The Cape Codder Condominium Wastewater Disposal System:

System Monitoring and Assessment

Phase I – Initial Screening

THE SIPPEWISSETT ASSOCIATION
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Executive Summary

The results of this study provide evidence of wastewater contamination of groundwater discharging in the intertidal zone of Gunning Point Beach in the vicinity of the Cape Codder condominiums. This water is elevated in dissolved organic matter and in nitrate concentration. The discharged water does not appear to contain viruses. These results suggest that further study is appropriate to rigorously delineate sources, pathways and impacts of wastewater from the Cape Codder condominium site. This conclusion becomes even more compelling in view of a pending increase of discharged wastewater at the condominium site by 170% over the next year.

Preface

This report expresses one function of the Sippewissett Association: to represent the best interest of the owners of about 170 residences making up our community, on topics of mutual concern. This specific report addresses a potential pollution problem affecting the swimming beach, to which we all share deeded rights, and other nearby wetlands and waterbodies. I think we all would have preferred the work reported on herein to have been conducted through the Town of Falmouth, but in the absence of their action we found it necessary to take the initiative ourselves.

In this report we refer to the new condominium structures located at the site of the old Cape Codder Hotel at Hamlin Point as the "Cape Codder condominiums" although that is not the official name of any or all of the condominiums, which were constructed by separate companies over several years time and bear separate names

The work was carried out by a committee drawn from our membership: Dr. Arthur Gaines (Chairman), Mr. Sam Trotz, and Dr. John Pierce. This report has been reviewed by Mr. Robert Busby, Dr. Carl Bowin, and myself. We are grateful to Ms. Marjorie Parmenter for her laboratory assistance. Funding for parts of the project ($2,000) was approved at the August 1999 Annual Meeting of the Sippewissett Association. Hard copies of the report are available at a nominal cost from the Sippewissett Association, P.O. Box 501, Falmouth, MA 02541.

Maureen Conte, Ph.D., President
Sippewissett Association
December 2000 Draft

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Introduction

Goals of the Study

The objectives and rationale of this project are described in a proposal by the Sippewissett Association (Sippewissett Association, 1999). Briefly, the larger project will assess the effectiveness of the Cape Codder wastewater treatment facilities in protecting environments that ultimately receive the effluent from damage, and in protecting swimmers at the nearby Gunning Point Beach from health hazards. The "Phase I - Initial Screening", addressed by the present study, will determine the level of nutrients from this system discharged with groundwater at the adjacent beach, and will determine whether viruses from the Cape Codder septic system are currently released into the waters of Buzzards Bay. The results of the overall study will be used to initiate (or not) actions to remediate any problems uncovered. The present report containing the results of the "Phase I - Initial Screening" will aid decision-making regarding the subsequent, more extensive program.

Concern over wastewater treatment

For many years Sippewissett residents have been concerned about the adequacy of wastewater treatment for buildings sited at the location of the historical Cape Codder Hotel (Fig. 1). This concern stemmed initially from the appearance on the Sippewissett Association beach ("Gunning Point Beach"), adjacent to the Cape Codder site, of heavy growth of green attached seaweeds (probably *Enteromorpha*) in a patch down-gradient from the hotel septic system. This algal patch, within the intertidal and subtidal zone in Buzzards Bay, has been identified as a possible manifestation of groundwater discharge, possibly enriched in nutrient-containing wastewater (Fig. 1; also see the cover photograph).

During the 1980s at hearings on proposed zoning exceptions to permit the construction of new condominium units at the site of the old hotel, a representative of the proponent indicated the new wastewater system would take into account and rectify possible public health and environmental implications of waste disposal at this site. Although the first phase of new construction was completed in 19**, we are aware of no evidence this assertion has been fulfilled; and the algal feature remains conspicuous to date at the same location.

New Reason for Concern

Since the 1980s additional evidence has become available, adding new concerns. Studies of the movement of viruses with groundwater suggest disease-causing viruses can travel considerable distances through an aquifer (e.g., Rose, 19**). While bacteria are usually filtered out within a few feet from leach fields (or even cesspools) the much smaller viruses can travel considerably farther through the pore space in the sediments. The minimum distance from the Cape Codder leach field area to the water's edge is about 200 feet. Furthermore, if groundwater channeling is present (such as through bedrock cracks or coarse sediment) both bacteria and viruses can move still farther. Given that the Cape Codder site is located on a glacial end moraine, with complex layering of sand,

