Interagency Transportation, Land Use, and Climate Change Pilot Project

Technical Scenario Report

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Introduction

The Interagency Transportation, Land Use, and Climate Change Pilot Project (the Pilot Project) was a scenario planning process to develop a multi-agency development strategy for Cape Cod, Massachusetts focused on transportation and land use, and with the intention of achieving a reduction in future greenhouse gas (GHG) emissions and considering the potential impacts of sea level rise (SLR). The resulting refined scenario will inform and support the region's long-range transportation planning and related efforts, as well as the planning efforts of local, state, and federal agencies. The Pilot Project is documented in detail in a separate report developed by the Pilot Project's main coordinating agency, the U.S. Department of Transportation's Volpe National Transportation Systems Center (the Volpe Center). This supplemental report was developed by the scenario planning consultant for the project. It details the methodology and results of the scenario development and includes discussion on limitations and future opportunities.

The consultant's project team (project team) included PlaceMatters, Inc., Placeways, LLC, and the University of Colorado Denver Center for Sustainable Infrastructure Systems and Transportation Research Center. The project team was tasked with assisting in the development of 10 scenarios, consisting of the following:

Scenarios 1-5	Preliminary scenarios developed by the project team for demonstrative purposes, consisting of: 1. Trend 2. Dispersed – Standard Transportation 3. Dispersed –Enhanced Transportation 4. Targeted – Standard Transportation 5. Targeted – Enhanced Transportation
Scenarios 6-9	Four scenarios developed by stakeholder participants at a November 2010 workshop
Scenario 10	One refined scenario developed by stakeholders after the workshop. This scenario is not a final product, but a framework for informing the next series of conversations on Cape Cod about planning for a collective future.

The scenario planning software used for the Pilot Project was CommunityViz®, an extension for ArcGIS® Desktop. Planners, resource managers, local and regional governments, and many others use CommunityViz to help them make decisions about development, land use, transportation, conservation and more. As a GIS-based decision-support tool, CommunityViz "shows" you the implications of different plans and choices. Through an open framework of related spatial and non-spatial attributes and assumptions linked together through custom formulas, CommunityViz can report the performance of various spatial scenarios through charts, indicators, and alerts. The Pilot Project focused on using these capabilities to customize a set of assumptions and formulas to measure transportation related GHG emissions, new population vulnerable to sea level rise, and other spatial constraints detailed in this report.

This report consists of three sections that provide an explanation of the metrics and measures used to develop the scenarios, a description of each of the resulting scenarios, and a comparison of the performance of the scenarios on each of the selected indicators.

Metrics and Measures

All measures in the Pilot Project were based on 2008 data. Because the scenarios relied on spatially explicit allocation of population and employment, the project team used a methodology, described in this section, to ensure that allocations were realistic and representative. All scenarios were then developed with consistent population and employment growth assumptions for 2030 based on state projections, which relied on data from the U.S. Census 2000.

Data for the scenario development primarily came from the Cape Cod Commission (CCC), the regional planning agency for Cape Cod, as well as the U.S. Census, the Massachusetts Department of Transportation (MassDOT), and the Cape Cod Regional Transit Authority. Many spatial datasets were available through Massachusetts' own GIS clearinghouse, MassGIS.[1]

The Pilot Project focused primarily on how to reduce transportation-related GHG emissions (mitigation) and how to respond to impacts of SLR (adaptation). Additionally, the Pilot Project looked at transit access and other land use restraints, such as habitat and water resources.

The primary variables that the project team and stakeholders manipulated to change scenario outcomes were the placement of population, employment, and transit service areas and the selection of frequency for transit service. Population, employment, and transit service areas were added to maps overlaid with ¼ square mile grid cells representing the basic neighborhood unit. The indicators introduced in this section are only a small subset of what can be measured on Cape Cod. This analysis could include increasingly more specific and refined data provided by partners that measure economic development potential, growth suitability, transit feasibility, and more. Potential improvements to the analysis are reviewed in the final part of this section.

Baseline data and future growth assumptions

In preparation for baseline and future trend analysis, three existing datasets were reviewed for potential use (Appendix A includes the total amounts for each):

- Massachusetts Department of Transportation Travel Demand Model
- Cape Cod Commission Transportation Travel Demand Model

[1] Available at http://www.mass.gov/mgis

- Project Team's Prepared Estimates (based on U.S. Census 2000 and land cover data; see methodology starting on page 20)

The project team first reviewed the CCC data for potential use, as the CCC modeling contained relatively complete network link data for transportation analysis. Projected overall change in population and employment for the horizon year (2030) seemed to correspond closely with Census-based projections. Upon further inspection, however, employment quantities did not correspond well with mapped employment areas.

Next, the project team reviewed the MassDOT modeling data. While overall employment amounts corresponded well with other estimates, population projections showed much lower change quantities. As with the CCC model data, employment quantities did not correspond well with mapped employment areas.

Ultimately, for both baseline and future trend, the development layers were recalibrated to correspond with parcel data, zoning maps, and aerial imagery. The future projected growth values used in all scenarios were held constant across scenarios to provide a one-to-one comparison of any differences among the scenarios. The growth values were derived from U.S. Census 2000 projections for 2030 new growth in population, employment, and households.

Residential and population base year data

The project team started with the Land Use (2005) data layer acquired from MassGIS. This data layer is a Massachusetts statewide, seamless digital dataset of land cover / land use, created using semi-automated methods, and based on 0.5 meter resolution digital ortho-imagery captured in April 2005. The dataset includes five unique residential density delineations allowing for highly specific location and development density types. The project team used U.S. Census estimates for 2008 to adjust the totals at the municipal level (the smallest area for which 2008 estimates were available).

Employment base year data

The project team used two layers for spatial placement:

- Land Use (2005) data layer (obtained from MassGIS, as described in the above paragraph)
- Parcel-based Existing Land Use (obtained from CCC, utilizing state-based existing land use classes)

The Land Use (2005) data layer provided highly specific boundaries for developed zones, while the Parcel-based Existing Land Use data layer gave unique employment types for employment intensity purposes. Again, the project team used U.S. Census estimates for 2008 to adjust the totals at the municipal level.

Estimates for 2030 horizon year

Projected amounts for 2030 new households and employees were applied directly to the various scenarios. Population was converted from households based on existing municipal average number of persons per household estimates from the 2000 Census.

Table 1 Population, employment and household estimates used in analysis

BASE YEAR [2008]			HORIZON YEAR [2030]			DELTA [2008 - 2030]		
Pop	**Emp**	**HH**	**Pop**	**Emp**	**HH**	**Pop**	**Emp**	**HH**
224,335	91,238	95,660	284,335	107,738	123,660	60,000	16,500	28,000

Pop = Population; Emp = Employment; HH = Households

Complexities of summer/winter fluctuations

The estimates for future growth did not include the summer and winter fluctuations on Cape Cod. Neither Census projections nor the transportation modeling results provided by MassDOT and the CCC included summer population and employment. Later in the report, there is a detailed description of what basic assumptions are contained in the resulting analysis, but the true dynamics of summer population could not be analyzed without supporting data.

Land use vision map

As part of the recent Cape Cod Regional Policy Plan, the CCC has been developing a land use vision map (LUVM) for the entire region. At the time of the workshop, eight of the 15 municipalities had adopted local initiatives to implement regional policy recommendation. The LUVMs were used to help make some of the scenario decisions, detailed later in the report, regarding targeting development in areas identified as economic centers and industrial and service trade areas.

Mitigation: VMT and GHG estimation using 5D analysis

In Cape Cod, the two primary levers to mitigate transportation-related GHG are changes in technology (fuel and vehicle improvements) and changes in transportation behavior (increasing transit or non-motorized trips). The latter mitigation strategy was estimated in the scenario-planning context using the 5D estimation method[2]. This method enables the estimation of local effects on vehicle miles traveled (VMT) due to five factors: design, density, diversity, destination accessibility, and distance to transit. This method can be used to augment an existing transportation model as it did in the case of the Pilot Project.

Traditional approaches to estimating VMT for a region are primarily done using what is often referred to as "four-step regional transportation models" consisting of the following steps:

1. Trip Generation – Estimation of the number of trips that occur daily within the study area
2. Trip Distribution – Development of assumptions about where trip origins and destinations
3. Modal Choice or Split – Estimation of the percentage of trips made by different modes (e.g., personal vehicle, mass transit, bicycle, walking)
4. Trip Assignment – Assignment of the trips calculated in steps 1-3 to specific transportation routes

Both MassDOT and the CCC have four-step models that cover Cape Cod and that were used for baseline data for the Pilot Project. In analysis done by Ewing and Cervero based on empirical observations, the four step model has been found to underestimate the impact of transit, land use, and design elements on reducing VMT[3]. These regional models may not capture local effects of various changes in the urban design and planning of neighborhoods that can also decrease travel demand. For example, a community with accessible neighborhood uses like grocery stores, restaurants and retail will most likely generate fewer miles traveled and trips than a similar sized community where these uses exist in the adjoining or more distant towns. 5D analysis operationalizes this concept into parametric relationships among the five "d" variables mentioned above and VMT. In other words, 5D analysis adjusts existing four step variables and adds additional elements in an attempt to get a more accurate estimate of projected changes in VMT as a result of changes in land use, transportation and design.

The variables are measured individually. While there are a number of approaches for each measurement, the Pilot Project used available data to inform what could be measured. Design was measured as street network density (road miles per square mile). Density was measured in terms of household density (units per acre). Diversity is a measure of the land use mix; in this case, the project team used a normalized ratio of population to jobs.

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[2] Ewing, R., and R. Cervero. 2010. Travel and the built environment. Journal of the American Planning Association 76(3): 265-294.

[3] Ewing, R., and R. Cervero. 2010.

Destination accessibility approximates the proximity of neighborhoods to other regional destinations. Distance to transit was measured as the number of people served by traditional transit service areas.

The basic premise of the 5D analysis is that many variables can interact to make measurable changes on travel demand. The most powerful changes occur when the five variables interact in one location; any one variable does not have much of an effect on its own.

Requirements

The 5D analysis requires an existing travel demand model for the time horizon being analyzed. In the case of Cape Cod, there were two applicable travel demand models: a Cape Cod travel model, which is maintained by the CCC, and a Massachusetts statewide travel model, which is maintained by MassDOT. Initially, the project team thought the CCC analysis, completed in 2007, would be the better transportation model to use for trend VMT estimates instead of the state model because it was presumed that the modeling would have been more sensitive to regional factors. The project team still believes this is probably true given that the model was generated using Cape Cod assumptions; however, the team is unclear about the assumptions made and both the CCC model and state model exhibited inconsistencies mentioned above. These issues could not be resolved with the resources and time available so the CCC model VMT outputs were used as the trend assumption, but all numbers were reported as relative changes. At the end of this section are recommendations related to clearing up any potential issues introduced by these inconsistencies in the regional transportation model.

All future scenario VMT and GHG impacts were measured in comparison to the trend. It is also important to measure the variables on discernable neighborhoods that are generally no larger than two square miles.[4] Each of the five variables was measured on the standard quarter square mile grid unit for all scenarios to avoid wide variability and then aggregated across the region and represented as percent change for the region.

General measurement approach

The basic approach to measuring each of the five variables was to:

1. measure the variable in the trend,
2. measure the variable in the alternative scenario,
3. calculate the percent change, and

[4] Criterion Planners/Engineers Inc. 2002. Smart Growth Index, A Sketch Tool for Community Planning, Indicator Dictionary

4. multiply by a specific variable elasticity (see below for detailed description of elasticities) to calculate related decreases in VMT.

Each of the measurements and elasticities are detailed in the next sections.

5D elasticities

Generally, an elasticity is a ratio used to measure the change of one variable due to the change in another variable. In this case, the project team was measuring the responsiveness of changes in VMT to one of the 5D variables. So for every percent increase in any one “D” variable, there is a related decrease in VMT. The relationships used in this study are represented in the next table.

Table 2 Elasticity values for each of the 5 D variables

D Variable	Elasticity of VMT[5]
Density	-0.04
Diversity	-0.02
Design	-0.12
Destination accessibility	-0.20
Distance to transit	-0.05

For example a 10 percent increase in density will result in a related 0.4 percent decrease in VMT. It is important to note that these assumptions are taken from a meta-analysis completed by Reid Ewing and Robert Cervero[6]. Cape Cod-specific assumptions were not available at the time of the study, but these elasticities are easily adjustable within the CommunityViz analysis.

5 Ewing and Cervero 2010

6 2010

Measuring D variables

The following are the specific ways in which each variable was measured in the Pilot Project:

Density = % change in [Households per acre]

Diversity[7] = % change in $\left\{1-\left[\frac{\text{ABS}\ (b*\text{population}-\text{employment})}{(b*\text{population}+\text{employment})}\right]\right\}$

where; $b =$ regional employment /regional population

Design = % change in $\left[{}^{\text{street miles}}/_{\text{square mile}}\right]$

Destination Accessibility = % change in gravity model index measured from study grid (i) to all other grids (j)

$$\text{where; gravity index } A_i = \sum_i \left[{}^{a_j}/_{\exp(t_{ij}*\beta)}\right] \quad {}^{8}$$

Distance to Transit = % change in [population served by transit][9]

Accounting for over-estimation

In order to avoid overestimation, some additional floor and ceiling measures are placed on the estimates at each stage of measurement.[10] These measures come from a study by Fehr & Peers Transportation Consultants in San Joaquin County, CA and were the best available values without doing sensitivity testing on the data. These values are available as adjustable assumptions in the CommunityViz analysis, making it possible to potentially test these values with an updated regional transportation model. These values are necessary to avoid overestimation of developing densely on rural or undeveloped land. For example, and

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[7] Criterion Planners/Engineers Inc. (2002); this formula normalizes jobs/housing balance so comparisons can be made so that perfect balance is a 1 and anything lower represents imbalance.

[8] Handy, S. 1993. Regional versus local accessibility: implications for non-work travel. Transportation Research Record 1400: 58-66; ß=0.1302

[9] Population served by transit was used as a proxy to explicitly measuring distance to transit in the model. Transit stops and stations were given a ¼-mile or 1-mile radius depending on mode.

[10] Fehr & Peers Transportation Consultants. 2009. San Joaquin COG 4D Model Enhancements.

increase in density from one unit per 10 acres to one unit per acre is a 1000 percent increase in density. It would be unreasonable to think that this would result in a 40 percent decrease in VMT from density alone. Table 3 shows the caps used for this analysis.

Table 3 Floor and ceiling values for 5D estimation process

D variable	Minimum	Maximum
Change for ANY variable	-80%	500%
Change in VMT from ANY single D variable	-30%	30%
Change in grid unit VMT for ALL D variables	-25%	25%

Calculating regional change in VMT

The final indicator for the VMT measure is a percent change in VMT. This is aggregated over the entire region from each of the grid units on the map and calculated from the trend VMT and VMT per capita derived from the Cape Cod transportation model.

Converting VMT to related GHG emissions

In terms of transportation related emissions, carbon dioxide (CO_2) contributes most directly to climate change inducing emissions. CO_2 emissions are directly proportional to fuel economy so that a one percent increase in fuel consumption will result in a one percent increase in CO_2 emissions.[11] Other contributing gases (such as methane, nitrogen dioxide and hydroflorocarbons) are most directly related to VMT but vary based on a number of factors and are not as easily estimated from a vehicle as CO_2. To simplify this calculation, the U.S. Environmental Protection Agency (EPA) recommends multiplying CO_2 estimates by 100/95 to get a carbon dioxide equivalent (CO_2e) factor that accounts for the global warming potential of these gases (on average other gases attribute about 5% additional CO_2 warming potential, hence the multiplier).[12]

[11] EPA Emission Facts Average Annual Emissions

[12] EPA. 2005. Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle. Available www.epa.gov/oms/climate/420f05004.htm.

To get from VMT to GHG, the total regional change in VMT attributable to the 5D variables is calculated for each scenario. Then this VMT is divided into four separate modes as used in the transportation model for Cape Cod:

1. Passenger Vehicles
2. Light Duty Vehicles
3. Medium Trucks
4. Heavy Trucks

Each of these is then multiplied by percent fuel type as appropriate (e.g., diesel or gasoline) to get the total VMT change for each mode by fuel type. Then, the average fuel efficiency is multiplied to arrive at the total gallons of fuel change. Each total can then be multiplied by the carbon equivalent per gallon of that fuel. The basic equation looks like this:

$$CO_2e = [\text{Change in VMT}] * [\%\ \text{Mode}] * [\%\ \text{Fuel type}] * [\text{Average fuel economy (mpg)}] * \left[{}^{CO_2}\!/_{\text{gallon of fuel}}\right] * \left[\frac{100}{95}\right]$$

Finally, GHG emissions are reported as a percent change so that the final indicator would be calculated as:

$$\{[\text{Scenario GHG -Trend GHG}]/[\text{Trend GHG}]\} * 100$$

It is important to note that these formulas exist in the analysis but were not directly manipulated during the Pilot Project as reliable estimates for fuel type splits did not exist for the trend to compare against. In effect, the assumptions remained fixed, meaning that percent changes in GHG mirror percent changes in VMT.

Adaptation: vulnerable areas to sea level rise and climate change impacts

Overlay measures were developed to track the percent of new population placed in various areas with growth constraints or critical areas of concern. The layer most directly linked to climate change was a layer of areas vulnerable to sea level rise developed by the Volpe Center in consultation with various experts. More information on the development of this layer is available in the Final Report. The indicator measured the number of population placed in these polygonal areas and informed where new development would be vulnerable to impacts of climate change, such as inundation, erosion and salt water intrusion. This indicator is most related to discussion on adaptation and forms the complement of mitigation strategies linked to the VMT and GHG indicators.

Transit access

Access to transit is not only one of the five D variables listed earlier, but a separately reported indicator. Transit access is reported in two ways: as total employees and population served by a transit service area and as population and employees served at various service levels (frequencies in 15 minute increments up to 60 minutes). While frequency of service is reported as an indicator, it is not factored into reductions in VMT at this time. Each transit service area is a ¼-mile radius for local buses and a one-mile radius for intercity buses and rail. Also, the analysis calculates the total number of employees and population served by each transit service area but can also show other factors like frequency or type of service.

At the time of the workshop, there was not a robust way to calculate ridership impacts based on service levels and other factors, such as price. However, the project team determined that the number of people and employees served by a standard transit service area could be used as a proxy. While ridership impact estimates are more powerful, when robust models or estimations are lacking, a discussion can still be informed by reporting what is currently measurable.

Critical overlays

Other overlay measures developed included those that reflected impact on water resources, the natural environment, and the existing built environment. For the majority of Cape Cod residents, drinking water is obtained from wells and wastewater is managed using septic systems. In addition, the unique shape of the Cape Cod peninsula creates impressive coastlines and active bays where residents and visitors have direct impact on the marine environment that forms their boundary. Cape Cod towns place great value on the historic character of local village centers. The CCC LUVM acknowledges historic villages with a special designation.

There are several types of data that were used to help form an understanding of potential development constraints in Cape Cod (See Appendix C for source and maps representing these layers):

- Wellhead Protection Areas (provided by CCC)
- Future Water Sources (provided by CCC)
- Critical Species Habitat Areas (from MassGIS based on data from the National Heritage and Endangered Species Program, updated October 2008)
- Cape Cod National Seashore Boundaries (provided by CCC)
- Historic Preservation Areas (provided by CCC)

Individually, each one of these data layers encompasses a large area of land on Cape Cod. Taken together as protection zones, they result in very limited options for future development. A scenario that avoids all these constraints completely is almost impossible.

To measure and track potential impacts resulting from the conflicts between development and constraints, the new population placed in areas of overlap was measured. Workshop participants had access to map data on all of the above areas of concern so they could visualize the location of development in relation to any layers of interest. CommunityViz calculated total population placed in each area and percent land converted as live feedback for participants as they placed jobs and housing on maps. These indicator values included:

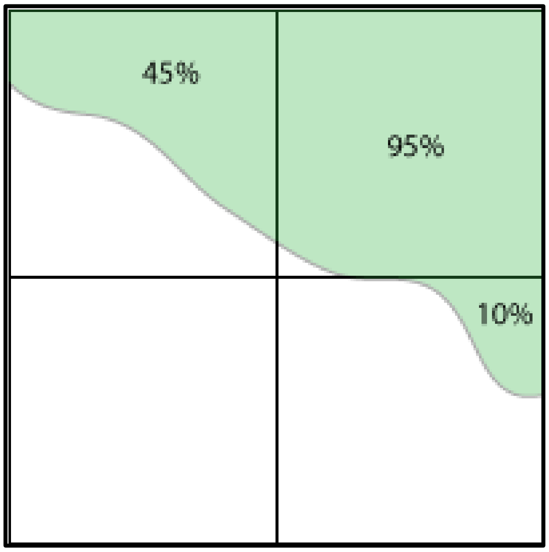
- Percent Undeveloped or Rural Land Converted to Developed Land

- Percent of New Population in Critical Habitat Areas
- Percent of New Population in Undeveloped Areas
- Percent of New Population in Conservation Areas
- Percent of New Population in Historic Preservation Areas
- Percent of New Population in Water Resource Areas
- Percent of New Population in Water Resource Areas at Low Density (less than or equal to one unit per 10 acres)
- Percent of New Population in Wellhead Areas
- Percent of New Population in Wellhead at Low Density (less than or equal to one unit per 10 acres)

The calculation of these overlaps was a straightforward spatial measure that is possible using CommunityViz or basic GIS functions. Essentially, for each of the above mentioned critical overlays, the percent overlap of the constraint layers was calculated for each grid unit on the map (see Figure 1 for illustration). The total new population placed in the affected grid multiplied by the percent overlap resulted in a total affected population. The indicator then showed the percent of total new population placed in each of the constraints for a particular scenario. Given that population assumptions remained fixed for the scenarios, this relative measure was the easiest to compare.

Performance of the scenarios for each of these indicators is included in the Scenario Assessment section.

Figure 1 Example map overlay used to calculate percentage of new population placed within a zone



Opportunities for improved metrics and measures

Population and employment assumptions

Many workshop participants believed the population assumptions extended to 2030 were too high. The demographic assumptions came directly from state projections, which could have been overestimated from previous periods of extremely rapid growth. The recession and other factors have probably dampened the expected population growth through 2030. However, the assumption for growth is variable and can be changed in the GIS analysis through proportionally decreasing placement of jobs and housing. It is also possible that a parallel land use and regional transportation effort could link this analysis even closer to VMT and GHG outcomes so that the land use and transportation visions inform each other in an iterative fashion. Specifically, allocations of population and employment would be exactly the same in the CommunityViz analysis as in subsequent transportation models.

The baseline was based on the best available data at the time, which were the 2008 estimates. The 2010 Census offers a much more accurate picture of the existing population and could be used to update the baseline and trend.

Using variable assumptions and a similar process used in the workshop, the CCC and towns could remove chips until they reach a new goal in the same way they placed chips to reach the original goal. CommunityViz will report the total households and employment for the region as well as by town in dynamically updating charts, making new scenarios under different growth assumptions possible.

VMT and GHG estimation

The general approach to VMT and GHG estimation works well, but there are some opportunities for the scenario analysis to become more closely matched with a regional transportation model.

On closer look at the MassDOT and CCC transportation models, the team noticed discrepancies in the underlying population and employment assumptions embedded in the Traffic Analysis Zones (TAZs)[13] provided to the team. This does not invalidate estimations as they are reported primarily as relative changes and measured in the same fashion across all scenarios. Also, the team is confident that baselines on current and trend population and employment were completed using a very robust method with consistent internal checks for outliers and anomalies. The resulting layers for existing and trend population and

[13] A Traffic Analysis Zone is a standard unit of analysis for transportation related modeling. They allow modelers to forecast changes in commuting patterns across a region. TAZs are designed to use Census data like the decennial census and American Community Survey (ACS)

employment are not exact measurements but are close to what would be expected from the data provided including the most recent aerial photography.

It is best practice to make sure that the trend distribution assumptions are similar or the same for the scenarios as they are for the transportation model. The team would have adapted the transportation modeling assumptions to the scenario analysis, but this would have left very large holes in places where there was known employment and overestimated population in certain parts of Cape Cod. The opportunity exists to take an agreed upon trend growth pattern through a common methodology and apply it to both the scenario analysis and the transportation analysis. This will ensure that the analyses are linked as closely as possible and minimize error.

The current scenario framework is built to accept new data and can be used to produce trend growth assumptions for a future transportation analysis. CommunityViz can also be used independently of the scenarios built for the Pilot Project to create a build out analysis and allocation model for Cape Cod that can be plugged back into this framework.

Transit access

As noted previously, the existing transit measures are primarily informational. There exists an opportunity to build ridership impact analysis into the transit indicators. For example:

1. Ridership estimates could be derived from a number of external factors that are relevant to Cape Cod such as population served, frequency of service, and fares.
2. Fare structures could be tested through a parametric model that relates fares to ridership.
3. Commuter sheds could be derived from transportation networks in future scenarios to aid in route and stop planning.
4. A transit stop suitability analysis could be created using future scenarios to find the most appropriate places for stops.

Ultimately, the best indicators will help maximize ridership/revenue and minimize cost while serving as many Cape Cod residents as possible. This balancing of ridership, cost and social considerations is conducive to a scenario planning process.

Additionally, all transit service areas in the analysis are circular buffers and do not account for existing street networks or accessibility. This level of detail is possible with the right data. The circular buffers were used for practical means as running a network-based buffer would take too much time in a live workshop.

To bridge the gap between speed and detail, one approach would continue to use round buffers as a "back of the envelope" process in a workshop setting. Once there is general agreement on the placements of stops, technical staff can then calculate centroids and generate a map layer of network service areas in ArcGIS and substitute them for the round buffers in an analysis. This may seem like extra work, but part of scenario planning in the public setting is balancing accuracy against efficiency. If the greater accuracy of using network service areas in the analysis is desired, so some time would need to be built into the workshop agenda for such analysis (while not an overnight operation, it is also not instantaneous).

Critical overlays, alerts and thresholds

Overlay operations are fairly straightforward and easy to implement in a scenario planning process, especially if the overlay remains static during the analysis. For example, no households could be added within the Cape Cod National Seashore boundaries for any of the scenarios. These fixed constraints are great indicators to measure as they can be implemented quickly and provide important feedback. One of the areas of improvement for this analysis is to make the layers more interactive by embedding levels of constraint. For example, the National Seashore has some comparatively strict development constraints. CommunityViz enables the creation of alerts that let the user know when some critical rule was broken or a threshold passed. Using alerts, additional considerations that could be embedded into the analysis include:

1. A warning when a critical density is reached within areas with protected wellheads
2. Highlight development placed within the National Seashore zone in red and issue an alert
3. Code areas vulnerable to sea level rise by type and report when a critical population is placed in harm's way

Or, some positive thresholds:

1. Let participants set density targets for new development and report how close they are
2. Let participants set VMT reduction targets before a workshop and show this target on a chart so participants can iteratively change distribution to meet targets
3. Let participants set targets for population outside of constraints and report this on a chart

Summer/winter population considerations

From the beginning of the Pilot Project, population changes from summer to year-round were of interest. The analysis is embedded with some estimates of what summer population might be based on multipliers extrapolated from existing numbers on summer population crossed with vacant housing units from the 2000 Census. These multipliers are produced in the accompanying table and were estimated by the project team using overall summer population estimates provided by the CCC and Census data for unoccupied housing units by town.

Table 4 Summer population multipliers by town

Municipality	Multiplier
Barnstable	1.5
Bourne	1.5
Brewster	2.5
Chatham	3.5
Dennis	3
Eastham	3.5
Falmouth	2
Harwich	2.5
Mashpee	2
Orleans	2.5
Provincetown	4
Sandwich	1.5
Truro	4.5
Wellfleet	5.5
Yarmouth	2

For the analysis in this report, year-round numbers were used for most of the indicators, as there was not a robust understanding of how employment changed from winter to summer. Without reliable baselines, it is difficult to calculate consistent impacts. For now, the analysis has formulas that make two basic assumptions:

1. Population increases in the summer according to the multipliers in the table
2. Employment increases proportionally to the existing jobs/housing balance

These two assumptions omit a high degree of complexity that needs to be studied and understood before being used in a scenario process. First, year-round conversions are not taken into account. How much of the summer population converts into year-round population annually? Second, how does employment increase by town and type? This could be estimated from existing seasonal employment figures, but would need to be extrapolated to the 2030 time horizon, possibly using population to estimate supporting employment. Another complicating factor regards the number of times an occupied summer home turns over. If it is rented, this affects the inbound and outbound traffic on Cape Cod differently from a home occupied for the entire season.

CommunityViz is not primarily meant to perform automated Monte Carlo[14] or iterative procedures (except in the case of build-out analysis and allocation). Scenario planning at the regional level, especially with the public, is often represented as snapshots in time. Recommendations to obtain a full year's perspective on summer/winter dynamics in 2030 are:

1. Measure current occupied and unoccupied households for each grid
    a. Unoccupied households will most likely be filled in the summer, except for actual vacancies. This information needs to be checked and verified.
2. Measure current year-round and seasonal employment
3. Develop a defensible ratio between seasonal population and employment
    a. Good basic relationships can be created directly from historical data; however, there may be other external factors like greater economic trends that can impact this. It is important not to get into the details and ignore larger trends.
4. Project year-round population and employment growth for Cape Cod based on reasonable agreed-upon assumptions
5. Create reasonable factors for determining conversions and new development from those projections
6. Separate out new growth allocation from summer to year-round conversions, go through an exercise to identify converted households and new households
7. Apply reasonable assumptions for additional summer home growth through the time horizon
8. Use the "additional summer home growth" and remaining unoccupied units from the baseline, if any, and develop a formula to estimate the summer distributions based on best estimates or empirical historical data.
9. Extrapolate the new seasonal employment based on factors such as summer population or historic multipliers by locality
    a. For example, if in general Provincetown has attracted 2.5 seasonal employees per summer resident, apply the multiplier; more advanced relationships are possible, depending on what has been or can be measured and understood.

