Climate Change
Transportation Impact Study






Prepared by:

Old Colony Planning Council

70 School Street, Brockton, MA 02301

Prepared Under MassDOT Contract # 0052455

September, 2010

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Acknowledgements

The preparation of this report has been financed in part through grants from the Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation, under Metropolitan Planning Program, Section 104(f) of Title 23, U.S. Code, under Contract 0052455.

The views and opinions of the Old Colony Planning Council expressed herein do not necessarily state or reflect those of the U. S. Department of Transportation.

This Climate Change Transportation Impact Study was prepared by the following members of the Old Colony Planning Council staff under the direction of Pat Ciaramella, Executive Director, and the supervision of Charles Kilmer, Transportation Program Manager.

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1.0 Introduction

Climate Change is a problem that is affecting both people and the environment. Climate change is a direct result of increased greenhouse gases produced through human activity. Greater energy efficiency and new technologies hold promise for reducing greenhouse gases and solving this global challenge. The transportation system plays an important role as one third of greenhouse gas emissions in the United States come directly from transportation emissions. The purpose of this Climate Change Transportation Impact Study is to identify enhanced human, transportation, and land use practices that will help to reduce greenhouse gas emissions.

In addition, the transportation infrastructure in the United States is being affected as the climate warms, as the greatest impacts will be in the form of flooded roadways, railways, transit systems, and airport runways, especially in coastal areas due to rising sea levels and storm surges. Coastal housing and highways are already exposed to periodic storm flooding and erosion. Additionally, the loss of wetlands has removed crucial buffer zones that once protected many roads and houses. Lower summer river flows, impacts to farm and forest productivity, energy cost increases, public health effects, and increased pressures on many fish and wildlife species are other aspects of climate change effects anticipated by scientists. The impacts of such changes on our citizens, businesses and environment are likely to be extensive and destructive. These are man-made changes that we have unintentionally brought upon ourselves, but are also in our power to reverse. Reducing "carbon based" vehicle miles travelled (VMT) through adequate maintenance and expansion of transit services, using electric vehicle charge by non-carbon based sources, identifying alternatives to single occupant auto travel, and making changes in current land use patterns are some of the potential strategies, that follow the Green Massachusetts Department of Transportation's policy directive and the 2011 Old Colony Regional Transportation Plan's vision and goals. This report also looks at policies that examine current vehicle emission standards, as well as alternative funding mechanisms such as road pricing and the VMT tax.

This study analyses of the impacts that climate change will have on the Old Colony region's transportation and land use infrastructure, and offers recommendations for planning, design, construction, evacuation, operation, and maintenance of the system. In an effort to inventory high risk areas of flooding due to climate change, the Old Colony Planning Council developed a series of maps that highlight flood prone areas along federal-aid and other eligible roads, and transportation facilities for each of the region's fifteen communities. With this inventory, communities can address potential issues before they become major problems.

This study is intended to be the basis for conducting an in-depth community analysis of at-risk transportation infrastructure as a result of climate change effects. It is expected that the findings and recommendations will serve as a foundation for future studies, including the Climate Change Roadway Drainage and Runoff Program and the 2011 Pre-Disaster Mitigation Plan (PDM), both of which will be completed over the next few years. This study will also support a regional task force that will be developing the policies, goals, objectives, and performance measures for the Old Colony region's environmental protection and climate change initiatives.

2.0 Overview of Climate Change

What is Climate Change?

Climate Change is defined by the U.S. Environmental Protection Agency (EPA) as "any significant change in measures of climate (such as temperature, precipitation or wind) lasting for an extended period of time (decades or longer)." Throughout its history, the Earth's climate has endured many changes within a wide spectrum, from the extremes of ice ages to prolonged periods of extreme heat and warmth. These changes in climate can last from a period of decades to millions of years. Changes in climate can affect natural ecosystems, as well as the human economies and cultures that depend on them.

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There are many different types of climate in the world today. They vary from the warm temperatures and high rainfalls found in the rainforests in South America to the desolate lands in the tundra across the northern parts of Alaska, Canada and Russia, to the temperatures we have here in Massachusetts.

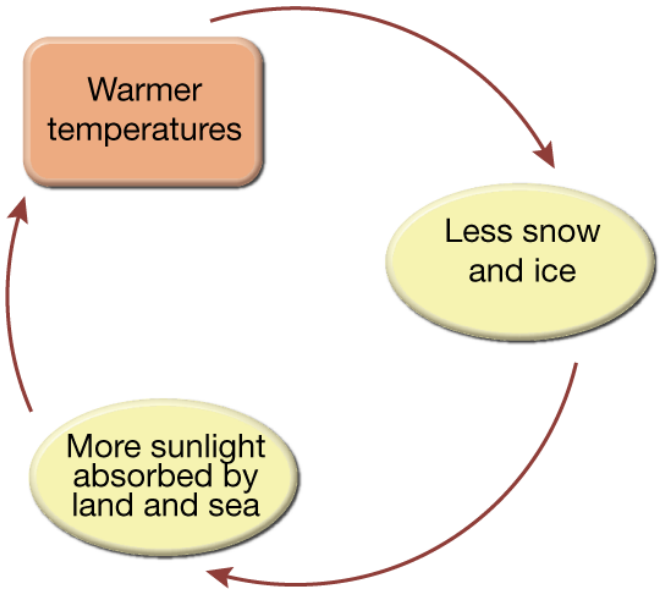


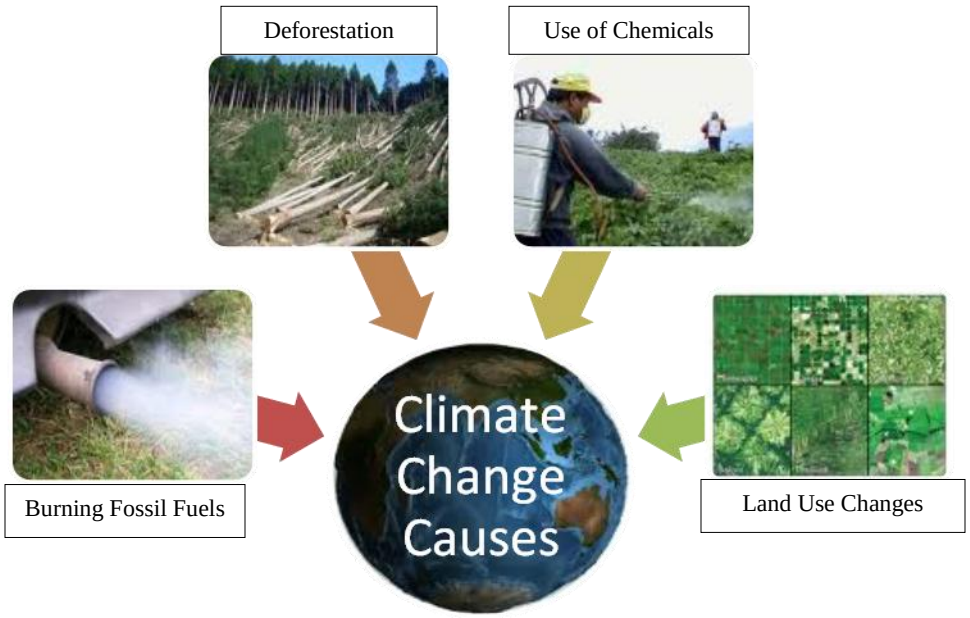
Figure 2.1: Climate Change - Ice and Snow and the Albedo Effect: *Changes in the Polar Regions can cause more warming in the entire planet earth system through feedback effects. One such effect is the reduction of ice and snow due to warmer temperatures. When the white and gray snow and ice disappears, fewer sun rays are reflected and instead the heat is absorbed by land and sea – which causes further the warming.*

Causes of Climate Change

The climate can change for a variety of reasons. The EPA separates the known "drivers" or "forcers" of climate change into two time periods: Prior to the Industrial Revolution (pre-1750), and after the Industrial Revolution (post-1750). In the period prior to the Industrial Revolution, the known drivers of climate change were changes in the Earth's orbit, as in how the Earth's tilt is either toward or away from the sun, which affects the amount of direct sunlight that Earth receives, changes occurring within or inside the sun affecting the amount of light and warmth it gives to the Earth; and volcanic eruptions that can emit carbon dioxide (CO^2) which can block the sun's light from reaching the Earth.

GHGs are emitted naturally and can be found in the atmosphere in small levels. GHGs consist primarily of water vapor, but also contain methane, carbon dioxide (CO^2), nitrous oxide (NO^2) and fluorinated gases. These gases form a natural "greenhouse effect" on the planet, where heat is trapped inside the Earth's atmosphere making it a habitable place for life.

Figure 2.2: Causes of Climate Change Diagram



Since the beginning of the Industrial Revolution (post-1750), there has been an increase in the amount of fossil fuels (petroleum, natural gas and coal) being used. These were first used to power industrial and commercial enterprises, and later fossil fuels were used at an increasing rate to power trains, homes, automobiles, and generate electricity. These man-made activities have contributed to the increase of the GHGs in the atmosphere, which is affecting and changing our current climate. The burning of fossil fuels to power industrial and commercial enterprises, transportation, and homes is only one of the causes for the increase in the GHGs in the atmosphere. Other causes are: increased deforestation, which is eliminating the plants and trees that convert the carbon dioxide to oxygen; an increase of chlorofluorocarbons (CFCs), a man-

made gas found in aerosol cans (now being reduced); changes in land use patterns, particularly sprawl, which causes an increase and reliance on the use of automobiles and the burning of fossil fuels.

The use of fossil fuels has been growing at an alarming rate over the past century, as it has come to be relied upon as the main source of energy worldwide. According to the U.S. Department of Energy, "more than 85% of the energy consumed in the United States comes from fossil fuels, as does nearly two-thirds of the electricity generated and virtually of all of our transportation fuels."

The increased burning of fossil fuels leads increased GHGs in the atmosphere, therefore increasing the greenhouse effect and increasing the temperature of the planet.

According to the National Oceanic and Atmospheric Administration (NOAA) the global surface temperature has increased about 0.74 degrees Celsius since the late nineteenth century, and the linear trend for the past 50 years of 0.13 degrees Celsius per decade is nearly twice that for the past 100 years. The warming of the planet has not been uniform; as some areas have experienced colder temperatures while others have seen a warming in the temperatures. Seven of the eight warmest years on record have occurred since 2001, while the ten warmest years on record have all occurred since 1995.

"All across the world, in every kind of environment and region known to man, increasingly dangerous weather patterns and devastating storms are abruptly putting an end to the long-running debate over whether or not climate change is real. Not only is it real, it's here, and its effects are giving rise to a frighteningly new global phenomenon: the man-made natural disaster."

-U.S. President Barack Obama-April 3, 2006 Speech on Energy Independence and the Safety of our Planet

What are the Potential Impacts of Climate Change?

There are many potential impacts of climate change on the planet. Below is a summary of the highlights from the Synthesis Report of the Intergovernmental Panel on Climate Change (IPCC) (A joint panel established by the United Nations Environment Program and the World Meteorological Society); the Fourth Assessment Report released in 2007:

Ecosystem Impacts

- Around 20-30% of the plant and animal species assessed are at risk of extinction if global average temperatures exceed 1.5 degrees Celsius to 2.5 degrees over late 20th century levels.
- There is a likelihood of "irreversible" impacts. For example, if temperature increases exceed about 3.5 degrees Celsius, between 40 percent and 70 percent of the species assessed will be at increased risk of extinction.
- Increases in sea surface temperatures of about one to three degrees Celsius would result in more "frequent coral bleaching events and widespread mortality."
- There is growing concern over the oceans and seas becoming more acidic with rising levels of CO^2 and the impacts on "marine shell-forming organisms" like coral reefs.

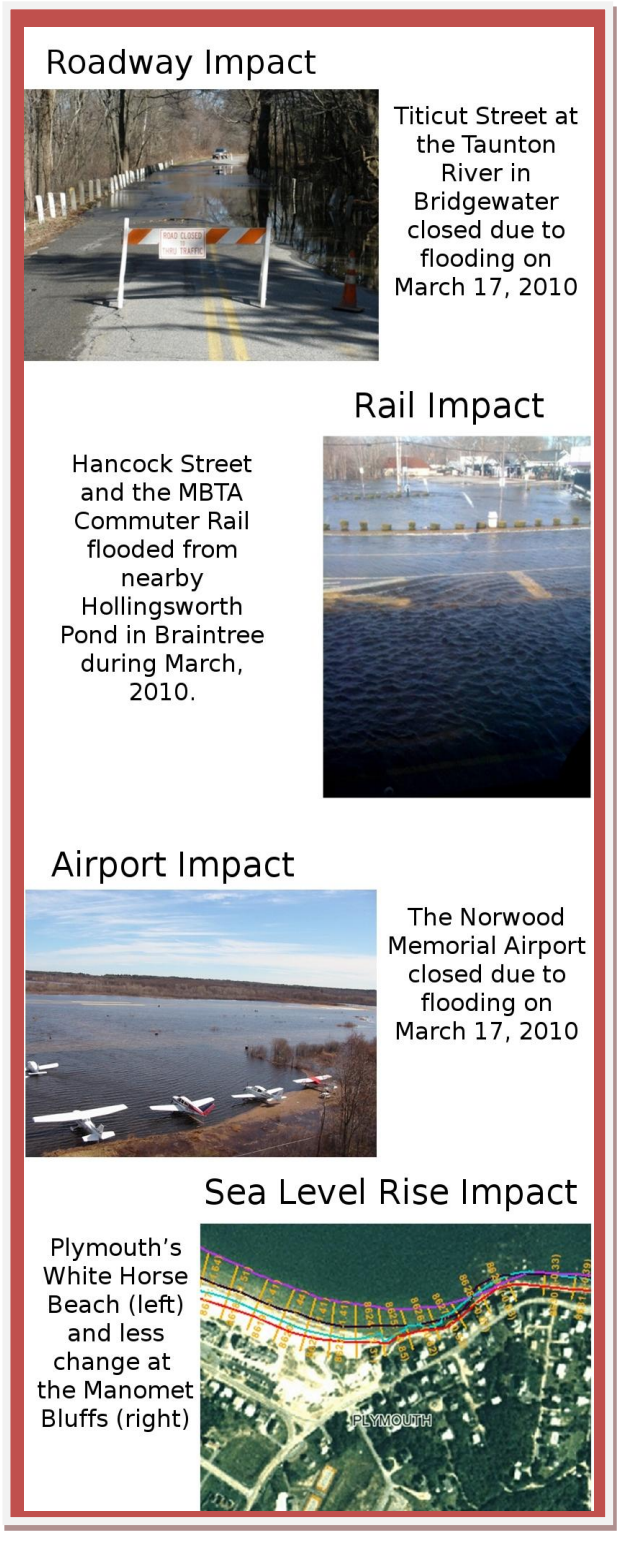
Flooding Impacts

- There is a higher confidence in the risks of extreme weather events and the projected increases in droughts, heat waves and floods as well as their adverse impacts.

Health Impacts

- Concern is growing that the poor and elderly in low-latitude and less-

Figure 2.3: Examples of Climate Change Impacts



developed areas (including those living in dry areas and on mega-deltas) are likely to suffer most.

Extreme Weather Impacts

- There is high confidence that by mid-century "many semi-arid areas, for example the Mediterranean basin, western United States, southern Africa and northeast Brazil, will suffer a decrease in water resources and hence greater aridity due to climate change."

Sea Level Rise Impacts

- New observations linked with the Greenland and possibly Antarctic ice sheets may mean that the rate of ice loss will increase above previous forecasts.
- There is growing concern that any benefits linked with climate change will be gone after more modest temperature rises.

Air Quality Impacts

- Climate change has the potential to increase ground-level ozone in many regions. Ground-level ozone is formed in the presence of sunlight by a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOCs), which are emitted from sources like motor vehicles and industrial facilities.
- Climate change also could increase the number of days with weather conditions conducive to forming ozone, potentially causing air quality alerts earlier in the spring and later in the fall.

In addition to the worldwide effects of climate change, there are potential local effects. Some of the possibilities according to the Massachusetts Climate Protection Plan include:

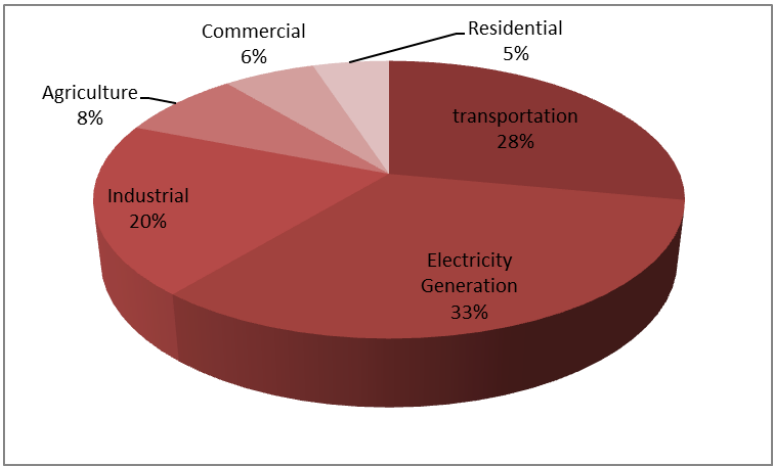
- Weather patterns in Boston, Massachusetts resembling those found in Richmond, Virginia by the end of the century if climate trends continue as expected,
- An increase in sea level which would affect coastal landowners and the tourism industry that depends on the coast for survival;
- An increase of health issues among the elderly and young children with the increasing temperatures;
- And a decrease in the amount of available water supply to lakes and ponds.

What is the Transportation Role in Climate Change?

Transportation plays a large role in climate change. As previously stated, virtually all the aspects of the transportation system use fossil fuels and produce greenhouse gases.

As Figure 2.4 shows, the transportation system is the second largest producer of greenhouse gas in the United States, accounting for 28% of all GHG emissions, second only to electricity generation at 33% of all GHG emissions. According to the U.S. Department of Transportation, since 1990 the transportation sector has been one of the fastest-growing sources of U.S. GHGs. The rise in such emissions represents 48 percent of the increase in total U.S. GHGs post 1990.

Figure 2.4: Percentage of U.S. Greenhouse Gas Emissions, 2006



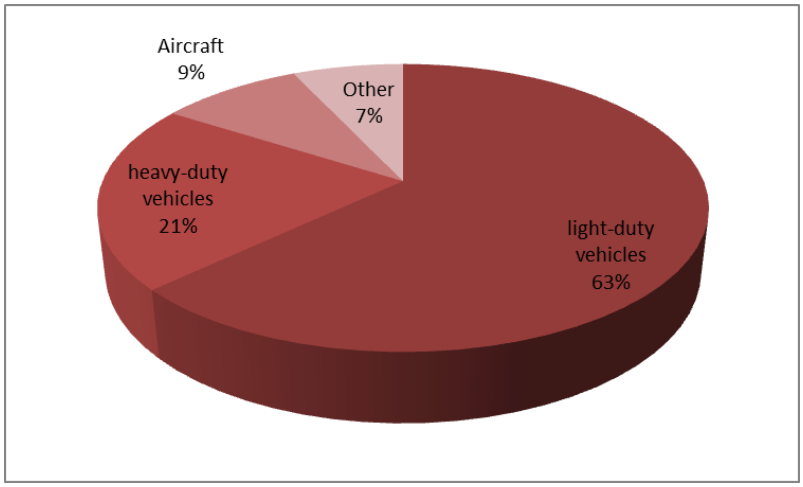
Source: U.S. Department of Transportation

Deforestation, urban sprawl, agriculture, and other human influences have substantially altered and fragmented our landscape. These changes then affect the travel patterns. As an example, the need for additional and longer trips by automobile. Also, land use alterations affect the global atmospheric concentration of carbon dioxide, the principal heat-trapping gas that affects local, regional, and global climate, by changing the energy balance on Earth's surface.

When taking a closer look at the biggest contributors of GHGs from the transportation system, 63% of emissions come from light duty vehicles, as seen in Figure 2.5.

These passenger and light duty trucks are driven by millions of Americans everyday. When the widespread use of these vehicles is combined with always seemingly longer commutes and changes in land use and sprawl, this is a major problem that needs to be addressed now.

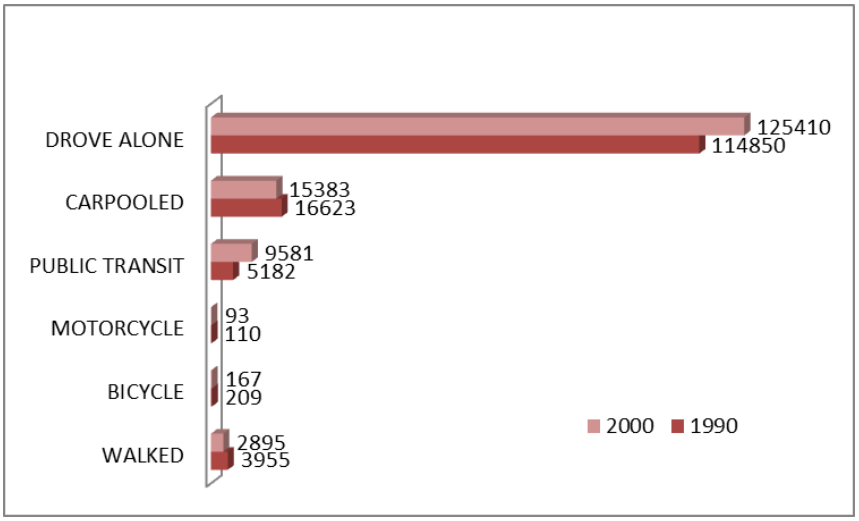
Figure 2.5: Percentage of Transportation Greenhouse Gas



Source: U.S. Department of Transportation

In the Old Colony region, single passenger vehicle trips are the most common means for commuting to work according to the US 2000 Census. Between 1990 and 2000, there has been an increase of more than 10,000 single occupancy vehicle trips (8.5 percent). During the same period, there was an increase of transit users by 4,399 riders (46 percent). Part of this considerable increase in transit use reflects the introduction of the MBTA Old Colony Commuter Rail lines in 1997. In addition, walking commuters declined by 1,060 walkers (25 percent) and carpooling commuters declined by a similar number, 1,360 carpoolers (7.5 percent). The Old Colony region's population gained 24,651 people (8.3 percent) between 1990 and 2000.

Figure 2.6: Modes of Transportation in the OCPC Region



Source: U.S. Census Bureau

The Old Colony Planning Council has developed environmental protection and climate change adaptation objectives for the short, medium and long-term. By 2020, the short-term goal is to reduce greenhouse gas emissions to 7.3 percent below 1990 transportation GHG levels. By 2035, the goal is to increase healthy transportation modes of walking, bicycling, and public transportation by 20% compared to 1990 census data. By 2050, the OCPC long term goal is to reduce transportation greenhouse gas emissions to 12.5 percent below 1990 GHG emissions. Supporting alternative options to driving alone, and supporting compact and mixed-used developments in downtowns and town centers, is the first attempt in reaching these goals.

3.0 Regional Climate Change Impacts

Description of Old Colony Planning Council Region

The Old Colony Planning Council (OCPC) region consists of fifteen communities in three counties in southeastern Massachusetts. Twelve OCPC communities are located in Plymouth County, including the City of Brockton and the Towns of Abington, Bridgewater, East Bridgewater, Halifax, Hanson, Kingston, Pembroke, Plymouth, Plympton, West Bridgewater, and Whitman. The OCPC communities of Avon and Stoughton are located in Norfolk County and the Town of Easton is located in Bristol County.

Population

The OCPC region is 330.5 square miles and consists of communities running northwest to southeast from Stoughton and Brockton, along Route 24, and to Plymouth on Route 3. The region is south of the concentration of activity and population in the Boston Metropolitan Area, but is oriented towards that center. It largely cuts across the north-south transportation lines between Greater Boston and the rest of Southeastern Massachusetts.

The 2000 U.S. Census found that the Old Colony region had a population of 321,515. This was an 8.3 percent increase over the 1990 regional population of 296,864. Between 1990 and 2000, the only community in the region to see a decrease in population was the Town of Avon. The Town of Plymouth experienced the largest absolute growth, while Kingston saw the highest growth rate. The City of Brockton has the highest population at 94,304, and approximately one-third of the OCPC population resides in the northwest portion of the region in the communities of Brockton and Stoughton, where development is denser than in most of the region.

Recent Growth Trends

The 1997 restoration of the commuter rail to the region significantly influenced development and population. The greatest proportional increase from 1990 to 2000 was the 30 percent increase in Kingston, a community served by a local rail station as well as nearby stations in Plymouth and Halifax.

The region's population has grown from 141,017 residents in 1950 to 321,515 in 2000, an increase of 128 percent. The region saw a very rapid rate of population growth during the "Baby Boom" years after World War II, which continued through the 1950s and 1960s, and slow somewhat through the 1970s and 1980s. During the 1990's, population began growing at a higher rate than it had in the previous decades.

From 2000 to 2005, much of the region's growth occurred in the southeastern half of the region, where many communities grew by over 6 percent. Many communities in the northwestern half experienced substantially less growth. Areas to the south have generally had more available developable land, leading to a substantial amount of subdivision and low-density, large-lot development.

In 1990, nine towns (Abington, Avon, Bridgewater, Brockton, East Bridgewater, Easton, Pembroke, Stoughton, and Whitman) had population densities of 600 or more persons per square mile and two additional towns (Hanson, and Kingston) had reached this level by 2000.

Geographic Description

The region's geography generally consists of low and gently rolling glaciated land with many drumlins, eskers and other glacial features. The region has a generally north-south drainage system, and extensive wetlands including the Hockomock Swamp, which is partly in Easton, West Bridgewater and Bridgewater, and the Great Cedar Swamp, which is partly in the southern portion of Halifax.

This "lowlands" region ranges in elevation from sea level along the coast to higher, with modest inland elevations. The highest points in the north are about 230 feet above mean sea level (msl) in the northern corner of Brockton, and an un-named 290 foot above msl hill east of Ames Long Pond in Stoughton. The highest point is the atypical 395 foot Manomet Hill close to the shore in Plymouth's Pine Hills.

The region's fifteen communities can be categorized into three geographical groups:

1. Greater Brockton; Abington, Avon, Bridgewater, Brockton, East Bridgewater, Easton, Stoughton, West Bridgewater, and Whitman.
This relatively developed area has many scattered streams and ponds (many man-made), and commonly tight glacial soils. While the extensive drainage system has many streams, none are very large because the communities are close to the headwaters of several basins. Though the streams are small, some segments are confined to narrow walled channels to allow or/protect nearby buildings. This leaves no room for safe flooding and informal flood storage. Thus streams can overflow during storms into nearby developed areas. The area also has many sections with relatively tight soils limiting on-site disposal opportunities and groundwater yields.

2. The Lake communities of Halifax, Hanson, Pembroke, and Plympton
The Lake region has a range of tight wetlands soils and porous areas of sand and gravel, with many lakes and ponds and fewer major streams.

3. The South Coastal area of Kingston and Plymouth
The South Coastal portion of the region has typically porous sandy soils and many ponds. It supports very few streams of any size since the coarse soils and irregular terrain absorb much rainfall before it can run off. Instead, the major surface waters consist of the frequent ponds and lakes, many of them consisting of exposed groundwater.

Land Use Characteristics

Regional growth in outlying areas continues to decentralize the population and to consume land at an increasingly high rate. Overall, housing grew from 31,706 acres in 1971 (10.5% of the region) to 53,151 acres in 1999 (24.22% of the region). This is a 68 percent increase in residential land from 1971 to 1999. Yet, the population grew by only 40 percent (from 230,379 to 321,515) in the period from 1970 to 2000.

The population within the OCPC Region is much denser in the northwest portion than southeast portion of the Region. Brockton is the most densely populated community in the Region, with nearly 4,400 persons per square mile. With only 7% of the Region's total land area, it contained 29% of the regional population in 2000. Plympton is the least densely populated community in the Region, with only about 180 persons per square mile.

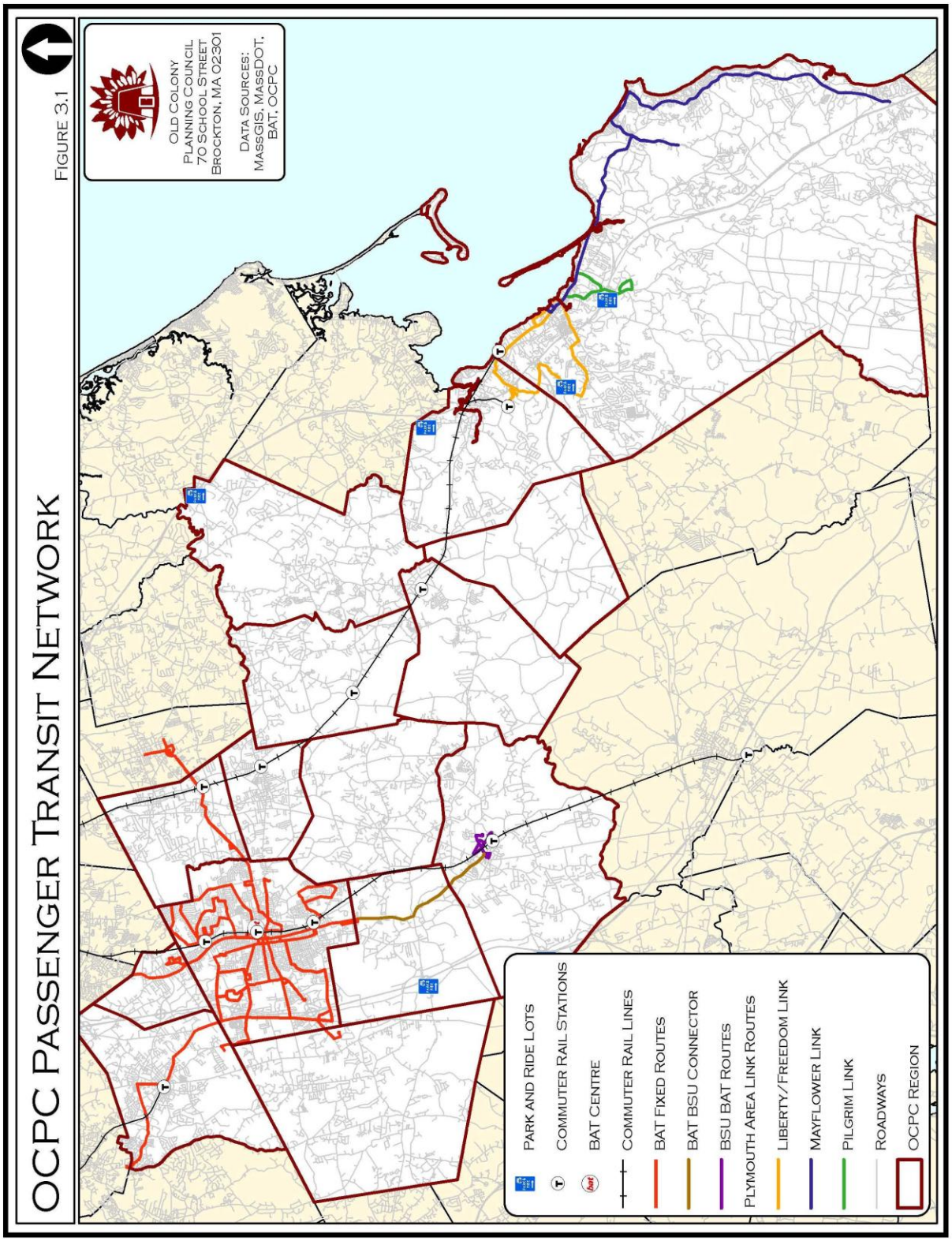
Population densities will continue to drop and land consumption will continue to rise as long as communities increase the area requirements on undeveloped land to an acre or more. This trend is occasionally countered by pockets of higher-density development done through Comprehensive Permits under Chapter 40B. Similar development is beginning to be pursued through locally chosen areas rezoned for higher density as-of-right development particularly under Chapter 40R. The local increase in population densities and affordable transportation options through these and other programs will encourage more concentrated development and a decrease in suburban sprawl.

The Old Colony Planning Council encourages developments that are compact, conserve land, protect historic resources and integrate uses. The OCPC also supports downtown and town center revitalization by promoting multimodal transportation centers that serve business, residential, and mixed-use development.

Transportation System in OCPC Region

The Old Colony Planning Council region offers a variety of transit services, such as bus transportation, paratransit services, commuter rail, airport and air services, commuter bus services, and a regional highway system. The variety of the modes of transportation gives users choices regarding the type of transportation they can use at a given time. The following map shows all transit services in the region, multimodal stations, and park and ride lots. The majority of the Old Colony communities are pedestrian friendly. Communities such as Bridgewater, Brockton, East Bridgewater, Plymouth, Stoughton and Whitman are considered very walkable, while Abington, Avon, Easton, Kingston Pembroke and West Bridgewater are considered somewhat walkable. Halifax, Hanson, and Plympton are more car-dependent due to their rural characteristics.

As part of the proposed performance measures of the 2011 Regional Transportation Plan, by 2020, the Old Colony region will reduce greenhouse gas emissions by 7.3 percent below 1990 transportation GHG levels. Increasing use of environmentally sustainable practices in transportation and reducing the dependence on oil are the primary goals of the U.S. Department of Transportation and the Old Colony region.


OCPC Passenger Transit Network
Figure 3.1
Old Colony Planning Council
70 School Street
Brockton, MA 02301
Data Sources:
MassGIS, MassDOT,
BAT, OCPC
Park and Ride Lots
Commuter Rail Stations
BAT Centre
Commuter Rail Lines
BAT Fixed Routes
BAT BSU Connector
BSU BAT Routes
Plymouth Area Link Routes
Liberty/Freedom Link
Mayflower Link
Pilgrim Link
Roadways
OCPC Region

Bicycle and Pedestrian Regional Network

Bicycle and pedestrian amenities can generally improve travel choices and the overall quality of life in communities. The presence of sidewalks is an important attribute in transportation. Adequate sidewalks can link residential areas to commercial areas, potential transit stops to surrounding areas, and can provide improved overall circulation as a viable alternative to the motor vehicle.

Figure 3.2: Sidewalks in Plymouth Town Center

The Old Colony Planning Council's vision calls for designing land developments and transportation projects to support proactively vibrant communities with bicycle and pedestrian amenities. The policies proposed in the 2011 Old Colony Regional Transportation Plan focus primarily on linkages between transportation modes and land use; however, substantial benefits can be realized from pedestrian and bicycle improvements to make the Old Colony communities more sustainable and livable.

As part of the FY2011 Unified Planning Work Program (UPWP), the Old Colony Planning Council will work on a Bicycle and Pedestrian Connectivity Study. This study will be collecting bicycle and pedestrian data from downtowns, town centers, and major corridors throughout the region. The goal is to identify bicycle and pedestrian deficiencies in the region and to connect different neighborhoods with these modes. OCPC staff will use the Pedestrian Accommodation Index analysis in order to evaluate intersections throughout the region, and the Pedestrian and Bicycle Level of Service (PLOS and BLOS) to evaluate the "friendliness" of the roads for these two modes.

By 2035, increasing the use of non-motorized transportation modes such as bicycle and walking by 20 percent compared to 1990 census is one of the goals of the Old Colony Planning Council.

