PLEASANT BAY ALLIANCE

2022 Annual Report
pursuant to
MassDEP Watershed Permit dated August 3, 2018

SUMMARY AND CONCLUSIONS

Under the terms of the 2018 Watershed Permit, the four towns in the Pleasant Bay watershed are required to report to MassDEP annually on their collective progress toward meeting their individual commitments for nitrogen removal. This document is the fourth annual report and summarizes progress through mid 2022.

Annual reports are called for in the Watershed Permit to track progress toward nitrogen removal goals, document findings related to monitoring of non-traditional technologies, summarize special-purpose studies, and facilitate the adaptive management approach that will enhance the overall nitrogen management program.

In the first four Annual Reports, the Alliance towns have documented these removals of attenuated nitrogen loads:

• Prior to permit issuance:	1,769 kg/yr
• First year:	60 kg/yr
• Second year:	115 kg/yr
• Third year:	1,622 kg/yr
• Fourth year:	485 kg/yr
Total	4,051 kg/yr

The cumulative to-date load removal of 4,051 kg/yr represents 82% of the five-year removal commitment of 4,916 kg/yr.

The four watershed towns have benefited from funding from U.S. EPA Southeast New England Program (SNEP) Watershed Grants. In the first four years of the Permit, important information on non-traditional technologies has been gathered:

- *On-site denitrification*: Through a SNEP-funded investigation, the towns learned more about the performance and cost of a municipal I/A program and that knowledge will allow Brewster to modify its nitrogen removal plans.
- *Shellfish harvesting*. Orleans used SNEP funding to better understand the technical and business issues related to oyster harvesting in Lonnie's Pond and to be able to explore opportunities to expand this program elsewhere.
- *Permeable reactive barriers*. Through a town-funded investigation of a PRB outside the Pleasant Bay watershed, Orleans made progress toward the possible use of this technology in the watershed.

SNEP funding has also allowed the updating of the Massachusetts Estuaries Project (MEP) linked watershed-embayment model to reflect growth in watershed loads, better estimates of natural attenuation, new information on benthic loads, improved hydrodynamics, and recent water quality data. The model update has shown that the current favorable hydrodynamics nearly offset a small increase in watershed loads. There is an ongoing assessment of the model update results and the implications for potential modifications to town plans.

Funding from SNEP also allowed the watershed towns to explore other issues:

- *Nitrogen credit trading*: Through a SNEP-funded investigation, the towns have identified potential cost savings through credit trading, where one town could remove more than its designated share of nitrogen load on behalf of another town which would remove less. The second town would pay the first town for its added removal, and both towns could save money.
- *Nitrogen credits for stormwater management*. The four watershed towns are making improvements to their stormwater management systems, in part to comply with the Massachusetts MS4 general permit. SNEP funds were used to set up a mechanism for measuring nitrogen removals from these activities. Although the magnitude of the credits is expected to be small, the towns may be able to use information collected under their MS4 programs to obtain these credits.
- *Natural attenuation*. A consultant addressed the levels of natural attenuation in three subwatersheds, where town nitrogen removal plans are dependent on the level of attenuation. The study confirmed prior estimate in one sub-watershed and recommended further investigation in two sub-watersheds.

These initiatives add measurably to the watershed towns' ability to adjust their removal plans in a true adaptive management approach. Plans in Harwich, Brewster and Orleans will be modified to account for these new findings. Chatham continues its whole-town approach.

Possible revisions to the nitrogen removal requirements for several sub-watersheds will necessitate modifications in the Watershed Permit's implementation schedule. This issue will be the focus of the Alliance's work in the upcoming year, so towns' nitrogen management plans can be modified before key projects are implemented. Last year's annual report anticipated that the next phase of Harwich's sewer program would allow the Year-5 nitrogen removal goal to be met. As possible changes in Harwich's plan are assessed, it is expected that over the next year the towns will have achieved about 85% of the Year-5 goal.

In addition to these important topics, this report summarizes current water use data, water quality monitoring programs, town capital commitments, growth in watershed nitrogen loads, and stakeholder involvement in the Bay restoration program.

Three basic goals of this fourth annual report have been accomplished:

- Compliance documentation
- Compilation of information to inform adaptive management

- Identification of key steps needed to ensure compliance with nitrogen removal goals.

At the end of Year 4, it is appropriate to conclude that:

- The four towns are proceeding under the terms of the permit;
- Collectively, the towns have been on track to meet the nitrogen removals stipulated under the permit, having accomplished 82% of the Year-5 goal in the first four years of the permit;
- Ongoing studies must be completed to define potential changes in load removal requirements.
- If revised load removal requirements are known by August 2023, then towns should be prepared to revise their plans by August 2024.

This program of annual reports allows the presentation of a snapshot of current data and an update of how new findings are being used to inform the towns' adaptive management approaches. Progress to date reflects the considerable effort and investments expended by the towns to address nitrogen contamination in Pleasant Bay, and the recognition that new technical information, changes in system dynamics and community needs must all be factored into local decisions.

BACKGROUND

The Pleasant Bay Alliance has prepared this fourth annual report in accordance with the August 3, 2018 Pleasant Bay Watershed Permit issued to the Towns of Brewster, Chatham, Harwich, and Orleans. This report is intended to address the annual reporting requirements identified in the Watershed Permit, the Pleasant Bay Targeted Watershed Management Plan (TWMP) and the Cape Cod Commission 208 Consistency Determination on the TWMP. This report was authorized by the four towns.

The Watershed Permit sets forth aggressive goals for achieving nutrient reductions over the twenty-year term of the permit. Adaptive management is one of the fundamental aspects of the Watershed Permit. It is expected that every five years there will be an updated permit that reflects progress already made toward nitrogen removal goals, as well as changes in the watershed and Bay that may modify those goals. An annual report is required under the permit so that key data are assembled as the five-year period unfolds.

The technical heart of the Watershed Permit is the May 2018 Targeted Watershed Management Plan. Section 15 of the TWMP Plan lists 10 items that were recommended be included in the annual report. When the Cape Cod Commission issued its Certificate of 208 Compliance for the TWMP, it requested information in 8 areas, some of which are the same as contained in the TWMP. The 14 items contained in one or both documents are discussed here.

A key part of the Watershed Permit is the one-page Implementation Schedule, which is reproduced in this report as Table 1. It shows the specific nitrogen removal projects included in each Town's plan, and the associated nitrogen removal expectations.

Table 1
Implementation Plan as Contained in the 2018 TWMP
(Expected Project Completion and Potential Annual Nitrogen Removals)

			Brewster		Chatham		Harwich		Orleans		Total
Phase	Years		Activity	kgN/yr*	Activity	kgN/yr*	Activity	kgN/yr*	Activity	kgN/yr*	kgN/yr*
	up to 2018		Res. fertilizer control Capt GC fertigation Capt GC fert. reduction	121 230 930	Res. fertilizer control Muddy Creek Bridge	247	Muddy Creek Bridge		Res. fertilizer control	241	1,769
			All towns: develop TWMP; demonstrate 208 consistency; execute IMA; obtain Watershed Permit								
1 **	1 to 5	2019 to 2023	Develop denit plan Devel. conting. plan Strengthen GC plan		Harwich connection		Ph 2 sewers Res. fertilizer control	2,672 200	Amended CWMP Lonnie's Pond aqua. PRB evaluation	273	3,145
			All towns: update monitoring data, re-model Bay, evaluate nitrogen trading options, prepare plan for next 5 yr								
2 ***	6 to 10	2024 to 2028	On-site denit systems	118			Ph 3 sewers	1,565	MtgHouse Pond sewers Other aquaculture On-site denit systems	2,014 1,516 674	5,887
3 ***	11 to 15	2029 to 2033	On-site denit systems	118	Frostfish Creek sewers Ryders Cove sewers	803 2,605			On-site denit systems Other aquaculture	675 906	5,107
4 ***	16 to 20	2034 to 2038	On-site denit systems	118	Muddy Creek sewers	1,597			On-site denit systems	675	2,390
	after year 20	after 2038	On-site denit systems	236	Crows Pond sewers Bassing Harbor sewers Pleasant Bay sewers Chatham Harbor sewers	1,214 511 901 5,181	Ph 8 sewers Harwich effl. disposal	970 (867)	****		8,146
			Total	**1,871**	**Total**	**13,059**	**Total**	**4,540**	**Total**	**6,974**	**26,444**

* Removals pertain to current nitrogen loads without growth, and represent estimates of removal potential.

** First Phase (Years 1 to 5) includes activities that are firm commitments by the towns and are necessary to gain DEP enforcement discretion.

*** Phases 2 through 5 (Years 6 to 20) include activities that are now planned and considered enforceable until such time as they may change depending on the outcomes of Phase 1 and application of each town's adaptive management program, as per the Watershed Permit.

**** The discharge of Harwich effluent within the Pleasant Bay watershed may become necessary if alternative disposal sites are not developed.

The projects are shown in each of four five-year segments of the 20-year term of the agreement. This annual report covers the fourth year of the first five-year segment, and includes information on how the Table 1 implementation schedule might change at the end of Year 5.

