Gerry Stahl's assembled texts volume #22

Studying Climate Locally: The Future of Chatham's Marshes

Gerry Stahl

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Studying Climate Locally: The Future of Chatham's Marshes

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Introduction: Studying Climate Locally

I have been concerned about the Earth for a long time. I protested against the threat of nuclear bombs in the 1950s and against nuclear power and napalm war in the 1960s. I demonstrated in favor of international climate agreements in the 1970s and helped start and run energy conservation programs in the neighborhoods of Philadelphia in the 1980s. I am still concerned about climate change and its consequences in the future for the lives of my granddaughters and the rest of life in the world. The documents reproduced in this volume describe a journey of thinking about the global issue of climate change and studying its impact and possible responses locally.

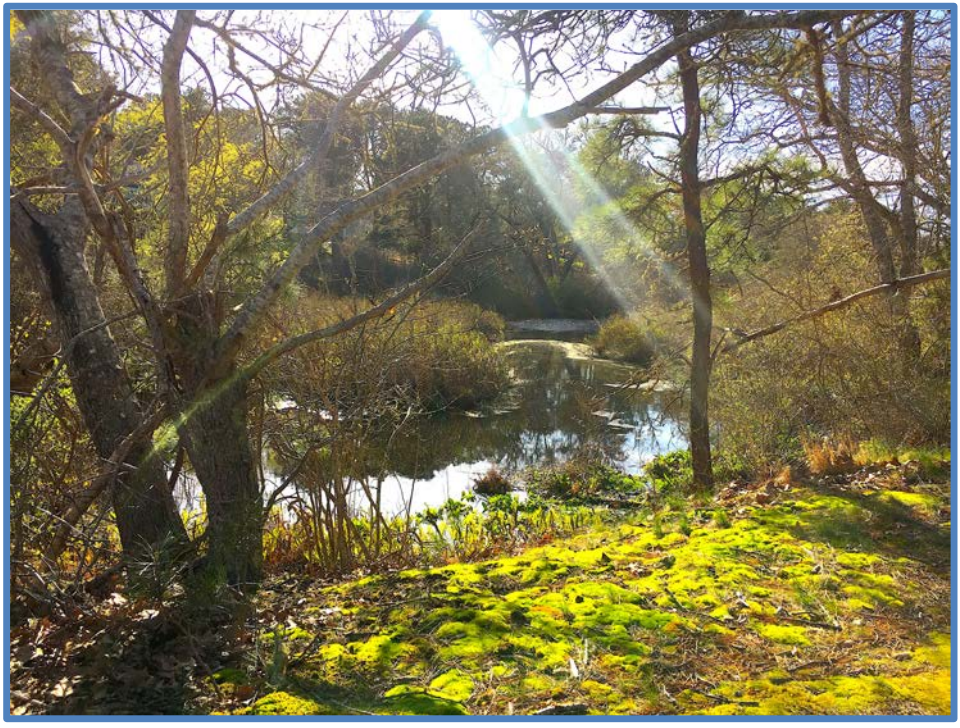
In the main section of this book (see "*Climate Change and the Marshes of South and West Chatham*"), I reflect on the detailed findings of the recently completed study of the marshes near my house from the perspective of a local resident who enjoys that marsh system on his daily strolls and as a retired researcher who tries to uncover the meanings hidden in scientific data.

The study of the system of the four major marshes on the Nantucket Sound side of Chatham provides baseline data to track marsh evolution during the critical decades of climate change, which have recently begun. It also offers insights and tools for analyzing and interpreting marsh processes—perhaps including providing knowledge to guide efforts to steward marsh health. The study itself does not deliver solutions so much as it facilitates and encourages the kinds of questioning, analysis and reflection undertaken in this book.

The section on "*Views of Chatham Neighborhoods*" follows the discussion of South and West Chatham to provide comparisons with the other neighborhoods of Chatham based on property appraisal data. These statistical analyses describe the current housing characteristics of Chatham parcels by neighborhood. It is important to relate the ecological view of the land to its residential usages and characteristics. In particular, the economics of private property will play an increasing role as low-lying parcels flood and as marshes migrate.

When I retired to Chatham in 2016, I joined the local land trust to help protect the environment in this lustrous corner of the world. As treasurer reviewing the assets of the Chatham Conservation Foundation (CCF), it struck me that much of the land it held was salt marsh. The land trust protected these properties from development, but did little to nurture them. There was no management plan and no vision of the marshes' future. I knew nothing about the ecology of marshes, but I felt that the burgeoning climate change needed to be reckoned with. I started a Salt Marsh Task Force at CCF and arranged for it to have a modest budget. I started to articulate a

vision of marshes in Chatham (see newsletter articles "*Frost Fish Creek: A Salt Marsh of Chatham*" and "*The Wonder of Chatham's Salt Marshes*").



The land trust's Salt Marsh Task Force started by having marsh researchers from the Association for the Preservation of Cape Cod (APCC) look at Frost Fish Creek, a marsh complex owned by CCF. This marsh was already suffering from a lack of tidal flushing due to damaged culverts under Route 28. MassDOT and other agencies became interested. The APCC study led to the recommendation of doing an in-depth hydrology study. I wrote a grant proposal for Chatham Preservation Act (CPA) funds for such a study (see "*Hydrology Study for Frost Fish Creek*"). To involve more state and federal agencies, I wrote an application to the Mass Division of Ecological Restoration (DER) for Frost Fish Creek to be designated a DER Restoration Priority Project (see "*Priority Project for Frost Fish Creek*"); it was one of the nine projects selected from across the state in 2021.

Next, we turned to Cockle Cove and Bucks Creek, with another study by APCC (see "*Early Study of Bucks Creek /Cockle Cove*"). This was a first attempt to gather basic statistics about tidal flow and vegetation in these two large marshes, largely owned by CCF. We produced videos to explain to residents what the APCC marsh studies involved (see "*Videos of Frost Fish Creek and Cockle Cove*").

After I left CCF, I saw that the Town's Energy and Climate Action Committee (ECAC) was particularly concerned about the potential impact of climate change on Chatham's marshes, so I joined the committee. In 2023, I wrote a grant proposal to the Chatham Community Preservation Act (CPA) committee to fund a year-long study of Forest Beach, Cockle Cove, Bucks Creek and Oyster Pond marshes (see "*Study of Four Marshes*"). That was to build on the APCC study findings and gather elevation, sedimentation and vegetation data to predict future marsh migration. When we saw the findings from that study, I wrote a proposal to CPA for a similar study of the other nine major marshes on Chatham, to be conducted in 2026 (see "*Study of Nine Marshes*"). These proposals were unanimously supported by ECAC, CPA, the Town and Annual Town Meeting. These studies—both conducted by the Center for Coastal Studies (CCS) in Provincetown—begin to provide baseline data for a systematic view of the future of Chatham's marshes and for tentative responses to some of the issues involved in preserving the marshes.

While this "*Introduction*" has focused on my personal activities and perspectives, it is important to acknowledge that all of these efforts have involved close collaborations with other people in the involved organizations and research groups. In addition, the Town of Chatham, various local organizations and involved individuals have made other important complementary efforts to preserve the salt marshes, which are not discussed in this book. For instance, the Town initiated comprehensive sewering to protect the water quality of marshes, ponds and sea; it opened up Muddy Creek to tidal flow and it is experimenting with living-shoreline erosion control at Jackknife Beach. The point of this book is to share what I have learned about climate change and the salt marshes of Chatham from my personal perspective.

Contents

Climate Change and the Marshes of South and West Chatham

This primary section of the book develops a prognosis for the future of climate change in South and West Chatham, based on current trends and the data from a recent study of four salt marshes in Chatham.

The Energy and Climate Action Committee (ECAC) in coordination with the Chatham Department of Natural Resources planned and oversaw a year-long scientific study in 2024 of the four major salt marshes of South and West Chatham: Forest Beach, Cockle Cove, Bucks Creek and Oyster Pond. The purpose of the study was to gather baseline data that could be useful for interventions to preserve these marshes into the future. The study was conducted by the Center for Coastal Studies (CCS) in Provincetown. The study produced very detailed maps of elevation, sampled marsh sedimentation and cataloged local vegetation. Using this data, the study predicted where marsh was likely to disappear in coming decades and analyzed areas surrounding the marshes to determine suitability for marsh migration. ECAC is now initiating a similar study of the other nine salt marshes in Chatham, to be undertaken during calendar year 2026.

The completed study by CCS found that the four marshes are generally quite healthy now, but are subject to a variety of threats from climate change. For the full findings from the study, including details on the calculation of areas most suitable for marsh migration at different levels of future sea level rise and other technical aspects, see the report by the Center for Coastal Studies at: www.chatham-ma.gov/DocumentCenter/View/9072/Chatham_Marshes_Final_reduced and www.chatham-ma.gov/DocumentCenter/View/9121/CCS_ChathamMarshes_Appendices_Final.

This ECAC report provides a supplement to the CCS report concerning elevation, vegetation and sedimentation data. This supplement incorporates information on housing and roads in Chatham, to envisage specific implications of climate change that may be of most interest to Chatham residents.

Closely related to the concerns of the marsh study are the projections of flooding, storm surge and wave depth based on the recent Massachusetts Coast Flood Risk Model (MC-FRM). This model of threats to the Massachusetts coastline has important consequences for the marshes, floodplain, low-lying roads and homes near the shore or marsh in South and West Chatham. These are also discussed below, complementing the issues raised by the CCS study results. First, this report begins with an overview of CO_2 emissions and global warming, which drive the sea level rise and storms.

Following the CCS marsh study, it remains for ECAC to use the data and analysis of the study to suggest Town actions to preserve the salt marshes and to mitigate anticipated consequences of climate change. This involves considering the outlook for sea level rise on the Chatham shoreline and situating the consultant's findings specifically within the local circumstances in Chatham, including the placement of residential properties, roads and beaches. It also involves presenting the likely outcomes of climate change generally in Chatham, and making recommendations to Town government and to the community.

Climate science is complicated and dependent upon factors like greenhouse gases in the atmosphere, global warming and sea level rise, whose values are constantly shifting. Most available sources of analysis become out of date rapidly. Furthermore, forecasting conditions locally requires data of higher resolution than is generally available. So, we need to find data that is current, locally relevant and can be viewed at the scale of homes and roads in Chatham. To begin this undertaking, this section addresses the following topics:

- Global and Local Warming Trends Caused by Greenhouse Gas Emissions
- Current Trends of Local Sea Level Rise (at Nantucket, Boston and Woods Hole)
- Loss of Salt Marsh in Chatham by 2050, 2070 and 2100 (Based on the CCS study)
- Chatham Parcels Most Suitable for Future Marsh Migration (Based on the CCS study)
- Flooding and Wave Surge for Residences (Based on MC-FRM)
- Low-lying Roads and Isolated Neighborhoods (Based on MC-FRM)

Global and Local Warming Trends Caused by Greenhouse Gas Emissions

Given the complexity and controversial nature of climate-change science, how can we forecast future impacts on Chatham? Despite the quantitative influences of many factors, the important trends seem consistent. The trend in global warming closely follows the trend in CO_2 content in the atmosphere and the trend in sea level rise closely follows the trend in global warming. Although there are many contradictory claims about how various countries and industries are emitting CO_2, it is possible to track the actual amount of CO_2 in the atmosphere. This has been done carefully ever since the theory of the greenhouse effect was proposed. The data from 1958 to the present is available from the carbon dioxide monitoring station on Mauna Loa (which Bill McKibben considers the most important scientific instrument in world history).

The percentage of carbon dioxide gas (CO_2) in the atmosphere is the major determinant of sea level rise, global warming and climate change in general. As documented in Figure 1 shown here, there has been an unprecedented increase in CO_2 and other greenhouse gases in the atmosphere, which has driven an historically exceptional rise in global temperatures and sea level.

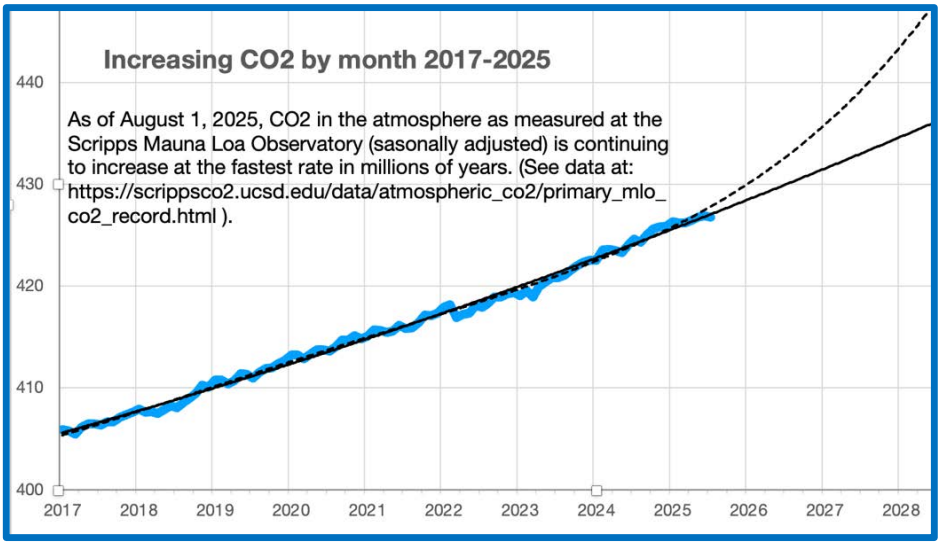


Figure 1. Global CO_2 atmospheric content in parts per million. (Data from Scripps.) This trend is a clear indicator of how things are changing. The graph shows that the percentage of the atmosphere which is CO_2 has been increasing steadily. If it is changing at all recently, this trend line is now accelerating, so that the percentage increases by more each year (on average) – compare the linear projection to a more sensitive polynomial projection.

How has the average global temperature changed with this increase in CO_2? Statistics compiled by NOAA indicate that a gradual decrease of average global temperature in the 1800s was reversed by the CO_2 emissions released by industrialization, with its reliance on fossil fuels. This increase of CO_2 was subsequently followed by a continuing increase of the average global temperature in sea and air (see Figure 2). The global warming in recent decades follows a trend line similar to that of the CO_2 growth, including an acceleration curve currently.

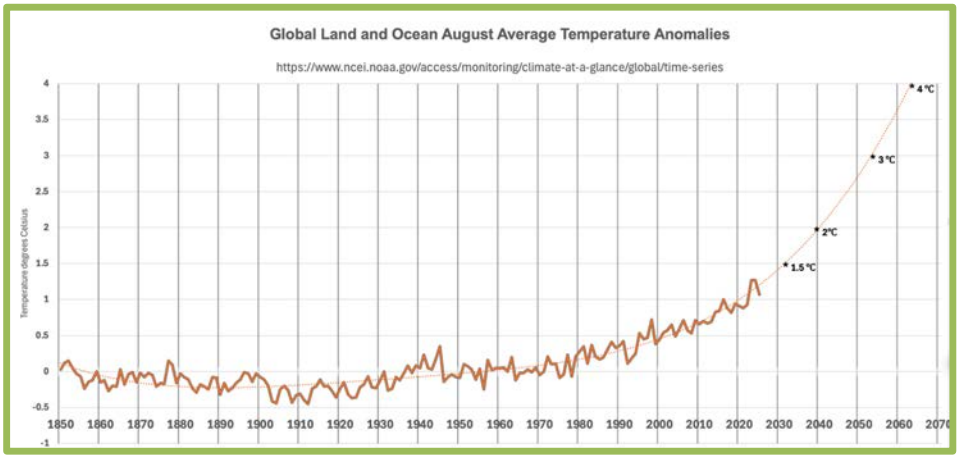


Figure 2. Trend of average global temperature on land and ocean, in degrees Celsius compared to 1850. (Data from NOAA.)

According to the NOAA website on "Climate change: global temperature" (https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature, published May 29, 2025): "The amount of future warming the Earth will experience depends on how much carbon dioxide and other greenhouse gases we emit in coming decades. Today, our activities—burning fossil fuels and to a lesser extent clearing forests—add about 11 billion metric tons of carbon (equivalent to a little over 40 billion metric tons of carbon dioxide) to the atmosphere each year. Because that is more carbon than natural processes can remove, atmospheric carbon dioxide amounts increase each year."

On Cape Cod specifically, the average temperature (measured at its daily high) has been rising even faster than the global rate (see Figure 3). Chatham juts into the Atlantic, where ocean currents cause higher temperatures and higher sea level than the worldwide averages. This also exposes Chatham to the likelihood of increasingly severe nor'easter storms and wave surge.

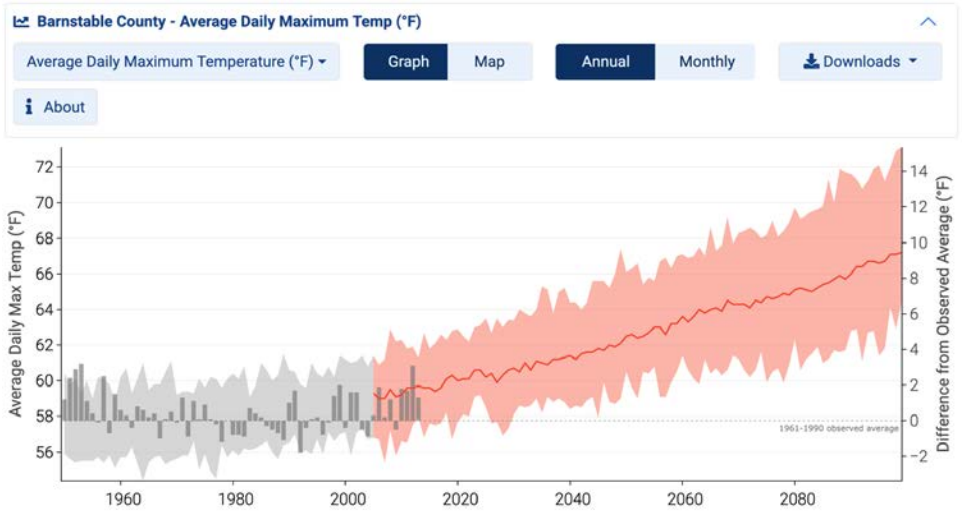


Figure 3. Trend of average daily maximum temperature on land on Cape Cod, in degrees Fahrenheit.

The increase in average global temperature tends to follow closely the rate of increase in global emission of carbon and other greenhouse gases. As shown on the left of

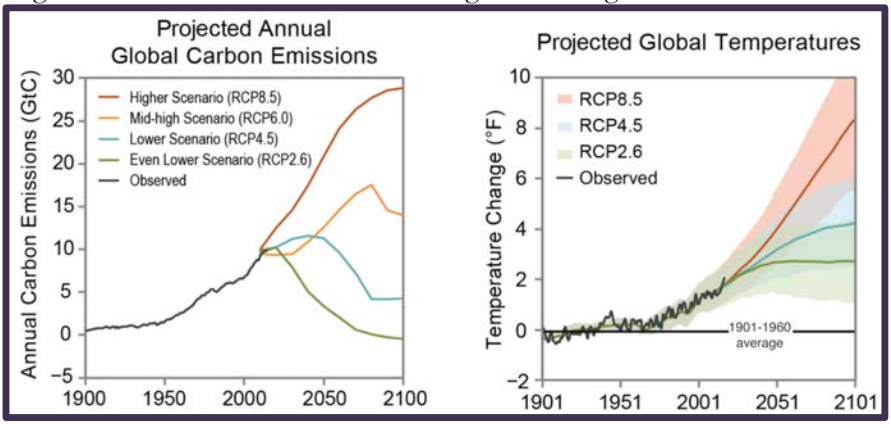


Figure 4, scientists have charted alternative possible scenarios of carbon emissions for the next 75 years. Most scenarios projected there assumed that emissions would be dramatically reduced, at least in line with the Paris Agreement. Only the "higher scenario" RCP8.5 assumes continuing high emissions – as suggested in Figure 4. The

global temperature is then predicted on the right of

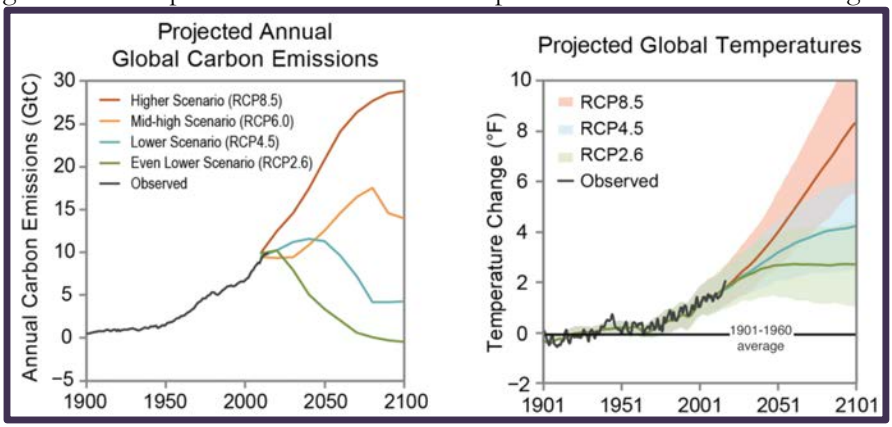


Figure 4 for each of these emission scenarios (with uncertainty ranges for each scenario colored in).

According to the 2017 U.S. Climate Science Special Report, if yearly emissions continue to increase rapidly, as they have since 2000, models project that by the end of this century, global temperature will be at least 5.0°F (2.8°C) warmer than the 1901-1960 average, and possibly as much as 10.2°F (5.7°C) warmer (see the range colored in pink for the year 2101 in

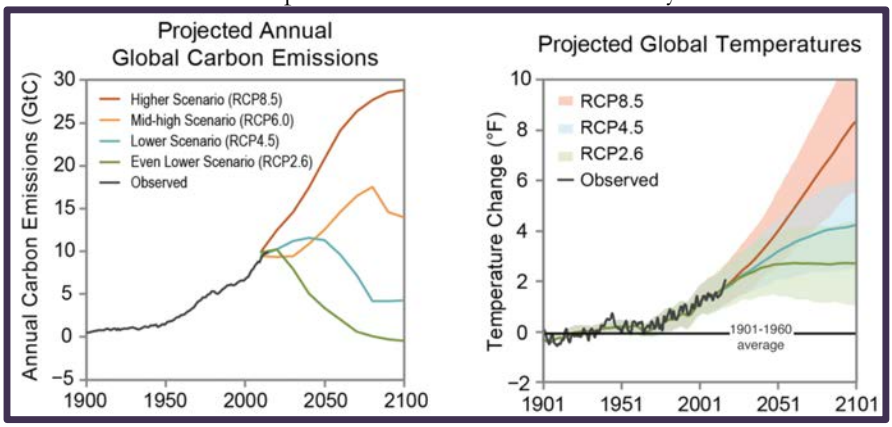


Figure 4 right). Even if annual emissions had stopped increasing after 2017 and begun to decline significantly soon after, models project global temperatures would still be at least 2.4°F (1.3°C) warmer than the first half of the 20th century, and possibly up to 5.9°F (3.3°C) warmer. However, in 2025 President Trump withdrew the US from the Paris Agreement, cancelled Biden's green initiatives, fought the worldwide movement to renewable energy despite its greatly increased economic competitiveness, and encouraged increased production and use of fossil fuels. This could keep emissions growth closest to the Higher Scenario.

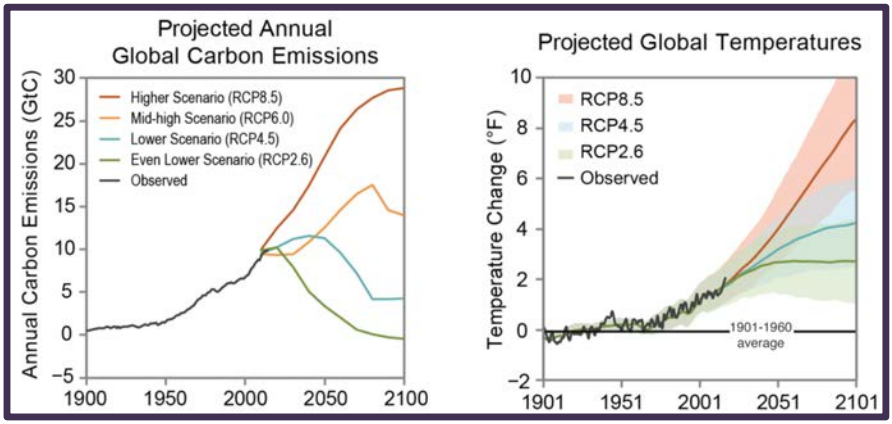


Figure 4. (left) Hypothetical pathways of carbon emissions ("representative concentration pathways," or RCPs) throughout the twenty-first century based on different possible energy policies and economic growth patterns. (right). Projected temperature increases relative to the 1901-1960 average depending on which RCP we eventually follow. Image by Katharine Hayhoe, from the 2017 Climate Science Special Report by the U.S. Global Change Research Program.

The UN Paris Agreement of 2015 aimed to "substantially reduce global greenhouse gas emissions to hold global temperature increase to well below 2.0°C above pre-industrial levels and pursue efforts to limit it to 1.5°C." The 1.5°C (2.7°F) goal was necessary to prevent low-lying islands and coastal areas from being submerged (see Figure 22). The 2.0°C (3.6°F) goal was to prevent disastrous storms, wildfires and sea level rise. We are already beginning to see the consequences of the 1.5°C increase, which we have basically now reached.

According to *Our Final Warning: Six Degrees of Climate Emergency* by Mark Lynas, an increase of 2.0°C (3.6°F) will stress human societies and destroy many natural ecosystems such as rainforests and coral reefs. At an increase of 3.0°C (5.4°F), the stability of human civilization will be seriously imperiled. An increase of 4.0°C (7.2°F) would probably bring a full-scale global collapse of human societies, accompanied by a mass extinction of plants and animals. By 5.0°C (9.0°F), most of the globe will be biologically uninhabitable, with humans reduced to a precarious existence in small refuges. At 6.0°C (10.8°F), we risk triggering a runaway warming process that would destroy the capacity of the planet to support life.

Climate scientists have long warned that climate change cannot be reversed as it passes certain "tipping points" because processes in nature like melting tundra, collapsing glaciers and warming ocean currents set into motion natural processes that drive further climate change regardless of human action. Proposed technical solutions to remove CO_2 from the atmosphere by future generations are proving to be infeasible or self-defeating. Furthermore, as climate change worsens, social structures will deteriorate, making worldwide efforts even harder to negotiate. For instance, as

major regions of the world become uninhabitable, masses of people will have to immigrate to survive – increasing global conflicts and competition for land, food, housing and other resources.

Current Trends of Local Sea Level Rise (at Nantucket, Boston and Woods Hole)

Climate change is a global issue, whose current impact is becoming visible in other parts of the world. What are the most immediate effects expected in Cape Cod and specifically in Chatham? Relevant new data are now available concerning the likely loss of salt marsh in parts of Chatham.

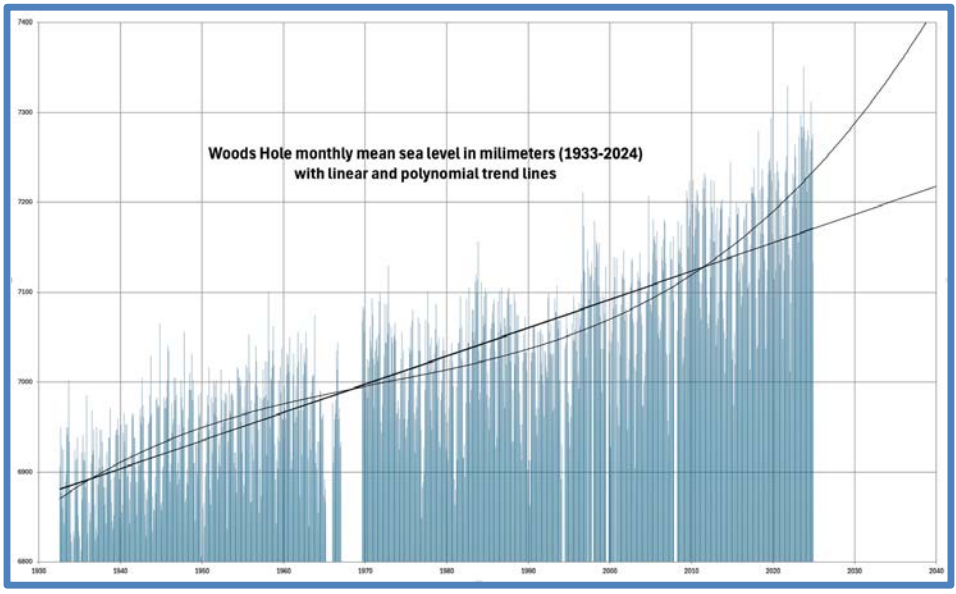
Estimates of sea level rise are critical to predicting future salt marsh extent, flooding and storm surge. Yet it is hard to estimate for the future, given seasonal effects, global warming, shifting currents and glacier melting. It varies considerably in different parts of the world, with recent and expected sea level rise along Chatham's coast higher than most places.

The State of Massachusetts, NOAA, the UN and local experts have adopted models of the likely sea level rise that can be expected over the next 75 years. It is hard to keep predictions up to date with current data. Many recent models assumed that countries would meet goals of the 2015 Paris Agreement, but that is not occurring. Scientists are concerned that indicators (such as melting glaciers) keep worsening faster than expected.

Global CO_2 emissions continue to rise, despite the increased competitiveness of solar and wind energy. Greenhouse gas emissions trigger natural processes in glacier melting, ocean currents, tundra thawing, etc., which in turn release more carbon and methane. The result is seen in the continually climbing trend of CO_2 in the air as measured in Hawaii since 1958 (as we saw in Figure 1).

The CCS study of four marshes adopted the predictions for Nantucket from the United Nation's 2021 Intergovernmental Panel on Climate Change (IPCC) 6th assessment report (AR6), which predicted 2.9 ft of sea level rise by 2100. However, this now seems to be a very conservative value. The Pleasant Bay *Climate Adaptation Action Plan* of 2024 arrived at estimates of 4.0 ft ("intermediate") to 8.0 ft ("high") by 2100 for different planning purposes. The Pleasant Bay "high" scenario corresponds to the Massachusetts Coast Flood Risk Model (MC-FRM) estimates recently adopted by the state of Massachusetts.