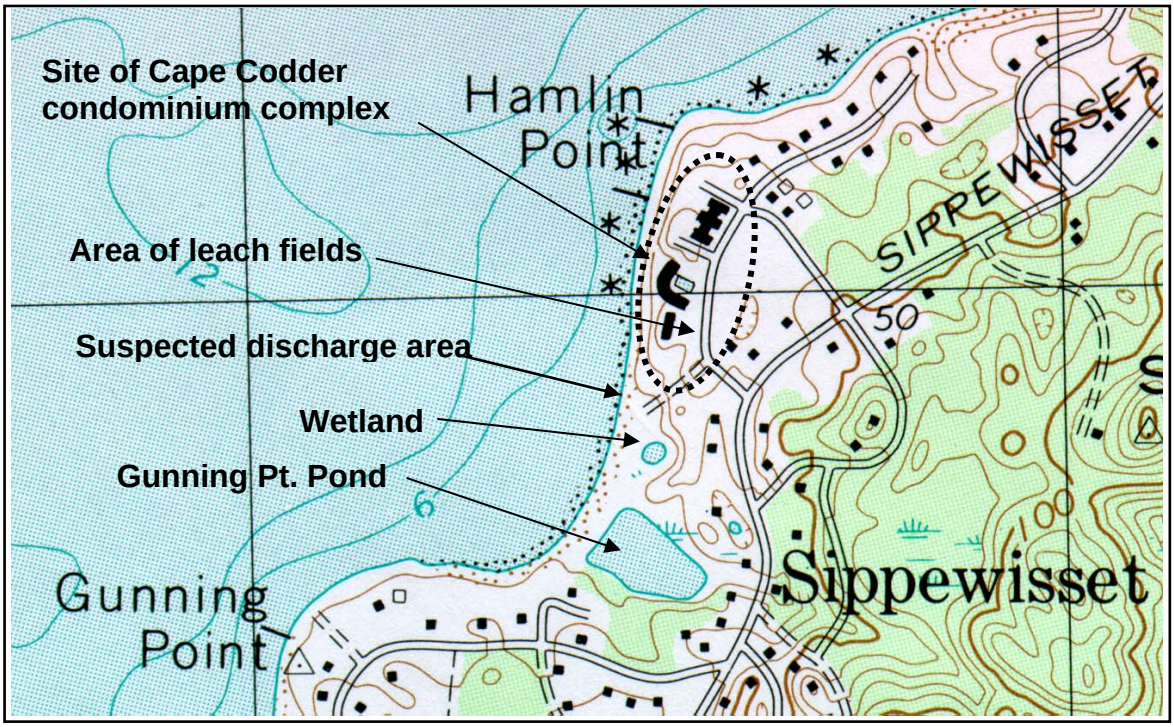

Figure 1. Location of Cape Codder condominium complex, suspected groundwater discharge zone and nearby wetlands. Buildings at Hamlin Point are the previous structures, now replaced by new condominiums (base map source USGS 1967).

clay, gravel, and boulders, the aquifer here may very well display groundwater channeling.

Inadequate Wastewater Engineering

Construction practices of the recent, second phase of the condominium units have also not inspired confidence that proper attention was paid to wastewater treatment engineering. Installation of parts of the system were not properly reviewed and permitted. Site-specific characteristics of this locale, such as proximity to wetlands, a swimming beach, and the Bay do not appear to have been expressly considered in wastewater treatment design. Certain records of the project application, review, and permitting process have been difficult or impossible to obtain.

Inferred Design of the Wastewater Treatment System

The phase I wastewater system of the Cape Codder condominium complex has been operating since 19**. This system serves 14 condominium units (containing 36 bedrooms) in two buildings, and discharges a total of 3,960 gallons of wastewater per day into five leaching pits or "galleries" (Fig. 2). Given that groundwater on Cape Cod typically moves at a rate of about 1 foot per day, it can be expected that the leachate from this part of the system has been discharging into Buzzard's Bay for many years, possibly at the suspected break-out area discharging on Gunning Point Beach.

The new part of the wastewater treatment system treats sewage from 20 new condominium units (containing 48 bedrooms) with a daily discharge of 5,280 gallons per day. In addition the system picks up 1,526 gallons per day from a clubhouse, for a total of 6,810 gallons per day. This represents an increase of 170% over the existing system for a new total of 9,830 gallons per day, discharging into nine new leaching galleries across Cape Codder Road from the old ones. As of autumn 2000 this part of the system has not yet begun operating.

Septic tanks catching the effluents from the two parts of the system total 500 gallons and 21,500 gallons in volume, respectively. Thus the residence time of wastewater passing the system are about 1.6 days and 3.2 days, respectively. These compares with about 7.5 days [1,500gallons/200 gallons per day] for a typical Title V on-site system. The short residence time of the Cape Codder wastewater treatment system becomes a source of yet additional concern. In typical septic tanks there is an attenuation of both nitrogen and viruses over time, as a result of bacterial and other processes. To curtail residence time favors survival of viruses and increases discharge of nitrogen pollutants.

The new wastewater system incorporates a commercial modular treatment technology known as "Bioclere" to help reduce nitrogen-containing nutrients. Effluent from the new condominium units and from the clubhouse will pass through the Bioclere system before discharge into the leaching field [however, it appears that under high loading conditions the effluent can bypass the Bioclere system and discharge into the ground without treatment] (Fig. 2). During low flow conditions it is possible that effluent can be recycled through the Bioclere back to the large septic tank. These design features of the system, or their purpose, are not entirely clear.

While the incorporation of the Bioclere appears to be desirable, the specific operational performance standards of model installed are not clear, and the system is not designed to remove viruses. If bacteria are significantly reduced in the Bioclere system (through chemical treatment) then survival of viruses could actually be enhanced by this wastewater treatment technology.

The Wastewater Plume and Groundwater Discharge Area

Wastewater from the Cape Codder treatment system is discharged into the ground through leach pits or galleries, where it becomes entrained into the natural flow of groundwater. The total flow from the wastewater system when operating at full capacity will be a significant addition to natural flow, amounting to about a doubling of annual infiltration over the area occupied by the condominium complex. This water and associated dissolved materials will move down-gradient and discharge into Buzzard's Bay (Fig. 3), although it is not clear whether the effluent will also enter the wetland and pond behind Gunning Point Beach on its way to Buzzards Bay. This information should have been obtained while the wastewater treatment facility was in the planning stages, before permitting.