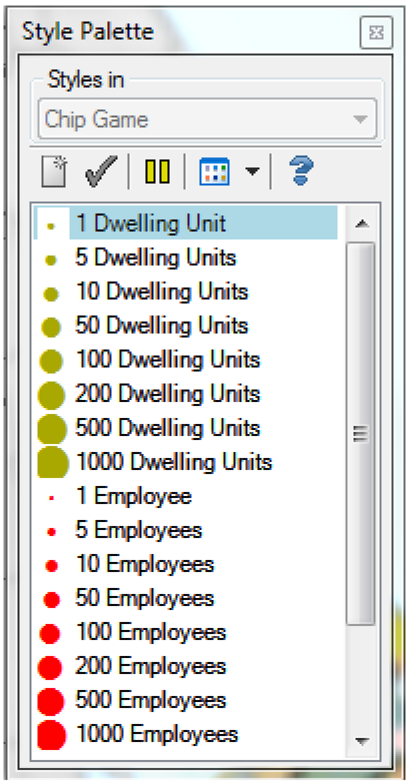
These steps will result in year-round and seasonal population changes in the baseline and trend. Essentially, very clear, transparent relationships must be developed to predict and measure summer population for a distant time horizon. These relationships are codified through formulas driven by the decisions made during a scenario process. Additionally, to summarize an entire year's worth of population, including a peak in the summer, indicators

[14] For information on the Monte Carlo method see http://en.wikipedia.org/wiki/Monte_Carlo_method

can be designed in CommunityViz to calculate weighted averages over the calendar year or can be divided into two seasons. This can only be done if both year-round and summer populations are coded in the underlying data for each of the grid units or whatever unit of analysis is used (Census tract, TAZ, etc.).

Scenario Overview

Figure 2 Style palette for adding dwelling units and employees to map



Two basic approaches were used for the development of scenarios. One was a semi-automated approach using CommunityViz's Build-Out Wizard to help place households and jobs according to preset goals. This approach is detailed below under pre-workshop scenarios, which included:

1. Trend
2. Dispersed – Standard Transportation
3. Dispersed – Enhanced Transportation
4. Targeted – Standard Transportation
5. Targeted – Enhanced Transportation

The trend was built around typical growth allocations experienced on Cape Cod from previous decades, using the base population and employment growth assumptions from the previous section. Both dispersed scenarios were built around a relaxed set of assumptions on constraints, allowing growth to occur at a much more spread out pattern than the trend. Both targeted scenarios allocated growth according to either the relevant LUVM or other considerations about existing downtowns and employment centers where a LUVM had not yet been adopted. All of these scenarios were illustrative of extreme future scenarios to demonstrate the range of possible future outcomes.

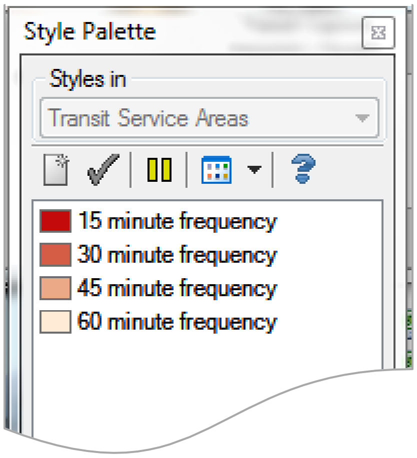
The next series of scenarios were developed in workshops by CCC staff and town planners from across Cape Cod. These workshop scenarios were driven by local knowledge and were manually created by stakeholders. Workshop scenarios were developed by four separate groups, resulting in four separate scenarios labeled Table A through D. Following the workshop, the Volpe Center coordinated a process to come down to a single refined scenario.

Placing population and employment in scenarios

The basic approach to placing population and employment involved the use of digital "chips," or map point features attributed and symbolized with various sizes to represent quantities of households and employment (see Figure 2). In workshop exercises and for the refined scenario, participants placed the chips themselves, while in the preliminary scenarios, the project team placed chips in a mostly automated fashion with a subsequent review by the team. Any reference to chips in this report refers to the digital representations of households and employment as shown in the accompanying image.

Adjusting transit assumptions

Figure 3 The transit service area style palette



As mentioned in previous sections, scenarios also contained changes in transit choices. The trend dispersed and targeted scenarios contained baseline assumptions about likely future transit. However, for the workshop and refined scenarios, participants could add new transit service areas and could use a palette of transit service areas based on service frequency divided into 15-minute frequencies up to 60 minutes (see Figure 3). Participants could change frequencies on existing stops using a paintbrush tool to apply the new frequency or they could place a new transit stop with a specified frequency.

As mentioned in the previous section, the frequencies were not linked directly to VMT reductions because a reasonable model or set of assumptions did not exist at the time of the workshop. However, the frequencies provided general information and allowed participants the ability to weigh in on where they would like to see increased frequency. This information can be used by the Cape Cod Regional Transit Authority for transit planning and could be used in future iterations of the analysis to make assumptions about mode shift.

Pre-workshop Scenarios

Five scenarios were prepared for educational and illustrative use at a November 2010 workshop. These scenarios represented themes for possible futures if extremes were carried forward. The themes utilized a two-by-two matrix of growth patterns (see Figure 4) for development intensity and transportation alternatives.

Growth Options for Development Intensity:

- Dispersed – Following a spread-out distribution of development
- Targeted – Allocating new development to specific, compact areas

Transportation Options:

- Standard – Existing transit with planned improvements
- Enhanced – More options for new transportation

Additionally, a trend scenario was prepared that represented “business as usual” in growth and transportation. This scenario was based on past growth, providing a benchmark for scenario effectiveness on various measures. More detail on the methodology and assumptions for development intensity and transportation options are provided below, followed by detail on each preliminary scenario.

Figure 4 Visual matrix of transportation choices crossed with development intensity

Development Intensity

All three preliminary development scenarios relied on a regional build-out analysis for potential development capacity. To define the maximum future gross development capacity, the project team used the Massachusetts statewide zoning GIS layer, obtained from MassGIS. This layer provides several primary land use codes based on, but not identical to, local zoning districts, which were provided by CCC.

Primary Use (PRIM_USE) codes (D.U. = dwelling units):

- CP - Conservation/Passive Recreation
- R1 - Single Family Residential, >= 80,000 sq. ft.
- R2 - Single Family Residential, 40,000 - 79,999 sq. ft.
- R3 - Single Family Residential, 20,000 - 39,999 sq. ft.
- R4 - Single Family Residential, 15,000 - 19,999 sq. ft.
- R5 - Single Family Residential, 5,000 - 14,999 sq. ft.
- RA - Residential/Agricultural Mix
- ML - Multi-family, low density (3-8 D.U./acre)
- MM - Multi-family, medium density (9-20 D.U./acre)
- MH - Multi-family, high density (> 20 D.U./acre)
- MU - Mixed Use
- IN - Institutional
- HC - Health Care

- OP - Office Park
- HB - Highway Business
- LB - Limited Business
- GB - General Business
- CB - Central Business
- LI - Light Industrial
- GI - General Industrial
- NZ - Not Zoned

Given that this data is compiled at the state and is dated August 2007, efforts were made to review and compare the district data with local zoning maps, obtained through online research of Township websites. In most cases the statewide data matched well with the local districts. In a few instances, minor edits were made to designations to better represent local zoning.

Once the zoning layer was prepared, a CommunityViz Build-Out analysis was prepared for the entire Cape Cod region. CommunityViz Build-Out Wizard is an automated build-out analysis tool to identify available development capacity of a zoning or land use plan. The zoning layer provided locations for potential future development types. Residential densities and non-residential floor area ratios (FAR) for the districts were approximated based on state and local definitions. Existing development, as defined previously from the analysis of parcel-based existing land use and 2005 land cover, was subtracted from the gross build-out results to obtain a net future capacity.

The build-out wizard creates both quantitative results for development numbers and potential spatial locations for buildings utilizing simple rules for setbacks and separation. These new building points were designed to represent chips for the future growth allocation exercise. Non-residential chips were created as consolidated locations for 100 employees. Residential chips were created as consolidated locations for 100 dwelling units. Zoning areas that were already built out to the extent that these increments could not be added were assumed to be fully built-out, and no chips were made available.

These capacity chips provided a pool for development options for all the future prepared scenarios.

Standard vs. enhanced transportation options

For both the targeted and dispersed options, two different transportation scenarios were considered. Standard transportation included existing and all planned improvements that were considered likely to be implemented by the 2030 time horizon (see Figure 7 and Appendix B for a list of these stops). This included:

1. New Bourne-Sandwich route
2. Commuter train running from Boston, MA region to Harwich, MA

Enhanced transportation was created as a comparison scenario to consider unplanned stops and routes that served the remaining densely populated areas of Cape Cod in 2030 under each of the scenarios. For the dispersed scenario, eight additional stops were placed and six were placed in the targeted scenario. These placements are shown in Figure 5 and Figure 6. It did not consider feasibility or cost but was purposely calibrated to increase service in each of the scenarios.

The project team maintained the existing baseline frequency of 60 minutes for all preliminary scenarios, although again, this did not factor into the indicator analysis.

Figure 5 Dispersed scenario enhanced transit stops

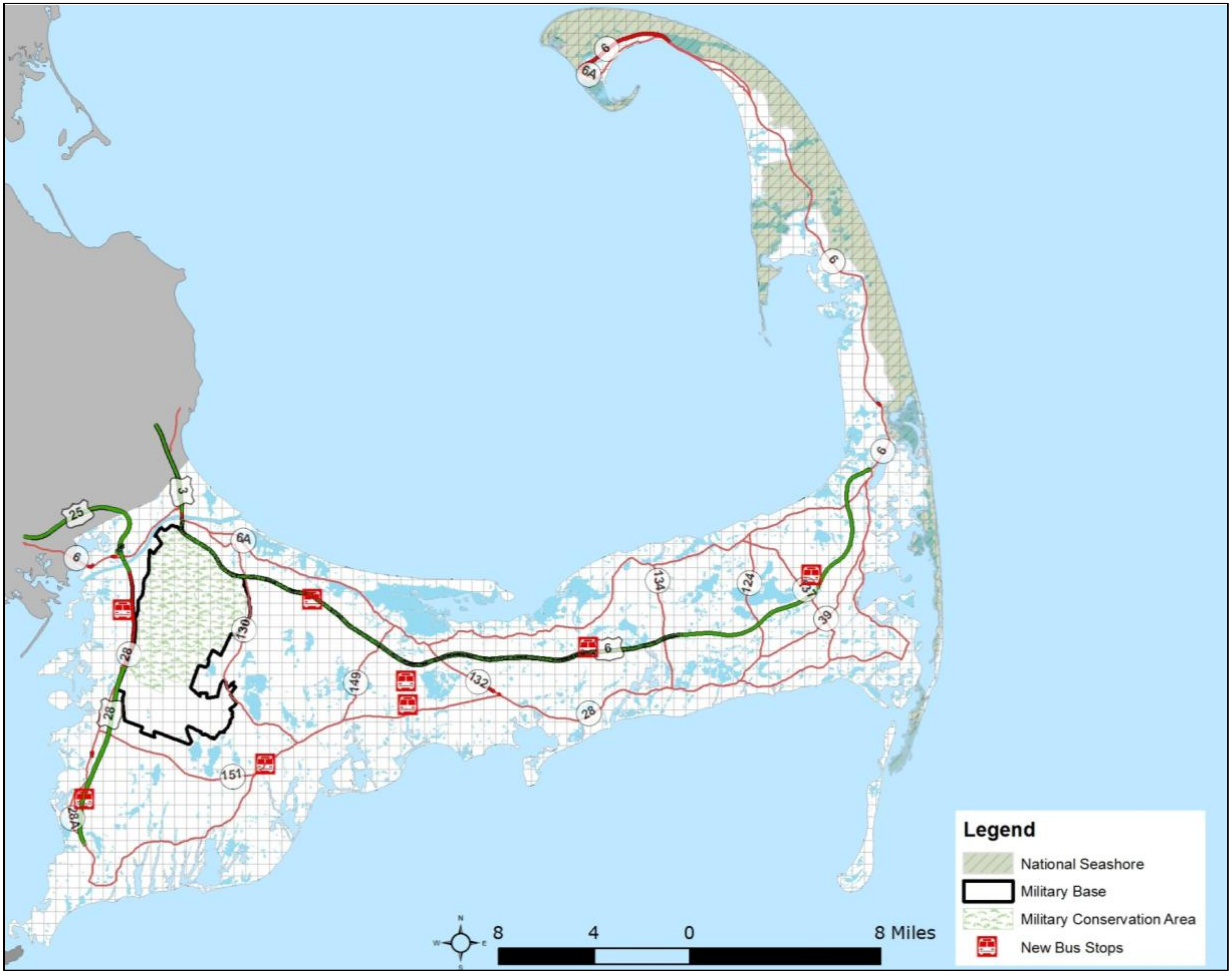


Figure 6 Targeted scenario enhanced transit stops

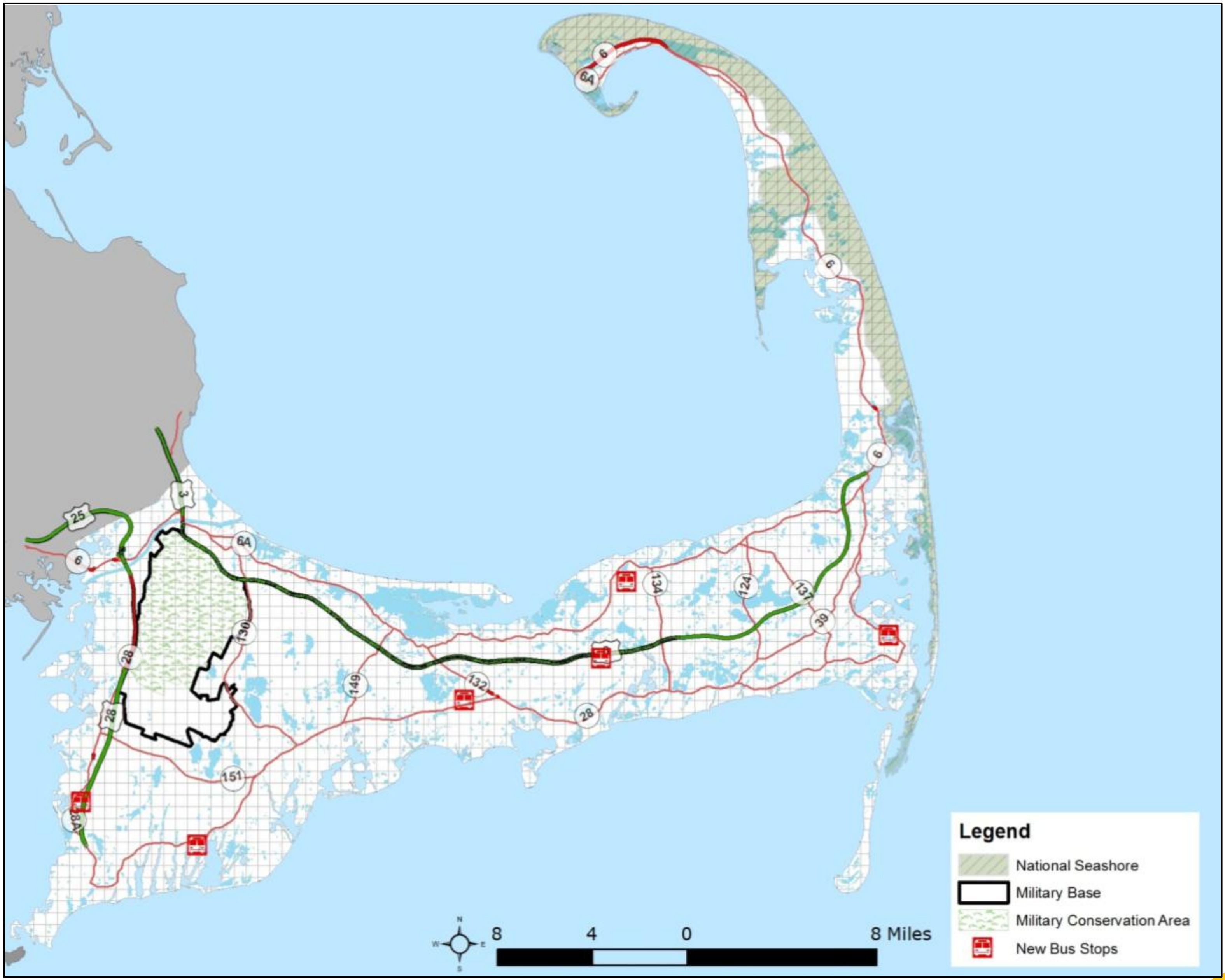
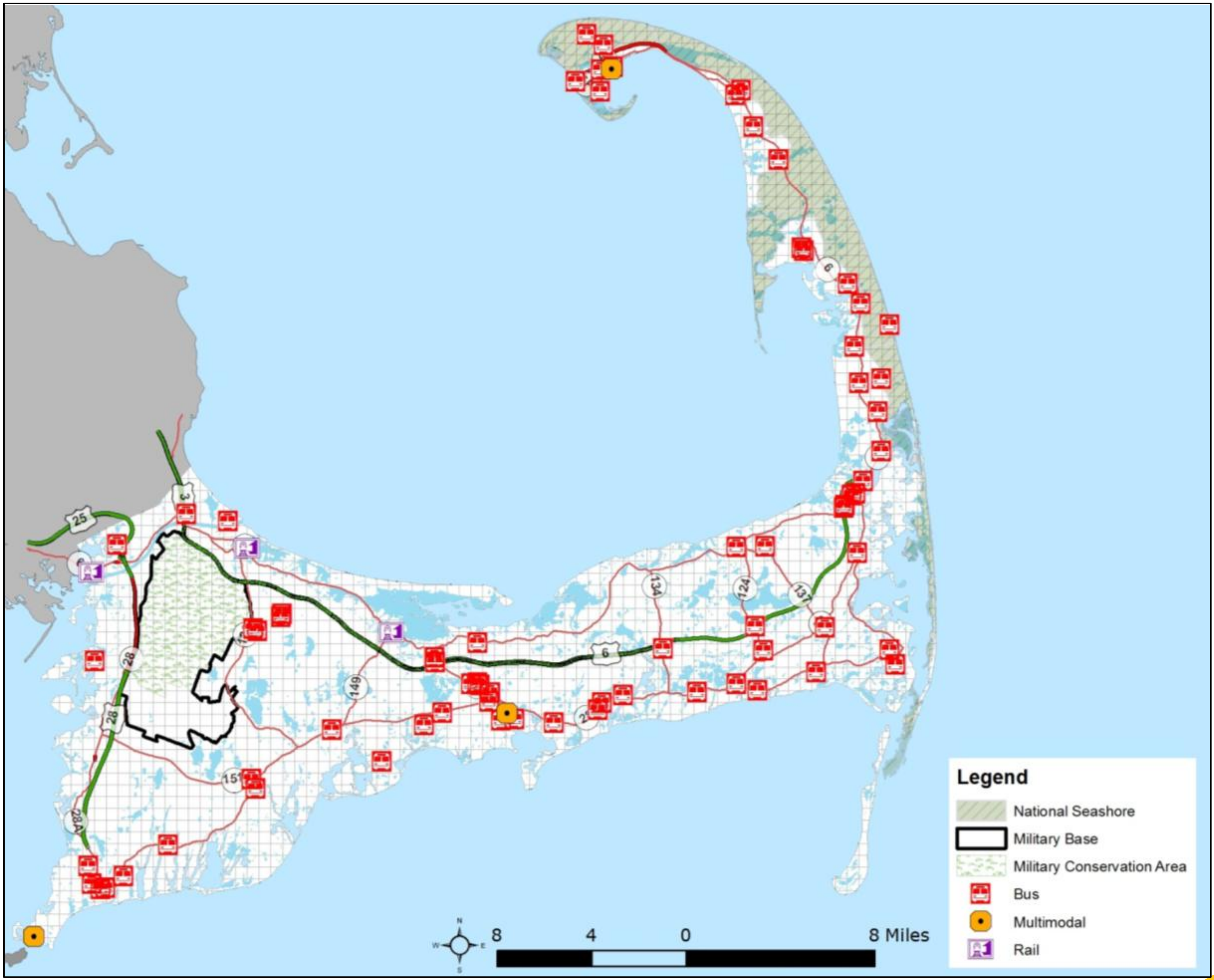


Figure 7 Standard transit baseline including planned and existing transit stops



Scenario 1: Trend

The trend growth pattern was not restricted to specific form (e.g., compact versus sprawl), but was built to accommodate development distribution at the municipal level from previous decades. The trend used Census data for the Cape Cod municipalities for 1980, 2000, and estimated 2008 households and employment to guide development amounts. Table 5, Table 6, and Figure 8 show the data used.

Using the zoning build-out capacity “chips” to mark the potential locations for future development, points were selected at random in each municipality to meet the trend quantities from the previous charts. In some of the townships, build-out did not allow for development to occur up to the trend amounts. In these locations, new “chips” were created in locations in or proximate to development centers of townships. Figure 9 and

Figure 10 show the allocations of households and jobs for this scenario.

Table 5 Census data for Cape Cod population trends

Municipality	1980	2000	2000 PPH	2008 HH	Change from 1980	% Change from 1980	2030 Trend Quantity
Barnstable	12,014	19,626	2.44	18,928	6,914	19.4%	5,400
Bourne	4,619	7,439	2.52	7,695	3,076	8.6%	2,400
Brewster	2,009	4,124	2.45	4,056	2,047	5.7%	1,600
Chatham	2,666	3,160	2.1	3,191	525	1.5%	400
Dennis	5,336	7,504	2.13	7,206	1,870	5.2%	1,500
Eastham	1,391	2,396	2.28	2,385	994	2.8%	800
Falmouth	8,836	13,859	2.36	14,035	5,199	14.6%	4,100
Harwich	3,720	5,471	2.26	5,442	1,722	4.8%	1,400
Mashpee	1,429	5,256	2.46	5,783	4,354	12.2%	3,400
Orleans	2,356	3,087	2.05	3,058	702	2.0%	600
Provincetown	1,763	1,837	1.87	1,805	42	0.1%	0
Sandwich	3,116	7,335	2.75	7,320	4,204	11.8%	3,300
Truro	595	907	2.3	924	329	0.9%	300
Wellfleet	970	1,301	2.11	1,291	321	0.9%	300
Yarmouth	7,736	11,520	2.15	11,060	3,324	9.3%	2,600
TOTAL	**58,556**	**94,822**		**94,179**	**35,623**	**100.00%**	**28,100**

Table 6 Census data for Cape Cod employment trends

Municipality	1980	2008	Change from 1980	% Change from 1980	2030 Trend Quantity
Barnstable	16,932	27,093	10,161	25.34%	4,200
Bourne	3,982	7,282	3,300	8.23%	1,400
Brewster	785	2,682	1,897	4.73%	800

Chatham	1,922	3,121	1,199	2.99%	500
Dennis	2,167	4,768	2,601	6.49%	1,100
Eastham	679	1,214	535	1.33%	200
Falmouth	8,832	14,502	5,670	14.14%	2,300
Harwich	2,061	3,840	1,779	4.44%	700
Mashpee	1,063	4,534	3,471	8.66%	1,400
Orleans	2,563	4,193	1,630	4.07%	700
Provincetown	1,912	2,397	485	1.21%	200
Sandwich	1,724	5,297	3,573	8.91%	1,500
Truro	366	586	220	0.55%	100
Wellfleet	816	1,048	232	0.58%	100
Yarmouth	5,583	8,924	3,341	8.33%	1,400
TOTAL	53,367	93,489	40,094	100.00%	16,600

Figure 8 Trend Scenario: Percent change in employment & households (1980-2008) by municipality

