski	26.5	31.3	4.8	5.7	19.3	22.9	$ 1,741	$ 2,059
Wyeth (PBM Nutritionals)	0.4	0.4	0.1	0.1	0.3	0.3	$ 25	$ 29

Table 6.4-14 New York WWTFs – Potential Sludge Increase Due to Chemical Phosphorus Removal for Phosphorus Removal to 1.0 or 0.2 mg/L TP

New York WWTFs	Sludge Increase with Additional Chemical P Removal, lb/d		Sludge Increase with Additional Chemical P Removal, dry US tons/yr		Sludge Increase with Additional Chemical P Removal, wet US tons/yr (at 25% TS)		Added Disposal Cost, $/year (assumes landfilled at $90/wet ton)	
	Alum	Ferric	Alum	Ferric	Alum	Ferric	Alum	Ferric
Adirondak Fish Hatchery	No additional treatment required to achieve 0.1 mg/L							
Altona Correctional	1.0	1.8	0.2	0.3	0.8	1.3	$ 69	$ 116
Au Sable Forks	12.2	13.3	2.2	2.4	8.9	9.7	$ 804	$ 877
Cadyville	0.4	0.4	0.1	0.1	0.3	0.3	$ 24	$ 27
Champlain	4.5	7.4	0.8	1.4	3.3	5.4	$ 297	$ 487
Champlain Park	14.2	18.6	2.6	3.4	10.4	13.5	$ 933	$ 1,219
Chazy	0.8	1.3	0.1	0.2	0.6	0.9	$ 53	$ 82
Crown Point	5.9	6.4	1.1	1.2	4.3	4.7	$ 387	$ 423
Dannemora	73.6	80.3	13.4	14.7	53.7	58.6	$ 4,834	$ 5,275
Essex	1.3	1.7	0.2	0.3	1.0	1.2	$ 86	$ 112
Fort Ann	4.5	6.1	0.8	1.1	3.3	4.5	$ 294	$ 403
Granville	4.9	11.1	0.9	2.0	3.6	8.1	$ 320	$ 730
Great Meadows Correctional	4.0	7.5	0.7	1.4	3.0	5.5	$ 266	$ 492
International Paper	No additional treatment required to achieve 0.2 mg/L							
Keeseville	No additional treatment required to achieve 0.2 mg/L							
Lake Placid	55.5	76.4	10.1	13.9	40.5	55.8	$ 3,643	$ 5,022
Peru	20.1	27.2	3.7	5.0	14.7	19.9	$ 1,323	$ 1,787
Peru/Valcour	0.9	1.2	0.2	0.2	0.7	0.9	$ 62	$ 81
Plattsburgh	431.3	585.1	78.7	106.8	314.8	427.1	$ 28,334	$ 38,441
Port Henry	25.2	35.0	4.6	6.4	18.4	25.5	$ 1,656	$ 2,297
Rouses Point	65.4	88.3	11.9	16.1	47.7	64.5	$ 4,294	$ 5,803
Saranac Lake	26.9	46.0	4.9	8.4	19.6	33.6	$ 1,765	$ 3,024
St Armand	9.1	10.0	1.7	1.8	6.7	7.3	$ 599	$ 654
Ticonderoga	59.2	81.9	10.8	14.9	43.2	59.8	$ 3,888	$ 5,380
Wadhams	1.2	1.3	0.2	0.2	0.8	0.9	$ 76	$ 83
Washington Correctional	0.6	1.5	0.1	0.3	0.4	1.1	$ 39	$ 99
Westport	6.4	7.0	1.2	1.3	4.7	5.1	$ 423	$ 462
Whitehall	11.3	18.3	2.1	3.3	8.3	13.4	$ 744	$ 1,202
Willsboro	5.9	6.4	1.1	1.2	4.3	4.7	$ 386	$ 421
Wyeth Research	0.8	1.2	0.1	0.2	0.6	0.9	$ 53	$ 79

Table 6.4-15 New York WWTFs – Potential Sludge Increase Due to Chemical Phosphorus Removal for Phosphorus Removal to 1.0 or 0.1 mg/L TP

New York WWTFs	Sludge Increase with Additional Chemical P Removal, lb/d		Sludge Increase with Additional Chemical P Removal, dry US tons/yr		Sludge Increase with Additional Chemical P Removal, wet US tons/yr (at 25% TS)		Added Disposal Cost, $/year (assumes landfilled at $90/wet ton)	
	Alum	Ferric	Alum	Ferric	Alum	Ferric	Alum	Ferric
Adirondak Fish Hatchery	No additional treatment required to achieve 0.1 mg/L							
Altona Correctional	2.1	2.5	0.4	0.5	1.5	1.8	$ 138	$ 163
Au Sable Forks	12.2	13.3	2.2	2.4	8.9	9.7	$ 804	$ 877
Cadyville	0.4	0.4	0.1	0.1	0.3	0.3	$ 24	$ 27
Champlain	8.8	10.4	1.6	1.9	6.4	7.6	$ 576	$ 682
Champlain Park	24.5	22.0	4.5	4.0	17.9	16.1	$ 1,608	$ 1,445
Chazy	1.5	1.7	0.3	0.3	1.1	1.3	$ 97	$ 115
Crown Point	5.9	6.4	1.1	1.2	4.3	4.7	$ 387	$ 423
Dannemora	73.6	80.3	13.4	14.7	53.7	58.6	$ 4,834	$ 5,275
Essex	2.2	2.0	0.4	0.4	1.6	1.5	$ 147	$ 132
Fort Ann	8.3	7.4	1.5	1.4	6.0	5.4	$ 544	$ 489
Granville	13.6	16.0	2.5	2.9	9.9	11.7	$ 891	$ 1,054
Great Meadows Correctional	9.0	10.6	1.6	1.9	6.6	7.8	$ 590	$ 698
International Paper	71.1	84.1	13.0	15.3	51.9	61.4	$ 4,669	$ 5,524
Keeseville	1.9	2.3	0.4	0.4	1.4	1.7	$ 128	$ 151
Lake Placid	88.6	104.8	16.2	19.1	64.7	76.5	$ 5,823	$ 6,888
Peru	36.4	32.7	6.7	6.0	26.6	23.9	$ 2,395	$ 2,152
Peru/Valcour	1.6	1.5	0.3	0.3	1.2	1.1	$ 106	$ 96
Plattsburgh	785.9	706.1	143.4	128.9	573.7	515.4	$ 51,630	$ 46,390
Port Henry	40.6	48.0	7.4	8.8	29.6	35.0	$ 2,666	$ 3,154
Rouses Point	118.4	106.4	21.6	19.4	86.5	77.7	$ 7,781	$ 6,991
Saranac Lake	54.8	64.8	10.0	11.8	40.0	47.3	$ 3,597	$ 4,256
St Armand	9.1	10.0	1.7	1.8	6.7	7.3	$ 599	$ 654
Ticonderoga	95.0	112.4	17.3	20.5	69.4	82.0	$ 6,242	$ 7,384
Wadhams	1.2	1.3	0.2	0.2	0.8	0.9	$ 76	$ 83
Washington Correctional	1.8	2.2	0.3	0.4	1.4	1.6	$ 122	$ 144
Westport	6.4	7.0	1.2	1.3	4.7	5.1	$ 423	$ 462
Whitehall	21.6	25.6	3.9	4.7	15.8	18.7	$ 1,421	$ 1,681
Willsboro	5.9	6.4	1.1	1.2	4.3	4.7	$ 386	$ 421
Wyeth Research	1.4	1.7	0.3	0.3	1.0	1.2	$ 93	$ 110

6.5 Cost for EBPR

Enhanced biological phosphorus removal (EBPR) can significantly reduce the quantity of chemical required for phosphorus removal. Because EBPR complicates the operation of the facility to a degree, it has only been considered for those WWTPs that need to improve phosphorus removal and are designed for more than 1.0 MGD ADF. Table 6.5-1 includes a list of those facilities. Note that each of these has also been evaluated for chemical phosphorus removal alone. Several of these facilities include unaerated zones that may have the potential to be operated for EBPR. However, details of the specific sizing and operation of these individual facilities is beyond the scope of this report so upgrade to EBPR was evaluated for each.