The Annual Report required by the Watershed Permit is due to DEP on or before the anniversary date of the Permit, August 3. Each annual report is to contain information and data for the previous calendar year. Given the fact that significant actions are typically taken at annual town meetings in May, this report includes such information even though it is several months beyond the end of the previous calendar year. Further, some data are regularly reported on a fiscal year basis, that is, through the end of June. Therefore, this annual report contains information spanning from August 2021 to July 2022.

WATER CONSUMPTION

Water consumption is the most important indicator of septic nitrogen load. Table 2 presents water consumption data for the four towns in a format that shows the total metered water in any year between 2014 and 2021, along with the per-service residential and commercial use.

Table 2
Summary of Water Consumption Data

	2014	2015	2016	2017	2018	2019	2020	2021	Avg
Number of Water Services									
Brewster	7,403	7,421	7,426	7,491	7,249	7,287	7,281	6,958	
Chatham	7,083	7,143	7,200	7,236	7,236	7,277	7,469	7,210	
Harwich	9,805	9,858	9,890	9,929	9,969	9,983	10,012	10,050	
Orleans	5,266	5,279	5,249	5,262	5,257	5,266	5,287	5,377	
Total	*29,557*	*29,701*	*29,765*	*29,918*	*29,711*	*29,813*	*30,049*	*29,595*	
Total Metered Water, Mgal/yr									
Brewster	395	475	454	381	402	382	452	433	422
Chatham	413	481	473	408	464	422	487	415	445
Harwich	673	781	810	670	706	677	803	725	731
Orleans	303	334	340	299	303	279	348	314	315
Total	*1,784*	*2,071*	*2,077*	*1,758*	*1,875*	*1,760*	*2,090*	*1,888*	*1,913*
Per-Service Residential Use, gpd									
Brewster	129	157	149	119	138	132	167	167	145
Chatham	143	172	170	140	169	140	169	151	157
Harwich	175	205	212	174	185	177	214	190	192
Orleans	142	158	163	140	144	130	176	156	151
Average	*147*	*173*	*174*	*143*	*159*	*145*	*182*	*166*	*161*
Per-Service Commercial Use, gpd									
Brewster	393	423	375	419	451	391	207	310	371
Chatham	336	296	331	382	266	252	253	259	297
Harwich	394	440	468	396	378	367	337	374	394
Orleans	252	271	280	272	251	240	194	200	245
Average	344	358	364	367	337	313	248	286	327
Town-wide data shown above for illustrative purposes only									
Rainfall at Chatham Airport, inches, in Jun, Jul, Aug, Sept	10.96	10.88	6.80	17.43	9.66	13.49	4.15	15.78	11.14
Deficit below 15 in.	4.04	4.12	8.20	-2.43	5.34	1.51	10.85	-0.78	3.86

The current version of Table 2 contains town-wide data. In future years, the Alliance will work with town water departments to explore the feasibility of reporting watershed-specific water consumption data. (Such data are not intended to be the basis for a new estimate of watershed nitrogen load each year, but instead should be a straightforward way to identify trends in the largest sources of load (residential and commercial septic flows)).

The calendar years 2016, 2018 and 2020 were relatively dry years. A review of water consumption data indicates that summer (June through September) rainfall below 15 inches may be correlated with higher water use for irrigation. Using summer rainfall below 15 inches as an indicator, the deficits in these three years were 8.2, 5.3 and 10.8 inches respectively. (The 5-year period of water consumption data being used in the SMAST update---2011 to 2015---has an average deficit of 2.8 inches. The bases for the TWMP and Watershed Permit are 1.3 inches of deficit for Brewster, Chatham, and Orleans, and 4.8 inches for Harwich.)

The June, July and August of 2021 were very dry, but there was over 5 inches of rainfall in September. For all of 2021, the four towns together billed for nearly 1.9 billion gallons in town-wide water use, about 10% less than 2020. Average per-service residential use in 2021 was 166 gpd, about 9% lower than 2020. (It should be noted that Chatham's water use in 2021 was affected by a summer watering ban.) The impacts of the Covid-19 Pandemic are reflected in the 2020 and 2021 per-service commercial water use, which was 25% below commercial usage typical of 2014 to 2018.

STATUS OF NITROGEN REMOVAL ACTIVITIES AND ESTIMATES OF REMOVALS TO DATE

The 2006 and 2010 MEP/SMAST reports estimated that a load removal of 17,717 kg/yr is needed to restore water quality in Pleasant Bay. In the Watershed Permit implementation table, Table 1, the four towns have committed to a total load removal of 4,914 kg/yr in the first 5 years of the permit.

Table 3 summarizes the nitrogen removals accomplished to date for each town. Watershed-wide, the four towns removed 1,769 kg/yr prior to the Watershed Permit issuance. In the first four years of the Watershed Permit, the single largest nitrogen removal project was a portion of Harwich's sewer program accounting for 1,598 kg/yr of removal. In addition:

- Orleans removed 84 kg/yr in the Lonnie's Pond shellfish harvesting demonstration;
- Chatham facilitated the Harwich sewer project with the connection of the Harwich sewers to the Chatham system;
- Chatham accomplished 400 kg/yr of removal though sewer construction in the Muddy Creek and Frostfish Creek sub-watersheds; and
- Harwich enacted a residential fertilizer control regulation with an associated credit of 200 kg/yr.

Table 3
Summary of Nitrogen Removal Achievements and Goals

	Brewster		Chatham		Harwich		Orleans		Total Load Removal
	Activity	Load	Activity	Load	Activity	Load	Activity	Load	
Nitrogen Load Removals Accomplished Prior to Watershed Permit, kg/yr	Res fertilizer controls GC fertilizer controls	121 1,160	Res fertilizer controls	247	None	-	Res fertilizer controls	241	1,769
New Nitrogen Load Removals Accomplished in FY 2019 to FY 2022, kg/yr			Frostfish Ck and Muddy Ck sewers	400	E. Harwich sewers * Res fert. controls	1,598 200	Lonnie's Pond pilot shellfish harvest	84	2,282
Cumulative Nitrogen Load Removals Accomplished by end of FY 2022, kg/yr		1,281		647		1,798		325	4,051
Expected Load Removals in FY 2023, kg/yr				120			Additional shellfish harvesting **	12	132
Projected Load Removals through mid 2023, kg/yr	***	1,281	***	767	***	1,798		337	4,183
2023 Goals, kg/yr		1,281		247		2,872		514	4,914
Accomplished by 2022, %		100%		262%		63%		63%	82%
Accomplished by 2023, %		100%		424%		63%		66%	85%
20-yr Goal (2038), kg/yr		2,262		4,076		4,399		6,980	17,717

* Sewers are constructed; tie-ins expected over next 2+ years
** Harvest data may change pending results of pilot project
*** Attenuated loads removals may be adjusted by ongoing re-evaluation of attenuation rates

Compared to the long-term target load removal of 17,717 kg/yr, the overall status of TMDL compliance is:

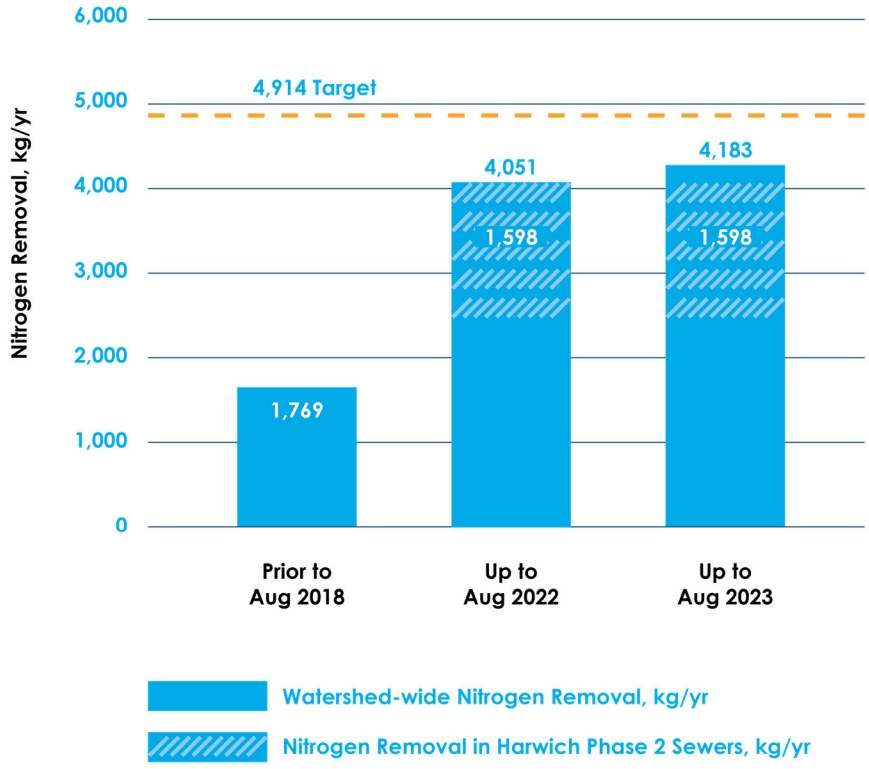
Load removed prior to Watershed Permit issuance:	10.0% (1,769 kg/yr)
Additional load removed through FY 2022:	12.9% (2,282 kg/yr)
Total load removed through FY 2022	22.9% (4,051 kg/yr)
Targeted load removal through FY 2023	27.7% (4,914 kg/yr)

The load removal through 2022 is 485 kg/yr higher than that documented in the 2021 Annual Report, due to the additional sewering in Harwich and Chatham, and increased removal in the Orleans shellfish demonstration.