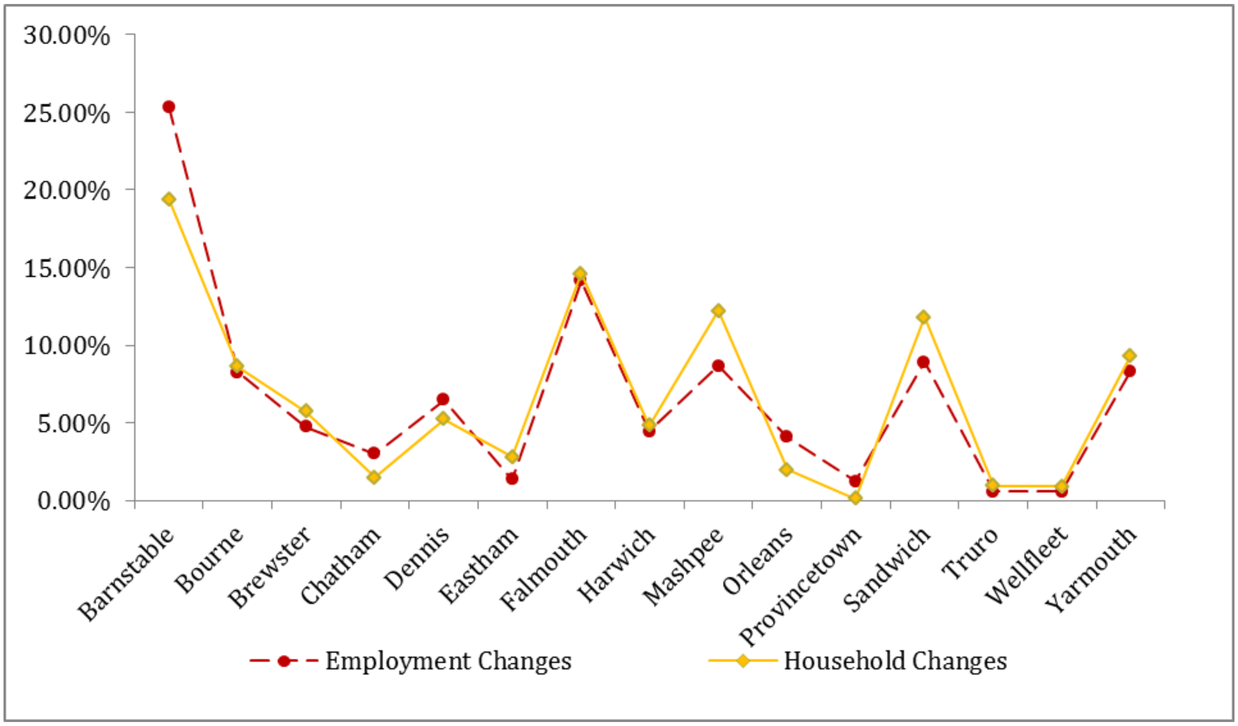


Figure 9 Trend Scenario: Change in housing density over existing

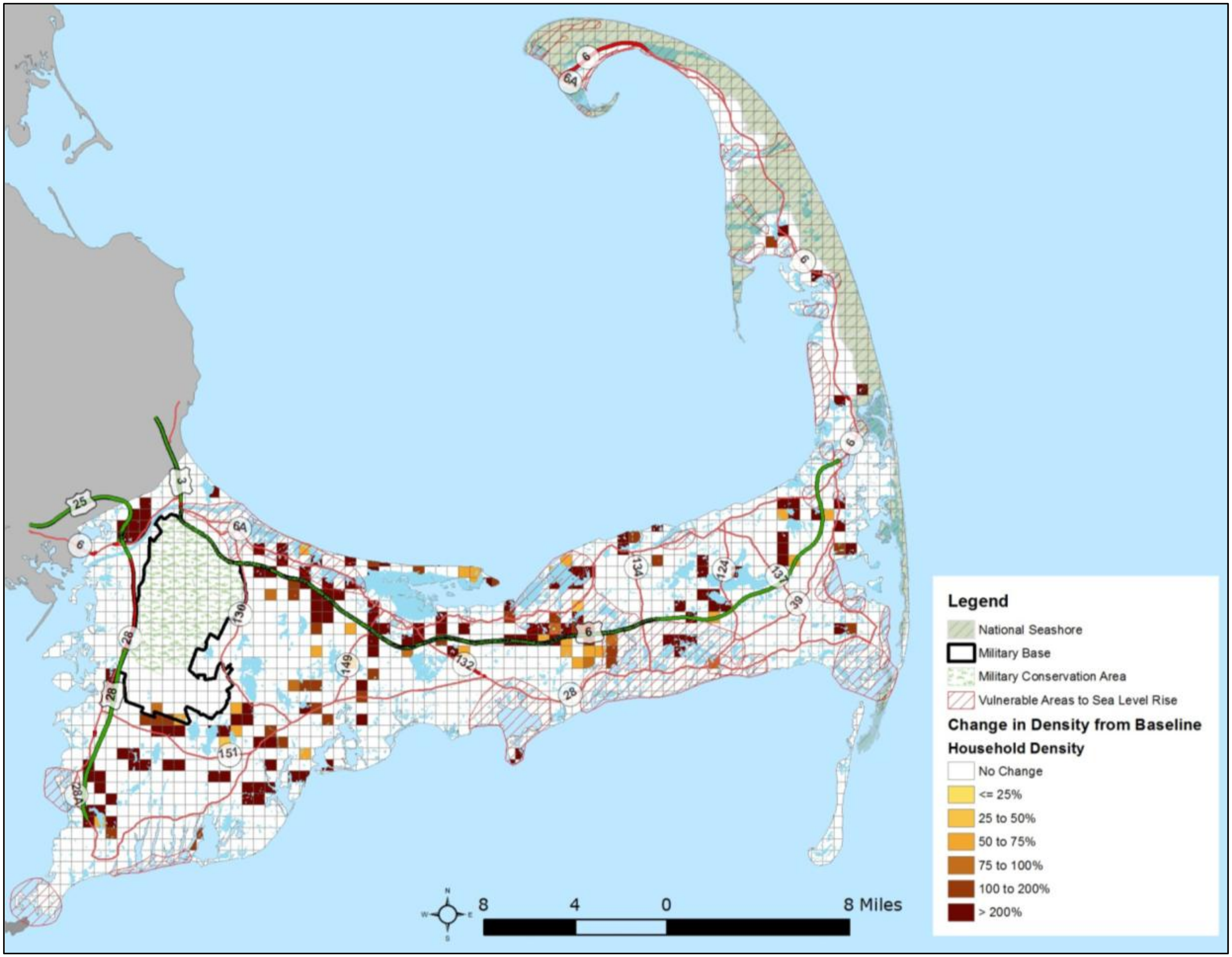


Figure 10 Trend Scenario: Change in jobs density over existing

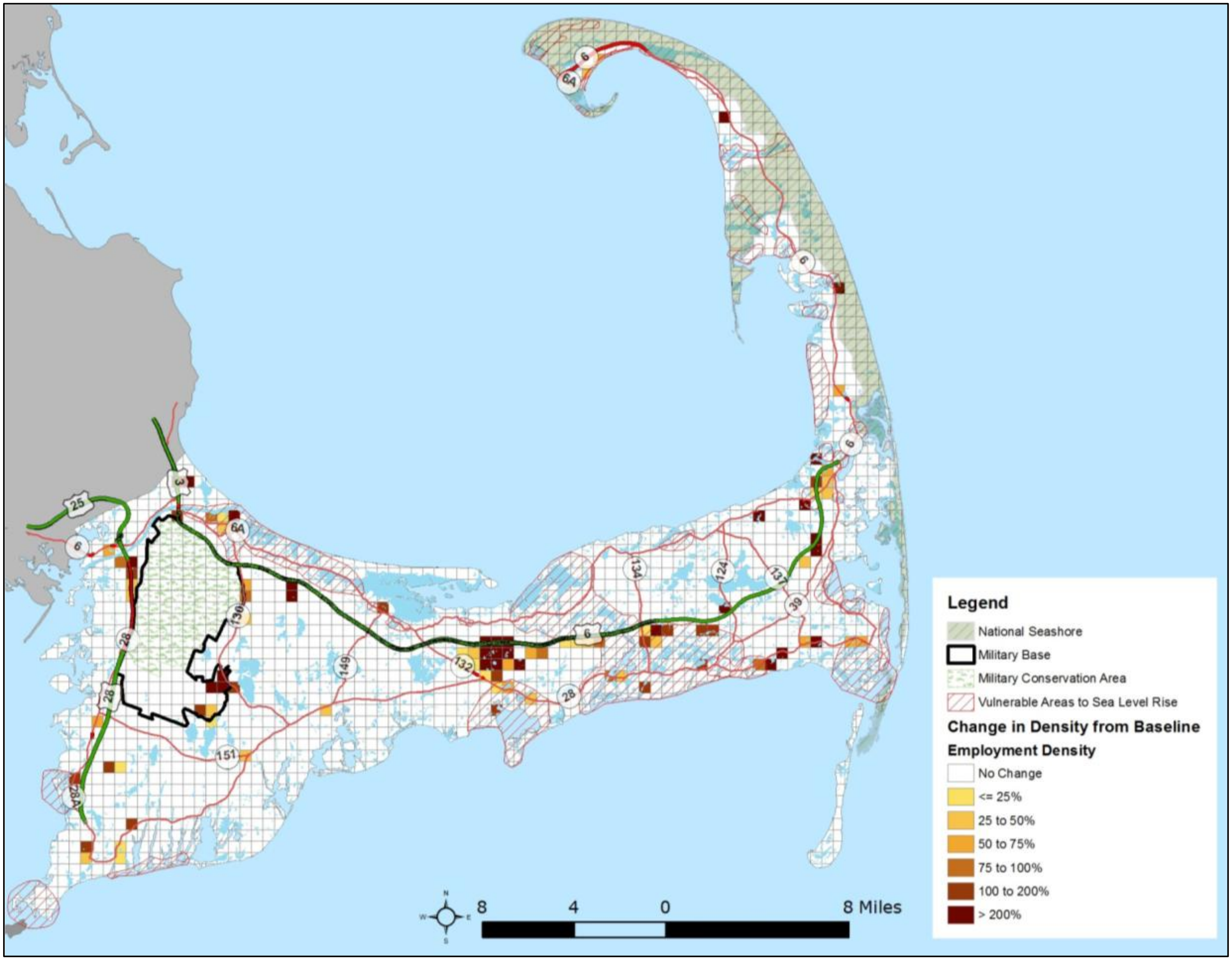
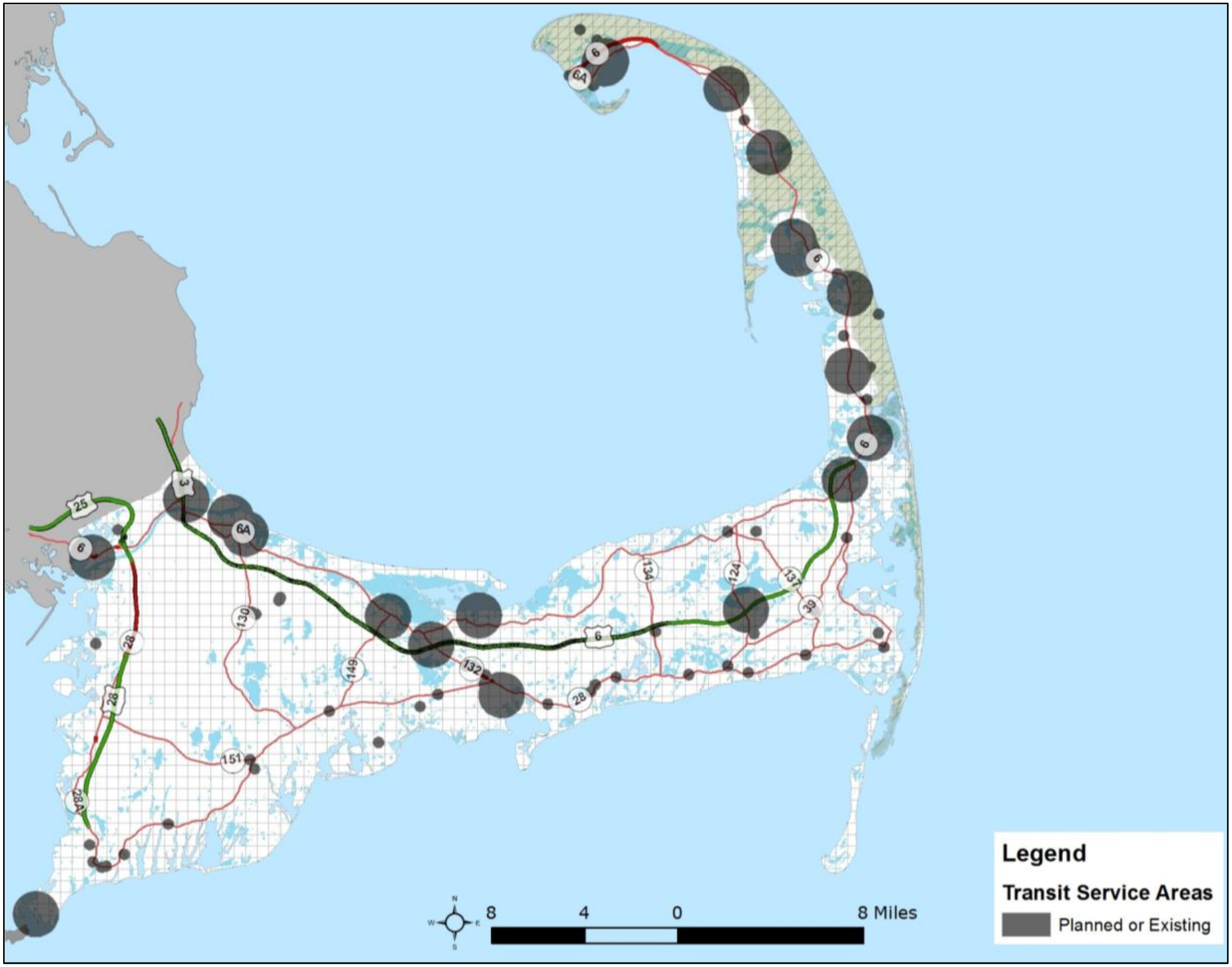


Figure 11 Transit service areas for existing and planned transit in 2030



Scenarios 2 and 3: Dispersed

The dispersed development scenario represents a random development pattern where no controls on or adjustments to development location from the build-out pool were made. The only condition was that development had to meet the forecasted regional quantities for Cape Cod. Chips were picked using a random number algorithm from the raw build-out locations. This resulted in a very dispersed and indiscriminate development pattern.

Scenarios 4 and 5: Targeted

The targeted development scenario represents a very compact form for all future development. Build-out results were reviewed and referenced for possible locations, but actual building placement results from build-out were not used in this scenario.

As mentioned, the CCC-prepared LUVM had been adopted by eight of the 15 municipalities at the time of the workshop. For the areas where the LUVM had been endorsed, the targeted development scenario utilized the boundaries defined for economic centers and industrial and service trade areas to guide the location of future growth concentrations.

For the townships where discussion is still underway on the LUVM recommendations, local zoning was reviewed for areas where higher concentration of development has been entitled. High density residential areas and intense commercial and industrial zones were seen as better locations for development infill in future growth.

Figure 12 Dispersed Scenario: Change in housing density over existing

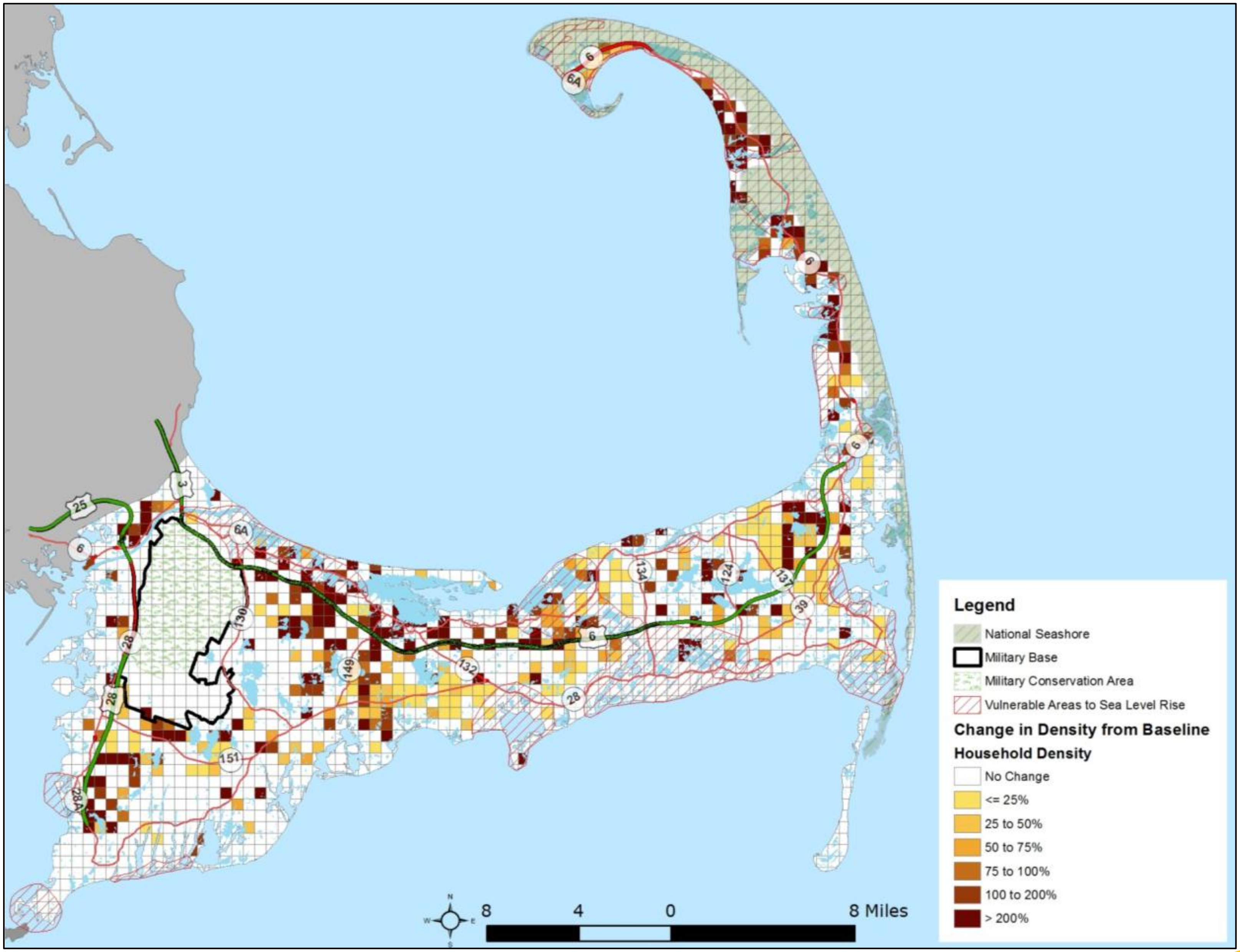


Figure 13 Dispersed Scenario: Change in jobs density over existing

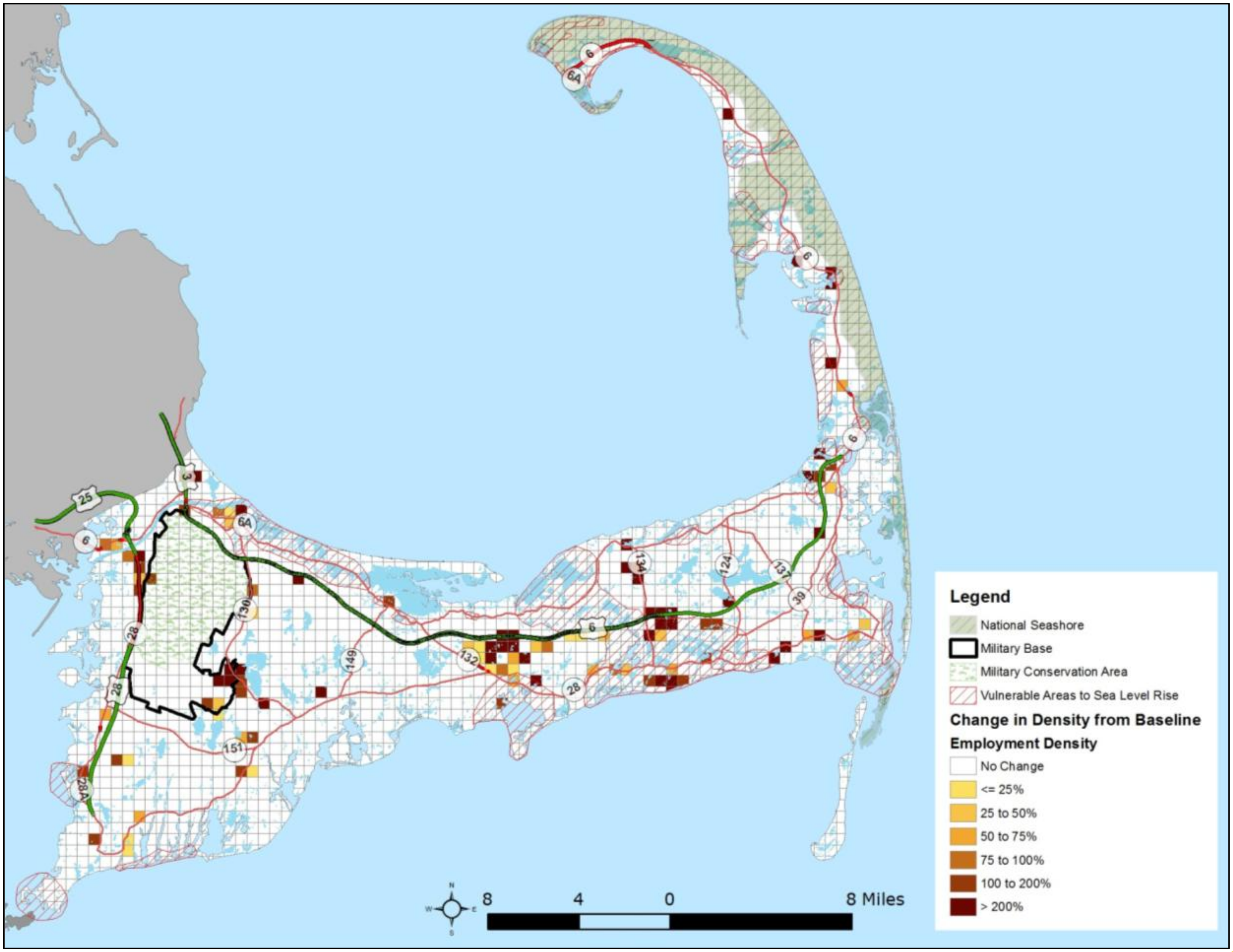


Figure 14 Dispersed Scenario: Enhanced transit stops

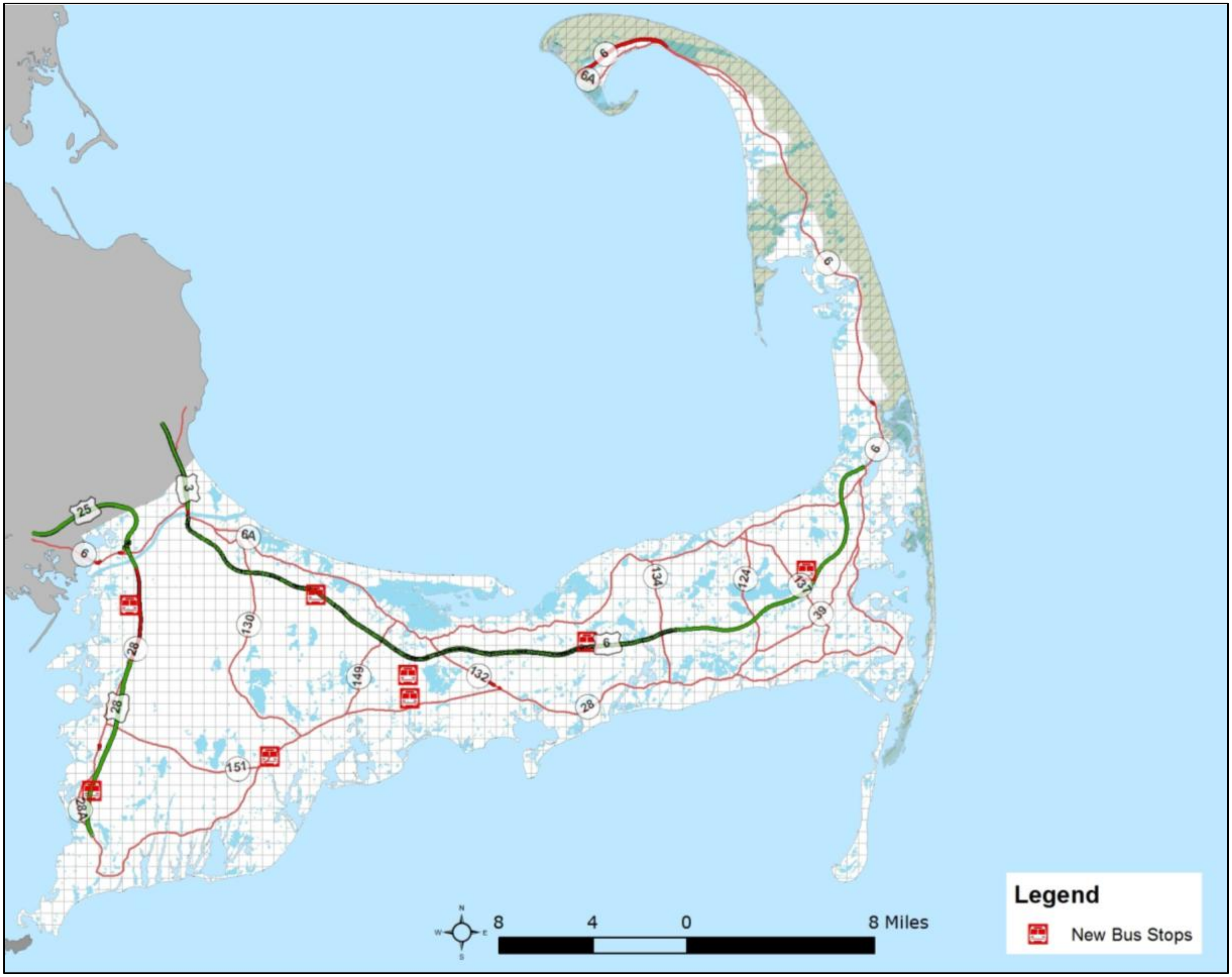


Figure 15 Targeted Scenario: Change in housing density over existing

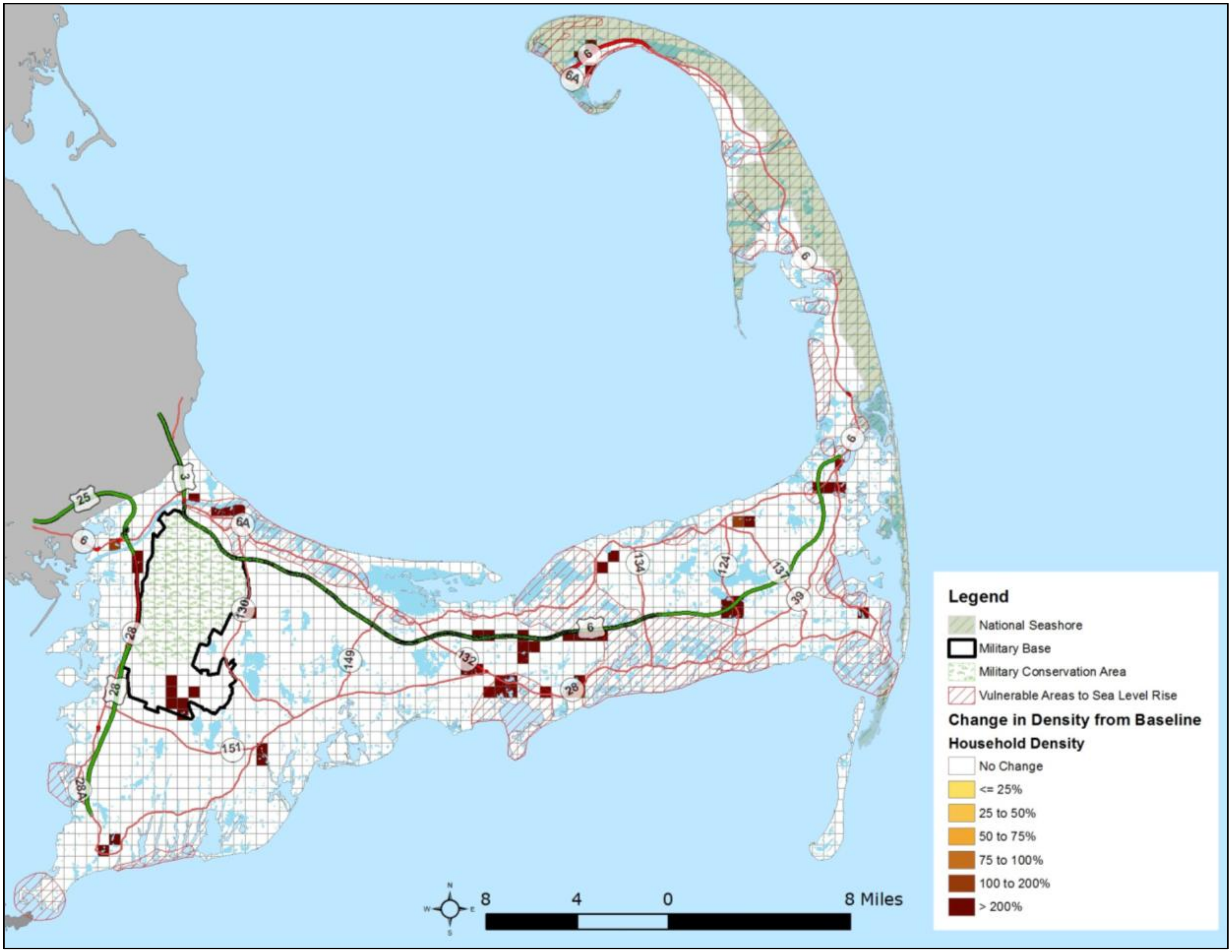


Figure 16 Targeted Scenario: Change in jobs density over existing

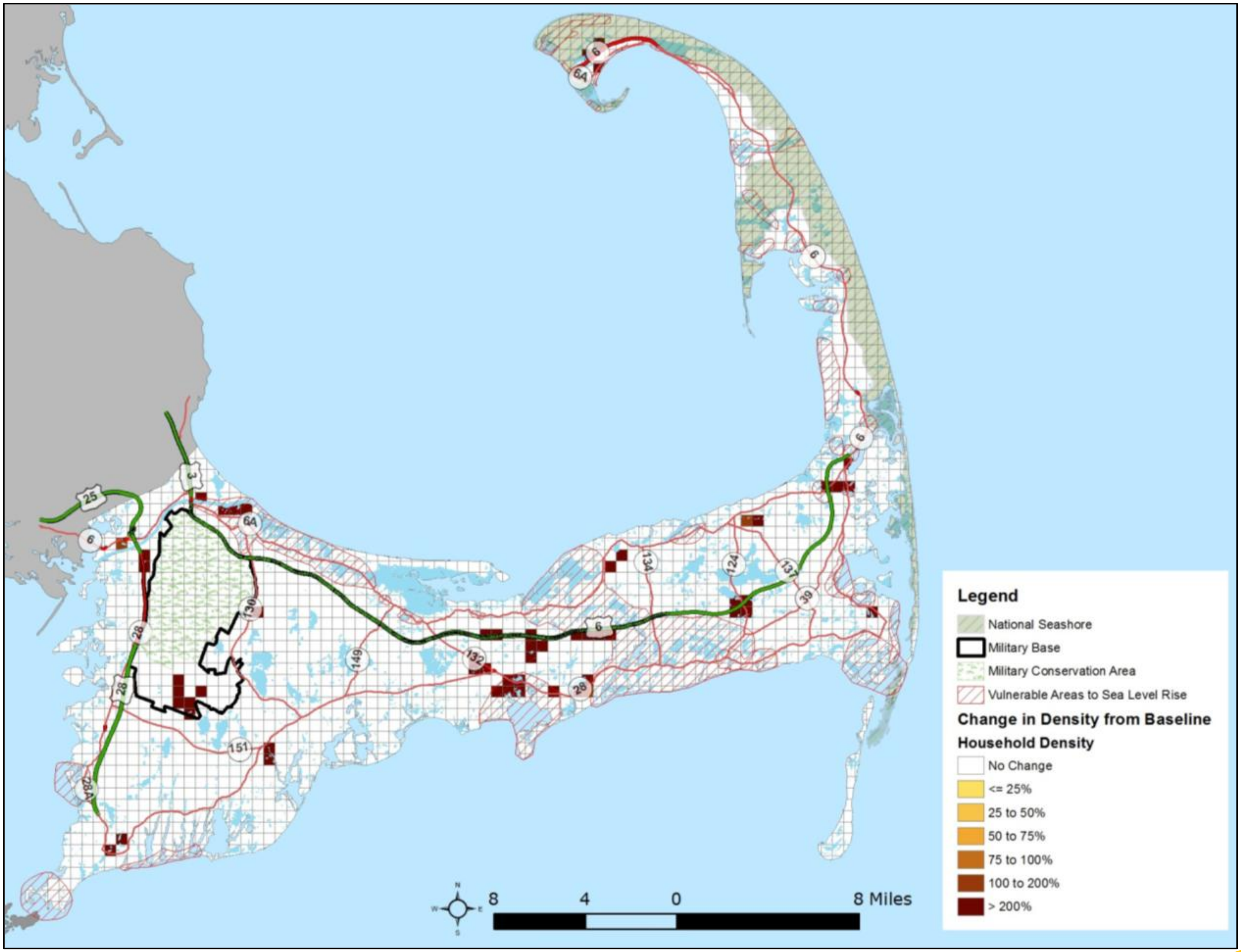
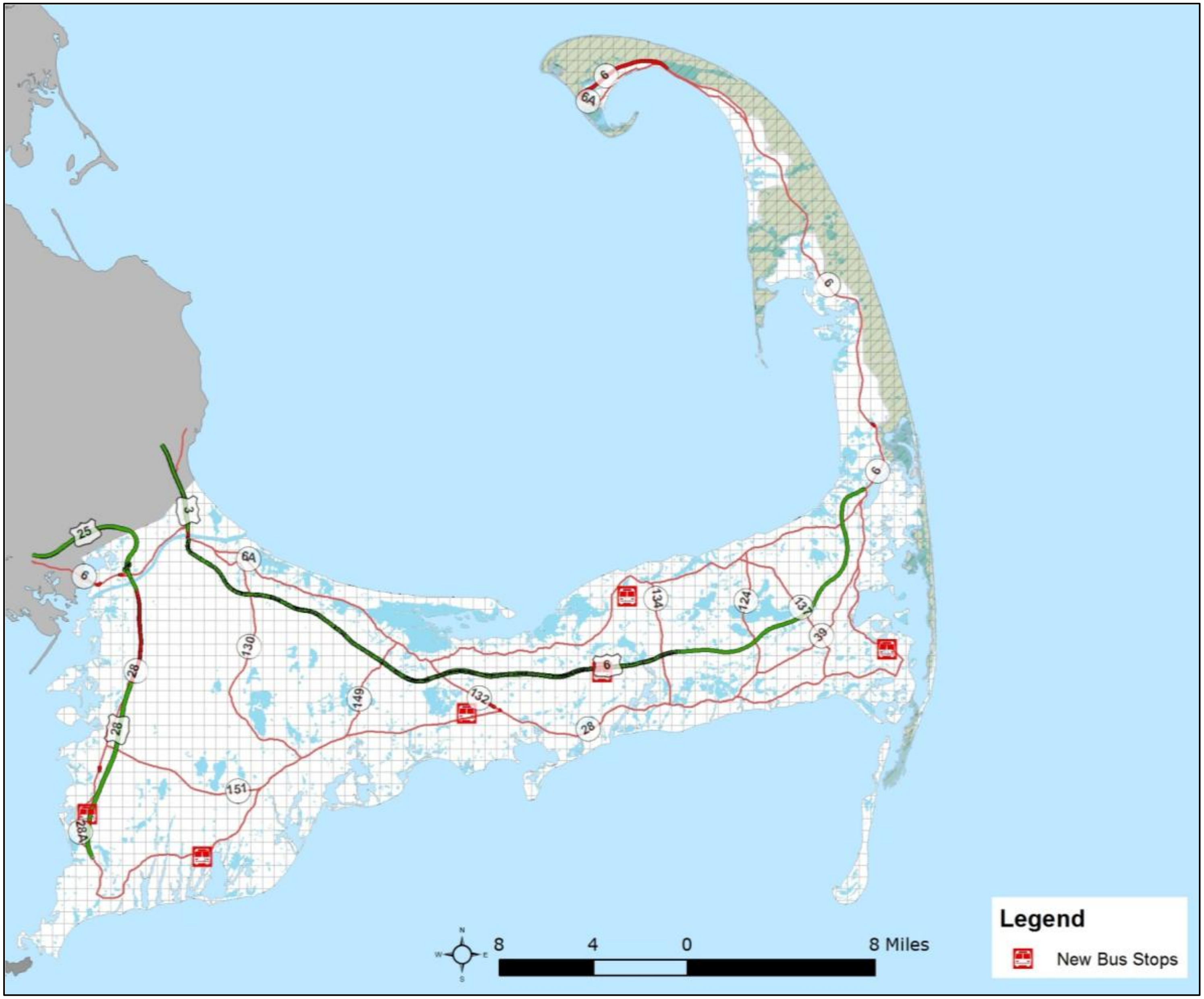