Table 6.5-1 WWTFs Evaluated for EBPR

Vermont WWTFs		New York WWTFs	
WWTF	Design ADF, MGD	WWTF	Design ADF, MGD
Burlington East	1.2	Dannemora	1.5
Burlington Main	5.3	Granville	1.3
Burlington North	2.0	International Paper	17.5
Essex Junction	3.1	Lake Placid	2.5
IBM	8.0	Plattsburgh	16.0
Middlebury	2.2	Rouses Point	2.0
Milton	1.0	Saranac Lake	2.62
Montpelier	3.97	Ticonderoga	1.7
Northfield	1.0		
Rock Tenn	2.5		
Rutland City	6.8		
South Burlington Airport Park.	2.3		
South Burlington Bart. Bay	1.25		
St. Albans City	4.0		
Winooski	1.4		

For the Dannemora WWTP, which is being evaluated at a 1.0 mg/L effluent TP limit, EBPR may be able to achieve the effluent TP limit and chemical phosphorus removal could be limited to the side-streams only. For each of the other large WWTPs, chemical addition will be needed in the side-streams and likely will be needed to supplement EBPR in the main treatment stream to achieve 0.2 mg/L or 0.1 mg/L TP. Costs for EBPR were presented in Section 4 in the form of cost curves based on treated ADF. The basis of the curves is summarized in Tables 4-2.1, 4-2.2, and 4-2.3.

Note that where it is not now present, enhanced solids removal would be required to meet the 0.2 mg/L and 0.1 mg/L effluent TP limits with EBPR just as would be needed with chemical phosphorus removal only. The costs for enhanced removal were presented in Section 6.4 and should be included with the costs for EBPR to develop a total system cost. Also, the addition of EBPR to a WWTP will significantly reduce the quantity of chemical required to achieve effluent limit compliance but for most situations will not eliminate it. Consequently, the cost associated with EBPR must be considered along with the capital cost for chemical feed systems (and enhanced solids removal). However, the rate of chemical usage and therefore the monthly cost for chemical should be estimated at only about 1/3 to 1/4 of the usage that would be required in the absence of EBPR. The reduction in chemical usage would include not just the increased chemical feed considered in this report but also the quantity of chemical currently used for chemical phosphorus removal. A more detailed assessment would be needed to determine whether EBPR would be an economic addition to a specific WWTP

Table 6.5-2 shows both the capital cost and combined O&M cost to add EBPR to each of the Vermont WWTPs under evaluation per the cost curves of Section 4.

Table 6.5-2 EBPR Cost for Vermont WWTPs

WWTF	Design ADF, MGD	Capital Budget	Annual O&M Budget
Burlington East	1.2	$0.904 M	$3847
Burlington Main	5.3	$3.008 M	$16,992
Burlington North	2.0	$1.344 M	$6412
Essex Junction	3.1	$1.918 M	$9938
IBM	8.0	$4.293 M	$25,648
Middlebury	2.2	$1.450 M	$7053
Milton	1.0	$0.787 M	$3206
Montpelier	3.97	$2.356 M	$12,728
Northfield	1.0	$0.787 M	$3206
Rock Tenn	2.5	$1.608 M	$8015
Rutland City	6.8	$3.727 M	$21,800
South Burlington Airport Parkway	2.3	$1.503 M	$7374
South Burlington Bartlett Bay	1.25	$0.933 M	$4007
St. Albans City	4.0	$2.371 M	$12,824
Winooski	1.4	$1.019 M	$4488

Table 6.5-3 shows both the capital cost and combined O&M cost to add EBPR to each of the New York WWTPs under evaluation per the cost curves of Section 4.

Table 6.5-3 EBPR Cost for New York WWTPs

WWTF	Design ADF, MGD	Capital Budget	Annual O&M Budget
Dannemora	1.5	$1.076 M	$4809
Granville	1.3	$0.962 M	$4168
International Paper	17.5	$8.615 M	$56,104
Lake Placid	2.5	$1.608 M	$8015
Plattsburgh	16.0	$7.945 M	$51,295
Rouses Point	2.0	$1.344 M	$6412

WWTF	Design ADF, MGD	Capital Budget	Annual O&M Budget
Saranac Lake	2.62	$1.671 M	$8400
Ticonderoga	1.7	$1.188 M	$5450

6.6 Rate Changes for Phosphorus Removal

While capital costs and O&M costs are obviously important, the potential sewer rate impact associated with these costs is what puts these costs into context. We have estimated the change in rates necessary to finance capital improvements for improved phosphorus removal and to operate and maintain those processes. Debt costs are based on capital improvements being financed by bonds over a 20 year period at an interest rate equal to the state SRF rate. As of July 9, 2013, the interest rate for Vermont-EPA Clean Water State Revolving Fund (CWSRF) loans was set to 0%. However, an annual fee of 2% of loan principal is assessed. For CWSRF loans in New York, the rate for long term loans (between 3 and 30 years) is equal to the AAA/Aaa borrowing rate with an interest rate subsidy of 50%. As of September 3, 2013 the AAA rate on 20 year municipal bonds was approximately 4.10% according to FMS Bonds (http://www.fmsbonds.com/Market_Yields/index.asp). This gives a current subsidized rate of 2.05% including the rate subsidy. There is also a 1% one-time initial fee and a 0.25% administrative fee on the outstanding balance annually so that the net annual rate would be equivalent to approximately 2.30%.

The portion of the rate change resulting from changes in operation and maintenance costs is based on 440 households sharing the capital and O&M cost for 100,000 gpd of treated water (assumes 150 gallons per day per household and 1/3 of the total flow is infiltration/inflow). This gives an average flow of 227 gpd per household. Therefore, the number of households was estimated by dividing the average ADF for the past 5 years by 227 gpd (0.000227 mgd) and the effect of O&M cost on rates was determined by dividing the monthly O&M cost by the number of households.

Rate Changes to Achieve 1.0 mg/L TP using Chemical Phosphorus Removal
Estimates of additional O&M (including additional sludge disposal) and capital costs and the rate increases to support them for facilities that need improvements to meet the 1.0 mg/L TP standard are shown in Table 6.6-1 and 6.6-2 for Vermont WWTPs and in Table 6.6-3 for New York WWTPs. The first of each pair of tables includes O&M cost categories and O&M cost totals. Estimates of monthly chemical cost are repeated from Tables 6.2-4 and 6.2-5 using the lowest cost option considered for each chemical. Estimates for capital cost of the additional chemical feed facilities are repeated from Table 6.2-3 based on a 1000 gallon bulk tank with a decrease of $4300 for facilities not needing a bulk tank and an increase for the 5000 bulk tank required at Dannemora. Estimates of additional sludge disposal costs are repeated from Tables 6.4-12 and

6.4-13. The second table in each pair combines the O&M cost with the capital and bonding costs to estimate a monthly rate increase that would recover the combined estimated costs.