As discussed below, significant changes in the estimated attenuation in the upper Muddy Creek watershed may result in revisions to the Harwich sewering program, and Harwich has deferred further sewering until its nitrogen removal needs are clarified. Past annual reports have projected that the Year-5 target would be met, on the strength of the next phase of the Harwich sewer project. Much more should be known on the nitrogen removal needs for Muddy Creek in the upcoming year, but not in time for Harwich to move ahead with a new (adjusted) sewer phase. Thus, the current projected load removal at Year 5 is 85% of the original target.

Figure 1 illustrates the progress to date and shows the importance of Harwich's sewering project to date.

Figure 1
Pleasant Bay Nitrogen Removal Progress



The next phase of the Harwich project was expected to remove over 1,200 kg/yr, an amount that would allow the current 5-year target of 4,914 kg/yr to be met. However, it is expected that that 5-year goal may be modified as a result of the studies to be complete by the end of Year 5.

Individual town performance toward the 2023 goal is listed in Table 3 and summarized as follows:

- **Brewster**: With residential and golf course fertilizer controls in place at the time of Watershed Permit issuance, Brewster had already accomplished its share of the 2023 watershed-wide goal. Additional reductions in fertilizer use on fairways and roughs at the Captains Golf Course are planned for 2022 and the estimate of nitrogen removal via fertigation is being refined.
- **Chatham**: Its existing residential fertilizer control ordinance addressed all of Chatham's goal for the first 5 years of the permit. In constructing the connection with Harwich, and addressing neighborhoods in the Frostfish Creek area, Chatham has provided sewer service to about 150 homes in the Muddy Creek and Frostfish Creek subwatersheds, accomplishing another 400 kg/yr, allowing it to exceed its 2023 goal.
- **Harwich**: To accomplish its share of the required nitrogen removal, Harwich needed to enact a residential fertilizer controls ordinance and completes Phase 2 of its proposed sewer system (East Harwich). On January 22, 2021, the Harwich Board of Health adopted the Town of Harwich Fertilizer and Nutrient Control Regulation. Harwich has now completed the first two contracts of its Phase 2 sewer construction and is taking advantage of its agreement with Chatham to receive the wastewater collected from the Pleasant Bay Watershed. Contracts 1 and 2 provide sewer service to about 500 parcels in the Muddy Creek (Upper and Lower), Mill Pond, and Muddy Creek Well sub-watersheds; these sewers provide for 1,598 kg/yr nitrogen removal.
- **Orleans**: Through its residential fertilizer control ordinance and the Lonnie's Pond shellfish harvesting demonstration, Orleans has addressed about 60% of its 2023 target. The remainder has been expected to be achieved through additional shellfish harvesting in Lonnie's Pond or at new sites.

Nitrogen removal progress reported in Table 3 and Figure 1 is based on prior estimates of natural attenuation, as established in 2006 and 2010. Based on recent updates in these attenuation estimates, it would appear that Harwich and Chatham may have gained more credit for their plans than previously thought, and the effects on Brewster are unclear. However, if these better estimates of attenuation had been known previously, different thresholds and removal requirements may have been established. The Alliance has developed a plan to re-assess watershed thresholds and load removal requirements. That new information will be available in late 2022, and will allow revisions in the nitrogen removal credits reported herein. These credit revisions will be reported in the 2023 annual report. They are very important to inform possible changes in town plans, particularly in Harwich.

PERFORMANCE OF SPECIFIC NITROGEN REMOVAL TECHNOLOGIES

Each town's plan is based on a set of nitrogen removal technologies. The nitrogen removal associated with each technology is determined by a few key parameters, as outlined in the appendices to the TWMP. Findings to date are reported below. Monitoring and reporting these key factors are an important part of the towns' adaptive management programs.

Shellfish Harvesting

Orleans is evaluating the regulatory, ecosystem, and private business issues of using aquaculture to remove nitrogen and improve water quality. Issues have included size and age of oysters, their marketability, the nitrogen removal in shell and flesh, nitrogen removal rates, sediment denitrification, scalability and transferability to other sites, and overall water quality impacts. After three years of using a pilot project in Lonnie's Pond to identify and evaluate these parameters, the Town contracted with an aquaculture firm to move this effort to the next step. Monitoring has shown that approximately 0.67% of oyster harvest weight is nitrogen (combined shell/flesh). The Town documented 60 kg of nitrogen removal in 2019, 93 kg in 2020, and 98 kg in 2021. The three-year average removal is 84 kg/yr. The program was modified in 2020 to improve nitrogen removal, and the average removal since then has been 96 kg/yr.

On-going monitoring will quantify the nitrogen removal and water quality improvements, as well as continuing to develop information on denitrification in the sediments below the aquaculture beds. Based on 2021 monitoring, the additional nitrogen removal through denitrification was at least 5 kg and perhaps twice as much. Further discussions are necessary with DEP to determine the amount of that removal that can be applied to the overall goals. Technical assistance to the Lonnie's Pond project was partially supported by the funding from EPA's Southern New England Program (SNEP).

The total nitrogen removal requirement for Lonnie's Pond is 286 kg/yr (272 kg/yr from Orleans and 14 kg/yr from Brewster). If the 2020-2021 performance continues, the shellfish harvesting project will accomplish about one-third of Orleans's responsibility in this sub-embayment.

Public Sewering

For determining nitrogen removal credits for sewering projects in Chatham and Harwich, the operative variables are the measured water use at a given home or business, the estimated 10% consumptive use (water used outside the building that does not become wastewater), and the 26.25-mg/l estimate of septic system impact on the embayment (adjusted for natural attenuation). No adjustment is needed for the nitrogen in the Chatham treatment plant effluent, since the discharge location is outside the Pleasant Bay watershed.

Harwich has measured the water use at homes and businesses in East Harwich within the Phase 2 sewer service area to be able to compute the nitrogen load removed from the watershed.

Construction activities under Phase 2 (Contracts 1 and 2) in East Harwich continued throughout 2021, making the public sewer system available to 498 parcels in the Upper and Lower Muddy Creek watersheds. Annual water use data from 2013 to 2019 were used to compute the anticipated unattenuated N load removal in both the Upper and Lower Muddy Creek subwatersheds. The Upper Muddy Creek sub-watershed includes 346 parcels generating an average wastewater flow of 72,200 gpd which results in an unattenuated N load removal of 2,608 kg/yr. The Lower Muddy Creek sub-watershed includes 152 parcels generating an average wastewater flow of 24,300 gpd resulting in an unattenuated N load removal of 879 kg/yr. Overall, these estimates translate to an average wastewater flow of 194 gpd per parcel and an average nitrogen removal of 7.0 kg/yr per parcel. These estimates will be reconciled with load removal estimates in the recent SMAST model update.

A wastewater flow measuring device exists at the Harwich connection point into the Chatham sewer system. Flow measurement can be used as a check against the computation above, once adjusted for infiltration/inflow and the nitrogen removal that would have occurred in the abandoned septic system.

A sensitivity analysis has been discussed for the future MEP modeling to address how several key input variables might change the estimated septic load and the overall watershed load. Those input variables include the 26.25-mg/l recharge concentration and the assumed consumptive use.

Prior estimates of attenuated nitrogen removal via East Harwich sewering were based on the SMAST's 2010 estimate of 57% attenuation in Upper Muddy Creek and 2% in Lower Muddy Creek. The 2021 model update by SMAST uses better attenuation estimates (10% and zero, respectively). Since the attenuation is now thought to be lower, Harwich's sewer program in these sub-watersheds will actually remove significantly more attenuated nitrogen load than first thought. With the prior attenuation estimates, Harwich's attenuated load removal is 1,598 kg/yr, compared with 3,205 kg/yr with the new estimates. See discussion above in the report section Status of Nitrogen Removal Activities and Estimates of Removals to Date.

On-Site Denitrification

For estimating nitrogen removal credits, the key variables are the measured water use at a given home or business, the estimated consumptive use (water used outside the building that does not become wastewater), and the effluent concentration compared to the 26.25-mg/l estimate of septic system impact on the embayment (adjusted for natural attenuation).

Research conducted under the SNEP grant on behalf of Brewster has determined that on-site denitrification systems would need to produce an effluent nitrogen concentration no greater than 12 mg/l to achieve the TMDL for the major subwatersheds in the Town. For systems that could potentially be used in Brewster, this indicates a potential removal credit of 14.25 mg/l.

As discussed in the 2021 annual report, the Barnstable County Department of Health and Environment completed an analysis of performance data for more than 15 proprietary treatment systems in use across the US as of 2020. That analysis found no system with general approval in Massachusetts able to reliably reach the 12-mg/l goal established by Brewster. Since then, Brewster has been reviewing data from an ongoing study of the NitROE technology being tested in the Shubaels Pond watershed in Marstons Mill, through a project led by the Barnstable Clean Water Coalition. The NitROE system has provisional approval from DEP for an effluent nitrogen concentration of 11 mg/L. Data from the Shubaels study are showing that the system has been able to produce an effluent with a nitrogen concentration at or below 11 mg/l. Based on the outcomes of the golf course projects discussed below, Brewster will continue to monitor the data from the Shubaels Pond program; the use of on-site denitrification systems could still be useful, depending on their performance and their installation and ongoing maintenance costs.