Figure 17 Enhanced transit stops for Targeted Scenario



Workshop scenarios

Workshop scenarios were developed by regional and local stakeholders at a November 2011 workshop. Instead of automatically placing chips under particular goals as the preliminary scenarios above were, the participants were asked to place the chips according to their own goals and local knowledge. There were four workshop groups, each equipped with a blank analysis requiring the placement of 28,000 households and 16,500 jobs in a limited timeframe. Each analysis contained a number of layers that could be turned on and off to facilitate discussion such as critical habitat, areas vulnerable to sea level rise, and the LUVM layer for those towns that had adopted one to date. Also, participants produced a conceptual map of residential, economic development, conservation, and transportation opportunities. These areas are reproduced in Figure 18 below. Participants talked about mitigation and adaptation strategies.[15]

This process produced four different scenarios with different indicator results. The resulting maps, including household distribution, employment distribution, and transit service area frequency, for each of the four workshop groups, labeled Table A through D, are produced below (see Figure 19 through Figure 34). Note that the baseline existing frequency for transit service areas is 60 minutes.

Refined scenario

Participants involved in developing the refined scenario agreed that the refined scenario will be used as the basis to inform further conversations in the future and should not be considered the final preferred scenario (see Figure 35 through Figure 37). The process for developing this scenario was similar to that of the workshop but happened over a period of time. More information on this process is also included in the Final Report. Also note that the refined scenario used the same standard transit pictured in Figure 7 and a 30 minute frequency assumption for each pictured in Figure 37.

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[15] More detail on the workshop is provided in the Final Report.

Figure 18 Map of conceptual exercise completed by workshop attendees on where to focus transportation, residential, economic development and conservation.