Regional Highway Network

The Old Colony region is served mainly by three limited access highways, Route 3, Route 24, and Interstate 495. Route 3 and Route 24 are limited access state highways that provide north-south access. I-495, which runs concentrically around Boston and the Route 128 ring, skirts Bridgewater in the southwest of the region, and provides access to the southeast to Cape Cod and to the northwest via I-90 (the Massachusetts Turnpike.) I-495 becomes Route 25 in south Plymouth as it approaches the Bourne Bridge for access to Cape Cod. Route 3 provides access to the south to Cape Cod and connects north to I-93 to Boston. Route 24 provides access to the south to Fall River and New Bedford and to points north including I-93 to Boston. In addition, north-south travel is served by Routes 3A, 18, 28, and 138, which offer alternatives to the limited access routes. These state-route corridors are mainly two-lane highways that traverse suburban and rural areas connecting community and urban centers. Retail and commercial land uses are interspersed along these two-lane highway corridors, especially where these state routes connect with the limited access highways.

The east-west highways in the region are mainly two-lane state numbered routes. Routes 27 and 106 are important east-west highways in the region while others are Routes 14, 44, 104, 123, and 139. The reconstruction and relocation project of Route 44 was completed in 2005, has added a limited access, high-speed connection (with increased capacity) between Route 3 and Route 58.

Commuter Rail

Three Massachusetts Bay Transportation Authority Commuter Rail lines operate in the region, the Middleboro/Lakeville line, the Kingston/Plymouth line, and Providence/Stoughton line. The Middleboro/Lakeville and Kingston/Plymouth Old Colony Lines were restored in the fall of 1997 and have become popular with commuters who work in Boston.

The Providence/Stoughton line services Stoughton and points north, from Monday to Friday. The Middleboro/Lakeville line services to the communities of Brockton and Bridgewater. The Kingston/Plymouth line serves the OCPC communities of Abington, Whitman, Hanson, Halifax, Kingston, and Plymouth. The Old Colony lines are served seven day a week including all holidays.

According to the 2000 U.S. Census, the restoration of the Old Colony commuter rail lines in 1997 helped reduce the number of vehicles on the road by 4,500 vehicles, leading to a substantial reduction in greenhouse gas emissions.

Brockton Area Transit

Brockton Area Transit (BAT) is the largest provider of fixed route and paratransit public transportation in the region, providing fixed route bus service to seven communities and paratransit service to nine communities. In 2006, BAT completed the final phase of its intermodal transportation facility (BAT Centre), offering a connection to bus and taxi service. The BAT Centre is located across the street from the downtown Brockton commuter rail station.

BAT provides fixed route bus services to: Abington, Avon, Brockton, Bridgewater, Easton, and Stoughton. The service in Bridgewater is provided through the Bridgewater State University

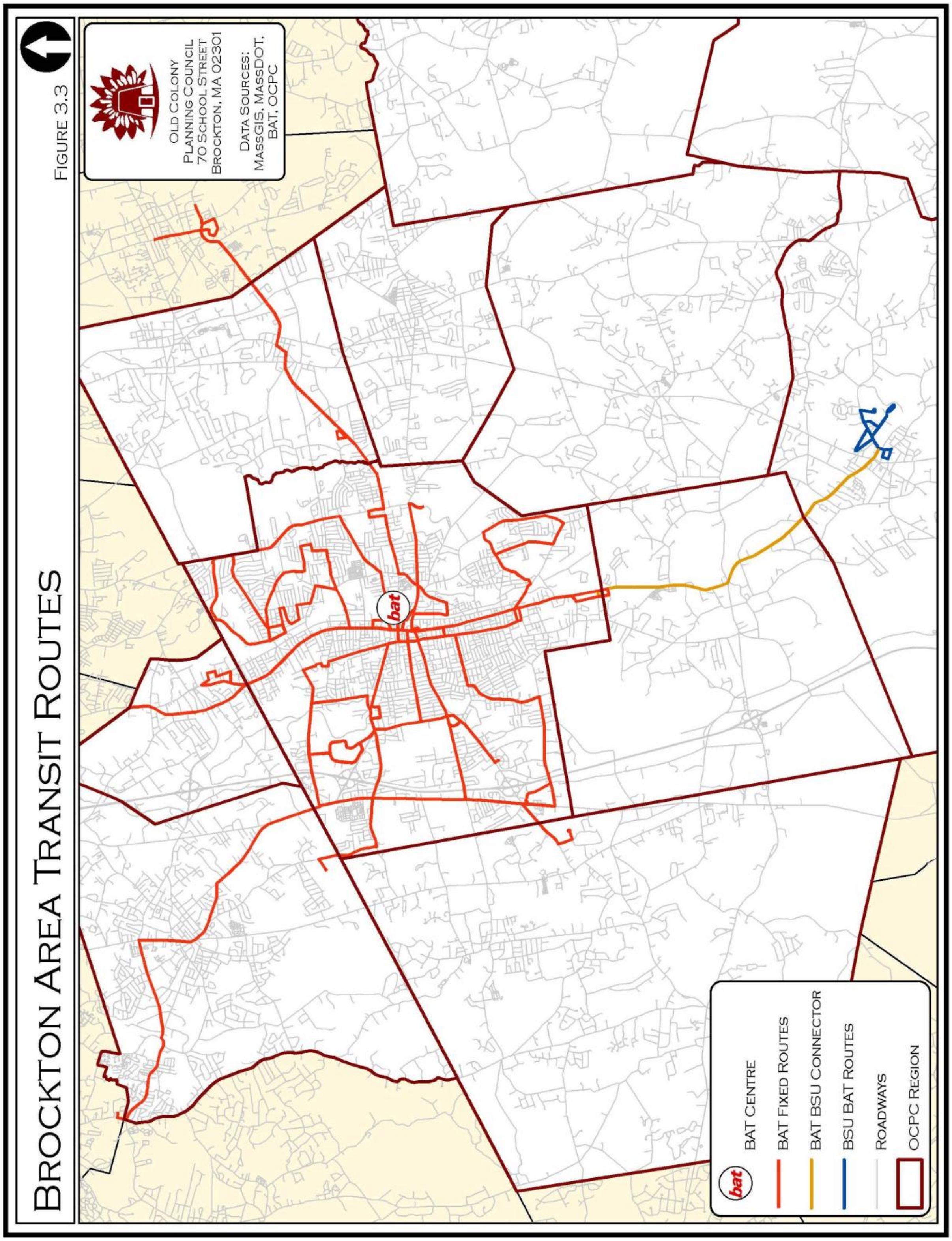
(BSU) Transportation Services, within the campus and to Brockton during the school year. The BAT system provides transportation to localities such as schools, medical facilities, shopping centers and industrial parks. In addition, BAT provides connections to the three commuter rail stations in Brockton, the station in Stoughton, the MBTA Ashmont Red Line and MBTA feeder bus routes to the Braintree and Quincy Center Red Line rapid transit stations. In February 2010 BAT began a new FlexRide service that runs Monday-Friday from Union Street in Rockland to Abington where it connects with connecting service to Brockton. The Service provides Rockland residents with a public transportation option to supermarkets and healthcare facilities in the neighboring towns, and is an example of a service that was made possible through the New Freedom Program.

BAT provides service on fifteen fixed routes. These routes operate from 6:00 A.M. to 9:20 P.M. Monday through Friday with reduced hours and routes on Saturday and Sunday. All but one BAT route originates at the BAT Centre on Commercial Street in Brockton. The routes are listed below.

Table 3.1: Brockton Area Transit Routes

Route Number	**Area/Description**
1	Montello via North Main Street
2	South Plaza/Campello via Main Street
3	V.A. Hospital via Belmont Street
4	Westgate Mall via Pleasant Street
4A	Westgate Mall via North Warren Avenue
5	Brockton Hospital via Centre Street
6	Massasoit via Crescent Street
8	Southfield via Warren and Plain Street
9	Pearl via West Elm and Torrey Street
10	Lisa & Howard via N. Quincy St & Court Street
11	Cary Hill & The Village
12	Ashmont
14	Stoughton
MM	Mini-Maller
BSU	Bridgewater State University Routes

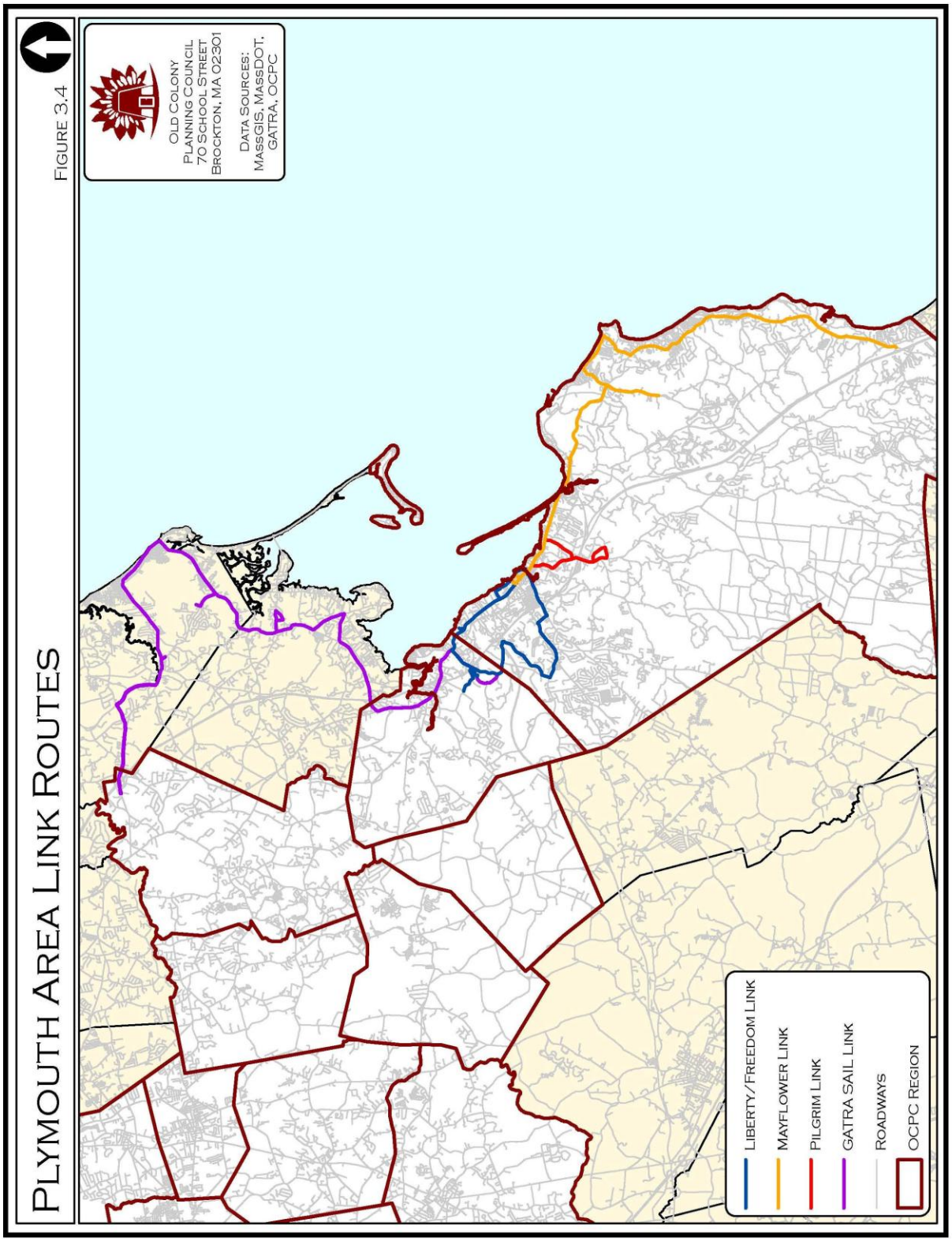
The BAT system links to the MBTA's Bus routes 230, 238, and 240. The MBTA bus 230 ends at the Montello Commuter Rail Station and connects with the BAT system bus route 10. The 238 bus connects at Crawford Square in Randolph with BAT bus 12 to Ashmont.


Brockton Area Transit Routes
Figure 3.3
Old Colony
Planning Council
70 School Street
Brockton, MA 02301
Data Sources:
MassGIS, MassDOT,
BAT, OCPC
BAT Centre
BAT Fixed Routes
BAT BSU Connector
BSU BAT Routes
Roadways
OCPC Region

Greater Attleboro Taunton Regional Authority (GATRA)

The Greater Attleboro Taunton Regional Transit Authority (GATRA) made up of twenty-six communities, of which Kingston, Pembroke and Plymouth are in the OCPC region. The Plymouth Area Link or PAL system is run by the Plymouth & Brockton bus company for GATRA and consists of four routes that operate Monday-Saturday and connect to the Plymouth and Kingston commuter rail stations.

GATRA has intermodal connections with the Plymouth and Brockton commuter buses at Exit 5 on Route 3. This connects the local service with an intercity carrier that travels both north to Boston and south to Cape Cod.


PLYMOUTH AREA LINK ROUTES
FIGURE 3.4
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
DATA SOURCES:
MASSGIS, MASSDOT, GATRA, OCPC
LIBERTY/FREEDOM LINK
MAYFLOWER LINK
PILGRIM LINK
GATRA SAIL LINK
ROADWAYS
OCPC REGION

Massachusetts Bay Transit Authority (MBTA)

MBTA bus routes #230, #238 and #240 operate in the OCPC region. The MBTA also contracts for provision of demand-responsive service for elderly and disabled passengers in their service region. The MBTA 230 bus serves the Montello station and connects to BAT Route 10. This bus runs to the Braintree Red Line, Quincy Adams, and then proceeds to the Quincy Center Stations. MBTA Bus 238 starts in Avon and connects with BAT Route 12 and the Red Line at both Quincy Adams Station and Quincy Station. The MBTA Bus 240 runs from Avon Center to the Ashmont Red Line Station via Crawford Square in Randolph. It operates on the same route as BAT's Ashmont service, Route 12. The routes operate seven days a week and on all holidays with more frequent service Monday-Friday.

Paratransit Services

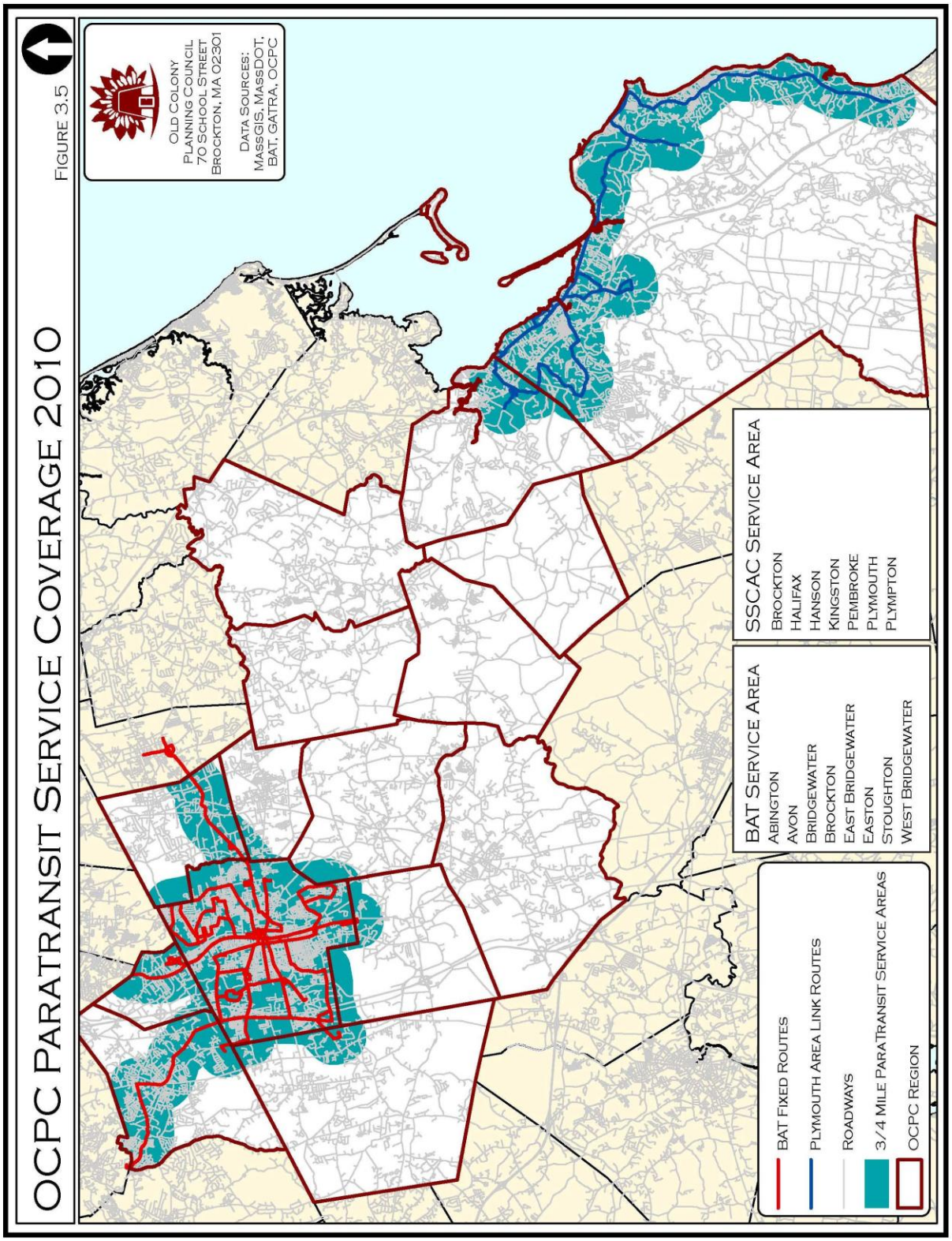
BAT and GATRA both offer paratransit services which are supported by additional human service trips provided by the South Shore Community Action Council, and several local Councils on Aging. In accordance with the Americans with Disabilities Act (ADA), BAT and GATRA provide service within ¾ of a mile of fixed transit routes. The MBTA provides service in communities within its region but not provide paratransit service in the Old Colony Region.

DIAL-A-BAT

BAT provides DIAL-A-BAT service for the towns of Brockton, Abington, Avon, Bridgewater, Easton, East Bridgewater, West Bridgewater, Whitman, and Stoughton. Individualized service provides curb-to-curb transportation for individuals ages 65 years and older, those who are disabled, and for authorized trips by clients of participating agencies. The only restriction is that the trip must start or end in any of these communities, with the exception of limited service to Boston area hospitals. DIAL-A-BAT transports passengers in subscription and dial-a-ride services using mini-buses specifically designed for transporting elderly and disabled persons. Additionally, DIAL-A-BAT provides limited service to Boston's medical facilities for treatment not available in the Brockton area.

GATRA Dial-a-Ride

GATRA provides Dial-a-Ride service for the towns of Kingston and Plymouth. Individualized service provides curb-to-curb transportation for individuals ages 60 years and older, those who are disabled, and for authorized trips by clients of participating agencies.


OCPC PARATRANSIT SERVICE COVERAGE 2010
FIGURE 3.5
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
DATA SOURCES:
MASSGIS, MASSDOT, BAT, GATRA, OCPC
SSCAC SERVICE AREA
BROCKTON
HALIFAX
HANSON
KINGSTON
PEMBROKE
PLYMOUTH
PLYMPTON
BAT SERVICE AREA
ABINGTON
AVON
BRIDGEWATER
BROCKTON
EAST BRIDGEWATER
EASTON
STOUGHTON
WEST BRIDGEWATER
BAT FIXED ROUTES
PLYMOUTH AREA LINK ROUTES
ROADWAYS
3/4 MILE PARATRANSIT SERVICE AREAS
OCPC REGION

Commuter Bus & Park-n-Ride Services and Locations

The Plymouth and Brockton Street Railway (P&B) and Bloom Bus companies provide commuter bus services in the Region. The commuter services are subsidized by the MBTA. P&B serves park and ride locations in Bourne, Plymouth, Kingston and Rockland and Bloom Bus serves park and ride locations in Raynham and West Bridgewater and pickup/drop-off locations (informal lots without parking) in Brockton and Easton. These services generally originate from points south of Boston with a final destination in Downtown Boston or Logan Airport.

Table 3.2: Park-n-Ride Locations and Services

Town	Location	Formal Lot	Informal Lot	Services Provided
Bourne	Route 3 at Route 6	X		Plymouth & Brockton, Carpool/Vanpool
Bridgewater	Route 24 & 104	X		Carpool/Vanpool
Brockton	Westgate Mall		X	Bloom Bus, No Parking Facilities
Easton	Route 106 at Route 138		X	Bloom Bus, No Parking Facilities
Kingston	Route 3A & 53 (Kingsbury Plaza)	X		Plymouth & Brockton, Carpool/Vanpool
Pembroke	Route 3 & 139	X		Carpool/Vanpool
Plymouth	Route 3 at Long Pond Road	X		Plymouth & Brockton, Carpool/Vanpool
Plymouth	Commerce Way at Route 44	X		Carpool/Vanpool
Raynham	Route 138 at Raynham Dog Track	X		Bloom Bus, Carpool/Vanpool
Rockland	Route 3 & 228	X		Plymouth & Brockton, Carpool/Vanpool
West Bridgewater	Route 24 & 106	X		Bloom Bus, Carpool/Vanpool

Air Transportation Network

Within the Old Colony Region there are three airports. Aviation services are provided at the Plymouth Municipal Regional Airport and two local private airports: Halifax and Hanson. The region's airports are a vital component of the overall transportation network serving personal, business and recreational purpose.

Five other municipally owned airports are located in communities adjacent to the region: Mansfield, Marshfield, New Bedford, Norwood and Taunton. Only New Bedford has scheduled passenger service.

Plymouth: Plymouth Municipal Airport

Plymouth's airport is the only publicly owned airfield in the region. The Town of Plymouth owns the facility with no scheduled passenger or freight service. The airport functions as a general aviation facility serving private operators and individuals and consists predominantly of recreational, business trips and land flight instructions. The facility contains 40 hangars and aviation fuel and repair services. In addition, the airport has implemented safety and security measures as required by the Massachusetts Aeronautics Commission (MAC) and has an emergency preparedness plan. The airport is the headquarters to the Massachusetts State Police Air Wing and Plymouth County Fire plane. Boston MedFlight helicopters are also an active tenant of the airport. The airport recently completed an extension of its two paved runways to a size of 4,350' x 75' and 3,350' x 75' respectively to better accommodate corporate aircraft.

Halifax: Monponsett Seaplane Base

This is a seasonal facility and is close to Hanson's Cranland Airport, which supplies services to the seaplane base. Halifax utilizes the waters of Monponsett Pond, where the seaplanes land on an unmarked area of the pond. Dock space and mooring facilities are available, as is flight instruction. Emergency-only fuel and repair services are also available from Cranland. Recreational trips are served at this facility. There is no scheduled freight or passenger service and air traffic growth is minimal.

Hanson: Cranland Airport

This small Hanson airport is privately owned and publicly accessible. It provides one non-illuminated asphalt runway 1,760' x 60'. The facility contains seven hangars and emergency-only aviation fuel and repair services. This general aviation facility serves recreational trips. There is no scheduled freight or passenger service. There are no plans for expansion of services or capital improvements at this time.

Impacts on Roadways & Bridges

Roads and bridges are a vital part of the transportation infrastructure in the OCPC Region and are used daily by almost all of the region's 320,000 residents who drive alone, carpool, and use public transit services such as BAT, GATRA, commuter buses or paratransit services. The roads and bridges in the Old Colony region are considered some of the oldest in the country and when combined with severe weather events, this infrastructure is susceptible to major damage.

Precipitation Impacts

The most immediate impact of more intense precipitation include the increased flooding of bridges and roads, especially those near the coastline and those located within 100 & 500 Year Flood Zones. While the potential changes in average annual precipitation are likely to have little impact, an increase in the intensity of individual extreme rainfall events may have significant implications for roads and bridges. An increase in the frequency of extreme precipitation events result in more frequent short-term flooding and bridge scour, as well as more culvert washouts that exceed the capacity of the current stormwater management infrastructure.[1]

3.6 Figure: Flooding during the March 2010 storm in the City of Brockton

Precipitation and moisture also contribute to the weathering of transportation infrastructure. The premature deterioration of roads, bridges, parking garages, and other concrete structures are magnified where climate change induces more frequent precipitation events, especially in areas such as the Northeast where acid rain is a problem.

Low-lying bridges and tunnel entrances for roads are also more susceptible to flooding, and thousands of culverts could be undersized for flows. In the near future, engineers must be prepared to deal with the resulting erosion and subsidence of road bases as well as erosion and scouring of bridge supports. Interruption of road and bridge traffic is likely to become more common with more frequent flooding.[2]

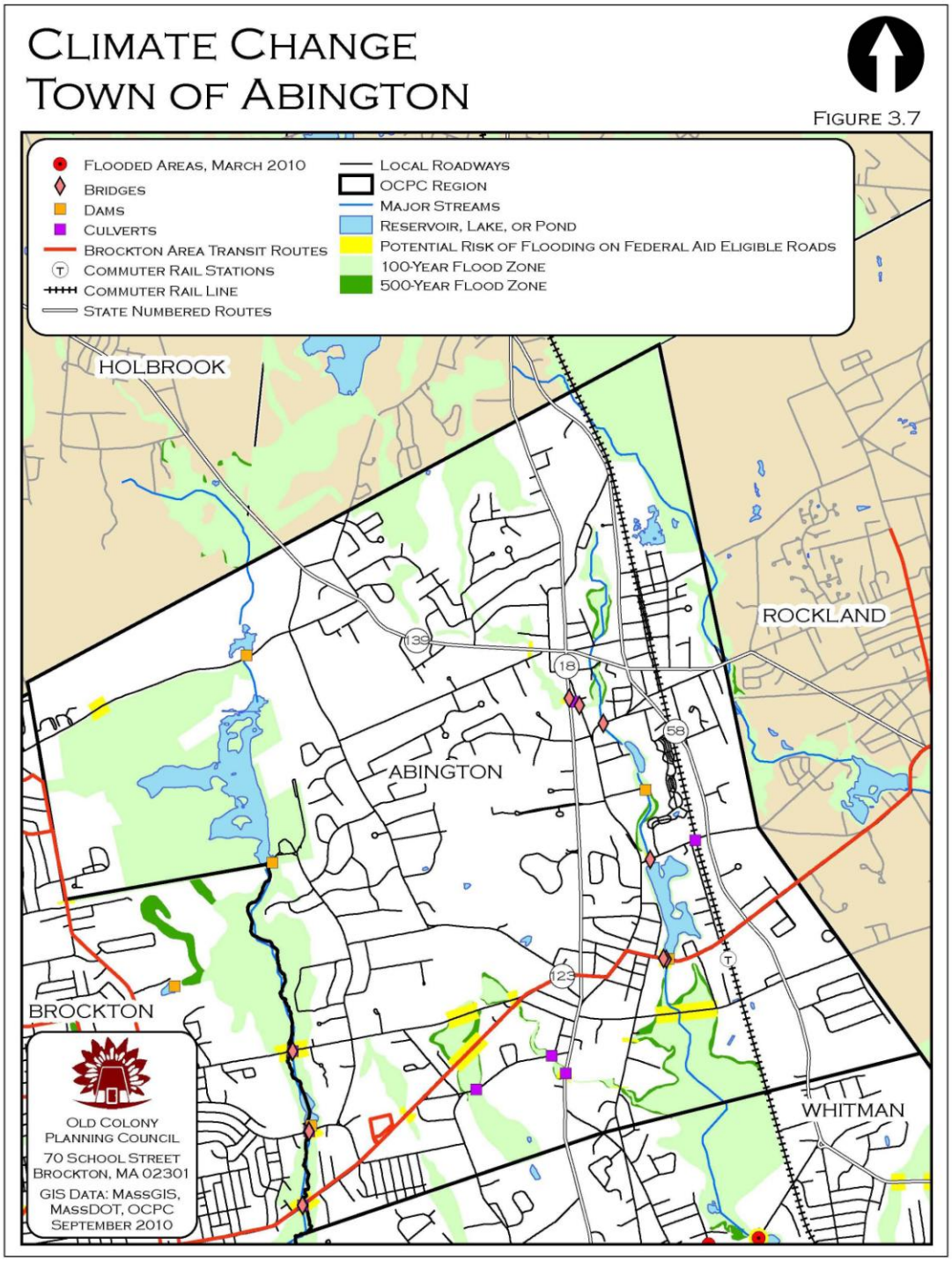
Although the impact of sea level rise is limited to coastal areas, the effect of intense precipitation on land transportation infrastructure and operations is more widespread. For example, two record-breaking rainstorms in March 2010 resulted in flash flooding in metropolitan Boston and

[1] *U.S. Climate Change Science Program Synthesis and Assessment Product 4.7, Impacts on Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 1: March 2008 http://www.climatescience.gov/Library/sap/sap4-7/final-report/sap4-7-final-all.pdf*

[2] *U.S. DOT Center for Climate Change and Environmental Forecasting, The Potential Impacts of Climate Change on Transportation, Federal Research Partnership Workshop, Summary and Discussion Papers: October 2002 http://climate.dot.gov/documents/workshop1002/workshop.pdf#page=84*

its suburbs. The two storms dumped approximately 15 inches of rain within a period of two weeks, making this past March the second wettest month on record, since records were kept beginning in 1872.

The storms of March 2010 caused extensive flooding on numerous streets and bridges in the OCPC Region causing travel delays as many roads and bridges were closed. In an effort to determine the locations affected by the flooding, the OCPC sent letters to each of the fifteen Public Works/Highway Departments in the region asking which areas were flooded by the March storms. A table of flooded areas and accompanying maps for each the fifteen communities in the OCPC region are posted below. The towns of Abington and Avon were not affected by these storms, but maps identifying potential flooding hazards are included. These maps will also highlight 100 & 500 Flood Zones, and locations of potential flooding risks on federal aid eligible roads. Please keep in mind that in regards to the letters that were sent out following the March 2010 storms, some communities are still in the process of responding to our request and other communities were not as severely affected as others.


CLIMATE CHANGE
TOWN OF ABINGTON
FIGURE 3.7
FLOODED AREAS, MARCH 2010
BRIDGES
DAMS
CULVERTS
BROCKTON AREA TRANSIT ROUTES
COMMUTER RAIL STATIONS
COMMUTER RAIL LINE
STATE NUMBERED ROUTES
LOCAL ROADWAYS
OCPC REGION
MAJOR STREAMS
RESERVOIR, LAKE, OR POND
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
HOLBROOK
ROCKLAND
ABINGTON
BROCKTON
WHITMAN
139
18
58
123
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC
SEPTEMBER 2010

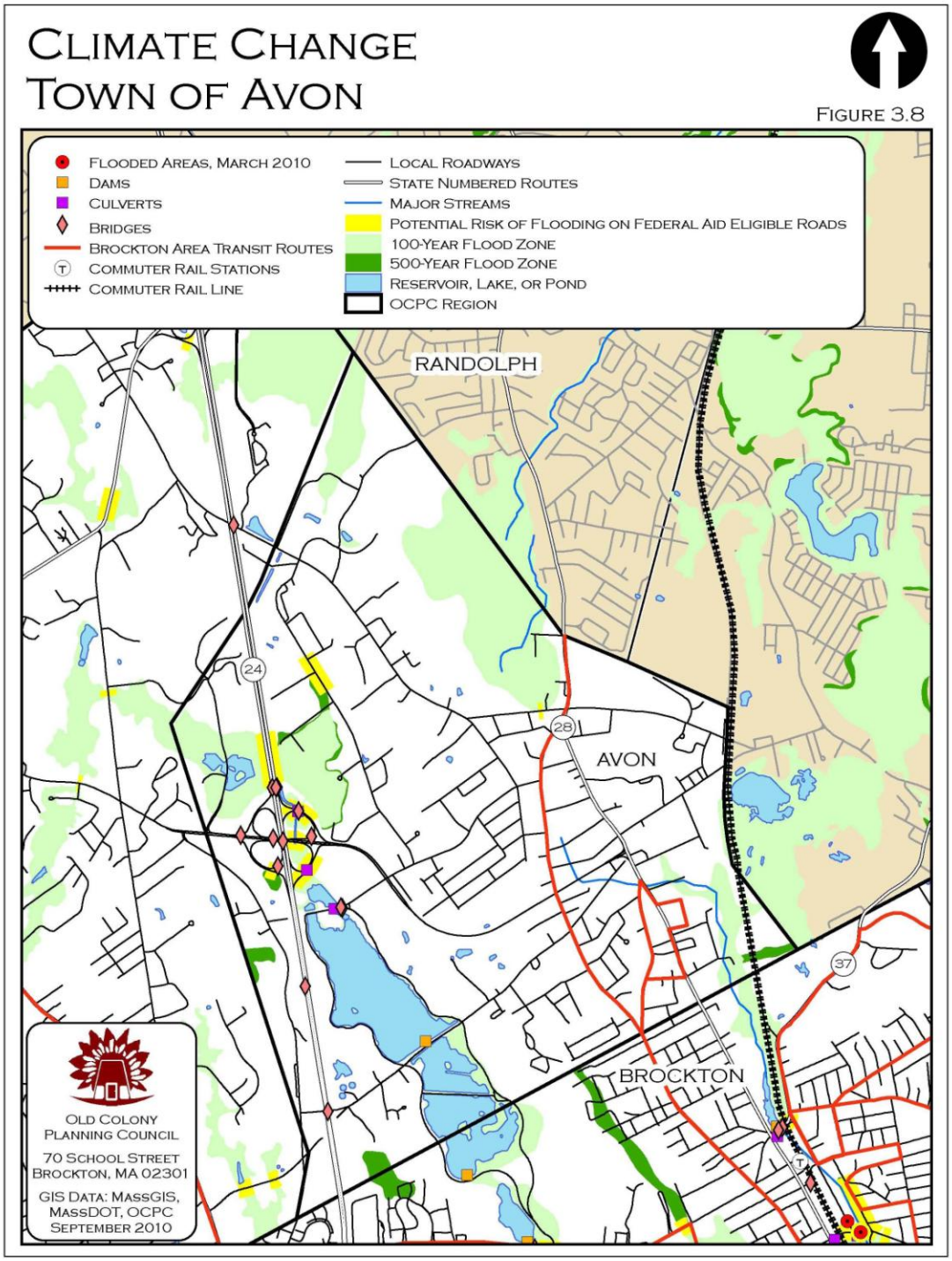

CLIMATE CHANGE
TOWN OF AVON
FIGURE 3.8
FLOODED AREAS, MARCH 2010
DAMS
CULVERTS
BRIDGES
BROCKTON AREA TRANSIT ROUTES
COMMUTER RAIL STATIONS
COMMUTER RAIL LINE
LOCAL ROADWAYS
STATE NUMBERED ROUTES
MAJOR STREAMS
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
RESERVOIR, LAKE, OR POND
OCPC REGION
RANDOLPH
AVON
BROCKTON
24
28
37
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC SEPTEMBER 2010

Table 3.3: Precipitation Impact Town of Bridgewater
List of Flooded Areas from Bridgewater's Highway & Forestry Department
▪ Bridge Street Bridge at the Matfield River ▪ Water/Wood Street at South Brook ▪ Cherry Street at the Taunton River ▪ Summer Street at the Taunton River ▪ Titicut Street at the Taunton River ▪ Hayward Street at the Town River ▪ Hayward Street (foot bridge) Brook from Skeeter Mill Pond ▪ Riverview Drive at the Matfield River