Table 6.6-1 Vermont WWTFs – O&M Cost Summary for Chemical P Removal to Achieve 1.0 mg/L TP

Vermont WWTPs	Monthly Chemical Cost		Monthly Energy Cost	Monthly Lab Supplies & Maintenance	Additional Monthly Sludge Disposal Cost		Total Monthly O&M Cost	
	Alum	Ferric			Alum	Ferric	Alum	Ferric
Benson	$ 125	$ 31	$ 21	$ 100	$ 8	$ 8	$ 253	$ 160
Fairfax	$ 354	$ 195	$ 21	$ 100	$ 49	$ 53	$ 524	$ 369
Jeffersonville	$ 586	$ 224	$ 21	$ 100	$ 81	$ 89	$ 788	$ 433
Marshfield	$ 169	$ 93	$ 21	$ 100	$ 23	$ 26	$ 313	$ 239
Orwell	$ 100	$ 55	$ 21	$ 100	$ 14	$ 15	$ 234	$ 191
Otter Valley Union High School	$ 56	$ 14	$ 21	$ 100	$ 3	$ 4	$ 180	$ 138
Pittsford	$ 186	$ 103	$ 21	$ 100	$ 26	$ 28	$ 332	$ 252
Plainfield	$ 254	$ 140	$ 21	$ 100	$ 35	$ 38	$ 410	$ 299
Sheldon Springs	$ 162	$ 40	$ 21	$ 100	$ 10	$ 11	$ 292	$ 171
Shoreham	$ 121	$ 67	$ 21	$ 100	$ 17	$ 18	$ 258	$ 206
Wallingford	$ 177	$ 98	$ 21	$ 100	$ 25	$ 24	$ 322	$ 242
West Pawlet	$ 204	$ 113	$ 21	$ 100	$ 28	$ 31	$ 353	$ 264
Williamstown	$ 367	$ 202	$ 21	$ 100	$ 51	$ 55	$ 538	$ 378

Table 6.6-2 Vermont WWTFs – Rate Increase for Chemical P Removal to Achieve 1.0 mg/L TP

Vermont WWTPs	ADF	Household Equivalents	Capital Cost	Total Monthly O&M Cost		Monthly Bond Payment	Monthly Rate Increase	
	MGD			Alum	Ferric	2%	Alum	Ferric
Benson	0.015	66	$ 96,444	$ 253	$ 160	$ 488	$ 11.22	$ 9.80
Fairfax	0.035	154	$ 100,744	$ 524	$ 369	$ 510	$ 6.70	$ 5.70
Jeffersonville	0.036	159	$ 100,744	$ 788	$ 433	$ 510	$ 8.18	$ 5.94
Marshfield	0.02	88	$ 100,744	$ 313	$ 239	$ 510	$ 9.34	$ 8.50
Orwell	0.021	93	$ 100,744	$ 234	$ 191	$ 510	$ 8.04	$ 7.57
Otter Valley Union High School	0.002	- n/a -	$ 96,444	$ 180	$ 138	$ 488	- n/a -	- n/a -
Pittsford	0.066	291	$ 100,744	$ 332	$ 252	$ 510	$ 2.90	$ 2.62
Plainfield	0.059	260	$ 100,744	$ 410	$ 299	$ 510	$ 3.54	$ 3.11
Sheldon Springs	0.018	79	$ 96,444	$ 292	$ 171	$ 488	$ 9.84	$ 8.31
Shoreham	0.01	44	$ 100,744	$ 258	$ 206	$ 510	$ 17.43	$ 16.24
Wallingford	0.071	313	$ 100,744	$ 322	$ 242	$ 510	$ 2.66	$ 2.40
West Pawlet	0.015	66	$ 100,744	$ 353	$ 264	$ 510	$ 13.05	$ 11.71
Williamstown	0.07	308	$ 100,744	$ 538	$ 378	$ 510	$ 3.40	$ 2.88

Table 6.6-3 New York WWTFs – O&M Cost Summary for Chemical P Removal to Achieve 1.0 mg/L TP

New York WWTPs	Monthly Chemical Cost		Monthly Energy Cost	Monthly Lab Supplies & Maintenance	Additional Monthly Sludge Disposal Cost		Total Monthly O&M Cost	
	Alum	Ferric			Alum	Ferric	Alum	Ferric
Au Sable Forks	$ 484	$ 185	$ 21	$ 100	$ 67	$ 73	$ 671	$ 379
Cadyville	$ 33	$ 8	$ 21	$ 100	$ 24	$ 27	$ 178	$ 155
Crown Point	$ 233	$ 129	$ 21	$ 100	$ 387	$ 423	$ 741	$ 672
Dannemora	$ 2,910	$ 1,113	$ 26	$ 100	$ 4,834	$ 5,275	$ 7,869	$ 6,514
St Armand	$ 361	$ 207	$ 21	$ 100	$ 599	$ 654	$ 1,081	$ 982
Wadhams	$ 103	$ 25	$ 21	$ 100	$ 76	$ 83	$ 300	$ 229
Westport	$ 255	$ 141	$ 21	$ 100	$ 423	$ 462	$ 799	$ 723
Willsboro	$ 232	$ 128	$ 21	$ 100	$ 386	$ 421	$ 739	$ 670

Table 6.6-4 New York WWTFs – Rate Increase for Chemical P Removal to Achieve 1.0 mg/L TP

New York WWTPs	ADF	Household Equivalents	Capital Cost	Total Monthly O&M Cost		Bond Fee	Monthly Bond Payment	Monthly Rate Increase	
	MGD			Alum	Ferric	1%	2.30%	Alum	Ferric
Au Sable Forks	0.059	260	$ 100,744	$ 671	$ 379	$ 1,007	$ 524	$ 4.60	$ 3.47
Cadyville	0.003	13	$ 96,444	$ 178	$ 155	$ 964	$ 502	$ 51.42	$ 49.70
Crown Point	0.031	137	$ 100,744	$ 741	$ 672	$ 1,007	$ 524	$ 9.26	$ 8.76
Dannemora	0.877	3863	$ 153,142	$ 7,869	$ 6,514	$ 1,531	$ 797	$ 2.24	$ 1.89
St Armand	0.04	176	$ 100,744	$ 1,081	$ 982	$ 1,007	$ 524	$ 9.11	$ 8.54
Wadhams	0.006	26	$ 96,444	$ 300	$ 229	$ 964	$ 502	$ 30.32	$ 27.64
Westport	0.136	599	$ 100,744	$ 799	$ 723	$ 1,007	$ 524	$ 2.21	$ 2.08
Willsboro	0.041	181	$ 100,744	$ 739	$ 670	$ 1,007	$ 524	$ 6.99	$ 6.61

Rate Changes to Achieve 0.2 mg/L TP using Chemical Phosphorus Removal

Estimates of additional O&M (including additional sludge disposal) and capital costs and the rate increases to support them for facilities that need improvements to meet the 0.2 mg/L TP standard are shown in Tables 6.6-5 and 6.6-6 for Vermont WWTPs and in Tables 6.6-7 and 6.6-8 for New York WWTPs.