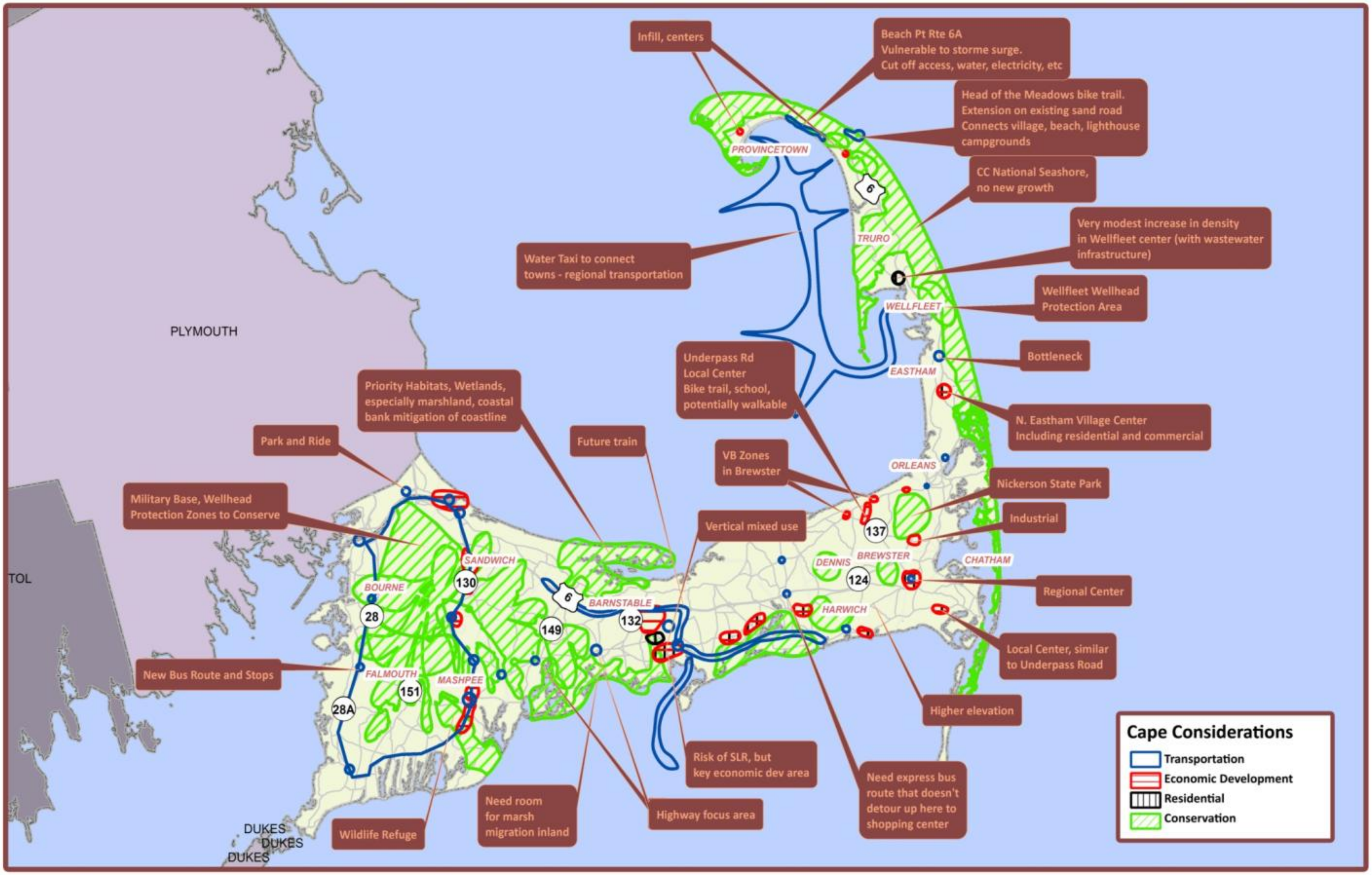


Figure 19 Table A Scenario: Change in housing density over existing

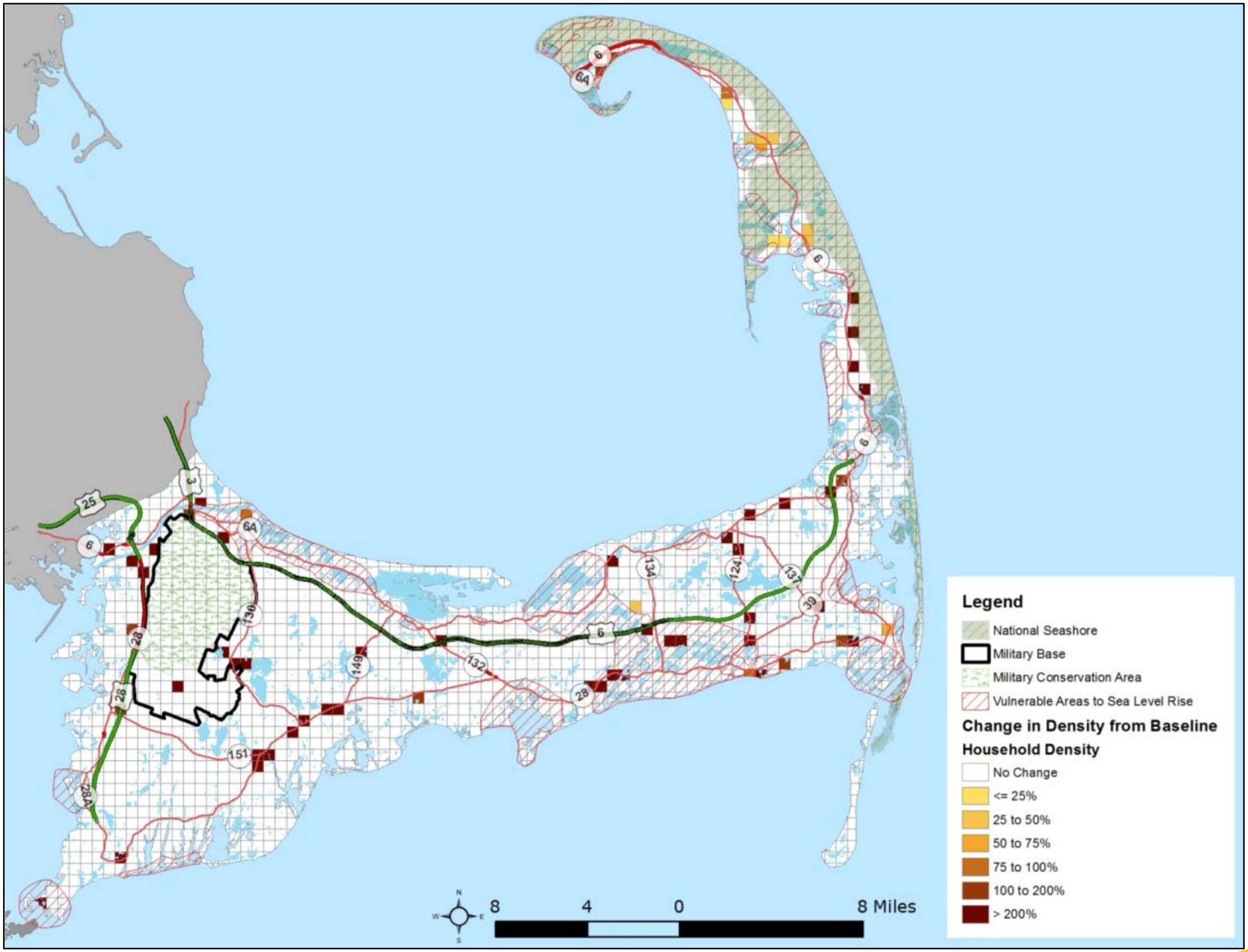


Figure 20 Table A Scenario: Change in jobs density over existing

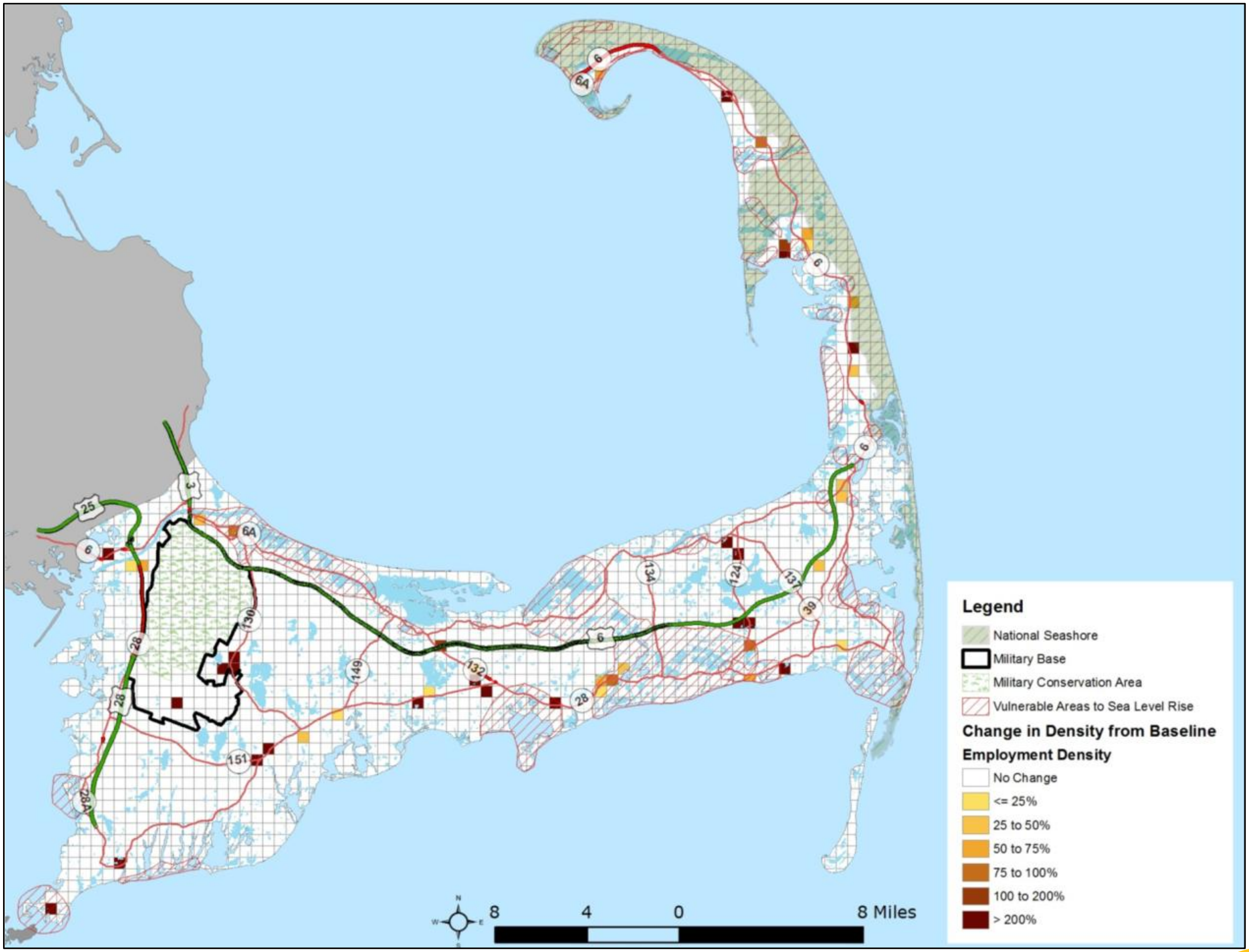


Figure 21 Table A Scenario: Transit choices

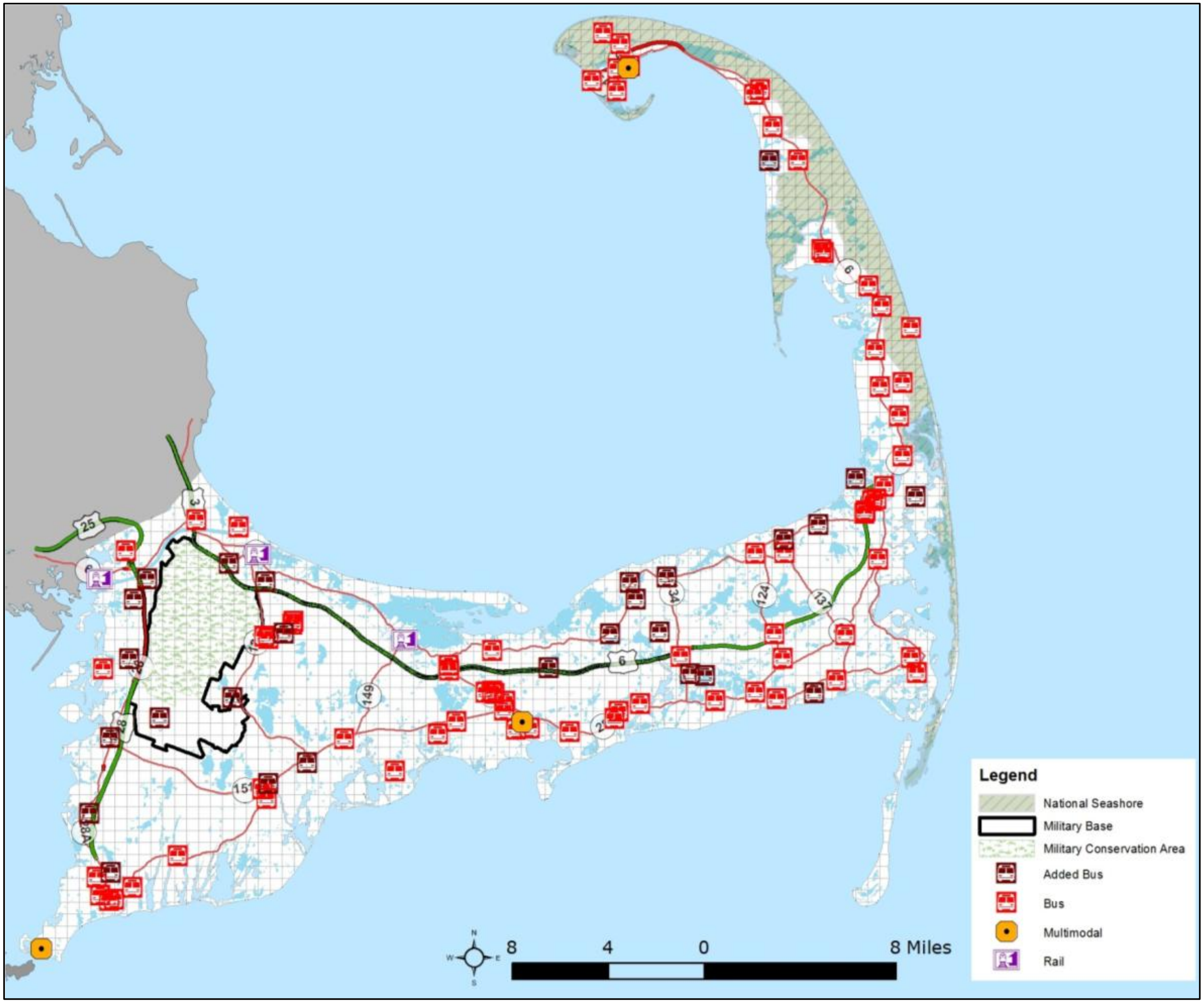


Figure 22 Table A Scenario: Transit frequencies

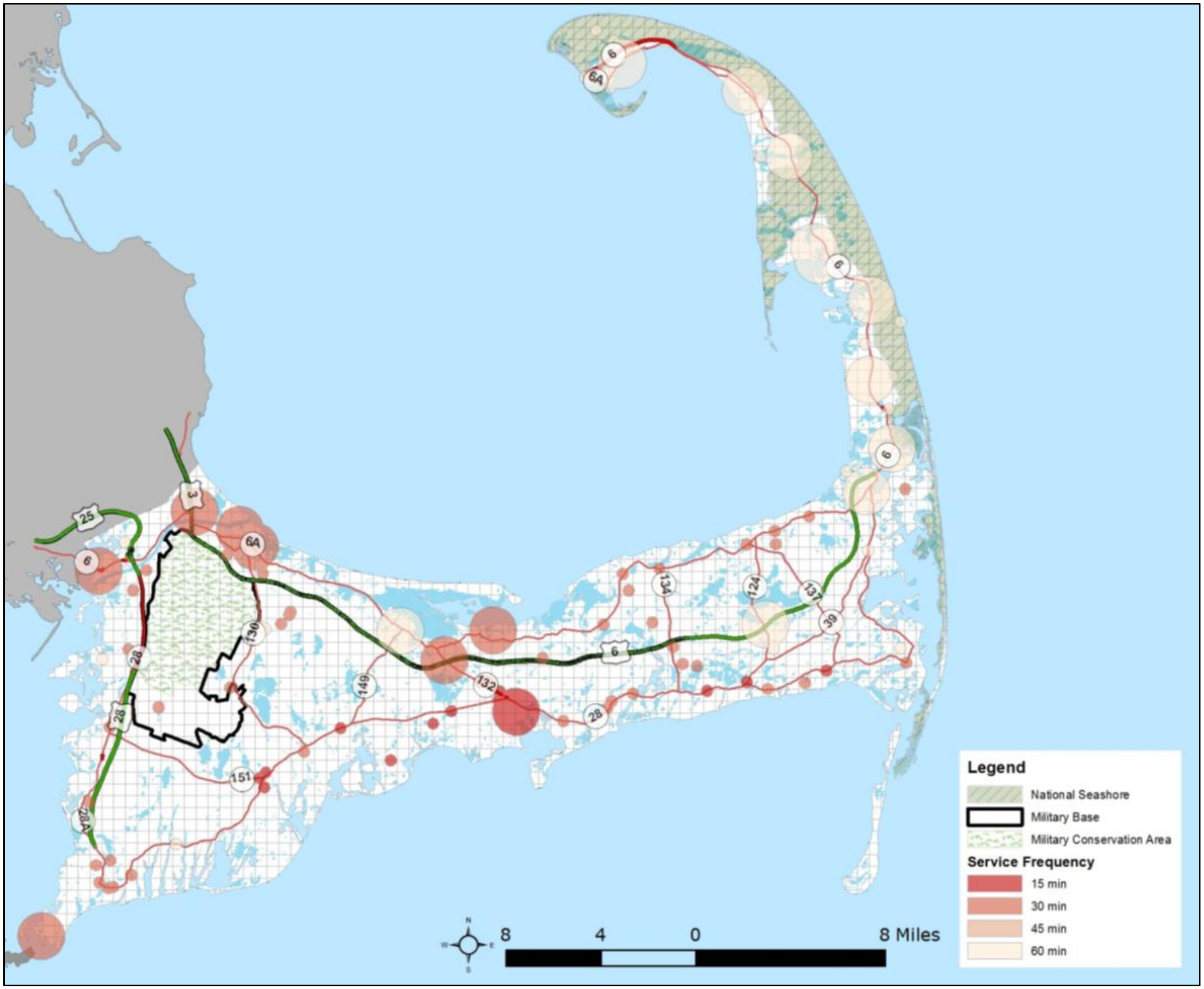


Figure 23 Table B Scenario: Change in household density over existing

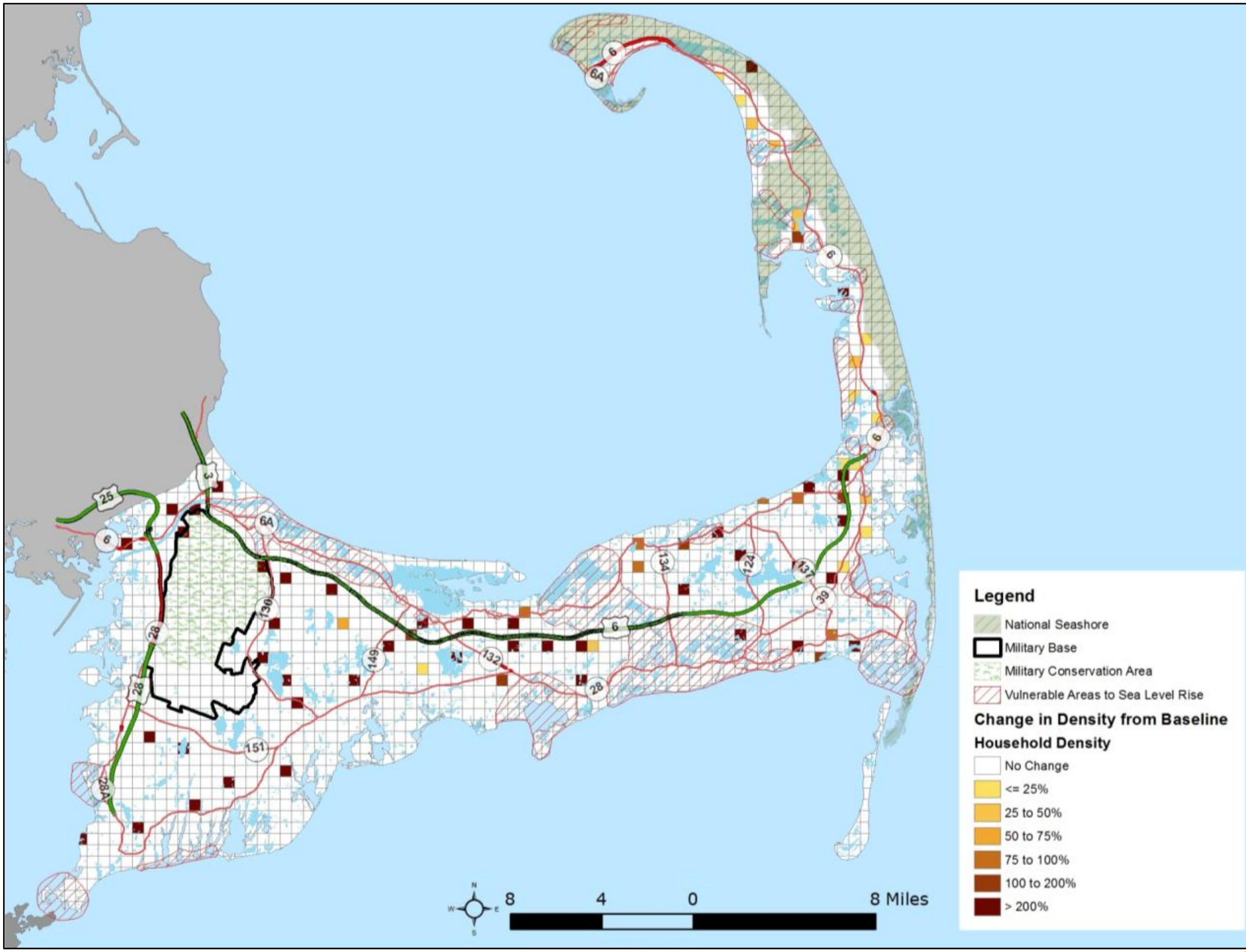


Figure 24 Table B Scenario: Change in jobs density over existing

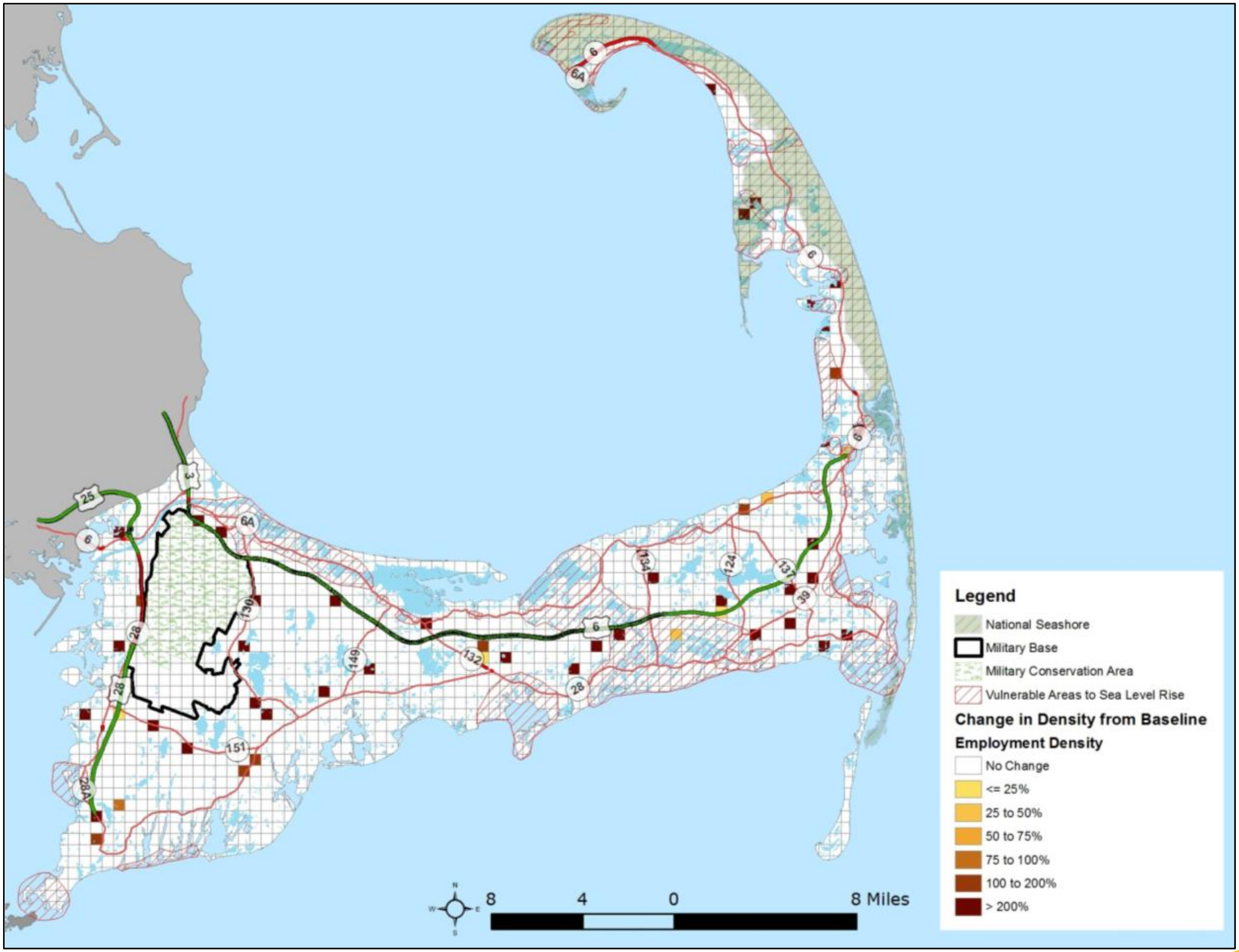


Figure 25 Table B Scenario: Transit choices

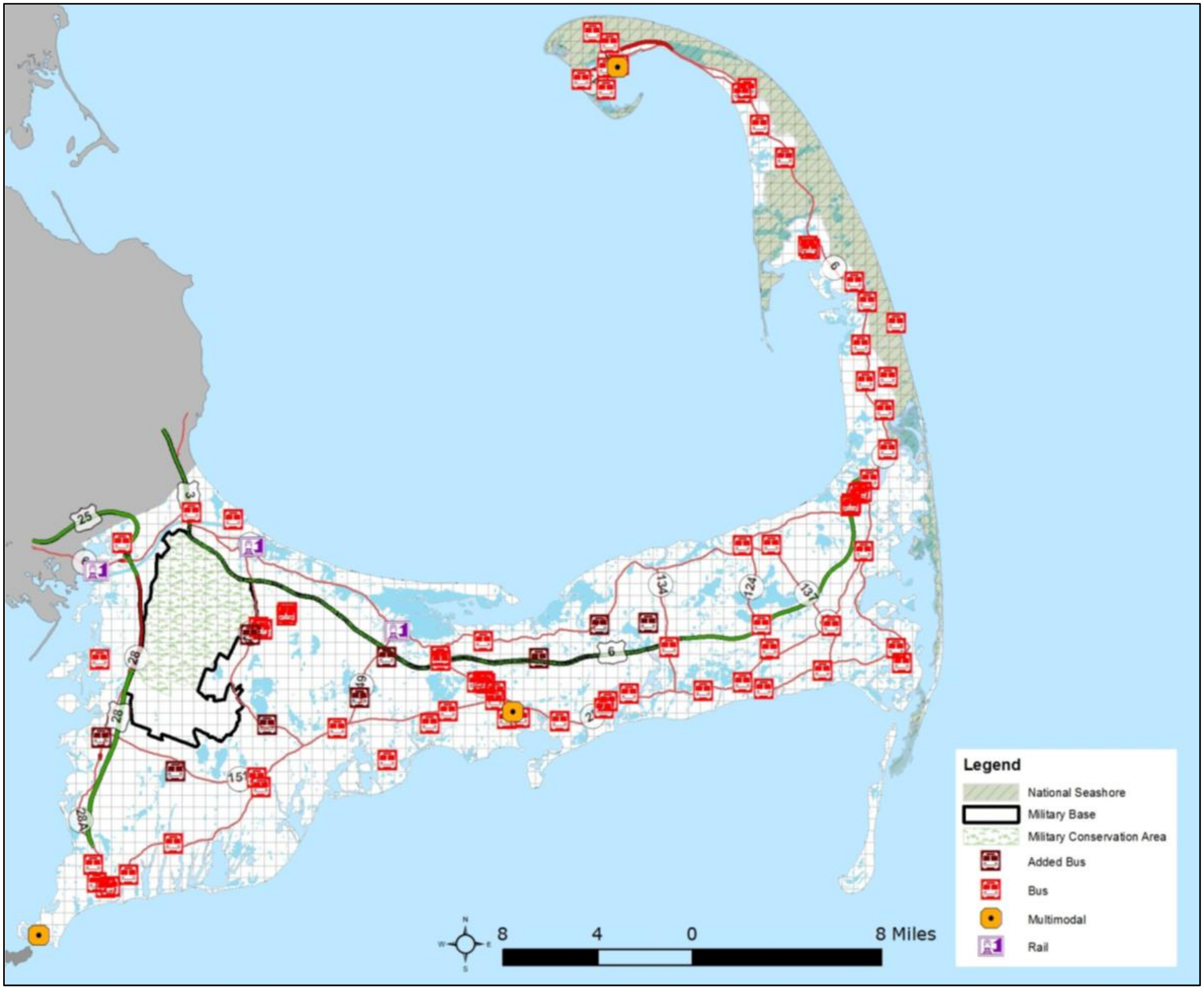


Figure 26 Table B Scenario: Transit frequencies

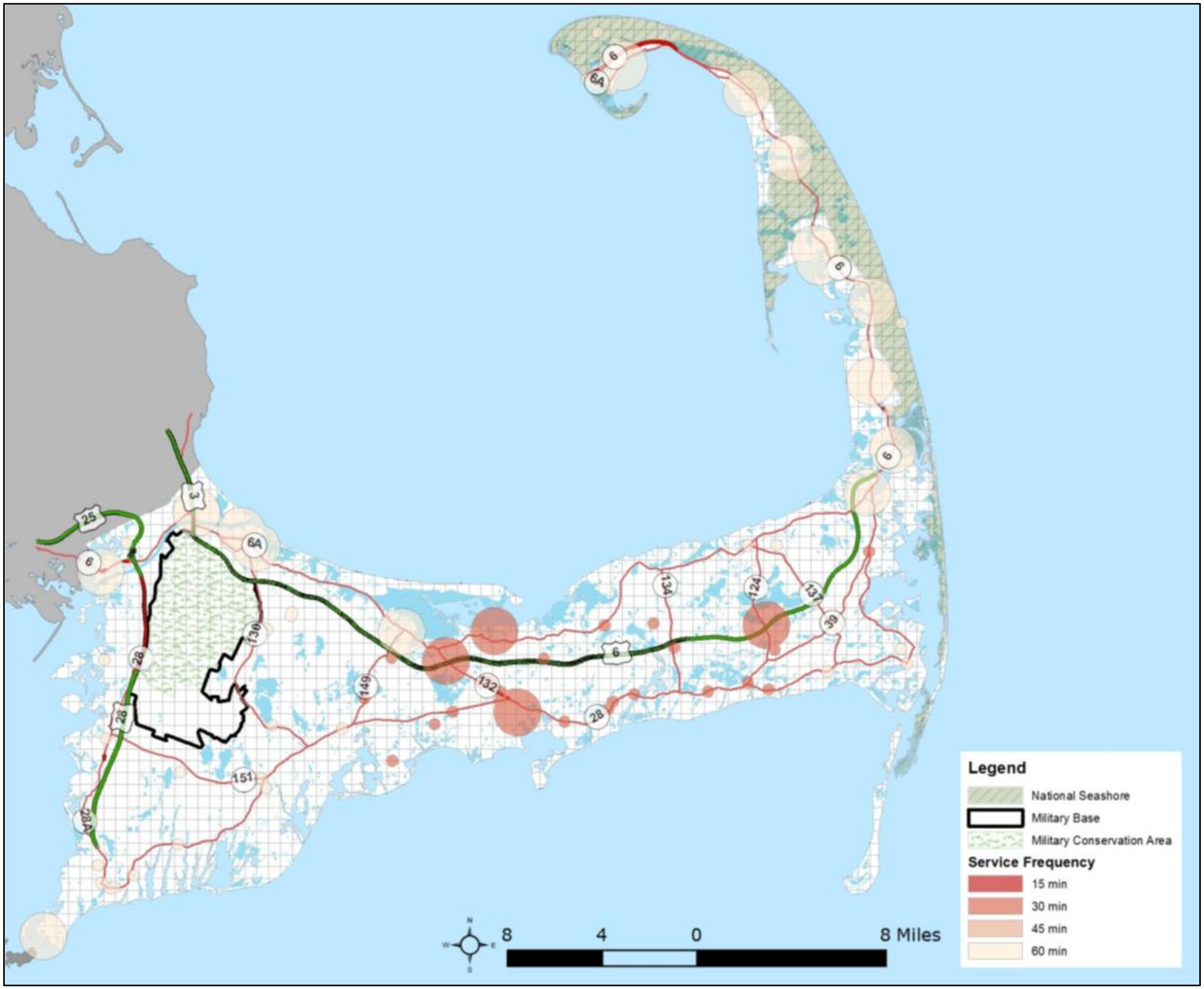


Figure 27 Table C Scenario: Change in housing density over existing

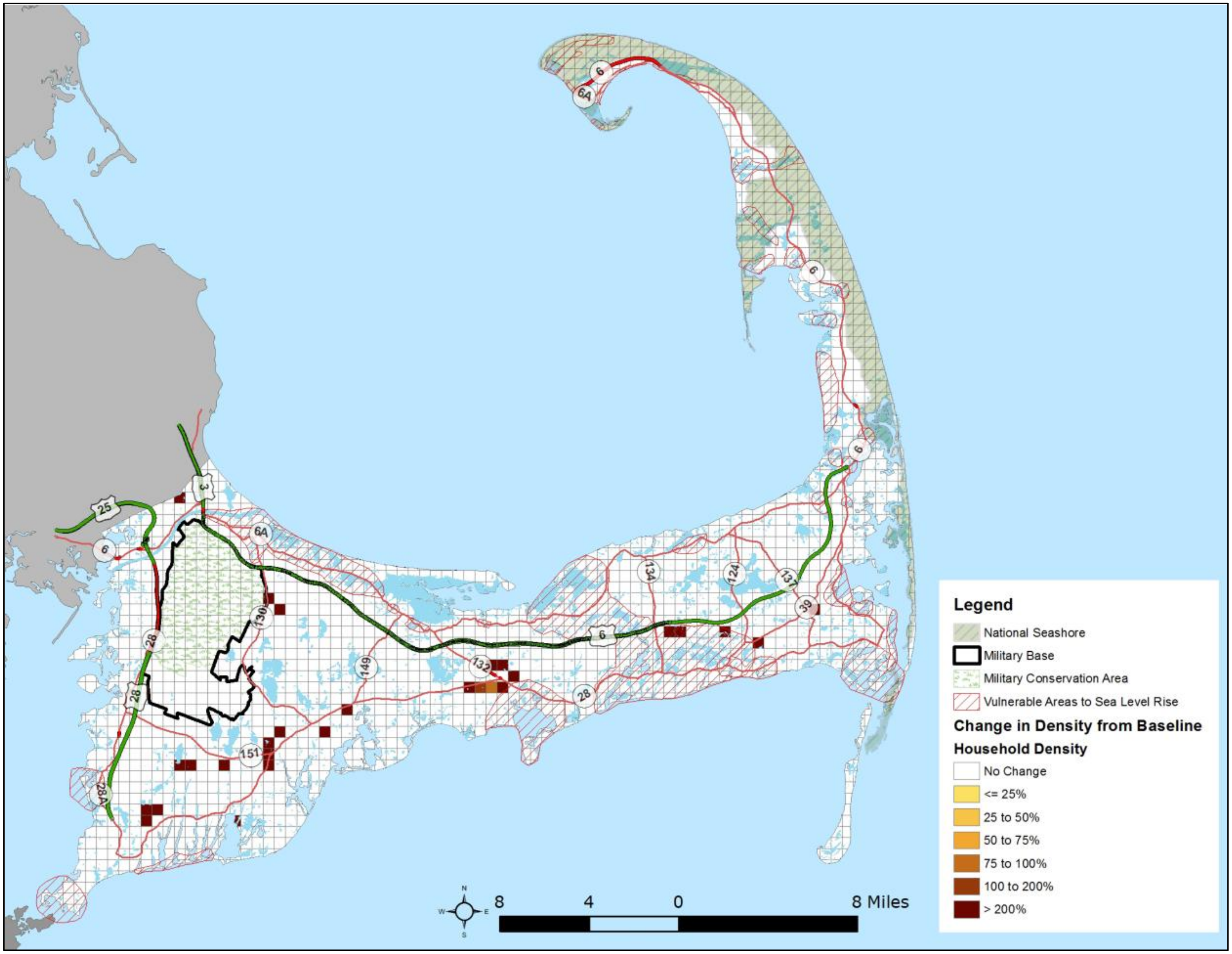


Figure 28 Table C Scenario: Change in jobs density over existing

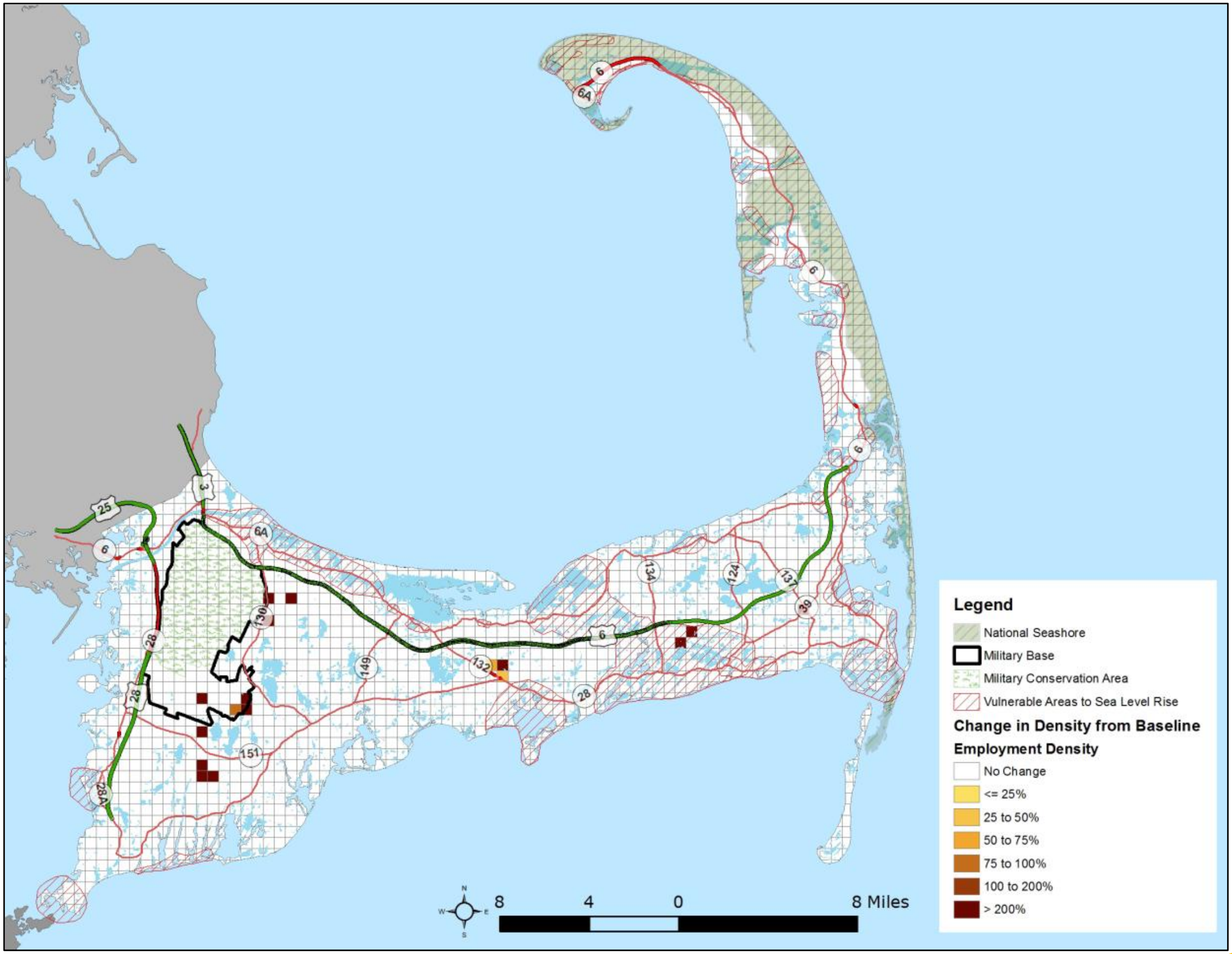


Figure 29 Table C Scenario: Transit choices

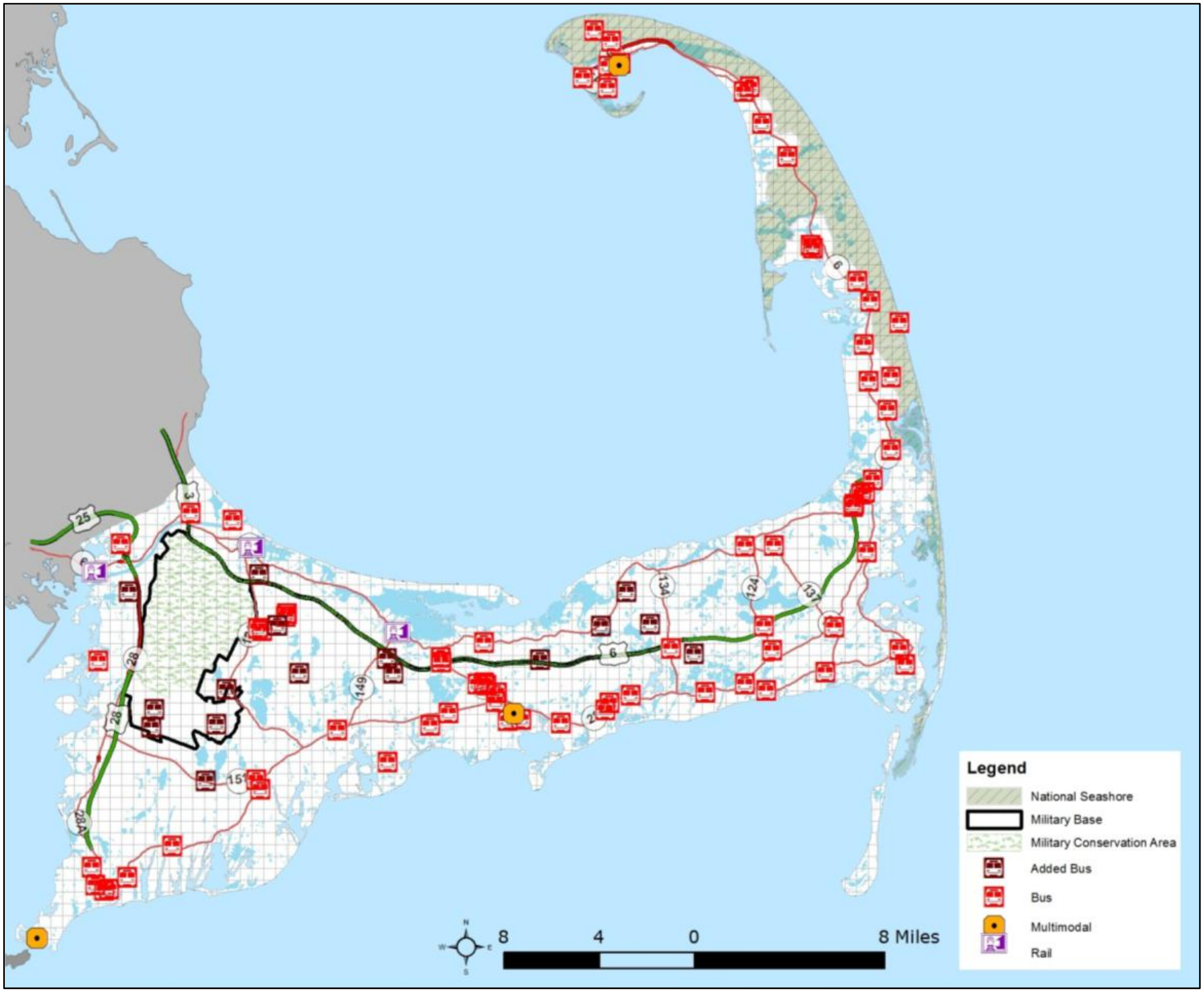


Figure 30 Table C Scenario: Transit frequencies

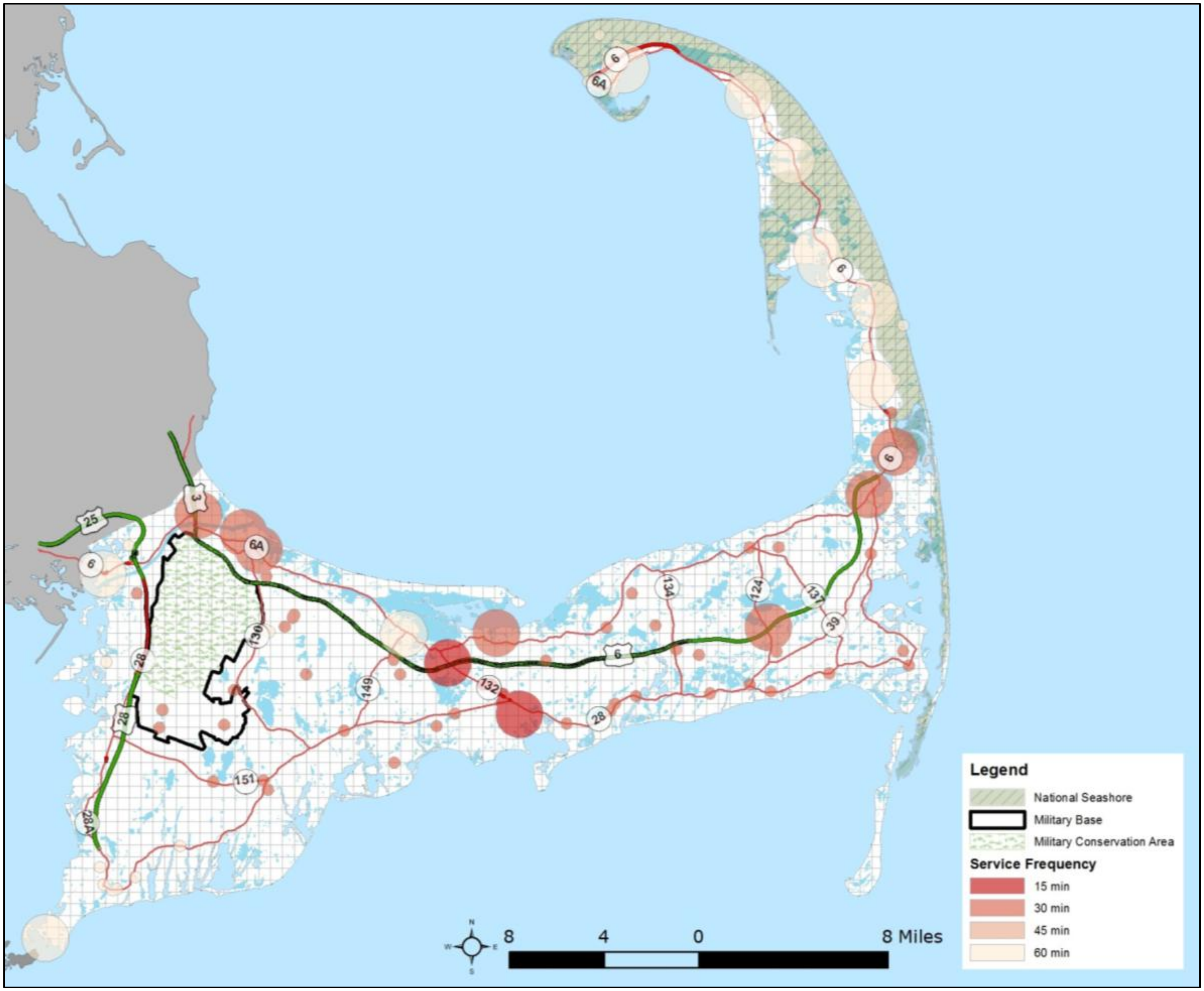


Figure 31 Table D Scenario: Change in housing density over existing

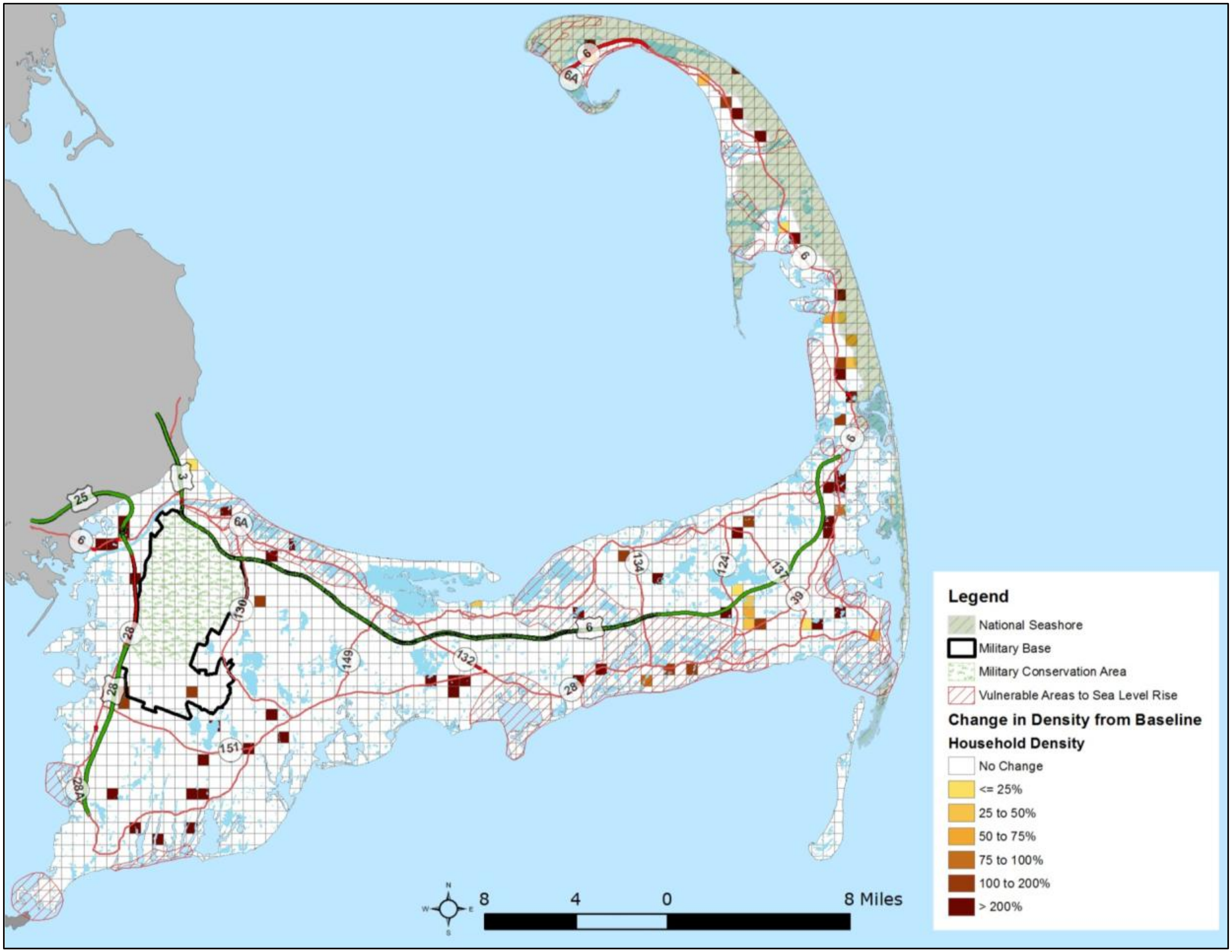


Figure 32 Table D Scenario: Change in jobs density over existing

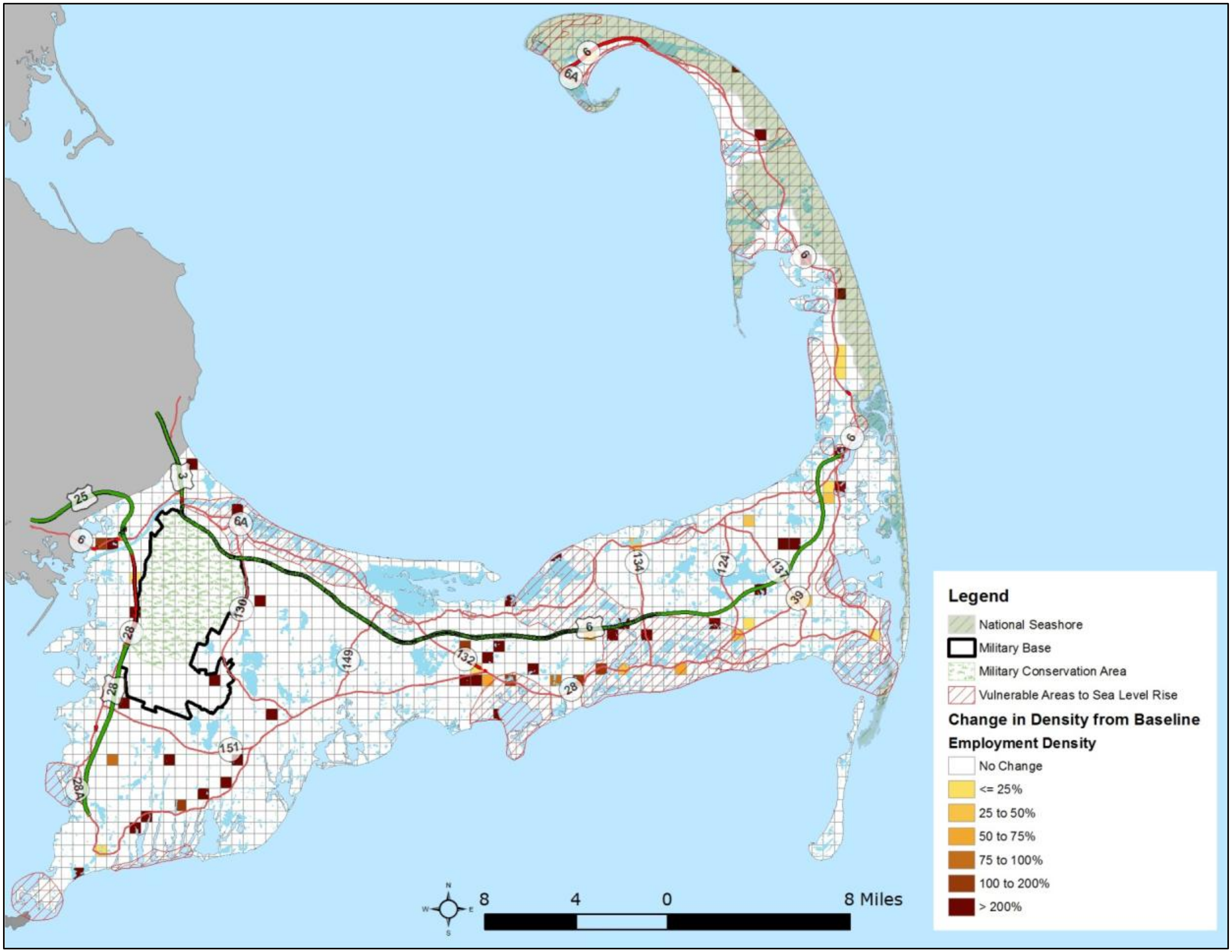


Figure 33 Table D Scenario: Transit choices

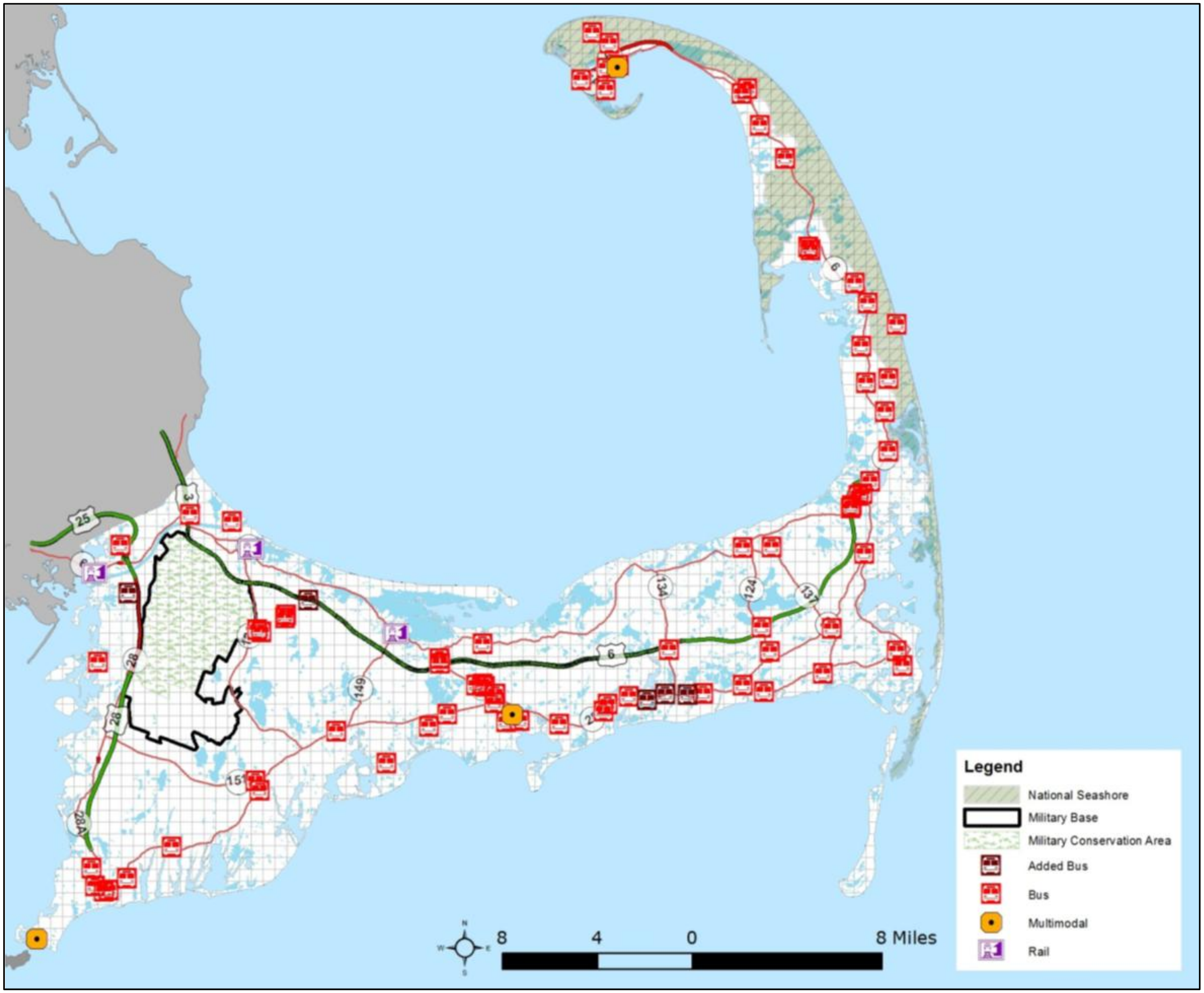


Figure 34 Table D Scenario: Transit frequencies

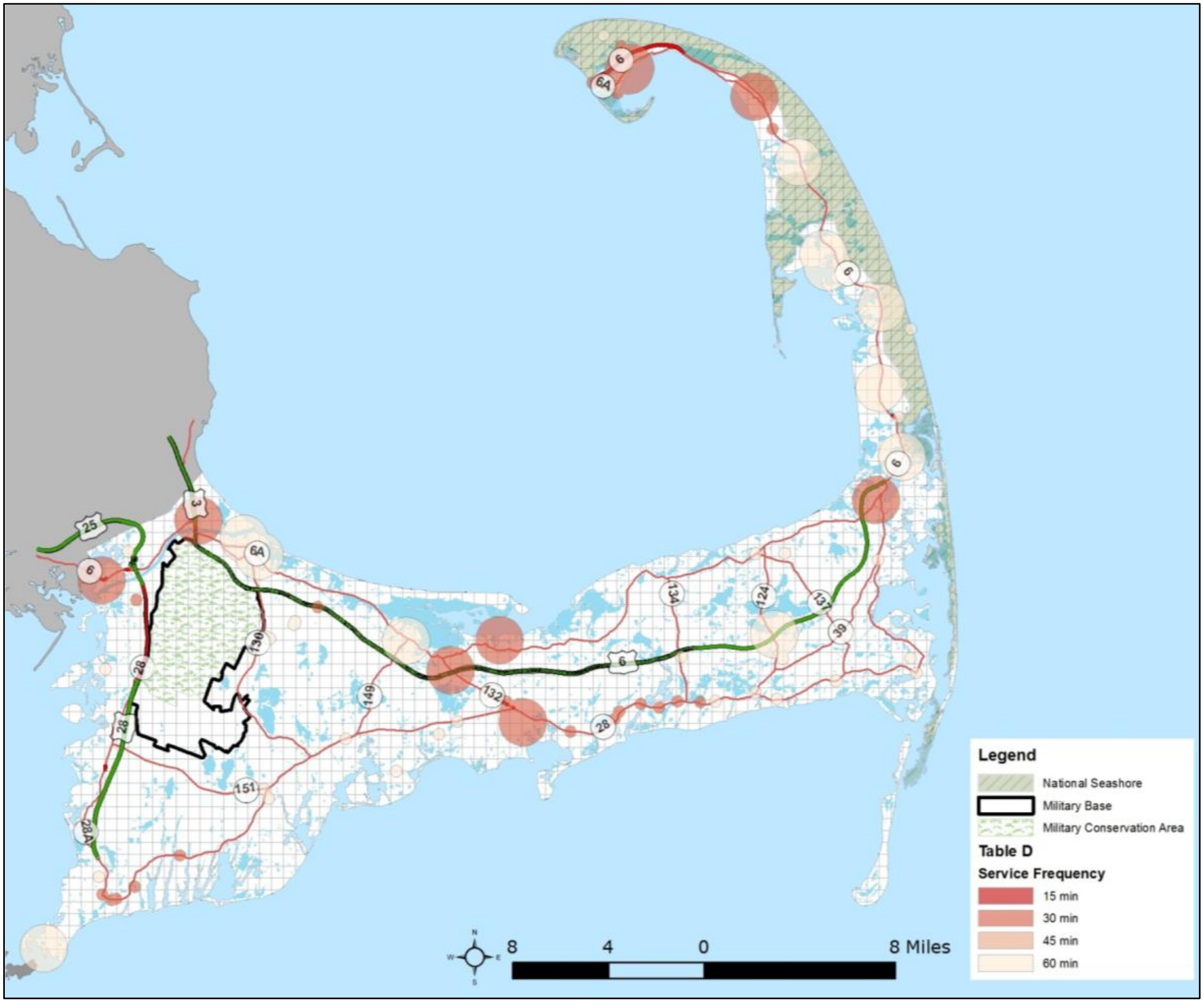


Figure 35 Refined Scenario: Change in housing density over existing

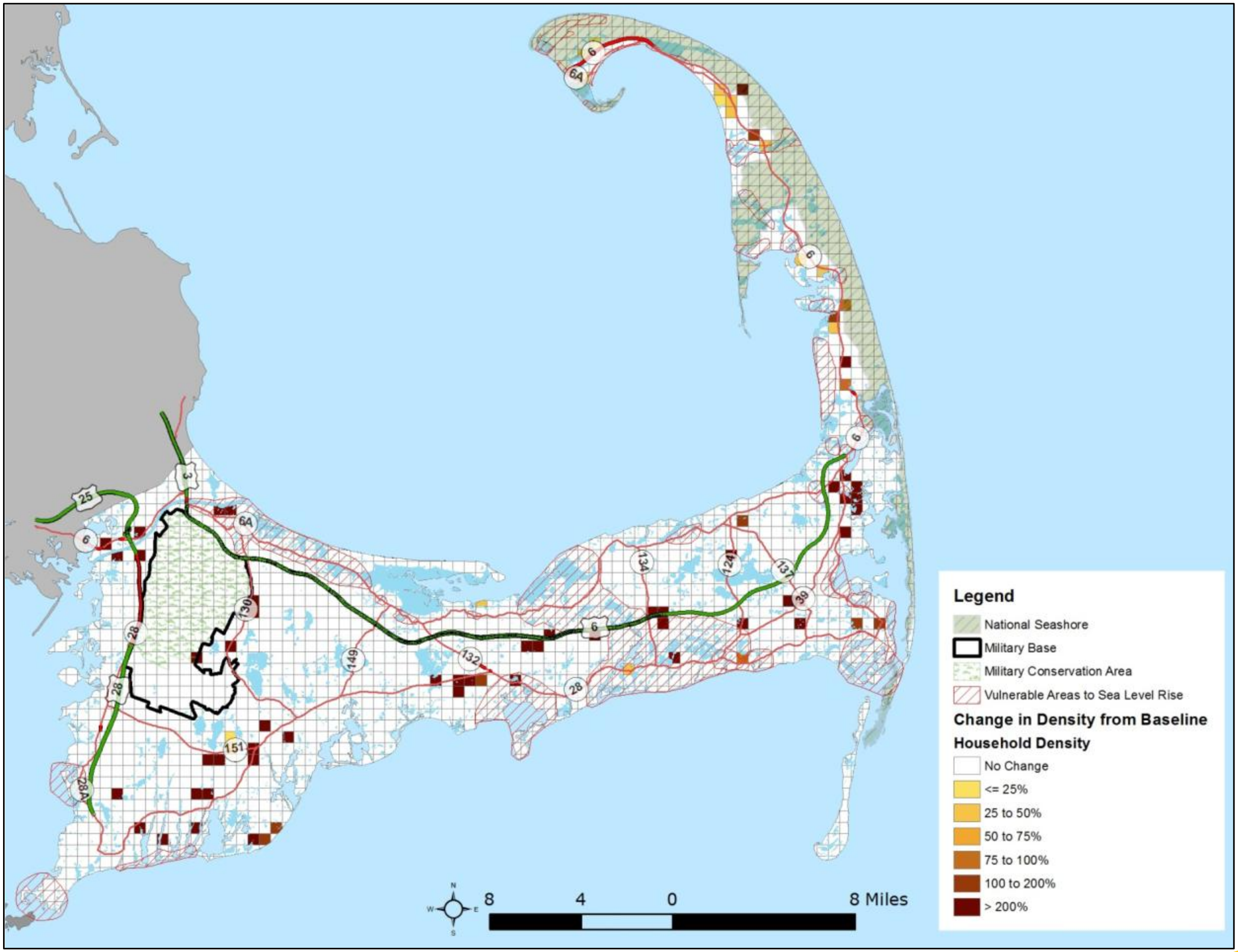


Figure 36 Refined Scenario: Change in jobs density over existing

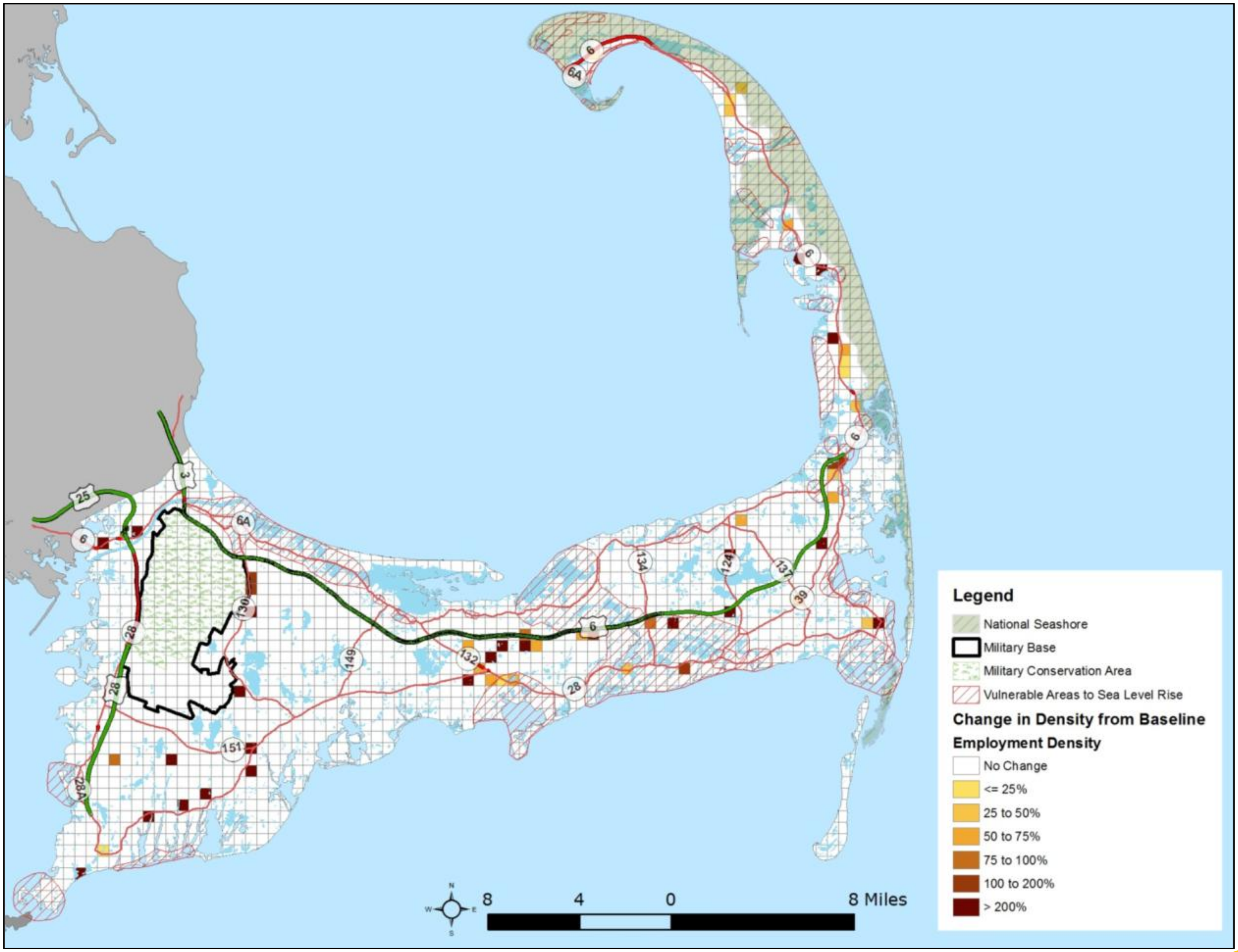
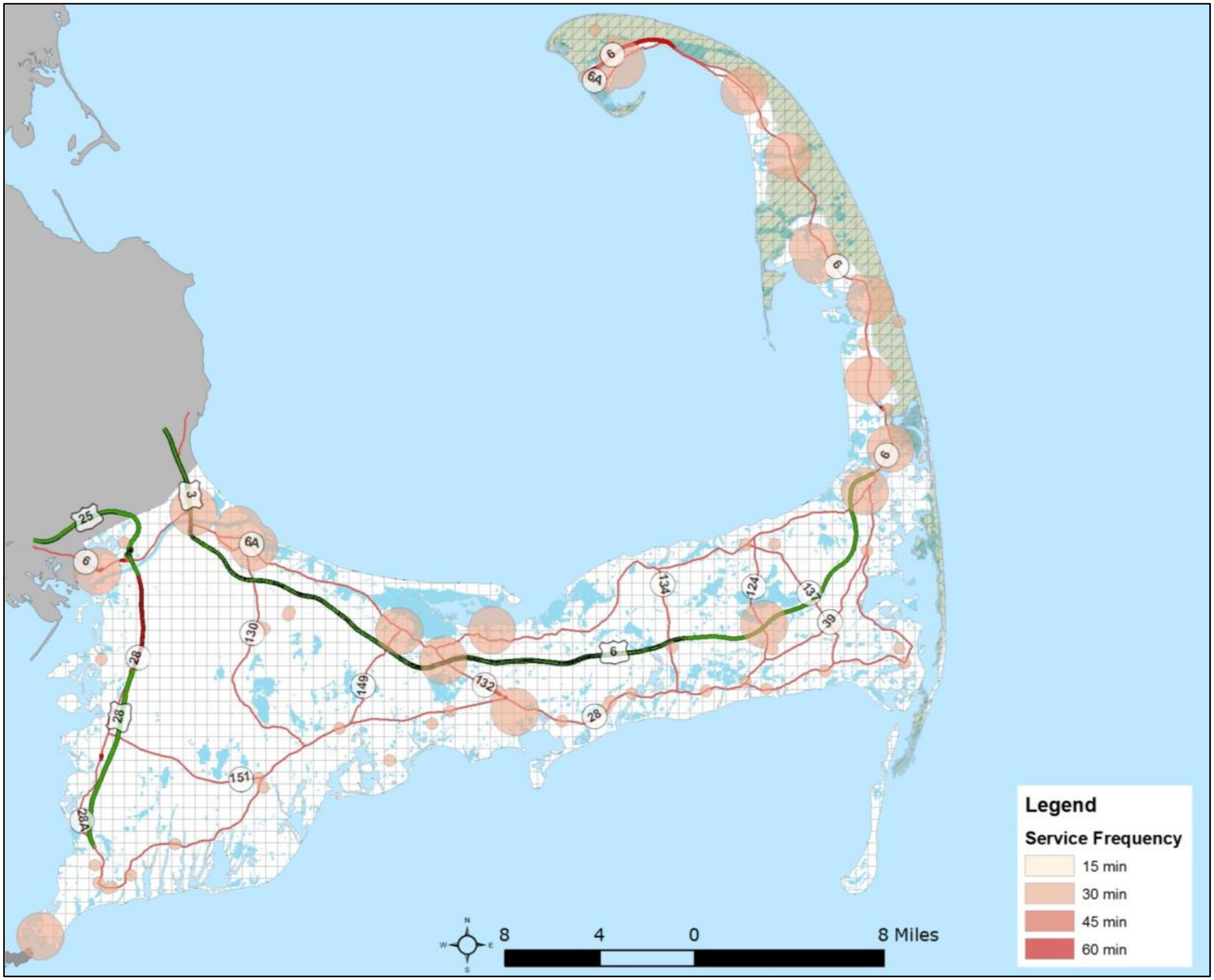


Figure 37 Refined Scenario: Transit frequencies



Scenario Assessment

This section contains charts from the scenario analysis. Indicators tracked fall under four categories:

1. Mitigation (vehicle miles traveled and greenhouse gases)
2. Adaptation (development in areas vulnerable to sea level rise)
3. Transit (new households and jobs served by transit)
4. Critical overlays (development in areas preferably left undeveloped).