One can compare these predictions with graphs of historic sea levels at Woods Hole (Figure 5) and Boston (Figure 6) as well. Figure 7 compares predictions from these sources (in feet) for 2030, 2050, 2070 and 2100:



	1980	2010	2030	2050	2070	2100
linear trendline predictions (mm)	7040	**7103**	**7180**	**7240**	**7310**	**7400**
polynomial trendline predictions (mm)	7020	**7103**	**7280**	**7590**	**8000**	**8800**

	1980	2010	2030	2050	2070	2100
linear trendline predictions (ft)	**23.1**	**23.3**	**23.6**	**23.8**	**24.0**	**24.3**
polynomial trendline predictions (ft)	**23.0**	**23.3**	**23.9**	**24.9**	**26.2**	**28.9**

	1980	2010	2030	2050	2070	2100
linear increase since 1980 (ft)	**0.0**	**0.2**	**0.5**	**0.7**	**0.9**	**1.2**
polynomial increase since 1980(ft)	**0.0**	**0.3**	**0.9**	**1.9**	**3.2**	**5.8**

Figure 5. Sea level rise measured at Woods Hole. (Data from NOAA at https://psmsl.org/data/obtaining/stations/367.php .)

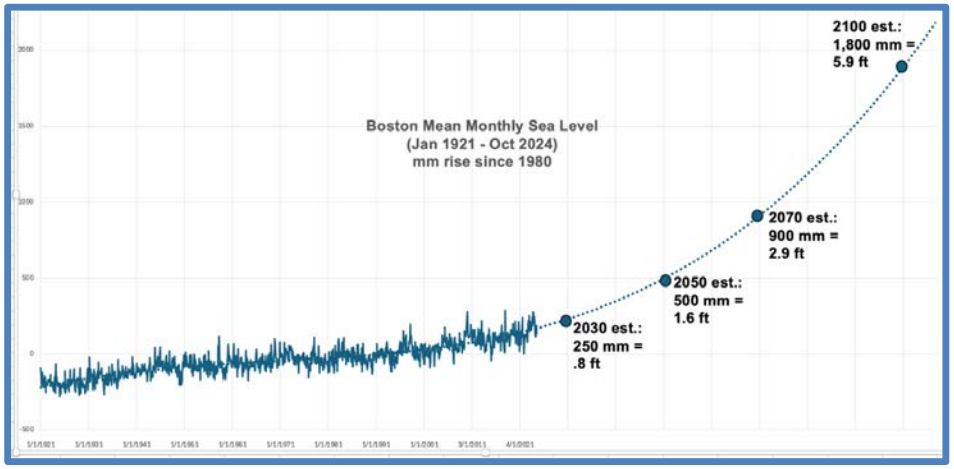


Figure 6. Sea level rise measured at Boston. (Data from NOAA at https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8443970 .)

sea level rise (feet)	source	2030	2050	2070	2100
CCS study	*IPCC AR6 '21*	---	**1.2**	**1.8**	**3.0**
Woods Hole	*NOAA '25*	**0.9**	**1.9**	**3.2**	**5.8**
Boston	*NOAA '25*	**0.8**	**1.6**	**2.9**	**5.9**
Nantucket - interm.	*PBA Plan '24*	**0.7**	**1.5**	**2.4**	**4.2**
intermediate-high	*PBA Plan '24*	**0.9**	**1.8**	**3.0**	**5.2**
high	*PBA Plan '24*	**1.2**	**2.5**	**4.3**	**7.9**
extreme	*PBA Plan '24*	**1.4**	**3.1**	**5.5**	**10.5**
MC-FRM	*MC-FRM '17*	**1.2**	**2.5**	**4.3**	---

Figure 7. Comparison of predictions of sea level rise in the next 75 years.

Based on this comparison, it may be that the CCS study predictions for 2100 will likely occur as soon as 2070 and the CCS study predictions for 2070 may occur nearer to 2050. For planning purposes, Chatham should be prepared for flooding by 2100 based on sea level rise of from 5 to 10 feet along Chatham's coasts. A series of maps showing the effects of these higher sea level rise values (MC-FRM or Nantucket "high" figures in the above comparison) will be shown in later sections below.

It is important to plan decades ahead, as it can take several years to propose, approve, fund, permit and construct projects; and, of course, the projects should continue to be viable for many years once implemented.

Loss of Salt Marsh in Chatham by 2050, 2070 and 2100 (Based on the CCS study)

Salt marshes are a major natural resource of Chatham. They provide much of the scenic charm of the town. They protect surrounding properties from the worst threats of storm surge and provide a wealth of ecological services to the flora, fauna, sea life and water quality. The ECAC has determined that Chatham's salt marshes face the greatest peril and represent the most important asset to protect as Chatham confronts rising sea levels.

The purpose of the CCS study was to generate information on the current condition of four Chatham marshes in order to predict their future trends and to recommend possible interventions. The goal is to preserve these marshes as much as possible in the face of sea-level rise and climate change, to support the ecology of the marshes, to prevent loss of habitat and natural resources, and to protect neighboring residences.

The study was based on a model of salt marsh evolution during sea level rise. A salt marsh is defined as "intertidal," that is, the marsh consists of plants that are adapted to being exposed for daily periods both to the air and to saltwater (or brackish water from creeks mixing with the seawater) as the tide ebbs and flows. The marsh lives between in the elevation between low tide and high tide. In the lower marsh areas with substantial tidal flooding, a monoculture of smooth cordgrass (*Spartina alterniflora*) dominates; in the higher marsh which is only flooded at the peak of high tide, lie zones of salt hay (*Spartina patens*) and other vegetation adapted to those conditions.

During sea level rise, the water level increases, raising the height of both low and high tide correspondingly. Assuming that the ground level remains constant from year to year, the rising sea will gradually drown the marsh, beginning with the low marsh and eventually converting the whole area to open water. This will eliminate the benefits of the marsh as a productive ecology and as a buffer against storms.

To preserve the marsh, one must take into account changes to the ground level: (1) The ground in many areas tends to "subside" or lower over time; however, that is negligible compared to the predicted rate of sea level rise. (2) The marsh bottom also tends to build up or "accrete" as sediment accumulates and turns into peat or soil. There are several kinds of sedimentation: sand gets carried into the marsh from the sea and drops or gets caught by the plants; the marsh plants themselves die and decay in place; or the roots merge with peat in the bottom. In some cases, sedimentation can keep pace with sea level rise. In other cases, the marsh can "migrate" by spreading uphill to adjacent higher ground, or "accommodation space." Accommodation space is the land available for additional sediments to accumulate and marsh vegetation to colonize laterally. Only some of the accommodation space will be fruitful or "suitable" for marsh migration. The slope of the transitional ground must not be too great for grass marshes to spread, take hold and flourish – generally, the slope of the

ground between the established marsh and suitable migration areas must be less than 20%.

In South and West Chatham, much of the suitable area for marsh migration is blocked by roads, fences, steep inclines or other barriers to migration. Much of it is on private property, so regulation of migration is not under public control. Even some of the current marsh acreage is privately owned. Thus, preservation of marshes through natural migration or other methods requires study of where suitable marsh migration paths might develop and where existing marsh could disappear beneath rising tides, in order to prepare for where interventions may be possible or necessary in the future. This requires collecting a variety of data on current conditions, as well as anticipating relevant trends.

Expectations related to climate change shift considerably as new theories develop and new phenomena are observed, so it is important to base predictions on data that is both current and local. Most data that is readily available from state and federal websites is not sufficiently fine-grained to apply on the neighborhood or individual property scale. It is also often inconsistent or out-of-date. That is why it was important to have CCS collect a systematic database of baseline data about Chatham's marshes.

The view of the future of South and West Chatham visualized in the maps of this document is founded on scientific theories of climate change and salt marsh preservation, as discussed above. The climate model starts with the trend in the increase of CO_2 in the global atmosphere as the primary driver of global warming. It then tracks the trend of accelerating sea level rise around Cape Cod, which is largely determined by the global warming and which threatens to drown Chatham's marshes. The climate model suggests probable ranges of sea level rise for selected target dates in future decades.

This book section brings together the climate model with its predictions of sea level rise (based on NOAA data), the CCS's model of salt marsh evolution and migration (using data from the CCS study), property ownership information (from the Chatham Appraiser), and the new MC-FRM model of flooding and severe storms (from the state of Massachusetts).

Here are the major sets of data assembled for this section:

- Percent of CO_2 in the atmosphere, measured since 1958, (as of August 2025). – See Figure 1.
- Average daily temperature globally, measured since 1850, (as of May 2025). – See Figure 2.
- Sea level rise measured monthly since 1933 at Woods Hole (as of 2024) and since 1921 at Boston (as of 2024). – See Figure 5 and Figure 6.
- Sea level rise predicted for target years 2050, 2070 and 2100 based on current trends. – See Figure 7.
- Elevation: The ground level of the bottom of the four Chatham marshes and the land around them to which the marsh might migrate, measured by drone in 2024.

- The slope of the ground computed from the elevation contours.
- Sedimentation of sand and plant sediment collected during the study in 2024 to model average rate of increase of marsh bottom from accretion.
- Predicted areas of accommodation space for marsh migration by target years. – See Figure 8.
- Predicted areas of suitable space for marsh migration by target years. – See Figure 9.
- Predicted levels of severe flooding for target years (by the MC-FRM model as of 2023). – See Figure 15.
- Storm surge and wave overflow for target years (by the MC-FRM model as of 2024). – See Figure 17.
- Properties isolated by low-lying roads during flooding. – See Figure 18.
- Statistical comparisons of South and West Chatham to other neighborhoods (based on 2025 data from the Chatham Assessor). – See Table 1.
- Property characteristics in and around the four marshes (housing, ownership, assessment values as of 2025). – See Table 6.

The CCS study measured the ground elevation with adequate precision and presented it in layers of data for generating maps. These elevation contours were then used to compute "available" space for marsh migration and to determine where in those areas might be "suitable" for marsh migration, given ground slope and other factors. Samples of sedimentation were also taken to estimate rates of accretion. See the CCS study report for details about how the data was collected and used in predicting future marsh possibilities.

The previous section of this essay tried to derive reasonable expectations about sea level rise during the remainder of this century given current measurable trends. This section will build on the study's data and theory to foresee the future of the marshes in South and West Chatham.

Figure 8 and Figure 9 predict potential migration of salt marsh to suitable upland. Suitability here is based on land elevation and slope, tide heights and adjacency to other marsh areas, as just discussed. However, the CCS study does not take into account existing human infrastructure – that will be addressed in a later section of this document.

Figure 8 shows the areas around Cockle Cove and Bucks Creek marshes projected to the year 2100, with a projected 3 feet of sea level rise. All the current marsh areas have been flooded, even during low tide, so they do not support marsh grass. It is the marsh grass that defines a healthy marsh, that sequesters CO_2 from the air, and that protects neighborhoods from wave surge. Only the uplands areas shown in red are suitable for marsh migration. The marsh may be able to migrate there if not blocked by residences, roads, walls, etc.

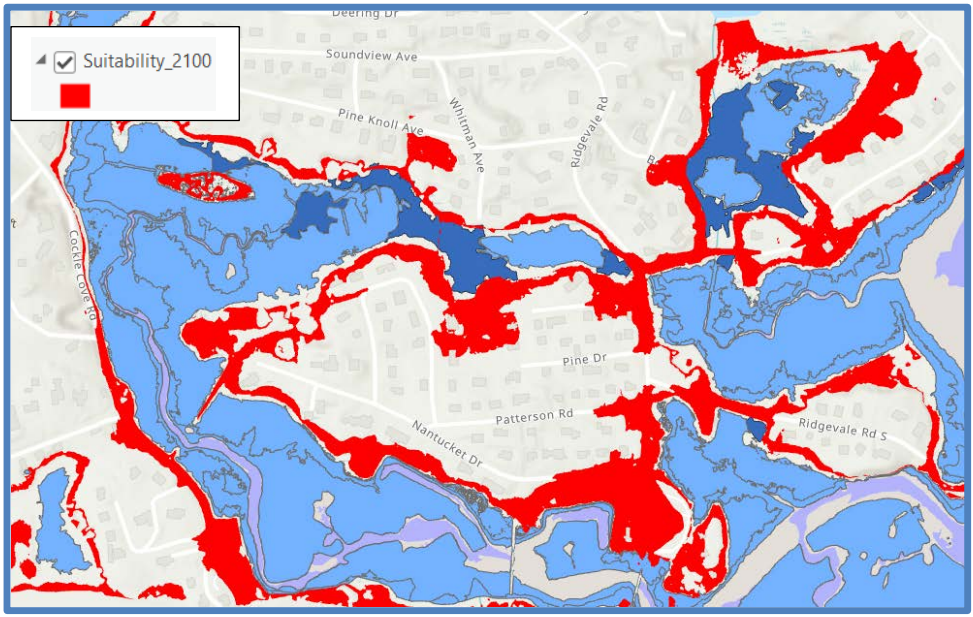


Figure 8. Detail of area of Chatham around Cockle Cove and Bucks Creek marshes in 2100, with 3 ft of SLR. Red areas are computed to be suitable for marsh migration.

Figure 9 shows the whole study area, with projections of the marsh migration suitability area as it expands from one target year to another, gradually moving upland, as the sea inundates the former marsh lands.

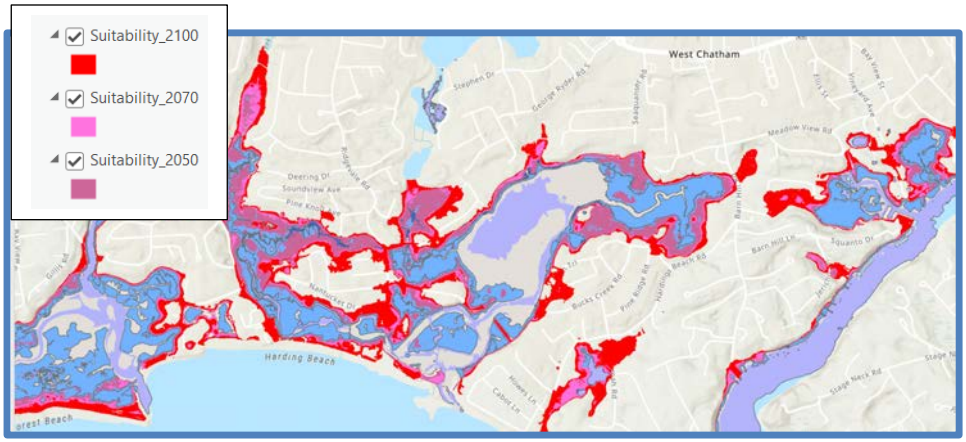


Figure 9. Marshes projected to 2050, 2070 and 2100, using the CCS estimates of 1.15, 1.8 and 3.0 ft of sea level rise, indicated in purple, pink and red, respectively. Successive layers overlap and obscure earlier ones. Color coding in upper corner.

Figure 10 is a chart from the CCS study final report showing how the amount of land available for marsh is shrinking with sea level rise. It shows a reduction from the present to 2100 from 205.5 acres to 78.5 acres – *a loss of over half (62%) the marsh land in the study area of South and West Chatham.* This is based on the study's assumptions of sea level rise, so it may occur by 2070 or sooner. This also does not take into account private property ownership, which will further limit marsh migration. Additional analysis of this is presented in the next section.

		Loss from previous		Loss from 2025	
Year	Acres	Acres	%	Acres	%
2025	205.5	-	-	-	-
2050	124.2	81.3	40%	81.3	40%
2070	83.4	40.8	33%	122.1	59%
2100	78.5	4.9	6%	127.0	62%

Figure 10. Loss of marsh extent in the four marshes.(See CCS final report.)

Figure 11. Photograph of a purple marsh crab. (Photo from Wikipedia.)

A surprising – and disturbing – discovery in the study of the four marshes was the abundance of purple marsh crabs (*Sesarma reticulatum*, shown in Figure 11). While native to New England, they are thought to be responsible for considerable recent salt marsh loss in many areas throughout the Cape Cod region. Their population explosion in areas of the Cape may be due to climate change, pushing ecosystems northward and reducing natural predators of these crabs, especially fish. Unlike fiddler crabs and other local varieties, purple marsh crabs are nocturnal and eat salt grasses,

thereby destroying the marsh. There is no known practical solution to the over-population of these crabs.

As illustrated by the threat from purple marsh crabs, sea level rise is not the only threat to salt marshes in Chatham. In the past, marsh was extensively eliminated by development (agriculture, roads, housing, etc.). Now the results of that development constrict the ability of the remaining marshes to survive sea level rise by migrating.

Chatham Parcels Most Suitable for Future Marsh Migration (Based on the CCS study)

If our marshes are gradually being submerged by sea level rise, what can be done to preserve them? Salt marshes do have mechanisms to extend their lives. Sedimentation (accumulation of sand brought in by the tides and organic material from old marsh grass) will prolong the viability of existing marsh, preventing marsh grasses from drowning. It may even be possible to supplement this natural sediment with an intervention called "thin layer deposition," where sand is carefully sprayed to gradually build up the ground level without killing the marsh grass. However, this technique has not yet been adopted in Massachusetts.

Also, with rising tide levels, marshes can migrate into adjacent land that is slightly higher than the high-marsh border – if not too steeply sloped. However, houses, roads, stone walls and other man-made structures can prevent such marsh migration. The CCS study produced fine-grained elevation contours around the existing marshes and sampled sedimentation rates over time. But the consultant study could not take into account the locations of residences, roads and other barriers to marsh migration – that is addressed in this section.

Figure 12 and Figure 13 indicate locations in South and West Chatham rated as most suitable for marsh migration, based on the CCS study, assuming sea level rise of 1.15 ft, 1.80 ft and 2.95 ft by 2050, 2070 and 2100, shown in purple, pink and red, respectively. They also take into account sedimentation rates (which vary considerably across each marsh) and slope of the land (which must be under 20% for marsh migration). Residential parcels (not including parcels owned by the Town or the local land trust) that include area considered suitable for marsh migration are highlighted in yellow. Town owned properties are shown in dark green and land trust properties are in light green.

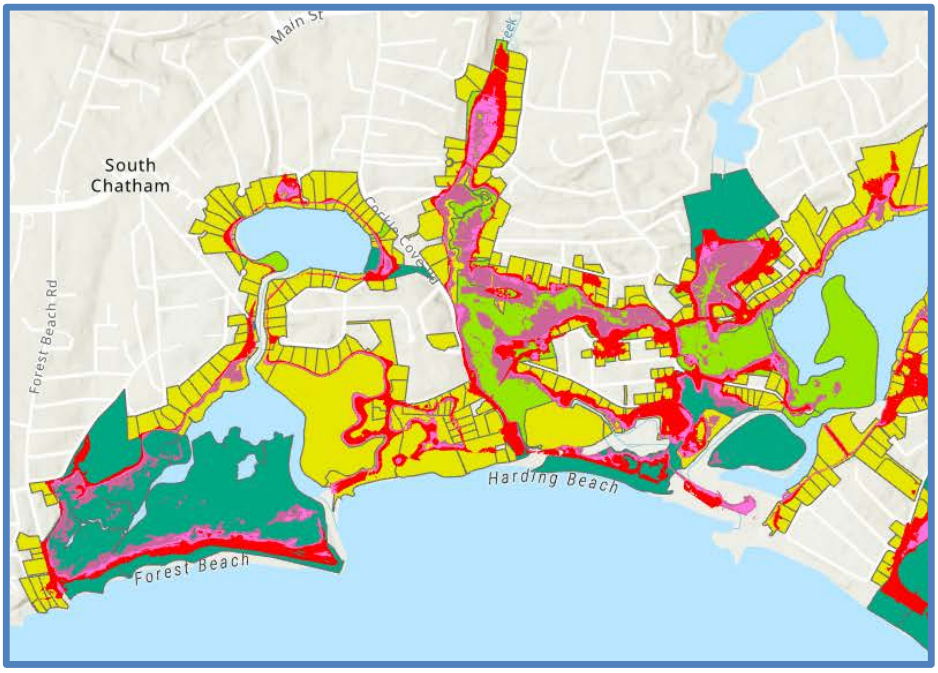


Figure 12. Map of parcels in South Chatham that include potential marsh migration areas, given 3 ft of sea level rise.

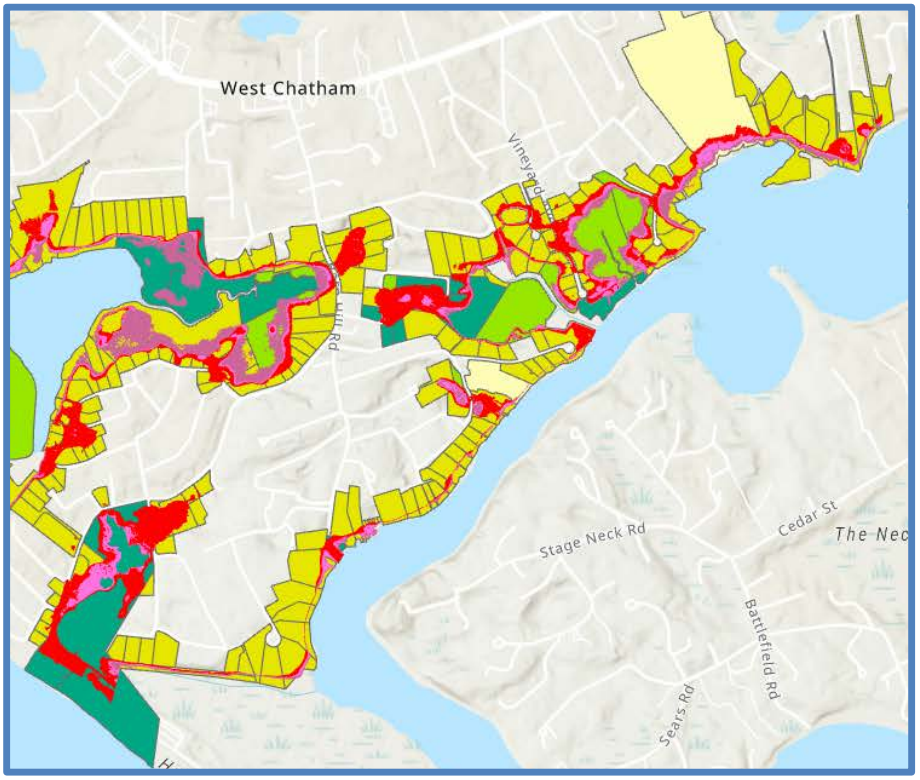


Figure 13. Map of parcels in West Chatham that include potential marsh migration areas, given 3 ft of sea level rise.

A closer look would be needed to see which of these 423 highlighted properties contain significant areas for marsh migration, where homes are located on the property, and how much new marsh could be established there. Most of the properties highlighted just overlap the potential marsh areas along thin strips, at a distance from any building. Many of these areas may already be protected by wetlands bylaws, conservation restrictions or public ownership.

However, about 40 houses actually overlap or abut the potential marsh area. In some cases, it might be desirable to subdivide a property and to donate the wetland part to the Town or the local land trust. Alternatively, a conservation restriction on the subdivided section might suffice. Where a substantial part of a property including the residential building is threatened by flooding, the Town might want to offer a "managed retreat" plan. Such options would, of course, require careful investigation of individual properties and extensive community discussion in the coming years – including prioritizing compared to properties around the nine other marshes to be studied in 2026.

Perhaps a first place to look for establishing some public control would be the parcels in Figure 12 or Figure 13 that have no buildings and are not already owned by the Town or the land trust. Figure 14 indicates 37 such properties, appraised at a total of $4.8 million. The Town and land trust could contact the owners of these properties and negotiate a way to ensure that these parcels would be available for marsh migration in the future.

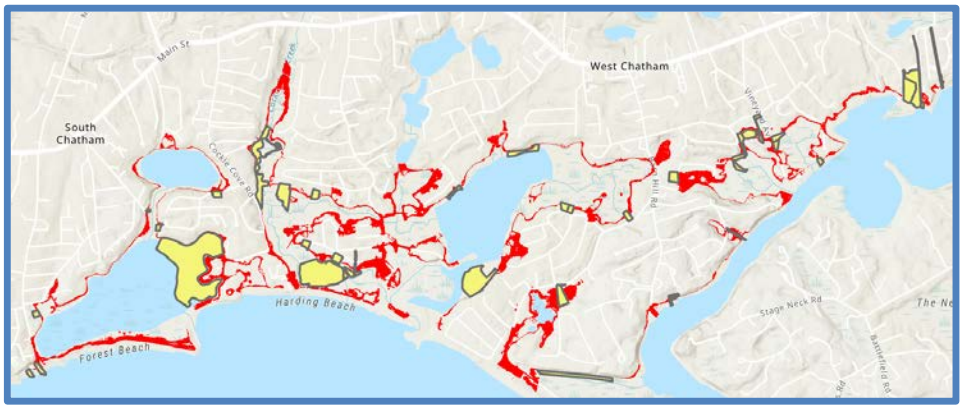


Figure 14. Parcels abutting suitable migration areas in South and West Chatham marsh areas that contain no buildings and are privately held, shown in yellow.

Flooding and Wave Surge for Residences (Based on MC-FRM)

The CCS study was focused on the salt marshes, not on homes. The threat to residences is best analyzed through use of the new model of tides and waves along the Massachusetts coast, recently developed by the state. The Massachusetts Coast Flood Risk Model (MC-FRM) for 2030, 2050, and 2070 simulates sea level rise and coastal storms to predict the consequences of climate change events in Chatham. This probabilistic model uses the "Nantucket high" predictions of sea level rise (1.2, 2.5 and 4.3 feet), in accordance with official state predictions (https://www.mass.gov/info-details/massachusetts-sea-level-rise-and-coastal-flooding-viewer). This model differs from FEMA's "bathtub model," which simply depends upon ground elevation compared to sea level. MC-FRM is a probabilistic model taking into account increasingly severe flooding, storm surge and wave heights, as well as inundation paths for flooding to flow in and ebb out. It is a more appropriate tool for forecasting future conditions in an era of climate change and accelerating sea level rise.

Nevertheless, it is important to note limitations of the MC-FRM predictions for Chatham marshes. First, this model does not include water from precipitation and groundwater runoff. These can be important for predicting inundation of marshes. Given Chatham's runoff patterns, much of the water runoff in the town empties into marshes. In the severe storms strengthened by climate change and global warming, rain or snow can be significant factors adding to flooding from wave surge. Second, the MC-FRM predictions do not factor in sand replenishment efforts at the Town beaches and shore dunes. Each year, the tides shift coastal sand and transform the topology encountered by incoming storms; and then the Town dredges boating channels and piles the sand on eroded beaches. The beaches and dunes provide significant protection for the marshes against storm surge. These factors are hard to model in long-term predictions, but should be kept in mind, especially when considering future interventions.

The remainder of this report concerns predictions of this model for the floodplain in South and West Chatham, to complement the findings of the CCS marsh study. Figure 15, Figure 16 and Figure 17 map predictions for flooding, storm surge and wave effects along Chatham's southern coast in 2070 during a major ("hundred-year") storm event, assuming 4.3 ft of sea level rise, high tide and additional storm surge.

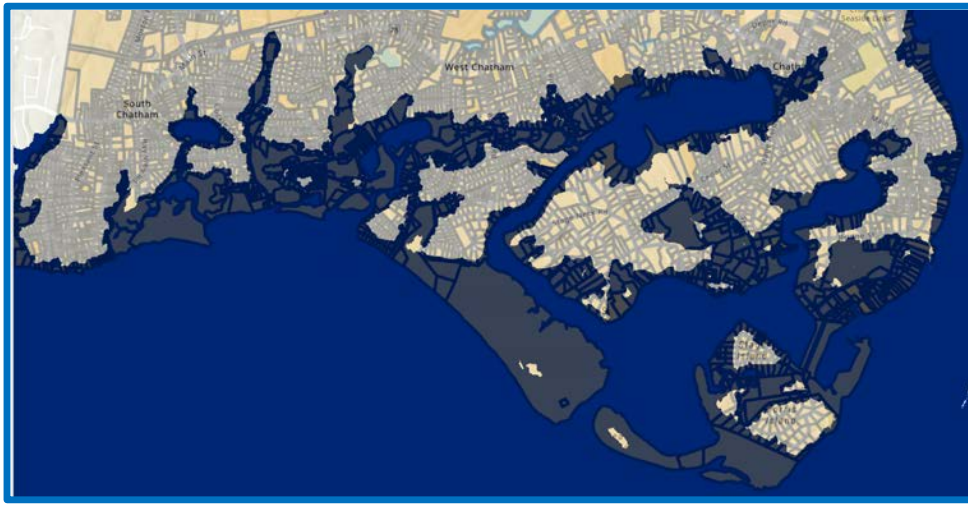


Figure 15. Map of flooding (black areas) predicted by MC-FRM in 2070 at a 1% probability (hundred-year flood).

Figure 16. Map of flooding predicted by MC-FRM for 2070 with 1% probability (a hundred-year flood), overlain with the FEMA 2014 floodplain. The projected flooding extends out beyond the floodplain in the black areas. The FEMA 2014 floodplain (with colors showing flood depths) is currently used for the wetland bylaws regulated by Chatham's Conservation Commission, as well as for flood insurance regulations.

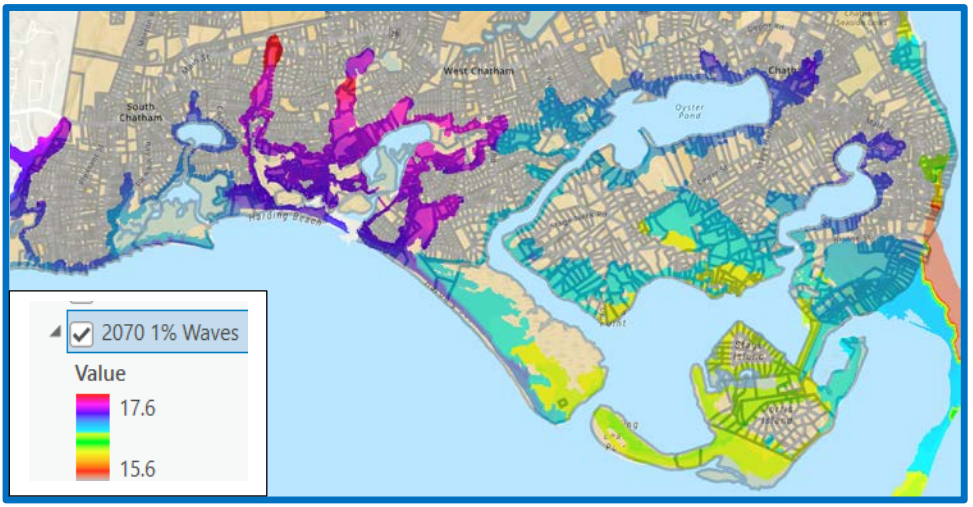


Figure 17. Map of wave depth (in feet) predicted by MC-FRM for 2070 with a 1% probability hundred-year wave surge.

Low-lying Roads and Isolated Neighborhoods (Based on MC-FRM)

Due to the topology of marshes dividing up the residential land near the shore along South and West Chatham, some neighborhoods have only a single road connecting them to the Route 28 highway. Flooding events can isolate these neighborhoods, cutting off access and escape by residents as well as by emergency responders. As most of the isolated residences are in the floodplain, they are likely to be in need of assistance themselves during severe weather events.