The first of each pair of tables includes O&M cost categories and O&M cost totals. Estimates of monthly chemical cost are repeated from Tables 6.4-8 and 6.4-9 using the lowest cost option considered for each chemical. Estimates for capital cost of the necessary additional chemical feed facilities are repeated from Table 6.4-3 based on a 1000 gallon bulk tank with a decrease of $4300 for facilities not needing a bulk tank. For facilities needing a bulk tank larger than 1000 gallons, the capital cost estimate is taken from Tables 6.4-4 and 6.4-5. For WWTPs that do not currently include filtration nor some other enhanced solids removal process, the estimated costs to add and operate those processes (from Tables 6.4-6 and 6.4-7) are included in the capital and energy cost columns. Estimates of additional sludge disposal costs are repeated from Table 6.4-12 and 6.4-13. The second table in each pair combines the O&M cost with the capital and bonding costs to estimate a monthly rate increase that would recover the combined estimated costs.

Table 6.6-5 Vermont WWTFs – O&M Cost Summary for Chemical P Removal to Achieve 0.2 mg/L TP

Vermont WWTPs	Monthly Chemical Cost		Monthly Energy Cost	Monthly Lab Supplies & Maintenance	Additional Monthly Sludge Disposal Cost		Total Monthly O&M Cost	
	Alum	Ferric			Alum	Ferric	Alum	Ferric
Burlington East	$ 125	$ 84	$ 51	$ 100	$ 40	$ 73	$ 316	$ 308
Burlington Main	$ 1,159	$ 537	$ 168	$ 100	$ 373	$ 628	$ 1,800	$ 1,434
Burlington North	$ 210	$ 140	$ 64	$ 100	$ 68	$ 129	$ 442	$ 433
Enosburg Falls	$ 33	$ 10	$ 24	$ 100	$ 5	$ 16	$ 162	$ 150
Essex Junction	$ 652	$ 302	$ 11	$ 100	$ 210	$ 334	$ 973	$ 747
Fair Haven	$ 68	$ 20	$ 24	$ 100	$ 10	$ 20	$ 202	$ 164
Hardwick	$ 167	$ 112	$ 24	$ 100	$ 54	$ 75	$ 345	$ 311
Hinesburg	$ 45	$ 13	$ 19	$ 100	$ 6	$ 14	$ 170	$ 146
IBM	$ 37	$ 11	$ 168	$ 100	$ 5	$ 118	$ 310	$ 396
Johnson	$ 65	$ 19	$ 19	$ 100	$ 9	$ 19	$ 193	$ 156
Middlebury	$ 132	$ 88	$ 77	$ 100	$ 43	$ 91	$ 352	$ 356
Milton	$ 211	$ 63	$ 38	$ 100	$ 30	$ 46	$ 379	$ 247
Montpelier	$ 392	$ 182	$ 116	$ 100	$ 126	$ 230	$ 734	$ 628
Morrisville	$ 132	$ 39	$ 24	$ 100	$ 19	$ 35	$ 275	$ 198
Newport Center	$ 36	$ 11	$ 13	$ 100	$ 5	$ 7	$ 154	$ 131
North Troy	$ 118	$ 79	$ 14	$ 100	$ 34	$ 46	$ 266	$ 239
Northfield	$ 134	$ 90	$ 38	$ 100	$ 43	$ 75	$ 315	$ 302
Proctor	$ 458	$ 212	$ 24	$ 100	$ 132	$ 177	$ 714	$ 513
Richford	$ 114	$ 34	$ 24	$ 100	$ 16	$ 29	$ 255	$ 188
Rock Tenn	$ 155	$ 46	$ 77	$ 100	$ 22	$ 36	$ 354	$ 259
Rutland City	$ 405	$ 187	$ 207	$ 100	$ 130	$ 358	$ 842	$ 852
Shelburne 1	$ 51	$ 15	$ 11	$ 100	$ 7	$ 20	$ 169	$ 146
Shelburne 2	$ 116	$ 35	$ 11	$ 100	$ 17	$ 35	$ 244	$ 181
South Burlington AP	$ 396	$ 183	$ 11	$ 100	$ 128	$ 219	$ 635	$ 513
South Burlington BB	$ 77	$ 23	$ 11	$ 100	$ 11	$ 37	$ 199	$ 171
St. Albans City	$ 220	$ 65	$ 11	$ 100	$ 31	$ 139	$ 362	$ 315
Swanton	$ 152	$ 102	$ 38	$ 100	$ 49	$ 81	$ 339	$ 321
Troy/Jay	$ 38	$ 11	$ 17	$ 100	$ 5	$ 8	$ 161	$ 137
Vergennes	$ 118	$ 35	$ 11	$ 100	$ 17	$ 36	$ 246	$ 182
West Rutland	$ 44	$ 13	$ 24	$ 100	$ 6	$ 15	$ 175	$ 153
Winooski	$ 237	$ 158	$ 63	$ 100	$ 76	$ 123	$ 477	$ 444

Table 6.6-6 Vermont WWTFs – Rate Increase for Chemical P Removal to Achieve 0.2 mg/L TP

Vermont WWTPs	ADF	Household Equivalents	Capital Cost	Total Monthly O&M Cost		Monthly Bond Payment	Monthly Rate Increase	
	MGD			Alum	Ferric	2%	Alum	Ferric
Burlington East	0.614	2705	$ 1,095,000	$ 316	$ 308	$ 5,539	$ 2.16	$ 2.16
Burlington Main	4.451	19608	$ 2,921,000	$ 1,800	$ 1,434	$ 14,777	$ 0.85	$ 0.83
Burlington North	1.213	5344	$ 217,000	$ 442	$ 433	$ 1,098	$ 0.29	$ 0.29
Enosburg Falls	0.275	1211	$ 840,744	$ 162	$ 150	$ 4,253	$ 3.64	$ 3.63
Essex Junction	1.969	8674	$ 153,000	$ 973	$ 747	$ 774	$ 0.20	$ 0.18
Fair Haven	0.212	934	$ 840,744	$ 202	$ 164	$ 4,253	$ 4.77	$ 4.73
Hardwick	0.214	943	$ 1,275,000	$ 345	$ 311	$ 6,450	$ 7.21	$ 7.17
Hinesburg	0.158	696	$ 850,744	$ 170	$ 146	$ 4,304	$ 6.43	$ 6.39
IBM	2.999	- n/a -	$ 4,110,000	$ 310	$ 396	$ 20,792	- n/a -	- n/a -
Johnson	0.186	819	$ 700,744	$ 193	$ 156	$ 3,545	$ 4.56	$ 4.52
Middlebury	1.035	4559	$ 1,355,000	$ 352	$ 356	$ 6,855	$ 1.58	$ 1.58
Milton	0.231	1018	$ 880,744	$ 379	$ 247	$ 4,456	$ 4.75	$ 4.62
Montpelier	1.972	8687	$ 2,268,000	$ 734	$ 628	$ 11,473	$ 1.41	$ 1.39
Morrisville	0.308	1357	$ 840,744	$ 275	$ 198	$ 4,253	$ 3.34	$ 3.28
Newport Center	0.021	93	$ 596,444	$ 154	$ 131	$ 3,017	$ 34.28	$ 34.03
North Troy	0.078	344	$ 600,744	$ 266	$ 239	$ 3,039	$ 9.62	$ 9.54
Northfield	0.565	2489	$ 885,000	$ 315	$ 302	$ 4,477	$ 1.93	$ 1.92
Proctor	0.258	1137	$ 1,298,000	$ 714	$ 513	$ 6,566	$ 6.41	$ 6.23
Richford	0.246	1084	$ 1,270,744	$ 255	$ 188	$ 6,428	$ 6.17	$ 6.11
Rock Tenn	0.231	1018	$ 1,350,744	$ 354	$ 259	$ 6,833	$ 7.06	$ 6.97
Rutland City	5.313	23405	$ 3,913,000	$ 842	$ 852	$ 19,795	$ 0.88	$ 0.88
Shelburne 1	0.307	1352	$ 100,744	$ 169	$ 146	$ 510	$ 0.50	$ 0.49
Shelburne 2	0.389	1714	$ 100,744	$ 244	$ 181	$ 510	$ 0.44	$ 0.40
South Burlington AP	1.645	7247	$ 128,000	$ 635	$ 513	$ 648	$ 0.18	$ 0.16
South Burlington BB	0.62	2731	$ 100,744	$ 199	$ 171	$ 510	$ 0.26	$ 0.25
St. Albans City	2.69	11850	$ 115,000	$ 362	$ 315	$ 582	$ 0.08	$ 0.08
Swanton	0.548	2414	$ 885,000	$ 339	$ 321	$ 4,477	$ 1.99	$ 1.99
Troy/Jay	0.045	198	$ 876,444	$ 161	$ 137	$ 4,434	$ 23.18	$ 23.06
Vergennes	0.401	1767	$ 100,744	$ 246	$ 182	$ 510	$ 0.43	$ 0.39
West Rutland	0.202	890	$ 840,744	$ 175	$ 153	$ 4,253	$ 4.98	$ 4.95
Winooski	0.76	3348	$ 1,095,000	$ 477	$ 444	$ 5,539	$ 1.80	$ 1.79