All indicators are reported as changes in population or employment from the baseline conditions in 2008 except for the mitigation indicators, which are referenced against the trend. Setting VMT and GHG against the modeled trend provided an easier point of comparison for this analysis.

A key observation from the scenario exercise was the difficulty in placing jobs and housing units on the map without some sort of negative impact. It was very hard to place all the projected jobs and housing units on the maps without impacting at least one of the constraint layers (protected wellhead areas, areas of critical habitat, designated conservation areas, areas with historic preservation protections, and water resource areas).

Mitigation: VMT, GHG

The two graphs below show changes in vehicles miles traveled (VMT) and greenhouse gas (GHG) emissions from vehicles for each of the scenarios. The “Dispersed – Standard” scenario performed nearly identically to the Trend scenario, which is set at zero as a baseline comparison to all other scenarios. The workshop Table group scenarios and Refined scenario all showed a 4-5% improvement (decrease) in VMT with workshop Table C coming the closest to the performance of the Targeted – Standard scenario (created by the project team with the goal of maximizing indicator performance). Because changes in mode mix or technology adoption were not made directly, relative GHG reductions are in line with relative VMT reductions.

Figure 38 Regional percent change from trend in VMT

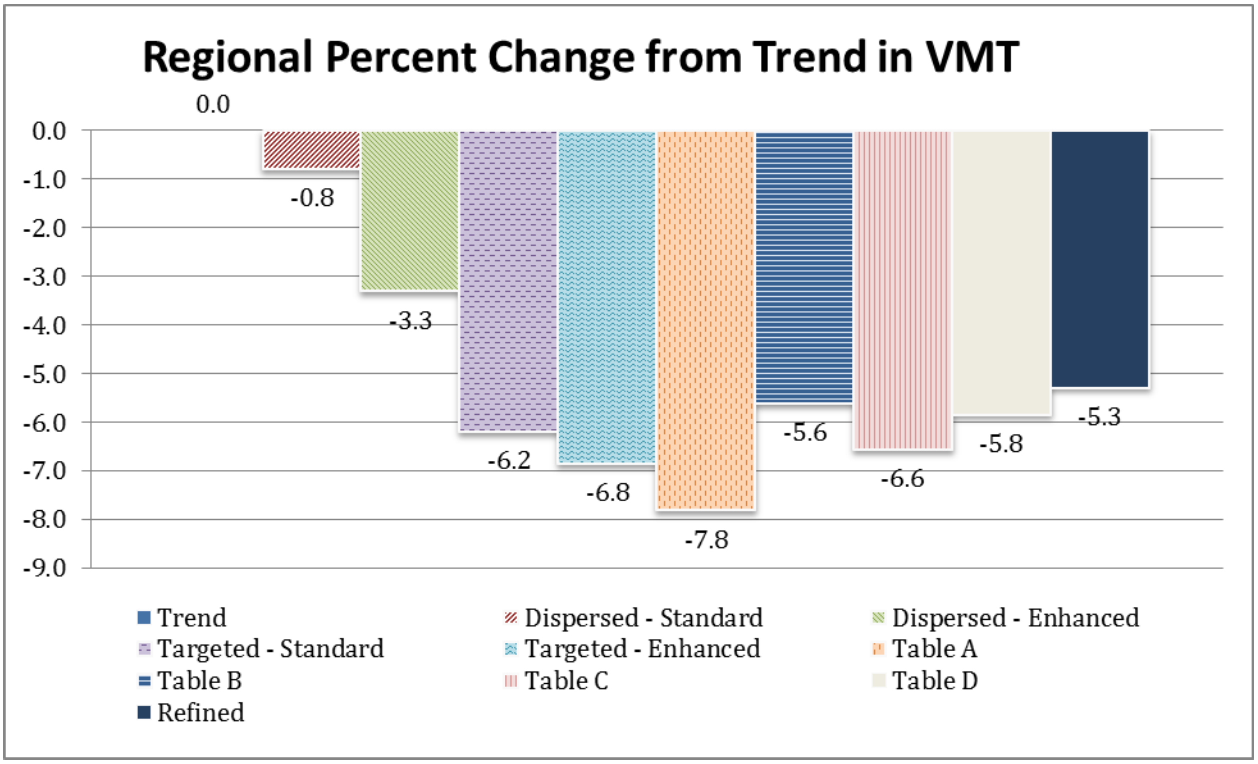
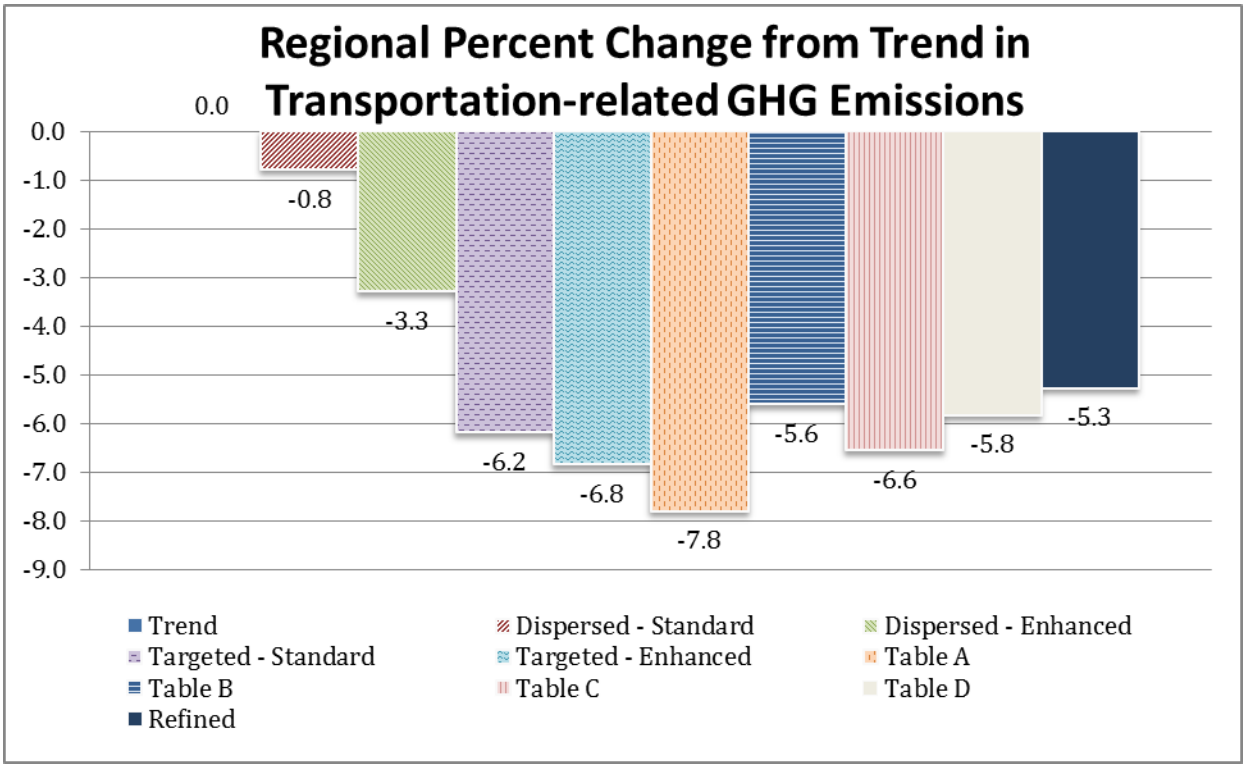


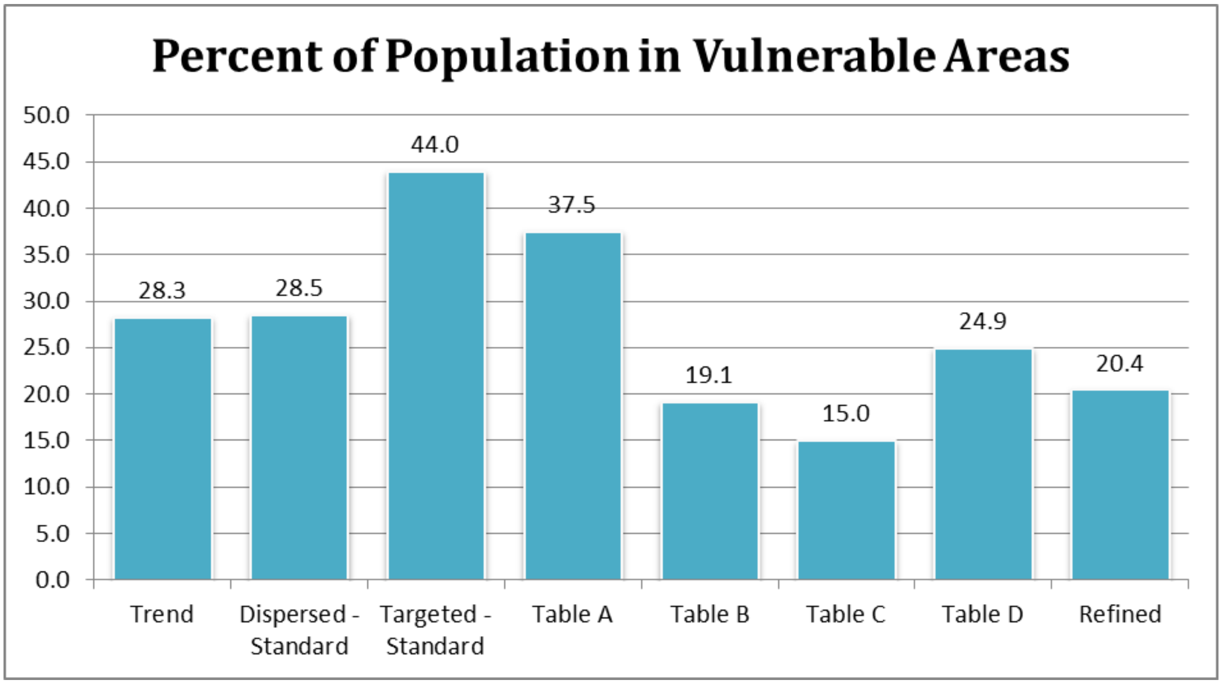
Figure 39 Percent change in regional GHG



Adaptation: Vulnerable Areas

This graph shows the percentage of new population placed in areas identified vulnerable to sea level rise. Table C created a scenario that performed the best in this analysis with only 15% of new growth occurring in vulnerable areas. The definitions of these areas are available in more detail in the Final Report, but in general there were many populated locations in areas vulnerable to the effects of sea level rise, making it hard to avoid placing population in these areas. This realization led to conversations about the potential of moving towns or other adaptation methods that may be required to continue living safely on Cape Cod.