Figure 18 is a map of flooding predicted by MC-FRM for 2050 with 1% probability (a hundred-year flood), assuming 2.5 ft of sea level rise. The grey area indicates the part of the study area of South Chatham and West Chatham predicted by the MC-FRM flooding model to be flooded. The thick red lines show three local roads that would be under water in such a flood, The map indicates residential properties in the three neighborhoods that would be cut off from the rest of Chatham by such a flood.

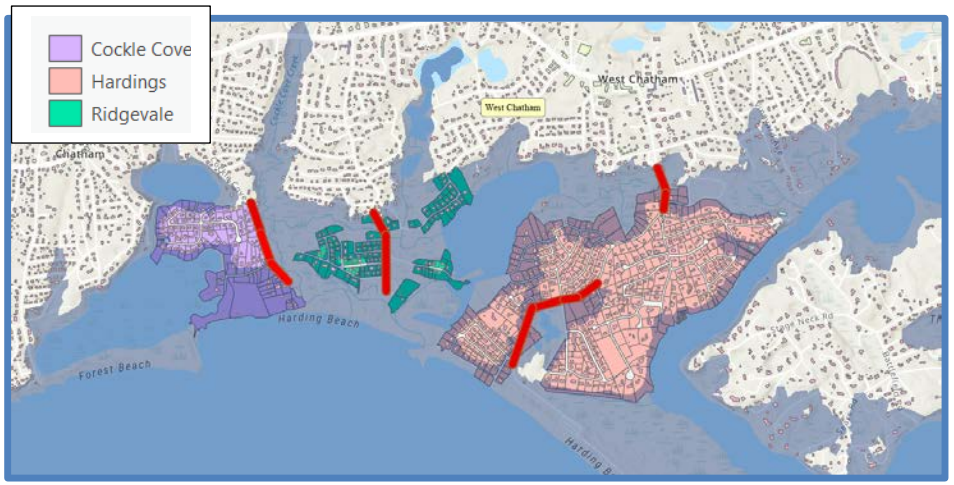


Figure 18. Low lying roads in the study area: Cockle Cove Road, Ridgevale Road, Hardings Beach Road during a 2050 hundred-year flood.

Figure 19, Figure 20 and Figure 21 are close-up maps of neighborhoods that will be affected by the flooding of major roads in South and West Chatham during the 2070 hundred-year flood depicted in Figure 18.

Many low-lying roads lie between areas of marsh that will expand toward each other over time. Interventions to maintain the viability of these roads (e.g., by raising the roadbed) should be careful not to increase tidal restriction. It may be helpful to install culverts under these roads to facilitate the drainage of water through the marsh systems and to increase water circulation through increased connectivity within these

systems. In addition to indicating the flooded low-lying roads (in red), the figures suggest locations for possible new or existing culverts connecting marsh areas (in light brown) to increase flushing and drainage of the marshes.

Figure 19. Properties isolated by a flooded Cockle Cove Road. Approximately 97 homes.

Figure 20. Properties isolated by a flooded Ridgevale Road. Approximately 122 homes.

Figure 21. Properties isolated by a flooded Hardings Beach Road. Approximately 423 homes.

The critically endangered neighborhoods served by these three low-lying roads include about 642 homes worth over $1 billion, with no alternative access. This presents a potentially serious threat to residents during increasingly frequent and severe future storm events. It raises challenges for Town departments charged with ensuring safety, such as planning for evacuation and emergency shelter.

There are about 1,650 properties with buildings in Chatham's overall floodplain defined by FEMA – about 22% of the total number of homes in Chatham. These properties will virtually all be threatened by flooding during high tides and major storms in the coming decades. Properties in the floodplain cannot be further developed; following floods they will probably have decreased market value and increasing difficulty securing flood insurance and reasonable mortgages. The Town could consider forms of "managed retreat" to help residents transition out of these areas, as some other coastal towns have done – see Figure 22. Public ownership or strict conservation restrictions of properties in the floodplain may be important for implementing interventions to preserve the marshes and to otherwise respond to climate change.

Figure 22. At some point, putting houses on stilts, raising roads and using boats is not sustainable. Villages in the South Pacific have already had to retreat (displace or migrate) due to climate change and sea level rise. (Photo from The Atlantic, 9/22/2025.)

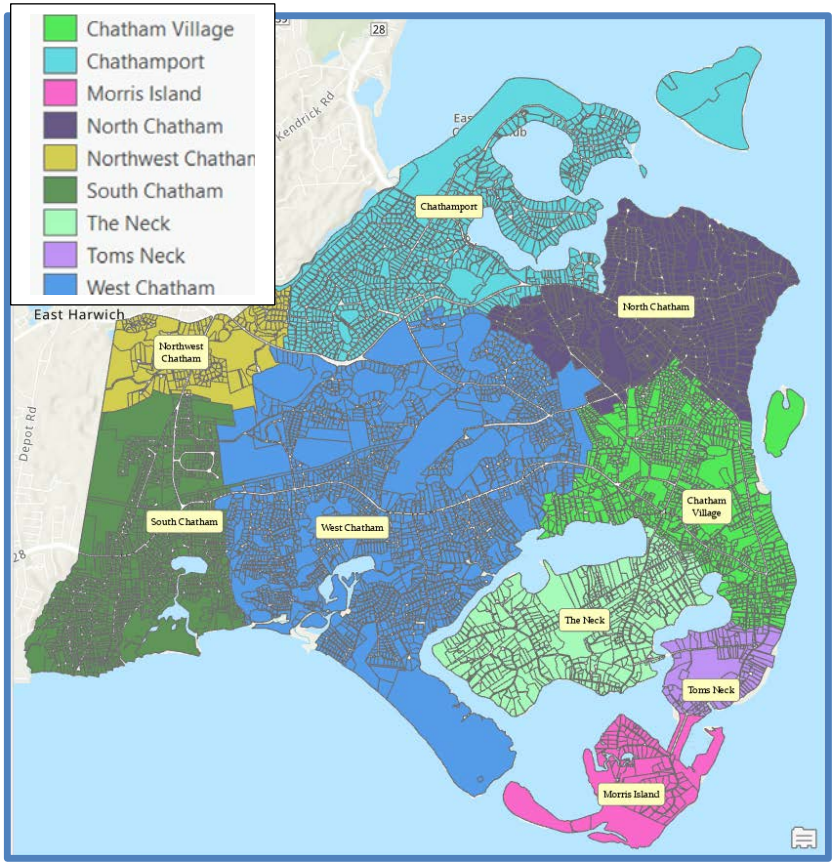
MC-FRM predictions for the beaches (shown in the preceding maps, which do not assume sand replenishment or other interventions, or even reflect natural sedimentation or rain runoff) show major beach areas completely swallowed up by the ocean. In addition, parking lots and roads to beaches are increasingly flooding. Some beaches of Chatham are already topped over by high tides each year and require substantial sand replenishment annually. As the sea level rises, it will become harder (and more costly) to maintain these beaches, which are Chatham's major tourist attraction and prized recreational areas.

This report has focused on the probable effects of climate change on the salt marshes of South and West Chatham, based on the recent CCS study of those marshes. The marshes are key resources for Chatham, defining its environment, drawing tourists and protecting properties from storm surge. Next year, ECAC will be looking similarly at the other nine major marshes of Chatham. There are also additional likely impacts of climate change upon Chatham that have not been considered in this report, such as violent storms, wildfires and scarcity of drinking water. Just when habitable land area in Chatham will be decreasing from erosion and flooding, population pressure will skyrocket with migration from increasingly uninhabitable regions of the world. Long-term planning should assess these varied threats and design a balanced response.

Views of Chatham Neighborhoods

The Neighborhoods of Chatham

The neighborhoods of Chatham each have their own character, although they are not clearly or officially distinguished. There are demographic differences between them, such as the average value of properties and housing density. Map 1 shows the approximate extent of the neighborhoods of Chatham as recognized in 1975, but including all roads and properties as they exist in 2025.



Map 1. A division of Chatham into nine neighborhoods. (Based on analysis of 1975 documents by East-Southeast.)

The Neck, Toms Neck and Morris Island were originally considered part of Chatham Village. Three of the neighborhoods currently have their own post offices: South Chatham (02659), West Chatham (02633) and North Chatham (02650).
Average values of properties (land + buildings) in each of these neighborhoods, are listed in Table 1, based on the assessments for fiscal year 2027. These figures in Table 1 include tax-exempt properties and some expensive infrastructure (non-residential) buildings – these are separated out in the following sections.

neighborhood	# of properties	average value	highest value	total value	stand deviation
Chatham Village	1,510	$2,024,089	$25,289,700	$3,056,374,300	$2,322,481
Chathamport	1,029	$1,783,142	$58,082,100	$1,805,843,400	$2,568,358
Morris Island	104	$4,413,221	$21,697,200	$458,975,000	$3,769,865
North Chatham	949	$1,765,313	$14,639,100	$1,675,282,100	$1,953,492
Northwest Chatham	195	$786,684	$2,351,800	$153,403,400	$355,303
South Chatham	1,345	$989,656	$6,869,600	$1,331,087,300	$749,511
The Neck	536	$2,900,865	$21,637,400	$1,554,863,800	$2,403,538
Toms Neck	195	$2,230,333	$11,129,100	$433,820,370	$2,247,720
West Chatham	2,473	$1,151,390	$32,224,400	$2,847,271,090	$1,205,682
Grand Total	8,336	$1,601,145	$58,082,100	$13,316,920,760	$1,950,597

Table 1. Average values of properties in each neighborhood. (Appraisal data accessed from the Chatham Assessor on 10/30/2025.)

Comparison of the neighborhoods is obscured in these statistics because the neighborhoods vary considerably in size and include a variety of non-residential properties, including some with high property values. Note that Northwest Chatham (which is quite small) and South Chatham have relatively consistent property values (small standard deviation). They also have the lowest average property values (under a million dollars), with West Chatham close behind. Morris Island, with the smallest number of properties, has the highest average value.
Table 2 provides detail about the properties in each neighborhood. Many properties contain more than one building, so the comparison of building costs must take this into account. (Note that this Table has many columns, so it is presented on two pages; the first column is repeated on each page, listing the neighborhood and numbers of houses on each parcel.)

Neighborhood	# of properties	sum of building sf	sum of building value	sum of land value	sum of land sf
# of houses on property					
Chatham Village	**1,525**	**3,308,772**	**$1,415,846,300**	**$1,624,675,900**	**30,916,680**
0	101	0	$0	$76,963,700	3,606,401
1	1,266	2,842,876	$1,134,434,300	$1,264,177,100	21,618,266
2	124	351,948	$202,451,000	$229,700,300	3,734,712
3	14	47,396	$36,297,500	$33,083,300	1,183,353
4	3	61,766	$25,217,500	$19,999,900	345,356
11	1	1,360	$5,621,300	$377,400	199,517
13	1	3,426	$11,824,700	$374,200	191,632
Chathamport	**1,040**	**2,221,487**	**$931,656,900**	**$892,752,490**	**45,729,022**
0	110	0	$0	$75,815,790	10,512,480
1	857	2,037,282	$828,294,100	$663,591,500	25,822,703
2	55	148,804	$77,212,400	$83,434,600	2,588,164
3	3	14,413	$12,164,000	$13,183,900	240,792
4	2	12,548	$5,907,400	$53,562,100	5,689,794
6	1	2,460	$3,244,500	$991,600	565,813
11	1	5,980	$4,834,500	$2,173,000	285,754
Morris Island	**106**	**314,590**	**$220,669,200**	**$236,255,600**	**13,369,103**
0	23	0	$0	$42,601,600	8,024,826
1	72	277,851	$180,897,100	$176,300,000	4,605,790
2	9	36,739	$39,772,100	$17,354,000	738,487
North Chatham	**954**	**2,109,741**	**$847,177,700**	**$820,361,900**	**34,800,928**
0	85	0	$0	$38,411,100	8,607,953
1	774	1,759,147	$665,236,700	$600,540,900	20,532,440
2	84	331,358	$169,095,800	$172,172,200	4,660,703
3	5	15,042	$12,355,400	$7,992,300	376,534
4	1	4,194	$489,800	$1,245,400	591,557
Northwest Chatham	**199**	**283,822**	**$83,899,900**	**$68,441,600**	**13,550,435**
0	27	0	$0	$11,639,900	7,509,340
1	160	270,416	$78,918,000	$53,457,700	5,571,402
2	7	11,916	$4,261,200	$2,894,100	364,440
3	1	1,490	$720,700	$449,900	105,253
South Chatham	**1,362**	**2,138,758**	**$665,239,600**	**$660,759,700**	**37,870,428**
0	118	0	$0	$46,798,300	11,661,010
1	1,159	1,977,488	$601,804,500	$566,219,400	21,060,788
2	58	139,469	$53,743,600	$37,862,800	4,708,731
3	7	19,449	$7,835,200	$6,975,200	288,702
4	1	863	$557,400	$556,200	24,500
5	2	1,489	$1,298,900	$2,347,800	86,051
The Neck	**541**	**1,321,322**	**$668,548,700**	**$875,855,800**	**25,658,406**
0	80	0	$0	$84,048,600	5,225,277
1	370	1,015,249	$454,056,300	$562,915,800	14,064,025
2	80	284,778	$193,424,900	$205,396,600	5,829,642
3	4	16,192	$16,511,300	$20,623,900	480,296
4	1	2,600	$2,589,600	$1,428,200	28,712
5	1	2,503	$1,966,600	$1,442,700	30,454
Toms Neck	**196**	**313,449**	**$154,019,400**	**$278,374,510**	**7,392,929**
0	37	0	$0	$34,019,900	3,150,136
1	137	265,125	$123,483,900	$194,450,710	3,326,427
2	19	43,444	$28,634,000	$44,484,700	807,971
3	2	4,880	$1,901,500	$5,419,200	108,395
West Chatham	**2,513**	**4,306,844**	**$1,533,181,380**	**$1,280,386,700**	**96,288,996**
0	232	0	$0	$84,361,700	23,631,142
1	2,141	4,057,404	$1,420,553,780	$1,109,251,100	58,323,828
2	85	197,309	$81,980,500	$61,405,100	4,551,651
3	9	28,329	$16,790,000	$7,716,400	1,416,781
4	1	1,593	$774,700	$359,400	78,812
6	3	19,782	$3,996,600	$13,268,900	4,541,356
13	1	2,000	$8,344,200	$2,307,500	3,484,800
34	1	427	$741,600	$1,716,600	207,774
Grand Total	**8,437**	**16,318,785**	**$6,520,239,080**	**$6,737,864,200**	**305,576,927**

Neighborhood	sun of acres	# of buildings	av cost per sf	av. Value per acre	density
# of houses on proper					
Chatham Village	**710**	**1,592**	**428**	**$2,287,921**	**2.2**
0	83	0		$929,064	
1	497	1,266	399	$2,546,024	
2	86	248	575	$2,677,472	
3	27	42	766	$1,217,193	
4	8	12	408	$2,522,055	
11	5	11	4,133	$82,402	
13	4	13	3,451	$85,045	
Chathamport	**1,050**	**1,001**	**419**	**$849,998**	**1.0**
0	241	0		$314,093	
1	593	857	407	$1,118,607	
2	59	110	519	$1,403,442	
3	6	9	844	$2,384,069	
4	131	8	471	$410,060	
6	13	6	1,319	$76,336	
11	7	11	808	$331,250	
Morris Island	**307**	**90**	**701**	**$769,612**	**0.3**
0	184	0		$231,241	
1	106	72	651	$1,666,509	
2	17	18	1,083	$1,023,231	
North Chatham	**799**	**961**	**402**	**$1,026,492**	**1.2**
0	198	0		$194,359	
1	472	774	378	$1,273,466	
2	107	168	510	$1,608,485	
3	9	15	821	$925,035	
4	14	4	117	$91,708	
Northwest Chatham	**311**	**177**	**296**	**$219,970**	**0.6**
0	172	0		$67,521	
1	128	160	292	$417,769	
2	8	14	358	$345,771	
3	2	3	484	$185,909	
South Chatham	**870**	**1,310**	**311**	**$759,861**	**1.5**
0	268	0		$174,797	
1	484	1,159	304	$1,170,818	
2	108	116	385	$350,128	
3	7	21	403	$1,052,066	
4	1	4	646	$993,214	
5	2	10	872	$1,185,758	
The Neck	**589**	**551**	**506**	**$1,486,366**	**0.9**
0	120	0		$700,522	
1	323	370	447	$1,742,665	
2	134	160	679	$1,534,299	
3	11	12	1,020	$1,869,801	
4	1	4	996	$2,163,939	
5	1	5	786	$2,061,000	
Toms Neck	**170**	**181**	**491**	**$1,639,426**	**1.1**
0	72	0		$470,278	
1	76	137	466	$2,544,833	
2	19	38	659	$2,396,805	
3	2	6	390	$2,176,386	
West Chatham	**2,211**	**2,407**	**356**	**$579,122**	**1.1**
0	543	0		$155,480	
1	1,339	2,141	350	$828,294	
2	105	170	415	$587,328	
3	33	27	593	$237,209	
4	2	4	486	$198,564	
6	104	18	202	$127,267	
13	80	13	4,172	$28,844	
34	5	34	1,737	$359,874	
Grand Total	**7,017**	**8,270**	**400**	**$960,183**	**1.2**

Table 2. Properties in each neighborhood are separated by how many buildings are on the property. Then the sizes and values of the buildings and their land are summed up. The average cost per square foot of construction and the average value per acre are calculated.

Table 2 focuses in on contrasts between the neighborhoods. It calculates the sizes and values of the buildings and their land for each neighborhood, taking into account the number of buildings on each property. From this, it computes the average cost per square foot of construction, which is a common measure of the relative value of a building. It also computes the average value of the land per acre, to compare the relative value of the site. While it is necessary to calculate these measures depending on the number of buildings on each property, the averaged results for each neighborhood are more meaningful. The next table summarizes these.
Table 3 compares the average cost per square foot of building construction, the average value per acre of land and the housing density of each neighborhood. As can be seen in this summary table, the building costs in Northwest, South and West Chatham are below the town-wide average; Morris Island is substantially higher.

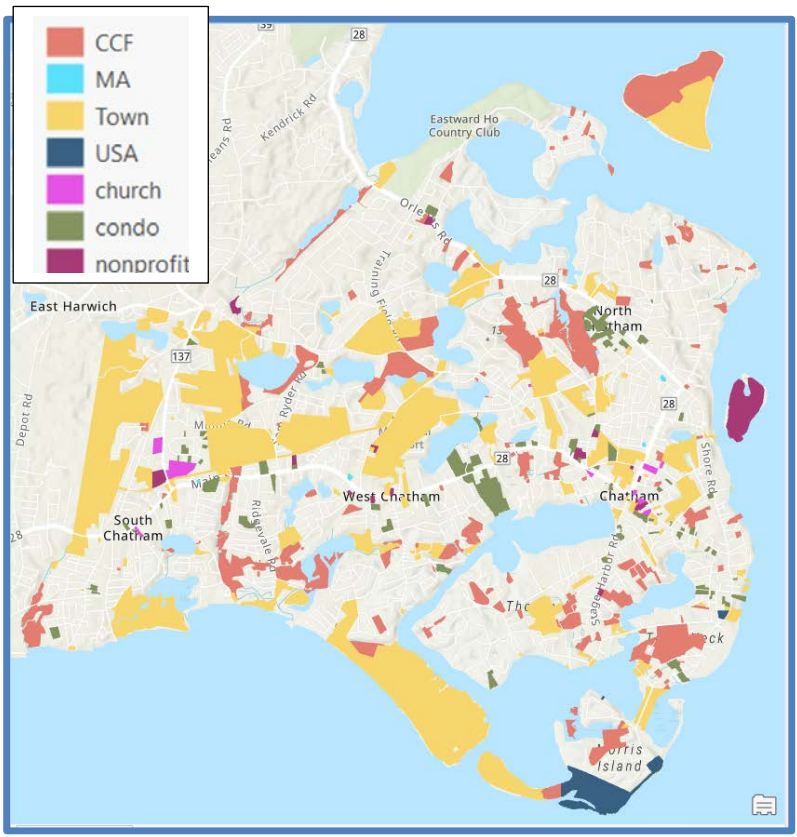
Neighborhood	# of props	av. cost per sf	av. value per acre	density
Chatham Village	1,525	428	$2,287,921	2.2
Chathamport	1,040	419	$849,998	1.0
Morris Island	106	701	$769,612	0.3
North Chatham	954	402	$1,026,492	1.2
Northwest Chatham	199	296	$219,970	0.6
South Chatham	1,362	311	$759,861	1.5
The Neck	541	506	$1,486,366	0.9
Toms Neck	196	491	$1,639,426	1.1
West Chatham	2,513	356	$579,122	1.1
Total for Chatham	**8,437**	**400**	**$960,183**	**1.2**

Table 3. Summary of Table 2. The density of each neighborhood is the number of buildings divided by the total acreage.

Housing density is a concern related to continuing development in Chatham. Average density in Chatham is just over one building per acre – averaging in forests, marshes, beaches, the airport, parks, etc. Of course, downtown in Chatham Village is almost twice as dense. Morris Island is much less dense. By comparison, the affordable housing projects planned at 1533 Main Street and Meetinghouse Road will have a density of about 16 and 11 units per acre, respectively.

Tax-exempt Properties in Chatham

A demographic analysis of Chatham must distinguish different property uses. For instance, there are many large properties owned by the nonprofit land trust. These do not contribute to the Town's property tax income and they do not contain any housing – they are important for preserving the woodlands and marshes of Chatham's ecology. There are a variety of other tax-exempt properties in Chatham. Map 2 shows the distribution of tax-exempt properties in Chatham. This includes properties owned by the Town, state (MA) and federal government (USA) as well as by the local land trust (Chatham Conservation Foundation, CCF), churches, condominium corporations and various other nonprofit organizations.



Map 2. Tax-exempt properties in Chatham, color-coded by category.

Table 4 lists the total appraised values and the total acreage of the properties in each tax-exempt category.

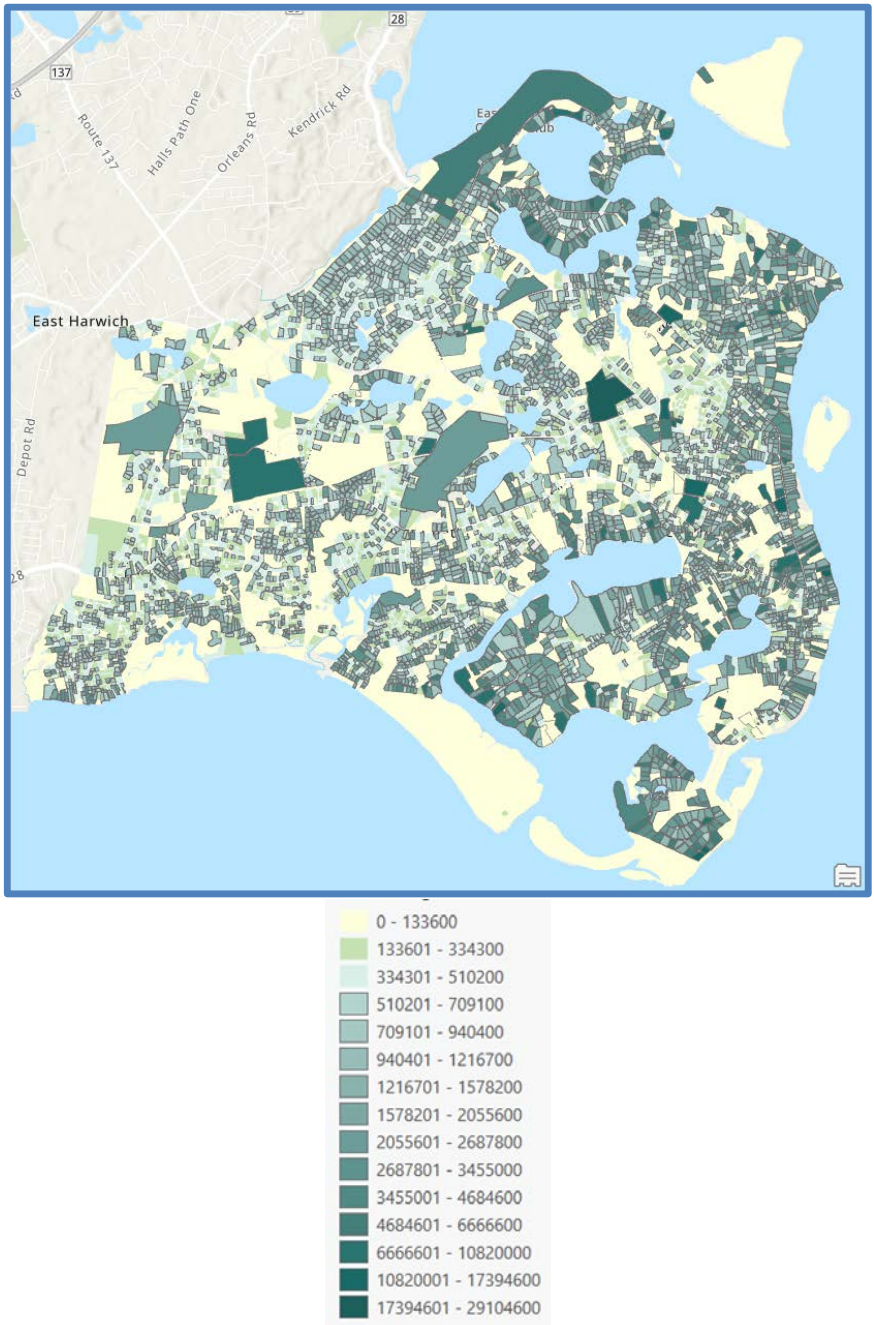
tax-exempt	count	property value	acres
CCF	189	$124,558,400	620
church	11	$27,546,100	21
condo	98	$20,634,100	137
MA	4	$2,048,400	2
nonprofit	23	$31,331,700	22
Town	194	$354,592,500	1,569
USA	4	$30,771,300	73
Total	**523**	**$591,482,500**	**2,442**

Table 4. Values and acreage of tax-exempt properties in Chatham.

Town-owned properties include woodlands, beaches, roads and infrastructure such as water treatment, airport, office buildings. CCF properties include primarily woodlands and marshland.

Distribution of Properties of Different Values Across Chatham

Map 3 shows the distribution of property values in Chatham, excluding tax-exempt properties. The full range of $0 to $30 million is divided into 15 sub-ranges, which are color-coded.



Map 3. Taxable properties in Chatham, coded by assessed value.

Table 5 displays statistics for sub-ranges of these taxable properties, grouped by their building appraised values.

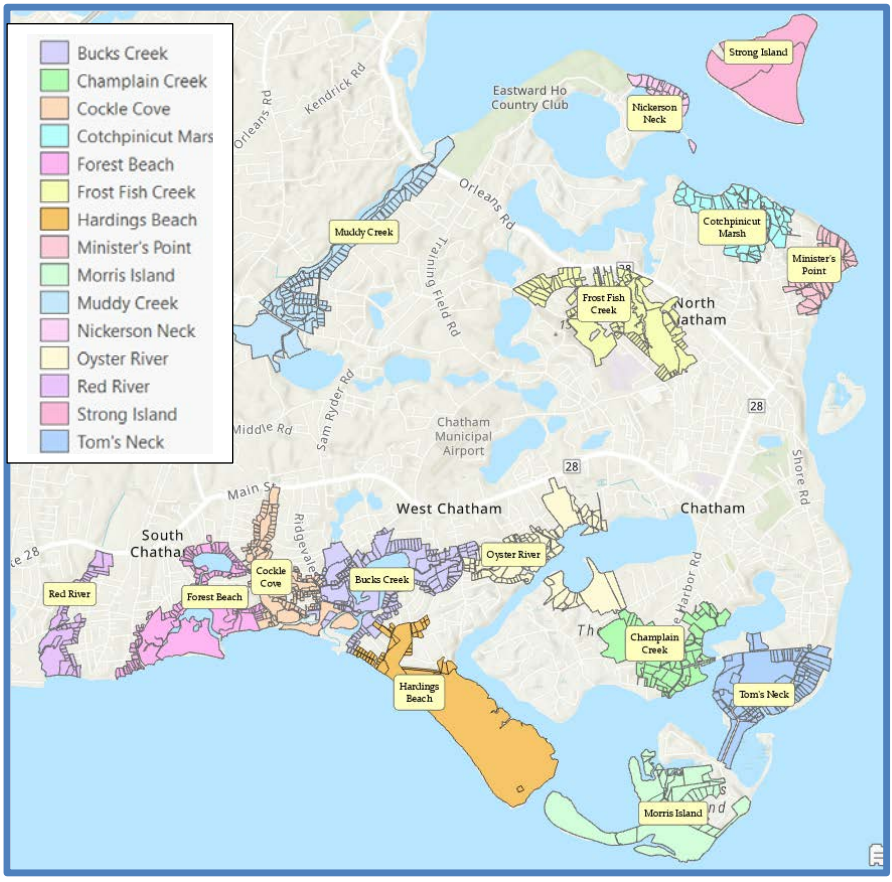
building value	# of properties	sum of acres	property value
no building	625	453	$267,336,350
0.1 M	396	123	$230,288,280
0.2 M	606	229	$464,525,600
0.3 M	998	389	$813,083,300
0.4 M	990	430	$967,624,000
0.5 M	751	369	$885,727,300
0.6 M	629	346	$863,081,450
0.7 M	426	233	$631,595,800
0.8 M	365	221	$617,629,600
0.9 M	278	179	$548,038,600
1.0 M	236	153	$510,324,100
1.1 M	171	107	$375,970,100
1.2 M	156	88	$369,082,200
1.3 M	182	133	$465,458,100
1.4 M	99	75	$275,009,100
1.5 M	98	71	$282,118,800
1.6 M	80	67	$262,564,600
1.7 M	67	59	$229,525,600
1.8 M	51	42	$179,408,900
1.9 M	56	45	$197,925,900
2.0 M	186	163	$741,678,500
2.5 M	100	104	$475,006,700
3 M	140	136	$775,744,400
4 M	35	64	$274,273,300
5 M	34	176	$330,566,500
6 M	20	29	$196,109,600
7 M	21	47	$244,652,700
8 M	2	5	$22,384,400
9 M	5	7	$75,359,000
10 M +	10	28	$183,565,800
totals	**7,813**	**4,571**	**$12,755,658,580**

Table 5. Value of taxable properties in Chatham, by range of value of buildings on the property. For instance, there are 625 taxable properties with no buildings; together they cover 453 acres and are appraised at a total of $263 million. There are 396 properties with buildings valued at $100,000 to $199,999, covering 123 acres and appraised at a total of $230 million.

There appear to be two distributions of building values. The largest segments of values are at about $300,000 – 500,000. These may be largely traditional Cape homes. Then there is a bump in the curve at about $2 million – $4 million. These may be primarily larger and newer homes. Further analysis would be needed to see which neighborhoods these different categories are located in, although visually Map 3 indicates that the more expensive homes are clustered near the water.