Source: Data collected during March 2010 Storm

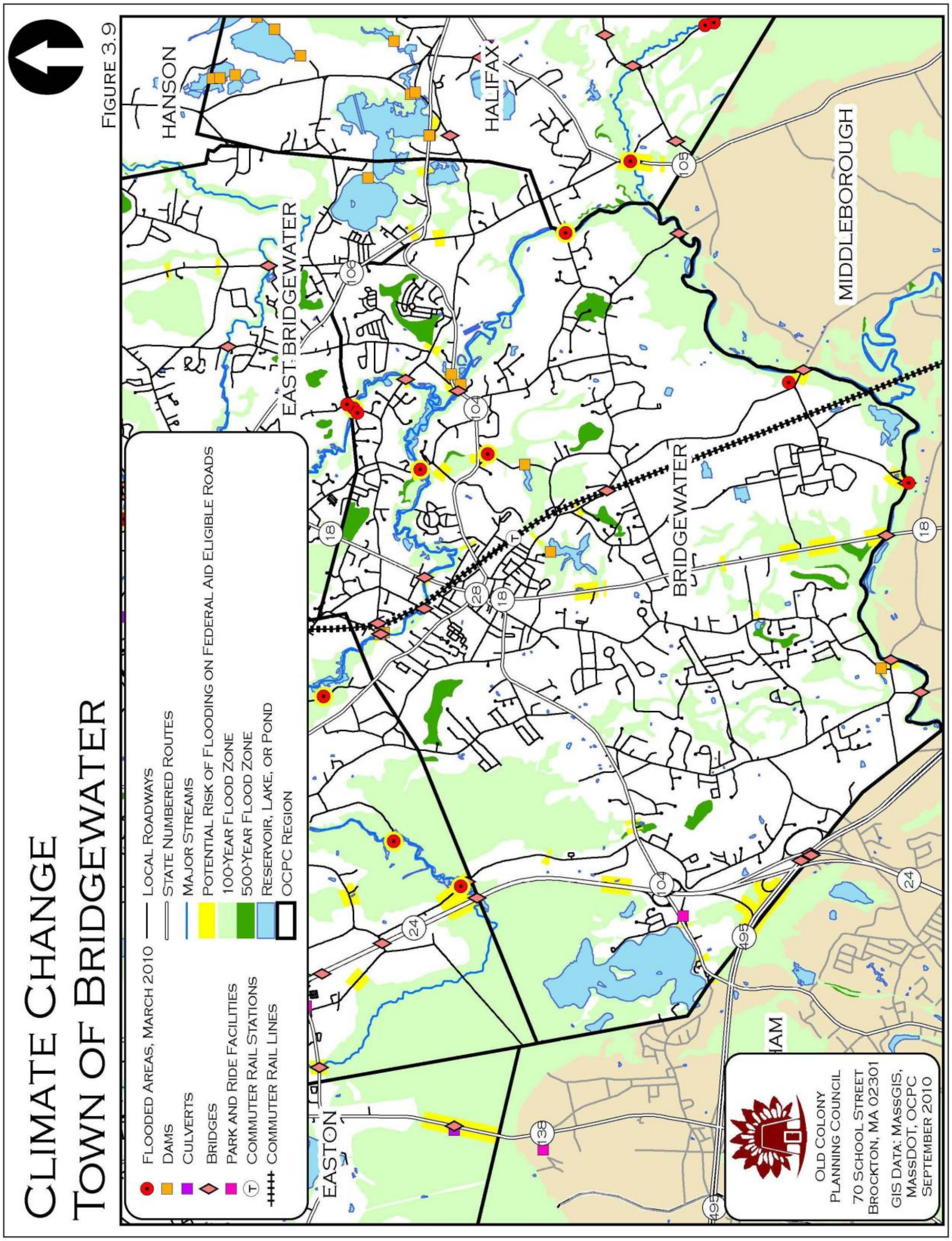

Climate Change
Town of Bridgewater
Figure 3.9
Flooded Areas, March 2010
Dams
Culverts
Bridges
Park and Ride Facilities
Commuter Rail Stations
Commuter Rail Lines
Local Roadways
State Numbered Routes
Major Streams
Potential Risk of Flooding on Federal Aid Eligible Roads
100-Year Flood Zone
500-Year Flood Zone
Reservoir, Lake, or Pond
OCPC Region
HANSON
HALIFAX
EAST BRIDGEWATER
BRIDGEWATER
MIDDLEBOROUGH
EASTON
Old Colony Planning Council
70 School Street
Brockton, MA 02301
GIS Data: MassGIS, MassDOT, OCPC
September 2010

Table 3.4: Precipitation Impact City of Brockton
List of Flooded Areas from Brockton's Public Works Department
▪ Alger Street from Route 14 to the East Bridgewater Town Line ▪ Ames Street from Montello Street to Intervale Street ▪ Spark Street from Ames Street to Field Street ▪ Poplar Road from Spring Street to Fenway Circle ▪ Spring Street from Poplar Road to Belmont Avenue ▪ Belmont Avenue from West Elm Street to Pleasant Street ▪ Fenway Circle from Poplar Road to Belmont Avenue ▪ Silver Road from Ash Street to Belmont Avenue ▪ Park Road from Ash Street to Belmont Avenue ▪ Sycamore Avenue from Ash Street to Belmont Avenue ▪ Newbury Street from West Elm Street to Highland Street ▪ Ellsworth Street from North Arlington Street to Newbury Street ▪ Prospect Street from Belair Street to Pleasant Street (BAT Bus Route) ▪ Meadowbrook Road from Sargent's Way to Plain Street ▪ Riverview Avenue from Perkins Avenue to North Leyden Street ▪ Tiffany Drive from Pearl Street to Hatchfield Drive ▪ Teele Street from Riverside Street, Westerly to Trout Brook

Source: Data collected during March 2010 Storm

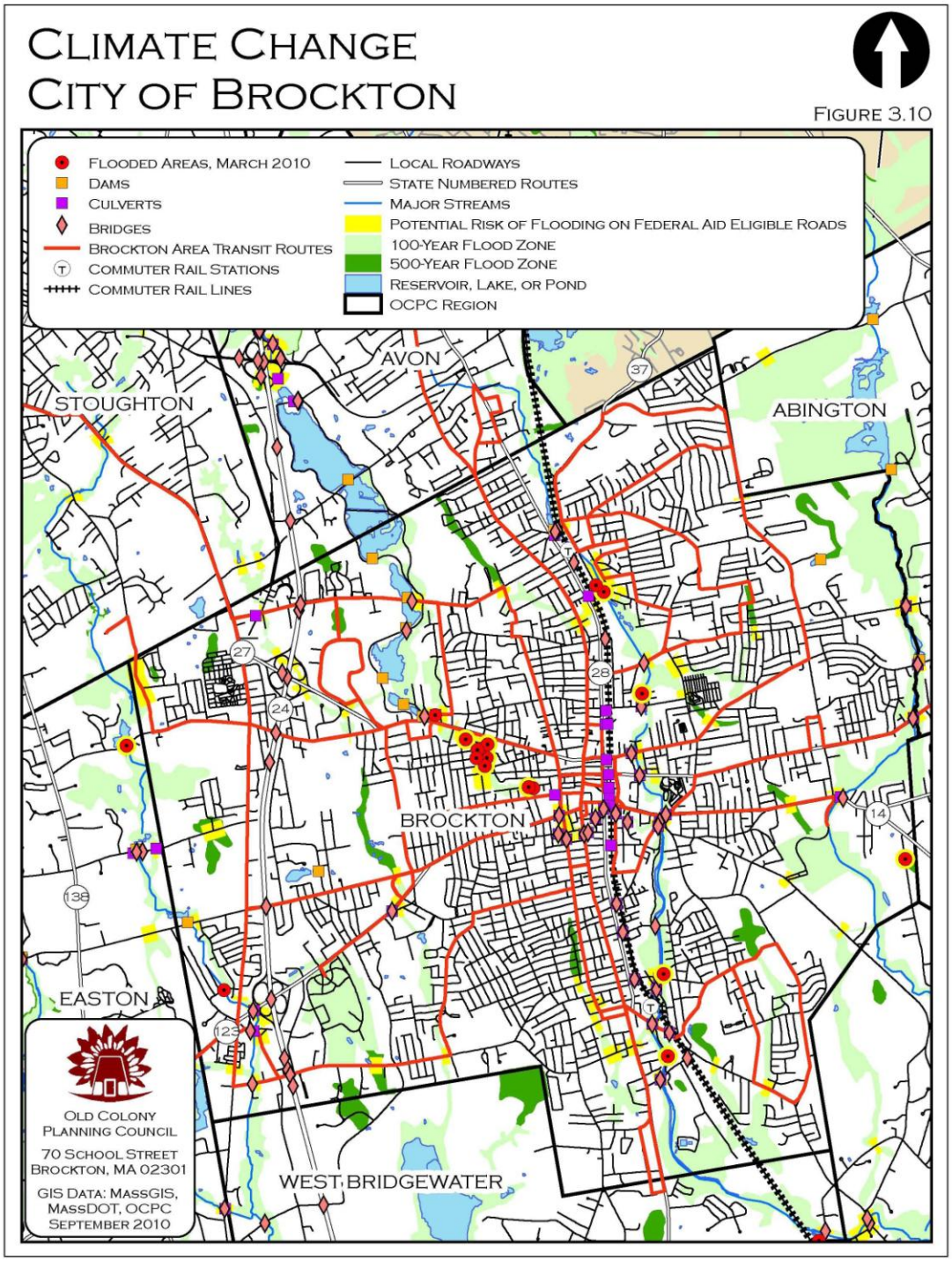

CLIMATE CHANGE
CITY OF BROCKTON
FIGURE 3.10
FLOODED AREAS, MARCH 2010
DAMS
CULVERTS
BRIDGES
BROCKTON AREA TRANSIT ROUTES
COMMUTER RAIL STATIONS
COMMUTER RAIL LINES
LOCAL ROADWAYS
STATE NUMBERED ROUTES
MAJOR STREAMS
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
RESERVOIR, LAKE, OR POND
OCPC REGION
AVON
STOUGHTON
ABINGTON
BROCKTON
EASTON
WEST BRIDGEWATER
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC
SEPTEMBER 2010

Table 3.5: Precipitation Impact Town of East Bridgewater
List of Flooded Areas from East Bridgewater's Public Works Department
▪ Spring Street at the Matfield River ▪ Bedford Street (Route 18) and Whitman Street (Route 106) at the Matfield River ▪ Winter Street at an unnamed brook ▪ West Union Street at the Matfield River ▪ Pleasant Street at the Matfield River ▪ Belmont Street at the Matfield River ▪ South Street at a low-lying property ▪ Church Street at a low-lying property ▪ Harvard Street at Meadow Brook ▪ Willow Avenue at an unnamed brook

Source: Data collected during March 2010 Storm

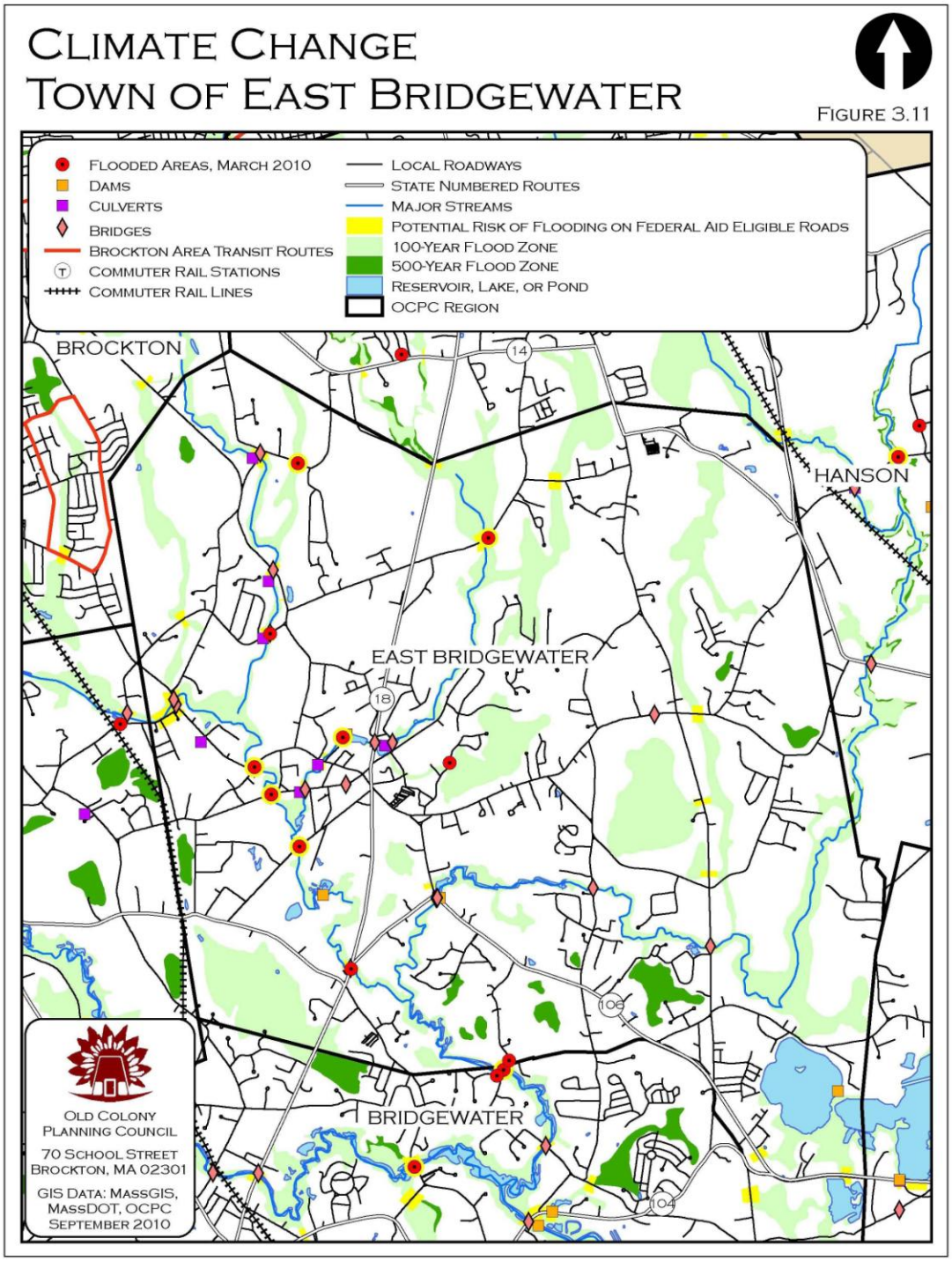

CLIMATE CHANGE
TOWN OF EAST BRIDGEWATER
FIGURE 3.11
FLOODED AREAS, MARCH 2010
DAMS
CULVERTS
BRIDGES
BROCKTON AREA TRANSIT ROUTES
COMMUTER RAIL STATIONS
COMMUTER RAIL LINES
LOCAL ROADWAYS
STATE NUMBERED ROUTES
MAJOR STREAMS
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
RESERVOIR, LAKE, OR POND
OCPC REGION
BROCKTON
HANSON
EAST BRIDGEWATER
BRIDGEWATER
14
18
106
104
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC SEPTEMBER 2010

Table 3.6: Precipitation Impact Town of Easton
List of Flooded Areas from Easton's Public Works Department
▪ Bay Road between Highland Street and Dean Street ▪ Union Street at French's Pond ▪ Depot Street between Blackbrook Road and Center Street ▪ Elm Street near Whitman Brook Drive ▪ Chestnut Street ▪ Canton Street near the Stoughton Town Line ▪ Purchase Street near the Easton Country Club ▪ Prospect Street near the Railroad Right-of-Way

Source: Data collected during March 2010 Storm

Climate Change
Town of Easton

Figure 3.12

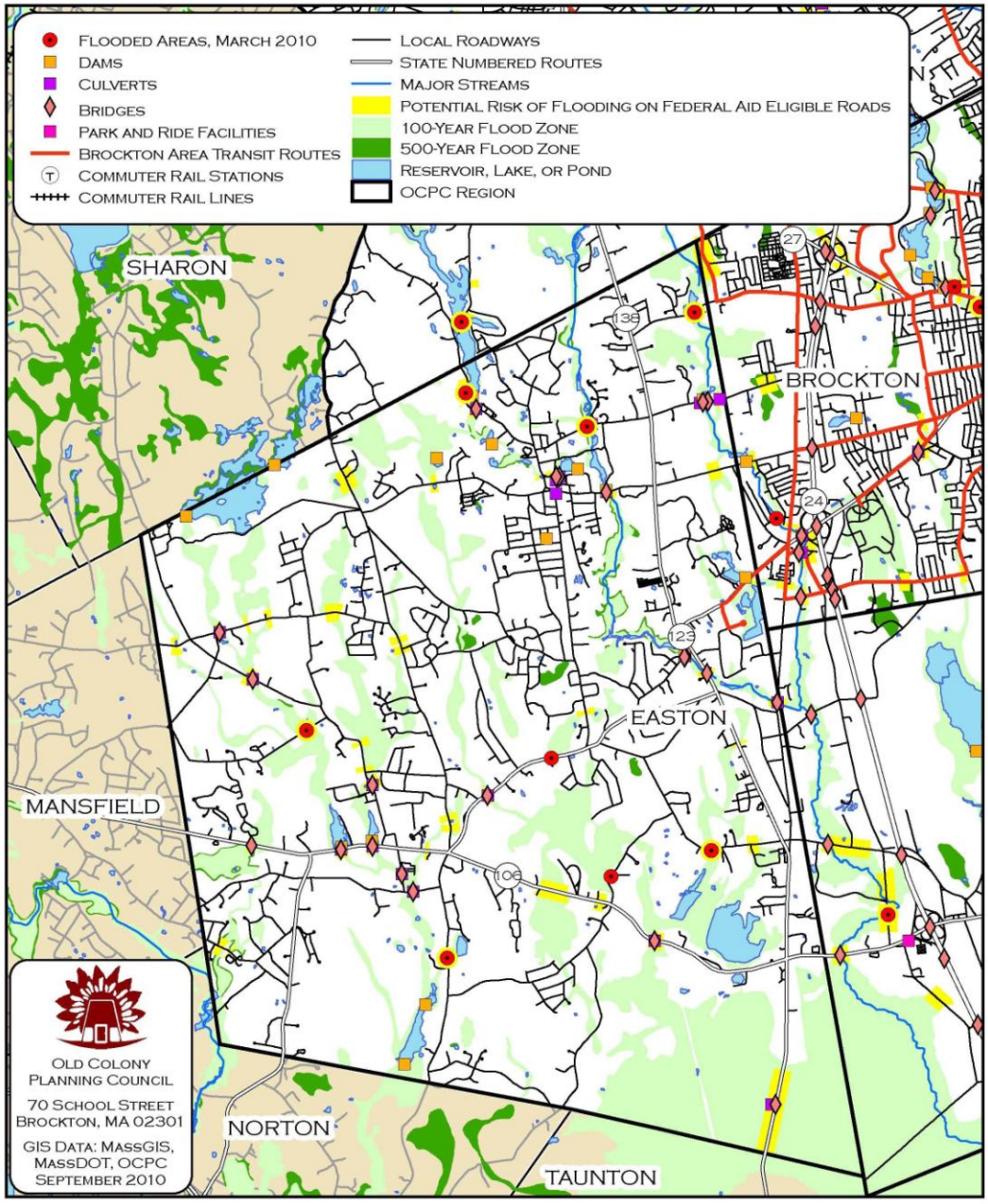


Table 3.7: Precipitation Impact Town of Halifax
List of Flooded Areas from Halifax's Highway Department
▪ Two Areas on South Street, a total of 500 feet ▪ Hayward Street on the north side of the culvert, 300 feet ▪ Three Areas on Wood Street, a total of 600 feet ▪ Pratt Street at Thompson Street, 300 feet at intersection ▪ Before and after the Bridge on East Street, 250 feet ▪ Oak Street and Aldana Street, 200 feet under Railroad Bridge

Source: Data collected during March 2010 Storm

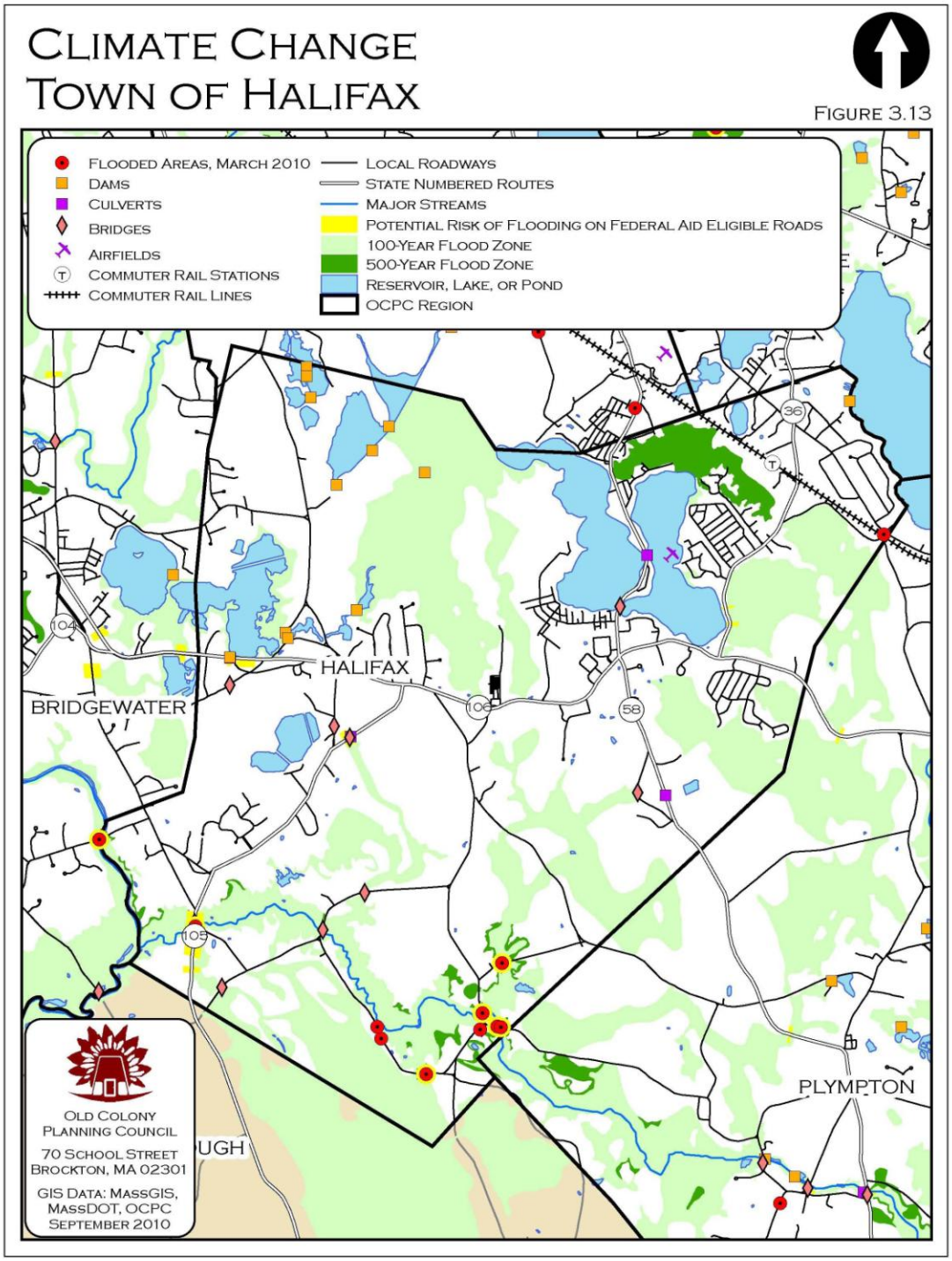

CLIMATE CHANGE
TOWN OF HALIFAX
FIGURE 3.13
FLOODED AREAS, MARCH 2010
DAMS
CULVERTS
BRIDGES
AIRFIELDS
COMMUTER RAIL STATIONS
COMMUTER RAIL LINES
LOCAL ROADWAYS
STATE NUMBERED ROUTES
MAJOR STREAMS
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
RESERVOIR, LAKE, OR POND
OCPC REGION
HALIFAX
BRIDGEWATER
PLYMPTON
104
106
58
36
105
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC SEPTEMBER 2010

Table 3.8: Precipitation Impact Town of Hanson
List of Flooded Areas from Hanson's Highway Department
▪ Maquan Street (Route 14) near Pinegrove Avenue ▪ West Washington Street (Route 14) near House #708 ▪ West Washington Street near Pennsylvania Avenue ▪ Indian Trail near House #97 ▪ Pleasant Street near House #564 ▪ East Washington Street at the Pembroke Town Line ▪ Winter Street near House #264 ▪ King Street near House #264 ▪ Robinson Street near Main Street (Route 27) ▪ Squantum Avenue near Monponsett Street (Route 58)

Source: Data collected during March 2010 Storm

Climate Change
Town of Hanson

Figure 3.14

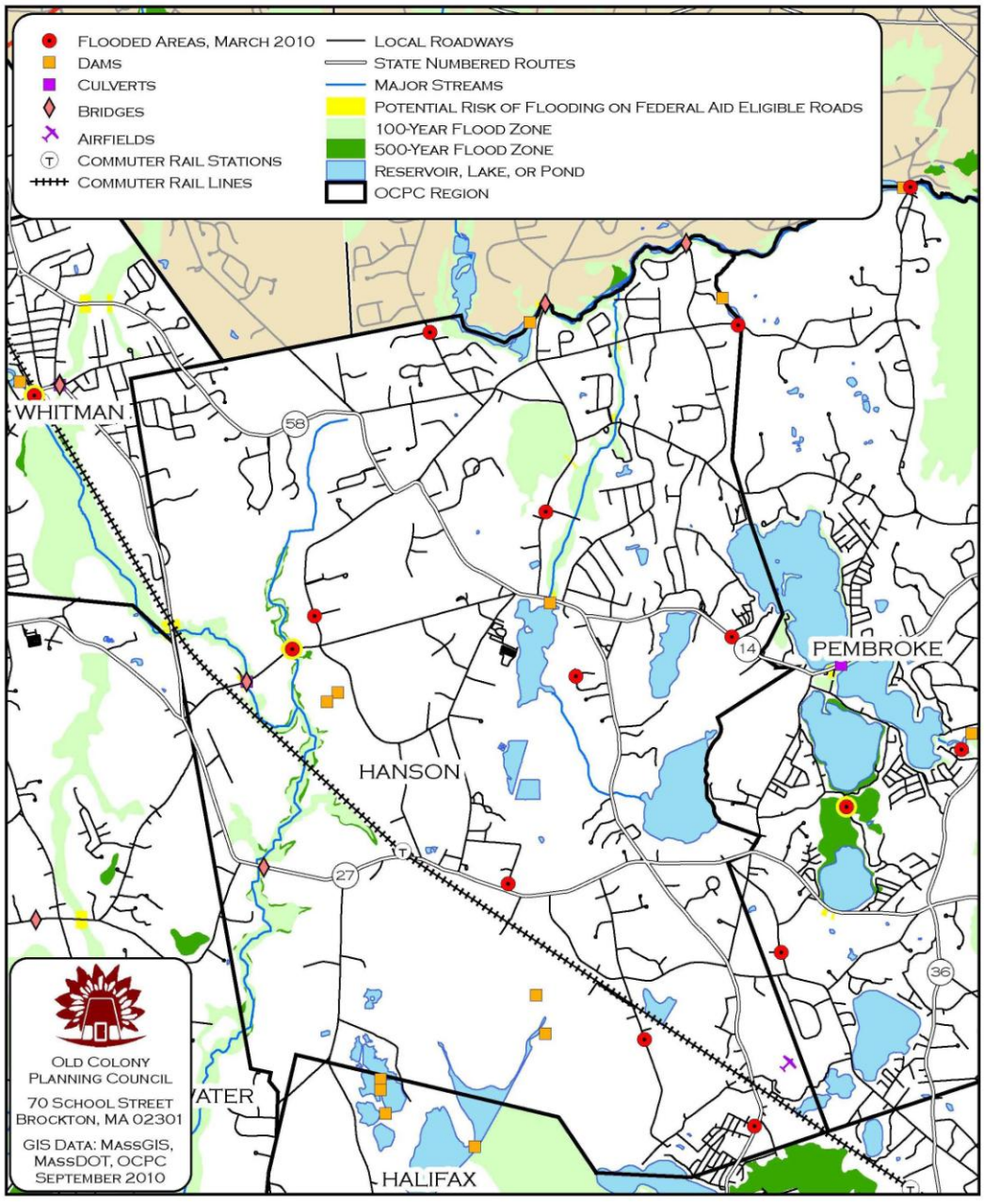


Table 3.9: Precipitation Impact Town of Kingston
List of Flooded Areas from Kingston's Highway Department
▪ Brook Street (Route 80) at the Second Brook ▪ • Main Street (Route 106) in front of St. Joseph's Church

Source: Data collected during March 2010 Storm

Climate Change
Town of Kingston

Figure 3.15

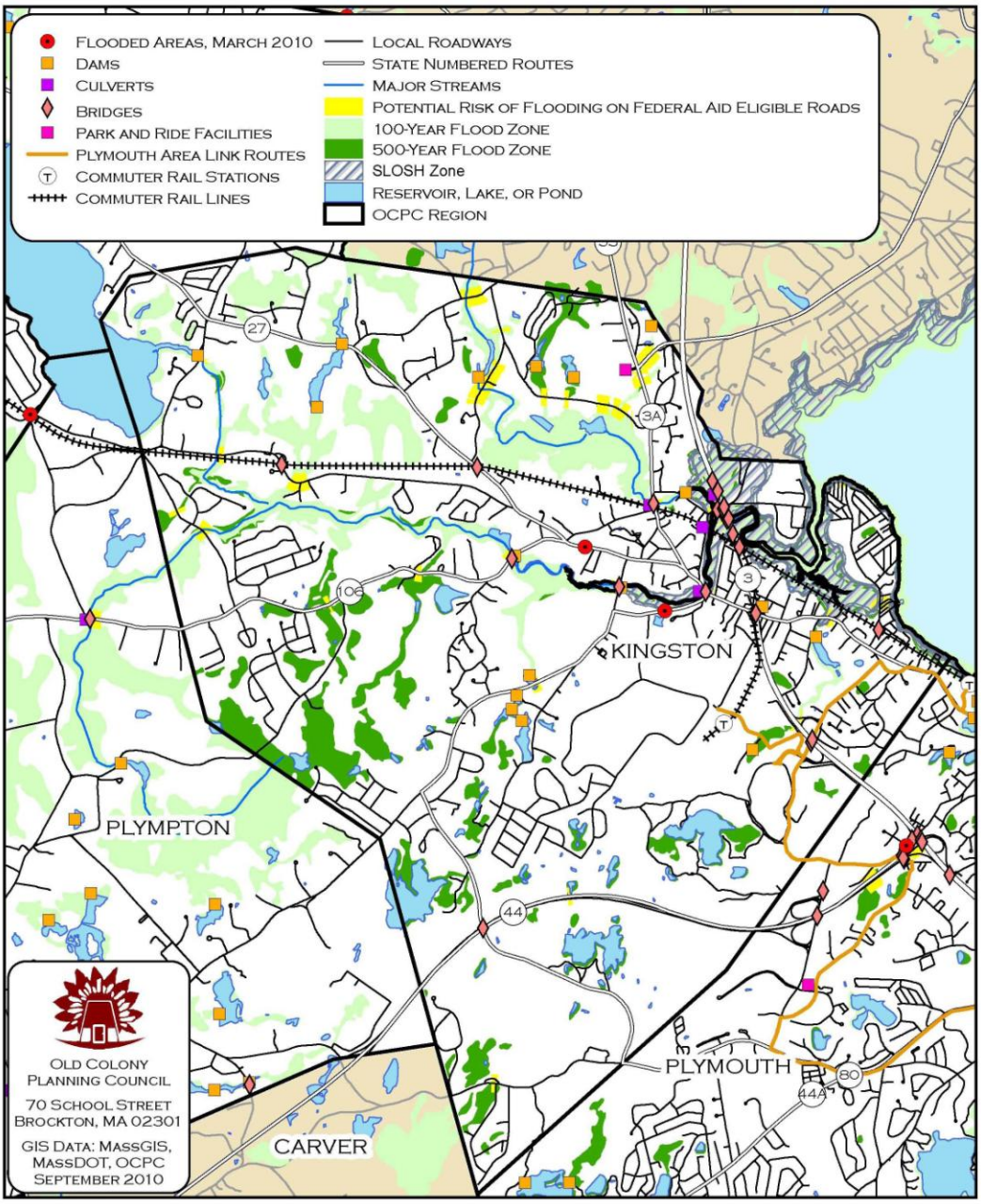


Table 3.10: Precipitation Impact Town of Pembroke
List of Flooded Areas from Pembroke's Public Works Department
▪ Mill Pond Road (Homes flooded, DPW assisted) ▪ Glenwood Road (Homes flooded, DPW assisted) ▪ Brenda Lane at Plymouth Street (Water flowing across the street, not pumped, leech CB's back-up and culvert (cross) can't handle) ▪ Dwelley Street at the Hanson Town Line ▪ Birch Street at the Duxbury Town Line ▪ Mill Street (Houses getting flooded, pumped off for first time on April 1 via fire truck. ▪ Low point was at House #54 and #66 and it was crossing the road) ▪ Lake Shore Drive (Culvert from Lower Chandler Pond could not handle the volume and went over road, with a danger of washing out the road, but eventually subsided) ▪ Mill Pond off Hobomock Street (Control structure could not handle, danger washing out Hobomock Street, removed fish ladder and sandbagged to prevent structure from failing) ▪ Indian Head River dam at West Elm Street at the Hanover Town Line ▪ Valley Street at Duxbury Town Line-Upper Chandler Pond (Culvert handled it, road not breached with these last 2 storms, but has in the past. Cranberry owners dropped level before storm and it was O.K.)