Captain's Golf Course Fertilizer Reduction

MEP modeling established baseline conditions for calculating golf course fertilizer impacts, including application rates and nitrogen leaching. Nitrogen removals from that baseline are computed based on the reduction in applied nitrogen and the assumed 20% fertilizer leaching rate. Brewster previously documented the 930-kg/yr removal already taken by Brewster for fertilizer reductions at the Captain's Golf Course that occurred before issuance of the Watershed Permit.

In 2020, Brewster conducted further studies that indicate fertilizer applications could be reduced by lowering the amounts applied to golf course fairways and roughs and switching from granular fertilizers to sprayed fertilizers during the spring and summer that have lower nitrogen application rates and are applied in a manner that promotes uptake by the golf course turf. This is followed by one granular application in the fall. The new practices were initiated in the fall of 2020 and continued throughout all of 2021.

In 2020, the nitrogen loading rate to the golf course fairways was reduced from 3.0 lb/1,000 sq.ft. to 2.75 lb/1,000 sq. ft. In 2021, the fairway loading rate was reduced further to 1.9 lb/1,000 sq. ft. In addition, the fertilizer application to the golf course rough areas was lowered from 2.0 lb/1,000 sq. ft to 1.0 lb/1,000 sq. ft. Overall, the nitrogen applied to the golf course (factoring in the 20% leaching rate) was 157 kg/yr lower in 2020 than in 2019, and 433 kg/year lower in 2021 than in 2020. The fertilization practices used in the last two years are continuing in 2022. At the end of 2022 it will be possible to better quantity the average annual reduction in fertilizer applications that can be taken as a credit in the watershed permit. There will likely be some variation from one year to the next and that will have to be considered as a credit is established.

Brewster's long-term credit for nitrogen removal at Captains depends on documented reductions in fertilizer use, the data generated from the ongoing fertilizer leaching rate study, and refined estimates of downgradient natural attenuation in the Tar Kiln subwatershed. The prior credit of 930 kg/yr is based on the 2006 estimate that no downgradient attenuation

occurred, but the recent SMAST model update uses a more current attenuation estimate of 60% in the Tar Kiln sub-watershed. Brewster is working with the Pleasant Bay Alliance to quantity the impact of this new attenuation number, including how it impacts the value of the nitrogen reductions taking place at the golf course as well as how it affects the load from existing developed properties in this subwatershed.

Captain's Golf Course Fertigation

To estimate the nitrogen removal credit for fertigation, the key variables are the annual volume of groundwater withdrawn for golf course irrigation, the average nitrogen concentration of that groundwater and the nitrogen leaching rate. Brewster originally estimated that an annual load reduction of 230 kg was accomplished with this approach and that figure is included in the Watershed Permit as having occurred prior to permit issuance.

Brewster has compiled the following data to update that original estimate:

- 2018: 44.429 million gallons pumped @ 2.1 mg/l: 282 kg/yr removed
- 2019: 41.999 million gallons pumped @ 2.3 mg/l: 293 kg/yr removed
- 2020: 50.866 million gallons pumped – no nitrogen sampling conducted
- 2021: 40.146 million gallons pumped @ 3.4 mg/l: 413 kg/yr removed.

Due to an oversight, the irrigation well was not sampled for total nitrogen in 2020, but testing was conducted in 2021. Water use in 2021 was lower than the prior years but the nitrogen concentration was slightly higher. Given the data from 2018, 2019 and 2021, an average of 329 kg/year of nitrogen was removed by the irrigation well on an annual basis. This takes into account a 20% leaching rate for nitrogen in the irrigation water applied onto the course that is assumed to reenter groundwater flowing towards Pleasant Bay. This three-year average represents a 99-kg/yr increase over the original credit of 230 kg/yr.

Brewster has committed to review nitrogen data from monitoring wells at and around the golf course to reconcile an apparent increase in nitrogen concentrations after many years of reduced fertilizer use and several years of fertigation. It is likely that this phenomenon is related to the uptake of nitrogen in the golf course turf and subsoil since the construction of the course. Once saturation in the soil layer is reached, then more nitrogen will migrate down to the water table. A summary of this evaluation is expected to be available in the 2023 Annual Report.

Permeable Reactive Barriers

PRB performance is determined by the groundwater nitrogen load entering and leaving the reactor, as measured from multiple monitoring wells.

Orleans has installed a PRB at the Nauset Middle School (located in the Town Cove watershed) and has monitored its performance through an on-going demonstration project; preliminary performance has indicated total nitrogen concentrations of 1 to 2 mg/l on the downgradient side of the PRB. Additional monitoring is necessary to resolve other related issues, such as

quantification of overall nitrogen removal, predominant groundwater flow directions, and the portion of wastewater nitrogen flowing through the PRB. Orleans has established a long-term target removal of 80% as the trigger for the renewal of the injected carbon source.

Based on the success of the Middle School demonstration project, the Town has conducted further investigation into feasible PRB installations in the Pleasant Bay watershed. Fourteen possible locations have been identified, with a potential nitrogen removal of over 2,000 kg/yr. Thirteen of these locations have been recommended for further evaluation. The Town was successful in having these PRBs placed on the DEP 2022 Intended Use Plan for possible funding. An implementation schedule has not yet been established.

WATER QUALITY MONITORING DATA AND HABITAT ASSESSMENTS

Embayment Monitoring

The focuses of ongoing monitoring programs are:

- **Water column nitrogen and dissolved oxygen:** The Alliance's Water Quality Monitoring Program is currently conducting its 23rd monitoring season in 2022**.** Monitoring occurs at approximately 24 stations selected to track TMDL compliance. A DEP-approved Quality Assurance Project Plan (QAPP) is in place and includes the following parameters: nitrogen (DON, PON, DIN, TON, TN), oxygen, temperature, salinity, and phytoplankton pigments. Sample collection occurs five times annually from July through September. Water samples are analyzed by the Coastal Systems Analytical Facility at the UMass Dartmouth School for Marine Science and Technology (SMAST) and results are reported to the Alliance. The Alliance issues periodic reports reviewing the sampling results and conducts in-depth statistical trend assessments. The most recent statistical trend assessment was further evaluated by SMAST to recommend assessment improvements to better address ecological and regulatory implications. The Alliance monitoring program is funded annually by the towns and will continue.

  The most current report on statistical trends in water quality data is the Cadmus Group report, July 2015 *(Pleasant Bay Alliance Water Quality Monitoring Program: Statistical Analysis of 2000-2014 Water Quality Monitoring Data)*. Water quality data are being further reviewed as part of the updating of the SMAST linked model as funded by a grant from SNEP. Subsequent to this model update, the Alliance plans to resume updating of the statistical trend assessment.

  Alliance-generated water quality data for the period 2015 to 2019 were used by SMAST in its 2021 update of the linked watershed-embayment model.

- **Eelgrass coverage and vitality:** Eelgrass coverage is a key parameter for TMDL compliance. The Alliance and its member communities have utilized eelgrass surveys conducted by the MassDEP Eelgrass Mapping Project. The project conducted mapping

using aerial imagery and field verification methods. Data are available for the following years: 1994, 2001, 2006, 2010, 2012 and 2019. The MassDEP reports for 1994 to 2012 can be found at:

https://docs.digital.mass.gov/dataset/massgis-data-massdep-eelgrass-mapping-project?_ga=2.170582688.1209249591.1560872870-1878295305.1557759152

The 2019 report is not yet available at this site.

The Alliance will work with the MassDEP and others to identify the schedule and extent of future mapping needed to effectively monitor future changes in Pleasant Bay eelgrass beds and to gauge restoration needs.

An analysis of eelgrass coverage from 1951 to 2019 is presented in the 2021 SMAST update of the linked watershed-embayment model.

- **Benthic infauna health and diversity** – The diversity and species in the sediment animal population is a key indicator of ecosystem health in Pleasant Bay. As part of the integrated MEP assessment, quantitative sediment sampling for benthic animals was completed at 34 locations throughout the Bay and this information was compared with water quality and eelgrass measurements. This information was utilized in the characterization of ecosystem health and the development of Pleasant Bay TMDLs. In 2008, as part of the Muddy Creek inlet improvement plan, SMAST conducted an updated assessment of benthic infauna at six locations. In 2014, the Center for Coastal Studies (CCS) collected benthic infauna samples at all MEP locations except Muddy Creek. (The samples were collected at a different time of year, using different protocols from prior MEP work.) This effort was undertaken in concert with a benthic mapping project for the Cape Cod National Seashore. The results of this CCS study are provided in a report entitled *Below the Surface of the Bay, Marine Ecosystem Assessment of Pleasant Bay, Cape Cod, MA*, and is available at:

  https://fopb.wildapricot.org/resources/Documents/FCRV/FoPB-Below%20the%20Surface-CLEAN.pdf

  The SNEP-funded SMAST 2021 model update was based on assessments of water quality and eelgrass and includes the appropriate benthic infauna data needed for assessing ecological health in Pleasant Bay.