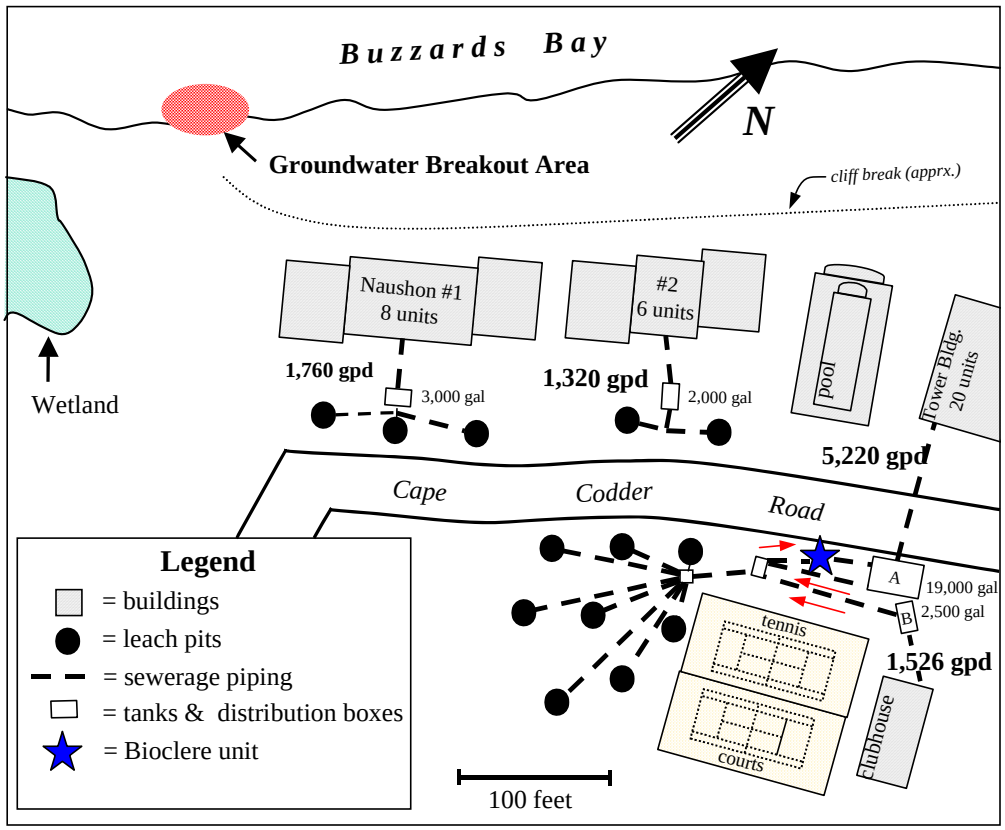

Figure 2. Schematic diagram of a portion of the Cape Codder condominium complex, showing wastewater treatment infrastructure.

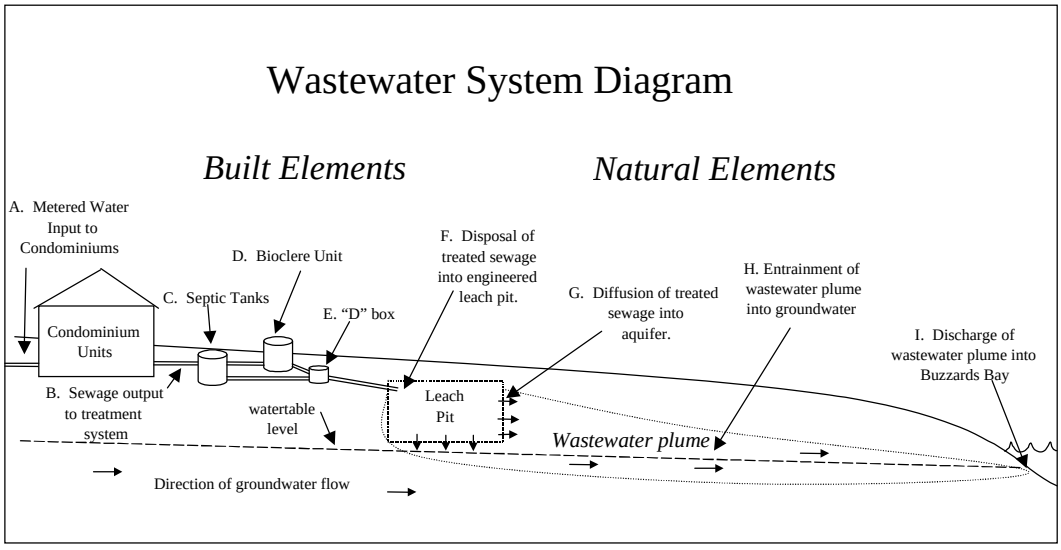

Figure 3. A simplified wastewater system diagram including both built and natural components of the system and the pathway by which the wastewater plume discharges into the receiving waters.

Methods

Variables monitored

Several chemical and biological variables were monitored in the vicinity of Hamlin Point during the autumn of 2000 (Table 1) in order to determine whether the observed algal patch could be related to sewage discharge, and, if so, whether the discharge contains anthropogenic viruses. In addition, analyses of natural waters from local ponds, streams, and groundwater were performed to provide additional perspective.