Table 6.6-7 New York WWTFs – O&M Cost Summary for Chemical P Removal to Achieve 0.2 mg/L TP

New York WWTPs	Monthly Chemical Cost		Monthly Energy Cost	Monthly Lab Supplies & Maintenance	Additional Monthly Sludge Disposal Cost		Total Monthly O&M Cost	
	Alum	Ferric			Alum	Ferric	Alum	Ferric
Altona Correctional	$ 88	$ 12	$ 51	$ 100	$ 6	$ 10	$ 244	$ 172
Champlain	$ 169	$ 51	$ 168	$ 100	$ 25	$ 41	$ 462	$ 360
Dannemora	$ 5,892	$ 1,240	$ 168	$ 100	$ 403	$ 440	$ 6,563	$ 1,948
Essex	$ 124	$ 17	$ 64	$ 100	$ 7	$ 9	$ 295	$ 190
Fort Ann	$ 187	$ 57	$ 24	$ 100	$ 24	$ 34	$ 336	$ 215
Granville	$ 182	$ 55	$ 11	$ 100	$ 27	$ 61	$ 320	$ 227
Great Meadows Correctional	$ 151	$ 46	$ 24	$ 100	$ 22	$ 41	$ 297	$ 211
Lake Placid	$ 2,075	$ 437	$ 24	$ 100	$ 304	$ 418	$ 2,503	$ 980
Peru	$ 841	$ 177	$ 19	$ 100	$ 110	$ 149	$ 1,070	$ 445
Peru/Valcour	$ 89	$ 12	$ 168	$ 100	$ 5	$ 7	$ 362	$ 286
Plattsburgh	$ 18,021	$ 3,793	$ 19	$ 100	$ 2,361	$ 3,203	$ 20,501	$ 7,115
Port Henry	$ 943	$ 198	$ 77	$ 100	$ 138	$ 191	$ 1,258	$ 567
Rouses Point	$ 2,731	$ 575	$ 38	$ 100	$ 358	$ 484	$ 3,226	$ 1,196
Saranac Lake	$ 1,005	$ 212	$ 116	$ 100	$ 147	$ 252	$ 1,368	$ 680
Ticonderoga	$ 2,214	$ 466	$ 24	$ 100	$ 324	$ 448	$ 2,662	$ 1,039
Washington Correctional	$ 50	$ 7	$ 13	$ 100	$ 3	$ 8	$ 166	$ 128
Whitehall	$ 424	$ 129	$ 14	$ 100	$ 62	$ 100	$ 600	$ 343

Table 6.6-8 New York WWTFs – Additional Rate Increase for Chemical P Removal to Achieve 0.2 mg/L TP

New York WWTPs	ADF	Household Equivalents	Capital Cost	Total Monthly O&M Cost		Bond Fee	Monthly Bond Payment	Monthly Rate Increase	
	MGD			Alum	Ferric	1%	2.3%	Alum	Ferric
Altona Correctional	0.069	- n/a -	$ 596,444	$ 244	$ 172	$ 5,964	$ 3,103	- n/a -	- n/a -
Champlain	0.265	1167	$ 840,744	$ 462	$ 360	$ 8,407	$ 4,374	$ 4.14	$ 4.05
Dannemora	0.877	3863	$ 1,966,000	$ 6,563	$ 1,948	$ 19,660	$ 10,227	$ 4.35	$ 3.15
Essex	0.005	22	$ 550,744	$ 295	$ 190	$ 5,507	$ 2,865	$ 143.47	$ 138.71
Fort Ann	0.067	295	$ 550,744	$ 336	$ 215	$ 5,507	$ 2,865	$ 10.84	$ 10.43
Granville	0.75	3304	$ 1,050,744	$ 320	$ 227	$ 10,507	$ 5,466	$ 1.75	$ 1.72
Great Meadows Correctional	0.365	- n/a -	$ 730,744	$ 297	$ 211	$ 7,307	$ 3,801	- n/a -	- n/a -
Lake Placid	1.114	4907	$ 1,454,000	$ 2,503	$ 980	$ 14,540	$ 7,564	$ 2.05	$ 1.74
Peru	0.238	1048	$ 752,000	$ 1,070	$ 445	$ 7,520	$ 3,912	$ 4.75	$ 4.16
Peru/Valcour	0.004	18	$ 496,444	$ 362	$ 286	$ 4,964	$ 2,583	$ 167.09	$ 162.80
Plattsburgh	5.48	24141	$ 7,672,000	$ 20,501	$ 7,115	$ 76,720	$ 39,911	$ 2.50	$ 1.95
Port Henry	0.539	2374	$ 862,000	$ 1,258	$ 567	$ 8,620	$ 4,484	$ 2.42	$ 2.13
Rouses Point	0.78	3436	$ 1,341,000	$ 3,226	$ 1,196	$ 13,410	$ 6,976	$ 2.97	$ 2.38
Saranac Lake	1.87	8238	$ 1,515,000	$ 1,368	$ 680	$ 15,150	$ 7,881	$ 1.12	$ 1.04
Ticonderoga	1.238	5454	$ 1,676,000	$ 2,662	$ 1,039	$ 16,760	$ 8,719	$ 2.09	$ 1.79
Washington Correctional	0.114	- n/a -	$ 696,444	$ 166	$ 128	$ 6,964	$ 3,623	- n/a -	- n/a -
Whitehall	0.625	2753	$ 845,000	$ 600	$ 343	$ 8,450	$ 4,396	$ 1.81	$ 1.72

Rate Changes to Achieve 0.1 mg/L TP using Chemical Phosphorus Removal

Estimates of additional O&M (including additional sludge disposal) and capital costs and the rate increases to support them for facilities that need improvements to meet the 0.1 mg/L TP standard are shown in Table 6.6-9 and 6.6-10 for Vermont WWTPs and in Table 6.6-11 and 6.6-12 for New York WWTPs.