Source: Data collected during March 2010 Storm

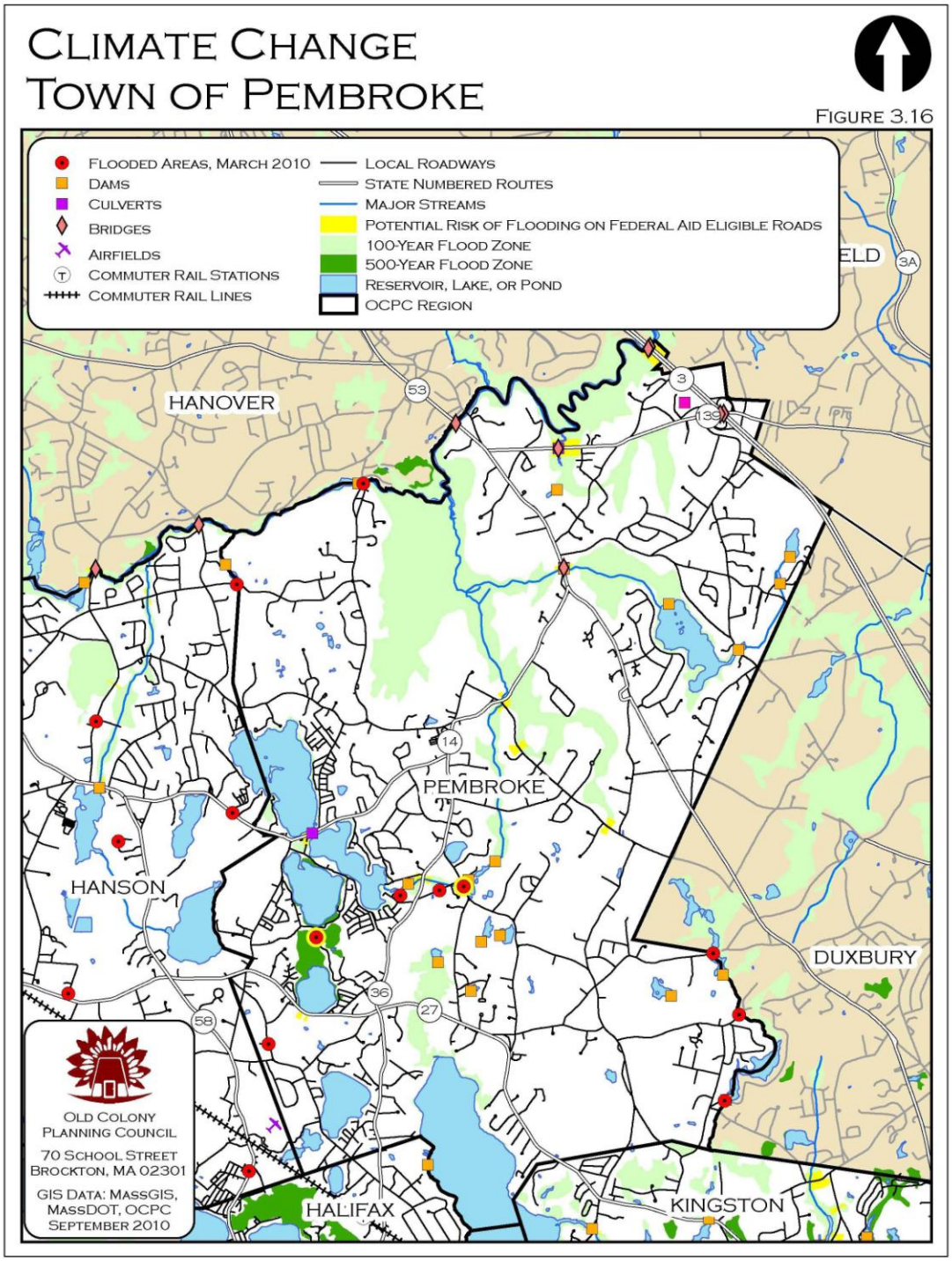

CLIMATE CHANGE
TOWN OF PEMBROKE
FIGURE 3.16
FLOODED AREAS, MARCH 2010
DAMS
CULVERTS
BRIDGES
AIRFIELDS
COMMUTER RAIL STATIONS
COMMUTER RAIL LINES
LOCAL ROADWAYS
STATE NUMBERED ROUTES
MAJOR STREAMS
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
RESERVOIR, LAKE, OR POND
OCPC REGION
HANOVER
PEMBROKE
HANSON
DUXBURY
HALIFAX
KINGSTON
53
3
139
3A
14
36
27
58
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC SEPTEMBER 2010

Table 3.11: Precipitation Impact Town of Plymouth
List of Flooded Areas from Plymouth's Public Works Department
▪ Cherry Street at P.A. Landers ▪ Fitzgerald Avenue at Beacon Street ▪ Goldfinch Lane ▪ Newfield Street ▪ Lisa Avenue ▪ Sandwich Street by Obery Street ▪ 11 Hallorans Way ▪ Madlyn Street at Lancaster Avenue ▪ 18 Nickerson Street ▪ Standish Avenue System behind Goddard Court ▪ Buttermilk Bay Area-Multiple Locations ▪ Blueberry Lane ▪ Long Pond Road (Unpaved Southern Section) ▪ Kings Pond Plain Road Subdivision ▪ Taylor Avenue ▪ Hedge Pond System near Hedge Elementary School, Standish Avenue ▪ Tall Pines Subdivision ▪ Federal Furnace Road in the vicinity of House # 590, Diane Lane, Saby's Pond and the American Legion Building

Source: Data collected during March 2010 Storm

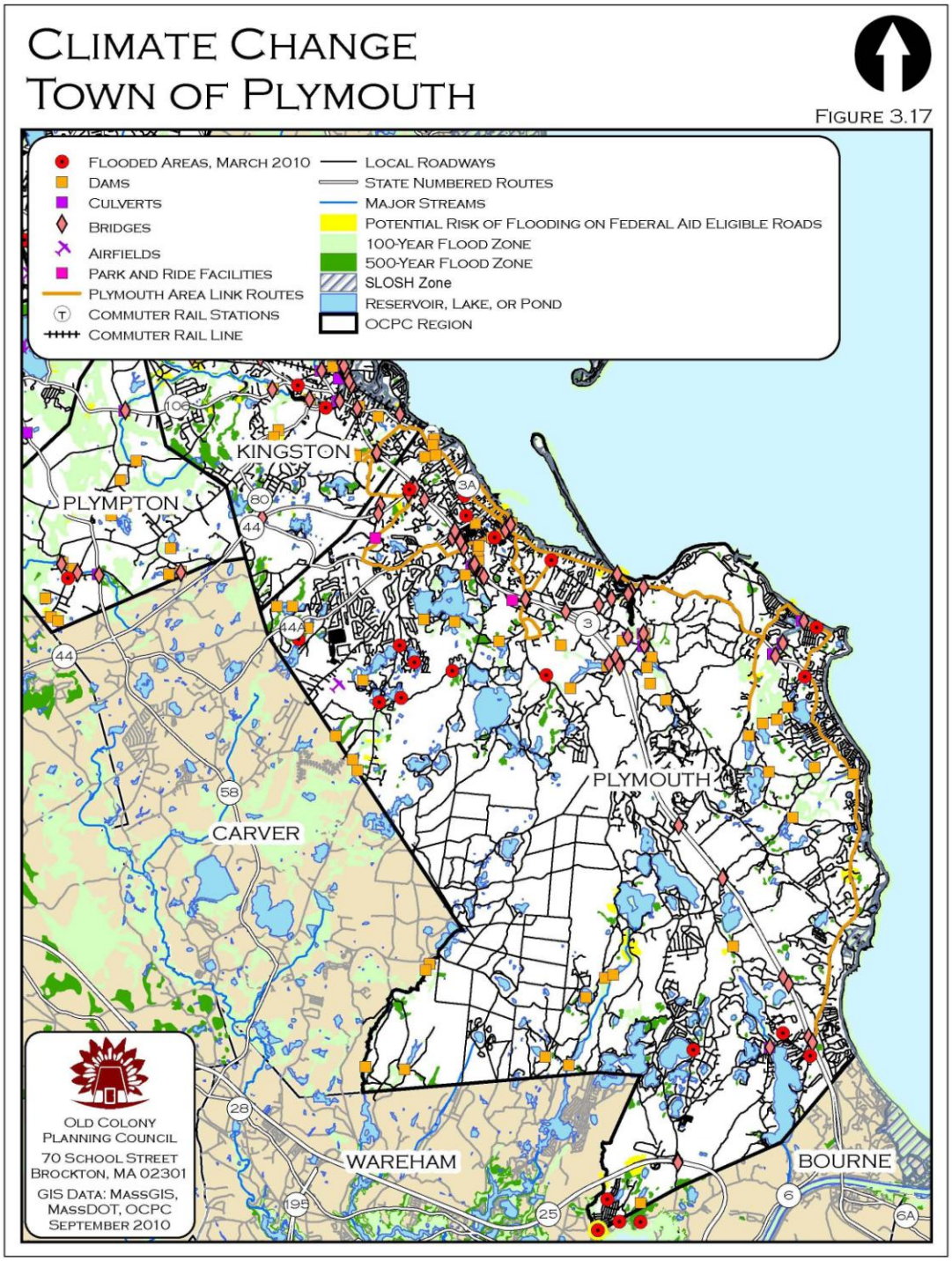

CLIMATE CHANGE
TOWN OF PLYMOUTH
FIGURE 3.17
FLOODED AREAS, MARCH 2010
DAMS
CULVERTS
BRIDGES
AIRFIELDS
PARK AND RIDE FACILITIES
PLYMOUTH AREA LINK ROUTES
COMMUTER RAIL STATIONS
COMMUTER RAIL LINE
LOCAL ROADWAYS
STATE NUMBERED ROUTES
MAJOR STREAMS
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
SLOSH Zone
RESERVOIR, LAKE, OR POND
OCPC REGION
KINGSTON
PLYMPTON
PLYMOUTH
CARVER
WAREHAM
BOURNE
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC
SEPTEMBER 2010

Table 3.12: Precipitation Impact Town of Plympton
List of Flooded Areas from Plympton's Highway Department
▪ Prospect Street, just south of Parsonage Road and Winnetuxet Road

Source: Data collected during March 2010 Storm

CLIMATE CHANGE
TOWN OF PLYMPTON

FIGURE 3.18

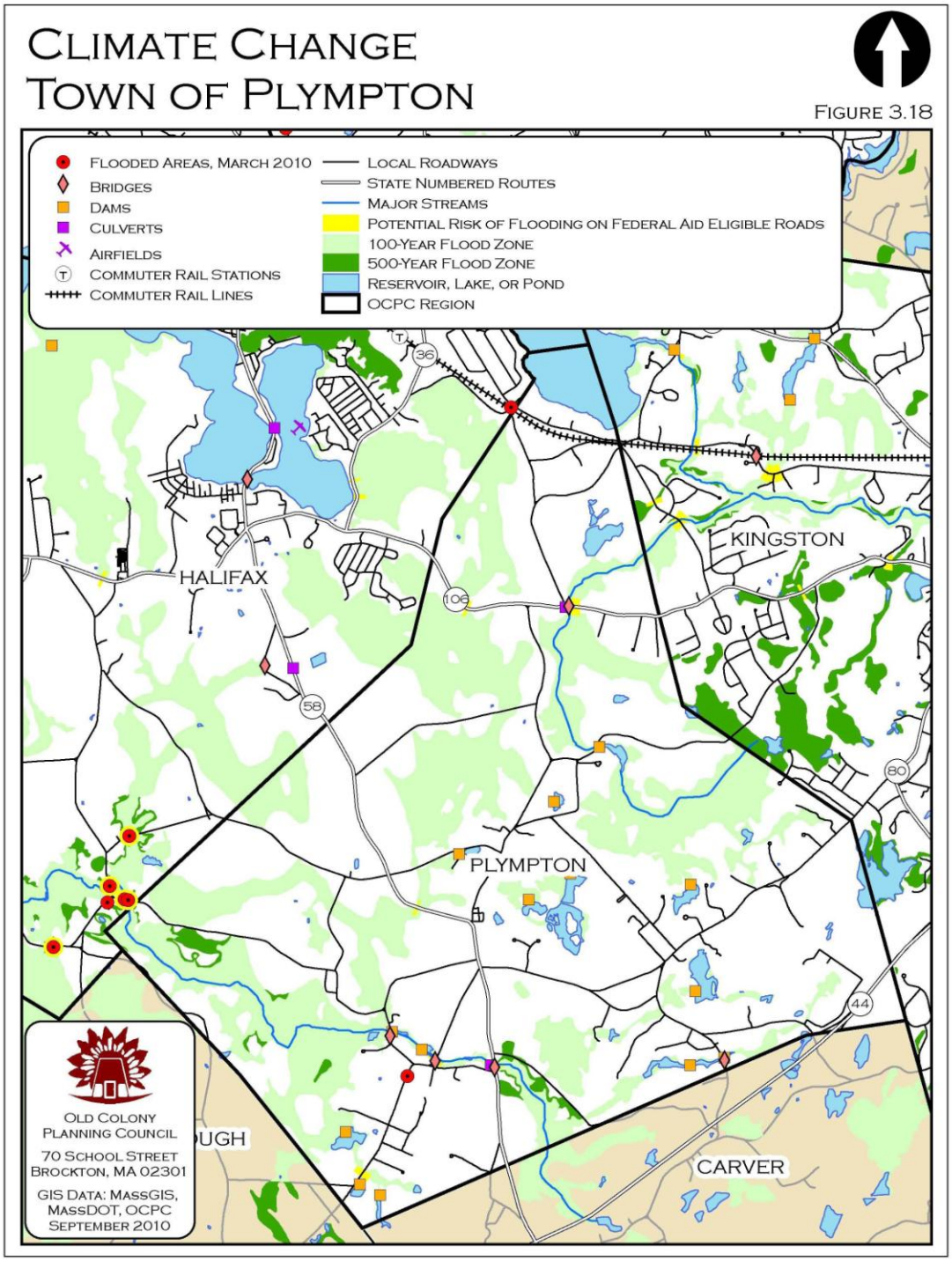


Table 3.13: Precipitation Impact Town of Stoughton
List of Flooded Areas from Stoughton's Public Works Department
▪ Gay Street at Mead's Meadow ▪ Morton Street at Route 138 ▪ School Street & Elm Street ▪ West Street at Ames Pond

Source: Data collected during March 2010 Storm

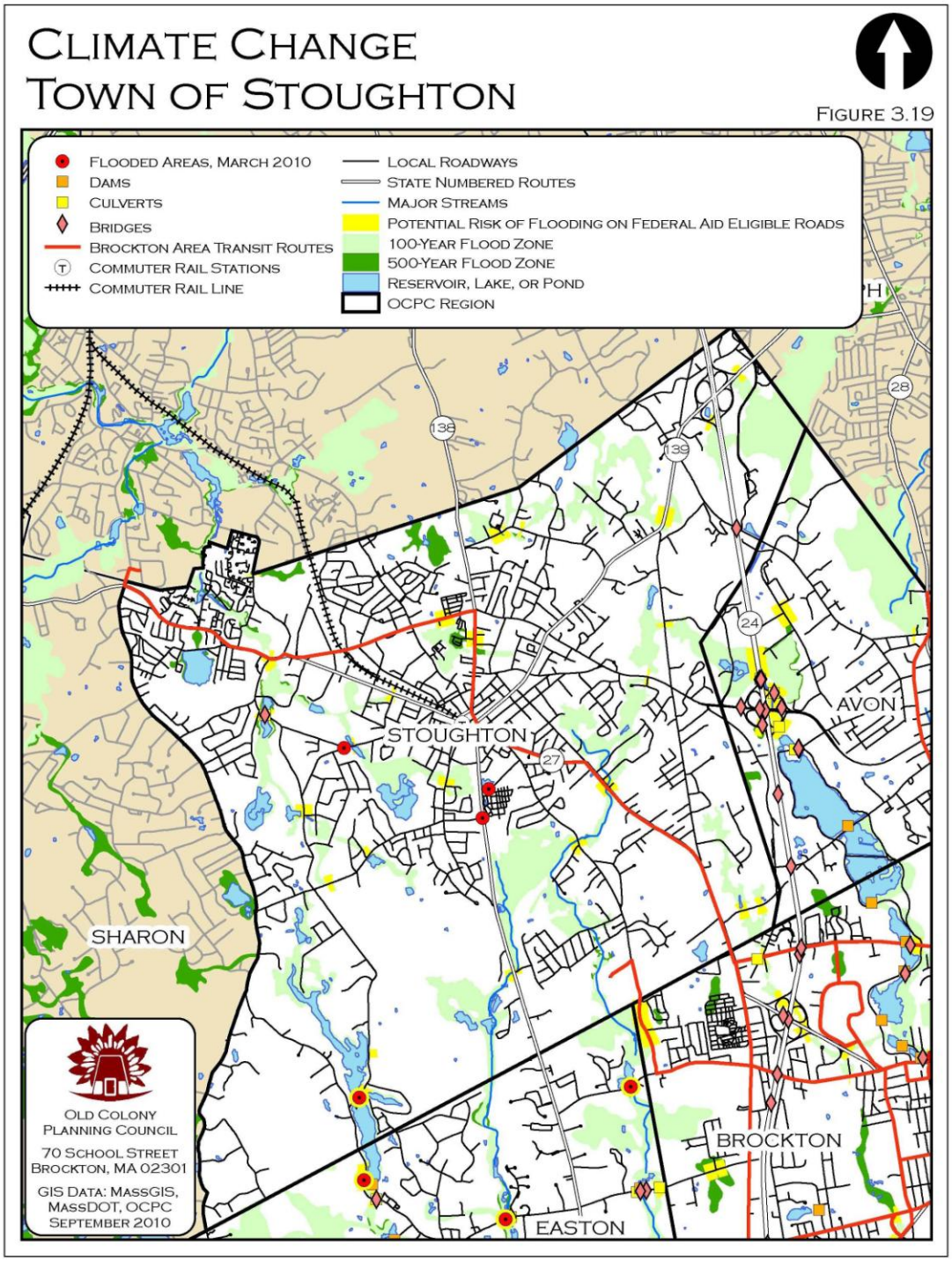

CLIMATE CHANGE
TOWN OF STOUGHTON
FIGURE 3.19
FLOODED AREAS, MARCH 2010
DAMS
CULVERTS
BRIDGES
BROCKTON AREA TRANSIT ROUTES
COMMUTER RAIL STATIONS
COMMUTER RAIL LINE
LOCAL ROADWAYS
STATE NUMBERED ROUTES
MAJOR STREAMS
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
RESERVOIR, LAKE, OR POND
OCPC REGION
STOUGHTON
AVON
SHARON
BROCKTON
EASTON
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC SEPTEMBER 2010

Table 3.14: Precipitation Impact Town of West Bridgewater
List of Flooded Areas from West Bridgewater's Highway Department
▪ Scotland Street ▪ Forest Street ▪ Manley Street Extension ▪ Forest Street and Clinton Road ▪ Ash Street ▪ Belmont Street and Matfield Street

Source: Data collected during March 2010 Storm

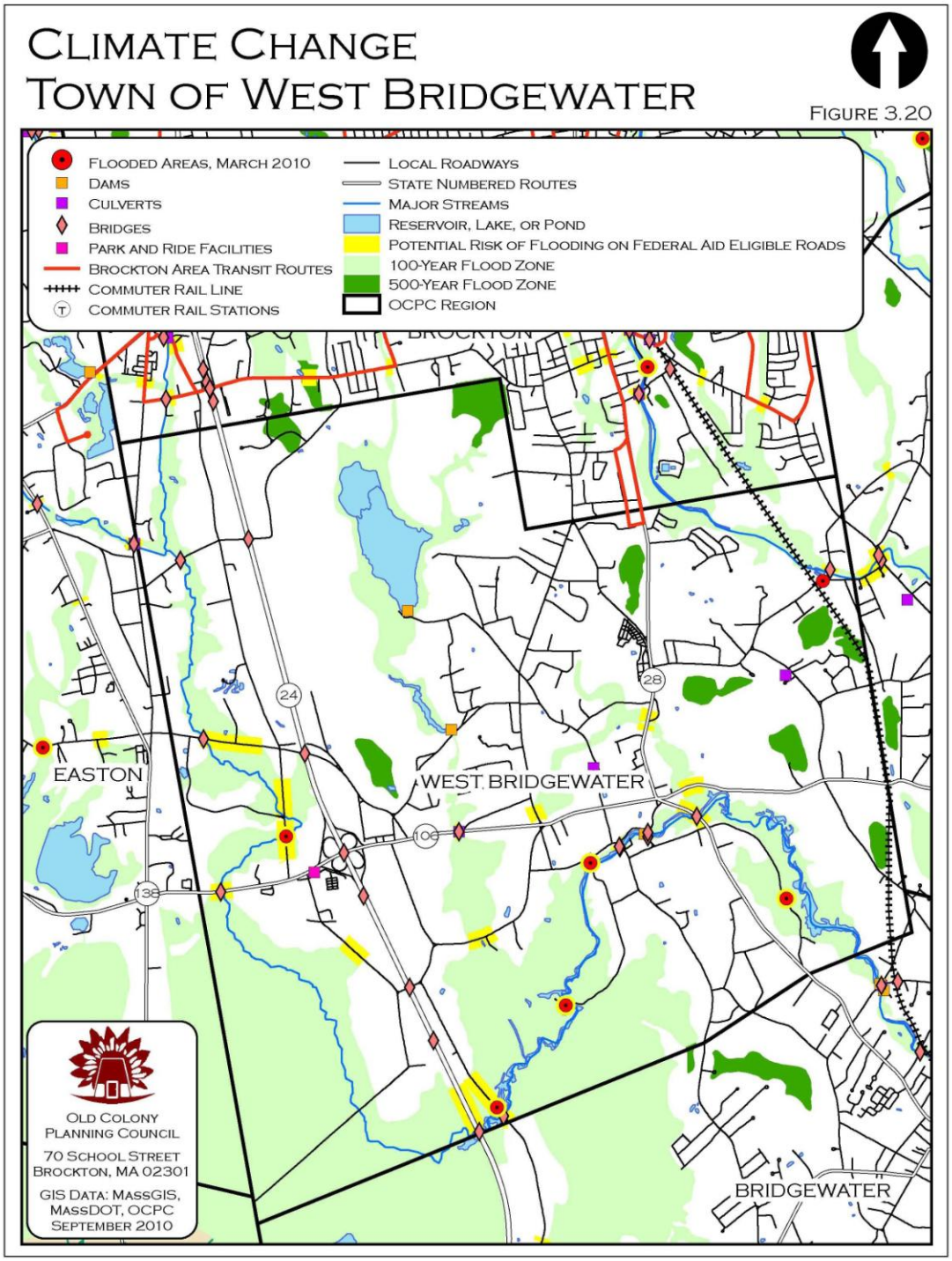

CLIMATE CHANGE
TOWN OF WEST BRIDGEWATER
FIGURE 3.20
FLOODED AREAS, MARCH 2010
DAMS
CULVERTS
BRIDGES
PARK AND RIDE FACILITIES
BROCKTON AREA TRANSIT ROUTES
COMMUTER RAIL LINE
COMMUTER RAIL STATIONS
LOCAL ROADWAYS
STATE NUMBERED ROUTES
MAJOR STREAMS
RESERVOIR, LAKE, OR POND
POTENTIAL RISK OF FLOODING ON FEDERAL AID ELIGIBLE ROADS
100-YEAR FLOOD ZONE
500-YEAR FLOOD ZONE
OCPC REGION
BROCKTON
EASTON
WEST BRIDGEWATER
BRIDGEWATER
24
28
106
138
OLD COLONY PLANNING COUNCIL
70 SCHOOL STREET
BROCKTON, MA 02301
GIS DATA: MASSGIS, MASSDOT, OCPC
SEPTEMBER 2010

Table 3.15: Precipitation Impact Town of Whitman
List of Flooded Areas from Whitman's Public Works Department
▪ South Avenue at Pond Street at the Shumatuscacant River ▪ Intersection of Bedford Street (Route 18) and Rock Street ▪ Intersection of Rock Street Extension and Hancock Street at Meadow Brook ▪ Homeland Drive ▪ Bedford Street (Route 18) at Access Point to Stop & Shop and Carpet Max at an unnamed ▪ brook ▪ Intersection of Alden Street and Jenkins Street ▪ Intersection of Washington Street and West Street ▪ Area around 100 Essex Street

Source: Data collected during March 2010 Storm

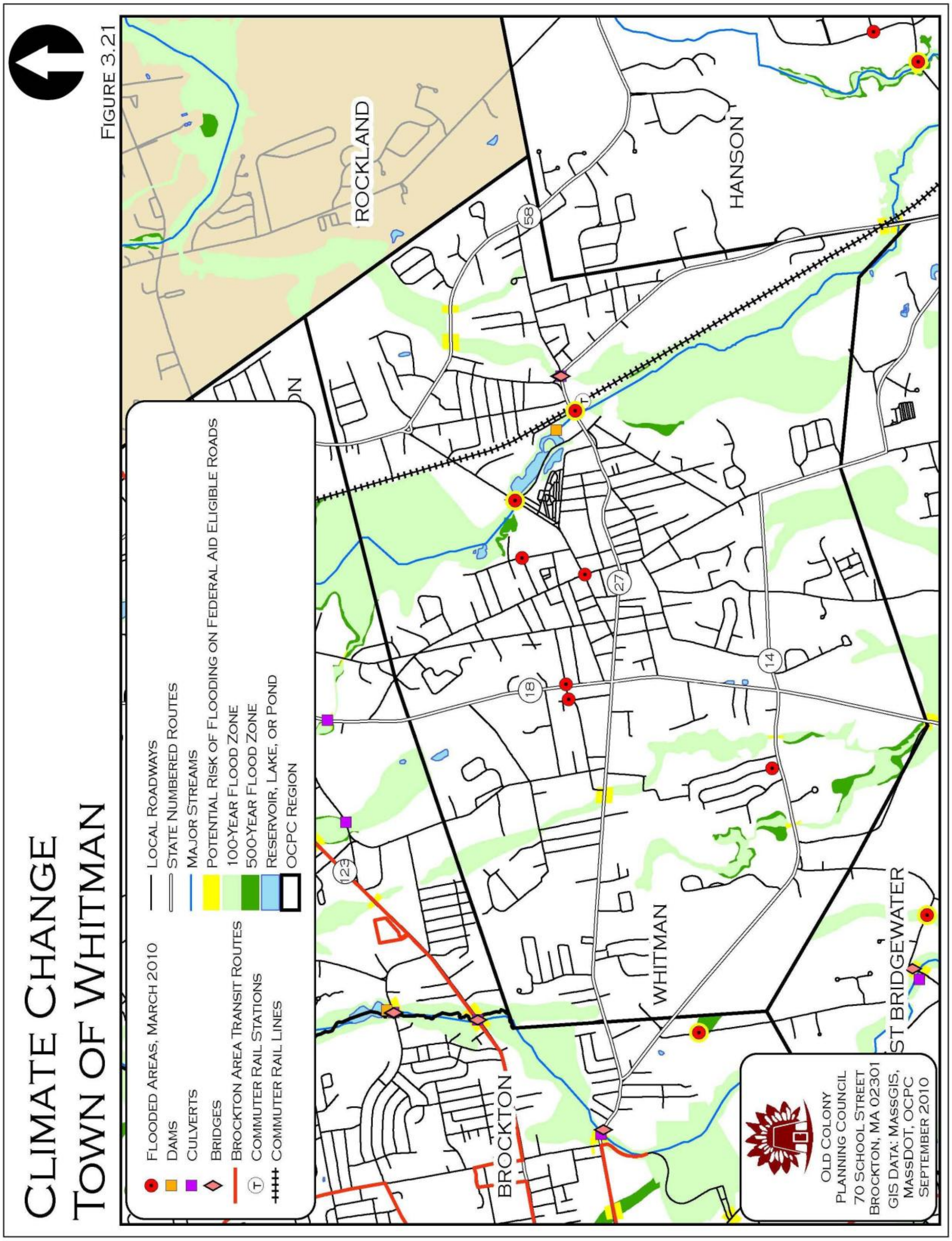

Climate Change
Town of Whitman
Figure 3.21
Flooded Areas, March 2010
Dams
Culverts
Bridges
Brockton Area Transit Routes
Commuter Rail Stations
Commuter Rail Lines
Local Roadways
State Numbered Routes
Major Streams
Potential Risk of Flooding on Federal Aid Eligible Roads
100-Year Flood Zone
500-Year Flood Zone
Reservoir, Lake, or Pond
OCPC Region
ROCKLAND
HANSON
WHITMAN
BROCKTON
ST BRIDGEWATER
58
27
18
14
123
Old Colony
Planning Council
70 School Street
Brockton, MA 02301
GIS Data: MassGIS,
MassDOT, OCPC
September 2010

Figure 3.22 is of the Bridge Street Bridge that spans the Matfield River in Bridgewater. The bridge was closed on March 17 due to the subsidence of the road base due to the overflow of water from the Matfield River. According to Bridgewater Town Manager Troy Clarkson, it will cost approximately $1.5 million to repair the road and bridge. As of September 2010 the bridge remains closed, as funding is being sought to make the necessary repairs. In the interim, drivers must use alternate routes to go around the bridge.

Figure 3.22: The Bridge Street Bridge spanning the Matfield River in Bridgewater was damaged and closed due to extreme flooding in March, 2010.

Figure 3.23: The Titicut Street Bridge spanning the Taunton River in Bridgewater was closed as a result of extreme flooding in March, 2010.

Figure 3.23 is of the Titicut Street Bridge spanning the Taunton River in Bridgewater. This bridge, as well as other bridges that spanned the Taunton River, were closed during the floods. The nearby heavily travelled north-south Route 18 Corridor remained open throughout the storms, but was very nearly flooded, which would have caused massive traffic problems throughout southeastern Massachusetts.

To manage the condition of the roadways in the Region, OCPC uses a Pavement Management System that was developed in cooperation with MassDOT to monitor roads eligible for federal aid. Field surveys and the Road Manager software program are used to determine the condition of the pavement to see if the pavement suffers from any one of the following conditions; potholes and patching, alligator cracking, distortion, rutting, weathering/block cracking, transverse and longitudinal cracking, bleeding/polished aggregate, surface wear and raveling, corrugations, shoving, and slippage. The information on road surface conditions obtained in the field via the field survey is entered into *Road Manager* software, which assigns a PCI and recommends a repair and associated cost for each road and road segment. Each road or road segment is placed in a condition category based on the PCI, which includes "Poor" (PCI = 0 to 64), "Fair" (PCI = 65 to 84), "Good" (PCI = 85 to 94), and "Excellent (PCI = 95 to 100).

To monitor the structural integrity and overall condition of bridges in Massachusetts, MassDOT personnel regularly inspect each bridge in the Commonwealth and rate them on a scale of 0 (worst) to 100 (best); and also rates them as (1) structurally deficient; (2) functionally obsolete

(FO); or (3) meeting standards. Bridges can categorized as structurally deficient if the bridge deck, pavement or supporting structure fails to meet standards. For example, if the bridge has experienced deterioration significant enough to potentially reduce its load-carrying capacity, such bridges are frequently subject to weight restrictions. A functionally obsolete (FO) bridge cannot accommodate its normal traffic due to inadequate width, inadequate under clearance, changes in adjacent roadway layout, such as widening or added lanes, or to changed engineering standards. According to the MassDOT 2010 Bridge Inventory and Ratings Report, five (3.4%) of the 149 bridges in the Old Colony Region are categorized as structurally deficient. Four of those five structurally deficient bridges span waterways and should be monitored closely in the future.

Figure 3.24: Route 18 spanning the Taunton River in Bridgewater, March 2010

To address the overall state of bridges in Massachusetts, the Commonwealth embarked upon the Accelerated Bridge Program (ABP) in 2008 whose aim is to improve the condition of bridges in every part of the state. This program will last eight years and nearly three billion dollars will be spent to greatly reduce the number of structurally deficient bridges in the state system, while creating thousands of construction and engineering jobs on bridge projects. As of September 2010, there have been seven Accelerated Bridge Program projects in the OCPC Region, with three currently under construction, three currently in the design phase and one that has been completed. A description as well as the estimated timeline and cost for each bridge construction project is listed below.

Table 3.16: Brockton Bridge Replacement, Bartlett Street over the Salisbury Brook

Description:	BROCKTON- BRIDGE REPLACEMENT, B-25-060 (AVA), BARTLETT STREET OVER SALISBURY BROOK		
Extended Description:	The work under this contract consists of the demolition of the existing superstructure and partial demolition of the substructure. The proposed structure is an integral abutment bridge comprised of spread prestressed concrete box beam supported on steel piles. The proposed work includes full depth roadway reconstruction in the immediate vicinity of the bridge construction along with the removal and stacking of existing granite curbs, installation of new granite curbing, reconstruction of driveway aprons and sidewalks, temporary and permanent utility relocation, and all other as shown on the construction plans. The roadway will be closed during the construction of the bridge and roadway approaches. A detour will be in place during the construction, but access to local residences shall be maintained at all times.		
Contractor Info:	LM Heavy Civil Construction, LLC 10 Commerce Way Westford, MA 01886	**Contact:**	Steve Harrington (Vice President) phone: (978) 692-1901 fax: (978) 692-1903
Advertised Date:	06/27/2009	**Bid Open Date:**	09/01/2009
Contract Award Date:	09/30/2009	**Est. Completion Date:**	03/30/2011
Construction Start Date:	10/21/2009	**Bid Amount:**	$933,932.44
Office Estimate:	$1,069,600.00		


Table 3.17: Hanson-Hanover Bridge Replacement, Broadway over the Indian Head River

Description:	HANOVER- HANSON- BRIDGE REPLACEMENT, H-06-003=H-07-003, BROADWAY OVER INDIAN HEAD RIVER		
Extended Description:	MassHighway is proposing to replace-in-kind the existing Broadway over Indian Head River bridge cast-in-place concrete arch structure. One lane of traffic will be maintained during construction.		
Contractor Info:	Will Corporation, A. A. 145 Island Street Stoughton, MA 02072	**Contact:**	Alexander A. Will (President) phone: (781) 341-4800 fax: (781) 341-4404
Advertised Date:	08/29/2009	**Bid Open Date:**	11/04/2009
Contract Award Date:	12/03/2009	**Est. Completion Date:**	05/22/2012
Construction Start Date:	12/28/2009	**Bid Amount:**	$1,391,768.25
Office Estimate:	$1,483,928.00		

Table 3.18: Brockton Bridge Betterment, Belmont Street over Route 24

Description:	BROCKTON- BRIDGE BETTERMENT, B-25-048, ROUTE 123 (BELMONT STREET) OVER ROUTE 24		
Extended Description:	This project consists of a replacing the superstructure of the Belmont Street Bridge over Route 24. The existing superstructure will be replaced with a 128'-2" continuous two span steel beam bridge. The proposed bridge will be 60 wide from curb to curb with a 4 foot wide raised median and a 7'-2" wide sidewalk on each side of the bridge. The roadway shall be cold planed and overlaid from station 24+00 to the west abutment (approximately 793 ft) and from the east abutment to station 41+45 (approximately 832 ft). The proposed roadway will provide two 12 foot travel lanes in each direction, replacing the existing 4 foot wide raised median in kind, and shoulders of varying width. Roadway reconstruction entails improvements to guardrail at the bridge, relocation/installation of approximately 400 feet of 12 inch ductile iron water main, pavement markings, and a section of new sidewalk. Traffic on Belmont Street will be reduced to a minimum of one lane in each direction during the bridge construction. Traffic on Route 24 shall have three lanes open in each direction during daytime construction and shifted as shown on the plans for construction required during night time hours.		
Contractor Info:	Aetna Bridge Company 30 Lockbridge Street Pawtucket, RI 02860	**Contact:**	Hugo R. Mainelli, Jr. (President) phone: (401) 728-0400 fax: (401) 724-6350
Advertised Date:	06/28/2008	**Bid Open Date:**	09/23/2008
Contract Award Date:	10/31/2008	**Est. Completion Date:**	03/31/2011
Construction Start Date:	11/21/2008	**Bid Amount:**	$3,425,215.70
Office Estimate:	$4,188,457.75		

Table 3.19: Kingston Bridge Replacement, Elm Street over the Jones River

Description:	KINGSTON- BRIDGE REPLACEMENT, K-01-002, ELM STREET OVER THE JONES RIVER		
Extended Description:	This project consists of the replacement of a structurally deficient town-owned bridge in the Town of Kingston. The existing bridge was closed to traffic and MassHighway provided a temporary ACROW Panel bridge to span the existing structure until a replacement could be constructed. The temporary bridge remains in place until a more permanent structure can be designed that meets design standards. The existing, structurally deficient bridge is to be replaced with a precast concrete structure or precast NEXT beam structure.		
Contractor Info:		**Contact:**	
Advertised Date:		**Bid Open Date:**	
Contract Award Date:		**Est. Completion Date:**	
Construction Start Date:		**Bid Amount:**	
Office Estimate:			

Table 3.20: Bridgewater-Middleborough Bridge Replacement, Summer Street over the Taunton River

Description:	BRIDGEWATER- MIDDLEBOROUGH- BRIDGE REPLACEMENT, B-23-005=M-18-002, SUMMER STREET OVER THE TAUNTON RIVER		
Extended Description:	The proposed project consists of replacing the existing two-span bridge at Summer Street over the Taunton River with a single span bridge. The proposed bridge superstructure will consist of a reinforced concrete deck slab supported by prestressed concrete spread box beams. The proposed substructure will consist of integral abutments located behind the existing abutments. The existing pier will be completely demolished. The project also includes new bridge railings, highway guard rail and improvements to the approach roadways. The bridge structure will be closed to traffic during construction and a detour route will be implemented.		
Contractor Info:		**Contact:**	
Advertised Date:		**Bid Open Date:**	
Contract Award Date:		**Est. Completion Date:**	
Construction Start Date:		**Bid Amount:**	
Office Estimate:			

Table 3.21: Brockton Bridge Replacement, White Avenue over the Salisbury Brook

Description:	BROCKTON- BRIDGE REPLACEMENT, B-25-032, WHITE AVENUE OVER SALISBURY BROOK		
Extended Description:	The proposed project consists of replacing the existing concrete superstructure with pre-stressed concrete deck beams and a composite concrete deck constructed on new concrete abutments on the back side of the existing stone abutments and reconstructing approximately 100 feet of White Avenue on each side of the bridge with new drainage, asphalt pavement, granite curbing and concrete sidewalks.		
Contractor Info:		**Contact:**	
Advertised Date:	03/27/2010	**Bid Open Date:**	05/25/2010
Contract Award Date:	06/29/2010	**Est. Completion Date:**	
Construction Start Date:		**Bid Amount:**	$994,726.00
Office Estimate:	$1,332,971.50		

Table 3.22:West Bridgewater Bridge Rehabilitation, West Center Street over the Hockomock River

Description:	WEST BRIDGEWATER- BRIDGE REHABILITATION, W-18-012, SR 106 (WEST CENTER STREET) OVER THE HOCKOMOCK RIVER		
Extended Description:	The existing stone arch and reinforced concrete arch are anticipated to be replaced with a 75 foot precast-prestressed concrete NEXT beam superstructure system. The proposed curb-to-curb roadway width of the bridge is to be 32 feet with a 6 foot sidewalk along the north side. The proposed integral abutments, supported on steel H-piles, will be located behind the existing footings, which are left in place for scour protection.		
Contractor Info:		**Contact:**	
Advertised Date:		**Bid Open Date:**	
Contract Award Date:		**Est. Completion Date:**	
Construction Start Date:		**Bid Amount:**	
Office Estimate:			

Temperature Impacts

Roadways and bridges in the OCPC region are exposed to a wide-variety of temperatures, from the extreme heat and humidity of the summer months to the freezing cold and snow of the winter. According to the U.S. Global Change Research Program, impacts related to projected changes in average temperatures appear to have only moderate implications for bridges and highways, while increases in extreme heat (temperatures over 90°F are a significant threshold for such problems) may be significant. Longer periods of extreme heat may compromise pavement integrity, such as softening asphalt and increasing rutting, the buckling of pavement (especially older, jointed concrete), and flushing or bleeding of asphalt from older or poorly constructed pavements. In addition, an increase in the freeze–thaw conditions may occur, creating frost heaves and potholes on roads resulting in load restrictions on certain bridges and roads to minimize damage.[3]

Extreme heat can also cause the thermal expansion of bridge joints, which adversely affects bridge operation. This will generally lead to increased maintenance costs wherever pavement thermal tolerances are exceeded.