Table 1. Indicators and variables monitored in the "Phase I - Initial Screening" study, and associated rationale.

Nutrients	**Comments**
Nitrate Ammonia	Nitrate and Ammonia are the principal active forms of nitrogen that can cause eutrophication. They are both ingredients of sewage. High ammonia can indicate recent addition of sewage; high nitrate can indicate sewage that has oxidized so that ammonia has been transformed to nitrate.
Phosphate	A nutrient present in sewage but normally rapidly removed in the sediment unless channeling is present or the groundwater is anoxic.
Dissolved organic matter (DOM)	DOM would be expected to be much higher in sewage than in natural groundwater. High DOM can lead to excessive oxygen demand and anoxia in natural waters.
Viruses (ICC/nPCR)	
Adenovirus Astrovirus Enterovirus (Coxsackie, Echovirus, Poliovirus) Rotavirus	Their presence suggests contamination of water by human feces and the potential for affected water to disseminate human disease. Separate tests indicate the presence of viral protein as well as the presence of viable viruses
Coliphage	Male-specific coliphage are linked to fecal contamination. Passage of this indicator through the aquifer would suggest the potential for passage of pathogenic viruses. Additional testing on positive results can determine if human-specific coliphage is present.

Since new portions of the Cape Codder condominium wastewater system were not operating at the time of sampling, anthropogenic impacts from that site would be limited to those of the older system and associated plume and discharge. Though not an

indicator of the new system, our data are expected to serve as valuable background data to evaluate the impact of the new system in the future.

Sampling

For groundwater samples, short temporary wells were emplaced in the intertidal zone at Gunning Point Beach (Fig. 4) and water was collected using a small electrical pump. Before sampling the well was pumped down several times until clear groundwater flowed upward through the bottom sediment. Sterile water sample "cubitainers" and vinyl hose were provided by Analytical Services, Inc., Williston, Vermont, the company providing virus analyses. The electric pump had been cleaned and flushed with 5% calcium hypochlorite and rinsed with tap water and natural ground water for several minutes before catching samples. Samples for virus analysis were held in darkness between 0^{o}-$8\ ^{o}$C and delivered by courier to the laboratory in New Hampshire actually conducting the analysis, within the prescribed 24-hour time limit.

Surface water samples were taken at a depth of about one foot in clean plastic bottles. Water samples for nutrient analysis were transferred immediately to an ice chest and stored in the dark until processing. Field logs are summarized in Appendix 1.

Figure 4. A temporary sampling well used to collect intertidal groundwater samples for virus and nutrient analysis. The plastic well casing is 8.25 inches in diameter and 14 inches in length. Samples were collected using a plastic submersible electric pump placed in the well. The green seaweed is probably a species of *Enteromorpha.*

Nutrient and Virus Analyses

Nutrients were analyzed using Hach chemistries (Hach, 2000). Standardization curves used to determine nutrient concentrations are given in Appendix 2. Virus analyses were conducted at the University of New Hampshire by arrangement with by Analytical Services, Inc., Williston, Vermont.

Aquifer Sediment Analysis

A sample of sediment removed from the bottom of the well was dried and passed through sediment sieves. The results (Table 2) indicate it is a moderately well sorted medium sand. Examination of these sediments under a dissecting scope revealed no shells or other biogenic components. It is believed this sediment is a late-glacial terrestrial sediment.

Table 2. Textural analysis of sediment from the aquifer exposed in well SA083000DA1 located in the suspected intertidal groundwater breakout zone.

phi	mm	g	%	Cum %
-1	2.00	0.21	0.55	0.55
0	1.00	1.50	3.95	4.50
1	0.50	9.78	25.7	30.2
2	0.25	22.41	59.0	89.0
3	0.125	3.93	10.3	99.5
>4		0.18	0.47	99.97
		Total 38.01	100	

Groundwater Discharge Observations

To gain insight into the potential rates of groundwater discharge at the intertidal discharge site, observations were made on the rate of refilling of the well after it had been pumped down by the sampling pump. The results (Table 3) indicate, not surprisingly, that the rate of refilling is proportional to the amount of drawdown inside the well. The calculations listed in Table 3 suggest the order of magnitude of groundwater discharge (in a variety of units) associated with various gradients.

Table 3. Groundwater discharge estimates based on watertable recovery rate in test well SA083000DA1 after being pumped down to -12 inches (well diameter = 8.25 inches).

Watertable Elevation (ins.)	Elapsed Time (min)	Δ Time (min)	Well yield rate (gal/min)	Equivalent Discharge Rate ($m^3/m^2/min$)	Equivalent Discharge Rate ($m^3/m^2/day$)	Equivalent Discharge Rate ($gal/m^2/day$)
-8.0	6.53	2.01	0.058	0.00629	9.1	2,400
-8.5	4.52	1.30	0.089	0.00973	14.0	3,700
-9.0	3.22	1.60	0.14	0.0158	22.8	6,020
-10.0	1.62	0.89	0.26	0.0284	40.9	10,800
-11.0	0.73	0.73	0.31	0.0347	50.0	13,200
-12.0	0.00	-	-	-	-	-

Results and Discussion

Nutrients

Chemical data for samples from the suspected septic discharge area are consistent with the hypothesis that this water contains septic leachate (Table 4). The low salinity indicates a strong freshwater source; total organic carbon is very high; and nitrate is clearly elevated (e.g., relative to town drinking water). The low ammonia suggests that the effluent is sufficiently old that oxidation of ammonia is complete.