The first of each pair of tables includes O&M cost categories and O&M cost totals. Estimates of monthly chemical cost are repeated from Tables 6.4-8 and 6.4-9 using the lowest cost option considered for each chemical. Estimates for capital cost of the necessary additional chemical feed facilities are repeated from Table 6.4-3 based on a 1000 gallon bulk tank with a decrease of $4300 for facilities not needing a bulk tank. For facilities needing a bulk tank larger than 1000 gallons, the capital cost estimate is taken from Tables 6.4-4 and 6.4-5. For WWTPs that do not currently include filtration nor some other enhanced solids removal process, the estimated costs to add and operate those processes (from Tables 6.4-6 and 6.4-7) are included in the capital and energy cost columns. Estimates of additional sludge disposal costs are repeated from Table 6.4-12 and 6.4-13. The second table in each pair combines the O&M cost with the capital and bonding costs to estimate a monthly rate increase that would recover the combined estimated costs.

Table 6.6-9 Vermont WWTFs – O&M Cost Summary for Chemical P Removal to Achieve 0.1 mg/L TP

Vermont WWTPs	Monthly Chemical Cost		Monthly Energy Cost	Monthly Lab Supplies & Maintenance	Additional Monthly Sludge Disposal Cost		Total Monthly O&M Cost	
	Alum	Ferric			Alum	Ferric	Alum	Ferric
Barre City	$ 689	$ 417	$ 21	$ 100	$ 87	$ 103	$ 897	$ 641
Brandon	$ 219	$ 132	$ 21	$ 100	$ 28	$ 33	$ 367	$ 285
Burlington East	$ 689	$ 289	$ 51	$ 100	$ 87	$ 103	$ 927	$ 543
Burlington Main	$ 5,902	$ 2,476	$ 168	$ 100	$ 746	$ 883	$ 6,916	$ 3,627
Burlington North	$ 1,227	$ 515	$ 64	$ 100	$ 155	$ 183	$ 1,546	$ 862
Cabot	$ 27	$ 7	$ 21	$ 100	$ 2	$ 2	$ 149	$ 129
Castleton	$ 141	$ 86	$ 21	$ 100	$ 18	$ 21	$ 279	$ 228
Enosburg Falls	$ 159	$ 97	$ 24	$ 100	$ 20	$ 24	$ 303	$ 245
Essex Junction	$ 3,115	$ 1,307	$ 11	$ 100	$ 394	$ 466	$ 3,620	$ 1,884
Fair Haven	$ 191	$ 116	$ 24	$ 100	$ 24	$ 29	$ 339	$ 269
Hardwick	$ 686	$ 288	$ 24	$ 100	$ 87	$ 103	$ 897	$ 515
Hinesburg	$ 133	$ 80	$ 19	$ 100	$ 17	$ 20	$ 269	$ 219
IBM	$ 1,213	$ 509	$ 168	$ 100	$ 153	$ 181	$ 1,634	$ 958
Johnson	$ 176	$ 107	$ 19	$ 100	$ 22	$ 26	$ 317	$ 252
Middlebury	$ 876	$ 368	$ 77	$ 100	$ 111	$ 131	$ 1,164	$ 676
Milton	$ 429	$ 180	$ 38	$ 100	$ 54	$ 64	$ 621	$ 382
Montpelier	$ 21,758	$ 913	$ 116	$ 100	$ 275	$ 325	$ 22,249	$ 1,454
Morrisville	$ 330	$ 200	$ 24	$ 100	$ 42	$ 49	$ 496	$ 374
Newport Center	$ 150	$ 40	$ 13	$ 100	$ 8	$ 10	$ 271	$ 163
North Troy	$ 542	$ 232	$ 14	$ 100	$ 62	$ 56	$ 718	$ 402
Northfield	$ 703	$ 295	$ 38	$ 100	$ 89	$ 105	$ 929	$ 538
Poultney	$ 75	$ 20	$ 21	$ 100	$ 4	$ 5	$ 200	$ 145
Proctor	$ 2,072	$ 616	$ 24	$ 100	$ 237	$ 213	$ 2,433	$ 953
Richford	$ 277	$ 168	$ 24	$ 100	$ 35	$ 41	$ 436	$ 334
Richmond	$ 30	$ 8	$ 21	$ 100	$ 2	$ 2	$ 152	$ 130
Rock Tenn	$ 338	$ 205	$ 77	$ 100	$ 43	$ 51	$ 558	$ 433
Rutland City	$ 3,505	$ 1,471	$ 207	$ 100	$ 443	$ 524	$ 4,255	$ 2,302
Shelburne 1	$ 200	$ 121	$ 11	$ 100	$ 25	$ 30	$ 336	$ 262
Shelburne 2	$ 337	$ 204	$ 11	$ 100	$ 43	$ 50	$ 491	$ 365
South Burlington AP	$ 2,065	$ 866	$ 11	$ 100	$ 261	$ 309	$ 2,437	$ 1,286
South Burlington BB	$ 362	$ 219	$ 11	$ 100	$ 46	$ 54	$ 519	$ 384
St. Albans City	$ 1,388	$ 582	$ 11	$ 100	$ 175	$ 208	$ 1,674	$ 901
Stowe	$ 221	$ 134	$ 21	$ 100	$ 28	$ 33	$ 369	$ 288
Swanton	$ 761	$ 320	$ 38	$ 100	$ 96	$ 114	$ 995	$ 571
Troy/Jay	$ 177	$ 47	$ 17	$ 100	$ 10	$ 12	$ 304	$ 176
Vergennes	$ 343	$ 208	$ 11	$ 100	$ 43	$ 51	$ 497	$ 370
West Rutland	$ 148	$ 90	$ 24	$ 100	$ 19	$ 22	$ 291	$ 236
Winooski	$ 1,147	$ 481	$ 63	$ 100	$ 145	$ 172	$ 1,455	$ 816

Table 6.6-10 Vermont WWTFs – Rate Increase for Chemical P Removal to Achieve 0.1 mg/L TP