Periods of excessive summer heat are also likely to increase wildfires, threatening communities and infrastructure directly and bringing about bridge and road closures in affected areas. Higher temperatures will also increase refrigeration needs for goods during transport, therefore raising transportation costs. Vehicle overheating and tire deterioration are additional concerns for drivers.[4]

On the positive side, fewer extremely cold days and warmer minimum temperature thresholds may reduce thermal cracking of pavement during winter and offset some of the increased summer maintenance costs. In New England, the warming temperatures will reduce in snow and ice removal costs, and lessen the adverse environmental impacts of the use of salt and chemicals on roads. The warmer temperatures will also improve the mobility and safety of passenger and freight travel through reduced winter hazards. The increases in very hot days and heat waves are also expected to lengthen the construction seasons, which will be a benefit in colder locations.[5]

Storm Activity Impacts (Sea Level Rise & Wind)

While most of the OCPC is located inland, the coastal communities of Kingston and Plymouth also have to deal with the potential rise in sea level. According to the Transportation Research Board, expected sea level rise will aggravate the flooding because storm surges will build on a higher base, reaching farther inland. In fact, the chapter in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report on North America identifies coastal flooding

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[3] *U.S. Climate Change Science Program Synthesis and Assessment Product 4.7, Impacts on Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 1: March 2008*

[4] *U.S. Global Change Research Program, Global Climate Change Impacts in the United States, Climate Change Impacts by Sector: Transportation: 2009 http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/climate-change-impacts-by-sector/transportatoin*

[5] *U.S. DOT Center for Climate Change and Environmental Forecasting, The Potential Impacts of Climate Change on Transportation, Federal Research Partnership Workshop, Summary and Discussion Papers: October 2002*

from expected sea level rise and storm surge, especially along the Gulf and Atlantic coasts, as one of the most serious effects of climate change. Several studies of sea level rise project that transportation infrastructure in some coastal areas along the Gulf of Mexico and the Atlantic will be permanently inundated sometime in the next century.

Higher sea levels and storm surges can also erode road bases and undermine bridge supports. The loss of coastal wetlands and barrier islands will lead to further coastal erosion due to the loss of natural protection from wave action.

Strong winds from storms also damage highway signs, traffic signals, and luminaries throughout the area. More significant safety and operational impacts are likely from debris blown onto roadways and from crashes precipitated by debris or severe winds.

Impacts on Rail

The Old Colony Commuter Rail Line has 14 stations in the OCPC Region and most of the stations are on low-lying sites near the railroad tracks, except for the three stations on Brockton's viaduct. Some stations and rail lines are located in or near mapped flood plains, such as is the case in the Town of Whitman, where the station is next to a 100 year flood zone and the track in the southern portion of the town actually crosses a mapped flood plain. These facilities however are designed for the sites and unlikely to be affected by local flooding. Other concerns with rail lines include extreme heat that may cause the track to buckle and cause derailments and storms that can knock down signs and potentially cause safety issues.

Precipitation Impacts

The primary impacts on rail infrastructure from flooding can cause erosion of the track subgrade and the rotting of wooden crossties according to a report by the U.S. Climate Change Science Program. Erosion of the subgrade can wash away ballast and weaken the foundation, making the track unstable for passage of heavy locomotives and railcars. As with buckling, subgrade erosion and rotting crossties are difficult to detect using methods other than visual inspection. This situation is improving, though, through remote sensing advances that detect standing water and air pockets.

However, an increase in the frequency and/or the intensity of extreme rainfall events could lead to higher rates of erosion and railroad bridge scour, as well as higher safety risks and increased maintenance requirements.[6]

Figure 3.25: This photo was taken from the Old Colony Commuter Rail in Braintree during the March 2010 storm

The interruption of rail traffic is likely to become more common with more frequent flooding. The impact of sea level rise is limited to coastal areas, but the effect of intense precipitation on land transportation infrastructure and operations is not. For example record-breaking rainstorms in March 2010 resulted in flash flooding of the entire metropolitan Boston area, with major impacts on the entire area. Local examples of this include the MBTA Old Colony Commuter Rail Line in Braintree being flooded by the nearby Hollingsworth Pond (Figure 3.25). Also, the MBTA Old Colony Commuter Rail Line rail bed was washed out between the Holbrook/Randolph and Braintree stations. While the repairs were being made at this location, buses were used to transport passengers, which added an extra 20-30 minutes to the average commute time.

[6] U.S. Climate Change Science Program Synthesis and Assessment Product 4.7, Impacts on Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 1: March 2008

Temperature Impacts

According to a report by the U.S. Climate Change Science Program, the average temperature increases are unlikely to require immediate design changes to track or other rail infrastructure, as these ranges generally fall within the current standards for existing rail track and facilities. However, the increase in temperature extremes – very hot days (air temperatures above 95°F) – increases the incidence of buckling or "sun kinks" on rail tracks.

Track buckling occurs predominately on continuously welded track, though it also can occur on older jointed track when the ends of the track become frozen in place. Track buckling is most prevalent on an isolated hot day in the springtime or early summer, rather than mid to late summer when temperatures are more uniformly hot. Buckling also is more likely to occur in alternating sun/shade regions and on curves.

The most serious problem associated with track buckling is derailments. Derailments occur when a buckled section of track is not observed in time for the train to safely stop. One way to overcome this problem is to reduce the speed of trains. In hot weather (more than 95 °F), railroads can issue orders to slow train speeds by 10 mph to help prevent derailments caused by buckling. This has several negative consequences, such as longer transit times, higher operating costs, shipment delays, reduced track capacity, and increased equipment cycle time leading to larger fleet sizes and costs. Reduced train speeds similarly affect passenger rail schedules, causing delays in travel schedules.[7]

One example of an accident caused by a heat induced track buckle was an April 2002 incident when an Amtrak Auto Train derailed near Crescent City, Florida. The accident claimed four lives and injured 142. The National Transportation Safety Board (NTSB) concluded that "heat-induced track buckle that developed because of inadequate CSX Transportation track-surfacing operations. These operations included the misalignment of the curve, insufficient track restraint, and failure to reestablish an appropriate neutral rail temperature."

During the Heat Wave of July, 1995, the City of Chicago experienced a period of extreme heat that caused hundreds of heat-related deaths, but also warped rail lines, making them impassable and disrupted commuter rail and freight service for weeks while repairs were made. Each period of excessive summer heat is also likely to increase wildfires, threatening communities and infrastructure directly and bringing about road and rail closures in affected areas.

Research into improved track design and installation has greatly reduced the derailments attributable to buckling. For example, concrete crossties with improved fasteners can withstand greater track stress than wooden ties with spikes. During installation, the rail is pre-stressed to a target neutral temperature. Since the track is more stable when the rail is in tension at temperatures below the neutral temperature, the target neutral temperature is generally 75 percent of the expected maximum temperature of the region. In northern climates, the neutral temperature is typically 90F, while 100F is used in the Gulf Coast region. Pre-stressing can occur either thermally (by actually heating the steel during installation) or mechanically by stretching the steel to introduce the desired stress prior to fastening it to the crossties.

[7] *Ibid*

A temperature change of 1.5 °C (2.7 °F) over the next 50 years may slightly raise the neutral temperature used for installation but would have little impact on track design otherwise. A temperature increase in this range would not necessitate replacing existing track. This would most likely be replaced as part of normal maintenance, upgrades to handle increased traffic volumes, or replacement due to storm surge or other catastrophic events. The typical cost to upgrade track can vary greatly depending upon the type of upgrade, the slope and curvature, and the number of bridges and tunnels. Costs to replace track range from ($0.5 million to $3 million per mile), excluding any additional right-of-way expenses.[8]

If incidences of buckling arise, it will be increasingly important to develop improved methods of detection. It is relatively easy to detect a broken rail by running a light electric current through track, but manual observation remains the best method for identifying track buckling. Research is underway to develop improved methods that measure temperature and stress of the track.

The projected increases in average temperature and number of hot days, coupled with possible increases in humidity, would create serious safety concerns for workers in rail yards and other rail facilities, and would require investments to protect rail workers. This might include increases in crew size to allow for more frequent recovery breaks or greater use of climate-controlled facilities for loading and unloading the railcars. Regardless of the solution, providing the necessary relief for workers will lead to increased operating or capital expenses, which will be reflected in higher transportation costs.

Storm Activity Impacts (Sea Level Rise & Wind)

Frequent inundation and interruptions in travel on coastal and low-lying roadways and rail lines due to storm surge are projected in the coming century, potentially requiring changes to minimize disruptions.

According to the U.S. Global Change Research Program wind from storms may impact the railroad signs, signals, and grade crossings throughout the area. This may cause an increase in rail accidents at grade crossing. To reduce the possibility of such accidents, operators may decide not to run the trains at all, without the proper safety equipment being operational. More significant safety and operational impacts are likely from debris blown onto roadways and from crashes precipitated by debris or severe winds.[9]

Impacts on Air Travel

Each of the Region's three airports are outside of a mapped flood plain and are unlikely to be affected by flooding. Precipitation, heat, and storms can each affect air travel in other ways, like extreme heat affecting lift, requiring longer runways, storms that create more turbulence, and an increase in precipitation events causing flight delays, cancellations, and a more challenging flying environment for pilots.

[8] *Ibid*
[9] *Ibid*

Temperature Impacts

Extreme temperatures can affect air travel in a variety of ways. According to the U.S. Global Change Research Program, warming temperatures and possible increases in temperature extremes will affect airport ground facilities, runways in particular, in much the same way they affect roads. Airports in some areas are likely to benefit from reduction in the cost of snow and ice removal and the impacts of salt and chemical use, and from the reduced need to de-ice planes. More heat extremes will create added operational difficulties, for example, causing greater energy consumption by planes on the ground. Extreme heat also affects aircraft lift; because hotter air is less dense, it reduces the lift produced by the wing and the thrust produced by the engine – problems exacerbated at high altitudes and high temperatures. As a result, planes need to take off faster, and if runways are not sufficiently long for aircraft to build up enough speed to generate lift, aircraft weight must be reduced. Thus, increases in extreme heat will result in payload restrictions, causing flight cancellations and service disruptions at affected airports, and could require some airports to lengthen runways. Recent hot summers have seen flights cancelled due to heat, especially in high altitude locations.[10]

Precipitation Impacts

In general, airlines, airports, and aircraft operate more efficiently in dry weather than in wet. Weather is a critical influence on aircraft performance and the outcome of the flight operations for taking off, landing, and while aloft. Precipitation affects aircraft and airports in several ways, such as decreasing visibility, slowing air traffic by requiring greater separation between aircraft, and decreasing braking effectiveness. On the ground, effects include creating turbulence, increasing the risk of icing of wings, and affecting engine thrust.

Figure 3.26: The Norwood Memorial Airport runway and taxiway system were under up to two feet of water.

A wetter climate would reduce the number of visual flight rules (VFR) operating time periods and would impact the general aviation sector. General aviation pilots would either learn to fly in instrument flight rules (IFR) conditions by becoming "instrument rated", or not fly during periods of reduced visibility and precipitation. In order for pilots to fly in IFR conditions, aircraft flight decks must be equipped with complex navigation instruments, which is a significant investment for aircraft owners.

Increased extreme precipitation events also impact operations by increasing flight delays and cancellations. During severe thunderstorm activity, it is not unusual for an airline to cancel flights or at a minimum experience delays in operations. Navigation in heavy precipitation is possible and currently occurs on a daily basis in the national air system; however, precipitation almost always creates delays, particularly at the most congested airports.

[10] *Ibid*

Stormwater runoff that exceeds the capacity of collection and drainage systems causes flooding, delays, and airport closings. Heavy downpours affect the structural integrity of airport facilities, through flood damage to runways and other infrastructure. In March 2010, extreme rains flooded the Norwood Memorial Airport (Figure 3.26), as the Neponset River and Purgatory Brook overflowed their banks causing the airport to close twice in a period of two weeks.

Storm Activity Impacts (Sea Level Rise, Wind)

According to the Transportation Research Board, some airport runways are particularly vulnerable to storm activity, such as flooding and erosion from increased intense precipitation. and, in the longer term, from sea level rise. Some airports, such as New York's LaGuardia, are protected by dikes, but others may require increased protection. At a minimum, increased intense precipitation is likely to cause increased disruptions and delays in air service and periodic airport closures. Additionally, with the increased storm activity, airport facilities including terminals, navigational equipment, perimeter fencing, and signs are likely to sustain increased wind damage.[11]

[11] *Ibid*

Impacts on Marine Travel

Temperature Impacts

According to the Transportation Research Board, marine transportation infrastructure includes ports and harbors, supporting intermodal terminals, and the ships and barges that use marine facilities. Expected climate change impacts differ for coastal and inland waterways. Higher temperatures will increase costs of terminal construction and maintenance, particularly of any paved surfaces that will deteriorate more quickly if the frequency of high temperatures increases. Additionally, higher temperatures lead to increased stress on temperature-sensitive structures. Container handling cranes, warehouses, and other marine terminal assets are made of metals. With increasing record temperatures and days over 90 °F, it may be necessary to design for higher maximum temperatures in replacement or new construction. On the other hand, most dock and wharf facilities are made of concrete and lumber, which are generally less sensitive to temperature fluctuations.

The warming winter temperatures, particularly in northern coastal areas, could also be seen as a boon for marine transportation. Fewer days below freezing would reduce problems with ice accumulation on vessels, decks, riggings, and docks; the occurrence of dangerous ice fog; and the likelihood of ice jams in ports. The continued reduction in Arctic sea ice should result in more ice-free ports, improved access to both ports and natural resources in remote areas, and longer shipping seasons. In the longer term, shippers are looking forward to new Arctic shipping routes that could provide significant cost savings in shipping times and distances. For the next several decades; however, warming temperatures and melting sea ice are likely to result in increased variability in year-to-year shipping conditions and higher costs due to requirements for stronger ships and support systems (e.g., ice-capable ship designs, icebreaker escorts, search and rescue support).[12]

Precipitation Impacts

Coastal ports and harbor facilities will be affected by increased intense precipitation. Landside facilities will be particularly vulnerable to flooding from an increase in intense precipitation events and to the impacts of higher tides and storm surges from rising seas. Sea level with respect to dock level is an important consideration at both wet and dry docks, general cargo docks, and container berths for clearance of dock cranes and other structures. Changes due to increased intense precipitation could require some retrofitting of facilities. At a minimum, they are likely to result in increased weather-related delays and periodic interruption of shipping services. The navigability of shipping channels is also likely to change. Some channels may be more accessible to shipping farther inland because of sea level rise. The navigability of others; however, could be adversely affected by changes in sedimentation rates and the location of shoals. In other areas, a combination of sea level rise and storm surge could eliminate waterway systems entirely. The increase in intense precipitation events could require the capacity of some stormwater retention and treatment facilities to be increased.[13]

[12] Ibid

[13] National Research Council of the National Academies, Transportation Research Board Special Report 290: Potential Impacts of Climate Change on U.S. Transportation: 2008 http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf

Storm Activity Impacts (Sea Level Rise, Wind)

According to the U.S. Climate Change Research Program, impacts on harbor infrastructure from wave damage and storm surges are projected to increase. Waves and storm surge will damage harbor infrastructure such as cranes, docks, and other terminal facilities. Changes will be required in harbor and port facilities to accommodate higher tides and storm surges. There will be reduced clearance under some waterway bridges for boat traffic. Changes in the navigability of channels are expected; some will become more accessible (and extend farther inland) because of deeper waters, while others will be restricted because of changes in sedimentation rates and sandbar locations. In some areas, waterway systems will become part of open water as barrier islands disappear. Some channels will likely have to be dredged more frequently, which has been done across large open-water bodies in Texas.[14]

Sea level rise is the most well-known effect of climate change. The effect can be very abrupt when a section of cliff slides towards the ocean. Ocean-side houses and docks are vulnerable to shoreline change. However, the process is generally quite slow, particularly compared to cliff subsidence or barrier beach penetration. Figure 3.27 shows shoreline changes in the Town of Plymouth from 1844 to 1994. The purple line shows the shore line in 1844 and the red line shows the shore line as of 1994. The indicated rate of change from 0.8 to 1.4 feet/year suggests that approximately the 30 foremost houses along Whitehorse Beach and other in similar settings could be affected by the advancing shoreline over the next several decades unless the intervening dunes and/or seawall are enhanced.

Figure 3.27: Sea level rise impact at Plymouth's White Horse beach (left) and less change at the Manomet Bluffs (right)

[14] *U.S. Climate Change Science Program Synthesis and Assessment Product 4.7, Impacts on Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase 1: March 2008*

Drainage System

During this past March 2010 more than 15 inches of rain fell during two major storms that were just two weeks apart. These storms demonstrated both the vulnerabilities and the lack of adequate drainage structures in the region.

The Region's drainage system is decentralized. It consists largely of short segments of piped drainage flowing from streets, parking lots or roofs to nearby natural watercourses or retention ponds, sometimes with sediment-trapping forebays. These facilities may face potential damage from very infrequent geologic episodes or other hazards that could increase risks immediately downstream; however individual retention/detention ponds rarely hold crucial amounts of water.

The Region's many old, under-maintained, low-head mill dams, and other impoundments are little-used parts of the overall drainage system. They could be either storm water management assets or potential hazards.

Stormwater is not just a threat in the case of flooding; it also transports pollutants. Soil that erodes from a construction site, cigarette butts and other litter from parking lots, antifreeze and oil dripped from cars, fertilizers and pesticides from turf management, and grit and salt left from de-icing operations on roadways can be deposited untreated into waterways. Water can contain and transport sediments, metals (copper, cadmium, chromium, lead, zinc), nutrients (nitrates, phosphates, ammonia), salt, petroleum products, and coliform bacteria among other materials. Overall, stormwater pollutants originate from nutrients, solids, pathogens, metals, hydrocarbons, organics, and salt.

Stormwater runoff occurs as a result of rainfall and melting snow and ice from roadways, bridges and parking lots. Rain or snow that falls soaks into the ground to become groundwater, or it evaporates or flows off over the land surface. The overland flow is called runoff or stormwater and is the primary source for vernal pools, wetlands, streams, rivers, lakes and water-supply reservoirs. Stormwater washes along or dissolves some of the materials in its path. Vegetative surfaces slow the flow, filter out sediments, and can break down pollutants in the root zone. In contrast, buildings, roads, parking lots, and exposed bedrock increase the volume and speed of stormwater runoff since none can soak in and the hard surface presents little resistance to flow. To prevent flooding and protect property in developed areas, stormwater drainage systems collect stormwater runoff and carry it away from roadways and structures to a discharge point or retention or detention basins; however, most discharges are into natural waters. Stormwater drainage systems consist of curbs, gutters, storm drains, channels, ditches, pipes, and culverts that do not treat the stormwater.

In addition, the quantitative effect as wet weather discharges need consideration. Wet weather discharges refer collectively to point source discharges that result from precipitation events, such as rainfall and snowmelt. Wet weather discharges include stormwater runoff, combined sewer overflows (CSOs), and wet weather sanitary sewer overflows (SSOs). Stormwater runoff accumulates pollutants such as oil and grease, chemicals, nutrients, metals, and bacteria as it travels across land. CSOs and wet weather SSOs contain a mixture of raw sewage, industrial

wastewater and storm water, and have resulted in beach closings, shellfish bed closings, and aesthetic problems.

In Massachusetts, polluted stormwater runoff and discharges in urbanized areas cause serious water-quality problems. Polluted runoffs to water bodies have affected aquatic plant and animal life in streams and lakes, closed shellfish beds, reduced recreational activities such as boating and swimming, and increased existing flooding conditions caused by natural events. The untreated runoff poses a major threat to water quality and is identified as a major source of nonpoint source pollution (NPS). Nonpoint source pollution or "polluted runoff", which enters our water bodies from septic systems, agricultural uses and runoff from roads, parking lots, construction sites, lawns and other locations, is now the dominant cause of water quality problems to our lakes, rivers, and coastal areas. Point sources still have significant impacts in certain water bodies, but across the state, nonpoint source pollution affects more total miles and acres of water. Although these pollution sources are lumped under the single heading of nonpoint sources, in fact there are a huge variety of nonpoint sources from farms to parking lots that result from a similarly wide range of activities, from cars with leaking oil to construction of new structures. It is easier and less costly to prevent problems from occurring than it is to fix them after they occur.

In response to rapid loss of wetlands, Massachusetts adopted the nation's first wetlands protection laws in the early 1960s. The Wetlands Protection Act [Massachusetts General Laws (MGL) Chapter 131, Section 40] protects wetlands and the public interests they serve, including flood control, prevention of pollution and storm damage, and protection of public and private water supplies, groundwater supply, fisheries, land containing shellfish, and wildlife habitat. The law protects wetlands and other resource areas, such as land subject to flooding (100-year floodplains), the riverfront area (added by the Rivers Protection Act), and land under water bodies, waterways, salt ponds, fish runs, and the ocean. The Massachusetts Department of Environmental Protection (DEP) oversees administration of the act, develops regulations and policies, and provides technical training to local conservation commissions. DEP also hears appeals of decisions made by these commissions.

At the local level, the community's conservation commission administers the Wetlands Protection Act. The commission is a volunteer board of three to seven members appointed by the selectmen or city council. The conservation commission ensures that proposed activities will not alter resource areas and the public interests they provide by reviewing projects on a case-by-case basis according to regulations [310 Code of Massachusetts Regulations (CMR) 10.00]. The regulations describe how each type of resource area protects one or more of the public interests. The regulations also spell out the type and extent of work allowed in resource areas. Proposed work must meet these standards. This information helps landowners and developers plan their work and helps commissions apply the law to specific projects. The law regulates many types of work in resource areas, including vegetation removal, construction of roads, sidewalks, bikeways, driveways, and commercial, industrial, or residential buildings.

The regular cleaning and maintaining of catch basins is also important in preventing the flooding of streets and roadways. Cleaning catch basins of debris, trash, and vegetation that build up around the basins will allow stormwater to flow freely into the drains and reduce the chance of

flooding and as a result keep roadways clear for traffic. Additionally there are filters that can be installed on catch basins that can filter out pollutants and sediments and protect water quality.

Dam Infrastructure

Dams in the Old Colony region are mostly small earthen stone structures impounding streams to create shallow mill ponds or very low-head cranberry bog reservoirs; however there are a few concrete and stone structures for industrial or water supply usage. These dams have created ponds as well as a form of flood control during heavy precipitation events.

Over time, many of these dams have been abandoned or not maintained properly, either by their private owners or the municipalities that own them, due to the high cost of maintenance and repair. The lack of maintenance and management of these dams do present some risk according to the Massachusetts Bureau of Dam Safety. Some dams are under greater stress than others due to a greater amount of impervious surface that leads to larger stream flows, and thus a more frequent full head against the dam. During the two massive rain storms of this past March, 2010, a number of dams around the state were threatened, but none failed, which would have caused catastrophic damage downstream if any did fail.

The recent storms once again brought attention to the problem of dam maintenance and dam management across Massachusetts. Maintaining and managing all of the dams in the state is difficult due to limited funding of the State's Dam Safety Program. The Dam Safety Program rates dams on an ongoing basis and rates their condition with the following range: "Good", "Satisfactory", "Fair", "Poor", "Unsafe" and "Unknown". According to the 2005 OCPC Regional Multi-Hazard Pre-Disaster Mitigation Plan there were about 159 dams in the OCPC Region, with one, the Murray-Carver Dam in East Bridgewater listed as "Unsafe". More recently, a December 2009 Report from the Massachusetts Department of Conservation and Recreation Office of Dam Safety's Inventory of Regulated Dams, noted that there were 73 regulated dams in the OCPC Region, and three of the dams were categorized as unsafe, including the privately owned Cotton Gin Pond Dam in East Bridgewater, the Standish Mill Pond Dam in Plymouth, and Dennetts Pond Dam in Plympton. Opportunity to upgrade and manage these flood controlled structures should be examined as part of the Hazard Mitigation Plan.

Information on Emergency Evacuations

New England weather is quite variable and sometimes dramatic and dangerous. Late summer hurricanes, major winter blizzards, and summer droughts are all part of life in Southeastern Massachusetts, but most are at a manageable level. Thunderstorms can be very destructive, as the flooding of this past March 2010 has shown, when two massive rain events in a period of two weeks dropped more than 15 inches of rain on the region. Other threats, such as, earthquakes, landslides, and major fires are less common. These events can have disastrous effects on natural features, our built communities, and transportation infrastructure.

The Massachusetts Emergency Management Agency, (MEMA) manages and coordinates emergency response efforts for the Commonwealth. It also operates the state Emergency Operations Center (EOC), where it monitors emergencies statewide on a twenty-four hour per day, seven-day per week basis. The EOC serves as the command and control center for the Commonwealth during an emergency. On a local level, each community within the OCPC Region has a local Emergency Management Agency. These agencies have a director whose responsibility it is to coordinate with state and federal authorities to protect the public during disasters and emergencies.

If evacuation is necessary, for any type of Natural or Man-Made Emergency, Public Safety Officials can alert the public by one of several methods. They could include any of or more of the following:

- Outdoor sirens or horns
- The Emergency Alert System (EAS) - information provided on the radio and television
- NOAA Weather Alert Radio
- "All Call" or 'Reverse 911' - an automated telephoning system for sending recorded messages
- Alert messages through Twitter, Facebook and other electronic means
- Mass.Gov Citizen Alert
- Commercial News Media
- Residential Route Alerting, which dispatches Public Safety vehicles through neighborhoods announcing messages with Public Address systems

To assist in evacuation efforts, Intelligent Transportation Systems (ITS) technologies may be used to assist with communication, traffic control, surveillance and navigation efforts that aid in the management of the evacuation process. ITS elements, such as traffic cameras, signal preemption devices, and variable message signs (VMS), would provide timely responses for emergency vehicles and the ability to monitor evacuations during times of natural, or other disasters.

Additionally, both the Brockton Area Transit (BAT) and the Greater Attleboro Taunton Regional Transit Authority (GATRA) have contingency plans and local interagency agreements to coordinate emergency and disaster response plans. Examples include evacuation requirements for local elderly populations and blood dialysis operations. The agencies also plan an important safety role for the Pilgrim Nuclear Power Plant emergency response plan.

Infrastructure Needs

Short-Term Infrastructure Needs

The short-term infrastructure needs give priority emphasis and consideration to the areas in the greatest need due to distresses caused by climate change effects. The short-term needs assessment also includes regulatory and educational recommendations. Some of the short-term recommendations are very specific for certain communities and other recommendations apply to the Old Colony region as a whole.

Infrastructure

- Improve local storm drainage in urban areas, such as in Brockton's Belmont Avenue /Sycamore Avenue neighborhood and Ames Street/Spark Street neighborhood, which flood during times of heavy rainfall.
- Repair and upgrade dams suitable for safe flood storage and storm flow management as needed.
- Reduce fallen tree risk with selective trimming and infill planting by private firms and community tree departments.
- Continue creating / expanding fire breaks upwind of critical facilities and other developments, particularly via controlled burns along roads and power lines; expand efforts to key out-of-forest locations
- Inspect, maintain and upgrade older dams for present functions and storm water management potential – particularly:
    - The Avon Reservoir / D.W. Field Park System
    - Kingston's Silver Lake Dam
    - Halifax's Stump Brook Dam
    - East Bridgewater's Murray –Carver Dam
    - Pembroke's Mill Pond / Furnace Pond Dam controlling Oldham Pond and Furnace pond
    - Halifax's South Pond / "Robbins Reservoir" Dam
- Reduction of Sea, Lake Overland Surge from Hurricane (SLOSH) damage by repairing/ modifying seawalls for minimum erosion.
- Reduction of SLOSH damage and personal injury by elevating structures at risk before they are damaged.
- Sweep streets to remove trash, debris, and sediments from the roadside that may impede water flow.
- Remove / modify obstacles to flow in confined streams, e.g., bridges with inadequate clearance.
- Maintain clear spillways and operable boards or sluices to allow purposeful dam operation.
- Directly reduce streamside risks, e.g., by removing selected structures from floodway and reconfiguring banks for flood storage and safe dry weather open space / habitat use.
- Identify opportunities to increase safe flood storage by improving potential multi-use detention/retention basins.

Regulatory

- Exploration / implementation of opportunities for flood control though repair and operation of local dams.
- Acquire homes and properties in areas that flood consistently during storms.
- Enforce current flood hazard zoning.
- Adoption of storm water treatment and retention provisions (maximizing recharge and allowing no increase in runoff) where missing in the local subdivision regulations
- Encourage communities to record information about potential damages made by climate change effects.
- Develop and/or update local stormwater and floodplain management plans.

Education

- Increase public awareness of flood hazards (e.g., posting signs showing past high water lines).
- Publicize continuing long-term beach loss, potential storm surges, and the function of and need for sand dunes.
- Inform home owners, residents, and agencies / firms of defensive space principals.

Long-Term Infrastructure Needs

The long-term needs require forward-looking suggestions that can support and sustain renewed economic growth and accommodate the growing population for climate change impacts over the next 40 years. Similar to the short-term infrastructure needs, the long-term infrastructure needs also include regulatory recommendations. In addition, the long-term recommendations also suggest preventative methods for future climate change effects in the Old Colony communities and transportation system.

Infrastructure

- Create drainage channels connected to detention ponds on roadways located in high risk flooding zones.
- Dredge shallow streams and rivers to increase water flow.
- Consider rail track elevation in potentially flooded or low-lying inland areas.
- Use porous asphalt when replacing paved roads to assist in managing stormwater.
- Integrate transit, bicycle, and pedestrian infrastructure amenities into residential and commercial/industrial developments.
- Increase usage and capacity for public transit services.
- Increase connectivity of neighborhoods, enrich urban design, especially as it relates to transportation options.

Regulatory

- Improve national and international warning system.
- Promote Transit Oriented Development and Smart Growth principals.
- Revise zoning accordingly – promote compatible, mixed-use development that is compact, conserves land, protects historic resources and integrates uses.
- Eliminate the negative impacts of transportation infrastructures on low-income and minority neighborhoods.

4.0 Strategies and Recommendations to Reduce Greenhouse Gas Emissions

Before presenting the target goals, strategies, and recommendations to reduce greenhouse gas emissions in the Old Colony region, it is important to examine the current and forecasted conformity analysis for the Eastern Massachusetts region. Federal and state regulations require that the region assess the air quality consequences of proposed transportation improvements. Current laws mean that the region must assess the carbon monoxide emissions from surface transportation sources to meet the Clean Air Act, which includes both volatile organic compounds (VOCs) and nitrogen oxides (NO_x), the two major precursors to ozone formation to achieve attainment of the ozone standard.

The Old Colony Planning Council has developed goals and objectives based on the air quality conformity analysis to minimize environmental and climate change impacts on both the public in general and on various infrastructure facilities. With these goals and objectives, there are outcomes and proposed performance measures that the Old Colony Planning Council will utilize in its planning process.

Eastern Massachusetts Air Quality Conformity Analysis

The State of Massachusetts has prepared an air quality conformity determination for the federal component of the 2011 Old Colony Regional Transportation Plan (RTP) and 2011-14 Transportation Improvement Program (TIP) for the eastern Massachusetts area as required by state and federal law. The analysis shows that the OCPC area, including the 15 communities and the urban portions of two counties of the OCPC region, will continue to meet federal and state air-quality standards to the year 2035.

This conformity determination analysis has been prepared in accordance with EPA's final conformity regulations. The air quality analyses outlined in the following tables demonstrate that the implementation of the TIP satisfies the conformity criteria where applicable and is consistent with the air quality goals in the Massachusetts (State Implementation Plan) SIP. Specifically, the Old Colony MPO has found the emission levels from this FY 2011-2014 TIP – in combination with the emission levels from the other MPOs in its nonattainment area – demonstrate conformity with the SIP. Therefore, the FFY 2011-2014 Transportation Improvement Program (TIP) is in conformity with the SIP where required. The table below show the emissions estimates for the Eastern Massachusetts ozone nonattainment area. These emissions are calculated in tons per summer day.

Table 4.1 VOC Emissions Estimates for the Eastern Massachusetts Ozone Nonattainment Area (all emissions in tons per summer day)				
Year	**Old Colony Action Emissions**	**Eastern MA Action Emissions**	**Budget**	**Difference (Action-Budget)**
2007	N/A	86.558	N/A	N/A
2017	2.0212	41.389	63.50	-22.111
2020	1.9220	34.293	63.50	-29.207
2030	1.8317	32.157	63.50	-31.343

Table 4.2 NOx Emissions Estimates for the Eastern Massachusetts Ozone Nonattainment Area (all emissions in tons per summer day)				
Year	**Old Colony MPO Action Emissions**	**Eastern MA Action Emissions**	**Budget**	**Difference (Action-Budget)**
2007	N/A	234.850	N/A	N/A
2017	3.1090	66.418	174.96	-108.542
2020	2.3979	50.694	174.96	-124.266
2030	1.5957	34.259	174.96	-140.701

Conformity Test

The conformity test is to show consistency with the emissions budgets set forth in the SIP, and to contribute to reductions in CO nonattainment areas. In addition, the format of the conformity test is determined by evolving regulations. These regulations set specific requirements for different time periods depending on the timeframe of the Commonwealth's SIP submittals to EPA. These periods are defined as follows:

Control Strategy Period: Once a control strategy SIP has been submitted to EPA, EPA has to make a positive adequacy determination of the mobile source emission budget before such budget can be used for conformity purposes. The conformity test in this period is consistency with the mobile source emission budget.