In comparison, a second intertidal well located 100 meters south on Gunning Point Beach contained water of much higher salinity, suggesting the groundwater (porewater) here largely originates as Bay water. Groundwater here is not largely derived from Pond drainage through the beach because the Pond salinity at the time of sampling was 0 $^{o}/_{oo}$ (Table 4). Total organic carbon was also very high in this well, possibly reflecting the presence of fibrous peat and other particulate organic matter in the sample (in the future, samples should be filtered to clarify this point). The aquifer sediment here is clearly of beach or ancient pond origin, judging from shells and other obvious biogenic constituents.

Based on nitrate concentrations in surface waters the following increasing order of nutrient enrichment or eutrophication is evident in area waterbodies:

Increasing Nutrient Enrichment ↓

Falmouth Town drinking water
Miles (Ice House) Pond
Buzzard's Bay
Gunning Point Pond
Evangeline Pond
Gunning Point Wetland
Gunning Point Brook
Clowes Pond
Flume Pond

The range of phosphate values in our samples occupied the low end of the range for Hach chemistries. Values reported in Table 4 for phosphorus are in units 1/1000 of those for other nutrients. The highest phosphorus values were from water entering the pond from Gunning Point Brook, but these values (equivalent to less than 0.5 μM) cannot be considered high concentrations for natural waters.

Viruses

Virus analyses on samples from the suspected septic discharge area indicated no viruses present in either sample (Table 5). This suggests sufficient filtering of wastewater effluent from existing condominiums occurs within the aquifer to remove viruses.

Table 4. Results of chemical analyses of water samples (unfiltered) from the vicinity of Hamlin Point, Falmouth, Mass. Samples were collected on two occasions, a) September 14, 2000; and, b) September 28-29, 2000. "WW Discharge Area" is the site of suspected intertidal septic system breakout on Gunning Point Beach.

Sample	Salinity (‰)		TOC (mgC/L)		Nitrate (mgN/L)		Ammonia (mgN/L)		Phosphate (µgP/L)	
	a	b	a	b	a	b	a	b	a	b
WW Discharge Area	2	6	10.9	16.8	3.3	3.5	-	0.0	4.0	3.4
Beach well	27	20	>20[b/]	16.6[b/]	1.1	2.2	-	0.2	5.4	4.4
Gunning Pt. Pond	0	0	7.6	5.2	1.9	1.2	-	0.0	1.1	0.3
Gunning Pt. Wetland	0	0	-	9.5	2.8	3.4	-	0.0	0.6	0.4
Gunning Pt. Brook	0	0	-	0.7	5.5	3.0	-	0.2	13.7	11.9
Clowes Pond	-	0	-	5.3	-	6.5	-	0.3	-	3.2
Flume Pond[a/]	0	2	-	18.6	8.9	3.7	-	0.2	9.6	1.4
Miles Pond	0	0	-	1.6	0.7	0.3	-	0.0	-	0.0
Evangeline Pond[a/]	0	-	-	-	2.8	-	-	-	8.9	-
Town water	-	0	-	0.6	-	0.1	-	0.0	-	0.6
Buzzard's Bay	32	32	-	-	0.9	-	-	-	3.5	-

a/ Strong natural yellow discoloration present.

b/ Possible chemical interference (salt) and/or suspended particulate organic material present.

Table 5. Results of virus screening of groundwater samples collected from the suspected discharge zone at Hamlin Point, Falmouth, on two sampling dates (N/R = test not performed).

Parameter	August 30, 2000	September 14, 2000
Adenovirus	*negative*	*negative*
Enterovirus	*negative*	*negative*
Astrovirus	*negative*	*negative*
Rotavirus	*negative*	*negative*
Male-specific coliphage	*negative*	*N/R*
Somatic coliphage	*negative*	*N/R*

Natural Systems Analysis

Chemical results reported here suggest water discharging at the intertidal zone characterized by intensive algal growth is significantly enriched by wastewater. This is represented in Fig. 5 by pathway A-C. Contamination of the wetland (pathway A-B) would also be consistent with our data. Flow from either the wetland or Gunning Point Pond to the algal/discharge area is not suggested by nitrogen, or total organic carbon data.