The Major Marshes of Chatham

Map 4 outlines each of the 15 major marshes on the map of Chatham. The areas indicated in this map are based on the current extent of each marsh in 2025 and all the property boundaries of properties that are partially or entirely included in the marsh.



Map 4. The major marshes of Chatham.

Table 6 provides statistics on the properties associated with each of the marshes. It shows how much of each marsh area is privately owned. Most of the properties owned by the Town and CCF are protected from development by registered conservation restrictions, as well as by Chatham's wetland bylaws. Most of the properties with buildings are owned privately.

Marsh	# of properties	Sum of Acres	Sum of Appraisals	# of buildings
property owner				
Bucks Creek	**163**	**151**	**$ 255,459,600**	**135**
CCF	14	34	$ 1,050,200	
Town	3	21	$ 2,936,700	
private	146	95	$ 251,472,700	135
Champlain Creek	**73**	**122**	**$ 163,452,200**	**49**
CCF	14	29	$ 13,605,100	
Town	7	29	$ 11,225,400	2
private	52	63	$ 138,621,700	47
Cockle Cove	**119**	**188**	**$ 150,797,400**	**99**
CCF	9	37	$ 3,014,600	
condo	1	0	$ 1,409,600	1
Town	3	100	$ 14,048,200	
private	106	51	$ 132,325,000	98
Cotchpinicut Marsh	**58**	**101**	**$ 185,076,000**	**41**
CCF	4	10	$ 730,000	
Town	1	0	$ 2,000,900	
private	53	91	$ 182,345,100	41
Forest Beach	**121**	**158**	**$ 226,116,400**	**105**
CCF	2	1	$ 44,300	
Town	4	77	$ 8,533,800	
private	115	80	$ 217,538,300	105
Frost Fish Creek	**129**	**176**	**$ 101,123,300**	**99**
CCF	8	82	$ 3,712,900	
condo	4	9	$ -	
Town	10	11	$ 3,880,200	1
private	107	75	$ 93,530,200	98
Hardings Beach	**47**	**291**	**$ 107,036,600**	**32**
CCF	2	8	$ 2,090,700	
Town	4	260	$ 8,381,300	
private	41	23	$ 96,564,600	32
Minister's Point	**43**	**54**	**$ 184,498,400**	**34**
CCF	5	4	$ 2,845,900	
Town	1	0	$ 3,803,000	
private	37	50	$ 177,849,500	34

Morris Island	**37**	**194**	**$**	**170,438,000**	**23**
CCF	7	28	$	4,360,300	
Town	1	35	$	804,700	
USA	2	70	$	23,164,400	
private	27	60	$	142,108,600	23
Muddy Creek	**95**	**144**	**$**	**98,144,800**	**78**
CCF	7	22	$	2,556,400	
nonprofit	1	2	$	31,400	
Town	3	50	$	2,854,100	
private	84	70	$	92,702,900	78
Nickerson Neck	**41**	**35**	**$**	**125,331,300**	**20**
CCF	9	7	$	14,019,400	
private	32	28	$	111,311,900	20
Oyster River	**150**	**145**	**$**	**227,286,200**	**95**
CCF	6	27	$	6,032,600	
condo	1	18	$	-	
Town	8	11	$	4,661,800	
private	135	90	$	216,591,800	95
Red River	**48**	**61**	**$**	**74,520,500**	**38**
CCF	2	28	$	3,171,400	
condo	1	1	$	-	
Town	4	11	$	924,700	
private	41	21	$	70,424,400	38
Strong Island	**2**	**142**	**$**	**17,144,800**	
CCF	1	73	$	14,404,800	
Town	1	69	$	2,740,000	
Tom's Neck	**149**	**151**	**$**	**304,068,810**	**115**
CCF	9	47	$	3,380,200	
condo	2	5	$	-	
Town	3	20	$	12,103,500	
private	135	79	$	288,585,110	115
Total Marsh	**1,275**	**2,111**	**$**	**2,390,494,310**	**963**
% of Total	**15%**	**30%**		**18%**	**13%**

Table 6. For each of the 15 marshes in Chatham shown in Map 4, this table lists the number of properties that extend at least partially into the marsh area, the number of acres covered by those properties, the total appraised value of those properties and the number of those properties having a building. Within each marsh, the number of properties is sub-grouped by the owner (CCF, Town or USA) or type of owner (nonprofit, condominium or private). At the bottom, each total is expressed as a percentage of the grand totals for all properties in Chatham, as displayed in Table 7

Table 6 provides an accounting of just how important the marsh areas are to the population of Chatham. A total of 1,275 properties are in and around the 15 listed salt marshes, with a total of 963 buildings on 2,111 acres. This compares to a total of 8,437 properties with 7,267 buildings on 7,017 acres in Chatham, as shown in Table 7.

Not Marsh				
CCF	92	187	$ 62,060,700	4
church	11	21	$ 27,546,100	11
condo	89	105	$ 19,224,500	10
MA	4	2	$ 2,048,400	
nonprofit	22	20	$ 31,300,300	16
Town	141	874	$ 275,694,200	34
USA	2	2	$ 7,606,900	1
private	6,800	3,696	$ 10,531,165,670	6,228
Total Not Marsh	**7,161**	**4,906**	**$ 10,956,646,770**	**6,304**
Grand Total	**8,437**	**7,017**	**$ 13,347,141,080**	**7,267**

Table 7. , This table lists the number of properties in Chatham that do not extend into one of the marsh areas, the number of acres covered by those properties, the total appraised value of those properties and the number of those properties having a building. These numbers are then added to those in Table 6 to list the grand totals.

The 15 marshes listed in Table 6 lie in the FEMA floodplain and are already considered subject to flooding by a hundred-year storm. These areas represent 13% to 30% of Chatham according to Table 6, depending upon the comparison criterion. This accounting does not take into consideration other areas of the floodplain, including the coastal shores of Chatham, which are also subject to flooding and erosion. In coming years and decades, the probability of flooding, its frequency and its depth will increase dramatically through climate change and sea level rise.

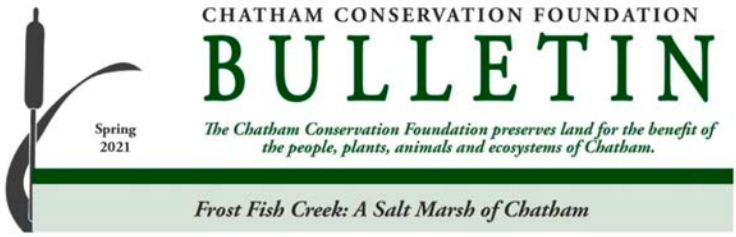
This will present challenges to homeowners and the Town. It is already becoming harder and more expensive to obtain flood insurance. Home values will deteriorate. It will become harder to live in many of these properties. FEMA will be less able to reimburse for property losses. Consequently, there will be increasing pressure on Town resources, such as emergency services and infrastructure maintenance.

While a severe storm could strike Chatham at any time (e.g., combining Spring tide, heavy rain or snow with storm surge), people may be stubborn about preparing for events that they hope will be several years in the future. It may well be necessary to begin a community discussion about "managed retreat" from coastal areas and marsh wetlands. This could involve the Town in encouraging or even assisting homeowners in moving out of the floodplain. Restrictions on development in those areas may need

to be made stricter – e.g., rejecting applications for elevating existing, renovated or new structures on stilts.

It does not seem politically or scientifically likely that climate change and sea level rise will be prevented or even slowed any time soon. One of the few safeguards to mitigate their effect on Chatham is the presence of healthy salt marsh to buffer severe storms and wave surge. This, of course, assumes we can preserve existing marsh and prepare the way for future marsh migration. This is a central theme of the following sections of this book.

Frost Fish Creek: A Salt Marsh of Chatham



by Gerry Stahl
Chair of CCF Salt Marsh Task Force

Chatham is rich in salt marshes and CCF is committed to preserving them and where necessary restoring their healthy functioning. Salt marshes are wonderful natural environments for people, plants, animals, birds, fish and shellfish. They could also provide Chatham's most effective means for combatting both the causes and the effects of climate change.

Salt marshes act as multi-layered flood-protection systems by regulating river drainage and groundwater flow, helping to stabilize coastlines. They filter water, removing nitrates from lawn run-off that contribute to algal blooms and drinking-water degradation. Crucially, they also store quantities of carbon in their sediments, representing the largest sink for CO_2 among all terrestrial ecosystems—several fold better than even trees in tropical forests.

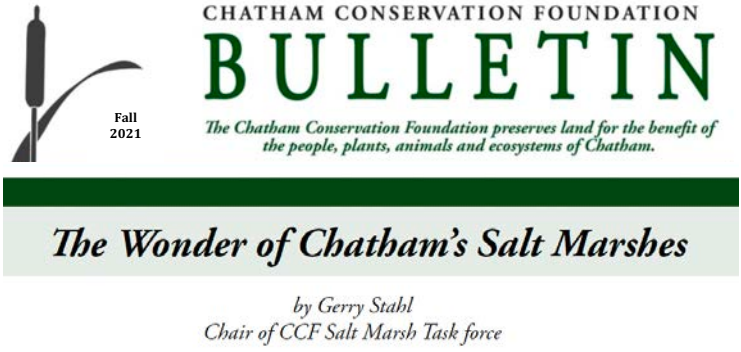
Recent analysis of wetlands in the United States suggest that there is immense potential for gains in terms of nitrate removal and water-quality improvements from targeted, modest investments in expanding wetlands. Wetland expansion and conservation aimed at locking carbon in wetland sediments can be used as an effective, natural climate-change mitigation strategy.

About half of CCF's land parcels are around salt marshes. CCF has established a Salt Marsh Task Force to study the health of Chatham's wetlands. The initial focus is on Frost Fish Creek. CCF's most popular and scenic walking trail runs through there. Occasionally, we lead group walks on the trail. You can view a video of the trail at: https://www.youtube.com/watch?v=OkUzTE3c2VM&t=197s.

Our next project at Frost Fish Creek is to install improved signage and plant tags along the trail to help walkers recognize native trees, shrubs and plants. This project is generously supported by an anonymous donation.

In 2019, we collaborated with APCC to conduct initial studies of the land and water in the Frost Fish area. This led to a recommendation to conduct more detailed water quality and hydraulic studies to assess the consequences of tidal restriction removal. A grant proposal to fund this has been approved by Chatham's Community Preservation Committee (CPC) and the Town. It is awaiting final approval at Town Meeting in June. Please support this to help us maintain Chatham's salt marshes to best serve the environment and the Chatham community.

The Wonder of Chatham's Salt Marshes



Gifts from salt marshes

Salt marshes are the lifeblood of Chatham. Much as your arteries bring salty blood to your body parts and flush away toxins, the salt marshes of Chatham allow vital services to flow in and out with the tides:

- Protecting coastal homes from storm impacts by dissipating surging wave action.
- Providing habitat for many species of fish, shellfish, migratory birds.
- Filtering pollutants and other harsh chemicals from the watershed before they reach the ocean.
- Absorbing carbon dioxide and other greenhouse gases that fuel climate change.
- Responding to sea-level rise by building marsh elevation and migrating upland.

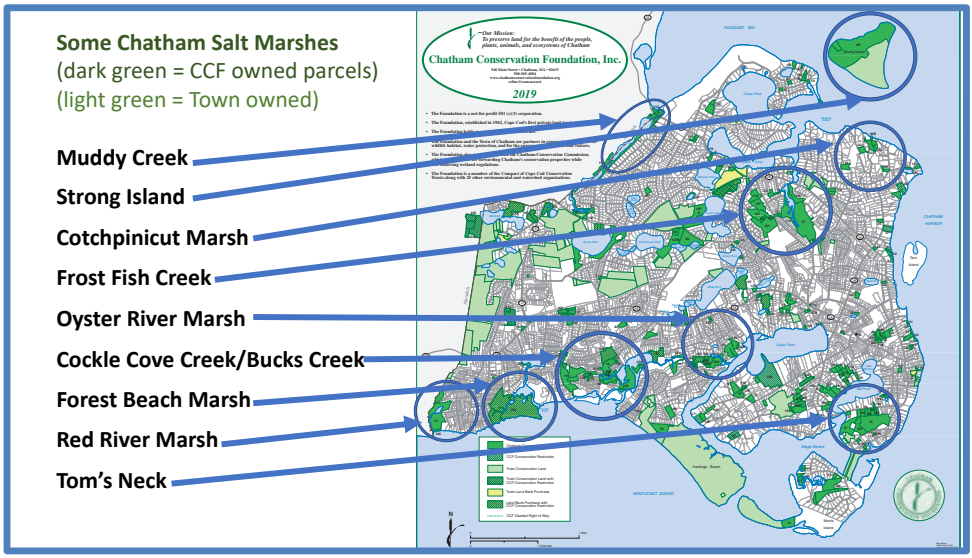


Figure 1. Some salt marshes in Chatham

Preserving the land of the salt marsh

Chatham's marshes were frequented by the Wampanoag natives, who enjoyed the plentiful fish and shellfish there. Later European settlers adapted the marshes for boating and agriculture. Eventually, roads and housing cut off tidal flow and many marshes were filled in for farming. Most of Chatham's major salt marshes were converted to cranberry bogs in the 1800s.

Since 1962, the Chatham Conservation Foundation (CCF) has been acquiring properties in Chatham and protecting them from development and preserving their natural beauty. Many of the land donations are in and around salt marsh.

CCF has successfully protected and preserved important and beautiful marshes in Chatham. However, in the face of tidal restrictions, invasive weeds and climate change, a more active approach is called for. So CCF formed a Salt Marsh Task Force and has begun to work with the Association to Preserve Cape Cod (APCC) and other non-profit and governmental agencies to monitor and restore salt marsh health, initially targeting Frost Fish Creek and Cockle Cove/Bucks Creek.

Figure 2. Researchers from CCF and APCC cataloging plant coverage in the marsh. Photo by Matthew Hamilton.

The flow of tides through the salt marsh

Tides roll into salt marshes every 13 hours. Their depth and penetration vary depending on the relative positions of the moon and sun, as well as weather and marsh conditions. They flush nutrients and small creatures into the marsh and then out to sea. This creates an active basis for the chain of life, particularly important to the fishing industry of Chatham.

Monitoring the health of a marsh begins with identifying tidal restrictions, such as damaged culverts, which constrain the eco-system processes which support flora and fauna that are adapted to periodic salt-water flushing.

Salt-tolerant grasses of the marsh

The most visible feature of a salt marsh is its vegetation. Flora in marshes is determined by the saltwater tides: only specialized grasses and reeds can thrive in daily flooding and high salinity. Where marshes are well flushed by the tides, "saltmarsh grass" (*Spatina alterniflora*) dominates, creating flowing waves of green. Toward the higher ground around the edges, "salt meadow grass" (*Spatina patens*) grows somewhat higher.

Where the tides are restricted or the salinity is reduced by mixing with fresh water from creeks, springs or runoff from roads and lawns, a non-native "common reed" (*Phragmites australis*) can establish an invasive presence, which can out-compete native plants and be hard to control.

Other plants observed in healthy local marsh areas include: "spike grass" (*Distichlis spicata*), "black grass" (*Juncus gerardii*) and "cattails" (*Typha angustifolia*). Areas with more

brackish water have more diverse flora, including bordering shrubs that are not specialized for marshes.

Figure 3. A view of Cockle Cove marsh from Cockle Cove Road.

Inhabitants of the salt marshes

Many birds frequent the marshes, some during migrations. Over 150 have been documented around Frost Fish Creek. At Cockle Cove marsh one can often see ducks, great blue heron, egrets or osprey soaring across the sky. Hidden in the brush, one can also find "saltmarsh sparrows" — an important reassurance of healthy salt marsh.

Tides pump nutrients in and out between the ocean and the marsh. This is the beginning of the food chain for shellfish, fish, birds and mammals. Micro-organisms nourish the smallest life forms, which in turn feed larger and larger creatures. Many fish, shellfish and other animals spend important stages of their lives in the marsh. The abundance of fish in the oceans is dependent upon the foundation of the food chain in the marshes along the shores.

Salt marsh eco-system evolution

The first step in actively preserving and restoring healthy marsh is to research the current functioning of the marsh as an ecosystem involving: (1) flowing water (mixing tidal salt water and fresh ground water), (2) vegetation (marsh grasses, native and

invasive reeds, bushes) (3) animal life (birds, fish, shellfish, small mammals) (4) soil (sedimentation, carbon capture, water filtering).
These complex and interrelated factors determine the quality of the marsh and of the services it provides to the environment and to people. A disturbance in one factor may influence others and it may take years for the multiple factors to co-evolve to a stable state, making restoration of marsh health a complex, slow and costly process.

Discoveries in Cockle Cove

Fiddler crabs are popular salt marsh inhabitants — for instance around Ridgevale Beach. However, our marsh research project just discovered a rare relative, somewhat larger, with red markings on their joints and favoring lower salinity waters: "brackish water" or "red-jointed fiddler crab" (*Minuca minax*). They live further upstream on Cockle Cove Creek and Bucks Creek. Although previously observed along Buzzards Bay, this is the first documented sighting on this part of the Cape.

Figure 4. Discovery of Minuca minax crabs. Photo by Adrianne Lovuolo.

Another exciting discovery in Cockle Cove marsh is the presence of a relatively rare native strain of phragmites. This is a non-invasive version, known as "American reed" (*Phragmites americanus*). It does not out-compete other native plants. It is rare outside of Massachusetts and is in danger of extinction.

Figure 5. Native phragmites in Cockle Cove marsh.

Chatham's future and its salt marshes

The Cockle Cove area is projected to undergo significant environmental change in the next decades, with sea-level rise and surge from increasingly harsh storms flooding the marshes, beaches and many roads and homes, unless the marshes can grow and migrate in response to the changes. We want to ensure that there are areas for the marsh to migrate to as the sea level rises, so we try to own and protect adjacent wetlands.

As stewards of the land, we need to track the marsh eco-systems over time. We want to monitor the presence of native plants, fish, birds and animals, so we know if they are continuing to thrive. We also want to optimize the growth of salt marsh grasses that sequester carbon.

Preserving healthy marshes is the most effective way to lower the carbon footprint of Chatham. Healthy salt marshes are key to Chatham's future economy, climate change resilience and natural beauty.

Hydrology Study of Frost Fish Creek

Proposal to the Community Preservation Committee (CPC) under the Chatham Community Preservation Act (CCPA)

Application Number: CPA-2020-17
Application Date: January 13, 2020
Project Title: Frost Fish Creek Salt Marsh Preservation
Organization Name: Chatham Conservation Foundation, Inc.
Organization Address: 540 Main Street, Chatham, MA 02633
Email: Gerry@GerryStahl.net
Website: https://ChathamConservationFoundation.org
Names of Governing Board of Trustees:
Robert Lear (President), Paul Chamberlin (Vice President), Gerry Stahl (Treasurer), Edyth Tuxbury (Clerk), Jeanne Branson, David Dougherty, Jack Farrell, Michael Franco, Jane Harris, Roy Meservey, Tony Murphy, Carol Odell, Peter O'Neill, Gary Toenniessen, Cathy Weston.
Federal Tax ID Number (if non-profit): 04-6047692
Submitter or Project Director: Gerry Stahl, Chair of the Salt Marsh Task Force
Amount Requested from CPA Funds: $75,000

Project description:

This project will study how best to preserve an important Chatham salt marsh from ongoing injury, harm and destruction due to development and climate change. The salt marsh is on and surrounded by land owned by the Chatham Conservation Foundation, Inc. (CCF)—see maps below. A preliminary study conducted by APCC in 2018 indicated multiple tidal restrictions and recommended systematic further study to plan for preserving the health of the marsh under likely scenarios of restriction removal, sea-level rise and storm surge.

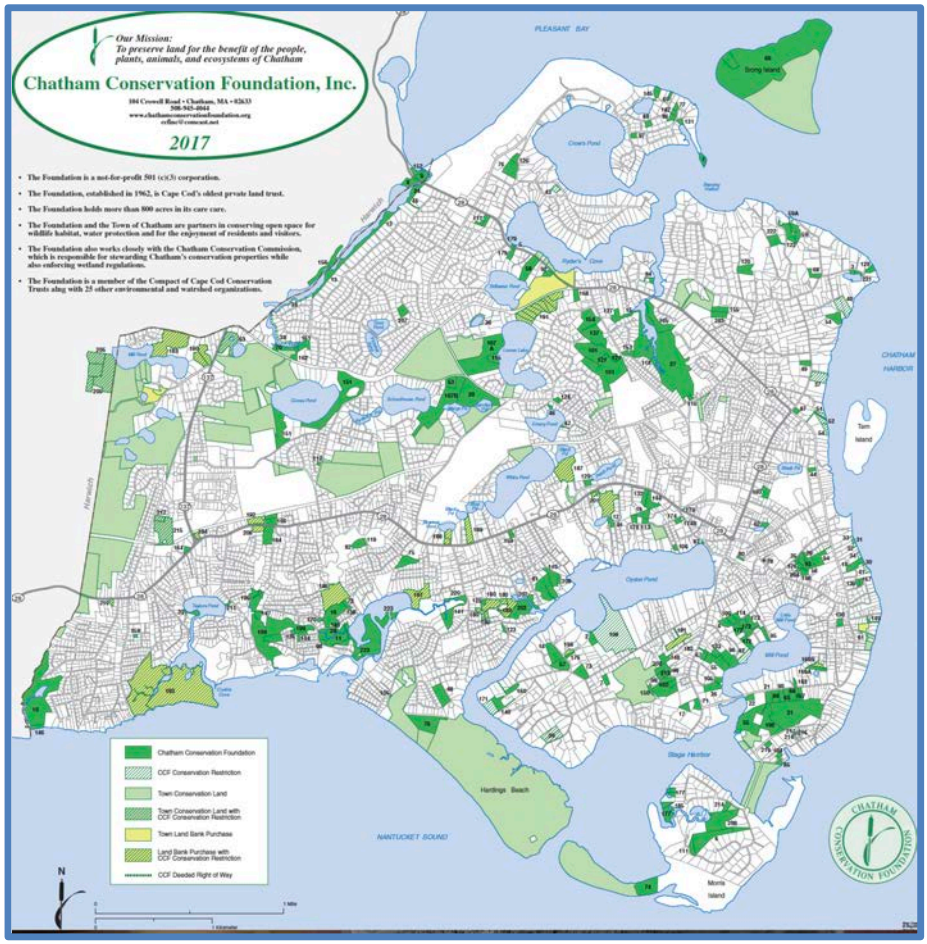


Figure 1. Map of CCF properties (dark green) and CRs (light green).

Recommended studies included: (A) a complete hydraulic and hydrologic modeling; (B) water quality modeling resulting from recommended tidal changes; (C) a ground penetrating radar survey of the bog area to determine sand depth, as needed; (D) a fish and shell fish survey to identify presence/absence of species; (E) expanded vegetation mapping; and (F) establishment of long-term vegetation monitoring transects.

Using CPC grant funds, this project will undertake only the first two of these studies (A and B) of the existing marsh and adjacent land onto which the marsh might migrate. The results of the hydraulic and hydrologic study (A) will suggest specific strategies such as potential opening of the existing restrictions, particularly under Route 28 from Bassing Harbor to Frost Fish Creek, to increase flushing without

impacting any private property. A water quality modeling study (B) will then consider whether removal of tidal restrictions would result in improved water quality parameters necessary for restoration of salt marsh habitat.

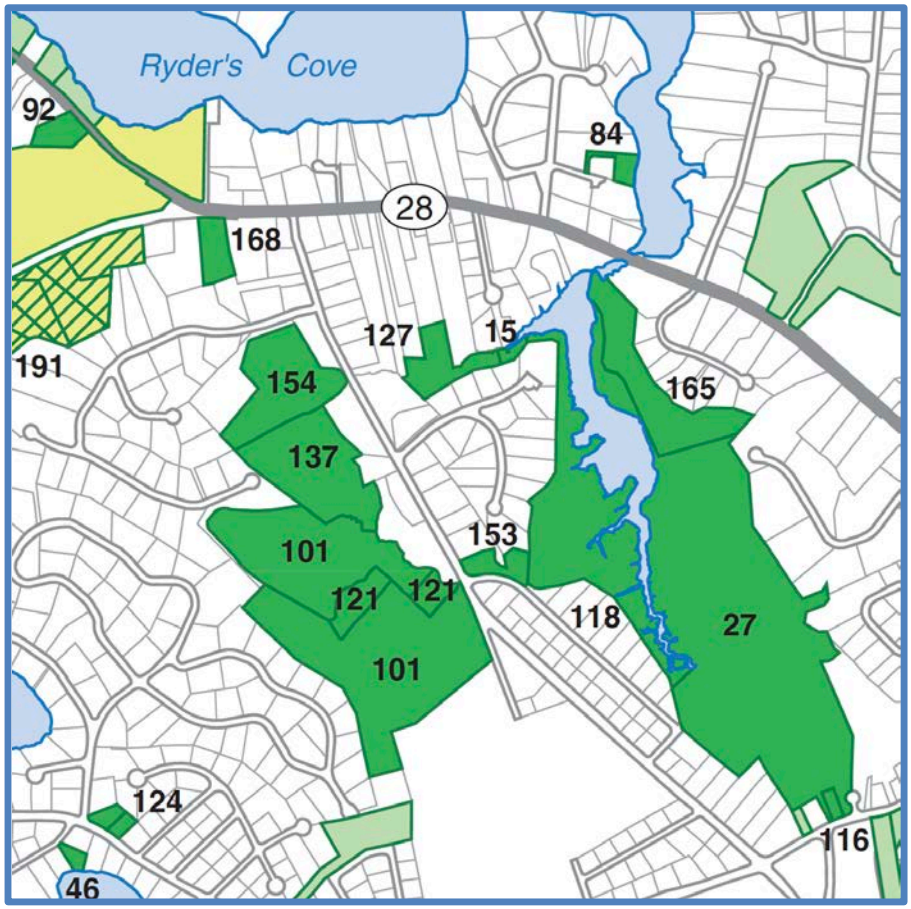


Figure 2. Frost Fish Creek salt marsh: CCF properties #15, 27, 84, 101, 118, 121, 127, 137, 153,154, 165. This is a total of about 90 acres of land surrounding and encompassing the marsh, including land that formerly was part of the marsh or might become part in the future.

The results of these studies (A and B) may lead CCF to conduct baseline studies (C, D, E and F) as appropriate, using its own funds. *CCF will then be in a position to assess the feasibility of possible scenarios for the preservation of the Frost Fish Creek salt marsh, based on systematic analysis of existing conditions, with potential increased flushing and improved water quality*. The proposed studies will prepare the way for future design, permitting and construction within a comprehensive holistic approach. Preservation of Frost Fish Creek will then be able to encompass a desired combination of the following:

improved water quality, salt marsh restoration, reestablishment of fish passage and potential for salt marsh migration—all measurable against baseline data.

CCF is the oldest land trust on Cape Cod, dating to 1962. It owns 620 acres of land in Chatham and manages conservation restrictions (CRs) on another 215 acres of land owned by the Town of Chatham. Of this land, approximately 163 acres of the owned land is salt marsh and 50 acres of the CRs is salt marsh, according to the map below. Additionally, this does not count CCF stewardship of dry land surrounding marsh or land where a salt marsh could migrate in the future with sea-level rise.

A major goal of CCF's 2019-2021 Strategic Plan is to "monitor and maintain health of salt marshes to prevent degradation and/or restore health." In 2019, CCF established a Salt Marsh Task Force to focus efforts on the preservation of the salt marshes in the Town of Chatham. Due to its position at the elbow of Cape Cod, adjoining Pleasant Bay, the Atlantic Ocean and Nantucket Sound, Chatham has a uniquely high percentage of its land covered by or adjoining salt marshes. The preservation of its salt marshes is essential to retaining the health and beauty of Chatham.

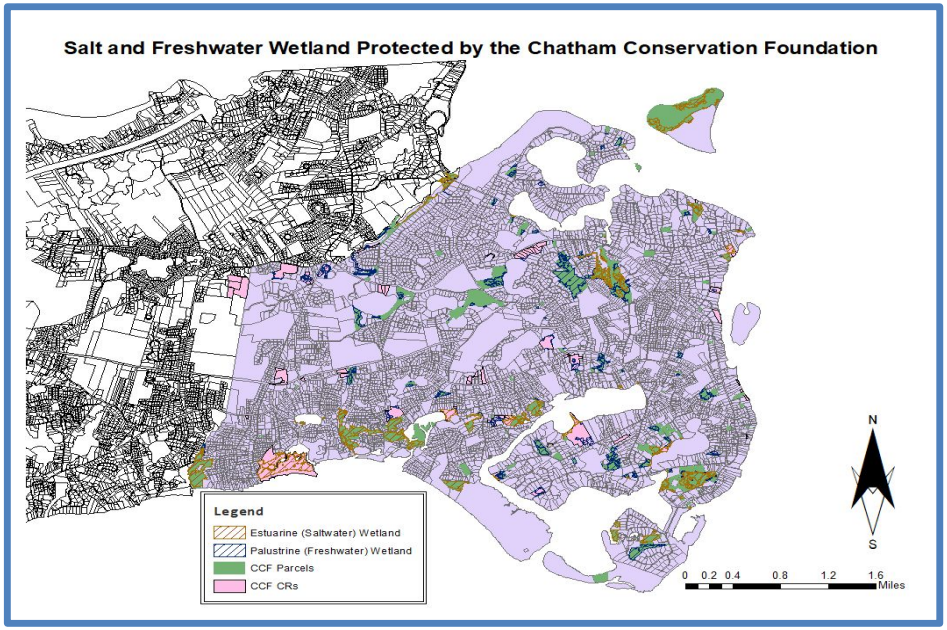


Figure 3. Wetlands protected by CCF.

The mission of CCF is "to preserve land for the benefit of the people, plants, animals and ecosystems of Chatham." Salt marshes have natural rhythms and mechanisms for preserving their ecosystems. These have long been threatened by development, such as roads restricting tidal flows and abutting residences polluting through septic

systems and chemical runoffs. Preservation of salt marshes is now additionally threatened by climate change, with, for instance, sea-level rise, extreme storm surges and climate shifts that favor invasive species.

CCF was founded to preserve open space in Chatham in its historical, natural state. It has done this by acquiring about 200 parcels and protecting these and an additional 50 parcels of Town-owned land under perpetual Conservation Restrictions. However, it has become clear that *it is no longer sufficient to simply acquire land.* One must also protect it from the impacts of invasive species, disturbance from surrounding development and escalating climate change.

Protection of salt-marsh resiliency is a subtle matter, requiring careful study of existing conditions and detailed modeling of possible interventions. Salt-marsh preservation has become doubly important in the era of climate change as salt marshes are particularly effective in sequestering carbon and thereby mitigating the *causes* of climate change, as well as mitigating its *effects*, such as sea-level rise and storm surges.