Project-Specific Monitoring

Monitoring programs related to mitigation measures for specific projects are:

- **Orleans** worked with SMAST to develop a management plan and monitoring program for an oyster growing pilot project in Lonnie's Pond. Orleans' latest

reporting of monitoring data related to the first two years of the Lonnie's Pond oyster growing project is contained in an SMAST report dated February 26, 2022.

- **Brewster** agreed to monitor groundwater irrigation water quality at the Captains Golf Course and to evaluate the ongoing reductions from fertilizer management at the golf course. This includes a two-year study to confirm the leaching rate for nitrogen applied in fertilizers at the course. Funding for this study was approved in May 2021, and the project is currently beginning with the installation of monitoring wells and pan lysimeters to measure nitrogen in water leaching through the golf course turf.

- **Chatham and Harwich** are undertaking bacterial and nitrogen-related water quality monitoring and vegetation monitoring to evaluate changes in water quality resulting from the Muddy Creek Restoration Bridge Project. The first Muddy Creek comprehensive monitoring report, and a vegetation monitoring report, are available at

  http://pleasantbay.org/programs-and-projects/wetlands-protection/muddy-creek-restoration/muddy-creek-restoration-monitoring-results.

Copies of Alliance-sponsored reports are available on the PBA website, *www.pleasantbay.org*.

CAPITAL COMMITMENTS AND EXPENDITURES

The four towns' financial commitments and intentions are summarized in Table 4. The high points are as follow:

Brewster

Since 2011 Brewster has invested approximately $1,200,000 in the development and implementation of the Town's Integrated Water Resource Management Plan (IWRMP). The IWRMP evaluates all the water resources in town, including management of the nitrogen load to Pleasant Bay from Brewster's portion of the watershed. The funding includes the golf course leaching rate study approved in May 2021 for $140,000 that is currently underway. The results of this study will help guide what additional nitrogen removals will be needed using either onsite denitrification systems or a neighborhood wastewater treatment plant. At that point funding for additional steps needed to meet the permit obligations will be requested.

Brewster is also developing a preliminary concept plan for a traditional neighborhood wastewater treatment facility as required under the watershed permit. Over the next few years this plan will be updated once more information is developed at the golf course and a better estimate of the facility's size can be developed.

Table 4
Summary of Capital Commitments

	Brewster	Chatham	Harwich	Orleans
Prior to July 2018				
Funds expended	$0.75 M for IWRMP	$75 M for sewers and WWTF	$2.265 M paid to Chatham for capacity	>$1 M for planning $2.7 M for sewer and WWTF design
Funds appropriated but not expended		$47.5 M for sewers	$22.45 M for sewer project (ATM 2018)	
FY 2019 to FY2023 *Permit Yr 1 to 5*				
Funds expended	$0.30 M for permit implementation and GC leaching study	$1M for sewers		$6 M for downtown sewers $59 M for sewer and and WWTF constr.
Funds appropriated	$0.075 M for on-site program (ATM 2019)	2019–$7.1 M for sewers 2021–$7 M for sewers 2021–$4.5 M for SW	$4.50 M to be paid to Chatham for capacity	2023--$33M Mtghse constr.
Anticipated future appropriations	$0.175 M to $0.325 M for on-site program	$10-20 M every 2 to 3 years for sewers		
FY 2024 to FY 2028 *Permit Yr 6 to 10*				
Anticipated future appropriations		$15-20 M every 2 to 3 years for sewers		2024--$7.8M PRB constr.

Note: Chatham expenditures and appropriations are town-wide, not just Pleasant Bay

The option of using this traditional facility to manage future nitrogen loads under buildout will be considered and will be evaluated in context with the onsite denitrification option recognizing that new information on these systems' performance will likely be available at the five-year point in the watershed permit.

Chatham

The Town of Chatham has an approved CWMP that partitioned the Town into two phases; Phase 1 includes areas to be sewered to achieve TMDL compliance in all Chatham watersheds (including Pleasant Bay), and Phase 2 calls for sewering of the remainder of the Town not needed to meet TMDLs. To date, the Town has appropriated over $140 million dollars toward these goals, and most recently appropriated approximately $4.5 million to address areas targeting the Pleasant Bay watershed, including stormwater improvements to the Frostfish Creek subwatershed.

The Chatham-Harwich Regionalization Connection Project is complete. This serves as the connection for East Harwich wastewater to be conveyed to the Chatham Water Pollution Control Facility for treatment, in addition to serving 60 properties within the Muddy Creek sub-watershed of Pleasant Bay. The Phase 1C 3&4 project that includes a neighborhood in the Frostfish Creek subwatershed is also complete, as is the Phase 1E Stony Hill/Crowell Road Infrastructure Improvements Project.

The Town also has other sewer projects in design or construction: Phase 1D-2: Route 137 – Morton Road Sewer Extension Project began construction in June of 2022. The Phase 1D-2 project will sewer 30 properties within sub-watersheds to Pleasant Bay (whereas the bulk of this project addresses the Town's southern facing estuaries). The Town is also proceeding with the Crowell Road Phase 2 Stormwater Improvements project that will continue to address stormwater needs of Frost Fish Creek and will include a portion of dry sewer that eventually will serve adjacent neighborhoods in both Pleasant Bay and Stage Harbor watersheds.

Harwich

The Town of Harwich has an approved Comprehensive Wastewater Management Plan (CWMP) that calls for sewering large sections of the Pleasant Bay watershed located in East Harwich. Implementation of Phase 2 of the CWMP is nearing completion and was funded by a 2018 Town Meeting appropriation of $22.45 million. The Phase 2 construction included two contracts and serves 440 parcels in the Upper and Lower Muddy Creek sub-watersheds. Due to field modifications that occurred during construction, the Town was able reduce the total project cost allowing for the execution of a change order in the amount of $1.5 million which resulted in the inclusion of an additional 57 parcels for a total of 497 parcels served by Phase 2. Harwich was successful in obtaining a state revolving fund (SRF) loan at a 0% interest due to its nitrogen removal efforts as well as regional cooperation with Chatham.

At the Special Town Meeting in Fall of 2021 Harwich funded two wastewater-related articles related to the Pleasant Bay watershed, including revisions to the CWMP in the amount of

$250,000, and $2.1 million to complete the design of the Phase 3 collections system within the Pleasant Bay and Round Cove sub-watersheds. Both projects are now underway, and the Town intends to submit project applications for the SRF Intended Use Plan this year with construction anticipated to begin late 2023 or early 2024. In addition to the Special Town Meeting appropriations, the Town also recently signed a contract to conduct effluent recharge investigations in the amount of $60,000. Fall town meeting also approved $200,000 for the Route 28 sewer design outside the Pleasant Bay watershed.

As revisions to the CWMP are ongoing, the Town maintains its effort to find a regional solution for wastewater generated outside the Pleasant Bay watershed. With the prospect of the Dennis-Harwich-Yarmouth Clean Waters Partnership now off the table, Harwich has engaged in preliminary discussions with the Town of Dennis who recently appropriated over $7 million to design a wastewater treatment plant.

Orleans

Prior to the Watershed Permit issuance, Orleans spent $3.4M on the design and installation of downtown sewers in the area of a Mass DOT construction project to avoid a road opening prohibition. Another $2.7M was spent in the design of a new WWTF. At the 2019 and 2020 Annual Town Meetings, voters approved a total of $59.1M for the construction of downtown sewers and the wastewater treatment plant. Construction began in September 2020. While these expenditures do not immediately accrue to the benefit of Pleasant Bay, they are part of the infrastructure that will eventually serve portions of Orleans in the Pleasant Bay watershed.

In May 2021, the Town Meeting authorized $658,000 for final design of sewers in the Meetinghouse Pond sub-embayment of the Pleasant Bay system. That design was completed in FY 2022. The May 9, 2022 Annual Town meeting authorized $32.9 million, enabling the construction to begin in FY 2023. Upon completion in FY 2025, septic nitrogen from households in the Meetinghouse Pond sub-watershed would be removed from this area and treated/disposed outside the Pleasant Bay watershed, at the WWTF mentioned above. The goal is the removal of an annual load of 2,015 kg, or about 30% of Orleans' share of the TMDLs. Under the current plan, those removals would begin in the second 5-year segment of the Implementation Schedule, consistent with the Watershed Permit.

Orleans has continued with its shellfish harvesting demonstration project in Lonnie's Pond. The Town has established an initial nitrogen removal target of 75 kg/yr through the Lonnie's Pond Management Plan. The Plan is implemented through an aquaculture contractor and a monitoring contractor. Ward Aquafarms of Buzzards Bay was selected as the aquaculture contractor, while SMAST was selected as the monitoring contractor. The Plan provides the option to place 5.5 million small oysters or 2.1 million larger oysters in the Pond to achieve the nitrogen removal target. The oysters are grown for the summer and removed by the end of the growing season in the same year. Oysters are then grown to market size in another location. In 2020, 2021 and 2022, the demonstration project removed an average of 84 kg/yr of nitrogen from the Pleasant Bay Watershed. This represents about 3% of the Town's overall goal for multiple shellfish harvesting operations in the Pleasant Bay watershed. The Watershed

Permit's Implementation Schedule calls for 272 kg/yr removal in place by the end of FY 2023, which translates to three other harvesting areas of comparable size to the Lonnie's Pond operation. Results of the Lonnie's Pond demonstration are being considered in upcoming revisions to Orleans' plans.