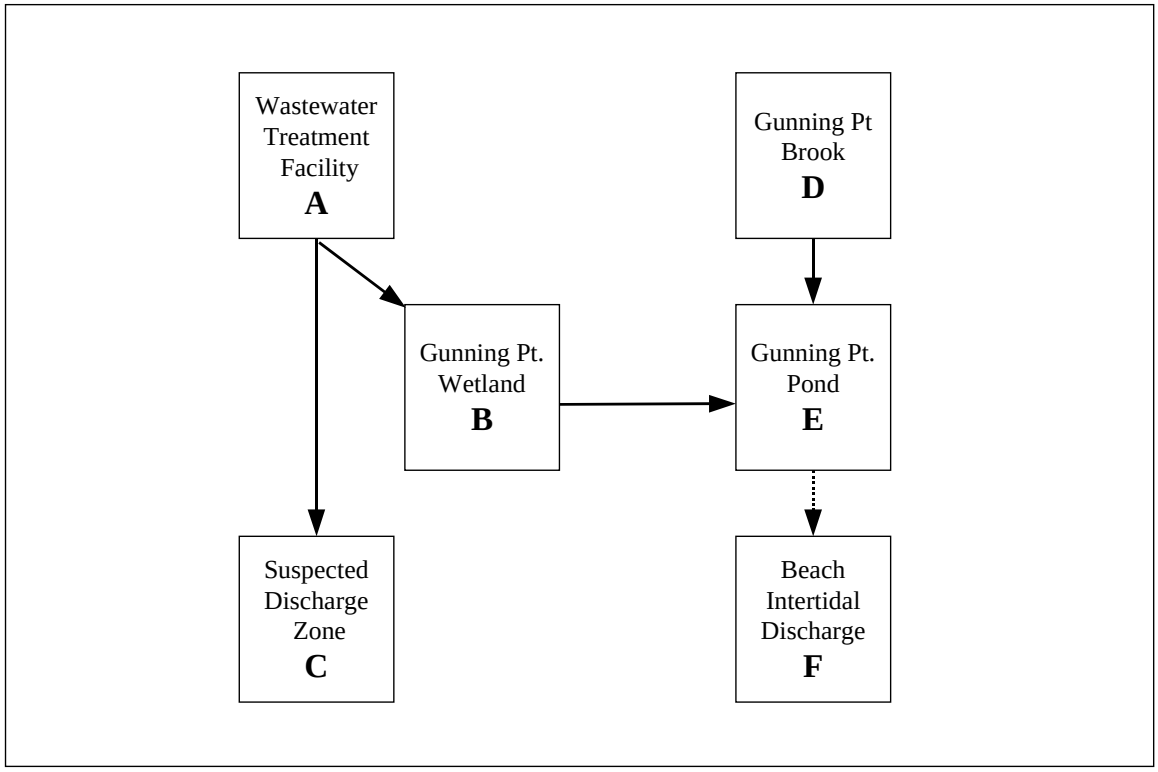

Figure 5. Materials flux pathways based in part on the chemical composition of water and groundwater samples from the vicinity of Hamlin Point, Falmouth, MA.

Materials flux from Gunning Point Brook to the Pond (D-E) is obvious, but flux from the Pond to the wetland is not suggested by nutrient data. Drainage through the beach is likely (E-F) but based upon salinity of the beach porewater there this flux is restricted.

Conclusions

The results of this study provide evidence of septic contamination of groundwater discharging in the intertidal zone of Gunning Point Beach in the vicinity of the Cape Codder condominiums. This water is elevated in dissolved organic matter and in nitrate concentration. The discharged water does not appear to contain viruses. These results suggest that further study is appropriate to delineate sources, pathways and impacts of wastewater from the Cape Codder condominium site. This conclusion becomes even more compelling in view of a pending increase of discharged wastewater by 170% over the next year.

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Appendices

Appendix 1. Notes on water sample collection

Appendix A1-1. Groundwater sample collected for virus analysis, August 30, 2000 (ca. 1500-1700 hr. EDT)

Groundwater Sample SA083000DA1 (August 30, 2000)

Well Location

Well DA1 was located at 41^{o} 34' 04.0"N; 70^{o} 38' 56.1" W by GPS, near where State Coordinate N20800 crosses the shoreline. This site is at the NE end of the small barrier beach SW of Hamlin Point, near the end of a public access footpath there. The well was established in the intertidal zone, about halfway across a conspicuous green macroalgal mass attached to cobble-sized sediment, about 20 ft. from the SW edge of the algal mass. The site of the well was documented by photograph.

Well Installation

An 8.25-inch diameter plastic cylinder 14 inches was buried into the beach face level with its surface. The watertable came to rest at about -7 inches elevation relative to the wellhead. The tide was at spring low, at a time the Woods Hole tide level was at +0.38 ft. (MLLW), and the Newport tide level was at -0.27 ft. (MLLW).

The surface cobbles bearing algae were removed by hand and underlying sediment shoveled out by hand trowel. The underlying sediments were uniform iron-stained, medium-sized sand (see Table 2). These sediment appeared to be of glacial origin--they lacked shells and were quite uniform in size, but coarser than typical wind-blown materials.

Upon completion of sampling the well was removed.

Appendix A1-2. Water and groundwater samples collected for nutrient and virus analysis, September 14, 2000 (ca. 1500-1700

Groundwater sample SA091400DA1 (September 14, 2000)

Same procedure as above. GW level came to rest at -0.75 inches after 18 minutes. Well pumped to -11 in. six times before sampling. Allowed to return to -6.0 in (2 min) each time. Samples at 1505; Newport tide at +0.57 ft.; Woods Hole tide at +0.69 ft. Wind offshore (SE) at 14 kts. Water calm. Sunny. No rain for 24 hours (light).