The Frost Fish Creek is CCF's initial salt-marsh preservation target. The following maps of Chatham show wetlands now and projected in a couple of decades, with the large bright green area in Figure 4 indicating Frost Fish Creek salt marsh.

Figure 4. Chatham with future flooding levels shown in light blue and bright green. Source: NOAA's Office for Coastal Management sea level rise viewer at 2 ft. level.

Figure 5 indicates areas for potential salt marsh migration as tidal restrictions are removed to preserve the original extent of the marsh, and as sea-level rise takes place

in the coming years. Note that CCF already owns the areas for probable migration as well as the area surrounding the current wetlands.

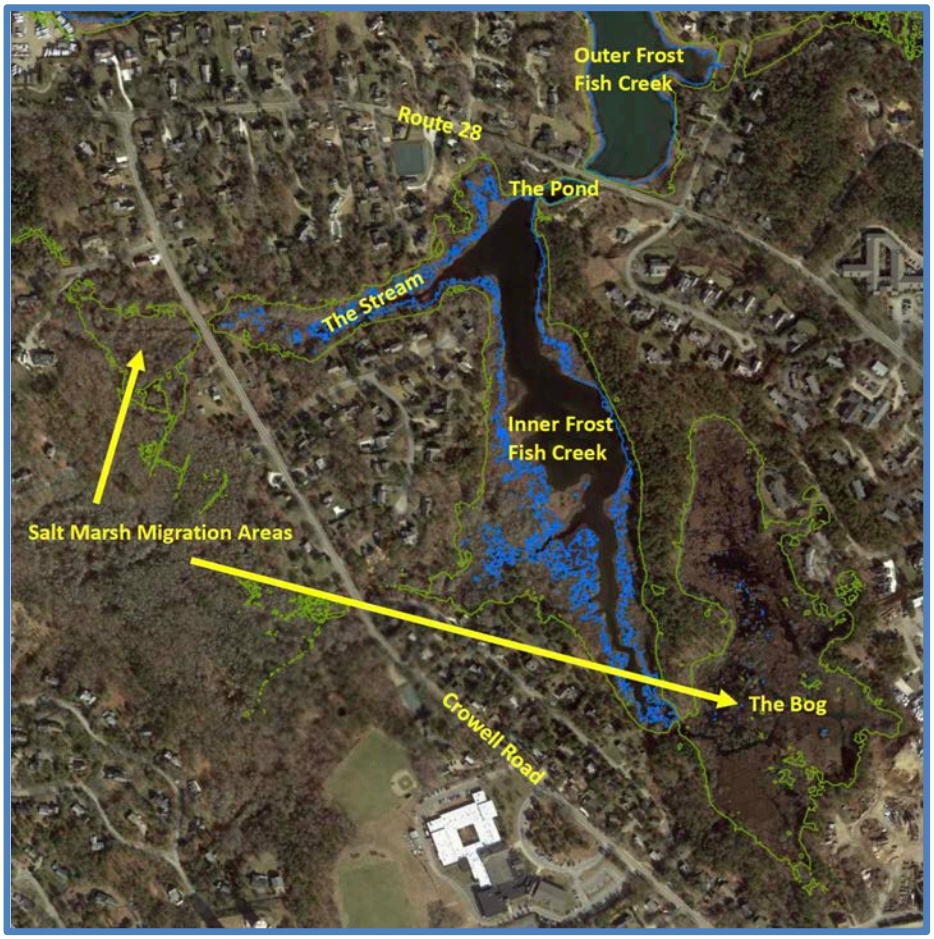


Figure 5. Migration paths of Frost Fish Creek. Blue lines show two-foot flooding and green lines indicate five-foot elevations. Yellow arrows point to areas that were formerly part of the marsh and could be preserved as such in the future.

The CCF Salt Marsh Task Force is beginning to coordinate with relevant expertise on Cape Cod and in Massachusetts governmental agencies concerned with salt-marsh preservation. The Frost Fish Creek salt marsh has been identified by the Association for the Preservation of Cape Cod (APCC) and other agencies in Massachusetts as a priority for preservation action. In 1987, it was designated by the state as part of the Pleasant Bay Area of Critical Environmental Concern (ACEC). An ACEC is a place in Massachusetts that receives special recognition and protection because of the

quality, uniqueness and significance of its natural and cultural resources. The ACEC Program's goal is to preserve, restore and enhance critical environmental resources and resource areas of the Commonwealth of Massachusetts through increased levels of protection, and to facilitate and support the stewardship of these areas. CCF will work closely with Town and state agencies to study and preserve the Frost Fish Creek area.

Frost Fish Creek is a salt marsh owned by CCF. One of CCF's most scenic and most popular trails for public access goes along Frost Fish Creek. In 2018, the CCF Board allocated funds from its operating budget to hire salt-marsh specialists from APCC to undertake an initial study of how to preserve Frost Fish Creek as a healthy salt marsh. Since 1968, APCC efforts have led to landmark achievements in water resource protection, land preservation and smart growth, earning APCC the reputation as Cape Cod's most prominent and influential nonprofit environmental organization working to preserve, protect and enhance the natural resources of the Cape. It conducts advocacy, studies and interventions to restore and protect natural landscapes and preserve wildlife habitat.

Working with CCF in 2018, the APCC (i) deployed data loggers at six locations throughout Frost Fish Creek to collect data on water level, temperature and salinity every 10-minutes during a full lunar-driven tidal cycle in October 2018; (ii) conducted an elevation survey throughout the area; and (iii) collected soil samples in an abandoned cranberry bog section of the former marsh. The report made a series of recommendations for further study to determine an optimal plan for preservation of Frost Fish Creek salt marsh. The 2018 APCC study concluded that the traditional tidal access to the Creek was being significantly restricted by Route 28. A culvert under the road to permit tidal flow had deteriorated, restricting flow in both directions, so that too little salt water enters the marsh to maintain its health and too little flow after storms escapes to relieve flooding. The salt marsh is also restricted at other points and is consequently much smaller than it was prior to local development, and is substantially tidally restricted.

The current proposal to the CPC is to take the next set of steps as recommended by the APCC study of Frost Fish Creek to study the feasibility of salt marsh preservation. The purpose of this is to plan how best to preserve this important natural resource from continuing injury, harm or destruction in the next decade. The land owned by CCF surrounding and encompassing Frost Fish Creek is a prized aquifer and watershed land, including forest land, fresh and salt-water marshes and other wetlands, stream and lake frontage, scenic vistas, land for wildlife, nature preserve, and land for recreational use. The current proposal does not include actual implementation of changes to the environment, but provides for the two major studies needed in order to understand the feasibility of alternative implementation approaches. Subsequent implementation would be carried out based on the findings of these studies in close collaboration with Town and state agencies. The proposed studies are necessary preconditions for future statewide funding.

Specific objectives and costs

The proposal is to undertake the two concrete studies listed below as project objectives A and B. This is a one-time effort, which will set the stage for a coherent, long-term preservation strategy. These proposed studies will be managed primarily by APCC. The studies will be done within a broader context of planning for Frost Fish Creek and other salt marshes on CCF land in consultation with relevant agencies at the Town of Chatham and the Commonwealth of Massachusetts, as well as other wetlands experts on Cape Cod. The long-term strategy will be implemented using other funding sources, under the direction of CCF, in collaboration with relevant agencies and accompanied by public outreach and education. Public access to trails will be guaranteed through appropriate Town agreements.

Objective A. *Complete hydraulic and hydrologic modeling (H&H).* This objective will determine options for tidal restoration, culvert sizing/design and expected extent of flooding under different scenarios.

Objective B. *Complete water quality modeling, based on the H&H.* This objective will model changes to water quality (e.g., salinity, nutrients) as a result of changed tidal flows.

Objective C. *Submit a report to the CCF Board, the Town of Chatham and the public, summarizing results and recommendations.* This report shall convey the major findings of each of the studies conducted. It will also outline data-based strategies for preservation of the salt marsh based on these findings.

These proposed studies are largely in response to the findings of the 2018 study, which CCF funded from its own funds and which was conducted by APCC, namely:

- That tidal flow is significantly restricted by the deterioration of the culvert under Route 28. However, if Mass DOT were to suddenly replace the damaged culvert (as could be possible in the near future), the consequences for homes abutting the marsh and for the salt marsh itself would not be sufficiently carefully controlled.
- That a migration path has not yet been determined and prepared for the marsh as sea-level rise impacts the marsh. The upper regions of the wetlands were artificially dammed off for cranberry bogs in the past, and fish corridors were closed off by development.
- That it is important to model the consequences of changing the existing tidal restrictions and to plan for carefully stewarded gradual changes.
- That in order to monitor preservation and restoration, we need to document current conditions, including the current existence of fauna and flora. The marsh is named after a particular fish, but it is not known if the fish currently exists in the marsh. Similarly, we need to know the extent of rare vegetation and of invasive species, as well as the presence of animals.

Following are the budgeted costs of each of the Objectives proposed under this CPC application. Together, these Objectives define the scope of the proposed project and their costs define the proposed budget:

Objective A. *Complete hydraulic and hydrologic modeling (H&H)*. $40,000 for APCC to hire and manage consultant to complete modeling, including up to $35,000 for subcontractor expense.

Objective B. *Complete water-quality modeling based on the H&H*. $35,000 for APCC to hire and manage consultant to complete modeling, including up to $30,000 for subcontractor expense.

Objective C. *Submit a report to the CCF Board, the Town of Chatham and the public, summarizing results and recommendations.* $5,000 for APCC to compile data from the above work into a final report by December 31, 2022.

Total Budget Proposal: $75,000 from CPC, $5,000 from CCF.

* * *

Which of the Following Goals of CPA does this project address?

X The acquisition, creation and **preservation of Open Space**.

How does this project impact Chatham's citizens and address a current need?

Healthy salt marshes are important to the Town of Chatham; to protection of property and infrastructure; to the water quality; to the Town's scenic beauty; to local fauna, sea life and flora; to recreation; to many other eco-systems; and to the climate. Healthy salt marshes sequester greenhouse gases that would otherwise contribute to climate change. They can mitigate flooding and dissipate storm surges. They respond naturally to sea-level rise if not tidally restricted. Degraded and dying salt marshes release dangerous methane gases to the atmosphere, which is significantly more impactful than CO_2. The Frost Fish Creek salt marsh is perhaps the largest salt marsh in Chatham that is most in need of preservation. Preservation of this marsh will provide a working model to guide preservation of other marshes under CCF stewardship.

What is the estimated or target number of people this project will benefit/affect?

This project will benefit the residents of Chatham in general. A preserved marsh will provide recreational opportunities for hundreds of people each year. The proposed studies will allow CCF to make data-based decisions about how best to preserve the marsh.

How will you measure the success of this project?

The proposed studies will capture baseline data concerning the land, water and tidal flows, under different scenarios. As part of the project, in addition to the collection of new measurements, CCF will gather together baseline historic data from previous studies of Frost Fish Creek by various sources and agencies to show changes over time. This will permit future assessment of increased health of the marsh and

associated ecology. In particular, potential future spread and migration of the marsh can be periodically measured and compared to the baseline and historic figures.

Projected Action Plan and Timeline, including anticipated completion date. List steps needed to complete the project?

It is anticipated that the studies and report funded as part of this CPC project will be completed within two and a half years from July 2020 through December 2022. Summer of 2020 will be used for project start-up. **Objective A**, the hydraulic and hydrologic modeling (H&H) will be conducted first. Findings from this will feed into **Objective B**, *the water quality modeling*. **Objective C**, *the final project report* detailing findings and recommendations will be completed by December 2022.

Please provide a full budget:

Full Project Budget	
Objective A – H&H modeling	
APCC – Restoration Ecologist	$2,400.00
APCC – Restoration Technician	$1,750.00
APCC – Grant/Contract Administrator	$795.00
Subcontractor	$35,000.00
Travel (130 miles) for 2 meetings	$75.00
Task 1 – Subtotal	***$40,020.00***
Objective B – Water quality modeling	
APCC – Restoration Ecologist	$2,400.00
APCC – Restoration Technician	$1,750.00
APCC – Grant/Contract Administrator	$795.00
Subcontractor	$30,000.00
Travel (65 miles) for 1 meeting	$35.00
Task 2 – Subtotal	***$34,980.00***
Objective C – Final Report	
APCC – Restoration Ecologist	$2,100.00
APCC – Restoration Technician	$1,070.00
APCC – Grant/Contract Administrator	$795.00
Subcontractor	$1,000.00
Travel (65 miles) for 1 meeting	$35.00
Task 3 – Subtotal	***$5,000.00***

TOTAL	**$80,000.00**

Total Amount of Project: $80,000.

Other revenue sources including private/public/in-kind:

CCF paid APCC $5,000 in 2018 to conduct a first phase of this preservation study. These funds came from CCF's operating budget.

CCF will provide volunteer services to assist with this CPC project.

CCF will contribute $5,000 to pay for Objective C, the final report.

Financial sustainability to secure project after the grant:

The project will be complete at the end of the grant period. Possible future design, permitting and construction suggested by the findings of this project would involve state-wide funding with Town collaboration, proposed using data from this study, and would not be part of this grant. Until the studies are conducted and new decisions made based on the findings, there are no additional costs planned after the grant.

Annual cost/expenditures once the project is operational, if any?

There will be no special on-going costs, other than the normal maintenance of the land and trails, which is covered by CCF's staff, volunteers and operational budget.

Annual cost to the Town once the project is operational, if any: None.

Potential revenue from project on an annual basis, if any:

None. Access to the trail will be free and open to the public. CCF is prepared to enter into a restriction or agreement with the Town to guarantee permanent public access to the trail.

What entity will collect and control future revenue? N/A.

What is the basis for your budget? What are the sources of information you used?

The budget was prepared with the assistance of the APCC salt-marsh staff, based on their experience conducting similar studies. APCC staff conferred with both Horsley Witten and the Woods Hole Group concerning reasonable costs for the two major studies.

Are there any legal ramifications/impediments to this project?

Not for the studies in this project. Any potential legal issues associated with future implementation steps will be identified and addressed as part of the planning process based on the findings of this project.

Is the project compatible with the Town's Comprehensive Plan?

Yes.

Cite specific sections if applicable:

This CPC project is particularly in support of Chatham's Comprehensive Plan 3: Natural Resources. Specifically, it is compatible with Goal 3-1: Protecting the quality of our air and water resources. The preservation of salt marshes like Frost Fish Creek contributes to Water Quality Protection, the control of Storm Water and the natural protection of Coastal Resources. It is also supportive of Goal 3-2: Protection of

Vegetation and Wildlife Habitat. In addition, the trail along Frost Fish Creek supports Chatham's Comprehensive Plan 4: Open Space and Recreation.

Do you have the authorization of the property owner? Yes.

Do you have a supporting letter from a Town Board, Commission, Committee?

Yes. We have supporting letters from Dr. Robert Duncanson of the Town of Chatham and from the Pleasant Bay Alliance.

What is your assessment of the nature and level of community support for the project?

The Chatham community is highly supportive of the work of CCF in preserving the land of Chatham, including the fresh-water ponds and salt-water marshes. CCF trails, kayak trips and guided tours are very popular. In addition, Chatham residents are increasingly concerned about climate change—especially sea-level rise and storm surges. They are looking for ways to mitigate these and are strongly supportive of CCF efforts to preserve healthy salt marshes. As CCF proceeds with exploring strategies to preserve healthy salt marshes in Chatham, public education about its importance will be a central component of the effort.

Priority Project for Frost Fish Creek

DER Restoration Priority Projects

Applicant's Name: Chatham Conservation Foundation, Inc. (Contact: Gerry Stahl, Treasurer; President: Robert Lear; Executive Director: Dorothy Bassett)
Project Name: Frost Fish Creek Restoration Project

Project location and setting:

Frost Fish Creek is a 90-acre conservation area and Critical Natural Landscape in North Chatham with a variety of natural features. In 1987, it was designated by the state as part of the Pleasant Bay Area of Critical Environmental Concern(ACEC).[1] The Creek is a tidally influenced tidal wetland system directly connected to Ryder's Cove, Bassing Harbor, Pleasant Bay and the Atlantic.

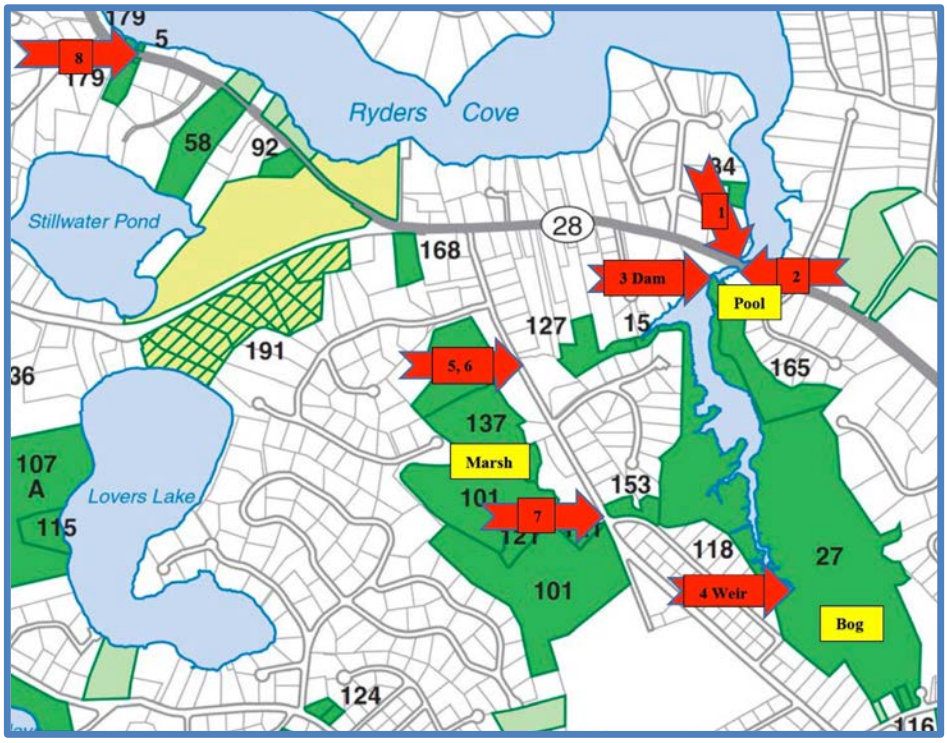
There is a major tidal restriction at Route 28, which is slated for replacement. There are other tidal restrictions that historically supported agriculture, especially cranberry bogs. The Creek is fed from a large wetland (the "Bog" in *Map 1*, below), which collects runoff from residential and small-industry neighborhoods, as well as from a forested wetland (the "Marsh" in *Map 1* — currently wooded swamp, shrub swamp and upland, but potentially a salt marsh migration site), which historically included a herring run to Lovers Lake and Stillwater Pond. The tidal restrictions and other anthropogenic activities have harmed the health of the salt marsh system, as indicated by phragmites, reduced extent of salt marsh and poor water quality. With restoration of ecological functions, the salt marsh in the Creek area could potentially migrate to the Bog and Marsh areas in response to sea-level rise.

The project site is owned by the project applicant, the Chatham Conservation Foundation, Inc., Cape Cod's oldest land trust. The project aims to evaluate and, where indicated, restore routine tidal action and healthy stream flow to extensive estuarine habitats as well as associated brackish and freshwater wetlands for the benefit of the people, plants, animals and ecosystems of Chatham, as well as to sequester coastal blue carbon, restore fish runs, improve natural habitats and increase recreational opportunities.

The following paragraphs detail the major sites within the project area. Three maps describe the extent, ownership and major features of the project area, overlaid on the Town of Chatham assessor's map.

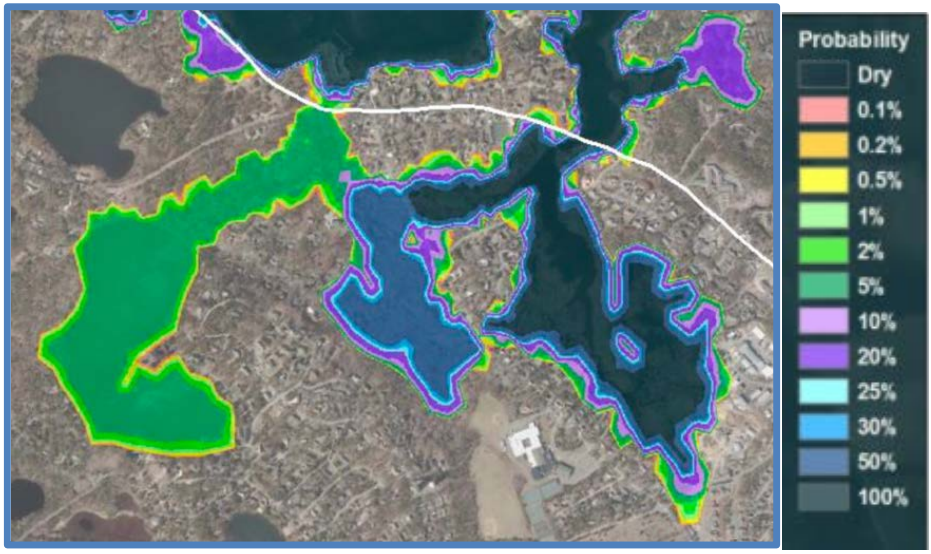
[1] The ACEC includes the entire project area plus Lovers Lake and Stillwater Pond, which were connected to it by a herring run.

Map 1 shows the project area with numbered arrows corresponding to existing culverts. A photographic site visit with pictures taken at the numbered sites can be downloaded at: https://gerrystahl.net/SMTF/ffc_site_visit.pdf. Certain sections of the project area are labelled for the sake of reference in this application.

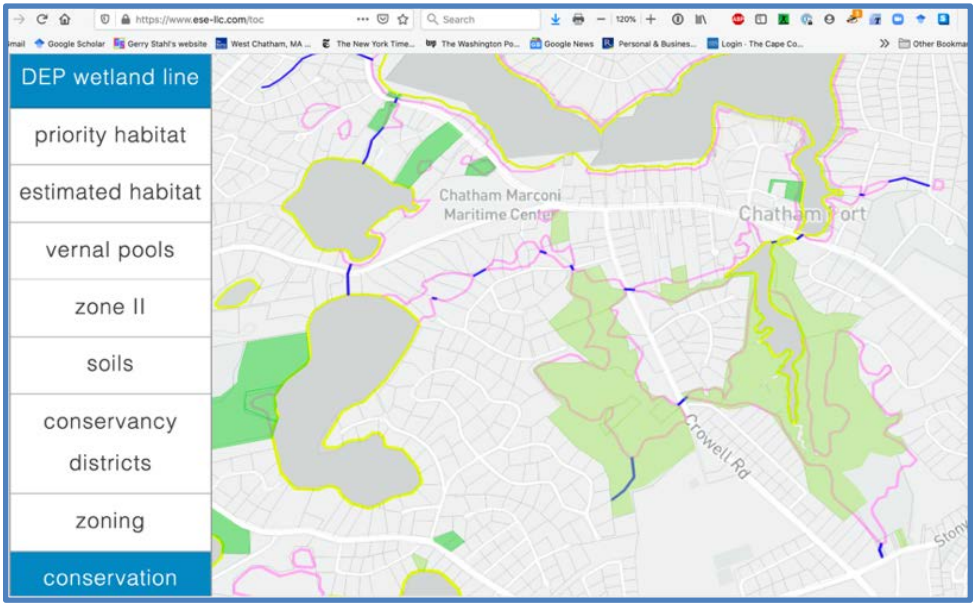


Map 1. Parcels near Frost Fish and Stillwell Pond owned by CCF (green) and the Town (yellow). Existing culverts (red arrows; numbers correspond to photo sites).

Map 2 is a projection of future flooding areas, showing how the areas marked "Bog" and "Marsh" on *Map 1* are likely migration paths for the salt marsh to be formed around Frost Fish Creek if the tidal restrictions at *Sites 1, 2* and *3* are removed. This would provide floodplain connectivity, supporting a natural flow regime under projected effects of climate change.



Map 2. Projection by The Woods Hole Group of flood probabilities in 2070.



Map 3. DEP wetlands map showing CCF conservation parcels: herring runs connecting FFC and Stillwell Pond.

Map 3 shows wetland lines connecting Frost Fish Creek to Lovers Lake and Stillwater Pond—historic and potentially future herring runs.

Much of the land in the project area owned by Chatham Conservation Foundation (CCF) is currently forested. CCF's most popular public trail goes along the entire length of the east side of Frost Fish Creek. The area marked "Bog" in *Map 1* is a former cranberry bog and is partially flooded and maintained at a water level about two feet higher than the Creek. The area marked "Marsh" is currently partially forested swamp and includes two vernal pools that CCF maintains for use by the local school.

The photographic site visit (https://gerrystahl.net/SMTF/ffc_site_visit.pdf) begins at *Site #1*, immediately downstream of a deteriorated culvert under Route 28. *Site #2* is immediately upstream of that culvert. Currently, two flows of water pass through this culvert. There is a metal pipe visible at both ends, partially below low-tide level. There is a smaller flow of water, whose entrance and exit are invisible below low-tide level. This culvert is not on CCF property. However, CCF is partnering with MassDOT to replace that culvert in order to restore optimal tidal flow to Frost Fish Creek. MassDOT may submit a separate application to DER for the culvert replacement project and CCF would support that application. The current application – CCF's Frost Fish Creek Restoration Project – is focused on managing the consequences of that restored tidal flow to create a healthy ecology throughout the project area. CCF is cooperating with MassDOT and other agencies in the design and replacement of the culvert under Route 28, including modeling of the CCF project area. CCF will also collaborate with the Town of Chatham and other partners on associated public relations.

Site #3 is a small earthen dam across Frost Fish Creek approximately 60 meters upstream of the Route 28 culvert (labelled "Dam"). The Dam has a deteriorating culvert. The Dam restricts tidal flow from the small area marked "Pool" to the CCF project area. The Dam is primarily on CCF property and marks the beginning of CCF's project area. A first decision of the proposed project will be whether or not to remove the dam and the timing for doing so.

Between *Site #3* and *Site #4* is the current extent of Frost Fish Creek. It is a scenic area that supports a variety of wildlife, including a diversity of birds. A number of private residences are perched uphill along the west side of the Creek. The further one goes upstream, the more phragmites dominate, as little saltwater reaches there.

Site #4 is the transition from the Creek to the Bog. The culvert there is a Weir with an adjustable height. For many years, the height has been set at about two feet higher than the Creek. Considerable watershed runoff from the surrounding residential and small-industrial neighborhood enters the Bog. Once MassDOT's modelling of the area is completed, CCF plans to undertake further H&H studies, particularly of the Bog and Marsh, as well as water-quality studies of the entire project area. These will inform a decision about what to do about the Weir. One possibility would be to encourage tidal flow up the Creek and into the Bog by eventually gradually removing

the Weir restriction. This could establish a migration path into the Bog for healthy salt marsh as sea level rises in the future.

Sites #5 and #6 are two sides of an existing culvert under Crowell Road near Northgate Rd. *Site #7* is another existing culvert under Crowell Road near Meadowbrook Rd. These culverts allow small streams from the Marsh to flow into Frost Fish Creek. An issue for the project is to determine the highest use for the Marsh area, given the results of studies and projections of potential water flow and flooding in this area over the next decades.

Site #8 is a culvert under Route 28 near Stillwater Pond that MassDOT will be replacing. This is not part of the CCF proposed project. (However, CCF owns the land on both sides of this culvert and will be cooperating with MassDOT on their effort there.) As shown in the third map, this culvert leads to Stillwater Pond, which is connected to Lovers Lake, which is connected to the CCF Marsh. Thus, there is a potential to reopen a system of fish runs that used to exist.

Project background:

Frost Fish Creek was home to Indigenous tribes and formed a boundary of Chatham when the Town land was initially purchased from the Wampanoag by William Nickerson in 1656. CCF's 1.1-mile walking trail meanders along the eastern edge of Frost Fish Creek, offering walkers glimpses of an old cranberry operation which has reverted into open wetlands. Along the high trail, borrow pits for sanding the bogs appear on either side of the path. With its outlooks of the wetland observed from upland pine/oak woodlands, this area offers the most varied views and numerous opportunities to experience seasonal bird and mammal life in Chatham. A 9-minute video on the Creek and the proposed project was publicly aired at the CCF 2020 Annual Meeting and is now available at: https://www.youtube.com/watch?v=OkUzTE3c2VM&t=197s. The video documents the history of the area, discusses and illustrates some of the wildlife, and briefly describes the proposed restoration project.

As Chatham's land trust, CCF has acquired parcels since the 1960s in order to preserve open space in the face of development. It has established charitable trust restrictions on the Frost Fish Creek parcels that they "be held in an open and natural condition exclusively for conservation purposes forever."

Recently, CCF has committed to taking increased action to restore parcels that are threatened by invasive species and climate change. For instance, CCF is currently using a CPA grant to restore land on Route 28 about a mile northwest of Frost Fish Creek at the homestead site of the founder of Chatham, creating a public path and native planting landscape at the historic site. Salt marshes are a particular focus of restoration due to their role in climate change and to the fact that much of CCF's land is associated with salt marshes. CCF formed a Salt Marsh Task Force in 2019 and targeted Frost Fish Creek as its first site for salt-marsh restoration. (It has recently added a large marsh complex in West Chatham as a second focus for study, but that

is not part of the present application.) See *2019 APCC Study* (downloadable at: https://gerrystahl.net/SMTF/FFC_Restoration_Report_2019.pdf.)

In 2018, CCF contracted with APCC (Association to Preserve Cape Cod) to conduct a preliminary study of Frost Fish Creek. This study showed the extent of tidal restriction due to the culvert at Route 28. It also pointed to the Dam (*Site #3*) and the Weir (*Site #4*) as further restrictions. It recommended further detailed studies. (The data from this study has been forwarded to MassDOT for their modelling effort.)

The study found human-induced degradation of the ecological system, including impaired water quality, loss of salt marsh, reduced salinity, limited habitat connectivity and fish passage, presence of invasive common reed, and reduced recreational access. It suggested that these factors could be improved by restoring tidal flow to the system. The vegetation survey completed by APCC indicated some loss and degradation of salt marsh, presence of invasive *Phragmites*, and shallowing of the creek. Restoration of tidal flow would increase tidal prism and salinity supporting salt-marsh health and potentially expansion/migration in the bog area while reducing the presence and extent of *Phragmites*, a salt-intolerant species. Increased flushing and tidal exchange would likely also improve sediment movement reducing the problem of creek shallowing due to impoundment of sediment behind the restrictions. However, reduction in *Phragmites* and improvement to salt marsh should be weighed against expected loss of other salt intolerant habitats or species like *Typha* when setting goals and objectives for preservation or restoration of Frost Fish Creek. While fish and wildlife were not surveyed by APCC, restoration of this site could also provide opportunity for restoration of species like the tomcod ("frost fish"). Improved water quality and habitat would also provide enhanced recreational opportunities for the community.