Maintenance Period is the period of time beginning when the Commonwealth submits and EPA approves a request for redesignation to an attainment area, and lasting for 20 years. The conformity test in this period is consistency with the mobile source emission budget.

Horizon years for regional and state model analyses have been established following 40 CFR 93.106(a) of the Federal Conformity Regulations. The years for which the regional and state transportation models were run for emission estimates are shown below:

- 2007: Milestone Year – This year is now being used by the statewide travel demand model as the new base year for calculation of emission reductions of VOCs and NOx.
- 2017: Milestone Year and Analysis Year: This year is used to show conformity with the 2009 emission budgets for ozone precursors in eastern Massachusetts
- 2020: Analysis Year
- 2030: Horizon Year – last forecast year of the regional transportation plan

Changes in Project Design since the Last Conformity Determination Analysis

The Commonwealth requires that any change in project design from the previous conformity determination for the region is identified. Changes that have occurred since the last conformity determination in 2009 are as follows:

- The modeled base year has changed from 2000 to 2007.
- A new analysis year has been included in the conformity determination. An air quality analysis has been completed for 2017. This complies with the conformity guidelines for no more than ten years between analysis years (2007 base to 2017 analysis year).
- Emission factors have been developed for 2017 using Mobile 6.2 with inputs approved by DEP and EPA.
- New HPMS adjustment factors have been developed for the new 2007 base year.

As stated in EPA guidance, all areas of serious ozone and carbon monoxide nonattainment must use FHWA's Performance Monitoring System (HPMS) to track daily vehicle-miles of travel (VMT) prior to attainment to ensure that the state is in line with commitments made in reaching attainment of the ambient air quality standards by the required attainment dates. MassDOT provided HPMS information to DEP. DEP used this information in setting mobile-source budgets for VOC, NOx, and CO in all SIP revisions prior to 1997. DEP has since revised its VOC and NOx budgets using transportation-demand model runs. However, the models must still be compared to HPMS data since HPMS remains the accepted tracking procedure as outlined in the regulations.

The conformity regulations require that all model-based VMT be compared with the HPMS VMT to ensure that the region is in line with VMT and emission projections made by DEP. An adjustment factor that compares the 2007 HPMS VMT to the 2007 transportation model VMT has been developed. This adjustment factor is then applied to all modeled VOC and NOx emissions for the years 2017 through 2030 to ensure consistency with EPA-accepted procedures.

2007 HPMS 6,932,000 VMT = 1.006 Adjustment factor for Old Colony Region
2007 Modeled 6,889,967 VMT for VOC and NOx

HPMS adjustment factors, calculated on a regional basis, are applied to the model output of future scenarios, and they change as base-year models are updated or improved, or as HPMS data is revised or updated.

The milestone and analysis year transportation model networks are composed of projects proposed in this FFY 2011-2014 TIP. Projects in these networks consist of all in-place "regionally significant" projects that can reasonably be expected to be completed by a given analysis/horizon year with consideration of available funding commitments. This project group would include, but not be limited to, regionally significant projects where at least one of the following steps has occurred within the past three years:

- Comes from the first year of a previously conforming TIP,
- Completed the NEPA process, or
- Currently under construction or are undergoing right-of-way acquisition

The Commonwealth requires that any changes in project design from the previous conformity determination for the region be identified. The last conformity determination was performed on the 2007 Regional Transportation Plan.

A complete listing of future regionally significant projects for the Old Colony Region is provided below:

Table 4.3
Regionally Significant Projects Included in the Transportation Models for the Old Colony Region within the Eastern Massachusetts Ozone Non-Attainment Area

Analysis Year	Community	Project Description – Old Colony Region
2020	Abington	Route 18 - Widening to 4 Lanes from Route 139 to Highland Place
2020	Brockton	Route 123 - Widen from Route 24 to Linwood Street
2030	Bridgewater	Route 24 - Add Northbound Slip Ramp from Route 104 WB to Route 24 NB Northbound
2030	Brockton	Main Street, Warren Avenue, Spring Street, West Elm Street, Belmont Street - Reestablish Two-Way Circulation
2030	Kingston, Plymouth	Route 3 - Widening from 4 to 6 Lanes between Hingham and Rt 44
2030	Plymouth	Route 25 - Add New Interchange Before Exit 1 and connect to Bourne Road
2030	Plymouth	Route 3 - Add NB Off-ramp to Plimouth Plantation Hwy. and SB On/off Ramp to Camelot Dr.
2030	Plymouth	Route 3 - Add Northbound on-Ramp at Long Pond Road (Exit 5)
2030	West Bridgewater	Route 106 - Widening from 2 to 4 Lanes between Route 24 and Route 28

Goals to Reduce Greenhouse Gas Emissions

For the 2011 Regional Transportation Plan, OCPC has set goals to improve air quality in the region for the short, medium and long-term. These goals could only be achieved with a constant collaborative effort between businesses, municipalities and residents to reduce personal carbon footprints. The carbon footprint is defined by the US Environmental Protection Agency as the "total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO^2)." In other words, when people drive a car, the engine burns fuel which creates a certain amount of CO^2, depending on its fuel consumption and the driving distance. (CO^2 is the chemical symbol for carbon dioxide). When we heat our house with oil, gas or coal, we also generate CO^2. Even if we heat our house with electricity, the generation of the electrical power may also have emitted a certain amount of CO^2. When we buy food and goods, the production of the food and goods also emitted some quantities of CO^2.

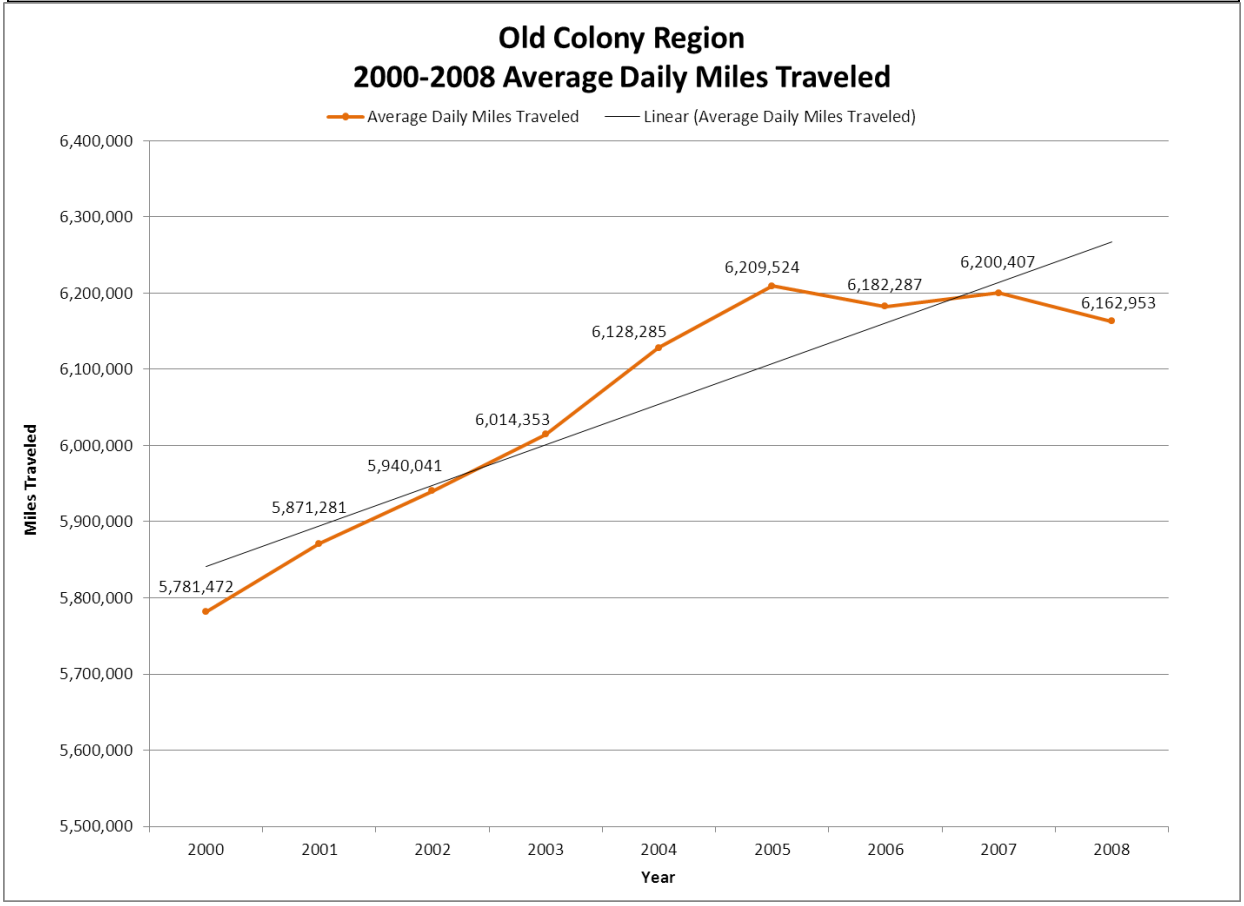
Table 4.4: Distance Travelled By Mode When Producing 2.2 Pounds of Personal Carbon Footprint

Transportation Modes	Distance Travelled
Travel by Public Transportation (bus or train)	7 miles
Travel by Car (single occupancy)	3.5 miles
Travel by Air	1.5 miles

As demonstrated in previous sections, transportation greenhouse gas emissions are mostly produced by air travel and single occupancy vehicular travel. The goal of the Old Colony region is to reduce single occupancy trips by enhancing and encouraging the use of alternative transportation modes such as bicycling, walking, carpooling and the use of public transportation. By using alternative transportation modes, people produce half of the personal carbon footprint than driving alone. As the Table 4.4 shows, public transportation (bus and train) can double the distance of a car, and a car can double the distance of an airplane while generating the same amount of personal carbon footprint.

When looking at the average daily miles travelled in the Old Colony Region in Figure 4.5, one can see that the average daily miles travelled increased steadily from 2000 to 2005, but declined in both 2006 and 2008. The reason for the decline in those years can most likely be attributed to steep rises in gas prices. These increases in gas prices caused drivers to look at alternative means of transportation, including, but not limited to: public transit, bicycling, walking, carpooling and telecommuting.

Table 4.5: Average Daily Miles Travelled in the Old Colony Region

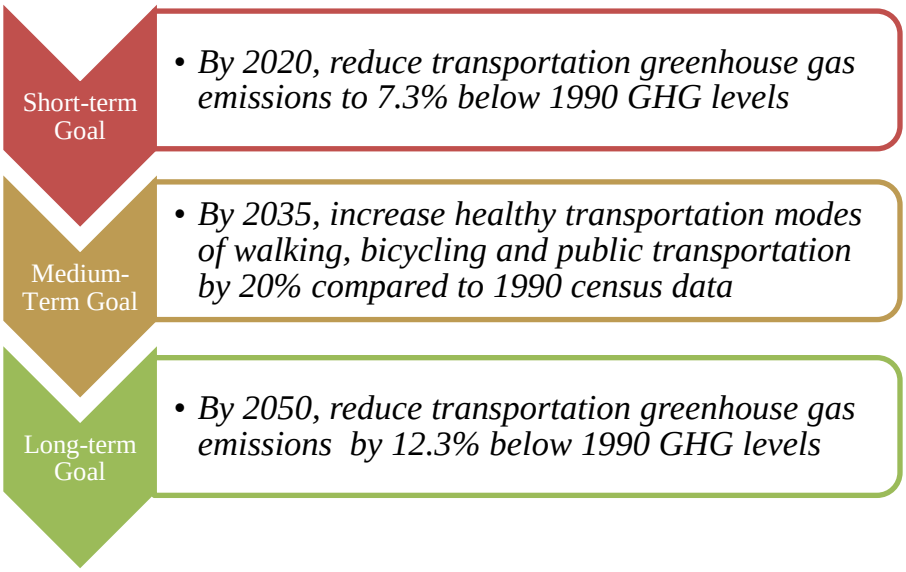


Source: Massachusetts Department of Transportation

There are other factors that influence greenhouse gas emissions, such as deforestation, use of chemicals, and land use changes that are not discussed in this study. The following transportation and land use strategies were developed to reduce greenhouse gas emissions.

In the United States, greenhouse gas emissions caused by human activities increased by 14 percent from 1990 to 2008. Carbon dioxide accounts for 93 percent of the nation's transportation greenhouse gas emissions. Electricity generation is the largest source of greenhouse gas emissions in the United States, at 33 percent, followed by transportation at 28 percent. For this reason, the following environmental protection and climate change goals and strategies were developed for the Old Colony region with the purpose of reducing carbon emissions, improving energy efficiency, and reducing dependency on foreign oil. The Old Colony region needs to increase the use of sustainable environmental practices in energy and transportation in order to achieve these goals, and the strategies recommended later in this section will support these efforts.

OCPC Target Goals to Reduce Transportation Greenhouse Gas Emissions



Massachusetts GreenDOT State Initiatives

Mission: The Massachusetts Department of Transportation is a leader in promoting sustainability in the transportation sector. Through the full range of its activities, from strategic planning to construction and system operations, MassDOT will promote sustainable economic development, protect the natural environment, and enhance the quality of life for all of the Commonwealth's residents and visitors. This will enable MassDOT to use resources in a manner that serves its existing customers while preserving our resources for future generations.

Policies: MassDOT will pursue the GreenDOT Vision and achieve the three GreenDOT goals by making sustainability an integral part of every MassDOT employee's job, and by integrating these objectives into their organizational vision and mission.

- Addressing short- and long-term greenhouse gas emissions at every stage of design, construction, and operation of the transportation system in order to minimize climate disruption and its effects on the environment and on their customers.
- Consider the needs of all customers, regardless of mode choice or ability, in the design and operation of MassDOT transportation facilities.
- Distribute staff resources and define department objectives in a manner that ensures adequate attention to all customers and modes.
- Design, build, and operate our transportation system so that it supports smart growth development that will in turn facilitate healthy modes of transportation-walking and bicycling, improve air quality, and enhance the quality of life for all customers.
- Measure its performance toward the GreenDOT goals with a robust set of performance measures that evaluate sustainability and service to our customers.

Performance Measures/Target Goals: GreenDOT policy implementation will be guided by a target for greenhouse gas reductions under the Climate Protection and Green Economy Act that was signed into law in 2008. This law requires the Massachusetts Executive Office of Energy and Environmental Affairs (EOEAA), in consultation with other state agencies and the public, to set economy-wide greenhouse gas (GHG) emission reduction goals for Massachusetts to achieve:

- By 2020, a reduction of between 10 percent and 25 percent below statewide 1990 GHG emission levels, which were 9.4 million metric tons of CO^2 equivalent (MMTC02e).
- By 2050, a reduction of 80 percent below statewide 1990 GHG emission levels.

The following is a summary of the projected reductions in greenhouse gas emissions levels that are expected to result from the GreenDOT Policy.

Table 4.6
GreenDOT Policy Projected GHG Reductions in 2020 and 2050, in million metric tons of CO^2 equivalent (MMTC02e)

Comparison Conditions			
1990 Baseline Case – Economy-wide GHG Emissions			94.4
1990 Baseline Case – Transportation Sector GHG Emissions			28.9
GreenDOT Policy Goals	2020 (% below 1990 level)	2050 (% below 1990 level)	Notes and Assumptions
Reduce Greenhouse Gas Emissions	1.53 (5.3%)	1.65 (5.7%)	Reduced GHG emissions from construction and operations, more efficient fleets, travel demand management programs, eco-driving, and mitigation of development projects
Promote Healthy Transportation Modes of Walking, Bicycling and Public Transit	0.20 (0.7%)	0.37 (1.3%)	Reduced automobile travel resulting from MassDOT transportation investments that improve pedestrian, bicycle, and public transit infrastructure and operations
Support Smart Growth Development	0.38 (1.3%)	1.53 (5.3%)	Reduced automobile travel that is enabled by denser, smart growth development patterns
GreenDOT Subtotal	2.11 (7.3%)	3.56 (12.3%)	

The GreenDOT Policy is expected to result in the following GHG emission reductions:

- By 2020, the proposed GreenDOT Policy would produce a reduction of 7.3 percent below 1990 transportation GHG emissions.
- If left unchecked by the Commonwealth and Federal government, transportation GHG emissions would be expected to increase to 34.4 MMTCO2e by 2020, a 19.0 percent increase from 1990 levels. Instead, the EOEAA stated that with GreenDOT, in conjunction with other state and federal policies, transportation GHG emissions are expected to be reduced 30 percent below the 34.4 MMTCO2e level of 1990.
- If GreenDOT measures are extrapolated to 2050, they are expected to reduce transportation GHG emissions by a total of 12.3 percent below 1990 levels. This number only reflects the further GHG reductions resulting from those policies that are within

MassDOT's direct control, such as impacts of travel behavior that are shaped by MassDOT project priorities, design and construction practices, and fleet emissions. In order to meet the 80 percent GHG emissions reduction called for in the Climate Protection and Green Economy Act, many other changes in the transportation sector and elsewhere that lie outside of MassDOT's direct control are necessary.

MassDOT plans to achieve these results using specific measures, initiatives, and programs to achieve the GreenDOT mission. These policies include making rail transportation system improvements, creating more bicycle and pedestrian amenities, employing and supporting sustainable design and construction practices, and employing more fuel efficient and alternative fuel vehicles.

Strategy 1: Maintaining and Expanding Transit Services

The increased use of mass transit, and the possible expanded regional transit service follow the state's guidelines on Smart Growth and Sustainable Development, as they reduce congestion on the roadways and reduce the use of fossil fuels and greenhouse gas emissions in the atmosphere.

Bus Transit Expansion

Two Regional Transit Authorities (RTA) provide most of the regional fixed route service. Brockton Area Transit (BAT) operates 14 routes in the metro Brockton area and the Greater Attleboro Taunton Regional Transit Authority (GATRA) operates the Plymouth Area Link (PAL) with four routes in the OCPC communities of Plymouth and Kingston.

BAT recently expanded its service area into the neighboring OCPC town of Rockland in February 2010 with the Rockland Flex Ride service. This service is offered to riders on a flexible route schedule, which features on-demand, as well as fixed-stop service. It brings riders to retail centers such as Target, Stop & Shop, and Walmart in Abington, and Signature Healthcare Brockton Hospital in Brockton.

OCPC will continue to work with these service providers by assisting in future transit feasibility studies as well as making improvements in service frequencies, reliability, and attractiveness on existing transit routes.

Figure 4.1: BAT Bus Fleet

Commuter Rail Expansion

Currently three MBTA Commuter Rail lines operating in the Region, the Middleborough /Lakeville, Kingston/Plymouth, and Stoughton/Providence lines. The current commuter rail lines in the Region handle approximately 11,000 one-way transit trips per day. The Middleborough/Lakeville and Kingston/ Plymouth lines were restored to service in the fall of 1997 and have become a popular choice for commuters who work in Boston.

Figure 4.2: MBTA Commuter Rail Station

The Providence/Stoughton line offers service to Stoughton and points north, with service Monday-Friday. The Middleborough/ Lakeville line offers service through the OCPC communities of Brockton and Bridgewater. The Kingston/Plymouth line serves the OCPC communities of Abington, Whitman, Hanson, Halifax, Kingston and Plymouth. The Old Colony lines have service seven days a week including all holidays.

Below are a few proposals to expand transit service within the region.

South Coast Rail Project-Fall River/New Bedford

The South Coast Rail project is an initiative of the Massachusetts Department of Transportation (MassDOT) to restore commuter rail transportation from South Station in Boston to the cities of Fall River and New Bedford along an existing freight rail corridor running south from Taunton to Fall River and New Bedford.

The original New Bedford/Fall River Commuter Rail Project Feasibility Study was prepared in March 1997 and explored the issues of cost, expected ridership, environmental impacts, and operational issues. There were three alternatives proposed: the Attleboro, Stoughton and Middleborough Lines. It was noted that a complete rebuilding of the New Bedford and Fall River Secondary Track would be required for all alternatives. The study concluded that the preferred Transportation Alternative, the Stoughton Alternative would attract the highest ridership, be most cost effective, and have the least environmental impact.

In July 2000, the MBTA submitted a Supplemental Draft Environmental Impact Statement (SDEIR) for the project in response to the requirements of Massachusetts Environmental Policy Act (MEPA) Certification of the DEIR. This document provided the detailed analysis and reporting on the environmental impacts of the Stoughton Alternative.

The Final EIR was submitted in April 2002. This document selected the Stoughton Alternative as the only viable option. It listed the Hockomock Swamp as the primary area of environmental concern. In August 2002, the State Secretary of Environmental Affairs concluded that the Stoughton route was the most feasible and met the most environmental hurdles except for the Hockomock Swamp that will require an elevated trestle.

The Stoughton Alternative would require the reconstruction of 14 miles of inactive and abandoned track from Stoughton to Taunton. The new stations on the Stoughton Line would be located in North Easton, Raynham, Taunton (Dean Street), and East Taunton. The New Bedford Main Line station would be in New Bedford and the Fall River Branch would locate new stations in Freetown, Fall River, and Battleship Cove.

The project is now undergoing a joint state and federal National Environmental Policy Act (NEPA) and Massachusetts Environmental Policy Act (MEPA) review process to determine all the necessary permits needed. The soonest a joint federal and state Draft EIS will be available is January 2011.

Wareham/Buzzards Bay

In January 2007, the Boston Metropolitan Planning Organization published the final draft study to look at the feasibility of reestablishing commuter rail services to Buzzards Bay. In 1996, a similar study was completed, but no action was taken.

The services include an extension of the MBTA commuter rail service from Middleborough to the town of Bourne and would use an existing rail line known as the Buzzards Bay Secondary Track. This line runs from Middleborough through the northeast corner of the town of Rochester, to the center of Wareham, to Bourne. Currently, the line is used for freight service operated by the Bay Colony Railroad, mainly trash trains that come up from the Cape Cod area. There were three alternatives proposed for the train service. The first and preferred alternative is simply to extend the current Middleborough/Lakeville line to Buzzards Bay. This would require additional sets of trains to provide the same service currently advertised on the existing portion of the line. The other two alternatives were to run trains express through stops beyond the extension, or to run a shuttle service along the extension, requiring a longer platform in Middleborough where the passengers would exit one train and board a second train heading to Boston.

The study's proposed route and stations, with the understanding that station siting may change based on the community need and the availability of land for parking and access roads, are Rock Village, Country Road, Wareham, and Buzzards Bay. Approximately 2,045 additional passengers would be added to the line because of the four additional stations. Some of these passengers would not be new to the service but would be shifting from other rail stations.

Upgrades to infrastructure would be necessary to run the service. The rail line is in good shape but would likely need to be replaced either before or shortly after the services were to begin. Additional stations and platform would need to be constructed at the estimated cost of $2.5 million each, in addition to adjacent parking facilities. In addition to taking cars off the road and

reducing environmental effects such as emissions, it is estimated that about 8% of the auto traffic heading into metro Boston through the Braintree split would be eliminated.

Expanding Commuter Rail Service to Downtown Plymouth

Plymouth currently has commuter rail service four times a day; these trains do not serve the station at peak commute times and the station is currently underutilized. Many Plymouth residents drive to the Kingston Station to catch a train at peak commute times. Increasing the amount of train service in Plymouth and extend service to downtown would not only alleviate some of the parking congestion at the Kingston station but it would also generate some reverse commute trips during the summer, during Plymouth's peak tourism season. It is estimated that 750,000 people visit Plymouth annually making tourism an important part of Plymouth's economy. An opportunity exists to meet the travel needs of tourists through the use of the current regional transportation infrastructure.

Adding a Station in West Bridgewater along the Middleborough/Lakeville Line

The town of West Bridgewater has expressed interest to the MBTA in acquiring a station along the Middleborough/Lakeville Commuter Rail Line. Currently the train passes through the town and thus the town pays an assessment to the MBTA. A station could provide convenient accessibility to the commuter rail for residents of both East and West Bridgewater. Additionally, access to rail service could have a positive effect on decreasing traffic on the nearby Route 106.

Recommendations

- **Support "Intermodalism."** Promote using "intermodalism" to better integrate all transportation modes such as: Automobile, Motorcycle, Transit, Rail, Bus, Water, Air, Walking, and Bicycling. Providing a hub that supports all transportation modes attracts more people and increases efficiency.

- **Improve mass transit linkages.** Every effort should be made to promote improved linkages between mass transit and other modes of transportation. One example would be a public private relationship utilizing private carriers to connect localized RTAs.

- **Increase intermodal connections at the Montello Station.** Currently, an MBTA route, a BAT route, and passenger rail to Boston are serviced by the station. Coordinating the fixed routes there and making the station a mini –intermodal center will enhance the transportation options for the people in the area using the station.

- **Encourage the development of a Plymouth Intermodal Center.** Plymouth is interested in building an Intermodal center that would enhance both commuters and tourist transportation experiences.

- **Continue commuter rail operations funding.** Support the funding of commuter rail operations in the Commonwealth through a statewide funding mechanism.

- **Support the extension of the commuter rail to Fall River/New Bedford and to Buzzard's Bay.**

- **Provide feeder service to Old Colony commuter rail stations.** Intercity bus carriers, such as P&B and JBL Bus Lines, Inc. should consider altering and/or adding routes, to serve as feeder routes to Old Colony commuter rail stations.

- **Encourage interagency agreements to enhance passenger service.** For example, currently the MBTA 230 bus ends at the Montello Station, but extending that service to the Bat Centre, would enhance passenger connections.

- **Expand commuter services by private commuter carriers.** In order to better meet mass transit needs in the region, the expansion of commuter services by private carriers is encouraged in areas where there is a demand for such services.

- **Support the creation of Bus Rapid Transit Facilities.** The creation of dedicated bus rapid transit lanes would combine the flexibility of buses with the efficiency of rail in an effort to encourage bus ridership and decrease congestion on busy city streets.

- **Support the integration of technologies across modes of transportation.** Examples of this would be a regional fare card or integrated automatic vehicle locater (AVL) systems to improve transit connections across systems.

- **Support the use of new technologies for transit vehicles.** Hybrid and hydrogen technology on buses can reduce fuel consumption and pollution and AVL technology for DIAL-A-BAT and BAT can improve safety and efficiency for the service.

- **Maintaining the nation's transit systems in a State of Good Repair (SGR)-** This is essential if public transportation systems are to provide safe and reliable services to the general public. State of Good Repair concepts include measuring the condition of transit capital assets, prioritizing local transit re-investment decisions and conducting preventive maintenance practices, all in an effort to save money and extend the useful life of all transit related assets.

Strategy 2: Carpooling, Car Sharing and Flexible Schedule Alternatives

Carpools & Vanpools

The concept of carpooling, and vanpooling - which may collectively be termed "ridesharing", are typically commuter-oriented strategies that seek to reduce vehicle miles travelled (VMT) by increasing vehicle occupancies for work trips. Carpooling involves formal or informal arrangements between two or more people to share a ride in a private vehicle. Vanpools generally consist of 5 to 15 people, including a volunteer driver-member, that commute together in a van. Participating in ridesharing gives people more time to read and relax during their commute, save money on gas and related automobile expenses, create less pollution from fewer auto emissions, and use available High Occupancy Vehicle (HOV) lanes. The state of Massachusetts encourages the use of carpooling and vanpooling through the MassRIDES website where their TripMatch program lets potential carpoolers/vanpoolers search a database of existing carpools and vanpools to travel with.[15]

Park-and-Ride Facilities

There are nine park-and-ride facilities formally maintained by MassDOT south of Boston as well as two informal lots that serve Bloom Bus customers. A majority of these facilities are located along major highways and provide intermodal connections for commuters who drive automobiles, walk, or bicycle, and wish to access commuter buses, car/van pools, rapid transit, and commuter rail and/or water shuttles. Park-and-Ride lots can be a viable alternative to automobile commuting and can lead to decreased traffic congestion and improved air quality.

Compressed Work Week

The concept of a compressed work weeks refers to a scheduling system where a regularly scheduled number of hours are worked in a shortened span of time. Often, compressed work weeks refer to 40 hours worked over the course of only four days (4/40) or 80 hours worked over the course of nine days (9/80). Under a compressed work week, each day worked is often longer than a standard 9:00 a.m. to 5:00 p.m. schedule. The 4/40 and 9/80 schedules are among the most common forms of compressed work weeks, and they give employees one day off every week or every other week, respectively. Compressed work weeks have been applied successfully in the commercial, public, and manufacturing sectors for many years. With recent energy cost concerns, some agencies and companies have expressed renewed interest in compressed work weeks; for example, in August 2008 the State of Utah implemented a mandatory four-day workweek for 17,000 state government employees.

Car Sharing

Another way to increase the connectivity of transit modes is by adding car-sharing programs. There are many local companies across the United States, but the most well-known is ZipCar. Areas, such as the BAT Intermodal Centre in downtown Brockton, Bridgewater State University, and Stonehill College, are communities that would be enhanced by a car-sharing program. Generally, a person needs to be 21 or older to use the service, but ZipCar has undergraduate

[15] MassRides Website: http://www.commute.com

programs, geared for college communities. In addition, colleges can benefit from such a program because they can offer cars to their students, faculty, and staff at a reasonable cost and the programs require little administration from the college.

Areas with downtown residential growth will benefit from the operation of car sharing to supplement public transit. One of the benefits of the car-sharing program, in contrast to the typical rental car program is that you can use the car by the hour, the day, or for longer periods if necessary. Car sharing gives people the flexibility that is much like owning your own car, and many areas have already seen the program work successfully.

Flexible Scheduling

Flexible work schedules refer to employer-facilitated alternatives to a standard 9:00 a.m. to 5:00 p.m. work schedule for employees. Employees are given more discretion over when they work so that they can accommodate other obligations and/or commute during less congested off-peak periods. Typically, so long as they are working a set number of hours each day, week, or month, employees with flexible work schedules are allowed to choose the times they begin and end work each day. While flexible scheduling can only work if your company can maintain these hours and days of operation and still providing excellent service and optimum performance, it offers a host of benefits to employers and employees, including increased employee morale and retention, reduced absenteeism and tardiness, and lower overtime costs. The benefits to the employer include increased attractiveness to job applicants, lower overhead costs, and the ability to offer extended hours for customer service/relations departments.

Telecommuting

Telecommuting is the practice of working from a location other than the regular workplace and using modern technology to bridge the resulting distance. In the United States, a majority of "teleworkers" work from their homes, while a much smaller number of individuals work from "telecenters", smaller offices in close proximity to the employee's home with direct communication access to the regular workplace. Although not all jobs are suitable for telework, many require face-to-face communication with clients or co-workers and would therefore be difficult to perform from home or a telecenter. In today's mobile society; however, the idea of working from home is seen has having a variety of benefits, including enhanced worker productivity and morale and improved employee attraction and retention. Companies benefit by having less overhead costs, including less office space to rent, a decrease in water and energy usage, smaller parking lots, and an overall smaller carbon footprint. The environmental benefits of telecommuting include a reduction in fuel consumption, traffic congestion, and improved air quality, as are there fewer commuters on the road.

Recommendations

- **Strive to reduce single occupancy vehicle travel.** Support programs that encourage means to reduce single occupancy automobile travel. Examples are flexible work schedules, preferential parking for ridesharing, and incentives for transit use. The MassRides program offers employers and their employees the benefits of carpooling and ridesharing.

- **Study the feasibility of High Occupancy Vehicle (HOV) lanes for buses, carpool and vanpools.** High Occupancy Vehicle lanes installed along Principal Arterials such as that on Interstate 93, which would improve commuting times in Boston, reduce congestion, and improve air quality. A feasibility study should be conducted to determine the potential for HOV lanes along Principal Arterials in the OCPC Region.

- **Enforce Massachusetts' rideshare regulation.** To comply with Massachusetts' environmental regulation (310 CMR 7.16), employers with more than 250 employees at a single location must implement commuter programs geared to reducing the drive alone community by 25%. Program options include instituting a transit pass program, creating incentives for bicycle commuting, posting transit schedules and maps, and promoting carpooling. In addition, companies with more than 1,000 employees at one facility must implement a vanpool program.

- **Support legislative initiatives affecting corporate commuter services program.** Under the Massachusetts General Laws, Chapter 63D, Section 31D, corporations doing business in Massachusetts are allowed a tax credit amounting to 30% of the cost of purchasing or leasing a commuter van for their employees to use in their daily work trips. This legislation also waives registration fees, creates a special license plate for commuter vans, and established insurance requirements for participating vehicles. Corporations are encouraged to implement commuter services programs that provide incentives through the above legislative initiatives.

- **Encourage the formation of Transportation Management Associations (TMAs).** Transportation Management Associations are private, non-profit, member-controlled organizations that provide transportation services in a particular area, such as a commercial district, mall, medical center, or industrial park. MassRides offers carpooling, vanpooling, parking management, and other techniques that allow employees to diversify their trips to and from work, thereby reducing congestion and improving air quality.

- **Support Car Sharing.** Car sharing programs like ZipCar can be a great way to offer residents flexible transportation options. Areas that would be great candidates for car sharing would be Bridgewater State University, Stonehill College, and the BAT Intermodal Centre in downtown Brockton.

- **Develop additional park-and-ride facilities and maximize the efficiency of current park-and-ride facilities.** OCPC transportation staff should interact with MassDOT in determining potential new sites for the construction of park-and-ride facilities to augment existing facilities. Current park-and-ride facilities should be maximized to include multimodal options.

- **Encourage staggered work hour initiatives.** Where feasible, encourage large employers to stagger their work hours to offset emissions from high concentrations of automobiles during peak hours.

Strategy 3: Land Use Strategies

Within the Old Colony Planning Council Region growth continues to decentralize the population and to consume land at an increasingly alarming rate. This continuing pattern of low-density residential development of outlying areas and the scattering of non-residential uses has become commonly referred to as "sprawl." The increase of sprawl within the region coincided with the end of World War II in the 1940's and the construction of the Interstate Highway System in the 1950's. At that time, new families were looking to purchase houses and the suburbs were an ideal place with a large amount of developable land, affordable housing, and access to highways and jobs.

Many communities that grew rapidly over the past fifty years were those that were sparsely populated, while the more densely settled areas having much less buildable land, experienced a much slower rate of growth. Land use within the OCPC Region has grown dramatically over this time as residential development has grown from 31,706 acres in 1971 (10.5% of the region) to 53,151 acres in 1999 (24.2% of the region). This is a 68% increase in residential land over that time period. Yet, the population only grew by 40% (230,979 in 1971 to 321,515) during the same time period. In recent years, most development has come in the form of low to moderate density single family housing development on relatively large lots. Most of the region's housing inventory can be classified as low to moderate densities with Brockton the only community considered to be having a "high density." Many of the Region's communities with room to grow are the least dense, whereas the densest communities experienced the lowest growth.