Figure 40 Percent of new population in vulnerable areas



Transit

Both of these graphs show the percentage of new jobs and new households within a mile of already rail stops and/or a quarter mile from bus stops. Two additional scenarios were analyzed (Dispersed – Enhanced, and Targeted – Enhanced) where the analysis was done including new bus and rail routes and increased frequency of service, which did not impact VMT or GHG above. The number of people captured within by frequency of service is also represented below. These are represented as absolute numbers of population as they were during the exercises.

Figure 41 Percent of new population served by transit

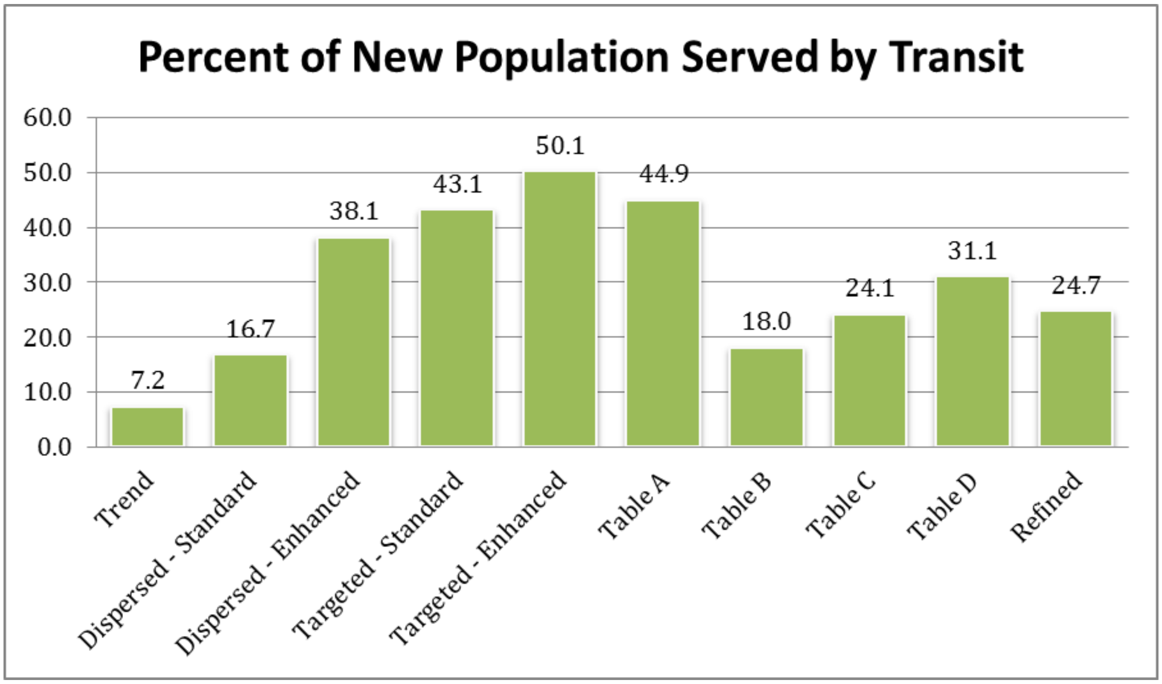


Figure 42 Percent of new jobs served by enhanced transit

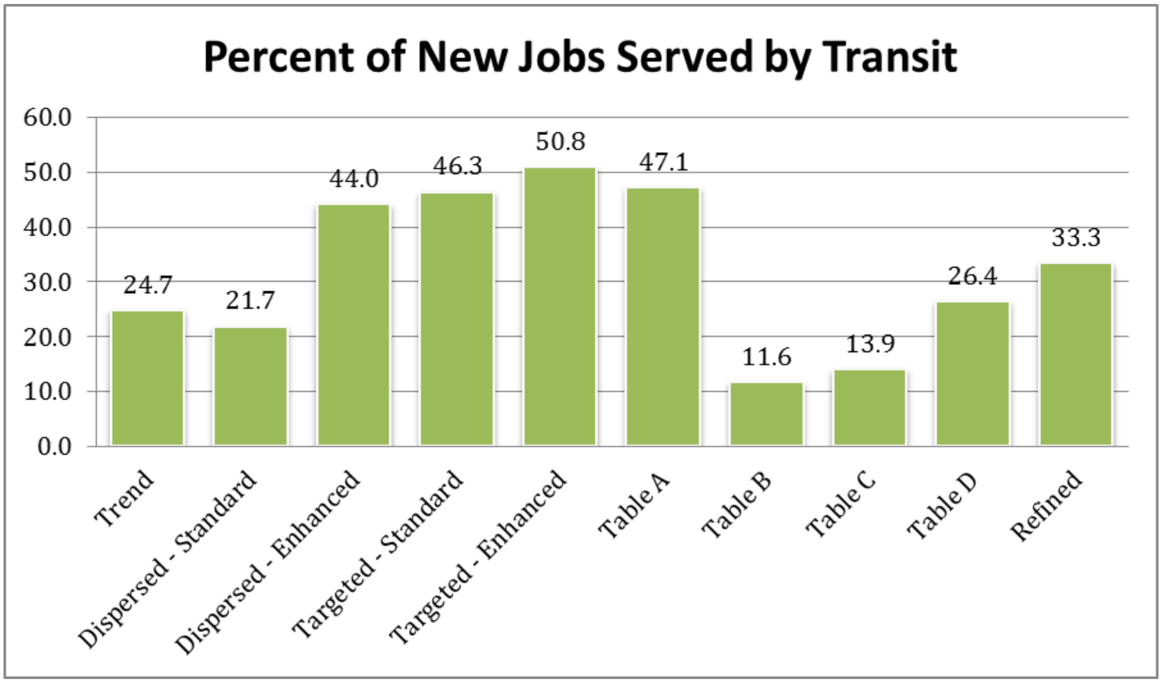
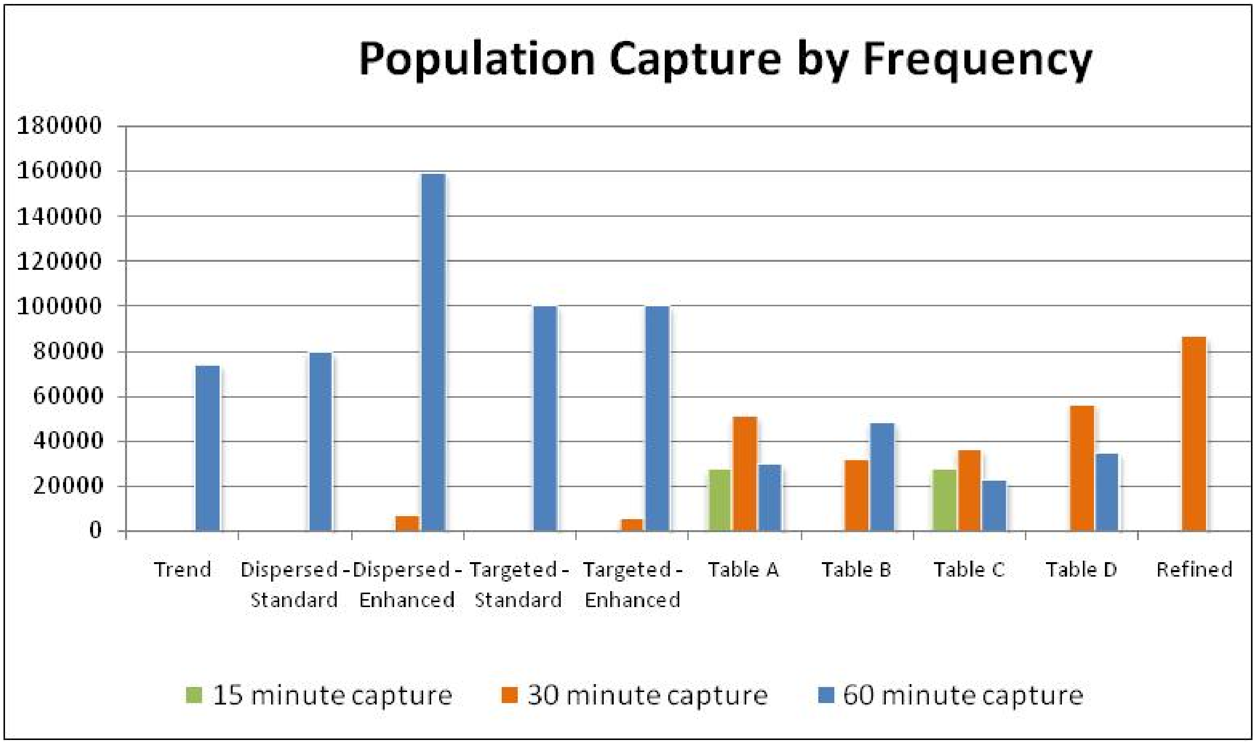


Figure 43 Population capture by different levels of service of transit (frequency of service)

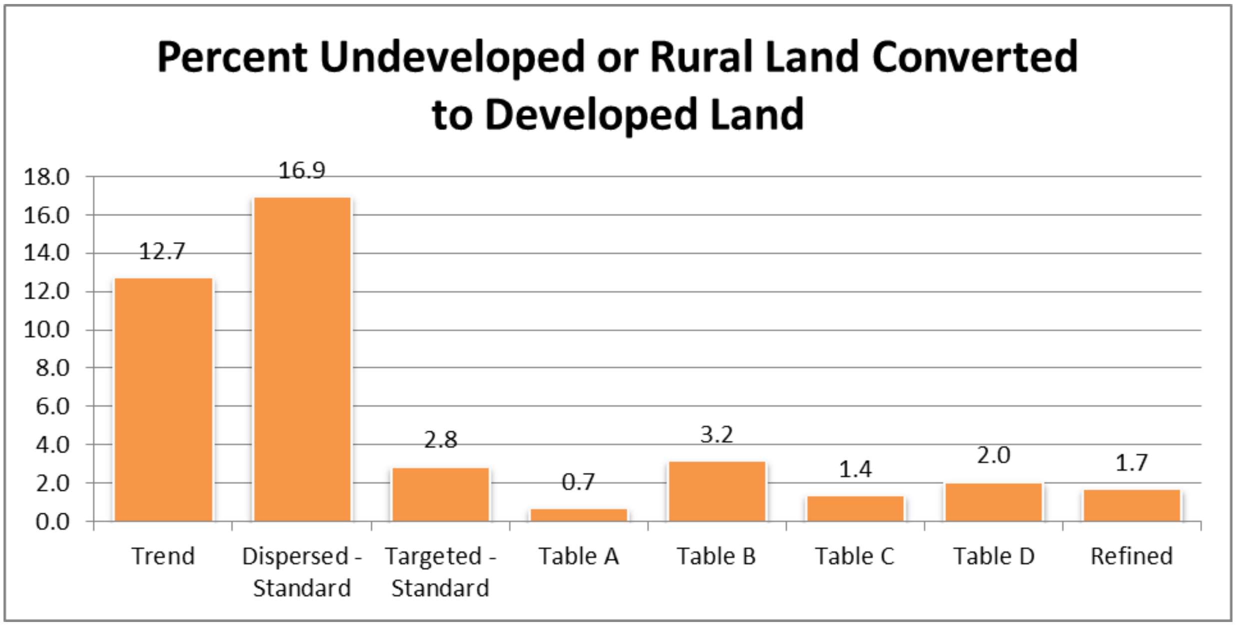


Critical Overlays

The following graphs show the percentage of new growth placed in areas with identified constraints. Overall, these graphs illustrate the challenge of finding enough places to add the jobs and housing to the map without some negative impacts on sensitive areas.

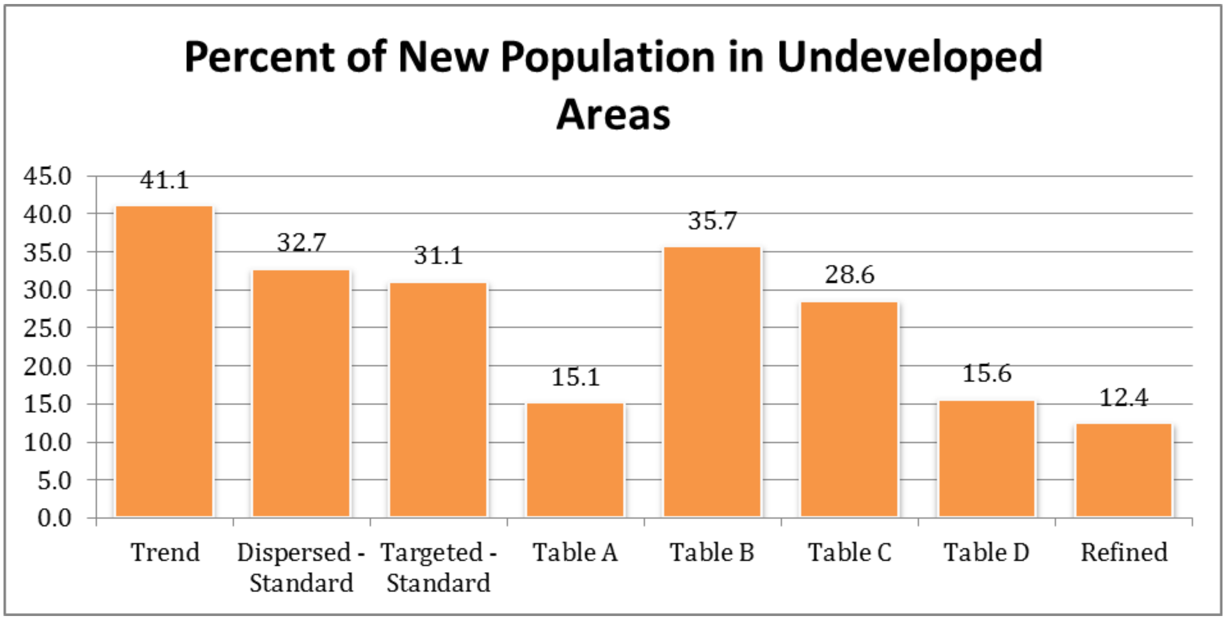
The graph below shows the percentage of land currently classified as rural or undeveloped converted to developed land (density exceeds 1 dwelling unit per 10 acres) as a result of growth added to the map. Low density development corresponds with septic systems for households and therefore has a greater negative impact on water resource areas and wellhead areas. These graphs show the percentage of low density development in each category.

Figure 44 Percent undeveloped or rural land converted to developed land



The number of people placed in undeveloped areas gives a sense of how much land is being lost to development. However, on its own, it does not represent the entire picture of the scenario. That is why the land area converted is reported above. For example, workshop Table B placed a large number of people in undeveloped land, but only converted 1.7 percent of the land area. That means the scenario most likely converted land at higher densities.

Figure 45 Percent of new population in undeveloped areas



The next three figures demonstrate less than ideal placement of population. While few of these areas have strict “no development” rules, they do have certain restrictions and should be harder to develop. However, with the amount of population and housing to place through 2030, it was hard to avoid all of these while maintaining regional cohesion. These really are high level indicators and a deeper scenario exercise could look at ways to develop on a site scale to mitigate impacts on each of these. Nonetheless, these indicators point toward these types of tradeoffs.

Figure 46 Percent of new population in critical habitat areas

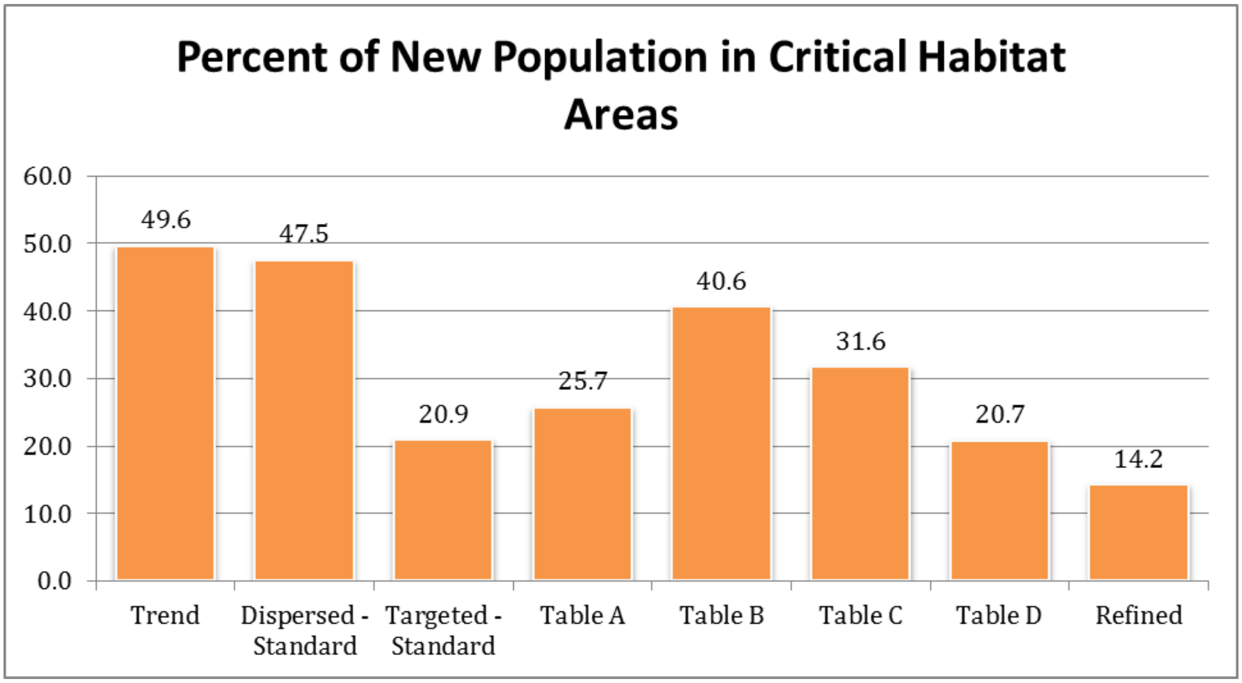


Figure 47 Percent of new population in conservation areas

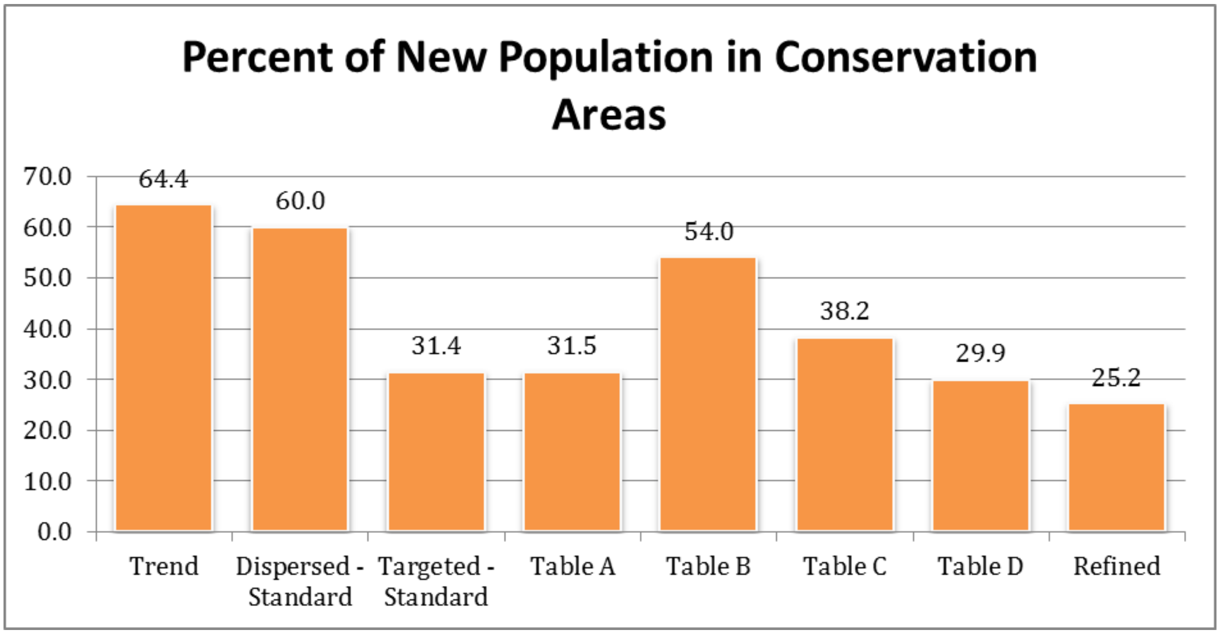
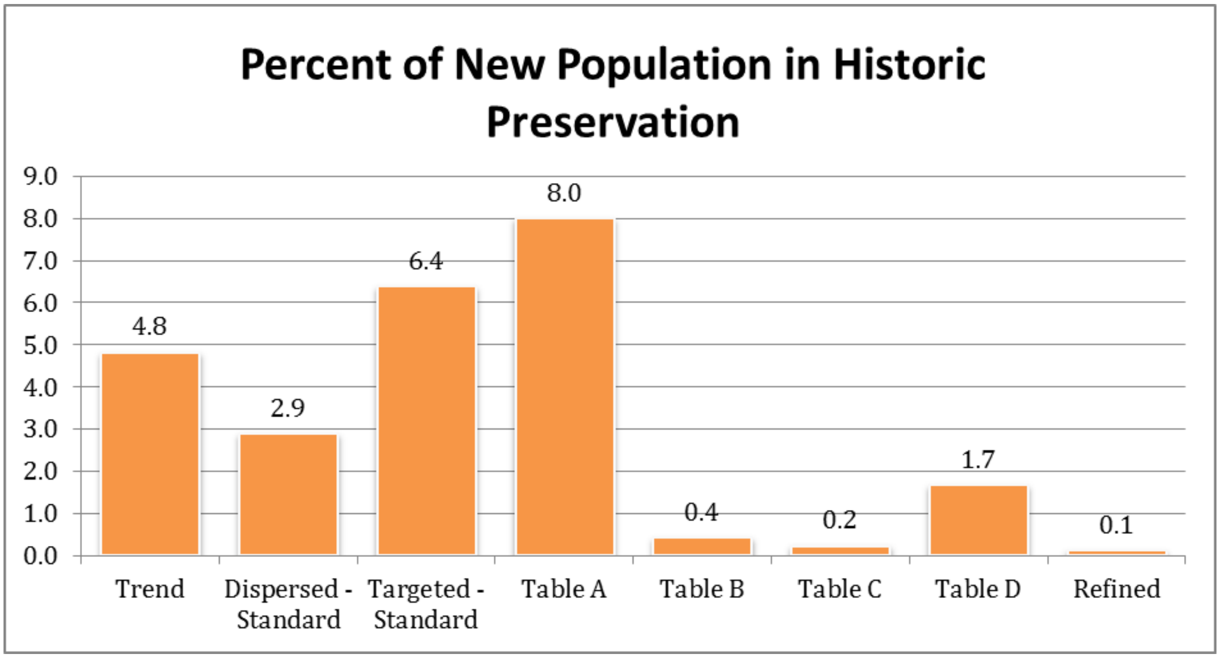


Figure 48 Percent of new population in historic preservation



The CCC identified water as one of the critical issues on Cape Cod. With many of the households sitting on septic systems, the ground water is vulnerable to nitrogen loading. Also, sea level rise could increase the threat of salt water intrusion. The costs of adapting to a limited water supply were not addressed directly as important data were not available at the time of the workshop. However, the following indicators were reported to help understand potential impacts of development scenarios.

Wellheads and water resource areas are two of the primary overlays where development has an influence on water quality. Wellhead areas are much smaller than the corresponding water resource areas and they overlap. Because people living at lower densities are more likely to live on septic systems, the percent of people living at or less than 1 dwelling unit per 10 acres is reported here. This is a very conservative metric of low density as single family homes on 1 acre could also have septic, pushing some of these indicators higher. These density assumptions are variable within the analysis and could be experimented with to get a sense of development typologies. Furthermore, cost figures could be attached to these measures to help understand what it would cost to provide infrastructure to new development at different scales.