The time-series monitoring of tidal hydrology completed by APCC indicated overall restriction by the culverts and upstream water-control structures resulting not only in reduced tidal flow and flushing contributing to decline in salinity and poor water quality, but also elevated water levels at low tide and increased residence time of water after storm events, increasing flood risk upstream of Route 28.

While the study called for further modeling, its initial elevation survey indicated minimal to no expected impact on structures (homes) on low-lying properties. One concern when starting this project was proximity to the existing Acme Laundry spill containment and potential for tidal restoration to impact the site. However, the elevation survey along with tidal hydrology indicated that the berm and containment area are located beyond the extent of potential flooding. Thus, this initial assessment would suggest there would be minimal to no impact of a full or partial tidal restoration on structures on neighboring properties or contamination from this contained spill.

In 2020, CCF submitted a grant proposal to the Chatham Community Preservation Committee for CPA funds to conduct two new detailed studies recommended by the APCC study: an H&H (hydraulic and hydrologic modeling) study of the entire project area, including the Creek, Bog and Marsh, as well as a water-quality study of the bodies of water throughout the project area. This proposal was approved by the CPC, Town

officials and Selectmen. It is currently pending approval at Town Meeting, which has been repeatedly delayed due to the pandemic. Approval is expected this summer. The project area historically supported commercial cranberry bogs, resulting in changes in land use and water flow. The old herring runs have been closed. Water quality in the Creek has deteriorated due to limitations on tidal flushing.

CCF acquired parcels in the project area over several decades. CCF maintains a scenic public trail along the Creek and over some of the adjacent forested hills. CCF is currently installing identification signs on some of the trees and plants along the trail. CCF periodically conducts group hikes along the trail and produced a video of the history of the area. CCF has begun public education efforts about the importance of salt-marsh restoration during climate change (see cover article on Frost Fish Creek in the *CCF Bulletin Spring 2021*.

Project goals:

The goal of the project is to restore the project area, including the fresh and saltwater wetlands, to a natural state that will be resilient to climate change and to local development over the next 20-to-50-year timeframe. This includes assessment and redesign of the tidal restrictions at Route 28, at the Dam, at the Weir and along Crowell Rd – to be followed by permitting and construction. Decisions on how to address the existing tidal restrictions require hydrologic and water-quality studies. The output of these studies will inform goals and objectives for final design, permitting, installation and resources monitoring. These decisions will be made in collaboration with project partners and in consultation with Town residents, especially abutters.

In line with CCF's mission, the project purpose is to "preserve land for the benefit of the people, plants, animals and ecosystems of Chatham." This includes improving water quality, providing expanded recreational opportunities in nature, and addressing the impacts of climate change by restoring, extending and managing salt marshes to increase carbon sequestration, reduce flooding and protect land from coastal storms. The desired outcome of this project is to optimize ecosystem benefits of tidal restoration as defined by the design decisions for the culverts and other tidal restrictions within the system. The details of the project will derive from those design decisions, including how best to foster a healthy natural state of each sub-area in accordance with its highest use.

Design and replacement of the culvert at Route 28. This goal will be pursued primarily by MassDOT, its consultants and its partners. CCF will collaborate on this effort and support it. This work will result initially in a hydrologic model of Frost Fish Creek corresponding to a redesign of the culvert. The redesign will have major consequences for CCF's proposed coastal wetlands restoration project, and the model will provide initial guidance to CCF. The MassDOT effort will include permitting and construction of the redesigned culvert and roadway along Route 28.

Probable removal of the Dam. It is likely that the Dam with its culvert will be removed to allow the new tidal flow from the Route 28 culvert to be restored up Frost Fish Creek.

A project goal is to plan for such a removal, including coordinating its timing with the replacement of the Route 28 culvert. The consequences of removing the
Potential lowering of the Weir. A more complex decision will be whether to gradually lower and/or eventually remove the Weir. This will involve additional studies of hydrology and water quality in the Bog, such as those planned with the expected CPA grant to CCF. The Bog collects considerable water and pollution from the surrounding watershed—and more will be added by a new Town storm drain. Assessment will be required concerning the consequences of tidal flow into the Bog area from the Creek and freshwater flow into the Creek from the Bog. Any change may have to be made over a period of years, taking into account sea-level rise and changing flood plains. A conversion into salt marsh or into a site for salt-marsh migration may be necessary. This will involve consultation with abutters, permitting, soil testing and possible amendment, and construction to define Bog boundaries.
Improvements to connecting streams. The two culverts under Crowell Road may be sound and adequate. Planning and model projections will be needed to see if interventions are needed to the stream beds connecting the Creek to the Marsh as well as the former herring run to Lovers Lake. The project may need to engage in permitting and construction to improve these stream beds. Acquisition by CCF of some small parcels of wetland may be useful and collaboration with abutters will in any case be important.

Project scope:

CCF has done substantial background work for the project:

- CCF has maintained parts of the project area for six decades. It has a small trailhead off Route 28 for a well-established trail it maintains along the Creek and through upland forest. In recent years, it opened another access to the other end of the trail from Meadowbrook Rd. CCF is currently adding tree and plant identifiers for public education. It maintains two vernal pools in the Marsh area for science education at the adjacent middle school. CCF is currently developing an ecology curriculum involving hands-on experiences for distribution to schools and has already organized school events at the project area. CCF holds periodic public education events about ecology and Frost Fish Creek.
- CCF hired APCC to do an initial study in 2018/19 (*APCC Study 2019*, downloadable at https://gerrystahl.net/SMTF/FFC_Restoration_Report_2019.pdf), taking account of previous studies of the area and conducting a series of new studies.
- The present proposed project is a follow-up to the recommendations of that 2019 study. An informal photographic site visit to the various relevant culverts (downloadable at: https://gerrystahl.net/SMTF/ffc_site_visit.pdf) provides visuals.

- CCF submitted a grant application (*CPA Grant Proposal*, downloadable at: https://gerrystahl.net/SMTF/FCC_CPC_application_2020.pdf) in January 2020 to the Chatham Community Preservation Committee for a CPA grant to fund more detailed studies of the hydrology and water-quality of Frost Fish Creek. The proposal was approved by the CPC and the Selectmen, as well as receiving letters of support from Dr. Robert Duncanson of the Town of Chatham, from the Pleasant Bay Alliance and from APCC. Final approval by Town Meeting is expected this summer. This grant will pay for studies to extend the APCC and MassDOT studies.
- Recently, CCF learned of MassDOT's project to replace the culvert under Route 28 leading into Frost Fish Creek. The CCF Salt Marsh Task Force had anticipated that such a project would be necessary at some time, given the deterioration of that culvert. However, the timing of the MassDOT project, their subcontracting of a new hydrologic modeling of the area and their willingness to collaborate with CCF on this project were fortunate and timely.

Once MassDOT has finalized the design of the culvert under Route 28, the associated modeling results are available, and the results of the CPA-funded studies are known, it will be time to plan the rest of the proposed project in more detail.

- Decisions about redesign or removal of the Dam and the Weir will come first.
- Restoration of each body of water (Creek, Pool, Bog and Marsh) will have to be planned based on the details of the tidal-restriction removals. For instance, a decision to convert the Bog to salt marsh over time will have to consider the soil composition and the possible need to remove or add soil.
- The streams through the Crowell Rd culverts and the herring run connection to Lovers Lake will need to be investigated to see if the culverts will be adequate over time and if the stream beds need upgrading.
- Based on decisions about the various culverts, permitting will have to be arranged and construction work contracted and supervised.

Assessment of current levels of invasive plants in the bodies of water and census of varieties of fish and shellfish will be needed as a basis for ecological interventions and on-going monitoring. The project will conduct comprehensive functional assessment of the site's baseline conditions.

The scope of the project will incorporate the following tasks:

Task 1. Feasibility studies and modeling

The DOT studies and modeling are already underway. CCF will undertake further H&H and water quality studies funded by its CPA grant, probably in Fall 2021, to extend the range of the MassDOT modelling. This will further assess effects of different tidal restoration scenarios to best understand potential positive and negative impacts on private landowners, natural habitat areas and infrastructure. Combined with the 2019 APCC study, this should provide a basis for deciding among project options.

Task 2. Public outreach

Public engagement will be an integral part of this project through all tasks and phases of the work. Already, CCF has begun public education about the importance of salt marshes to the resilience of Chatham and to the preservation of the local ecology with public lectures, publications in local newspapers and in the *CCF Bulletin*, and a video on Frost Fish Creek. For instance, CCF will be participating in an event on "protecting natural resilience" by project partner C-CAN on May 22, 2021.

Outreach to Chatham residents generally and to abutters in particular will begin in earnest once the studies and modeling have been completed and options are clearer. Over 700 individuals and households in Chatham have become paid members of CCF during the past three years; they receive periodic *CCF Bulletins* (such as the one at: https://gerrystahl.net/SMTF/ccf_bulletin_spring2021.pdf, which highlights plans for Frost Fish Creek).

CCF will work closely with the Town of Chatham to inform the public about restoration plans, including through articles in the widely circulated *Cape Cod Chronicle* and through special public meetings to solicit community input into the plans. Abutters to Frost Fish Creek will be contacted individually to discuss proposed changes.

Task 3. Design

Based on the feasibility studies and extensive review with the project team and the public, design development could advance from concept designs to 25% and 75% level designs. This would primarily concern plans for the Dam, the Weir, the Bog, the Marsh, the connecting streams and extended trails. Implementation steps will have to be planned as part of the proposed project, based on the findings of the feasibility studies. Implementation design will include drafting of a project budget. The budget for the replacement of the Route 28 culvert will be the responsibility of MassDOT and its partners. The costs of the CCF follow-up hydrology and water-quality studies will be covered by the CPA grant. Other budget considerations will be incorporated in connection with the design of further project activities.

Task 4. Permitting and Final Design

Permitting and final design of the replacement of the Route 28 culvert will be primarily the responsibility of MassDOT and its partners. Permitting for any changes at the Dam and the Weir or elsewhere will be conducted as part of CCF's project. The 75% design (permit-ready) plans will be submitted for permitting, with modifications integrated into final design. Different aspects of the project (e.g., the Dam, the Weir, the Bog, the Marsh and the connecting streams) might be staggered to allow the ecology to adjust to different changes. This could involve multiple permitting processes.

Task 5. Construction

Construction bid packages will be developed and the project components bid out to contractors for construction. Construction activities will need to be carefully specified with the assistance of DER, and qualified contractors hired and supervised. Coordination will be completed with DOT to integrate work on the Route 28 culverts with work upstream within the project area. Construction is anticipated to include

replacement of the Route 28 culverts, removal of the small Dam immediately upstream of Route 28, as well as potential removal of the bog Weir and restoration of the Bog and/or Marsh to natural wetlands. Again, construction of different aspects of the project will likely be staggered. In particular, the Marsh may be targeted as a migration path for the salt marsh over the coming decades; preparations for that would not be an early priority of the project. Fundraising was begun with the CPA grant application. Further fundraising will involve state and federal agencies—potentially with DER, NRCS and/or CCCD involvement. CCF could also consider doing community fundraising among Chatham residents interested in donating to specific aspects of the project.

Task 6. Monitoring

Pre- and post-restoration monitoring will at minimum incorporate vegetation sampling and deployment of data loggers to measure changes in tidal hydrology and salinity as a result of restoration. This monitoring is envisioned to mirror the pre-restoration assessment completed by APCC in 2019, with additional monitoring to be completed to measure the success at achieving the goals of this project. Monitoring of many aspects of this restoration project (e.g., water quality, tidal flushing and fish presence) will be central to quality control and public accountability. CCF will continue to monitor water flow, water quality, salt-marsh extent, ecosystem health, fish presence and animal presence during and after the project period to help evaluate and document project success. CCF will also continue to provide public education and to develop further recreation services beyond the DER Priority Project period.

V. Has any funding been identified or spent for this project? Yes ☒

CCF paid for the 2018 APCC study of Frost Fish Creek (report downloadable at: https://gerrystahl.net/SMTF/FFC_Restoration_Report_2019.pdf).

CCF anticipates final approval of a $75,000 CPA grant to conduct H&H and water-quality studies to extend the APCC and MassDOT studies.

The CCF annual operating budget includes a line item for the Salt Marsh Task Force. The CCF Board can also allocate special project funding from time to time at its discretion. CCF could also solicit donations from members and the public to support specific aspects of the restoration project.

Anticipated benefits

Ecological Benefits: What are the expected environmental benefits of your project? For instance, what positive changes do you expect to see in the natural areas within and near your project site? This could include improving the flow of water, reconnecting sections of waterway so fish can access them, improving water quality, etc.

The most obvious benefit will be improving the flow of water by removing tidal restrictions.

The considerable increase in flushing should dramatically improve water quality, as bodies of water have recently been confined. The 2006 MEP report states that

"culverts restricting tidal flow under Route 28 have had a negative influence on water quality in Frost Fish Creek." The expected result of tidal restoration may also offer a significant benefit to adjacent landowners in terms of mitigation of flood waters that back-up at the current flow restrictions.

Reconnecting sections of waterway will allow fish to access the bodies of water, and to move back and forth among them and in and out of the ocean. A historic herring run loop could be re-established through the Creek, Marsh, Lovers Lake, Stillwater Pond and back to Ryder's Cove.

The project will include monitoring the fish, sea-life, birds and mammals, both before and after restoration. CCF already maintains an outdoor camera to capture photos of animals, such as river otter and deer. Over 150 species of birds have been identified at Frost Fish Creek. It is not known if frost fish (*Microgadus* tomcod) are still present in the Creek. A restored Creek could improve shellfish potential and even create nursery habitat for commercial fish species.

Over time, there is potential for extensive improvement and recovery of salt marsh and freshwater wetland with healthy marsh grasses and cedar swamp habitat. The restoration of tidal flow to the existing fringing marsh will improve the health of this resource area, providing improved habitat for fish, shellfish, birds and other wildlife. Reconnection of tidal flow and restoration of the bogs has the potential to allow for long-term salt-marsh migration with near-term benefits for improvements to these wetlands to a freshwater or brackish system. Restoration of wetlands in this manner will aid in sequestration of carbon and prevent the release of greenhouse gases from the underlying peat and soils.

With sea-level rise, water flow between the Creek and the Bog or Marsh could provide migration paths for the salt marsh around the Creek.

Other benefits to wetland functions and ecosystem services are hard to predict in detail at this point. They will likely include: nutrient/toxicant/sediment retention in the areas that become salt marsh; short and long-term flood storage capacity during extreme weather; surface water erosion reductions; habitat for anadromous fish runs; better habitat for birds; improved organic carbon export to the estuaries; increased nursery stock for the coastal fisheries economy; improved birding opportunities for tourists; improved local aesthetic value for residents and hikers; and educational opportunities for local students.

As part of the project, we will survey conditions as a baseline for monitoring benefits and other changes – e.g., the planned water-quality study.

Community Benefits:

Climate projections indicate considerable flood potential in the project area as well as certain surrounding residential or industrial areas. Optimal tidal flushing will allow flood waters to drain out to sea. In the other direction, incoming storm surges on Chatham's coastline can be mitigated by partial absorption into the Creek system, with its connections open to additional holding areas. It will be important to undertake flexible planning and on-going monitoring to minimize negative community consequences and to maximize resiliency.

Improved water quality and increased fish access will have direct benefits for community recreation, such as kayaking and fishing. It could also benefit local commercial fishing by supporting the life cycle of herring and their role in fish ecology.

Landowner information

The Chatham Conservation Foundation, Inc., a 501(C)3 non-profit organization, is the landowner of the project site. As a land trust, CCF acquired the following parcels between 1966 and 1999:

CCF #	Date Acquired	Grantor	Acres	Registry Book / Land Court Certificate	Registry Page/ Land Court Document	Plan Book/Page; Lot(s)	CR overlay or CT Deed from Compact	Address	Assemblage Name	FY 19 Town Map No.	FY 19 Town Pcl. No.
15	7/20/1966	Moye	5.40	1375	1050	no plan	27238/340	Frost Fish Hill	Frost Fish Creek	13I-8	1B
27	12/31/1967	Nanly Homes-Lynch	36.00	1387	615	93/53	27238/340	Stepping Stones Rd	Frost Fish Creek	13H-0	1
101	12/23/1983	Marden	20.70	3969	253	338/4	27238/340	Crowell Rd	Frost Fish Creek	12H	17-2
116	8/13/1987	Burlin	0.36					Stony Hill Rd	Frost Fish Creek	13G-62	2
118	6/16/1988	Nickerson		6307	22	no plan	27238/340	Stepping Stones Rd	Frost Fish Creek	13H-0	1
121	5/10/1988	Nickerson	0.62	6957	55	no plan	27238/340	Crowell Rd	Frost Fish Creek	12H-19	3
127	12/29/1990	Robertson	1.50	7399	170	no plan	27238/340	Crowell Rd	Frost Fish Creek	12I-13	19
137	7/3/1992	Yasuna	10.20	8111	1	200/33	27238/340	Crowell Rd	Frost Fish Creek	12I-2	17
153	12/22/1995	Walther	0.97	9986	146	520/14: Lot 8B	27238/340	Court St	Frost Fish Creek	12H-24HB	H8B
154	8/28/1996	Gregorian	5.01	10397	74	527/76: Lot 2	27238/340	Crowell Rd	Frost Fish Creek	11I-3	6
165	6/8/1999	Frost Fish Realty Trst	5.43	12325	284	541/86: Lot 15	27238/340	Frost Fish Hill	Frost Fish Creek	13I-8	1B

See *Map 1* near start of application for location of these parcels on the Assessor's map of Town parcels, with CCF # shown. These parcels appear on the DFG BioMap2[2] as Conservation Open Space and as Critical Natural Landscape.

Qualifications/experience of the applicant to help lead a restoration project.

The Chatham Conservation Foundation (CCF) is the oldest land trust on Cape Cod. It currently owns 191 parcels in the Town of Chatham, covering 628 acres. Since 1966, it has been stewarding this land. Most of this land is either forested, salt marsh or fresh-water pond. In addition, CCF manages the Conservation Restrictions on 45

[2] https://maps.massgis.state.ma.us/dfg/biomap2.htm

parcels of Town and privately owned land totaling 214 acres. CCF has a staff Land Steward and several experienced volunteers and Trustees who maintain trails, monitor vegetation and maintain the land. CCF manages contracts with professionals and manages grants for special projects.
Several Trustees have served many years on the Chatham Conservation Commission and/or bring relevant training and experience.
CCF contracts with APCC to assist in restoration efforts, including planning, conducting studies and supervising subcontracts.
The Chair of the CCF Salt Marsh Task Force, Dr. Stahl, has experience in project management. As a professor of information science, he directed an internationally renowned research project with over $8 million in NSF grants over a 10-year period. Earlier, he was a neighborhood planner for community revitalization and energy conservation in Philadelphia for 7 years, with about $4 million in foundation, city and federal grants he raised. As CCF Treasurer, he developed online systems for CCF's management of land stewardship, finances (including grant management), donor tracking and record keeping.
CCF has a paid staff including Executive Director and Land Steward. It has a working Board of Trustees and a number of regular volunteers, as well as an assigned AmeriCorps Cape Cod Member.

Restoration partners

The proposed project will form a Working Group of project partners. The Working Group will meet at least quarterly online to review findings and decide on next steps. (At CCF's suggestion, MassDOT already convened a number of the partners to discuss the modelling and design of the culvert under Route 28.) Statements of support for the proposed project from many of the partners are attached. Restoration partners include:

- **Department of Transportation (MassDOT)** (David White, Timothy Dexter and Liana Dinunzio), which has contracted with Stantec (Jennifer Ducey) and The Woods Hole Group (Matt Schulz). Dexter, Supervisor of Wetland Resources & Wildlife Unit has been with MassDOT for 13 years and has worked on a variety of initiatives and programs involving stream and wetland restoration, and wildlife habitat. Dexter has been instrumental in several culvert restoration and replacement projects and is an author of MassDOT's *Stream Crossing Design Guide*, contributor to the fluvial geomorphology approach, and developed MassDOT's Rivers and Roads training program. White, Deputy Director of Environmental Services has been with MassDOT for 24 years and has been involved in a wide array of projects and program initiatives including Resiliency and Adaptation to address sea-level rise and extreme-weather events. White is presently working on the development of MassDOT's Culvert Assessment and Management Program, a statewide initiative to standardize the assessment of potentially vulnerable culverts and identify culverts that need maintenance or upgrade

for safety and resiliency. Dinunzio is with Environmental Services, Wetland Resources & Wildlife Unit of MassDOT.

- **Cape Cod Conservation District (CCCD)** (Richard DeVergilio). DeVergilio is looking to include costs of the Route 28 culvert replacement and the larger Frost Fish Creek tidal restoration in an upcoming CCWRRP funding request. The CCCD through the CCWRRP is particularly concerned about restoration of tidal restrictions and fish runs.
- **National Resources Conservation Service (NRCS)** (Stephen Spear). NRCS has been involved in restoration projects all over the Cape such as this one – providing planning, technical, and financial support for assessment, design, and construction.
- **Association for the Preservation of Cape Cod (APCC)** (April Wobst). APCC has worked with Cape Cod communities to identify more than 150 restoration projects aimed at restoring impaired salt marshes, fish runs and shellfish beds, as well as improving water quality through stormwater remediation. As APCC's Restoration Ecologist, Wobst provides technical, planning, permitting and management support to communities interested in completing restoration projects. APCC will work with the CCF and project team to support planning, design, implementation, outreach and monitoring for this project. APCC has experience and expertise in project management and public engagement for restoration projects of this scope and scale, including the current partnership working with the Falmouth Rod and Gun Club to restore the Upper Childs River stream channel and bogs.
- **Town of Chatham** (Robert Duncanson). Dr. Duncanson is Director, Natural Resources Department, Town of Chatham. The CCF, NRCS and the CCCD have been working closely with the Town during scoping and planning for this project. The Town has been supportive of the project and ranks it as a priority for restoration. The CCF anticipates approval of Chatham CPC funds to support further modeling and feasibility studies in 2021.
- **Pleasant Bay Alliance (PBA)** (Carole Ridley). Ridley is the Director of PBA, which conducts research and projects in the Pleasant Bay AECA in the following areas: watershed planning, coastal processes and structures, wetlands protection, water quality monitoring and waterways.
- **Chatham Climate Action Network (C-CAN)** (Jane Harris). Harris has degrees in biology and resource management and 20 years of experience as Conservation Administrator in 3 MA towns. She has served on the boards of CCF, PBA, C-CAN, FCW, APCC, Mass Assoc. of Conservation Commissions, AmeriCorps of Cape Cod, Chatham Land Bank.
- **Friends of Chatham Waterways (FCW)** (Jeff Mason). Mason is Director of FCW and is a Professional Wetland Scientist (PWS) and a Certified Environmental Restoration Practitioner (CERP) with expertise in

wetland/riverine/estuarine ecology; project management; regulatory support and permitting; mitigation/restoration site design, implementation and monitoring; and remote sensing/GIS analyses of aquatic ecosystems.

Community support

CCF is a well-established community-based organization with broad community support. CCF's Trustees are all Chatham residents. Over 700 Chatham residents and households have been dues-paying members of CCF during the past three years.

As Cape Cod's oldest land trust, CCF has preserved land in Chatham since the 1960s, through donations of land and purchases funded by Chatham residents. CCF now owns 191 parcels, preserving over 600 acres of land in a natural state. It also manages the Conservation Restrictions on 45 Town-owned parcels totaling over 200 additional acres. Many local volunteers assist in watching over these parcels and maintaining trails on these lands.

The Chatham Community Preservation Committee approved CCF's application for a CPA grant to conduct further detailed studied of the hydrology and water quality of Frost Fish Creek. This application was supported by the Chatham Select Board and is expected to be approved at Town Meeting this summer.

Anticipated role for DER

Coastal Wetland Restoration. Once tidal flow is restored through the redesigned Route 28 culvert, tidal flushing, restoration of water flow throughout the project area, increased water quality, salt marsh vegetation and fish population will need to be fostered. DER could provide guidance, technical assistance and funding to support this.

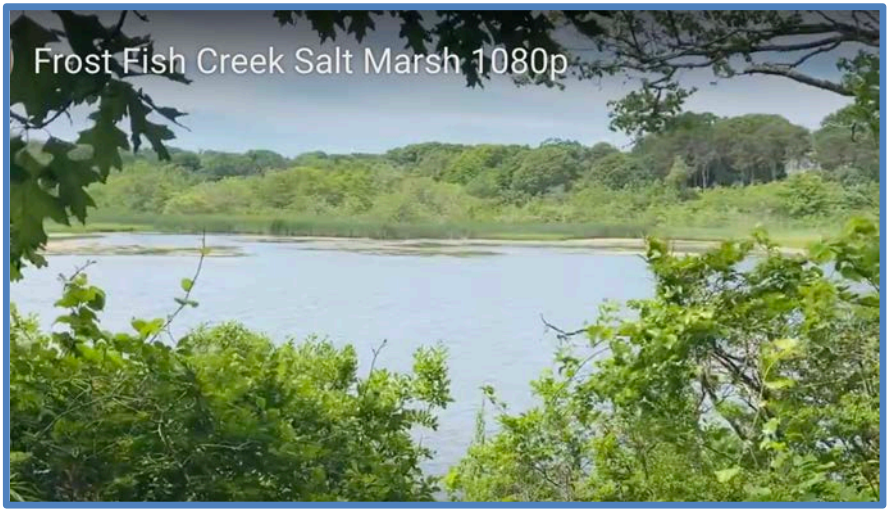
Dam Removal and River Restoration. It is likely that the restriction at the Dam and eventually the restriction at the Weir will need to be removed. DER could provide guidance in making this decision, planning the process, applying for permits, contracting for construction and raising funds to pay the associated expenses. In addition, the streams connecting the Creek to the Marsh and from there to Lovers Lake may need some restoration; DER could similarly support this.

Cranberry Bog Wetland Restoration. The restoration of the Bog will be a major undertaking. It was historically a cranberry bog and now collects watershed run-off. DER guidance and technical assistance in restoring this area would be valuable.

The proposed project covers a project area with diverse characteristics and needs. DER's experience would be invaluable in highlighting issues and helping to coordinate decisions, plans and actions. Each of the project stages listed under Section IV, Project Scope, will benefit from DER staff technical assistance, technical services by qualified DER contractors, and/or direct DER grant funding.

Videos of Frost Fish Creek & Cockle Cove

Video of Frost Fish Creek



https://www.youtube.com/watch?v=OkUzTE3c2VM&t=197s

Video of Bucks Creek / Cockle Cove study (See script below)

https://www.youtube.com/watch?v=fbw3qIw6L6g&t=8s

Researching Cockle Cove Video Script

Script written by Gerry Stahl, September 2021

Scene 1. Marsh vistas

Pan across large expanses of salt marsh grasses (about 1/2 min.).
Scroll titles over video:

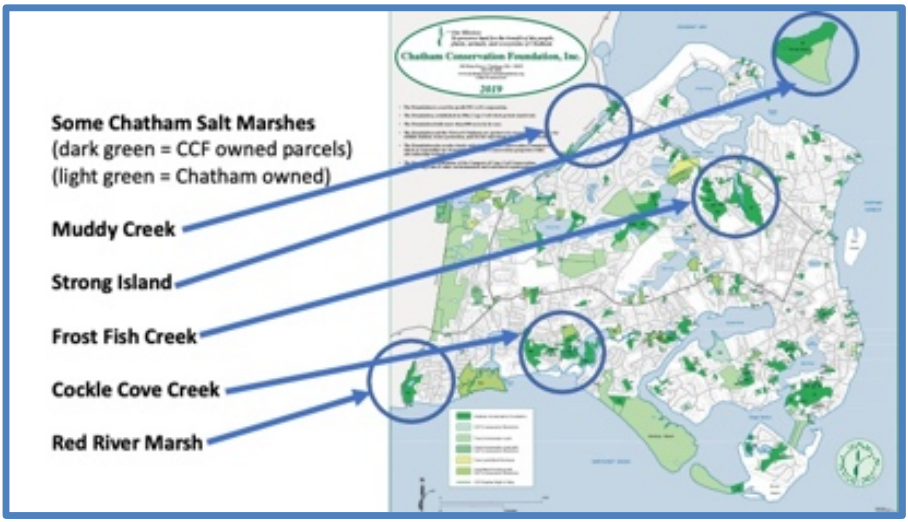
"*Researching the Cockle Cove Salt Marsh in Chatham, Mass*"
By the Chatham Conservation Foundation, Inc.

Scene 2. Marsh between creek and sea

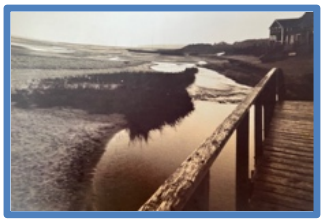
Continue video of expanses of salt marsh grasses.
After 15 seconds, begin narrative over video.
The Town of Chatham on Cape Cod juts into the Atlantic Ocean and Nantucket Sound, absorbing the tides into its many salt marshes.
These salt marshes are important to Chatham because they provide many environmental services, including:

- Protecting the coastal homes and businesses from storm impacts by dissipating wave action.
- Absorbing carbon dioxide and other greenhouse gases that fuel climate change.
- Improving water quality by filtering out pollutants and other harsh chemicals before they reach the ocean.
- Providing habitat for many species of fish, shellfish, and migratory birds.
- Responding to sea-level rise by building in elevation and migrating upland.

Chatham has many salt marshes. Here are some of them.



Chatham's marshes have been shaped by natural and human influences. In the past, humans created roads and the railroad which disrupted the tidal flow of creeks, and converted large areas of marsh to cranberry bogs. In addition, natural forces along the seashore constantly shifted sediments until the connection of marsh to sea at Cockle Cove beach was permanently closed off in the 1970s, as seen in photos contributed by neighbors of the bridge over the Cockle Cove inlet.



The federal Clean Water Act of 1972 effectively halted destruction of wetlands, including saltmarshes. Many acres of undevelopable land were donated or sold to CCF, Cape Cod's oldest land trust. CCF was started in the 1960s by neighbors to preserve beautiful marshes and woodlands. CCF ownership guarantees preservation in a natural state for perpetuity.

While CCF protected the land, it had no resources for maintaining the health of the marshes in the face of invasive non-native weeds. Recently, CCF has begun to restore the health of key properties and has established a Salt Marsh Task Force to begin to monitor and restore salt marshes in Chatham.