Vermont WWTPs	ADF	Equivalent Households	Capital Cost	Total Monthly O&M Cost		Monthly Bond Payment	Monthly Rate Increase	
	MGD			Alum	Ferric	2%	Alum	Ferric
Barre City	2.879	12683	$ 100,744	$ 897	$ 641	$ 510	$ 0.11	$ 0.09
Brandon	0.422	1859	$ 100,744	$ 367	$ 285	$ 510	$ 0.47	$ 0.43
Burlington East	0.614	2705	$ 1,095,000	$ 927	$ 543	$ 5,539	$ 2.39	$ 2.25
Burlington Main	4.451	19608	$ 2,921,000	$ 6,916	$ 3,627	$ 14,777	$ 1.11	$ 0.94
Burlington North	1.213	5344	$ 217,000	$ 1,546	$ 862	$ 1,098	$ 0.49	$ 0.37
Cabot	0.026	115	$ 96,444	$ 149	$ 129	$ 488	$ 5.56	$ 5.39
Castleton	0.366	1612	$ 100,744	$ 279	$ 228	$ 510	$ 0.49	$ 0.46
Enosburg Falls	0.275	1211	$ 840,744	$ 303	$ 245	$ 4,253	$ 3.76	$ 3.71
Essex Junction	1.969	8674	$ 153,000	$ 3,620	$ 1,884	$ 774	$ 0.51	$ 0.31
Fair Haven	0.212	934	$ 840,744	$ 339	$ 269	$ 4,253	$ 4.92	$ 4.84
Hardwick	0.214	943	$ 1,275,000	$ 897	$ 515	$ 6,450	$ 7.79	$ 7.39
Hinesburg	0.158	696	$ 850,744	$ 269	$ 219	$ 4,304	$ 6.57	$ 6.50
IBM	2.999	- n/a -	$ 4,110,000	$ 1,634	$ 958	$ 20,792	- n/a -	- n/a -
Johnson	0.186	819	$ 700,744	$ 317	$ 252	$ 3,545	$ 4.71	$ 4.63
Middlebury	1.035	4559	$ 1,355,000	$ 1,164	$ 676	$ 6,855	$ 1.76	$ 1.65
Milton	0.231	1018	$ 880,744	$ 621	$ 382	$ 4,456	$ 4.99	$ 4.75
Montpelier	1.972	8687	$ 2,268,000	$ 22,249	$ 1,454	$ 11,473	$ 3.88	$ 1.49
Morrisville	0.308	1357	$ 840,744	$ 496	$ 374	$ 4,253	$ 3.50	$ 3.41
Newport Center	0.021	93	$ 596,444	$ 271	$ 163	$ 3,017	$ 35.55	$ 34.37
North Troy	0.078	344	$ 600,744	$ 718	$ 402	$ 3,039	$ 10.93	$ 10.01
Northfield	0.565	2489	$ 885,000	$ 929	$ 538	$ 4,477	$ 2.17	$ 2.01
Poultney	0.265	1167	$ 96,444	$ 200	$ 145	$ 488	$ 0.59	$ 0.54
Proctor	0.258	1137	$ 1,298,000	$ 2,433	$ 953	$ 6,566	$ 7.92	$ 6.62
Richford	0.246	1084	$ 1,270,744	$ 436	$ 334	$ 6,428	$ 6.33	$ 6.24
Richmond	0.075	330	$ 96,444	$ 152	$ 130	$ 488	$ 1.94	$ 1.87
Rock Tenn	0.231	1018	$ 1,350,744	$ 558	$ 433	$ 6,833	$ 7.26	$ 7.14
Rutland City	5.313	23405	$ 3,913,000	$ 4,255	$ 2,302	$ 19,795	$ 1.03	$ 0.94
Shelburne 1	0.307	1352	$ 100,744	$ 336	$ 262	$ 510	$ 0.63	$ 0.57
Shelburne 2	0.389	1714	$ 100,744	$ 491	$ 365	$ 510	$ 0.58	$ 0.51
South Burlington AP	1.645	7247	$ 128,000	$ 2,437	$ 1,286	$ 648	$ 0.43	$ 0.27
South Burlington BB	0.62	2731	$ 100,744	$ 519	$ 384	$ 510	$ 0.38	$ 0.33
St. Albans City	2.69	11850	$ 115,000	$ 1,674	$ 901	$ 582	$ 0.19	$ 0.13
Stowe	0.31	1366	$ 100,744	$ 369	$ 288	$ 510	$ 0.64	$ 0.58
Swanton	0.548	2414	$ 885,000	$ 995	$ 571	$ 4,477	$ 2.27	$ 2.09
Troy/Jay	0.045	198	$ 876,444	$ 304	$ 176	$ 4,434	$ 23.90	$ 23.25
Vergennes	0.401	1767	$ 100,744	$ 497	$ 370	$ 510	$ 0.57	$ 0.50
West Rutland	0.202	890	$ 840,744	$ 291	$ 236	$ 4,253	$ 5.11	$ 5.05
Winooski	0.76	3348	$ 1,095,000	$ 1,455	$ 816	$ 5,539	$ 2.09	$ 1.90

Table 6.6-11 New York WWTFs – O&M Cost Summary for Chemical P Removal to Achieve 0.1 mg/L TP

New York WWTPs	Monthly Chemical Cost		Monthly Energy Cost	Monthly Lab Supplies & Maintenance	Additional Monthly Sludge Disposal Cost		Total Monthly O&M Cost	
	Alum	Ferric			Alum	Ferric	Alum	Ferric
Altona Correctional	$ 204	$ 55	$ 51	$ 100	$ 11	$ 14	$ 366	$ 219
Champlain	$ 380	$ 230	$ 168	$ 100	$ 48	$ 57	$ 696	$ 555
Chazy	$ 144	$ 39	$ 21	$ 100	$ 8	$ 10	$ 273	$ 169
Dannemora	$ 11,728	$ 3,484	$ 168	$ 100	$ 403	$ 440	$ 12,399	$ 4,192
Essex	$ 107	$ 46	$ 64	$ 100	$ 12	$ 11	$ 283	$ 221
Fort Ann	$ 397	$ 170	$ 24	$ 100	$ 45	$ 41	$ 567	$ 335
Granville	$ 587	$ 246	$ 11	$ 100	$ 74	$ 88	$ 772	$ 445
Great Meadows Correctional	$ 389	$ 235	$ 24	$ 100	$ 49	$ 58	$ 562	$ 417
International Paper	$ 3,078	$ 1,291	$ 26	$ 100	$ 389	$ 460	$ 3,593	$ 1,877
Keeseville	$ 189	$ 51	$ 21	$ 100	$ 11	$ 13	$ 320	$ 184
Lake Placid	$ 3,838	$ 1,610	$ 24	$ 100	$ 485	$ 574	$ 4,447	$ 2,308
Peru	$ 1,746	$ 519	$ 19	$ 100	$ 200	$ 179	$ 2,064	$ 817
Peru/Valcour	$ 175	$ 33	$ 168	$ 100	$ 9	$ 8	$ 451	$ 308
Plattsburgh	$ 37,653	$ 11,184	$ 19	$ 100	$ 4,303	$ 3,866	$ 42,074	$ 15,169
Port Henry	$ 1,757	$ 737	$ 77	$ 100	$ 222	$ 263	$ 2,156	$ 1,177
Rouses Point	$ 5,674	$ 1,685	$ 38	$ 100	$ 648	$ 583	$ 6,460	$ 2,405
Saranac Lake	$ 2,371	$ 995	$ 116	$ 100	$ 300	$ 355	$ 2,887	$ 1,565
Ticonderoga	$ 4,114	$ 1,726	$ 24	$ 100	$ 520	$ 615	$ 4,758	$ 2,466
Washington Correctional	$ 180	$ 48	$ 13	$ 100	$ 10	$ 12	$ 303	$ 173
Whitehall	$ 937	$ 393	$ 14	$ 100	$ 118	$ 140	$ 1,170	$ 647

Table 6.6-12 New York WWTFs – Rate Increase for Chemical P Removal to Achieve 0.1 mg/L TP