Based on the results of a successful PRB demonstration at the Middle School, Orleans is now planning to add this technology to its plan, and its 5-yr CIP includes $7.8 million in FY 2024 for constructing one or more PRBs in the Pleasant Bay Watershed.

The Orleans Amended CWMP is in draft form and the Town plans to complete it before the end of FY 2023, consistent with the Implementation Schedule. The Town is involved in ongoing evaluations as part of its adaptive management strategy that includes shellfish harvesting, PRBs, and other non-traditional nitrogen removal technologies. Refinements of the Orleans plan are expected to be available in the upcoming year and will be reported in the 2023 annual report.

(The Commission has requested annual documentation of each town's ability to support the level of funding that is proposed, as well as the financial impact on users. That request will be addressed in subsequent annual reports.)

PROGRESS IN NON-STRUCTURAL AND NON-SEWERING OPTIONS

Non-structural options include such techniques as residential lawn fertilizer controls, land set-asides, rezoning, etc. Non-sewering approaches include on-lot denitrification, inlet widening, etc. Progress through FY 2022 includes:

Brewster

Brewster initiated a fertilizer leaching rate study at Captains Golf Course in 2021. Six lysimeters and six monitoring wells were installed below the fairways at the golf course. Quarterly sampling of water captured in the lysimeters and water from the monitoring wells began in November 2021, with additional samples taken in March 2022 and June 2022. An interim report on the study will be prepared in the fall of 2022 after one year's worth of samples have been collected and analyzed.

At the November 2021 Town Meeting, the Town adopted a town-wide stormwater management bylaw that requires a permit for any project disturbing over 10,000 square feet of land or creating more than 500 square feet of impervious cover. The bylaw requires the utilization of best management practices for stormwater to minimize nutrient inputs to groundwater and surface waters. An update to the Town's Water Quality Review Bylaw was also approved, clarifying the methods to calculate nitrogen loading and meet the 5-mg/l nitrogen performance standard for new development and redevelopment projects in the Pleasant Bay watershed. Subsequently, the Board of Health adopted a new regulation providing the requirements for developing nitrogen loading calculations to comply with the Water Quality Review Bylaw.

Since 2008, the Town, along with the Brewster Conservation Trust, has permanently preserved approximately 250 acres of open space in the Pleasant Bay watershed, removing land from development that would impact the buildout nitrogen load to the Bay. Preserving this land reduces the impact of buildout development on the future nitrogen load to Pleasant Bay.

Chatham

Chatham continues to investigate opportunities to address stormwater infrastructure improvements throughout the town as part of its MS4 program. The Town adopted its Fertilizer Regulation in November 2014 and continues to support and enforce these requirements.

The Town, in cooperation with Harwich, completed construction of the Muddy Creek Bridge several years ago. The two towns in coordination with the Pleasant Bay Alliance are monitoring the success of that project. The project changed out small culverts which limited flow with a clear span bridge to allow for increased tidal flow during each tide cycle.

Chatham completed purchase of 4.17 acres of open space on the shore of Goose Pond within the Pleasant Bay Watershed.

The Town is cooperating with the Chatham Conservation Foundation (a private land conservation organization), MassDOT, USDA Natural Resource Conservation Service (NRCS) and Massachusetts Division of Ecological Restoration (DER) to evaluate alternatives to under-sized culverts where Rt. 28 crosses Frost Fish Creek.

Chatham is also working with MassDOT and NRCS on a new (enlarged) culvert where the herring run from Lovers Lake discharges to Ryders Cove.

Harwich

In 2016, the Town, in cooperation with the Town of Chatham, removed an earthen dike and culvert structure that blocked tidal flow between Muddy Creek and Pleasant Bay, and replaced it with a new Muddy Creek Bridge. The two towns in coordination with the Pleasant Bay Alliance are monitoring the success of that project. As a result of the project, tide range in Muddy Creek has increased and is nearly the same as for the main basin of Pleasant Bay.

The Harwich Board of Health adopted its Fertilizer and Nutrient Control Regulation in January 2021 to provide a regulatory framework that results in reducing nutrient loadings from the application of fertilizers. In October 2021, the Town was advised that the Attorney General determined that Chapter 262 of the Acts of 2012 preempts local regulation of fertilizer application, as such the Board of Health rescinded the regulations and adopted Town of Harwich Fertilizer Policy Guidelines for Nutrient Control in February 2022.

The Town of Harwich, working through its Board of Selectmen and its Conservation Commission, works closely with Harwich Conservation Trust to purchase property or obtain

the necessary conservation restrictions to protect environmental resources throughout the town. Over the past fifteen years this partnership has led to the purchase of the 43-acre Monomoy River Woodlands and the 49-acre Pleasant Bay Woodlands properties in the Pleasant Bay watershed. More recently this partnership led to the protection of the 17-acre Marini property adjacent to Muddy Creek in the Pleasant Bay Watershed.

Orleans

In 2020, the Town Meeting voted to acquire a 2.6-acre parcel fronting Arey's Pond, preventing development of the parcel. There are no current zoning changes anticipated in the Pleasant Bay watershed, although 2017 rezoning in the downtown area is expected to help concentrate growth there, outside the Pleasant Bay watershed. The Town, in conjunction with the Orleans Conservation Trust, has purchased two existing homes in the Pleasant Bay watershed and modified the parcels to eliminate future septic loads there.

Orleans continues to make improvements to its stormwater system, and is in compliance with its MS4 stormwater permit.

GROWTH IN NITROGEN LOAD

Growth in the watershed nitrogen load, to the extent not already accounted for in a town's plan, represents both a financial burden and the need to expand/modify the plan. Growth is defined as increased nitrogen load since the baseline years that are part of the 2006 MEP report and the 2010 update related Harwich water use. Those baseline years are:

Brewster:	2002 to 2004
Chatham:	2002 to 2003
Harwich:	2004 to 2007 (updated from 2004 in MEP-2006 report)
Orleans:	2002 to 2003

A broad assessment of growth trends is possible through analysis of the water use data described above and in Table 2. That assessment will be included in later-years' annual reports once watershed-specific data are available.

Reporting by SMAST, under the SNEP-funded update of watershed nitrogen loads, indicates an approximate 3.5% increase in watershed-wide un-attenuated load between the 2010 SMAST report (data mid-point of 2003), and the 2011-to-2015 basis for the 2021 update (data mid-point of 2013). The associated increase in attenuated load is approximately 5.7% over the 10-year period. The increase in attenuated load reflects both the increase in un-attenuated load and revised estimates of attenuation that are, in the aggregate, less than 2010 estimates.

In their CWMPs or other planning studies, the towns have projected nitrogen loads out to either build-out or to an earlier planning horizon. Those projections are for a 27% increase in nitrogen load watershed-wide, with individual town projections ranging from 19% to 41%. The towns have not clearly laid out their plans for accommodating the growth in load that has already

occurred (2003 to 2013) or the further growth anticipated through their planning horizons. Accommodating growth in watershed loads is an important task that the towns must address. Accordingly, funds from the 2020 SNEP grant are being used to update towns' growth projections and to predict the impacts of that growth on receiving water quality.

MODELING OF WATERSHED LOADS AND EMBAYMENT WATER QUALITY

The SMAST/MEP technical report on Pleasant Bay was completed in 2006 and was supplemented with further analysis in 2010. That report formed the basis for the Pleasant Bay TMDLs, and with the updated information allowed the establishment of the nitrogen load removal requirements of each by towns. With funding from the 2018 EPA SNEP grant, the Alliance has overseen the updating of the watershed loads and a re-modeling of receiving water quality under current hydrodynamic conditions. This effort has allowed the input of additional water quality and consideration of habitat data accumulated since the early 2000s. This remodeling was completed in June 2021 and is summarized in the SMAST report *Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Orleans, Chatham and Harwich, Massachusetts.*

The 2021 SMAST study updated all the key components of the Pleasant Bay MEP assessment including:

- An update of watershed water-use and nitrogen loads
- Updating nitrogen recycling from Bay sediments
- Assessment of status of eelgrass habitat based on MassDEP surveys
- Revised estimates of attenuation of two sub-basins (Muddy Creek and Tar Kiln Stream/Salt Marsh)
- Updated system tidal hydrodynamics, including new inlets (post-2006) and new bathymetry
- Scenarios to predict changes in water quality under current town nitrogen removal plans

There are three fundamental variables considered in the 2021 SMAST study, and their impacts on predicted water quality provide insight into potential changes in the Watershed Permit:

- An increase in watershed loads
- Better estimates of attenuation and benthic recycling, and improved hydrodynamics
- Implementation of town nitrogen removal plans, full and partial.

The "Composite Scenario" considered by SMAST reflects full sewering in Chatham (removing much more than Chatham's responsibilities under the Watershed Permit) and removals in Brewster and Orleans that are significantly less than their commitments. The "TMDL Scenario" considers just the specific nitrogen removal requirements of the Watershed Permit.

The SMAST study involved these two primary future scenarios, which are compared here with the 2010 work which is the basis for the Watershed Permit.