Scene 3. Marsh eco-services

The first step in actively preserving and restoring healthy marsh is to research the current condition of the marsh ecosystem involving:

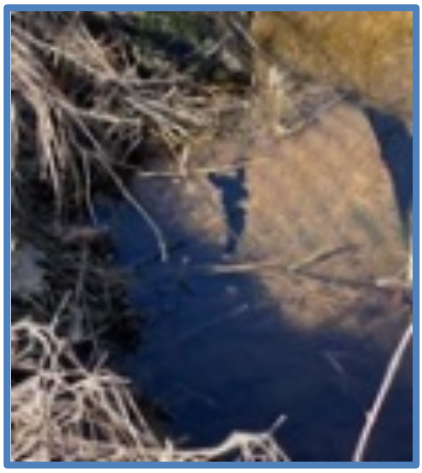
- Flowing water (mixing tidal salt water and fresh ground water),
- Vegetation (marsh grasses, native and invasive reeds, bushes)
- Animal life (birds, fish, shellfish, small mammals),
- Soil (sedimentation, carbon capture, water filtering).

These complex and interrelated factors determine the quality of the marsh and of the services it provides to the environment and to people. The Chatham Conservation Foundation hired APCC (the Association to Preserve Cape Cod) to undertake an initial study of the Cockle Cove / Bucks Creek marsh complex in summer 2021.

Cockle Cove is one of Chatham's largest salt marsh complexes. A large portion of the marsh, as well as its tributaries, managed by CCF.
Like a gigantic sponge, a salt marsh soaks up sea water at high tide and releases creek and groundwater into the ocean at low tide.

Four major creeks, along with general surface runoff, drain into the marsh while the whole Cockle Cove complex receives tidal influx through one channel from Nantucket Sound, between Ridgevale Beach and Hardings Beach.
The water flow through the marsh is complicated.

Tidal salt water takes a circuitous route to reach the middle of the complex, where two culverts control the further movement of water. An old, damaged culvert under Ridgevale Road permits little flow; a newer culvert under Cranberry Lane has restored more natural tidal flow.



Scene 4. Marsh research

The primary barrier to healthy marsh functioning is usually restrictions to tidal flushing by roads, agricultural landfill and man-made walls. That is why we are researching the functioning of the two culverts in the middle of Cockle Cove marsh.

APCC's initial study of the marsh includes analysis of tidal flows, vegetation and water quality. We asked Carl DePuy—an environmental teacher and the lead field researcher for the Cockle Cove study—about the importance of marshes.
Interviews of Carl – some over video of researchers in the field testing water.

Scene 5. Marsh preservation and restoration

The Chatham Conservation Foundation is concerned about the future of the local salt marshes.
Here you see a projection of the Cockle Cove area in less than 50 years with 3 feet of sea-level rise flooding beaches, roads, and homes unless the marshes can grow and migrate in response to the changes. We want to ensure that there are areas where the marsh can migrate as the sea level rises, so protecting adjacent land is critical.

In order to be effective stewards of the land, we need to track the marsh ecosystems over time, so we continually monitor the presence of native plants, fish, birds and animals.
We also want to optimize the growth of salt marsh grasses that sequester carbon. Preserving healthy marshes is the most effective way to lower the carbon footprint of Chatham.
Healthy salt marshes are key to Chatham's future economy, climate change resilience and natural beauty.

Closing credits

Scroll closing credits over video of expanses of salt marsh.
This video was filmed and produced by Matthew Hamilton in Summer 2021 for the Chatham Conservation Foundation.
Thanks to:

- Scott Hamilton, Narrator
- Gerry Stahl, Script Writer
- The Association to Preserve Cape Cod (APCC):
- April Wobst, Restoration Ecologist
- Jordan Mora, Restoration Ecologist
- Carl DePuy, Seasonal Restoration Technician, Interviewee
- Adrianne Lovuolo, Restoration Intern

Researchers from the Chatham Conservation Foundation, Salt Marsh Task Force:

- Gerry Stahl, Chair of the CCF Salt Marsh Task Force
- Julie Bacca, CCF Land Steward
- Tim Burt, CCF Board member
- Jeff Mason, President, Friends of Chatham Waterways

Early Study of Bucks Creek / Cockle Cove

Cockle Cove and Bucks Creek Salt Marsh Assessment

Project Purpose

The purpose of this project is to: 1) to complete an initial field assessment and report for the Cockle Cove and Bucks Creek salt marsh complex to document the condition and health of the wetlands resource areas, identify possible sources of impairment, and opportunities for improvement; and 2) to gather data to inform future restoration plans, feasibility studies and grant applications for the Cockle Cove/Bucks Creek complex. The proposed scope is divided into tasks that could be completed over the spring, summer and fall of 2021 according to APCC capacity and the ideal timing for monitoring during the field season. Task 6 includes more in- depth monitoring of the marsh vegetation which could be completed as part of this scope or removed to be completed at a later stage of site assessment and feasibility studies.

Proposed Scope

Task 1. Project kick off (April 2021)

APCC and the CCF salt marsh task force will initiate the project with a virtual meeting to review the project area, scope of work, timeline and existing knowledge and information about the site. This meeting will provide opportunity for the CCF to share concerns and knowledge about the site and for APCC to seek clarification on conditions, site access and scope of work. Following this meeting a joint site visit would be arranged to review the extent of the project area, key areas of concern and points of access to allow APCC to further refine field monitoring plans.
Deliverables:

- Revised project scope and timeline as needed (Word or PDF).
- Rough marked up of maps of draft monitoring locations and layout for review (PDF).

Estimated Cost: $500 (including staff time and travel charged at $0.56/mile)

Task 2. Desktop GIS analysis (May 2021)

To expand upon and update the existing GIS Map Assessment and Analysis completed by APCC for CCF in early 2020, APCC proposes to complete additional desktop and GIS assessment and analysis of the site. This assessment will include review of current and historical maps of the project area to better understand changes in development and land use around the site that has influenced the condition and health of the system.

APCC will review and provide updated information on overlap with key resource areas and ranking of the ecological value of this site according to criteria developed by APCC and the Cape Cod Conservation District as part of a regional restoration planning effort. Ranking of the site in this desktop assessment will include: connection to impaired waterbodies (MA 2016 303d List of Impaired Waters, shellfish growing area designations), connection to sensitive resources (Biomap2, NHESP Priority Habitats, eelgrass, fish and shellfish habitat), human use benefits to the site (swimming, boating, fishing), connectivity to protected areas (open space), resilience to the impacts of climate change and natural process (erosion, storm surge, sea level rise), and potential for tidal restoration (low-lying properties and extent of restriction). Part of this ranking and review will focus on an updated look at the sites resilience to sea level rise and the potential for salt marsh migration using the Sea Level Affecting Marshes Model (SLAMM) developed by the Massachusetts Office of Coastal Zone Management. This assessment will provide a comparison and improvement upon the Cape Cod Commission Sea Level Rise viewer tool GIS assessment previously completed for this and other sites.

APCC will also complete a desktop assessment of locations of potential or probable impairment of the site including, but not limited to: historic or current cranberry farming impacts, stormwater impacts from roads and private property, and tidal restrictions. APCC will review this with local and state agencies (DER, NRCS) to further refine our understanding of the current and historic impacts on the site. This information will inform and further refine plans for field assessment.

Deliverables:

- Site ranking describing criteria and scoring for the site (Excel).
- Maps and summary of rankings for this site along with comparison to regional ranking for other sites across the Cape (Word).

Estimated Cost: $1,000 (staff time only)

Task 3: Field assessment of sources of probable resource impairments (May to June for field assessment, June-September for water quality sampling)

The purpose of this task is to confirm on the ground the source and location of probable sources of impairment (invasive species dominance, poor water quality, impaired salt marsh) to the wetland resource. This will include a stormwater assessment identifying potential sources of runoff from roadways or private property including opportunities for possible installation of improved stormwater management. Assessment of culvert, road and stream crossings including documentation of the condition of the creek and structures crossing the creek, and where feasible measurement of the width and height of the restriction relative to the creek width. Assessment of impact of cranberry farming or other human activities upon the system. Spot sampling of water quality could be completed at these locations using a YSI probe to measure (pH, dissolved oxygen and temperature) and/or samples collected for lab analysis of cyanobacteria, nutrients, and/or bacteria levels. APCC proposes at minimum, one sample will be taken at each location with additional bi-weekly, monthly or storm event (1 inch or greater rainfall) sampling completed where relevant and feasible.

Deliverables:

- A geo-referenced map depicting locations of probable sources of impairment (JPEG/PDF).
- Photographs and written description of locations of concern with potential actions for intervention (JPEG and Word).
- Water quality monitoring data and written summary of results (Excel and Word).

Estimated Cost: $5,400 (including staff time and travel charged at $0.56/mile) includes $1600 for site assessment and $3,800 for sampling

Task 4: Time-series monitoring of tidal hydrology and physical parameters (July 2021)

The purpose of this Task is to collect data on existing conditions to determine if any remaining restrictions are negatively impacting the tidal hydrology and salinity in the salt marsh complex. Time-series monitoring of water level, temperature, and conductivity in the stream will be conducted using Solinst Levelogger LTC data loggers.

A minimum of three dataloggers will be placed around the Ridgevale Road and Cranberry Lane culvert intersection of Cockle Cove Creek and Bucks Creek (two upstream and one downstream of these crossings) and 1-2 additional loggers if available could be placed further upstream or at other locations of concern. A reference logger (Solinst Barologger) to measure barometric pressure will also be deployed on site, which will be used to correct water level logger data for changes in atmospheric pressure. Loggers will be surveyed to get accurate elevation of the loggers to be able to provide water surface elevation data for each location.

Dataloggers will be set to record at 10-minute intervals and will be in place for a full lunar cycle (minimum of 28 days). The time-series water level data collected along

with conductivity recordings will enable us to determine extent of restriction, impact on flow and salinity, and potential for restoration. This task includes equipment testing of dataloggers, completion of field survey to determine absolute logger elevation, mapping of logger deployment locations, setup on site and download of data for further analysis and reporting.

Deliverables

- Electronic copies of raw data for all parameters, field notes and survey data (Work, PDF and Excel)
- Final plots depicting tidal hydrology, including the restriction at the bridge (Excel)
- Final plots of temperature and salinity data (Excel)
- A geo-referenced map depicting locations of logger deployment (JPEG or PDF) Estimated Cost: $3,000 (including staff time and travel charged at $0.56/mile)

Task 5. Wetland assessment and vegetation mapping (July-August 2021)

Mapping of native and invasive vegetation along with soil assessment of the marsh is another valuable first step in assessment and data collection to determine extent of invasive, salt marsh and freshwater vegetation that could be improved or restored. For initial mapping APCC proposes to map the boundaries of Phragmites and any major unvegetated areas including sandy overwash, mudflats, pannes or ponding, and develop a final map with this data overlaid with existing GIS layers mapping resource areas.

An initial soil assessment will be completed in tandem with vegetation mapping to document presence of sand and depth to peat layer in any formerly farmed salt marsh areas to better understand potential impact of historic land use on the system. As feasible and if warranted, some additional assessment could be done in the current cranberry bogs if allowed by the owner. This work would entail digging holes in a few locations across the wetland surface to document the soil composition, measure depth of sand or depth to peat and map the locations of sampling. If feasible, a more in-depth soil survey will also be completed in coordination with NRCS staff.

Deliverables

- Electronic copy of field notes (Word or PDF).
- Soil composition description and depth of sand/depth to peat layer (Word and Excel).
- A geo-reference map depicting areas of Phragmites and unvegetated marsh along with locations of soil sampling (JPEG or PDF).

Estimated Cost: $2,000 (including staff time and travel charged at $0.56/mile)

Task 6. Vegetation monitoring (August 2021)

The purpose of this monitoring would be to get a more detailed understanding of the health and condition of the salt marsh within this complex system. This task would include establishment of monitoring transects and quadrats and collection of data on species present and percent cover within these one-meter square quadrats. The location and elevation of these quadrats would be mapped in tandem with monitoring. Analysis of this data can help inform our understanding of the health of the system including extent of low marsh relative to high marsh and invasive species in the upland edge, extent of unvegetated marsh, and current and future impact of sea level rise on this marsh. As proposed this task includes establishment and monitoring of 6 or 7 transects (three reference transects and 3-4 study transects further upstream).
Deliverables:

- Raw and analyzed data (Excel).
- A geo-reference map depicting location of transects and quadrats along with elevation of each quadrat (JPEG or PDF).

Estimated Cost: $2,800 (including staff time and travel charged at $0.56/mile)

Task 7. Final report (September - November 2021)

The information and data collected in Tasks 1-5 will be provided in raw form according to the deliverables above but APCC proposes to combine the results of the approved tasks in a final comprehensive report that will include figures, captions and more descriptive language on methods, results and the interpretation of results. This report and interpreted results could provide the basis for future grant applications and be easily shared with other potential project partners (DER, DMF, DOT, Town, etc.)
Deliverables

- Draft and Final summary report (PDF).

Estimated Cost: $2,500 (staff time only)

Total Cost not to Exceed for Tasks 1-7: $17,200

Study of Four Marshes

CPA Proposal from the Energy and Climate Action Committee of the Town of Chatham

Project Title:
"A Strategy to Acquire, Create, and Preserve Open Space for Salt Marshes"
Application Date:
October 25, 2022
Project Description:
The Energy and Climate Action Committee (ECAC) of the Town of Chatham requests $120,000 for the first year of its effort to acquire open-space property to facilitate salt-marsh migration in response to predicted sea-level rise.

Salt marshes are a major natural resource of Chatham [1]. They provide much of the scenic charm of the town. They protect surrounding properties from the worst threats of storm surge and provide a wealth of ecological services to the flora, fauna, sea life, and water quality [2]. Significant efforts are already underway to preserve some of Chatham's major salt marshes from current conditions, such as Muddy Creek, Jackknife Bay, Frost Fish Creek and Cockle Cove [3, 4]. (See Appendix G for references cited in [].)

However, many marshes will be at risk from increased flooding in the coming decades and it is prudent to foresee that and prepare for it. The current proposed project takes initial steps in that direction.

Salt marshes are threatened by escalating climate change, particularly sea-level rise. Recent studies show that the waters around Chatham are warming and rising faster than in other parts of the world and faster than previously predicted [5]. A new predictive model of local sea-level rise has recently been developed [6]. This Massachusetts Coastal Flood Risk Model projects that sea levels will rise 2.57 feet by 2050, and close to 8 feet by the start of the next century along the Cape [7].

Salt marshes have two natural defenses to sea-level rise, assuming the marsh is healthy (filled with native salt-marsh grasses) and unrestricted. One is to gradually rise in place by building up the soil level. The other is to migrate to slightly higher land nearby via an available migration path. The alternative is for the marsh to drown, merge into the open sea, and lose much of its ecological value [8].

This project will systematically overview Chatham's system of salt marshes to project likely futures. In particular, the project will use existing GIS data and sea-level-rise models to project sea-level rise at a fine grain around each marsh. It will then try to predict if the marsh can withstand that sea-level rise either by the marsh raising its floor or by migration to a nearby area through a migration path. In cases of potential migration, the project will look for possible barriers and issues, such as tidal restrictions or private ownership of land in the migration area and connecting

pathways. Where there are such barriers and restrictions, the project will target possible future acquisition or conservation restrictions for the parcels or partial parcels in question. The currently proposed project may investigate the potential acquisition of land, but actual acquisition would be carried out in subsequent projects. This project is an initial step in a larger effort to preserve Chatham's salt marshes as part of the Energy and Climate Action Committee's charge to enhance the Town's long-range resiliency in the face of climate change. The work on salt marshes is being conducted in collaboration with the Town's Natural Resources and Community Development Departments and several other entities, some of whom are included in the list of collaborators in Appendix F.

Specific Objectives:

1. To map the area around the salt marshes in Chatham using the Massachusetts Coast Flood Risk Model (MC-FRM) [6] to determine projected probability and depth of flooding – both currently and in the future (i.e., 2030, 2050 and 2070). Maps will include Town parcel ownership information and topological features.
2. To assess and rank priority of the marshes in terms of ecological health, sea-level-rise threat and migration potential by reviewing previous marsh surveys [e.g., 9, 10, 11, 12] and collecting data for a rapid assessment protocol [such as 13, 14].
3. To identify potential upland migration areas and associated migration paths through careful analysis of the maps and other data.
4. To target parcels or partial parcels for open-space acquisition to facilitate future salt-marsh migration.
5. To prepare for the acquisition of targeted parcels for open-space donation, acquisition or conservation restriction (CR). This includes discussion with parcel owners, surveying, possible subdivision of parcels and arrangements for future acquisition.
6. To plan for activities in future years with subsequent funding: including further research of the salt marshes, preparation of management plans for the open space and actual acquisition of parcels to be purchased.

Organization Name:

Energy and Climate Action Committee (ECAC) of the Town of Chatham

Address:

Chatham, MA 02633

Website:

https://www.chatham-ma.gov/348/Energy-and-Climate-Action-Committee, https://www.chatham-ma.gov/QuickLinks.aspx?CID=75

Federal Tax ID Number (if non-profit):

Names of Governing Board, Trustees, Directors or Members:

Robert Wirtshafter (Chair), Gerry Stahl, Katherine McClellan, John Scott, Brian Miner, Rachel Derrane, Sarah Griscom, Mike Schell (Select Board Liaison), Terry Whalen (Staff Liaison).

Relevant Town Committee (if applicable):

Energy and Climate Action Committee of the Town of Chatham

PROJECT INFORMATION

Which of the following goals of the CPA does this project address?

X The acquisition, creation and preservation of Open Space.

How does this project impact Chatham's citizens and address a current need?

This project will help the Town preserve healthy salt marshes in Chatham, including providing for their migration in response to sea-level rise. This will help to protect properties in Chatham from storm surge, flooding and increasingly severe storms. It will also provide increased sequestration of green-house gases (e.g., CO_2 and methane) and multiple ecological services for local flora, fauna and sea life.

What is the estimated or target number of people this project will benefit/affect?

This project will benefit the Town of Chatham as a whole, particularly the many people who live near salt marshes. It will also help preserve the scenic beauty of the town for residents and visitors.

How will you measure the success of this project?

1. The project will be successful if it produces detailed maps of Chatham, displaying MC-FRM projections for future decades.
2. The project will be successful if it identifies and maps the major salt marshes of Chatham.
3. The project will be successful to the extent that it determines which salt marshes have reasonable potential for upland migration in response to sea-level rise and identifies associated migration paths.
4. The project will be successful to the extent that it identifies target parcels or subdivided parcels for potential future acquisition, donation or CR.
5. The project will be successful to the extent that it contacts owners of targeted parcels and prepares for acquisition of some of those parcels.
6. The project will be successful to the extent that it explores and applies for possible funding to continue work to preserve Chatham's salt marshes in future years. In addition to funds to purchase targeted parcels, this would include support for further research of the salt marshes and preparation of management plans for the open space.

Projected Action Plan and Timeline, including anticipated completion date. List steps needed to complete the project:

1. Summer 2023: Using existing Town GIS layers and maps created by the MC-FRM Model, the project will create projected flooding layers for Chatham for 2030 and 2050 to determine probability and depth of flooding projected. This will identify:

Parcels near salt marshes in Chatham likely to be affected by sea-level rise and storm surge in the coming decades – e.g., 2030, 2050 and 2070. (*See Appendix A. Description of MC-FRM and Appendix B. Figure 1.*)

Sea-level rise effect on existing salt marshes.

Potential up-land migration areas for affected salt marshes and paths to those areas.

Parcels or partial parcels to target for open-space acquisition to facilitate future salt-marsh migration and removal of tidal restrictions.

2. Summer 2023: Assess and rank priority marshes in terms of threats to ecological health, risks of sea-level rise, and potentials for migration. Assessment of all the major

salt marshes in Chatham using a multi-dimensional comparison protocol based on initial study, both on-site and using maps. This assessment will rank the priority marshes in terms of sea-level threat and migration potential.
3. Fall 2023: Identify potential upland migration areas and associated migration paths. (*See Appendix C. Figure 2.*)
4. Fall 2023: Target parcels or partial parcels for open-space acquisition to facilitate future salt-marsh migration and removal of tidal restrictions. (*See Appendix D. Figure 3.*)
5. Winter 2023: Prepare for the acquisition of targeted parcels or subdivisions of parcels for open-space donation, acquisition of conservation restriction (CR). (*See Appendix E. Figure 4.*)
6. Winter 2023: Plan for activities in future years with subsequent funding. This includes future CPA grants for specific properties, Chatham Land Bank purchases of specific properties, donations to or purchases of properties by the Chatham Conservation Foundation, and other state and federal grant opportunities.

BUDGET

1. $20,000 – To create overlays of Chatham using the Massachusetts Coast Flood Risk Model to determine probability and depth of flooding projected for present, 2030, 2050 and 2070. To overlay Town parcel map with these layers as well as topological maps and aerial photography of marshes. To identify and name the salt marshes of Chatham, defining current boundaries as a baseline for systematic oversight.
2a. $20,000 – To conduct desktop assessment of approximately 14 major salt marshes in Chatham, including topological maps, past studies, reported tidal restrictions and former evaluations.
2b. $40,000 – To conduct field research of tidal flow, healthy salt marsh grasses, invasive species and other factors (as relevant to each marsh) to determine resilience of the marshes to sea level rise and other threats or risks.
2c. $10,000 – To assess and rank prioritize the marshes in terms of ecological health, sea-level-rise threat and migration potential, using an appropriate comparison protocol.
3. $20,000 – To identify and map potential upland migration areas and associated migration paths projected for 2030, 2050 and 2070.
4. In-kind – Committee and Town staff planning to target parcels or partial parcels for open-space acquisition to facilitate future salt-marsh migration.
5. $10,000 – To prepare for the acquisition of targeted parcels for open-space donation, and/or acquisition of conservation restrictions (CR). This includes negotiation with parcel owners, surveying, possible subdivision of parcels and arrangements for acquisition.
6. In-kind – Committee planning for activities in future years with subsequent funding. This includes identifying and applying for such funding.

Total amount of the project:

$120,000

Other revenue sources including private/public/in-kind:

This project will be conducted by the Energy and Climate Action Committee of the Town of Chatham and Chatham Town staff. Committee members will provide in-kind services helping to conduct all phases of the project and reviewing findings. In addition, Town staff will supervise the project and advise and collaborate on specific activities. Other revenue sources will be investigated for purchase costs of properties and for extending project activities in subsequent years.

Financial sustainability to secure project after the grant?

Objective #6 is focused on project sustainability to continue salt-marsh preservation efforts after the 2023 grant. Some of the continuing activity will be assumed by Town staff, as will be specified in salt-marsh Management Plans. Purchasing of targeted parcels can be undertaken in the future by organizations such as by CPA grants for specific properties, by Chatham Land Bank purchases of specific properties, and by donations to or purchases of properties by the Chatham Conservation Foundation. In addition, several state and federal grant opportunities are now available to support activities like salt-marsh preservation for purposes of green-house-gas sequestration, flood mitigation and town resiliency.

Annual costs/expenditures once the project is operational, if any:

There are not any necessary costs after the grant period. However, it is likely that a successful project will lead to subsequent projects that extend the work of this project.

Potential revenues from project on an annual basis, if any:

There are no projected revenues from the project, although it may lower costs to residents from storms and sea-level rise.

What entity will collect and control future revenue?

NA. All project finances will be controlled by Town staff and procedures.

What is the basis for your budget? What are the sources of information you used?

Most of the project tasks will be conducted by consultants like the Woods Hole Group for mapping or the Association for the Preservation of Cape Cod for salt-marsh evaluation. Experience contracting for services from such consultants at Frost Fish Creek and Cockle Cove/Bucks Creek suggests that the requested budget will suffice for substantial achievement of the project tasks. Experience with parcel surveying, subdividing and CRs suggests that a number of parcels can be prepared for acquisition with the proposed budget.

Are there any legal ramifications/impediments to this project?

Much of the land around salt marshes in Chatham is currently owned by the Chatham Conservation Foundation; they have agreed to collaborate with the Energy and Climate Action Committee in studying and preserving salt marshes in Chatham.

Is the project compatible with the Town's Comprehensive Plan?

The Energy and Climate Action Committee is working closely with the Town's staff, Select Board and other relevant Town committees to ensure that the project is compatible with the Town's Comprehensive Plan, its goals and its procedures.

Electronic Signature:
Gerry Stahl

Email address:
Gerry@GerryStahl.net
Attachments:

- Appendix A. Description of Massachusetts Coast Flood Risk Model
- Appendix B. Figure 1
- Appendix C. Figure 2
- Appendix D. Figure 3
- Appendix E. Figure 4
- Appendix F. Collaborators on ECAC's salt-marsh effort
- Appendix G. References
- Appendix H. Full Budget

Appendices.

Appendix A. Description of Massachusetts Coast Flood Risk Model (MC-FRM) dated 2021

The Massachusetts Coast Flood Risk Model (MC-FRM) is currently considered the most accurate representation of flooding risk because it is (1) a dynamic model that includes the critical processes associated with storm-induced flooding (winds, waves, wave setup, storm surge, wave run-up and overtopping, etc.), (2) calibrated to historical storm events that impacted Massachusetts with observed high-water data and measurements, (3) high enough resolution to capture flood pathways in complex urban topographies, (4) a model that includes both hurricanes and nor'easters under changing climate conditions, and (5) able to capture the net effect of varying storm types, magnitudes, and frequencies.

Most competing approaches model the water levels to the shoreline while using bathtub approaches overland that ignore important processes like wave runup and overtopping, so are not an accurate prediction of where flooding ls likely to occur. Accurate storm-surge modeling requires accurate representation of the physical processes. MC- FRM also (1) includes updated sea-level-rise projections consistent with the state standard; (2) expands the storm sets used to include more historical and recent storms as well as hundreds of additional future storms; (3) includes dynamic wave runup and overtopping of coastal structures like seawalls; and (4) adds regular nuisance flooding by projecting future tidal benchmarks.

MC-FRM determines future projected chronic and storm-based flooding, including sea-level rise (SLR) associated with the "high" projections as recommended by The Massachusetts Office of Coastal Zone Management (CZM), MassDOT, and the University of Massachusetts. It was developed specifically for the Commonwealth of

Massachusetts by Deconto and Kopp. This "high" scenario of SLR assumes that global greenhouse-gas emissions (GHG) continue in a similar fashion as today.

Appendix B. Figure 1

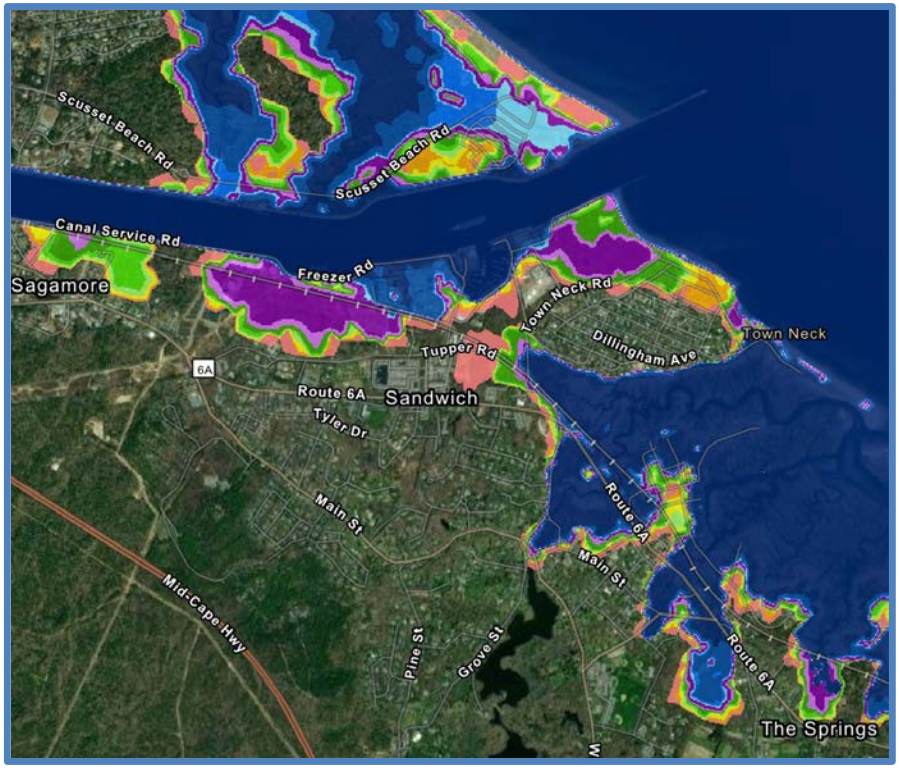


Figure 1. MC-FRM projection of Sandwich in 2070, showing color-coded detailed probability and depth of flooding.

Appendix C. Figure 2

Figure 2. Sample map with projected sea-level rise on potential migration paths. Note that several parcels have undeveloped areas along the creeks connecting Frost Fish Creek salt marsh with potential migration area in conservation land across Crowell Road (with two existing culverts). (See Figure 4 for some detail.)

Appendix D. Figure 3

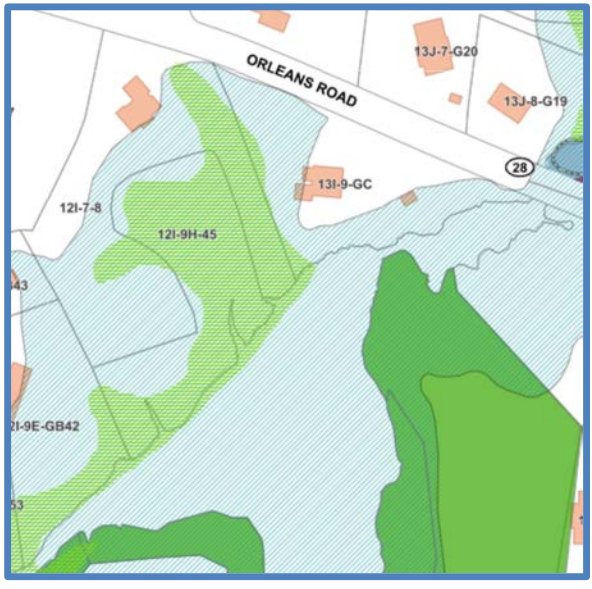


Figure 3. Sample parcel for partial acquisition on Frost Fish Creek tidal restriction. Rental property 131-9-GC includes wetlands area encompassing part of the dam and weir that forms a tidal restriction for the salt marsh.