Table 4.7: Reasons for the Increase of Sprawl

Sprawl has increased over time for a variety of reasons:

- Continued growth in population and the need for additional housing.
- Large lot zoning, where local towns can require that new single family houses be built on a minimum of 1-2 acres.
- A transportation system that is dominated by the private use of automobiles.
- Single use zoning, were large land areas are restricted to a single land use, ex. Only for residential, industrial, commercial etc.
- The affordability of single-family housing in the suburbs, where you can get more "bang for your buck" when purchasing a home- a larger house, bigger yard, etc.
- Extensive versus intensive development.
- Ease of driving to and from dispersed sites

Table 4.8 Negative Consequences of Sprawl:

Sprawl can have a variety of negative impacts on a region and are not limited to:

- Increased consumption of land for housing and a decrease in the amount of farmland, green space, and open space.
- Additional trips on the transportation network, contributing to an increase in traffic congestion and the burning of fossil fuels causing air pollution.
- An increase in the average commute time. The commute time for residents in the OCPC Region increased from 25.7 minutes in 1990 to 31.8 minutes in 2000. The State's average commute time was 27 minutes in 2000, compared to the 31.8 minute average commute time of the region.
- An increase in infrastructure costs associated with building, maintaining and repairing roads, bridges, and parking facilities.
- Loss of regional focus.

Land Management Mitigation Programs

The OCPC recognizes the threat to environmentally sensitive areas and works with communities to make environmentally and economically sound land use decisions. The OCPC promotes and supports transportation and land use plans that support integrated, multimodal transportation strategies, including the use of transit, ridesharing, bicycling, and walking. The OCPC also works to ensure that transportation improvement projects consider enhancement of aesthetics and character of neighborhoods, communities, and commercial districts.

Livability & Sustainable Development Concepts

The current-endorsed "Livability" and "Sustainable Development" movements encourage a "redevelop first" mentality, putting relatively high-density development near existing centers and in areas with well-established infrastructure, and doing so in ways that avoid additional energy consumption, minimize the effect on natural resources, and mitigate unavoidable impacts on environmental quality.

Livability and sustainable development principles are intended to be the antithesis of sprawl, but they can be applied at a great range of scales from individual projects to a regional scale. The effect on travel patterns and modal choices can vary with the scale of action. Communities that adopt these principles have a greater concentration of growth in regional centers that create more walkable neighborhoods and allow for a greater use of mass transit.

On July 16, 2009 the U.S. Department of Transportation (DOT), the U.S. Department of Housing and Urban Development (HUD) and the Environmental Protection Agency (EPA) announced the formation of the interagency Partnership for Sustainable Communities. With the formation of the Partnership for Sustainable Communities these three agencies agreed to collaborate to help communities become economically strong and environmentally sustainable by following the Partnership for Sustainable Communities Six Principles of Livability:

- **Provide more transportation choices** to decrease household transportation costs, reduce our dependence on oil, improve air quality and promote public health.

- **Expand location- and energy-efficient housing choices** for people of all ages, incomes, races and ethnicities to increase mobility and lower the combined cost of housing and transportation.
- **Improve economic competitiveness of neighborhoods** by giving people reliable access to employment centers, educational opportunities, services and other basic needs.
- **Target federal funding toward existing communities** – through transit-oriented and land recycling – to revitalize communities, reduce public works costs, and safeguard rural landscapes.
- **Align federal policies and funding** to remove barriers to collaboration, leverage funding and increase the effectiveness of programs to plan for future growth.
- **Enhance the unique characteristics of all communities** by investing in healthy, safe and walkable neighborhoods, whether rural, urban or suburban.

The Commonwealth of Massachusetts, through Governor Deval Patrick's office, also promotes the concepts of livability and sustainable development through ten sustainable development principles. These principles include promoting clean energy, in the form of energy efficiency and renewable power generation, in order to reduce greenhouse gas emissions and consumption of fossil fuels. They also encourage the creation of "pedestrian-friendly" districts and neighborhoods that mix commercial, civic, cultural, educational, and recreational activities with parks and homes. Massachusetts' List of Sustainable Development Principles are listed below:

- **Concentrate Development and Mixed Uses**
- **Advance Equity**
- **Make Efficient Decisions**
- **Protect Land and Ecosystems**
- **Use Natural Resources Wisely**
- **Expand Housing Opportunities**
- **Provide Transportation Choice**
- **Increase Job and Business Opportunities**
- **Promote Clean Energy**
- **Plan Regionally**

Transit Oriented Development (TOD)

Transit-Oriented Development (TOD) is compact, mixed-use, walkable development centered on transit stations, and generally includes a mix of uses such as housing, shopping, employment, and recreational facilities. TOD projects are designed with transit and pedestrians as high priorities. TOD is a key element of livable and sustainable communities and represents an opportunity for communities all across Massachusetts to enhance their quality of life. With TOD, parking lots and underutilized land near public transportation can be turned into vibrant mixed-use districts, diverse housing, and lively public places. This type of development reduces the impacts to the environment by concentrating usages to one particular area, thus decreasing the amount of daily vehicle trips to and around the site.

Brownfield Redevelopment

The U.S. Environmental Protection Agency defines a brownfield as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant." EPA's Brownfields Program provides funds and technical assistance to states, communities, and other stakeholders in economic redevelopment to work together to prevent, assess, safely clean up, and create sustainable reuse brownfields.

In 1998, Massachusetts passed into law the "Brownfields Act" which created financial incentives and liability relief for parties undertaking brownfields cleanup projects. The Brownfields Act provided agencies at the state level with $50 million dollars to administer programs targeted towards the cleanup and reuse of contaminated property. Massachusetts DEP brownfields program incentives are available to buyers, and sometimes sellers, of contaminated property provided there is a commitment to cleanup and redevelopment. Brownfields properties are often located where there is an existing infrastructure, workforce and other amenities. State incentives can help parties identify risk, limit liability, and fund the cleanup of brownfields sites enabling their reuse for industry, housing and other purposes.

The Brockton Brightfield, a 425-kilowatt (kW) photovoltaic (PV) solar energy system located on a 3.7 acre environmentally remediated brownfield in Brockton, Massachusetts is the largest solar energy plant in New England, and the largest brightfield transformed into a solar energy generating station in the nation.

Transfer of Development Rights

Transfer of Development Rights (TDR) is a system that assigns development rights to parcels of land and gives landowners the option of using those rights to develop or to sell their land. TDRs are used to promote conservation and protection of land by giving landowners the right to transfer the development rights of one parcel to another parcel. By selling development rights, a landowner gives up the right to develop his/her property, but the buyer could use the rights to develop another piece of land at a greater intensity than would otherwise be permitted.

Low Impact Design

Low Impact Development (LID) is an approach to environmentally friendly land use planning. It includes a suite of landscaping and design techniques that attempt to maintain the natural, pre-developed ability of a site to manage rainfall. LID techniques capture water on site, filter it through vegetation, and let it soak into the ground where it can recharge the local water table rather than being lost as surface runoff. An important LID principle includes the idea that stormwater is not merely a waste product to be disposed of, but rather that rainwater is a resource.

Chapter 40R-Smart Growth Zoning

In order to encourage housing production in the Commonwealth be consistent with the concept of smart growth, Massachusetts passed into law Chapter 40R. Chapter 40R provides financial rewards to communities that adopt special zoning districts allowing as-of-right high-density residential development.

Eligible locations: Smart growth zoning districts can be in one of three locations:

- Areas near transit stations, including rapid transit, commuter rail, and bus and ferry terminals.
- Areas of concentrated development, including town and city centers, other existing commercial districts in cities and towns, and existing rural village districts.
- Areas that by virtue of their infrastructure, transportation access, existing underutilized facilities, and/or location make highly suitable locations for residential or mixed-use smart growth zoning districts.

There are currently five locations in the OCPC Region designated as 40R Districts:

- Bridgewater-Waterford Village Smart Growth Overlay District
- Brockton-Downtown Brockton Smart Growth Overlay District
- Easton-Queset Smart Growth Overlay District
- Kingston-1021 Kingston Place Smart Growth District (Status: To Be Determined)
- Plymouth-Cordage Park Smart Growth District

Massachusetts Environmental Policy Act (MEPA)

The Massachusetts Environmental Policy Act (MEPA) requires that state agencies study the environmental consequences of their actions, including permitting and financial assistance. MEPA further requires that state agencies "use all practicable means and measures to minimize damage to the environment," by studying alternatives to the proposed project, and developing enforceable mitigation commitments, which will become permit conditions for the project if and when it is permitted.

MEPA applies to projects that exceed MEPA review thresholds and that require a state agency action, specifically that they are either proposed by a state agency or are proposed by municipal, nonprofit or private parties and require a permit, financial assistance, or land transfer from state agencies.

MEPA review is not a permitting process, but does require public study, disclosure, and development of feasible mitigation for a proposed project. It does not pass judgment on whether a project is environmentally beneficial, or whether a project can or should receive a particular permit. Those decisions are left to the permitting agencies. MEPA review occurs before permitting agencies act, to ensure that they are fully cognizant of environmental consequences of their actions.

Community Preservation Act

The Community Preservation Act (CPA) was passed into law in Massachusetts in September 2000 and has been amended five times since then, with the last amendment occurring in September 2006.

The Community Preservation Act (CPA) is an innovative tool for communities to address important community needs and finance specific community preservation acquisitions and initiatives. The CPA allows communities to create a local Community Preservation Fund to raise money through a surcharge of up to 3% of the real estate tax levy on real property for open space protection, historic preservation and the provision of affordable housing. The act also creates a significant state matching fund, which serves as an incentive to communities to pass the CPA.

Once adopted locally, the Community Preservation Act requires the legislative body to annually appropriate, or reserve for future appropriation, at least 10% of the estimated annual fund revenues for acquisitions or initiatives in each of the following three categories of allowable community preservation purposes: open space (excluding recreational uses), historic resources, and community housing. This allows the community flexibility in distributing the majority of the money for any of the three categories as determined by the community.

Coastal Smart Growth Program

The Massachusetts Office of Coastal Zone Management (CZM) launched the Coastal Smart Growth Program in 2004 to catalogue, develop, and distribute planning, technical, regulatory, and outreach tools for real-world growth management that protects coastal resources.

The priorities for the Coastal Smart Growth Program are:

Technical Assistance and Workshops - providing successful Massachusetts case studies, publications and slideshow presentations, model bylaws and regulations, site design manuals, and direct support to communities, developers, related businesses, and environmental groups.

Low Impact Development - using an integrated approach to site design, stormwater management, and water conservation that protects the natural terrain and hydrology.

Coastal Landscaping - supporting the use of native plants to prevent storm damage and erosion, provide wildlife habitat, and reduce coastal water pollution—all while improving a property's visual appeal and natural character.

Recommendations

- **Encourage Smart Growth Development Strategies.** Support the smart growth initiatives resulting in cluster and condensed development. These strategies aim to reduce vehicle trips and vehicle dependency; therefore, resulting in benefits to air quality and reduction of foreign fossil fuel dependency.

- **Encourage Brownfield Redevelopment.** Brownfield properties are often located where there is existing infrastructure, workforce, and other amenities and therefore, are attractive for potential new business. Reuse of these facilities cleanses the existing site and eliminates the need to clear-cut forest for more development. Fostering the cleanup and re-use of contaminated properties is a priority for the state and the OCPC, and is consistent with the Sustainable Development Principles established by the Massachusetts Office of Commonwealth Development.

- **Increase Accessibility at the Neighborhood Scale.** One approach is to use the Subdivision Rules and Regulations to encourage pedestrian and bicycle ways to connect cul-de-sacs and local streets in subdivisions to one another and to nearby schools, stores, and other destinations.

- **Develop Healthier and More Varied Centers**. This would increase opportunities available in compact settings, and reduce trips by concentrating local destinations and strengthening community character. Communities should seek means to guide public, commercial and high- density residential investment to selected multi-purpose centers. Larger communities with failed shopping centers should adopt Planned Unit Development regulations or other tools for redeveloping such sites with diverse complementary uses.

- **Continue to Study the Implications of Major Development Projects.** Even after MEPA review and local approval, many large and complex projects can have ill-defined impacts or significant changes in major factors, particularly involving actions not requiring State permits. It is important to have the capacity to continue reviewing major traffic-generating projects such as the reuse of the South Weymouth Naval Air Station and the Pine Hills project in Plymouth.

- **Increase Transit Accessibility to Nearby, Unserved, Employment Centers**. Put high priority on extending fixed-route service and on encouraging growth in industrial areas whose location and configuration fit such service, but be open to limited demand-responsive service where required to give residents needed employment opportunities.

- **Respond to the Potential Impacts of Major Highway and Rail Projects Potentially Encouraging Continued Overall Sprawl Development.** Southeastern Massachusetts remains a "Region at Risk" due to the impacts of unplanned growth and change. There is a need to continue exploring issues raised by the Southeastern Massachusetts Vision 20/20 project examining and publicizing alternatives to current trends, refining goals and objectives, developing a plan implementation effort, and working for region-wide acceptance of the program and meaningful commitments to it.

- **Strengthen Downtown Plymouth Commuter Rail Station.** Seeking extension of commuter rail service from Cordage to Downtown, and more frequent peak hour service, will increase convenient service to nearby high-density neighborhoods. This

recommendation would partially complete the originally planned system and greatly strengthen downtown Plymouth, giving the town a more fitting level of service.

- **Modify Transportation Improvement Projects and Priorities to Encourage the Compact Close-in Development Patterns Envisioned in the Plan's Goals and Objectives.** Take actions ranging from improving the flexibility and connectivity of minor arterials, major collectors, and minor collectors, to improving ease of pedestrian/bicycle movement in and between neighborhoods and facilities within the downtown. Examples in Brockton would be restoring the stairs at the Downtown Rail station, which allowed direct movement from the platform toward most downtown destinations, and reopening the recently blocked 100-year old pedestrian underpass between Lincoln Street and the Post Office.

- **Encourage/Promote Bicycle Riding and Walking as a Viable Alternative to Automobile Commuting and as a Means to Improve Air Quality**. Where feasible, bicycling or walking to work or to transit facilities instead of driving, would reduce "cold starts," which inject high levels of toxic emissions into the atmosphere with the starting and shutting off automobile engines. A coordinated effort of local officials, the Massachusetts Highway Department, Regional Planning Agencies, and interest groups, should encourage and promote the use of existing designated bicycle routes as a viable alternative to automobile commuting through public information and awareness efforts. Additionally these agencies should also support the creation of pedestrian walkway connections between residential areas, transit facilities, industrial parks, shopping centers, schools, and other key destinations.

- **Reduce CO^2 Emissions by Promoting LEED Construction.** Leadership in Energy and Environmental Design (LEED) is a green building certification system developed by the U.S. Green Building Council (USGBC) to improve energy and water usage, reduce CO^2 emissions, and improve indoor air quality with minimal disruption to the natural environment. To accomplish LEED certification, the USGBC gives owners and operators with concise framework for identifying and implementing practical and measurable green building design, construction, operations, and maintenance solutions.

- **Encourage the Adoption of Mileage Based "Pay-as-you-Drive" Automobile Insurance Reform.** Pay-As-You-Drive (PAYD, also called Distance-Based, Usage-Based and Per-Mile Pricing) means that premiums are directly based on the number of miles a vehicle is driven during the policy term. Most motorists should benefit overall, including those who currently drive less than average in their rate class, those who would reduce their mileage to below average in response to this incentive, those who drive uninsured but would purchase insurance if offered PAYD, and motorists who drive high annual miles but value benefits such as reduced traffic congestion, accident risk and pollution emissions.

Strategy 4: Intelligent Transportation Systems (ITS)

Intelligent Transportation Systems (ITS) are applications of advanced technology in the field of transportation, with the goals of increasing operation efficiency and capacity, improving safety, reducing environmental costs, and enhancing personal mobility.

The Old Colony Planning Council advocates the consideration of ITS solutions for transportation problems as a routine part of the transportation planning process. As a stakeholder in the Metropolitan Boston Regional ITS Architecture and the Southeastern Massachusetts Regional ITS Architecture, the Council is committed to continuing an active role in these ITS systems. This includes maintaining channels of communication between the Council and other stakeholders, including but not limited to: the Massachusetts Highway Department; the Southeastern Regional Planning and Economic Development District (SRPEDD); the Central Transportation Planning Staff (CTPS) and Metropolitan Area Planning Council (MAPC); the Cape Cod Commission, and Brockton Area Transit (BAT).

A regional ITS architecture is a framework that defines component systems and their interconnections. Successful ITS deployment requires an approach to planning, implementation, and operations that emphasizes collaboration between relevant entities and compatibility of individual systems. The regional architecture is a mechanism design to ensure this collaboration and compatibility occurs.

Inputs into ITS systems can involve any variety of collection devices, including:

- Loop detectors in the pavement and sophisticated ground level radar systems that are able to collect real time traffic volume and speed data.
- Video equipment is often used to monitor the transportation system. This is useful in allowing system operators to immediately detect areas of congestion that may be forming. It is also used to detect incidents such as crashes and disabled vehicles, in turn accelerating the emergency dispatch, and the overall incident management process. Video surveillance is also a useful tool for security and incident management in transit vehicles and around stops and terminals.
- Automatic vehicle locators (AVL) on board transit vehicles, emergency response vehicles, and roadside assistance vehicles allow operators to know where vehicles are in real time allowing for more efficient dispatch and adjustment of traffic controls if necessary.
- Transmitters onboard transit and emergency vehicles alike are used to pre-empt traffic signals ahead or to alert travelers at a transit stop that the vehicle is approaching.
- Remote weather stations and Doppler radar provide real time weather conditions occurring throughout the transportation network, and provide alerts regarding events such as icing or flooding that may be occurring.

These are some of the technological applications that can be utilized for managing the regional transportation network. All of this information travels over both hard-wired and wireless

communication systems to systems that manipulate the data and distribute it to users of the transportation system. End users of ITS system and the output media include:

MassDOT Traffic Operations Center (TOC)

The Massachusetts Highway Department operates several ITS systems on their highways from their Traffic Operations Center (TOC) in South Boston. Traffic data on MHD highways from all over the state flows into the TOC through hardwire and wireless communications. The TOC responds by relaying information out to the highway users and dispatching resources wherever and whenever needed.

One major system fed into the TOC is the Route 128/I-95 Advanced Traffic Management System (ATMS) for the Route 128/ I-95 circumferential highway and I-93 north of Boston. The ATMS includes a surveillance system (loop detectors, machine vision, radar, and lasers) that detects traffic anomalies or incidents, live roadside cameras to verify the type of incident (flat tire, road debris or accident), and dynamic message signs (DMS) to alert motorists of potential safety problems (accident ahead, slow speeds etc.). This system covers:

- Route 128/I-95 from Braintree to Wakefield (44 miles)
- I-93 from Braintree to Dorchester (6 miles)
- I-93 Boston to Medford (4 miles)

The current surveillance system operated from the Traffic Operations Center (TOC) consists of 40 CCTVs, 15 permanent overhead DMS, 75 portable DMS and 150 traffic detector stations. In addition, GPS enabled snow and ice vehicles, including 22 motorist assistance vehicles, transmit information to the TOC and also communicate with the TOC operators by cellular phone. "Icecast" weather sensors also transmit weather data to TOC.

This network of ITS technology throughout Boston and the circumferential highway system benefits Routes 3 and 24 on the South Shore by reducing both the frequency and duration of incident related bottlenecks in the Boston core, keeping traffic flowing in as smoothly as possible from the South Shore.

MassDOT Permanent Variable Message Signs

MassHighway owns and operates several permanent variable message signs and a large fleet of portable variable message signs throughout the Commonwealth. While there are not any permanent locations within the boundaries of the OCPC region, two are located just outside of the region: on Route 24 in Randolph and on Route 3 in Weymouth. These permanent stations are used to alert drivers to major events affecting the Route 128 belt and Interstate 93, as well as the tunnels. Additionally, these permanent variable message signs are operational components of the AMBER Alert Program, a voluntary partnership between law-enforcement agencies, broadcasters, transportation agencies, and the wireless industry, to activate an urgent bulletin in the most serious child-abduction cases.

MassDOT Portable Variable Message Sign Trailers

Portable variable message sign trailers are located throughout the state and may be dispatched to locations wherever and whenever needed. Often they are used for a major local event, such as a

road race or sidewalk carnival. They can also be dispatched for major unplanned events, such as the flooding of a roadway or a chemical spill, both of which would cause an extended closure of a highway. All variable message signs are controlled from the MassHighway Traffic Operations Center in South Boston.

511

Travelers are able to obtain real time traffic conditions for highways in the Commonwealth, including locally Routes 3 and 24 as well as the Cape Cod Canal bridges, through the State's 511 system. Through dialing 511 on wireless devices on hard-line phone systems, commuters are able to get updated traffic information on highways and bridges throughout eastern and central Massachusetts. On the State's 511 webpage, commuters are able to view live traffic camera imagers from dozen of camera locations throughout the coverage area. Much of these services are also available through other sources, such as the SmarTraveler website.

CaresVan Program

With the assistance of sponsorships from private partners (currently Commerce Insurance Company and Massachusetts' AAA Clubs), MassHighway operates a Motorist Assistance Program, called "CaresVan". This program consists of 22 roving service patrols or tow trucks that provide free roadside assistance to disabled motorists throughout eastern Massachusetts. In addition to assisting motorists with breakdowns, the CaresVan Program also promotes the rapid clearance of disabled vehicles and removal of in-road debris.

Roadside Weather Stations

Roadside weather stations provide the MassHighway TOC with real-time weather conditions on the highways. This information is useful in knowing when icing and/or snow accumulation may be occurring, expediting the dispatch of MassHighway maintenance vehicles.

Automated Vehicle Locators

The Massachusetts Highway Department is using automated vehicle locators on their snow removal and highway maintenance fleet, increasing the efficiency of dispatch of resources to where they are needed.

Intelligent Transportation System in Public Transportation

The Massachusetts Bay Transit Authority (MBTA), Brockton Area Transit (BAT), and the Greater Attleboro-Taunton Regional Transit Authority (GATRA) each employ a number of ITS applications in their operation.

Transit Operation Center (TOC)

Each transit agency operates their own Transit Operations Center that maintains communications between the Operations Center, fixed route vehicles, demand response vehicles, and maintenance facilities. The Center also monitors and maintains its fixed route schedule, provides passenger information services and security through video monitoring systems on their vehicles.

Website

Each agency operates a website providing schedule and fare information, system updates, customer service and feedback.

Recommendations

- **Increased Use of Variable Message Signage.** Variable message signs are a very useful tool in relaying traffic and event information to travelers. Increasing the use of variable message signs on Routes 3 and 24 can better inform drivers of congestion when it occurs. When the driver is aware of congestion ahead of time, he or she is better prepared to make decisions on their options, such as stay on the highway or use transit instead. Additionally, portable variable message signs are a great tool for local departments in the ability to inform drivers of events and incidents on the local system.

- **Increase of Local Traffic Operations Centers (TOC).** Many cities are beginning to develop Traffic Operations Centers (TOCs) to monitor and manage traffic conditions on their roadways, particularly in downtown areas. These TOCs can be operated either full time or on a part-time, as needed basis. A combination of loop detection and video surveillance systems are used to monitor and assess conditions on the transportation network. The operator has the opportunity to respond to situations with a variety of options depending on the type and severity, including adjusting traffic signal phasing, operating variable message signage, and dispatching resources such as highway maintenance and emergency services as needed. For example, if a crash on Route 27 is causing heavy congestion, an operator from a traffic operations center could place a message on a variable message sign at the Whitman town line to avoid Route 27 and use Route 123 instead. A Brockton TOC could also be very useful in monitoring and managing parking in the downtown area, monitoring the occupancy of parking areas and informing travelers of parking conditions via variable message signage.

- **Integration of ITS into all Aspects of Planning.** When conducting planning activities, it should be a routine practice to assess if ITS solutions are applicable, and if so how to incorporate them as options in the final product.

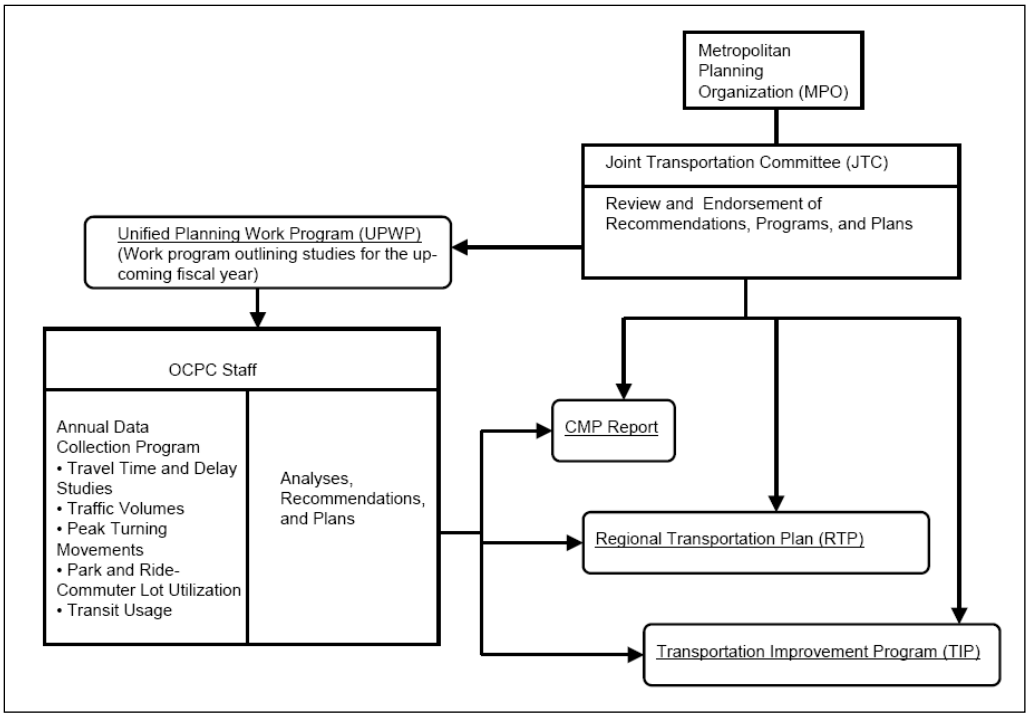
Strategy 5: Congestion Relief Methods

Congestion on a transportation facility may be defined as the level of performance that is deemed unacceptable due to traffic interference. The acceptable level of performance varies from state to state. In addition, the types of transportation modes and links also vary from place to place. Therefore, an effective Congestion Management Process (CMP) is required to provide information on enhancing performance and identifies effective congestion reducing strategies that meet the needs of a particular region.

The CMP is, "a systematic process for managing congestion that provides information on transportation system performance and on alternative strategies for alleviating congestion and enhancing the mobility of persons and goods to levels that meet state and local needs." The CMP includes serious consideration of the implementation of strategies that provide the most efficient and effective use of existing and future transportation facilities. In both metropolitan and non-metropolitan areas, consideration needs to be given to strategies that reduce single occupancy vehicle (SOV) travel and improve transportation system efficiency.

Figure 4.3 below illustrates the integration of the Congestion Management Process within the overall planning process. This process allows for monitoring transportation systems for congestion, reviewing and endorsing plans by local communities that make up the region, and revising monitoring of strategies and overall plans to account for a dynamic management system.

Figure 4.3: Congestion Management Process Diagram



In general, the root causes of congestion can be summarized into two main categories:

- Too much traffic on a facility for the available physical capacity to handle – There is a limited amount of traffic that can be moved on a roadway for a given time, or only so many transit patrons that can be accommodated in a given number of buses or trains. This is considered the physical capacity of the system. Bottlenecks occur at locations where the physical capacity is restricted, with flows from upstream sections (with higher capacities) being funneled into smaller downstream segments. When traffic flow breaks down to stop-and-go conditions, capacity is actually reduced. Bottlenecks can be very specific chokepoints in the system, such as a poorly functioning freeway-to-freeway interchange, or an entire highway corridor where a "system" of bottlenecks exists, such as a closely spaced series of interchanges with local streets. Physical capacity can be reduced by the addition of "intentional" bottlenecks, such as traffic signals and tollbooths. Bottlenecks can also exist on long upgrades and can be created by "surges" in traffic, as experienced around resort areas, or due to specific events (sports events, parades, etc.).

- Traffic Incidents – In addition to the physical capacity, external events can have a major effect on traffic flow. These include traffic incidents such as crashes and vehicle breakdowns; work zones; inclement weather; special events; and poorly timed traffic signals. When these events occur, their main impact is to subtract physical capacity from the roadway. Events also may cause changes in traffic demand by causing travelers to rethink their trips (e.g., snow and other types of severe weather). The level of congestion on a roadway is determined by the interaction of physical capacity with events that are taking place at a given time. The effect of a traffic incident depends on how much physical capacity is present. Consider a traffic crash that blocks a single lane on a freeway. That incident has a much greater impact on traffic flow if only two normal lanes of travel are present than if three lanes are present. Therefore, strategies that improve the physical capacity of bottlenecks also lessen the impacts of roadway events such as traffic incidents, weather, and work zones.

Specific issues that contribute to congestion include:

- Interchange spacing too short on limited access highways
- Inadequate acceleration/deceleration lanes
- Poor access control on arterials
- Lack of incident management plan
- Poor signal timing
- Lack of signal coordination
- Special events/other
- Inclement weather
- Low vehicle occupancy
- Work zones
- Bottlenecks due to too many trips occurring within a narrow time frame
- Adjacent land use development inconsistent with the transportation system
- Crashes

- Driver behavior/distractions
- Lack of adequate roadway, transit, and or parking capacity

The cost of congestion can be measured in dollars as well as time. There is a direct link between transportation investment, travel conditions (congestion and reliability), and economic productivity affected by freight movements. Two key trends have a substantial impact on the total cost of moving freight:

- As congestion spreads into the midday, which is typically the peak travel period for trucks, costs that are more direct will be incurred.
- Reliability – For trucks, the ability to hit delivery windows predictably will decrease and will add even more costs as firms struggle to optimize delivery schedules. This is especially a problem for truckers who must meet "just-in-time" delivery schedules set by shippers, manufacturers, and retailers.

The currently intensified congested corridors are summarized as follows:

- Route 3 From Plymouth/Bourne Town Line To Pembroke/Hanover Town Line
- Route 3A in Kingston and Plymouth
- Route 18 From Route 3 to Central Square in East Bridgewater
- Route 24 From Raynham/ Bridgewater Town Line To I-93
- Route 27 in Stoughton, Brockton, and East Bridgewater
- Route 28 in Avon, Brockton, West Bridgewater, and Bridgewater
- Carver Street/Samoset Street in Plymouth
- Route 106 in Easton and West Bridgewater
- Route 106 in Halifax and East Bridgewater
- Route 123 in Easton and Brockton
- Route 138 From The Canton/ Stoughton Town Line To Junction Of 138 / 27 / 139 In Stoughton
- Route 139 From The Junction Of Route 139/53 In Pembroke To The Pembroke/Marshfield Town Line
- Harrison Boulevard/Central Street In Avon And Stoughton (between Route 28 and Route 27)
- Main Street / North Main Street In Brockton From Plain Street To Avon Town Line

The CMP is also designed to identify key intersections that demonstrate congestion, excessive delays, and circulation problems. The CMP identifies these congested facilities through studies completed by OCPC and other agencies and organizations, and through the ongoing monitoring of facilities. Standard operating procedures have been adopted for data collection that allows the monitoring of intersections within the region specifically targeted due to congestion. The CMP has identified numerous congested intersections, based on a threshold of LOS "D" or less, within the Old Colony region.

In addition to the intersection locations, there are a number of community centers in the region including, Bridgewater Center (Central Square), East Bridgewater Center, Downtown Brockton, Stoughton Center, and West Bridgewater Center, that experience chronic congestion and circulation problems requiring on-going efforts to improve traffic flow and reduce delays.

The following strategies will support the reduction of bottlenecks in our region as well as providing congestion relieve opportunities to the most critical corridors and intersections identified in the Old Colony region.

Access Management

Access Management (AM) is the proactive management of vehicular access points to land parcels adjacent to all manner of roadways. Good access management promotes safe and efficient use of the transportation network. AM encompasses a set of techniques that state and local governments can use to control access to highways, major arterials, and other roadways. These techniques include:

- **Access Spacing**: increasing the distance between traffic signals improves the flow of traffic on major arterials, reduces congestion, and improves air quality for heavily traveled corridors.
- **Driveway Spacing**: Fewer driveways spaced further apart allows for more orderly merging of traffic and presents fewer challenges to drivers.
- **Safe Turning Lanes**: dedicated left- and right-turn, indirect left-turns and U-turns, and roundabouts keep through-traffic flowing. Roundabouts represent an opportunity to reduce an intersection with many conflict points or a severe crash history (T-bone crashes) to one that operates with fewer conflict points and less severe crashes (sideswipes) if they occur.
- **Median Treatments**: two-way left-turn lanes (TWLTL) and nontraversible, raised medians are examples of some of the most effective means to regulate access and reduce crashes.
- **Right-of-Way Management**: as it pertains to R/W reservation for future widenings, good sight distance, access location, and other access-related issues.[16]

The purpose of managing access to parcels along a roadway is twofold: 1) *To preserve capacity within the roadway*, thereby increasing the efficiency of traffic flow and avoiding congestion, and 2) *To enhance safety within the overall road corridor*, especially at access points and at places where vehicles make turning movements. The benefits of managing access include the conservation of lives and property within the transportation system and the relief of traffic congestion. The elimination of chronic congestion often involves road widening and reconstruction, which involves substantial capital investment. These investments can be lessened through conserving the existing capacity within a road corridor, and by improving the efficiency of traffic flow.

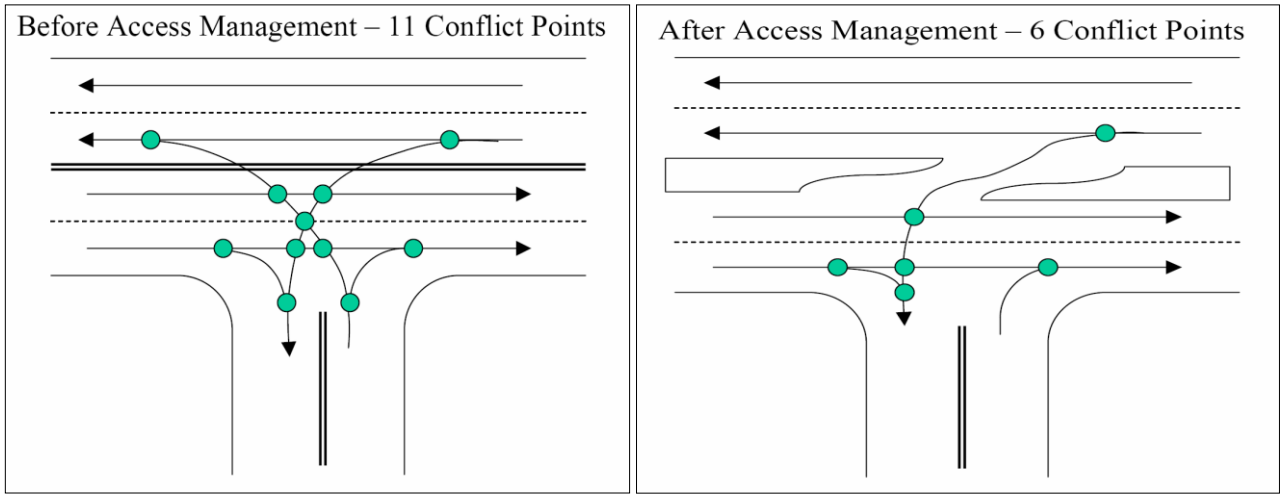
[16] *U.S. Federal Highway Administration-Office of Operations, "What is access Management?" http://www.ops.fhwa.dot.gov/access_mgmt/index.htm*

Reducing congestion offers additional important advantages:

1. Reducing total congestion saves time and fuel, and leads to decreased vehicle emissions.
2. Improving reliability leads to more predictable and consistent travel, something that all travelers seek: travelers do not have to budget as much extra time in order to arrive on time at their destinations. This is particularly important for truckers and shippers because many activities (e.g., manufacturing, sales) are now closely tied to the arrival of shipments. Many types of personal travel, such as retail shopping, getting to business appointments, and childcare pickup, are also sensitive to excessive and unreliable travel times.