Table A1-2. Water samples collected for nutrient analysis, September 14, 2000 (ca. 1500-1700)

Sample #	Site	Position (GPS)	Comments
1	Buzzards Bay @ DA1	41° 34' 04.1"N 70° 38' 56.1"W	15' offshore in ca. 1.5 ft. water depth.
2	Gunning Pt. Pond (N)	41° 34' 00.7"N 70° 38' 56.0"W	Sample from "Lily Pond" wetland adjunct to main pond at north end.
3	Gunning Pt. Pond (C)	41° 33' 58.3"N 70° 38' 57.3"W	Sample taken at 2nd overwash delta in main pond.
4	GW DA1 beach well	41° 34' 04.0"N 70° 38' 56.0"W	Sample from beach well at which virus sample was collected, in suspected discharge area of intertidal zone.
5	BW1 GW central beach	41° 34' 00.6"N 70° 38' 57.4"W	Sample from beach well about mid section of beach intertidal zone. Sediment contained brown organic detritus and fibers (aquifer of beach origin). Dark coloration in sand--possible anoxia.
6	Buzzards Bay @ BW1	41° 34' 00.6"N 70° 38' 57.4"W	Sample from offshore at BW1; fine algal fragments in water.
7	Miles Pond	41° 33' 19.3"N 70° 38' 57.3"W	Sample from Sippewissett Road side of pond.
8	Brook, Gunning Pt. Pond	41° 33' 55.8"N 70° 38' 49.3"W	Brook not running; sample from flooded channel where brook enters pond on E. side.
9	Town Water		Collected at 61 Haynes Ave.
10	Flume Pond drain	41° 33' 29.5"N 70° 39' 10.6"W	Sample from water level control structure where channel crosses under first road S. of Flume Pond.
11	Evangeline Pond	41° 33' 02.8"N 70° 38' 52.2"W	Sample from SW. side of pond shallows.

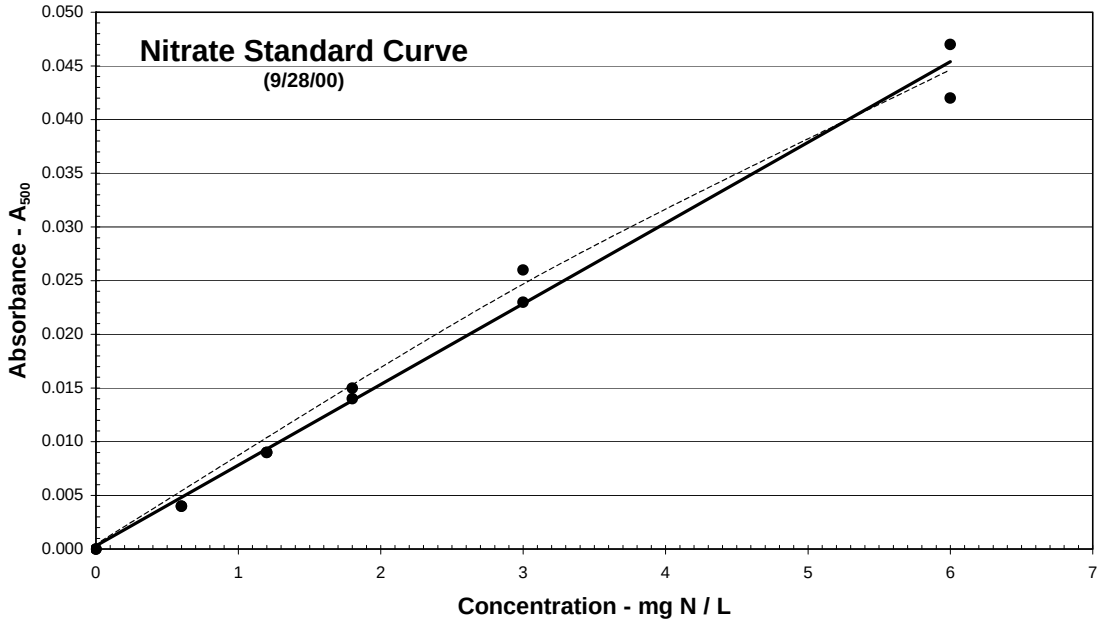
Appendix A1-3. Water and groundwater samples collected for nutrient and virus analysis, September 27-28, 2000 (ca. 1500-1700