Appendix E. Figure 4

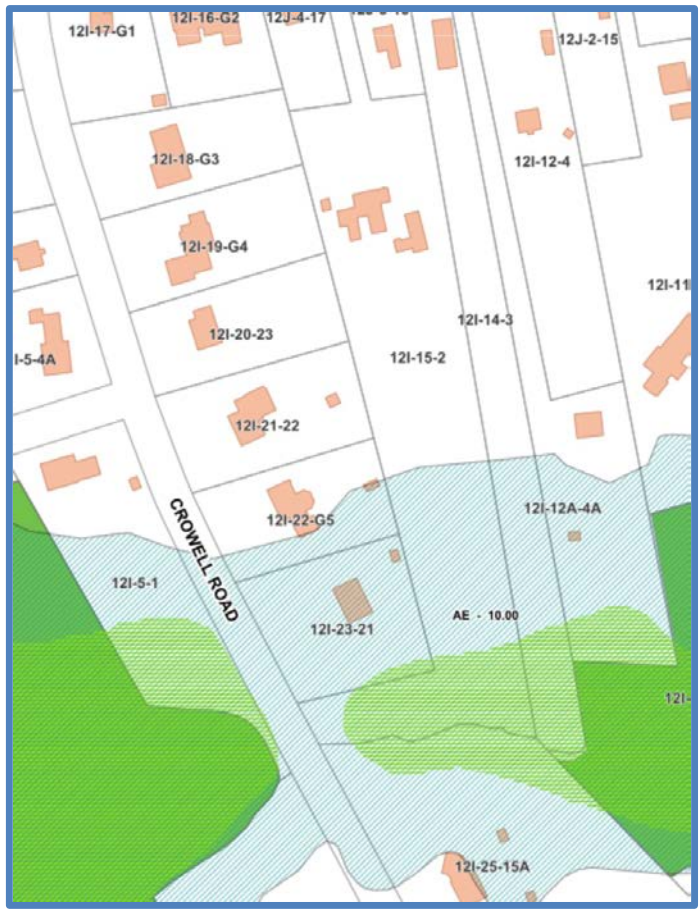


Figure 4. Sample parcels for partial acquisition on Frost Fish Creek migration path. Note undeveloped areas along creek on southern ends (light green) of parcels 121-12A-4A, 121-14-3, 121-15-2 and 121-5-1.

Appendix F. Collaborators on ECAC's salt-marsh effort

- Town of Chatham Natural Resources Department (Dr. Robert Duncanson, Ted Keon)
- Mass Division of Ecological Restoration (MassDER) (Georgeann Keer)

- Department of Transportation (MassDOT) (David White, Timothy Dexter, Liana Dinunzio)
- Cape Cod Conservation District (CCCD) (Richard DeVergilio)
- National Resources Conservation Service (NRCS) (Stephen Spear)
- Association for the Preservation of Cape Cod (APCC) (Andrew Gottlieb, April Wobst, Kristen Andres)
- Chatham Conservation Foundation (Bob Lear, Jane Harris)
- Pleasant Bay Alliance (PBA) (Carole Ridley)
- Chatham Climate Action Network (C-CAN) (Janet Williams)
- Friends of Chatham Waterways (FCW) (Jeff Mason)

References

[1] Stahl, G. (2021) *The Wonder of Chatham's Salt Marshes*. Bulletin of the Chatham Conservation Foundation, Fall 2021.

[2] Chatham Conservation Foundation (2021) *Researching Cockle Cove Salt Marsh*, 14 min video. Web: https://youtu.be/fbw3qIw6L6g .

[3] Chatham Conservation Foundation (2021) *Frost Fish Creek Restoration Priority Project*. Approved grant proposal to the Division of Ecological Restoration (Mass DER).

[4] Chatham Conservation Foundation (2020) *Frost Fish Creek Salt Marsh Preservation*. Approved CPA grant proposal.

[5] Gutiérrez, J.M., R.G. Jones, G.T. Narisma, L.M. Alves, M. Amjad, I.V. Gorodetskaya, M. Grose, N.A.B. Klutse, S. Krakovska, J. Li, D. Martínez-Castro, L.O. Mearns, S.H. Mernild, T. Ngo-Duc, B. van den Hurk, and J.-H. Yoon (2021) *Atlas*. In *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1927–2058, doi:10.1017/9781009157896.021.Web: http://interactive-atlas.ipcc.ch.

[6] Woods Hole Group (2021) *Massachusetts Coast Flood Risk Model (MC-FRM)*.

[7] McCarron, H. (2022) *How a Cape Cod restaurant is preparing to face rising seas alongside Woods Hole scientists*. Cape Cod Times. Oct. 22, 2022.

[8] Kuffner, A. (2022) *The Quonnie salt marsh was drowning. How a desperate plan is saving it and other marshes*. The Providence Journal. Aug. 26, 2022.

[9] Cape Cod Commission (2001) *Cape Cod Atlas of Tidally Restricted Salt Marshes*. Web: https://www.capecodcommission.org/resource-library/file?url=%2Fdept%2Fcommission%2Fteam%2FWebsite_Resources%2Fcoastalresources%2FTidalAtlas.pdf.

[10] Horsley, B., Stahl, G. (2020) *CCF Salt Marsh Planning Areas.*

[11] Association to Preserve Cape (2019) *Frost Fish Creek Restoration Assessment Report.*

[12] Association to Preserve Cape (2021) *Cockle Cove and Bucks Creek Salt Marsh System Site Assessment Report.*

[13] Kutcher, T. Raposa, K., Roman, C. (2022) *A rapid method to assess salt marsh conditions and guide management decisions.* Ecological Indicators 138 (2022) 108841. Web: https://doi.org/10.1016/j.ecolind.2022.108841.

[14] Galvin, W. (2022) *Analyzing Salt Marsh Health from Above; Drone Used to Monitor Red River Area.* Cape Cod Chronicle. October 5, 2022. Web: https://capecodchronicle.com/en/5740/harwich/9382/Analyzing-Salt-Marsh.

Appendix H. Project budget

1. $20,000 – To create overlays of Chatham using the Massachusetts Coast Flood Risk Model to determine probability and depth of flooding projected for present, 2030, 2050 and 2070. To overlay Town parcel map with these layers as well as topological maps and aerial photography of marshes. To identify and name the salt marshes of Chatham, defining current boundaries as a baseline for systematic oversight.
2a. $20,000 – To conduct desktop assessment of approximately 14 major salt marshes in Chatham, including topological maps, past studies, reported tidal restrictions and former evaluations.
2b. $40,000 – To conduct field research of tidal flow, healthy salt marsh grasses, invasive species and other factors (as relevant to each marsh) to determine resilience of the marshes to sea level rise and other threats or risks.
2c. $10,000 – To assess and rank prioritize the marshes in terms of ecological health, sea-level-rise threat and migration potential, using an appropriate comparison protocol.
3. $20,000 – To identify and map potential upland migration areas and associated migration paths projected for 2030, 2050 and 2070.
4. In-kind – Committee and Town staff planning to target parcels or partial parcels for open-space acquisition to facilitate future salt-marsh migration.
5. $10,000 – To prepare for the acquisition of targeted parcels for open-space donation, and/or acquisition of conservation restrictions (CR). This includes negotiation with parcel owners, surveying, possible subdivision of parcels and arrangements for acquisition.
6. In-kind – Committee planning for activities in future years with subsequent funding. This includes identifying and applying for such funding.
Total amount of the project:
$120,000

Study of Nine Marshes

Application for Funding Under the Community Preservation Act

Town of Chatham – Electronic Application for Funding Under the Community Preservation Act

Project Title: Field Studies to Preserve Open Space for Salt Marshes
Application Date: 10/24/2024

Contact Person's First Name: Gerry Last Name: Stahl
Phone Number: (215) 260-7467
Email Address: gerry@gerrystahl.net

Amount Requested from Chatham CPA: $140,000
Total Cost of Project: $140,000
Other Revenue Sources Including Private/Public/In-Kind: N/A

Name of Organization Applying to Chatham CPA:
Co-Applicants:
Energy and Climate Action Committee (ECAC) of the Town of Chatham
and the Department of Natural Resources of the Town of Chatham
Address: Chatham, MA
Website: https://www.chatham-ma.gov/348/Energy-and-Climate-Action-Committee, https://www.chathamma.gov/QuickLinks.aspx?CID=75
Federal Tax ID Number (if non-profit)

Names of Governing Board, Trustees and Directors:
Robert Wirtshafter (Chair), Adrianne Lovuolo (Vice Chair), Gerry Stahl, DeeDee Holt, Sarah Griscom, Katherine McClellan, Brian Miner, Rachel Derrane, Martin Flusberg.
Greg Berman (Director of Natural Resources).

Which of the following goals of the CPA does this project address?

The acquisition, creation and preservation of Open Space.

Project description including specific objectives:

Project background

The Energy and Climate Action Committee (ECAC) of the Town of Chatham requests $140,000 for the next year of its long-term effort to plan for the preservation, creation and acquisition of open-space property to facilitate salt-marsh migration and preservation in response to predicted sea-level rise and climate change.

Salt marshes are a major natural resource of Chatham. They provide much of the scenic charm of the town. They protect surrounding properties from the worst threats of storm surge and provide a wealth of ecological services to the flora, fauna, sea life and water quality.

Important field studies are currently being conducted by ECAC at Forest Beach, Cockle Cove, Bucks Creek and Oyster River marshes with a previous grant from CPC. Significant efforts are also already underway to preserve some of Chatham's other major salt marshes, such as Muddy Creek, Jackknife Cove and Frost Fish Creek. Muddy Creek and Red River marshes are shared with the Town of Harwich. This project will coordinate with research already undertaken, avoid duplication of effort, and consolidate data already collected to support a systematic approach to preserving Chatham's marshes.

Chatham's marshes will be at risk from increased flooding in the coming decades, and it is prudent to foresee that and prepare for it systematically. Interventions will take decades to target, plan, approve, permit, construct and adapt. Detailed data is needed for the urgently required long-term planning. The current proposed project takes necessary next steps in that direction through coordinated field studies in the following marshes (see map in Appendix): Champlain Creek, Cotchpinicut, Frost Fish Creek, Minister's Point, Morris Island, Muddy Creek, Nickerson Neck, Red River, Tom's Neck.

Salt marshes are threatened by escalating climate change, particularly sea-level rise. Recent federal studies show that the waters around Chatham are warming and rising even faster than in other parts of the world and faster than previously predicted. A new predictive model of local sea-level rise has recently been developed – see description in Appendix. This Massachusetts Coastal Flood Risk Model (MC-FRM) projects that sea levels will rise 2½ feet by 2050, and close to 8 feet by the start of the next century along the Cape (with a 5% chance that it could be even worse).

Salt marshes have two natural defenses to sea-level rise, assuming the marsh is healthy (filled with native salt-marsh grasses) and tidally unrestricted. One is to gradually rise in place by building up the substrate level through sedimentation. The other is to migrate to slightly higher land nearby via an available migration path. The alternative is for the marsh to drown, merge into the open sea, and lose much of its protective storm buffering and ecological value.

Project description

The ECAC project will systematically examine Chatham's system of salt marshes to project likely futures. In particular, the project will use new and existing GIS (digital geographic information systems) data and models to project sea-level rise impacts at a fine scale within each marsh. It will then be used as a predictive tool to determine

which marshes can withstand that sea-level rise, either by the marsh raising its floor or by migration to a nearby area through a migration path. In cases of potential migration, the project will look for possible barriers and issues, such as tidal restrictions or private ownership of land in the migration area and connecting pathways. Where there are such barriers and restrictions, the project will identify possible future acquisition or conservation restrictions for the parcels or partial parcels in question.

This project is an initial step in a long-range effort to preserve Chatham's salt marshes as part of the ECAC's charge to enhance the Town's continuing resiliency in the face of climate change. Preserving salt marshes ranked as the highest concern on the natural-resources risk assessment analysis by the Chatham Climate Action Network steering committee. ECAC's work on salt marshes is being conducted in collaboration with the Town's Natural Resources Department.

Previous CPA grant (FY 2024)

ECAC was awarded a CPA grant for the first year of its long-range effort to acquire open-space property to facilitate salt-marsh migration in response to predicted sea-level rise. This was an initial step in ECAC's ongoing "Strategy to Acquire, Create, and Preserve Open Space for Salt Marshes in Chatham."

This grant funded a contract with the Center for Coastal Studies of Provincetown to study four salt marshes along the Nantucket Sound: Forest Beach, Cockle Cove, Bucks Creek and Oyster River. This was intended as an intial trial of studying the major factors of local salt marshes affected by sea-level rise and climate change. The study is producing high-resolution contour maps of each marsh, establishing baseline maps of marsh vegetation, and analyzing local sedimentation rates.

The collected data will be combined with recent digital maps (GIS) from the state to provide projections of where salt marshes will or will not be able to grow (through sedimentation and/or migration) fast enough to keep from being drowned by sea-level rise. It will help predict flooding of roads and properties by future storms and the ability of the marshes to protect from this.

Work under this grant is proceeding well. The field studies will be completed by the end of calendar 2024, and initial findings and recommendations will be publicly presented. Some grant funds remain to continue project work at the four marshes through Spring 2025 in response to initial findings.

Proposed CPA grant (FY 2025)

The current proposal would allow ECAC to extend similar studies to the remaining salt marshes in Chatham. This will provide high-resolution data on local conditions for Chatham's entire salt-marsh system. Drone studies will provide elevation mapping that is more detailed and up to date than state and federal sources. Sedimentation data – which is not currently available at all – will be collected for each marsh. An integrated GIS system will combine this data in visual map formats with local tidal data and with high-resolution storm/flooding projections for 2030, 2050 and 2070,

released by the state this year (MC-FRM Level 1 and 2). This will help the Town prepare for sea-level rise and increasingly destructive storms. Interactive maps will be made available on the ECAC website to display projections in much greater detail than on existing county, state and federal websites.

This study will allow for analysis and planning of the future preservation of Chatham's salt marshes. It will provide data to support potential interventions for preservation and to suggest strategic properties for open-space acquisition by the Town or the local land trust. It will also provide baseline data and photos for comparing, computing and visualizing trends in future studies.

General goals:

- To establish baseline data defining the elevation contours, sedimentation rates and vegetative cover of all the major salt marshes in Chatham.
- To project the future development of each of the salt marshes in Chatham, including areas likely to drown from sea-level rise and areas likely to migrate upland. This may indicate interventions necessary to preserve the health of the marshes and their fauna and flora, such as removing barriers to tidal flushing or supplementing sedimentation.
- To provide data and projections for Town projects to mitigate climate change, such as modifying low-lying roads and siting utilities.
- To inform the public about likely changes due to climate change, including at the level of detail of individual properties, at various times in the future.
- To identify wetlands properties for donation or acquisition by the Town or land trust in order to facilitate future marsh migration or future Town interventions to preserve endangered areas of salt marsh.

Specific objectives of this proposal:

- Map marsh **elevation** contours of the remaining nine major marshes in Chatham. (This data has already been collected for four of the marshes by the 2024 project.) Drone survey to acquire high-resolution elevation data (NAVD88). Conduct survey of each marsh area up to its 20-foot-contour boundaries, at appropriate tides to determine extent of marsh and to optimize elevation capture.
- Map **vegetation** in each marsh in this study from drone photographs. Drone survey to produce a high-resolution map with automated identification of vegetation areas throughout project area. Conduct survey at appropriate tide(s). Distinguish at least the following area categories: open water, ditches, mud flats, low marsh vegetation, high marsh vegetation, phragmites, upland vegetation.
- **Transects** to manually catalog the flora and fauna, including invasive species, at select locations to be specified in consultation with ECAC. This can be

used to ground-truth interpretation of drone vegetation data. Physical quadrat and transect surveys to be conducted where most needed.

- Collect samples to measure current marsh-elevation accretion (sedimentation) rates. Place at least four **sediment traps** (plates and/or tubes) in each of the nine marshes for quarterly deployments for one-week collection periods, including surrounding a spring tide and a neap tide. Compare pre- and post-storm current sediment accretion rates.
- Collect **core sedimentation** samples to measure recent past and historic marsh elevation accretion rates where appropriate. Collect cores (e.g., 3" diameter, approximately 6'- 9' deep) to measure historical rates and sources of sedimentation. Analyze historical layers using isotope dating. Compare with historical maps and aerial photos to document the evolution of each marsh.
- **Analyze** collected data and relate it to other available sources. Suggest possible interventions to help preserve marsh extent and to protect nearby properties from storm surge and flooding. Prioritize and map salt marsh areas where interventions are likely to help the marsh keep pace with sea-level rise.
- Compile the analysis, findings and recommendations in a written **report** with appropriate data, figures, charts, methods and sources. Present high-level analysis and main findings from the final report in a public meeting.
- **Follow-up activities** will include further public outreach, supplementary studies, preliminary acquisition costs or small-scale experimental marsh interventions.

Project action plan including starting date, anticipated milestones and the expected completion date:

- Kick-off meeting June 2025 Planned project start
- Elevation August 2025 GIS maps of elevation for all marshes
- Vegetation Sept 2025 GIS maps of vegetation for all marshes
- Transects Sept 2025 Ground truthing of vegetation maps
- Sediment traps October 2025 GIS maps of current sedimentation rates
- Sediment cores October 2025 GIS maps of historic sedimentation rates
- Analysis December 2025 Report of findings with data
- Report and presentation February 2026 Public presentation of findings
- Follow up activities March 2026 Initial follow-up activities
- Project completion June 2026 Expected project conclusion

How does the project impact Chatham citizens and address a current need?

This project will help the Town preserve healthy salt marshes in Chatham, including facilitating their migration in response to sea-level rise in the coming decades. This will help to protect properties and infrastructure in Chatham from storm surge, flooding and increasingly severe storms. It will also provide increased sequestration of green-house gases (e.g., CO_2 and methane) and multiple ecological services for local flora, fauna and sea life. This will benefit the Town of Chatham as a whole, particularly the many people who live near salt marshes. It will also help preserve the scenic beauty of the town for residents and visitors.

How will you measure the success of this project?

- The project will be successful in the short-range project period if it produces detailed maps of Chatham, displaying MC-FRM Level 1 and Level 2 projections of flooding, tidal levels and wave surge for future decades (2030, 2050, 2070).
- The project will be successful if it identifies and maps the major salt marshes of Chatham, including high-resolution elevation contours, vegetation cover and sedimentation rates throughout the marsh areas.
- The project will be successful to the extent that it determines which salt marshes have reasonable potential for upland migration in response to sea-level rise and identifies associated migration paths. Also, if it determines marsh areas for interventions to support preservation and ecological health.
- The project will be successful to the extent that it identifies target parcels or subdivided parcels for potential future acquisition, donation or conservation restrictions to facilitate future Town planning and action to preserve salt marsh as open space.

Budget Information
Provide or attach an estimated and dated line-item budget for the overall project. What are the sources of information you used?

The following budget provides estimated costs and dates for each of the Specific Objectives listed above in the Project Description. The Objectives for the 2025 project are similar to those in the project that is currently underway in 2024. That project was put out for competitive bid and is currently on budget and on schedule. The new budget is based on the previous project's budget, adjusted for the data collection needs of the larger set of marshes to be studied. The 2025 project covers roughly twice the acreage of the 2024 project (1,176 vs 579 acres), but lowers certain costs through economies of scale and from generalization of the earlier findings.

- Elevation $30,000 August 2025
- Vegetation $20,000 September 2025
- Transects $10,000 September 2025
- Sediment Traps $10,000 October 2025

- Sediment Cores $20,000 October 2025
- Analysis $10,000 December 2025
- Report and Presentation $10,000 February 2026
- Follow Up Activities $30,000 March 2026

Total amount of the project: $140,000

Are project costs being split with other Towns and, if so, what is the split?

No, no other towns are directly involved.

If this is a Town project, will it lead to increased ongoing expenses? If so, how much and how will they be covered?

No, there will not be any ongoing expenses.

Have all appropriate Town agencies, committees and commissions reviewed and commented on the project? Attach all relevant letters and approvals.

This proposal is being submitted by ECAC and the Town's Department of Natural Resources as co-applicants.
This proposal was formally approved by the ECAC Saltmarsh Subcommittee on September 25, 2024, and by the Town's Energy and Climate Action Committee on October 15, 2024.
The proposal was developed with the participation of the Town's Director of Natural Resources and the Town's Projects and Operations Administrator – who regularly participate in ECAC monthly meetings. The grant and project will be administered by the Town's Director of Natural Resources.

Are there any legal ramifications or impediments to this project?

No.

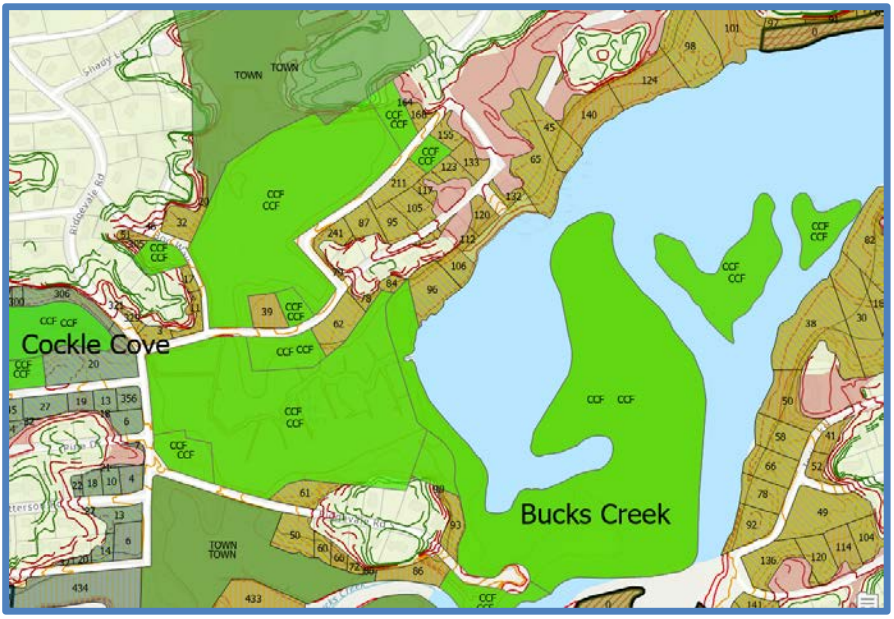
Is the project compatible with the Town's comprehensive plan?

Yes.

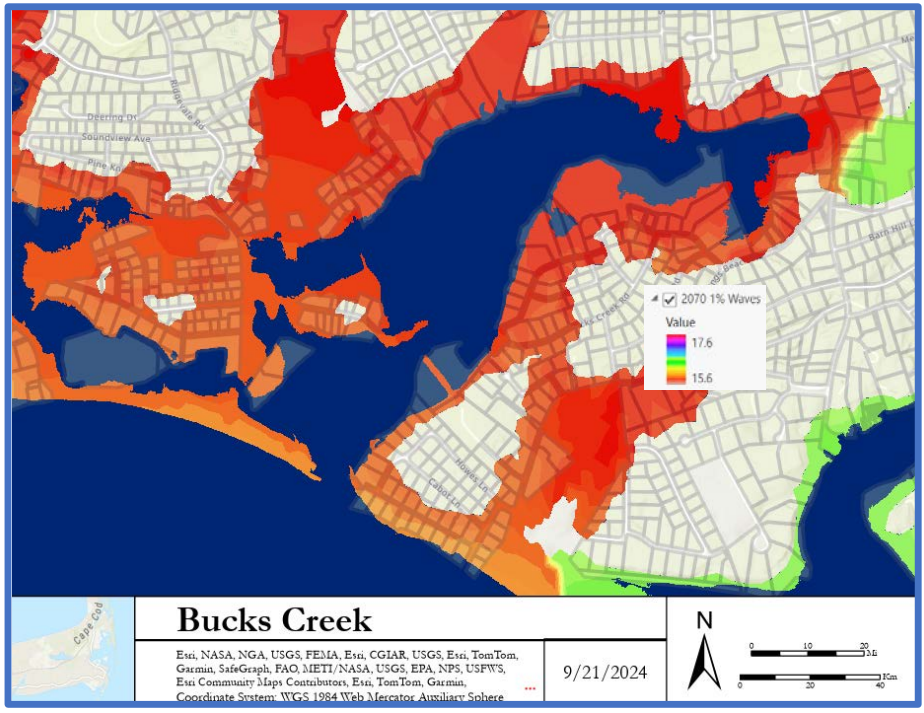
Attach letters of approval

See Appendix for letter of support from the Chatham Conservation Foundation as an interested property owner.

Appendices.



Close-up of properties in wetlands around Bucks Creek. Shows current elevation contours in the floodplain. Dark green properties are Town owned; bright green properties are in the land trust.



2070 hundred-year wave heights (MC-FRM Level 2 projections). Predicts wave heights (in feet) around the marsh during a very severe potential storm in 2070.

For Further Information

Websites

Gerry Stahl's salt marshes page: https://gerrystahl.net/SMTF
Energy and Climate Action Committee (ECAC): https://www.chatham-ma.gov/994/Public-Education
Town of Chatham Natural Resources Department: https://www.chatham-ma.gov/177/Natural-Resources-Department
Pleasant Bay Association (PBA) many reports, including on Muddy Creed and Jackknife Beach: https://pleasantbay.org/reports-and-documents
Chatham Conservation Foundation (CCF): https://www.chathamconservationfoundation.org
Association for the Preservation of Cape Cod (APCC) climate change page: https://apcc.org/our-work/advocacy/climate-change
Center for Coastal Studies (CCS): https://coastalstudies.org
Cape Cod Commission climate page: https://www.capecodcommission.org/our-work/topic/climate
Cape Cod Climate Change Collaborative: https://capecodclimate.org
MA Coastal Flood Risk Model (MC_FRM) interactive map: https://experience.arcgis.com/experience/23d861b79aed450eb8972013dd28579b/page/MA-Coast-Flood-Risk-Model
Sea Level Affecting Marshes Model (SLAMM) interactive map viewer: https://mass-eoeea.maps.arcgis.com/apps/MapSeries/index.html?appid=be25f9b2019a4f9d86605f1b89e82c9e

Downloads

Report on Frost Fish Creek study by APCC: https://gerrystahl.net/SMTF/ffc_apcc_report_2019.pdf
Report on Bucks Creek / Cockle Creek by APCC study: https://gerrystahl.net/SMTF/ccbc_report.pdf
Report on 4 marshes by CCS: www.chatham-ma.gov/DocumentCenter/View/9072/Chatham_Marshes_Final_reduced and www.chatham-ma.gov/DocumentCenter/View/9121/CCS_ChathamMarshes_Appendices_Final.

Books

Life and Death of the Salt Marsh – John & Mildred Teal

A landmark 1969 environmental book that uses New England salt marshes as its main stage; widely cited as a foundational, very readable blend of science and conservation advocacy.

Recently re-released

Our Cape Cod Salt Marshes – Dorothy Sterling

A concise, locally rooted introduction to Cape Cod's marshes by a Wellfleet author; often recommended by Cape conservation groups for its accessible natural history and sense of place.

Available from APCC

The Ecology of a Cape Cod Salt Marsh – Gil Newton

A short, practical guide written by a Cape naturalist and educator, covering plants, animals, and ecological processes in a typical Cape Cod marsh; sold through "Cape Cod Nature Adventures" as part of a local field-guide series.

Available from Barnstable Land Trust

Salt Marshes: A Natural and Unnatural History – Judith S. Weis & Carol A. Butler

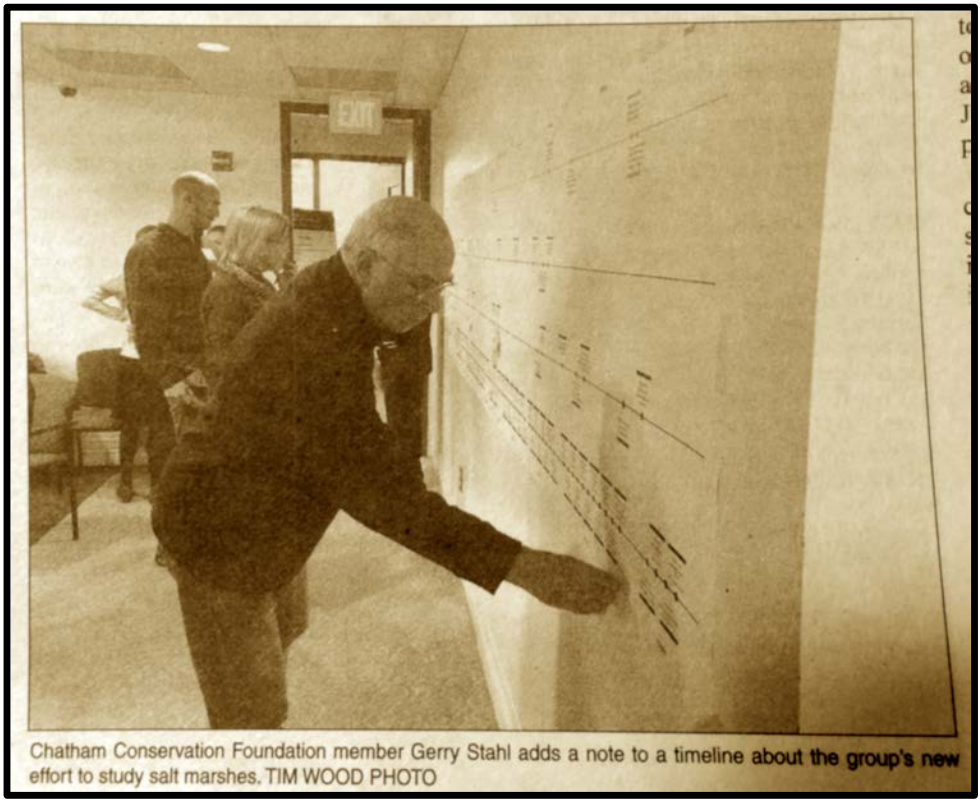
A modern, nontechnical overview of salt marsh ecology, biodiversity, human impacts, and restoration, with emphasis on Atlantic and Gulf coasts; recommended for students, planners, and coastal residents.

Salt Marsh Secrets (e-book) – Joy Zedler

Free online collection of research-based stories from one of the leading wetland ecologists, focusing on estuaries as "living laboratories" and illustrating key marsh processes and restoration lessons

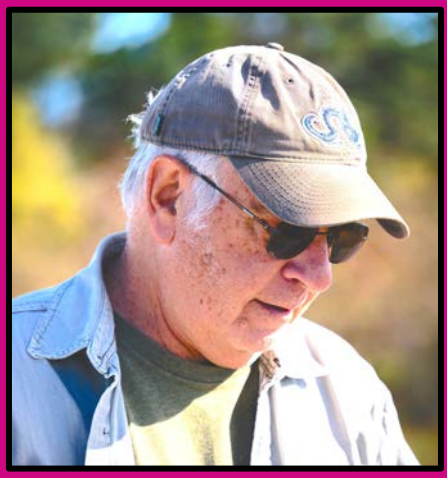
Download from: https://tijuanaestuary.org/library/salt-marsh-secrets .

Notes



Chatham Conservation Foundation member Gerry Stahl adds a note to a timeline about the group's new effort to study salt marshes. TIM WOOD PHOTO

Announcing the Salt Marsh Task Force at the 2019 Cape Cod Commission's climate change mitigation workshop in Chatham.



This book collects analysis and documents from my efforts to understand the importance and probable future of the salt marshes of Chatham, Massachusetts. In accordance with the spirit of thinking globally about climate change and acting locally to study my surrounding environment, I have tried to assemble information about the marshes, which I enjoy on my daily strolls. I hope this book helps my neighbors to understand and protect our world.

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