New York WWTPs	ADF	Household Equivalents	Capital Cost	Total Monthly O&M Cost		Bond Fee	Monthly Bond Payment	Monthly Rate Increase	
	MGD			Alum	Ferric	1%	2.30%	Alum	Ferric
Altona Correctional	0.069	- n/a -	$ 596,444	$ 366	$ 219	$ 5,964	$ 3,103	- n/a -	- n/a -
Champlain	0.265	1167	$ 840,744	$ 696	$ 555	$ 8,407	$ 4,374	$ 4.34	$ 4.22
Chazy	0.037	163	$ 66,908	$ 273	$ 169	$ 669	$ 348	$ 3.81	$ 3.17
Dannemora	0.877	3863	$ 1,966,000	$ 12,399	$ 4,192	$ 19,660	$ 10,227	$ 5.86	$ 3.73
Essex	0.005	22	$ 550,744	$ 283	$ 221	$ 5,507	$ 2,865	$ 142.93	$ 140.10
Fort Ann	0.067	295	$ 550,744	$ 567	$ 335	$ 5,507	$ 2,865	$ 11.63	$ 10.84
Granville	0.75	3304	$ 1,050,744	$ 772	$ 445	$ 10,507	$ 5,466	$ 1.89	$ 1.79
Great Meadows Correctional	0.365	- n/a -	$ 730,744	$ 562	$ 417	$ 7,307	$ 3,801	- n/a -	- n/a -
International Paper	15.148	- n/a -	$ 112,300	$ 3,593	$ 1,877	$ 1,123	$ 584	- n/a -	- n/a -
Keeseville	0.359	1581	$ 66,908	$ 320	$ 184	$ 669	$ 348	$ 0.42	$ 0.34
Lake Placid	1.114	4907	$ 1,454,000	$ 4,447	$ 2,308	$ 14,540	$ 7,564	$ 2.45	$ 2.01
Peru	0.238	1048	$ 752,000	$ 2,064	$ 817	$ 7,520	$ 3,912	$ 5.70	$ 4.51
Peru/Valcour	0.004	18	$ 496,444	$ 451	$ 308	$ 4,964	$ 2,583	$ 172.18	$ 164.07
Plattsburgh	5.48	24141	$ 7,672,000	$ 42,074	$ 15,169	$ 76,720	$ 39,911	$ 3.40	$ 2.28
Port Henry	0.539	2374	$ 862,000	$ 2,156	$ 1,177	$ 8,620	$ 4,484	$ 2.80	$ 2.38
Rouses Point	0.78	3436	$ 1,341,000	$ 6,460	$ 2,405	$ 13,410	$ 6,976	$ 3.91	$ 2.73
Saranac Lake	1.87	8238	$ 1,515,000	$ 2,887	$ 1,565	$ 15,150	$ 7,881	$ 1.31	$ 1.15
Ticonderoga	1.238	5454	$ 1,676,000	$ 4,758	$ 2,466	$ 16,760	$ 8,719	$ 2.47	$ 2.05
Washington Correctional	0.114	- n/a -	$ 696,444	$ 303	$ 173	$ 6,964	$ 3,623	- n/a -	- n/a -
Whitehall	0.625	2753	$ 845,000	$ 1,170	$ 647	$ 8,450	$ 4,396	$ 2.02	$ 1.83

Rate Changes to Incorporate Biological Phosphorous Removal

Estimates of additional costs and rate increases to modify existing facilities so that they will incorporate enhanced biological phosphorous removal capability are shown in Tables 6.6-13 for Vermont WWTPs and 6.6-14 for New York WWTPs. Estimates of EBPR capital O&M costs are repeated from Tables 6.5-2 and 6.5-3. As explained in Section 6.5, these estimates were prepared only for WWTPs designed to treat 1.0 MGD ADF or greater. The addition of EBPR to a WWTP will significantly reduce the quantity of chemical required to achieve effluent limit compliance but for most situations will not eliminate it. Nor will EBPR successfully achieve low effluent TP limits without enhanced solids removal. Consequently, the cost and rate increases associated with EBPR must be considered along with the capital cost and associated rate increases for chemical feed systems. However, the rate of chemical usage and therefore the monthly cost for chemical should be estimated at only about 1/3 to 1/4 of the usage that would be required in the absence of EBPR. The reduction in chemical usage would include not just the increased chemical feed considered in this report but also the quantity of chemical currently used for chemical phosphorus removal. A more detailed assessment would be needed to determine whether EBPR would be an economic addition to a specific WWTP. In addition, some of these facilities may already be practicing EBPR to some extent and would need more detailed assessment to determine the improvements needed to maximize EBPR.

Table 6.6-13 Vermont WWTFs – Rate Increase for EBPR

Vermont WWTFs	ADF	Equivalent Households	Capital Budget	Annual O&M Budget	Bond Fee	Monthly Bond Payment	Monthly Rate Increase
	MGD		Millions		0%	2%	
Burlington East	0.614	2705	$ 0.90	$3,847	$ -	$ 3,767	$ 1.51
Burlington Main	4.451	19608	$ 3.01	$16,992	$ -	$ 12,533	$ 0.71
Burlington North	1.213	5344	$ 1.34	$6,412	$ -	$ 5,600	$ 1.15
Essex Junction	1.969	8674	$ 1.92	$9,938	$ -	$ 7,992	$ 1.02
IBM	2.999	13211	$ 4.29	$25,648	$ -	$ 17,888	$ 1.52
Middlebury	1.035	4559	$ 1.45	$7,053	$ -	$ 6,042	$ 1.45
Milton	0.231	1018	$ 0.79	$3,206	$ -	$ 3,279	$ 3.48
Montpelier	1.972	8687	$ 2.36	$12,728	$ -	$ 9,817	$ 1.25
Northfield	0.565	2489	$ 0.79	$3,206	$ -	$ 3,279	$ 1.42
Rock Tenn	0.231	1018	$ 1.61	$8,015	$ -	$ 6,700	$ 7.24
Rutland City	5.313	23405	$ 3.73	$21,800	$ -	$ 15,529	$ 0.74
South Burlington Airport Parkway	1.645	7247	$ 1.50	$7,374	$ -	$ 6,263	$ 0.95
South Burlington Bartlett Bay	0.62	2731	$ 0.93	$4,007	$ -	$ 3,888	$ 1.55
St. Albans City	2.69	11850	$ 2.37	$12,824	$ -	$ 9,879	$ 0.92
Winooski	0.76	3348	$ 1.02	$4,488	$ -	$ 4,246	$ 1.38

Table 6.6-14 New York WWTFs – Rate Increase for EBPR

New York WWTFs	ADF	Equivalent Households	Capital Budget	Annual O&M Budget	Bond Fee	Monthly Bond Payment	Monthly Rate Increase
	MGD		Millions		1%	2.30%	
Dannemora	0.877	3863	$ 1.08	$4,809	$ 11	$ 5,597	$ 1.55
Granville	0.75	3304	$ 0.96	$4,168	$ 10	$ 5,004	$ 1.62
International Paper	15.148	66731	$ 8.62	$56,104	$ 86	$ 44,816	$ 0.74
Lake Placid	1.114	4907	$ 1.61	$8,015	$ 16	$ 8,365	$ 1.84
Plattsburgh	5.48	24141	$ 7.95	$51,295	$ 79	$ 41,331	$ 1.89
Rouses Point	0.78	3436	$ 1.34	$6,412	$ 13	$ 6,992	$ 2.19
Saranac Lake	1.87	8238	$ 1.67	$8,400	$ 17	$ 8,693	$ 1.14
Ticonderoga	1.238	5454	$ 1.19	$5,450	$ 12	$ 6,180	$ 1.22