Figure 4.4 below shows an intersection before and after access management techniques were implemented. The intersection had eleven potential conflict points before access management techniques were implemented and only six potential conflict points after the techniques were implemented.

Figure 4.4: Intersection Before and Access Management Techniques were Implemented



Recommendations

- **Utilize Access Management Techniques throughout the Region. Areas within the Region in which Access Management Techniques Should be a Prime Focus Include:**

    - Route 3A in Kingston and Plymouth
    - Route 3A in the Cedarville section of Plymouth
    - Route 18 in Abington
    - Samoset Street in Plymouth
    - Route 28 (Memorial Drive) in Avon from Harrison Boulevard south to Route 37 (Howard Street) in north Brockton
    - Route 28 through the Brockton downtown (between Route 37 and Plain Street)
    - Route 28 in south Brockton (Main Street)
    - Route 28 in West Bridgewater (North Main Street and south Main Street)
    - Route 28 (Bedford Street) Route 18 corridor south of Bridgewater center
    - Route 123 Belmont Street east and west of Route 24 in Brockton
    - Route 123 in Brockton east of the downtown to Abington
    - Route 104 east of Route 24 in Bridgewater
    - Route 106 east of Route 138 in Easton to West Bridgewater Center
    - Route 138 north of Stoughton Center
    - Route 138 in Easton

Strategy 6: Alternative Energies & Emission Standards

Federal and state agencies have both stressed the importance of transitioning away from foreign fossil fuel reliance, encouraging the research and usage of alternate fuels, power sources and reducing vehicle emissions. The Old Colony MPO supports such programs and reducing emissions, and consistently works with local, regional, and statewide partners to further the endeavor.

Alternative fuels and power source can be described as fuels derived from resources other than traditional petroleum and most being generally renewable. By increasing the use of alternative fuels the country will reap many beneficial impacts including:

- Improving air quality by reducing the amount of greenhouse gases and air pollutants currently emitted by automobiles using traditional petroleum based fuels.
- Increasing energy sustainability as traditional petroleum sources are not infinite.
- Reducing America's dependence on foreign oil, therefore strengthening national security.

Alternative Automobile Fuels

There are more than a dozen alternative and advanced fuels in production or in use today. Although government-regulated and voluntary private fleets are the primary users of these fuels, consumers are showing a growing interest in them.

These fuels are defined as alternative fuels by the Energy Policy Act of 1992 and are currently, or have been, commercially available for vehicles:

Biodiesel

Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils, animal fats, or recycled restaurant grease. Biodiesel is safe, biodegradable and reduces serious air pollutants such as particulates, carbon monoxide, hydrocarbons, and air toxics. Blends of 20% biodiesel with 80% petroleum diesel (B20) can generally be used in unmodified diesel engines. It can be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel can also be used in its pure form (B100), but it may require certain engine modifications to avoid maintenance and performance problems and may not be suitable for wintertime use. Biodiesel is simple to use, nontoxic, and essentially free of sulfur and aromatics. Since it is made in the United Stated from renewable resources such as soybeans, its use decreases our dependence on foreign oil and contributes to our own economy.

Electric Vehicles

Electric Vehicles (EVs) do not produce tailpipe emissions, but generators producing the electricity used to charge the EV batteries do emit pollutants. Electricity for EVs is produced by power plants which send it to substations through transmission lines and then to homes and businesses through distribution systems. An EVs electric motor converts electricity usually from a battery pack- into mechanical power that runs the vehicle. Electric vehicle batteries must be recharged after a certain limited vehicle driving range. Electric vehicles are not currently available from the major auto manufacturers but will be within the next few years.

Natural Gas-CNG & LNG

Natural Gas is domestically produced and readily available to end-users through the utility infrastructure. It is also clean burning and produces significantly fewer harmful emissions than reformulated gasoline or diesel when used in natural gas vehicles. In addition, commercially available medium and heavy-duty natural gas engines have demonstrated over 90% reductions in carbon monoxide (CO) and particulate matter and more than 50% reduction in nitrogen oxides (NOx) relative to commercial diesel engines. Natural gas can be stored onboard a vehicle as compressed natural gas (CNG) at either 3,000 or 3,600 psi or as liquefied natural gas (LNG) at typically 20-150 psi.

Hydrogen Fuel Cells

Hydrogen Fuel Cells are still in development but represent an attractive option for reducing petroleum consumption and improving air quality. Hydrogen vehicles are powered by fuel cells that produce no air pollutants and few greenhouse gases. If fueled with pure hydrogen, fuel cells emit only heat and water as a byproduct. Hydrogen fuel cell vehicles are not yet commercially available; however, they are currently being demonstrated in light and heavy duty applications in fleets throughout the country. For example, Honda has placed several prototype light-duty FCX fuel cell vehicles in city bus fleets, and California transit agencies are demonstrating fuel cell buses in revenue service.

Ethanol

Ethanol is term for motor fuel blends of 85% ethanol and 15% gasoline. E85 is an alternative fuel as defined by the U.S. Department of Energy. Besides it superior performance characteristics, ethanol burns cleaner than gasoline; it is a renewable, domestic, environmentally friendly fuel that enhances the nation's economy and independence. Government tests have shown that E85 vehicles reduce harmful hydrocarbon and benzene emissions when compared to vehicles running on gasoline. E85 can also reduce carbon dioxide (CO2), a harmful greenhouse gas and major contributor to climate change. Although CO2 is released during ethanol production and combustion, some of it is recaptured as a nutrient to the crops that are used in its production. Ethanol also degrades quickly in water and, therefore poses much less risk to the environment than an oil or gasoline spill.

Reformulated Gas (RFG)

Reformulated gasoline (RFG) is gasoline blended to burn cleaner and reduces smog-forming and toxic pollutants in the air we breathe. The Clean Air Act of 1990 requires those metropolitan areas with the worst smog problems to participate in the reformulated gasoline program. In addition, many communities and states also have voluntarily chosen to participate in the RFG program to meet pollution reduction goals of the Clean Air Act. The federal RFG program was introduced in 1995; RFG is currently used in 17 states, (including Massachusetts) and the District of Columbia and approximately 30% of gasoline sold in the U.S. is reformulated. Between 1995 and 1999, it cut smog forming pollutant levels by about 17 percent compared to conventional gasoline in communities where 75 million people live and work. Phase II which began January 1, 2000 took another step toward cleaner air. It reduces smog-forming pollutants 27 percent more than conventional gasoline.

Propane

Propane is liquefied petroleum gas (LPG) that is a byproduct of natural gas processing and crude oil refining, and is considered an alternative fuel under the Energy Policy Act of 1992. Propane produces few toxins and air pollutants. It is currently the third most used vehicle fuel in the United States behind gasoline and diesel respectively. Vehicles using LPG produce considerably lower amounts of harmful emissions and carbon dioxide (CO2). In addition to being used as an alternative vehicle fuel, propane is also used to heat homes and to power farm and commercial equipment. Most propane consumed in the United States is produced domestically which reduces the country's dependence on foreign oil.[17]

Other Alternative Fuels

Several other types of fuels are currently under development. Many of these fuels are also considered alternative fuels and may have other benefits such as reduced emissions or increased energy security.

- Biobutanol
- Biogas
- Biomass to Liquids (BTL)
- Coal to Liquids (CTL)
- Fischer-Tropsch Diesel
- Gas to Liquids (GTL)
- Hydrogenation-Derived Renewable Diesel (HDRD)
- P-Series
- Ultra-Low Sulfur Diesel

Alternative Energy Sources

One of the unique features of Massachusetts is its diversity of clean energy resources. The state boasts an abundant bio-energy stock, excellent wind potential in a number of areas, existing and potential hydropower facilities and infrastructure, and sufficient solar energy for widespread solar photovoltaic installations. The amount of clean energy that could be developed in the state is far greater than what is currently being utilized.

Solar Power

Solar photovoltaic technology, or "PV" for short, uses solar energy to produce electricity. PV is one of the most environmentally friendly technologies available and is very easy to install on a building or property. While cost can be a barrier to some installations, there are many incentives available for PV. There are over 400 systems are installed in Massachusetts today, more installations than any other source of electricity**.** Solar photovoltaic (PV) panels can be installed around Massachusetts at a variety of sites, most often on the rooftops of buildings. Because solar energy is an unlimited resource, the potential for PV development in the state depends more on the number of sites where these can be installed without being shaded or damaged.

[17] U.S. Department of Energy: Alternative Fuels & Advanced Vehicles Data Center: Alternative & Advanced Fuels http://www.afdc.energy.gov/afdc/fuels/index.html

An example of solar power in the Old Colony MPO region is the Brockton Brightfield, a 425-kilowatt (kW) photovoltaic (PV) solar energy system located on a 3.7 acre remediated brownfield in Brockton. It is the largest solar energy plant in New England and the largest brightfield transformed into a solar energy generating station in the nation.

Wind Power

Wind turbines provide significant amounts of energy using only the natural power of the wind. In fact, wind power is one of the fastest growing and most commercially viable forms of clean energy. Because it produces no emissions and can be installed locally, it is a growing energy choice for everyone from residential customers to communities, municipalities, and entire nations. Approximately 3.5% of Massachusetts land has sufficient average wind speeds and available land for the installation of utility-scale wind turbines. This number excludes areas that have already been developed or identified as environmentally sensitive. Because wind farms do not require significant areas of land, at most only 0.35% of the 3.5% of available land would be taken up by turbines and associated structures. The wind turbine projects in Hull, MA are an example of forward thinking, as they produce up to 2.6 M.W and provide electricity for the local street and traffic lights.

The recently approved Cape Wind project will consist of 130 off-shore wind turbines in Nantucket Sound, which when fully operational, will provide about the equivalent to 75% of the electricity that is needed for Cape Cod, Martha's Vineyard, and Nantucket.

Biomass

Bio-energy can be produced using a variety of materials that include wood, crops like corn and soybeans, and waste from consumer, municipal, industrial, and agricultural processes. Each of these materials are sources of fuels that can be burned to produce energy. Massachusetts has an abundant natural stock of bio-energy fuels, making it a clean energy source with great potential for the state; however, recovery of some types of biomass is expensive and not economically feasible at present, so the true role of biomass in local energy production may end up being smaller than projected. Liquid biofuels like ethanol, biodiesel, and bio-oil can be used to power cars and other transportation.

An example of biomass-energy near the Old Colony MPO region is the SEMASS Resource Recovery Center in West Wareham. Municipal waste from surrounding communities in the region is brought to the SEMASS Recovery Center where it is burned and the energy sold to NStar, which then sells the energy to the communities in the region. On average SEMASS burns enough waste to power 75,000 homes in the region.

Hydropower

Rivers, streams, and other flowing waters can be used to generate electricity through hydropower. Hydroelectric facilities represent the largest source of clean energy in the United States and around the world. A handful of massive hydro plants accounts for a significant percentage of this energy in Massachusetts. Development of hydropower in Massachusetts will likely be limited to the upgrade or repair of existing dams, as new river construction is heavily regulated. If all the potential hydropower sites that meet these regulations were developed, they could produce 4% of the state's energy consumption.

Nuclear Energy

Nuclear energy is a major source of energy produced in America, as the U.S. Department of Energy notes that approximately 20% of the electricity produced in America comes from nuclear power plants. Nuclear power is produced when uranium atoms are split, which releases a large amount of heat and radiation that is then harnessed to produce electricity. Nuclear energy is a source of energy that does use fossil fuels, which helps reduce America's reliance on foreign oil. Also nuclear energy, while not a clean energy, does emit fewer emissions than the burning of fossil fuels. While nuclear power does have its benefits, there are some drawbacks, including the possibility of an accident and the need for storing the radioactive waste that is a byproduct of creating nuclear power.

The Pilgrim Nuclear Power Plant located in Plymouth is currently the only active nuclear power plant in Massachusetts and is seeking re-licensing. The plant produces enough electricity to provide power to 600,000 homes.

Federal and State Efforts

Alternative Fuel Vehicle Tax Incentives

The federal government has expressed support in the increased use of alternative fuel vehicles by providing up to a $4,000 federal income tax credit for alternative fuel vehicles purchased between January 1, 2005 and December 31, 2010.

Energy Star Program

The Energy Star Program is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy to help citizens save money and protect the environment through energy efficient products and practices. In 2009 alone, with the help of Energy Star, citizens saved enough energy to avoid greenhouse gas emissions equivalent to that from 30 million cars, all while saving nearly $17 billion on their utility bills.[18]

Clean Cities Program

The Clean Cities Program is a nationwide initiative developed by the U.S. Department of Energy that advocates for the advancement of the economic, environmental, and energy security of the United States by supporting local decisions to adopt practices that contribute to the reduction of petroleum consumption in the transportation sector. Clean Cities carries out this mission through a network of nearly 90 coalitions, (including the Massachusetts Clean Cities Program), which develop public/private partnerships to promote alternative fuels, vehicles, fuel blends, fuel economy, hybrid vehicles, and idle reduction. Since its inception in 1993, the Clean Cities Program and its stakeholders have displaced more than 2 billion gallons of petroleum with the goal of reducing petroleum consumption by 2.5 billion gallons by 2020.

[18] *Energy Star Website, About Energy Star: http://www.energystar.gov/index.cfm?c=about.ab_index*

FreedomCAR and Fuel Partnership

The long-term goal of the FreedomCAR and Fuel Partnership is a clean and sustainable transportation energy future.

Through this program partners work together to examine the pre-competitive, high-risk research needed to develop the component and infrastructure technologies necessary to enable a full range of affordable cars and light trucks, and the fueling infrastructure for them, that will reduce the dependence of the nation's personal transportation system on imported oil and minimize harmful vehicle emissions, without sacrificing freedom of mobility and freedom of vehicle choice.

The Partnership provides a forum in which partners discuss technical requirements and R&D priorities, develop joint roadmaps that include technology-specific goals, and monitor and discuss R&D activities to evaluate progress toward Partnership goals.

The Partnership focuses on the following technical areas:

- Advanced combustion and emission control
- Batteries/electrochemical energy storage
- Electric propulsion systems (e.g., power electronics, electric motors)
- Fuel cell power systems
- Materials technologies (e.g., for lightweighting)
- Vehicle systems and analysis
- Vehicle-to-electricity grid interaction
- On-board hydrogen storage
- Hydrogen production and delivery
- Hydrogen codes and standards [19]

Weatherization Assistance Program

The Weatherization Assistance Program (WAP) enables low-income families to permanently reduce their energy bills by making their homes more energy efficient. Funds are used to improve the energy performance of dwellings of needy families using the most advanced technologies and testing protocols available in the housing industry.

The energy conservation resulting from these efforts of state and local agencies helps our country reduce its dependence on foreign oil and decrease the cost of energy for families in need while improving the health and safety of their homes. During the past 33 years, WAP has provided weatherization services to more than 6.4 million low-income households. Families receiving weatherization services see their annual energy bills reduced by an average of about $350, depending on fuel prices[20], with a proportionate reduction in GHG emissions.

[19] *U.S. Department of Energy-Vehicle Technologies Program-FreedomCAR & Fuel Partnership http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/freedomcar/index.html*

[20] *U.S. Department of Energy- Weatherization and Intergovernmental Program http://www1.eere.energy.gov/wip/wap.html*

Massachusetts Clean Energy BioFuels Act

In 2008 the Clean Energy BioFuels Act legislation was signed into law, which encourages the growth of an advanced biofuels industry as part of the growing clean energy technology sector in Massachusetts. In nation-leading provisions, this legislation gives preferential tax treatment to non-corn-based alternatives to ethanol, requires biofuel content in all the diesel and home heating fuel sold in the state, and proposes a new fuel standard for the region that will encourage a range of emissions-reducing technologies for cars and trucks.[21]

Massachusetts Green Communities Program

The Green Communities Division is located within the Massachusetts Department of Energy Resources. The Green Communities Program is charged with guiding all 351 cities and towns in the Commonwealth on a path of enhanced energy efficiency and renewable energy toward zero net energy. The goal of the Program is to help cities and towns maximize energy efficiency in public buildings, including schools, city halls, and public works, and public safety buildings; generate clean energy from renewable sources; and manage rising energy costs.

To achieve these goals, the Division, as the energy hub for cities and towns, provides:

- Education about the benefits of energy efficiency and renewable energy
- Guidance and technical assistance through the energy management process
- Facilitation of informed decisions and actions
- Collaboration through shared best practices among cities and towns
- Local support from regional Green Communities coordinators
- Opportunities to fund energy improvements [22]
- Enforcement of green communities requirements

Corporate Average Fuel Economy (CAFÉ) Standards

In response to the 1973-74 Arab oil embargo, Congress enacted the "Energy Policy Conservation Act", into law in 1975, adding Title V, "Improving Automotive Efficiency", to the Motor Vehicle Information and Cost Savings Act, and established Corporate Average Fuel Economy (CAFÉ) standards for passenger cars and light trucks.

The purpose of CAFE is to reduce energy consumption by increasing the fuel economy of cars and light trucks. Regulating CAFE is the responsibility of the National Highway Transportation Safety Administration (NHTSA) and the Environmental Protection Agency (EPA). NHTSA sets fuel economy standards for cars and light trucks sold in the U.S.; EPA calculates the average fuel economy for each manufacturer.

[21] *Massachusetts Clean Energy BioFuels Act*
http://www.mass.gov/?pageID=eoeeaterminal&L=4&L0=Home&L1=Energy%2C+Utilities+%26+Clean+Technologies&L2=Renewable+Energy&L3=Advanced+Biofuels&sid=Eoeea&b=terminalcontent&f=doer_renewables_advanced-biofuels_biofuels-act&csid=Eoeea

[22] *Massachusetts Green Community Program http://www.mass.gov/greencommunities*
http://www.mass.gov/?pageID=eoeeaterminal&L=3&L0=Home&L1=Energy%2c+Utilities+%26+Clean+Technologies&L2=Green+Communities&sid=Eoeea&b=terminalcontent&f=doer_green_communities_gc-about&csid=Eoeea

New CAFE standards set under the recently passed Energy Policy and Conservation Act (EPCA) and Energy Independence and Security Act (EISA) will apply to passenger cars and light trucks, categories which span the range of vehicles from sedans to crossovers to pickup trucks to vans, manufactured in model years (MY) 2012 through 2016. They will require these vehicles to meet an estimated combined average mile per gallon (mpg) level of 34.1 by MY 2016. Together with EPA's standards, which also enable manufacturers to achieve compliance by improving the air conditioners of their vehicles, the National Program overall is expected to result in improvement levels equivalent to 35.5 mpg.

Over the lifetimes of the passenger cars and light trucks sold in MYs 2012-2016, NHTSA projects that the CAFE standards will save 61.0 billion gallons of fuel and reduce carbon dioxide (CO2) emissions by 654.7 million metric tons (mmt). NHTSA also estimates that the lifetime benefits of the CAFE standards will total over $182 billion, including fuel savings, while the net costs of the standards total approximately $52 billion. For the National Program as a whole (that is, NHTSA's standards and EPA's standards), the agencies estimate that the lifetime benefits will total over $240 billion. NHTSA attributes most of these benefits, about $157 billion, to reductions in fuel consumption, valuing fuel savings (for societal purposes) at future pretax prices projected in the Energy Information Administration's (EIA's) reference case forecast from Annual Energy Outlook (AEO) 2010 Early Release.

Costs, in turn, represent necessary increases in technology application that will involve considerable monetary outlays. Because of these costs (and to a much less extent, civil penalties that some companies are expected to pay for noncompliance), the agency estimates that the standards will lead to increases in average new vehicle prices, ranging from $434 per vehicle in MY 2012 to $926 per vehicle in MY 2016. [23]

Massachusetts Vehicle Check Program

Clean air and safe roads have long been important for Massachusetts. The Commonwealth started to inspect vehicles for safety defects more than 60 years ago, and has one of the longest-running safety inspection programs in the country. In 1983, Massachusetts became one of the first states in the country to start testing vehicle emissions. As vehicles have become more sophisticated, the tests have been updated to ensure that, to the extent possible, problems are identified and repaired before they create risks to public health and safety.

The National Ambient Air Quality Standards (adopted by the U.S. Environmental Protection Agency) establish maximum levels for ozone, particulates, and other air pollutants. Since Massachusetts' air does not meet the standard for ground level ozone, we are required by the U.S. Clean Air Act to implement programs that will reduce ozone levels so that our air meets the standard. One important component of this effort is the Massachusetts Vehicle Check Program, which helps to ensure that vehicles run as cleanly as they were designed to run throughout their "life". Since its introduction, the Massachusetts vehicle testing program has helped to reduce air pollution across the Commonwealth. Annual emission tests (which replaced tests every two years in October 2008) mean that vehicles with faulty emissions control systems are identified

[23] *National Highway Traffic Safety Administration, "NHTSA and EPA Propose New National Program to Improve Fuel Economy and Reduce Greenhouse Gas Emissions for Passenger Cars and Light Trucks" http://www.nhtsa.gov/DOT/NHTSA/Rulemaking/Rules/Associated%20Files/MY2012-2016CAFEPRMfactsheet.pdf*

and repaired quicker, therefore reducing the amount of air pollution being released in the atmosphere.

The current Massachusetts Vehicle Check Program provides a combined safety and emissions inspection for the more than 4.6 million cars, trucks, buses, and SUVs registered in Massachusetts that are powered by internal combustion engines running primarily on petroleum-based fossil fuels. Details of the Massachusetts Vehicle Check Program include:

- The requirement of all vehicles driven on Massachusetts roads to pass an annual safety inspection.
- The requirement of vehicles with onboard diagnostic systems, manufactured after model year 1995, to pass an annual emissions test.
- Fleets of commercial vehicles can be tested by mobile inspectors who bring testing equipment to company lots, or by a company employee who is licensed to conduct inspections.
- The Massachusetts Vehicle Check for commercial vehicles is equivalent to the annual Federal Motor Carrier Safety Administration (FMCSA) "DOT" inspection. This allows commercial vehicle owners to meet state and federal requirements with one inspection.
- Creation of new Motorist Assistance Centers across the state that provide advice and technical assistance to motorists and repair technicians who have questions and problems relating to the emissions portion of the vehicle inspection process.

The annual emission inspections of the Program are the best way to check whether the emission control system on a vehicle is working correctly. Although all new passenger cars and trucks sold in the United States must meet stringent pollution standards, they can only retain this low-pollution profile if the emission controls and engine are working properly. The Program is part of a comprehensive plan to reduce air pollution and its impact on the health of Massachusetts' residents, particularly those with lung and respiratory ailments. [24]

[24] *Mass Vehicle Check Website: http://www.vehicletest.state.ma.us/about.html*

Recommendations

- **Reduce Dependency on Foreign Fossil Fuels and on Fossil Fuels Generally.** Promote research, development and implementation of standards policies, and programs to reduce fuel consumption and increase the investments made in alternative fuels.

- **Increase the Number of Alternative Fuel Stations within the Commonwealth and OCPC Region.** As alternative fuel technology increases, the number of fuel stations servicing these cars should as well. Currently there are only a few stations in the state that supply alternative fuel vehicles, including six biodiesel stations, 2 ethanol stations, 3 electric stations, 27 CNG stations, and 22 propane stations. Of the previously listed stations, the OCPC regions only houses two propane stations.

- **Encourage the Use of Renewable Energy.** Promote the use of renewable energies throughout the Commonwealth, such as solar and wind by assisting local communities in needed regulations. Using these sources in place of fossil fuels and nuclear energy reduces the depletion of natural resources and the creation of both toxic and non-toxic wastes.

- **Encourage Participation in the Commonwealth's Green Communities Program.** Assist communities within the OCPC Region in applying to become a "Green Community", that helps communities reduce energy costs and qualify for grants for energy efficiency projects.

- **Strive to Reduce Vehicle Emissions.** Encourage research and technology development to find new solutions to air pollution problems created by motor vehicles.

- **Promote the Increase and Enforcement of Corporate Average Fuel Economy/CAFÉ Standards for Passenger Cars and Light Truck Fleets.** Automobile manufacturers should be required to meet and exceed CAFÉ standards for passenger and light truck fleets and should be recognized for doing so.

- **Continue to enforce the emissions standards set by the Commonwealth.** Enforcing the emissions standards for all vehicles of the Commonwealth plays a large role in improving the air quality of the State.

- **Continue to use Congestion Mitigation and Air Quality Improvement Program (CMAQ) funding for projects that best improve air quality and reduce traffic congestion.** The Old Colony MPO is one of thirteen MPOs in Massachusetts charged with identifying and selecting CMAQ projects. To assist the Commonwealth in conforming with the National Ambient Air Quality Standards (NAAQS), the OCPC has previously awarded funding to Brockton Area Transit (BAT) to fund the purchase of hybrid buses and for diesel retrofit projects.

Strategy 7: Vehicle Mileage Tax/Road Pricing/Congestion Pricing

The Vehicle Mileage Tax (VMT), Road Pricing and Congestion Pricing are all alternative funding mechanisms that are being explored here in America and that are in use in many parts of the world. The premise for exploring these alternative funding mechanisms is that the current gasoline tax is not providing a sufficient source of revenue to fund highway infrastructure projects. The lack of funding from the gasoline tax can be attributed to rising gas prices, the recent downturn in the economy, and the increase of more fuel efficient automobiles. All of these alternatives would charge drivers not on the amount of gasoline they use, but on how far they drive, where they drive, and when they use specific roads. While there are concerns about privacy and fairness issues relating to these alternatives, they must be studied further to examine all potential benefits and drawbacks.

Vehicle Mileage Tax (VMT)

Vehicle Mileage Tax fees have been proposed both as an alternative or supplemental revenue source to the gas tax, and to reduce VMT by making travel more expensive. The gasoline tax – the primary funding mechanism for the construction and maintenance of the nation's highways, bridges, and roads, is proving to be an insufficient was due to the increasing vehicle miles travelled per person and increasing traffic congestion. For instance, from 1980 to 2006, the total number of miles traveled by automobiles increased 97 percent and the miles traveled by trucks 106 percent. Over the same period, the total number of highway lane miles grew a scant 4.4 percent—meaning that over twice the traffic was traveling on essentially the same roadway capacity.

Fees on vehicle miles of travel have been suggested by the National Surface Transportation Policy and Revenue Study Commission and the National Surface Transportation Infrastructure Financing Commission, and by reports from the National Chamber of Commerce, the Transportation Research Board, and the National Cooperative Highway Research Program. VMT fees would most likely vary by type of vehicle, to reflect principles of highway cost allocation, or perhaps to reflect also the different emissions characteristics of vehicles. Two basic approaches are available for monitoring VMT as a basis for assessing charges:

1. Administrative Reporting – Motor vehicle mileage would be reported through the motor vehicle registration and inspection process or on-board odometer readings. This approach uses existing technology and could be implemented quickly. While simplest from a reporting perspective, enforcement would be required to ensure proper reporting and to control odometer tampering.

2. Wireless Reporting – Motor vehicles would link to a receiver located at gas stations, where a radio frequency receiver would pick up a transmission from an on-board unit that would provide the odometer reading since the last gas station visit. This strategy would require additional technology deployment but would reduce or eliminate fraud and also reduce the labor associated with reporting. Electronic fee collection has the additional advantage that it could potentially be

used to implement congestion pricing as well, if used in conjunction with a global positioning system (GPS) unit to assess variable fees based on the time and location of travel. [25]

Road/Area Pricing

Road/area pricing is a fee for vehicles to drive on a selected area or road, such as a downtown area. Thus far, implementations of road and area pricing abroad have reinvested funds into transit—thereby achieving additional mode shifts and VMT reductions beyond what they would be. The funds could be used for mobility improvements or for other purposes. Road/area pricing has been implemented in a few European and Asian cities including London, Stockholm, and Singapore. While no U.S. cities have implemented road/area pricing, it has been considered in the Manhattan borough of New York City and in San Francisco, California.[26]

Congestion Pricing

Congestion pricing is the application of pricing to congested facilities in order to reduce traffic on those facilities and improve the level of service. From 1982 to 2005, hours of delay per traveler increased 171 percent and total hours of delay increased 425 percent; over this same period, the total cost of congestion increased 383percent and in the nation's 437 urban areas that cost is now estimated at over $78 billion per year. While the concepts most immediate application is on roads and bridges that are already tolled, congestion pricing also could be implemented on other limited-access facilities by adding toll collection. To date it has been studied on at least six other major facilities in the U.S. as well as for the Puget Sound region's highway network. The broader-scale application of this strategy beyond existing or proposed toll highway facilities is likely to require the universal deployment of electronic toll collection technologies. This will require coordination by a state or regional transportation agency (e.g., State DOT or MPO). The U.S. DOT is encouraging greater experimentation in this area.

Congestion pricing will have a somewhat lower overall impact on VMT than universal pricing measures such as VMT fees, because it will be applied only to congested facilities; however, this measure will decrease congestion and thus will improve fuel economy. In the rudimentary form of either simple off-peak discounts or more involved pricing structures, congestion pricing has been implemented on a number of tolled facilities in the U.S., such as the Dulles Greenway in Northern Virginia; New Jersey Turnpike; Midpoint and Cape Coral toll bridges in Lee County, Florida; and State Road 91 from Riverside to Los Angeles, however, it has not been implemented on an area wide basis to-date.[27]

State of Oregon Road User Fee Task Force Study

In 2001 the state of Oregon created the Road User Fee Task Force to look into alternatives to replace the state's gas tax. The Task Force focused on a mileage-based charged (VMT) tax and road pricing. In 2006 the state implemented a year-long voluntary pilot program in the City of Portland, Oregon to study and explore the viability of this concept.

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[25] *U.S. Department of Transportation, Transportation's Role in Reducing U.S. Greenhouse Gas Emissions, Volume 1: Synthesis Report to Congress: April 2010. http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf*

[26] *Ibid*

[27] *Ibid*

In 2007 the Oregon Department of Transportation released its final report of the pilot program, *Oregon's Mileage Fee Concept and Road User Fee Pilot Program*. The report's key findings were generally favorable and included the following:

The Concept is Viable
The pilot program showed that, using existing technology in new ways, a mileage fee could be implemented to replace the gas tax as the principal revenue source for road funding. At the conclusion of the pilot program, 91 percent of pilot program participants said that they would agree to continue paying the mileage fee in lieu of the gas tax if the program were extended statewide.

Paying at the Pump Works
The pilot program showed that the mileage fee could be paid at the pump, with minimal difference in process or administration for motorists, compared to how they pay the gas tax. Like the gas tax, collection of the mileage fee can be embedded within routine commercial transactions, with the bulk of it pre-paid by the distributor in the form of the gas tax. By including the mileage fee in the fuel bill, cash or credit payments are accommodated, just like the gas tax. Although many of the prototype components used in the pilot program did not, by definition, meet the standards of commercial products, the next stage of technology development would take the technology to commercial viability.

The Mileage Fee can be Phased In
The study showed that the mileage fee could be phased in gradually alongside the gas tax, allowing non-equipped vehicles to continue paying the gas tax, while equipped vehicles could pay the mileage fee. Retrofitting vehicles with mileage-calculating equipment appears expensive and difficult.

Integration with Current Systems can be Achieved
The study demonstrated the ability to integrate with two main existing systems: the service station point-of-sale (POS) system and the current system of gas tax collection by the state.

Congestion and other Pricing Options are Viable
The study showed that different pricing zones could be established electronically and the assigned fees could be charged for driving in each zone, even at particular times of day. This proves the mileage fee concept could support not only congestion pricing but also assessment and collection of local revenues and other "zone-oriented" features. Furthermore, the area pricing strategy applied in the pilot program produced a 22 percent decline in driving during peak periods.

Privacy is Protected
Many levels of privacy protection can be implemented in a system similar to that used in the pilot program. There is a trade-off between privacy and information stored for enforcement and dispute resolution. ODOT developed the system used in the pilot program with specific engineering requirements to maintain as much privacy as practicable while still allowing a

feasible way to audit and challenge billings. Key privacy related requirements for the pilot program were:

- No specific vehicle point location or trip data could be stored or transmitted
- All on-vehicle device communication must be short range
- The only centrally-stored data needed to assess mileage fees were vehicle identification, zone mileage totals for each vehicle and the amount of fuel purchased

The System would Place Minimal Burdens on Businesses

While distributors and gas stations bear some new accounting burdens, administration is essentially automated and can be integrated easily into existing transaction processes.

Potential for Invasion is Minimal

Tampering with the on-vehicle device would result in default payment of the gas tax. The difference between gas taxes and mileage fees would likely be very small, providing very little incentive to try to evade the basic mileage fee. The eventual fee level, on-vehicle engineering, fee structure, fuel tax rates and penalties for tampering will determine the degree to which equipment tampering will occur.

Cost of Implementation and Administration is Low

Costs originate from three areas: service stations, on-vehicle and DOT administration. Service station capital costs include installing the mileage reading equipment while operating costs include communications of the mileage information with a central database in order to calculate mileage fees and modifications to the station's point-of-sale system. On-vehicle capital costs will be determined by auto manufacturers and included in the price of new vehicles. ODOT will incur operating costs for auditing and providing technical assistance to service stations and motorists. Auditing should cost $1.0 million annually, a small fraction of expected annual mileage fee revenue.[28]

[28] *Oregon's Mileage Fee Concept & Road User Fee Pilot Program-Final Report http://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUFPP_finalreport.pdf?ga=t*

5.0 Conclusion

Climate Change is already affecting our lives and the places we live, and has the potential to dramatically impact the lives of future generations. Climate Change is an issue that will continue to affect the Earth unless we become more proactive in protecting our natural environment.

Ten of the warmest years on record have all occurred within the past fifteen years and glaciers in the Arctic continue to melt at a record rate each year. These two facts are disturbing enough for more attention to be paid to the climate change phenomenon. All of us need to plan and prepare for a future where the effects of climate change will not be just one severe storm every ten years, but several severe storms every year and not having a flood once every five years, but floods occurring every year.

The short-term recommendations of this study are directed to the communities in the Old Colony region as well as to federal and state agencies in the hope that they examine existing land use and transportation infrastructure measures and make the necessary changes to mitigate the damage from future climate change effects. For the long-term, this document proposes strategies and policies that will help improve the air quality of the region by reducing vehicle miles travelled (VMT) through adequate maintenance and expansion of transit services, identifying alternatives to single occupant auto travel, and making changes in current land use patterns. These efforts can only be achieved with a constant collaboration of all agencies – federal, state, local government and the private sector. The Old Colony Planning Council is committed to continue incorporating policies and strategies that prevent future impacts of climate change into all aspects of transportation planning, encouraging communities to share best practices of climate change mitigation, and participating in Pre-Disaster Mitigation (PDM) Planning. The ramifications of climate change on the transportation system could be severe, with roads, bridges, and rail lines shut down for weeks or months, while undergoing expensive and extensive repairs.

The seven strategies laid out in this report can help to mitigate these effects and reduce greenhouse gas emissions by diminishing vehicle miles travelled and increasing the number of smart growth/livable projects. The findings and recommendations contained in this report will serve as a basis for future OCPC studies, including the Climate Change Roadway Drainage and Runoff Program and the 2011 Pre-Disaster Mitigation Plan (PDM), both of which will be completed in the upcoming years.