	SMAST-2010 (basis for Permit)	SMAST-2021 Composite Scenario	SMAST-2021 TWMP Scenario
Un-attenuated load, kg/yr	54,460	54,894	56,389
Attenuation, kg/yr	5,960	4,623	5,104
Attenuated load, kg/yr	48,500	50,271	51,285
Load removal, kg/yr	17,720	25,947	17,720
Remaining load, kg/yr	30,780	24,324	33,565
Sentinel station compliance			
Primary stations	2 of 2	2 of 2	2 of 2
Secondary stations	8 of 8	6 of 8	7 of 8

Comparing the first 2021 SMAST model run (Composite Scenario) with the 2010 evaluation shows the effect of increased watershed loads and a partial, unbalanced set of town load removals in the face of improved hydrodynamics. In this scenario, two of the secondary stations are predicted not to meet the target concentrations, even though the remaining load (after town removals) is only 79% of the threshold loads. This is because the load removals, although larger than required under the Watershed Permit, are heavily influenced by larger-than-required removals in Chatham. The less-than-required removals in Brewster and Orleans do not allow two of the northerly secondary stations to reach their target concentrations.

Comparing the second 2021 SMAST model run (Composite Scenario) with the 2010 evaluation shows the effect of increased watershed loads and the balanced set of town load removals that the towns have committed to in the Watershed Permit. In this scenario, the Watershed Permit removals (17,720 kg/yr) result in a remaining attenuated load (after town removals) of 33,565 kg/yr, 7% higher than the threshold load. In this scenario, only one of the secondary stations is predicted not to meet the target concentrations. The near full compliance at the sentinel stations indicates that the improved hydrodynamics nearly offset the 5.7% increase in attenuated watershed load if the town remove their 17,720 kg/yr commitments.

Neither scenario considers the effect of future growth on any town's ability to meet nitrogen reduction targets.

In the upcoming year, it is proposed that the SMAST model will be run to help estimate possible new threshold loads that would apply to current hydrodynamics, and to consider added watershed loads through build-out. The results of these further studies will be reported in full in the fifth annual report due in August 2023.

THIRD-PARTY REVIEW OF ATTENUATION ESTIMATES

The TWMP showed that natural attenuation reduces the unattenuated nitrogen load across the watershed by about 11%. In some watersheds, the role of natural attenuation is greater than average. Those sub-watersheds are the ones shared by Brewster and Orleans, and the Muddy Creek sub-watersheds shared by Chatham and Harwich.

SNEP-funded studies by SMAST in 2021 allowed re-estimation of attenuation percentages. Compared with the 2006 MEP report and SMAST updates in 2010, this more current SMAST work revised the attenuation estimates significantly downward in upper Muddy Creek and significantly upward in Tar Kiln Stream. Further, SMAST recommended that Orleans consider the possible attenuation in the salt marshes in the Pochet Neck sub-watershed where attenuation was not previously addressed. These new estimates could result in significant changes in the nitrogen removal requirements for Harwich, Brewster and Orleans.

Given the importance of attenuation in determining towns' removal responsibilities, the Alliance retained HydroAnalysis in 2021 to conduct a review of prior and new estimates of attenuation in the Muddy Creek, Tar Kiln and Pochet Neck sub-watersheds. HydroAnalysis' February 2022 report generally agreed with the new attenuation estimate for Tar Kiln Stream, and recommended further investigations to refine or confirm the estimates for Muddy Creek and Pochet Neck. HydroAnalysis emphasized that future nitrogen management planning should recognize the high degree of uncertainty associated with any attenuation estimate.

Further analysis of the attenuation in these sub-watersheds, based on new field work, will be conducted in 2022 by SMAST under the current SNEP grant.

GROUNDWATER DISCHARGE PERMITS AND I/A SYSTEMS

There are 16 Groundwater Discharge Permit holders in Brewster, Chatham, Harwich, and Orleans. There are four facilities with GWD permits located in the Pleasant Bay watershed:

- Pleasant Bay Health & Living Center (Brewster), 26,500 gpd permitted maximum
- Chatham Bars Inn (Chatham), 60,000 gpd permitted maximum
- Wequassett Inn (Harwich), 45,000 gpd permitted maximum
- Nickerson State Park (Brewster), 50,900 gpd permitted maximum

Each of the first three facilities has a total nitrogen discharge limit of 10 mg/l of total nitrogen. In 2021, The Pleasant Bay Health & Living Center regularly met its permit requirements with only one exceedance. The Chatham Bars Inn regularly met its permit requirements with no exceedances. The Wequassett Inn has experienced some minor excursions, but generally produces very good effluent with respect to nitrogen and its other permitted parameters. The SMAST 2021 model update reports that the aggregate nitrogen load from these three facilities is 705 kg/yr.

The permit for Nickerson State Park allows Title 5 discharges up to the stated maximum and limits total nitrogen recharge to 2,120 kg/yr. Not all of the permitted activities are in the Pleasant Bay watershed.

As of July 2022, there are no applications pending for new GWD permits in the watershed.

There are two other GWD permits of note in the region. The municipal wastewater treatment facility in Chatham discharges outside the Pleasant Bay watershed but is soon to receive wastewater and nitrogen load from the Pleasant Bay watershed in Harwich. Similarly, the Town of Orleans has obtained a GWD permit for the under-construction Orleans municipal WWTF discharge at a site off Lots Hollow Road. That Orleans facility will receive and treat wastewater and nitrogen load from at least the Meetinghouse Pond sub-watershed.

SMAST has reported that there are now 119 I/A systems in the watershed (3 in Brewster, 84 in Chatham, 5 in Harwich and 27 in Orleans). Analysis of reported effluent data indicates an average total nitrogen concentration of 21.9 mg/l, or an average 17% reduction from the 26.25 mg/l baseline for traditional septic systems.

DATA FROM BUILDING DEPARTMENTS AND ASSESSORS

In future annual reports, town departments will provide information on development and redevelopment as derived from the towns' traditional annual reports that are released before Town Meetings. The Commission has also requested data on the location and square footage of new structures and the number of new bedrooms in the watershed. The Alliance and the towns will work with Commission staff during the fifth year of the permit to develop a practical cost-effective approach toward meeting this reporting goal.

EVALUATION OF NITROGEN TRADING OPPORTUNITIES

The Alliance has investigated "nitrogen trading", whereby one town could remove more than its share of nitrogen load on behalf of another town that would remove less than its share. The second town would pay the first town for the nitrogen load removed on its behalf. That investigation was funded in part by the 2018 EPA SNEP grant.

In early 2021, data were obtained from the towns to compute overall costs for nitrogen control and to estimate expected annual nitrogen removals. These costs and removal estimates were adjusted for a common set of assumptions to allow comparison of each town's plans on a "dollar per pound of nitrogen removed" basis. Of the five technologies being used or considered by the towns (sewers, I/A systems, permeable reactive barriers, golf course fertilizer controls and shellfish harvesting), these unit cost were found to vary from less than $10/lb to over $700/lb. The cost differentials among technologies can provide the impetus for nitrogen trading.

The investigation identified three trading scenarios, wherein some towns would scale back their use of the relatively more expensive technologies (I/A systems and permeable reactive barriers) and other towns would increase their use of relatively less technologies (principally sewers). The identified scenarios would result in savings in equivalent annual costs of $660,000 to the "buyers" and an equivalent cost benefit to the "sellers".

The report summarizing this investigation was completed in early fall 2021; it is entitled *Report on Nitrogen Trading Opportunities Among Watershed Towns*. The towns now have this

tool available to them as they refine and update their nitrogen management plans. Should towns elect to pursue trading opportunities, a change in the Watershed Permit would be needed to modify towns' nitrogen removal commitments. It is unlikely that nitrogen-trading-related changes would be known before the end of the first 5-year period of the current Permit.

CONSIDERATION OF NITROGEN REMOVAL CREDITS FOR STORMWATER MANAGEMENT ACTIVITIES

None of the watershed towns has yet proposed to gain nitrogen removal credits from their stormwater removal activities, on the premise that such removals are apt to be small. The attenuated nitrogen load from impervious surfaces estimated in the 2006 MEP report is 3,796 kg/yr (9% of the total load from all sources), and only about one-third of that load originates from town roadways. Nonetheless, towns are required to address stormwater issues under the EPA General Permit for Municipal Small Storm Sewer Systems (the MS4 Permit) and the nitrogen removal from those activities may be worth documenting. Using funds from the 2020 EPA SNEP grant, the Alliance has estimated the nitrogen removals from several Best Management Practices (BMPs), including non-structural practices (such as street sweeping and catch basin cleaning) and structural facilities (such as grassed swales and rain gardens).

The nitrogen removal capabilities of some BMPs can be estimated from EPA performance curves, largely for structural BMPs. (If those BMPs include infiltration of stormwater, the performance curves should be adjusted for Cape Cod conditions.) A computational procedure has been developed by the Alliance to account for nitrogen removals from non-structural BMP removals. Initial investigations, based on a sample sub-watershed, show that current non-structural practices may remove about 5% of the total impervious nitrogen load, and that about 15% removal may be possible with enhanced practices. A draft report on this investigation has been reviewed by the SNEP Technical Assistance Network and is expected to be complete by the summer of 2022. A program is being formulated for the towns to compile data on the amount of street sweeping and catch basin cleanings that are collected, as a basis for quantifying the nitrogen removed from the watershed by these activities. It is expected that the Alliance may be able to document some small credits for stormwater management in the 2023 Annual Report.