Table A1-3. Water samples collected for nutrient analysis, September 27-28, 2000

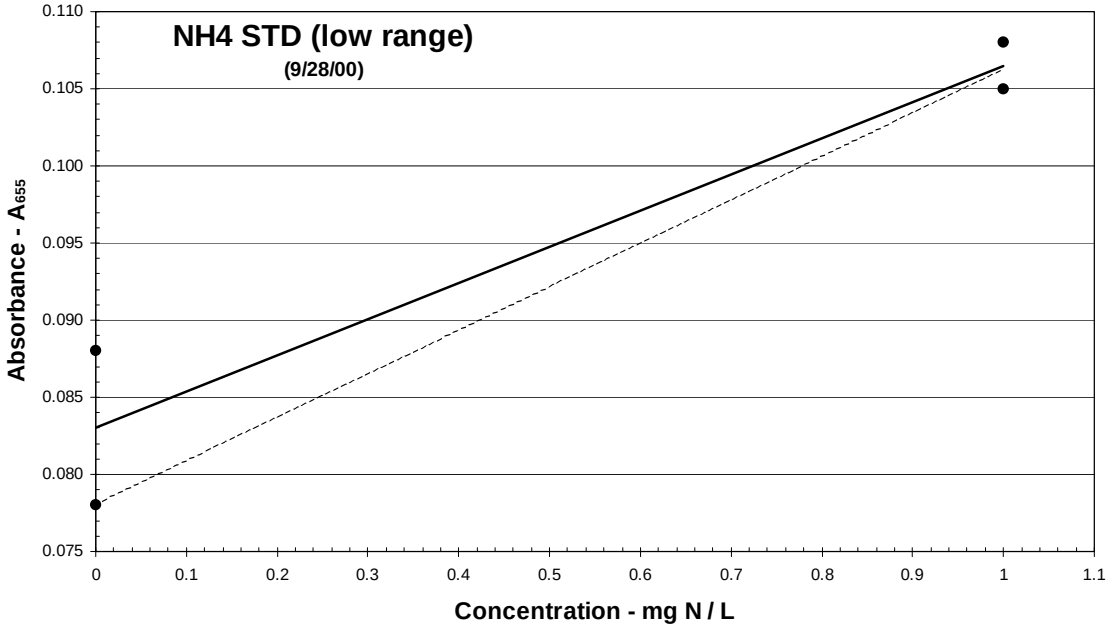
Sample #	Site	Position (GPS)	Comments
1	Gunning Pt. Pond (C)	41° 33' 58.3"N 70° 38' 57.3"W	Surface sample taken at north overwash delta in main pond. Sept 28, 0730.
2	Gunning Pt. Pond (N)	41° 34' 00.7"N 70° 38' 56.0"W	Surface sample from "Lily Pond" wetland adjunct to main pond at north end. Sept 28, 0735.
3	GW DA1 beach well	41° 34' 03.9"N 70° 38' 55.9"W	Groundwater collected at 15:00, 9/27. Newport tide + 0.50; Woods Hole Tide + 0.50; wind offshore 13 kts. Rain 24 hrs ago moderate.
4	BW1 GW central beach	41° 33' 59.6"N 70° 38' 59.9"W	Groundwater collected at 15:20, 9/27. Newport tide + 0.51; Woods Hole tide + 0.42; wind offshore 13 kts. Rain 24 hrs ago moderate.
5	Brook, Gunning Pt. Pond	41° 33' 55.4"N 70° 38' 52.5"W	Brook not running; surface sample from flooded channel where brook enters pond on E. side. Sept 28, 0745.
6	Town Water		Tapwater, 61 Haynes Ave, Falmouth.
7	Clowes Pond	41° 34' 00.6"N 70° 38' 57.4"W	Surface sample from end of paved road-drain. Sept 28, 0825.
8	Flume Pond drain	41° 33' 29.5"N 70° 39' 10.6"W	Surface sample from water level control structure where channel crosses under first road S. of Flume Pond. Sept 28, 0830.
9	Miles Pond	41° 33' 16.4"N 70° 38' 56.7"W	Surface sample from fishing rock. Sept 28, 0840.

Appendix 2. Nutrient analysis laboratory standardization curves.

A2-1. Nitrate

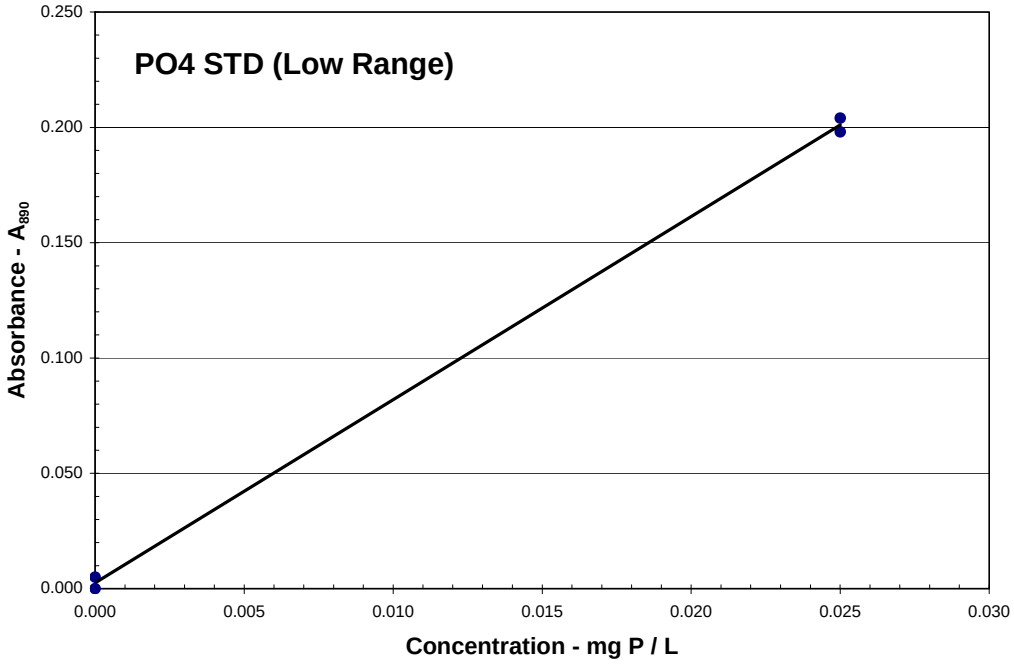


A2-2. Ammonia (low range)



Appendix 2. Nutrient analysis laboratory standardization curves (cont.).

A2-3. Phosphate (low range)



A2-4. Total Organic Carbon