POSSIBLE CHANGES IN THE IMPLEMENTATION PLAN AND PERMIT

The Watershed Permit anticipates "mid-course corrections" at the end of each 5-year segment of the permit term. Those adaptive management adjustments might include revised nitrogen removal requirements due to changing conditions in the Bay, changes in the technologies that towns propose to manage nitrogen loads, and the timing of the implementation of those technologies.

Over the past year, significant new information has been obtained: updated watershed load estimates, remodeling of water quality impacts, and a third-party assessment of natural attenuation. In light of those recent findings, the towns in the Pleasant Bay watershed expect

to accomplish the following tasks in Year 5, to evaluate the need for potential permit modifications:

1. Consider changes in watershed loads resulting from growth since the 2006 MEP report;
2. Adjust nitrogen attenuation estimates in Muddy Creek, Tar Kiln Stream and Pochet Neck;
3. For planning purposes, adopt the hydrodynamics that existed before the 2007 breach, with adjustment for the Muddy Creek bridge;
4. Re-estimate threshold nitrogen loads; and
5. Recompute nitrogen removal requirements based on all of the above steps.

Studies are underway to accomplish these tasks. Once new nitrogen removal requirements are determined, and agreed to by all towns, then each town may need to adjust its nitrogen removal plan, both in load removal magnitude and in technology. Given the complexity of these ongoing studies, it is unlikely that towns will be able to refine their nitrogen removal plans by August 2023. Towns should stand ready to refine their nitrogen removal plans so that permit modifications can be accomplished by the end of Year 6 (August 2024).

It is also acknowledged that DEP's intended watershed permitting program and revisions to Title 5, announced in June of 2022, may lead to the need for additional analyses and permit adjustments. The Alliance will work with DEP to share information related to the experiences of the Pleasant Bay communities in developing and implementing the 2018 Pleasant Bay Watershed Permit, and to explore whether some aspects of the new program may require changes in addition to those listed above. As needed, additional tasks will be undertaken that may be mandated by the new DEP permitting program. Detailed discussions with DEP about the new permitting program are expected to occur in the summer of 2022.

STAKEHOLDER INVOLVEMENT

Over the past year, outreach activities undertaken by the towns and Pleasant Bay Alliance have been curtailed due to the Covid-19 Pandemic. It is anticipated that outreach efforts will be renewed now that public meeting restrictions have been relaxed.

Since the issuance of the Watershed Permit in August 2018, the following public meetings and hearings have been conducted related to Pleasant Bay nitrogen reductions:

Brewster

Brewster developed an update to its Integrated Water Resources Management Plan in January of 2022, outlining the options being evaluated to meet the Town's nutrient reduction requirements described in the Watershed Permit. This update discussed ongoing work related to the Captains Golf Course fertilizer leaching rate study. It also described the other options to meet the nitrogen reduction goals and their potential costs. A joint meeting of the Select Board and Board of Health was held on January 27 to present this information and answer questions from the Boards and the public.

Public hearings were held with the Planning Board between August and November 2021 to review the proposed stormwater bylaw that was passed at Town Meeting in November 2021. In addition, updates to the Town's Water Quality Review Bylaw were evaluated by the Planning Board and the Board of Health in the fall of 2021, and the proposed revisions were also adopted at the November Town Meeting. These revisions clarified the requirements to meet a 5-mg/l nitrogen loading standard for any proposed development in the Pleasant Bay watershed. The Board of Health also held a public meeting to receive input on a new regulation that governs how nitrogen loadings calculations must be performed for compliance with the Water Quality Review Bylaw.

Chatham

Chatham is well into implementation of Phase 1 of its Comprehensive Wastewater Management Plan that was completed in 2009. The Town has had many successful votes at Town Meetings to support multiple projects (totaling over $130 million to date), including the most recent votes of $7 million for wastewater and $4.5 million for stormwater passed in May 2021. Portions of these projects include work in the Pleasant Bay watershed.

The Town also maintains a detailed site on its webpage that provides information regarding the approved plan and links to current sewer infrastructure projects.

https://www.chatham-ma.gov/comprehensive-wastewaternutrient-management-plan

In addition, the Town through its consultant GHD provides a construction implementation webpage to inform residents of ongoing work related to the sewer implementation that can be found at:

https://chathamscproject.info/

Harwich

The Town of Harwich is currently in the process of revising its 2016 Comprehensive Wastewater Management Plan(CWMP). To kick off the CWMP revisions, the Town hosted two public input sessions (one in-person and one remote) to obtain stakeholder input on recommended changes. The input sessions were recorded and broadcast by Harwich Channel 18 and resulted in 38 comments on a range of categories with a strong emphasis on addressing freshwater ponds. In addition to the two public input sessions, Town staff and consultant GHD have also hosted private information/education sessions with various homeowners' associations and residents covering topics such as nutrient management, stormwater, wastewater and their impacts on fresh and salt water bodies. The Town's wastewater project is actively covered on the Town website and regularly discussed by the Board of Selectmen and Water & Wastewater

Commissioners. The Board of Selectmen, Board of Health and Water/Wastewater Commission will continue outreach efforts throughout this project.

Orleans

Orleans developed a Consensus Plan to move forward with wastewater management solutions through a comprehensive public process involving local boards, citizens, and regional and state officials. The public process was critical to a successful program. Since adopting a plan for limited public sewers augmented by non-traditional remediation technologies in March 2015, the Town has made all wastewater planning decisions at the Board of Selectmen level, with opportunity for public input at every step.

In May 2022, the Orleans Town Meeting approved construction funding for public sewers in the Meetinghouse Pond watershed. Further, the Town hired an engineering consultant to conduct strategic planning with regard to future sewer extensions and implementation of non-traditional technologies. In June 2022, the Select Board is scheduled to appoint a new Wastewater Advisory Committee to engage the public on future infrastructure decisions.

Lonnie's Pond residents have been advised of the Town's ongoing demonstration project to grow oysters in Lonnie's Pond. All pond abutters were notified as part of the Conservation Commission approval process.

Alliance

The Alliance has made public presentations on the Pleasant Bay watershed permitting approach at well-attended conferences:

- The Cape Cod Commission's OneCape conference in Harwich in August 2018 (an update presentation occurred at the 2019 OneCape conference.)
- WBNERR's Cape Coastal Conference in Hyannis in December 2018, and
- The Annual Conference of the New England Water Environment Association in Boston in January 2019.

Specific elements of the Pleasant Bay approach have been shared in public forums in 2022:

- Alliance staff participated in a January 22 charette on alternative septic system sponsored by the New England Water Environment Association
- The Alliance's nitrogen trading study was presented to a municipal officials, state regulators and environmental planners during a webinar on April 2022, sponsored by SNEP.

In the upcoming year, additional stakeholder involvement will occur as follows:

Brewster

Additional meetings with the Select Board, Board of Health and the public are planned in 2022 and 2023 to discuss the implementation of the Watershed Permit and how Brewster will meet its nitrogen reduction goals. Interim results on the golf course fertilizer leaching rate study will be presented and will be used to help predict what other nitrogen reduction strategies will be needed to meet Brewster's nitrogen reduction goals.

Chatham

The Town continues as an active member of the Pleasant Bay Alliance, the Cape Cod Water Protection Collaborative, and the Cape Cod and Islands Water Protection Fund Management Board.

In addition, the Town actively engages the public through its Select Board meetings, Town Meeting process, and Water & Sewer Advisory Committee, who provide advice and recommendations to the Water & Sewer Commissioners (Select Board) regarding the water and sewer infrastructure of the Town.

Harwich

With ongoing revisions to the CWMP and design of the Phase 3 collections system underway, the Town anticipates hosting several stakeholder meetings over the next year. Stakeholder meetings will provide an opportunity for the public to review and comment on proposed changes to the CWMP and receive updates on the design of the Phase 3 collections system. The Town's past efforts will continue to be modified and improved to seek additional input from the various stakeholders involved in the Town's compliance with its Comprehensive Wastewater Management Plan. The Town continues to be an active member of the Pleasant Bay Alliance.

Orleans

The Board of Water & Sewer Commissioners will hold regular, formally-noticed meetings to review progress on public sewer construction. Regular reporting to the Town regarding the Lonnie's Pond oyster project will be made to the Water Quality Committee, and all reports will be posted on the Town website. The Town's engineering consultant will meet with the Board of Selectmen to report on progress of a demonstration Permeable Reactive Barrier currently installed at Nauset Middle School. The new Wastewater Advisory Committee is expected to meet monthly to engage the public on future infrastructure decisions.

Alliance

A public outreach program is part of the watershed permit implementation activities funded by EPA under the SNEP grant and is now ongoing. That outreach program was rolled out in the second half of 2021. The Alliance prepared a series of video recordings to provide a citizen-friendly summary of each task funded by the 2018 SNEP grant:

- Municipal program for I/A systems
- Orleans shellfish harvesting program
- Opportunities for nitrogen trading
- The 2021 SMAST update to the linked watershed-embayment model

These and other public outreach materials are available on the Alliance website: https://pleasantbay.org/programs-and-projects/watershed-planning/pleasant-bay-watershed-permit

Key issues for the public are:

- The large cost of nitrogen removal programs
- Fairness in allocation of costs among users and non-users and between residential and commercial property owners.
- Proper incorporation of non-traditional approaches to nitrogen removal.