Figure 49 Percent of new population in wellhead areas

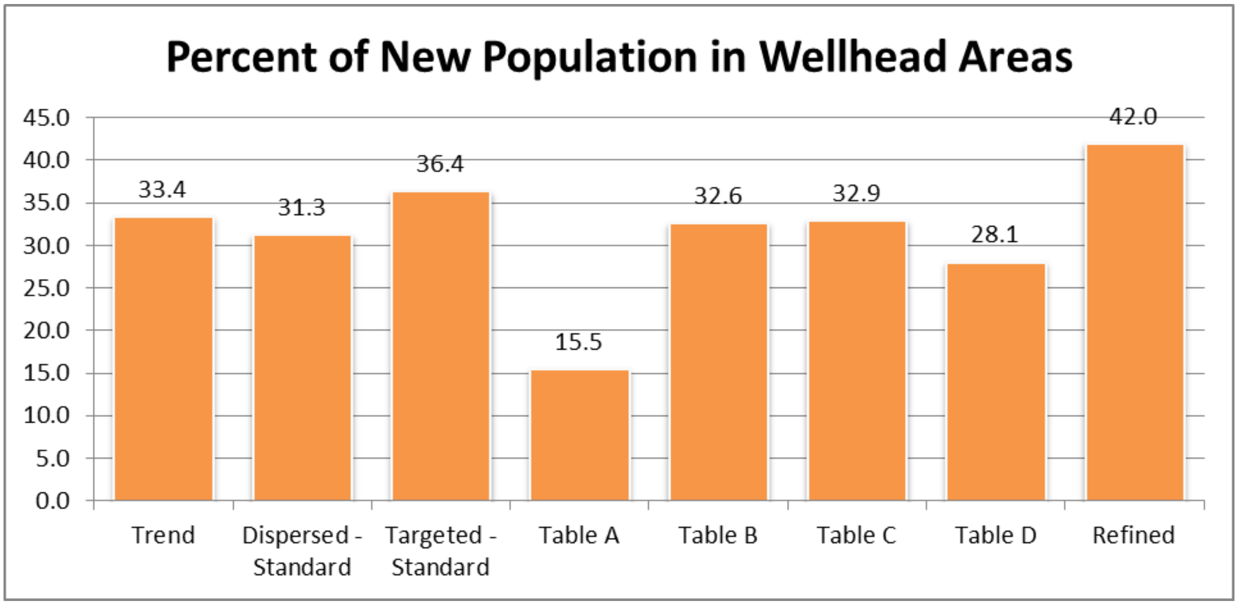


Figure 50 Percent of new population in water resource areas

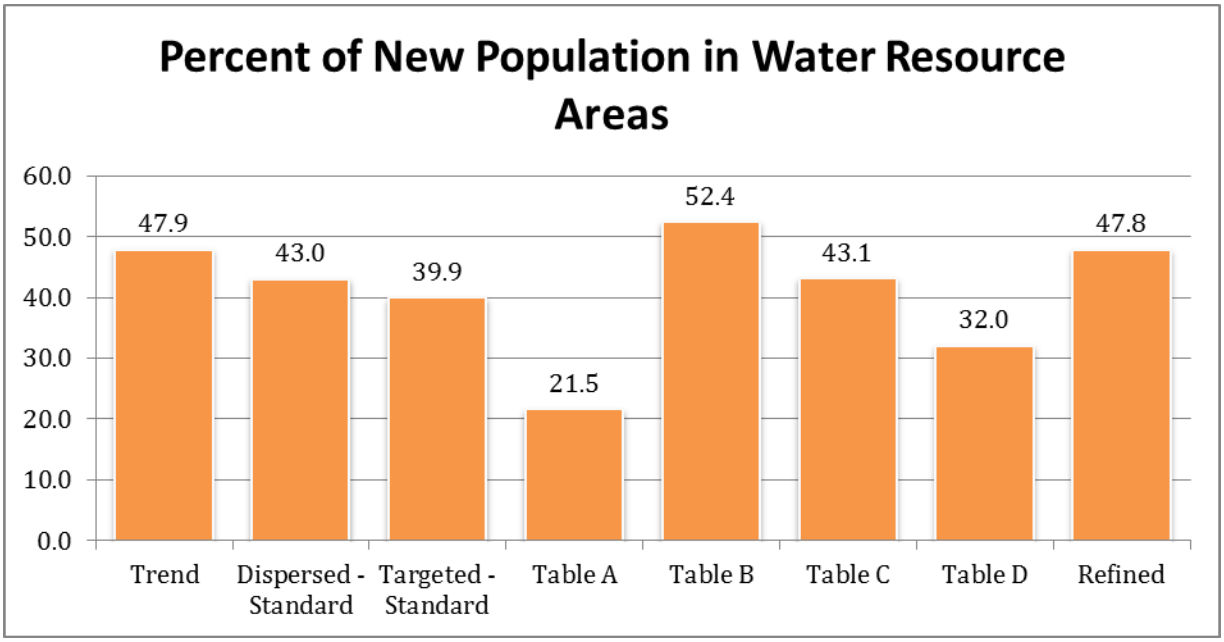


Figure 51 Percent of new population in wellhead areas at low density

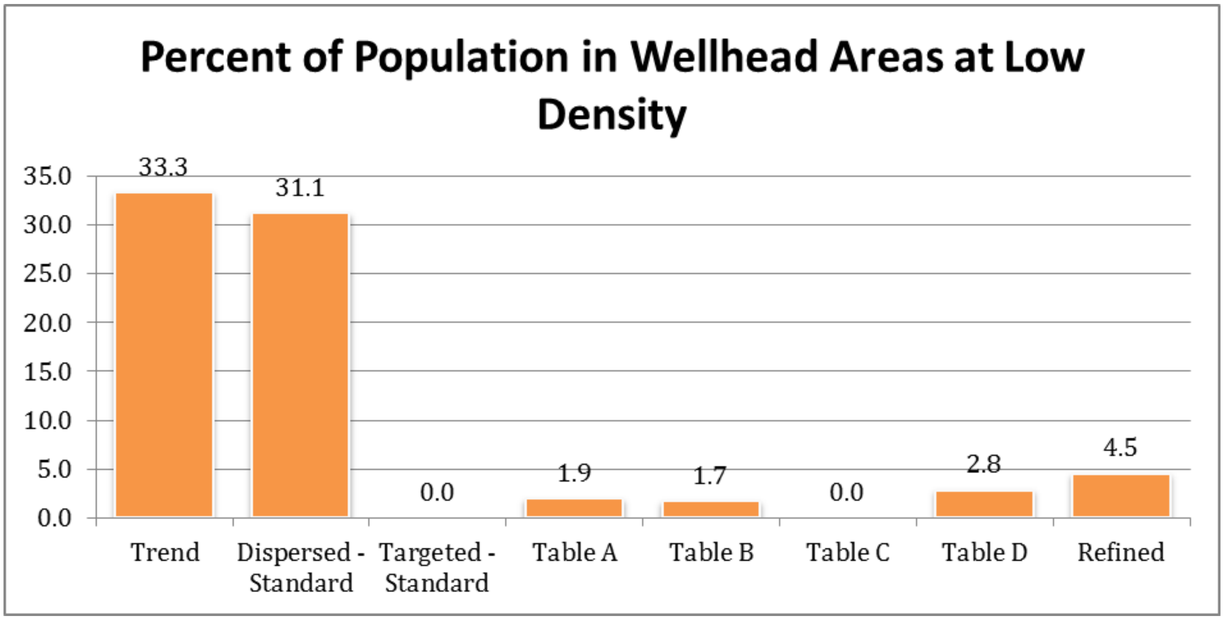
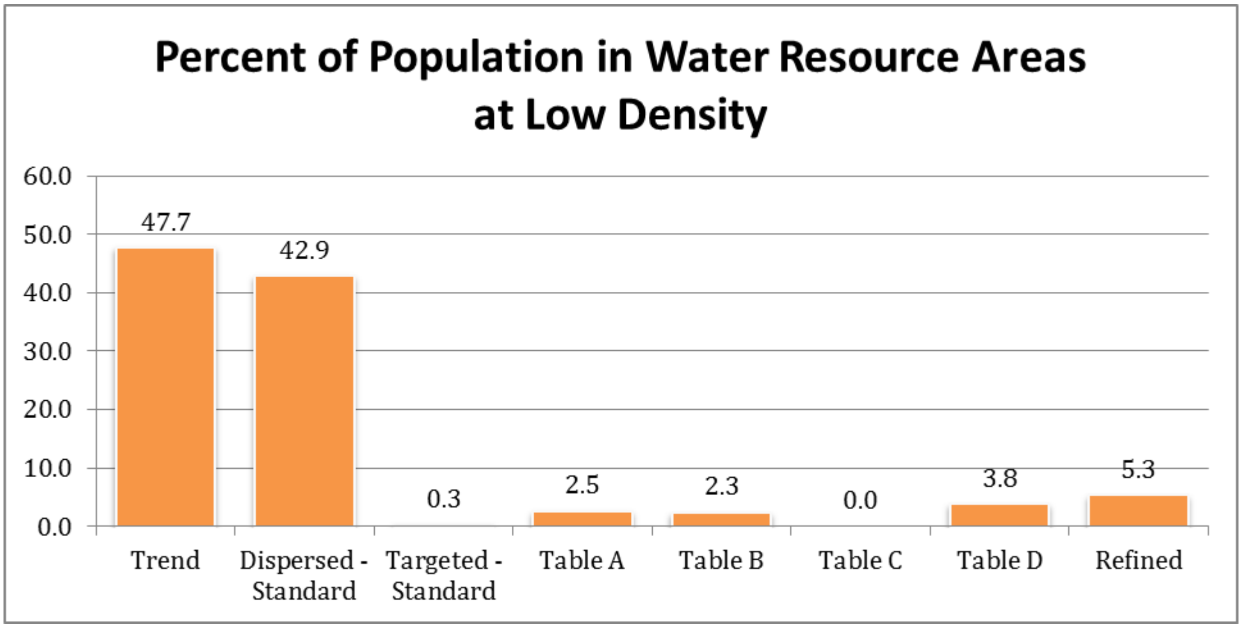


Figure 52 Percent of new population in water resource areas at low density



Conclusion

This Pilot Project represents the potential for an integrated regional planning process that considers climate change and its related causes and impacts. While care was taken to match up data when available to assumptions and indicators, there is room for syncing up this analysis more closely with a transportation modeling process and other factors like the differences in summer and winter populations.

The next steps will take the CCC and other partners through a process of adjusting the refined scenario to potentially new growth assumptions. With the release of the 2010 census, this is an opportune time to recalibrate those assumptions. With updated allocations of possible growth, regional transportation models can be synchronized to trend growth assumptions and all scenarios can be linked to cost and benefit outcomes for the region.

The successful adaptation of this approach to the particular issues facing Cape Cod can have many benefits for regions facing similar issues. A result of next steps could potentially be a model methodology to address issues that many coastal and tourist regions face.

Appendix A

Table 7 Comparison of Model Options and Inputs

PlaceMatters/Placeways Estimates								
BASE YEAR [2008]			HORIZON YEAR [2030]			DELTA [2008 - 2030]		
Population	Employees	Households	Population	Employees	Households	Population	Employees	Households
224,335	91,238	95,660	284,335	107,738	123,660	60,000	16,500	28,000

MASS DOT Transportation Model								
BASE YEAR [2010]			HORIZON YEAR [2030]			DELTA [2010 - 2030]		
Population	Employees	Households	Population	Employees	Households	Population	Employees	Households
220,000	96,706	96,886	268,732	106,288	121,731	48,732	9,582	24,845

CCC Transportation Model								
BASE YEAR [2007]			HORIZON YEAR [2030]			DELTA [2007 - 2030]		
Population	Employees	Households	Population	Employees	Households	Population	Employees	Households
232,740	121,062	101,171	287,734	140,962	131,068	54,994	19,900	29,897

Figure 53 Model comparison base year estimates

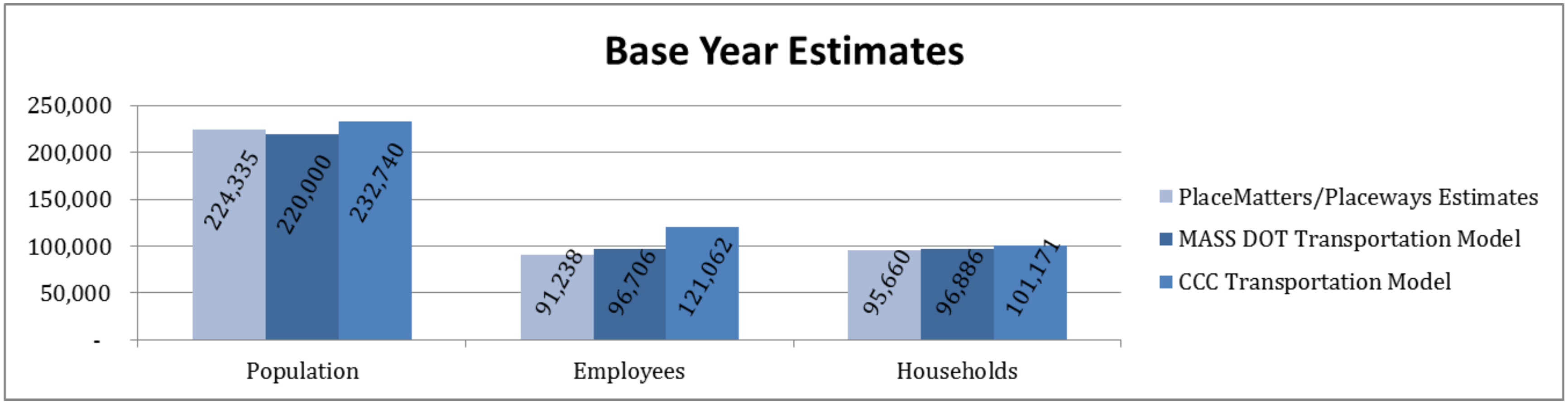


Figure 54 Model comparison horizon year (2030) estimates

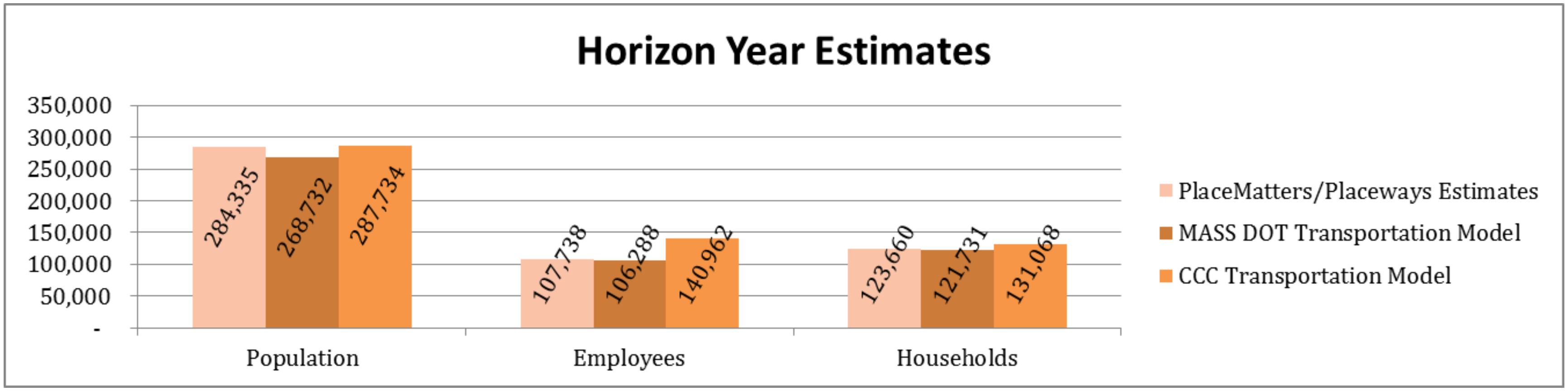
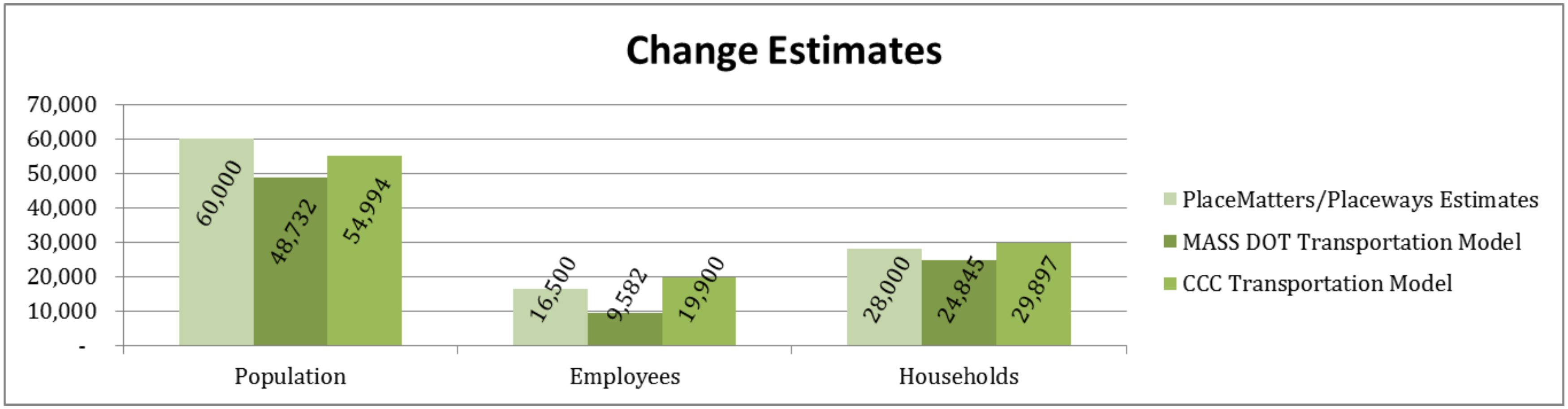


Figure 55 Model comparison change estimates



Appendix B

Table 8 Standard assumptions for transit stops including existing and planned

NAME	Latitude	Longitude	Existing	Type	Planned	PB_bus	RTA_bus	Rail	Ferry	Other
West Main St & Route 28	41.65769	-70.3335	1	Bus	0	0	1	0	0	0
Centerville	41.65016	-70.3484	1	Bus	0	0	1	0	0	0
Barnstable - Park/Ride Lot - Rte 6 & 132	41.68881	-70.3385	1	Bus	0	1	1	0	0	0
Hyannis Transportation Center	41.65667	-70.2804	1	Multi	0	1	1	0	0	0
Woods Hole Steamship Authority	41.52308	-70.6697	1	Multi	0	1	1	1	0	0
Falmouth Bus Depot	41.55538	-70.6218	1	Bus	0	0	1	0	0	0
Osterville - Tower Hill Rd & Main	41.628	-70.3833	1	Bus	0	0	1	0	0	0
Marstons Mills Marketplace	41.64809	-70.424	1	Bus	0	0	1	0	0	0
South Cape Village - Marshalls	41.61251	-70.4868	1	Bus	0	0	1	0	0	0
Mashpee Commons - Stop & Shop	41.61825	-70.4904	1	Bus	0	0	1	0	0	0
East Falmouth	41.57852	-70.5589	1	Bus	0	0	1	0	0	0
Falmouth Mall - Clock Tower	41.55985	-70.5957	1	Bus	0	0	1	0	0	0
Route 28 at Gifford Street	41.55266	-70.611	1	Bus	0	0	1	0	0	0
Falmouth Library	41.552	-70.6148	1	Bus	0	0	1	0	0	0
St. Francis/Sturgis Schools	41.65236	-70.2851	1	Bus	0	0	1	0	0	0

NAME	Latitude	Longitude	Existing	Type	Planned	PB_bus	RTA_bus	Rail	Ferry	Other
Cape Cod Hospital	41.65281	-70.2741	1	Bus	0	0	1	0	0	0
W. Yarmouth - Higgins Crowell Rd	41.65063	-70.2421	1	Bus	0	0	1	0	0	0
S. Yarmouth - Stop & Shop	41.65805	-70.2061	1	Bus	0	0	1	0	0	0
S. Yarmouth - Shaw's Supermarket	41.66228	-70.2023	1	Bus	0	0	1	0	0	0
S. Yarmouth - Main Street	41.66677	-70.1851	1	Bus	0	0	1	0	0	0
S. Dennis - Patriot Square	41.69481	-70.1516	1	Bus	0	0	1	0	0	0
Dennisport - Main Street	41.66769	-70.1243	1	Bus	0	0	1	0	0	0
Star Market - Harwich	41.67268	-70.092	1	Bus	0	0	1	0	0	0
S. Chatham - Morton Rd	41.67874	-70.0267	1	Bus	0	0	1	0	0	0
Chatham - Anchorage/Crowell Rd	41.69166	-69.9661	1	Bus	0	0	1	0	0	0
Chatham - Rotary	41.68269	-69.9617	1	Bus	0	0	1	0	0	0
S. Orleans - Route 39	41.75175	-69.9909	1	Bus	0	0	1	0	0	0
Orleans - CVS - Main Street and Route 6A	41.78804	-69.9917	1	Bus	0	1	1	0	0	0
Orleans - Underground Plaza	41.77947	-70.0016	1	Bus	0	0	1	0	0	0
Orleans - Skaket Corners/Star Market	41.781	-70.0005	1	Bus	0	0	1	0	0	0
Orleans - Old Colony Village	41.78694	-69.9949	1	Bus	0	0	1	0	0	0
Orleans - Stop & Shop	41.79574	-69.9853	1	Bus	0	0	1	0	0	0

NAME	Latitude	Longitude	Existing	Type	Planned	PB_bus	RTA_bus	Rail	Ferry	Other
Capetown Plaza	41.66957	-70.2939	1	Bus	0	0	1	0	0	0
Cape Cod Mall	41.66401	-70.2948	1	Bus	0	0	1	0	0	0
Southwind Plaza	41.67437	-70.3021	1	Bus	0	0	1	0	0	0
Cape Codder Resort at Liberty Square	41.67508	-70.3097	1	Bus	0	0	1	0	0	0
Festival Mall	41.67572	-70.3043	1	Bus	0	0	1	0	0	0
Cape Cod Community College	41.69144	-70.3392	1	Bus	0	0	1	0	0	0
Courthouse Complex	41.70017	-70.3039	1	Bus	0	0	1	0	0	0
Stop & Shop - Provincetown	42.0506	-70.1955	1	Bus	0	0	1	0	0	0
Harwichport - Route 28	41.6683	-70.0748	1	Bus	0	0	1	0	0	0
Harwich Community Center/High School	41.69263	-70.0696	1	Bus	0	0	1	0	0	0
Stop & Shop - East Harwich	41.70629	-70.0188	1	Bus	0	0	1	0	0	0
Underpass Road/Snow Road - Brewster	41.75655	-70.0664	1	Bus	0	0	1	0	0	0
Brewster Senior Housing/COA	41.7567	-70.0901	1	Bus	0	0	1	0	0	0
Salt Pond Visitor Center - Eastham	41.83791	-69.9722	1	Bus	0	0	1	0	0	0
Sagamore - Park/Ride Lot - Sag. Circle	41.78149	-70.5409	1	Bus	0	1	1	0	0	0
Harwich - Park and Ride Lot - Route 6 and 124	41.70778	-70.076	1	Bus	0	1	1	0	0	0
Eastham - Town Hall	41.81393	-69.97	1	Bus	0	1	1	0	0	0

NAME	Latitude	Longitude	Existing	Type	Planned	PB_bus	RTA_bus	Rail	Ferry	Other
North Eastham - Village Green	41.85601	-69.9874	1	Bus	0	1	1	0	0	0
South Wellfleet - Marconi Road	41.90463	-69.9847	1	Bus	0	1	1	0	0	0
Farrell's Market - Wellfleet	41.91704	-69.9949	1	Bus	0	0	1	0	0	0
Wellfleet - Town Hall - Main Street	41.93762	-70.0308	1	Bus	0	1	1	0	0	0
Wellfleet Center	41.93929	-70.0326	1	Bus	0	0	1	0	0	0
Nauset Regional High School - Eastham	41.85823	-69.9689	1	Bus	0	0	1	0	0	0
Truro - Post Office - Jam's Store	41.99371	-70.0502	1	Bus	0	0	1	0	0	0
Whitmanville Road @Rte. 6 - North Truro	42.01417	-70.0706	1	Bus	0	0	1	0	0	0
Truro - Post Office - Jam's Store	41.99371	-70.0502	1	Bus	0	1	1	0	0	0
Highland Road @Rte. 6	42.03661	-70.0801	1	Bus	0	0	1	0	0	0
MacMillan Pier - Provincetown	42.05096	-70.1866	1	Multi	0	0	1	0	1	0
Provincetown - Chamber of Commerce	42.05248	-70.1855	1	Bus	0	1	1	0	0	0
North Truro - Dutra's Store	42.0339	-70.0849	1	Bus	0	1	1	0	0	0
Provincetown Inn	42.0372	-70.1962	1	Bus	0	0	1	0	0	0
Herring Cove Beach	42.0438	-70.2162	1	Bus	0	0	1	0	0	0
Beech Forest	42.0657	-70.1926	1	Bus	0	0	1	0	0	0
Stop & Shop/Merchant's Square	41.77695	-70.5068	0	Bus	1	0	1	0	0	0

NAME	Latitude	Longitude	Existing	Type	Planned	PB_bus	RTA_bus	Rail	Ferry	Other
Osprey Lane	41.7196	-70.4635	0	Bus	1	0	1	0	0	0
George Fernandes Way	41.71774	-70.4647	0	Bus	1	0	1	0	0	0
Tom's Way	41.71069	-70.4875	0	Bus	1	0	1	0	0	0
Stop & Shop Sandwich	41.70932	-70.4842	0	Bus	1	0	1	0	0	0
Roland Place Apartments	41.69195	-70.6177	0	Bus	1	0	1	0	0	0
Dr. Julius Kelly Lane	41.76312	-70.5981	0	Bus	1	0	1	0	0	0
Falmouth Hospital	41.56608	-70.6244	0	Bus	1	0	1	0	0	0
Marconi Beach	41.89129	-69.9611	1	Bus	0	0	1	0	0	0
Provincetown Airport	42.07246	-70.2068	0	Bus	1	0	1	0	0	0
Wellfleet Drive In	41.87807	-69.9904	0	Bus	1	0	1	0	0	0
West Barnstable Depot	41.70702	-70.3741	0	Rail	1	0	0	1	0	0
Sandwich Depot	41.75981	-70.492	0	Rail	1	0	0	1	0	0
Buzzard's Bay Depot	0	0	0	Rail	1	0	0	1	0	0

Appendix C

The following maps represent constraint layers used In this GIS analysis. Here are the sources for each:

Figure 56 Map of critical species habitat

Natural Heritage & Endangered Species Program (NHESP). Priority Habitats of Rare Species. October 2008. Available at http://www.mass.gov/mgis/prihab.htm

Figure 57 Map of future water sources

Cape Cod Commission

Figure 58 Map of historic preservation areas

Cape Cod Commission

Figure 59 Map of National Seashore

Cape Cod Commission. Cape Cod National Seashore Park Boundary. 1997. Available at http://woodshole.er.usgs.gov/pubs/of2005-1048/htmldocs/data_catalog.htm

Figure 60 Map of wellhead protection areas

Cape Cod Commission

Figure 56 Map of critical species habitat

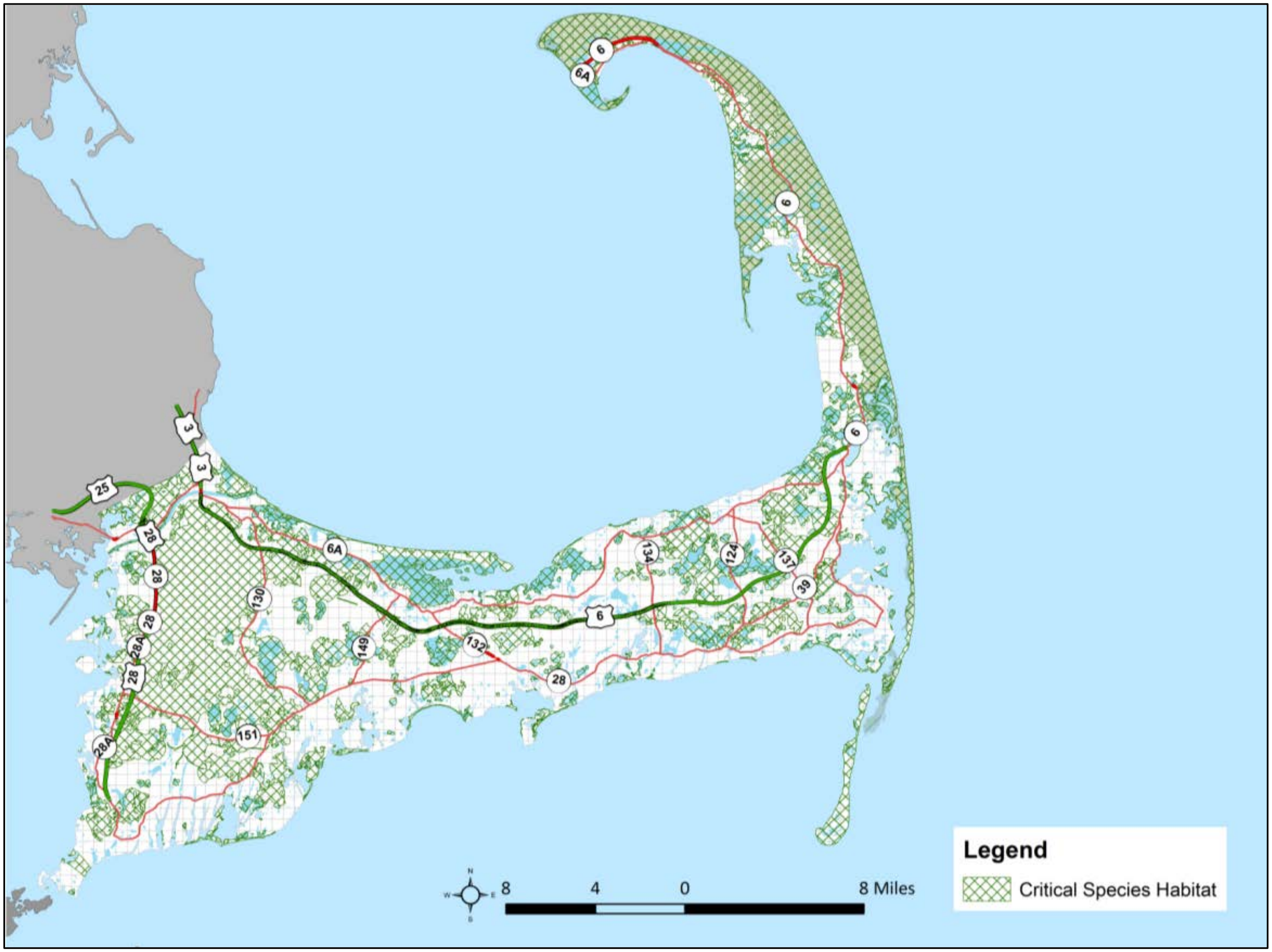


Figure 57 Map of future water sources

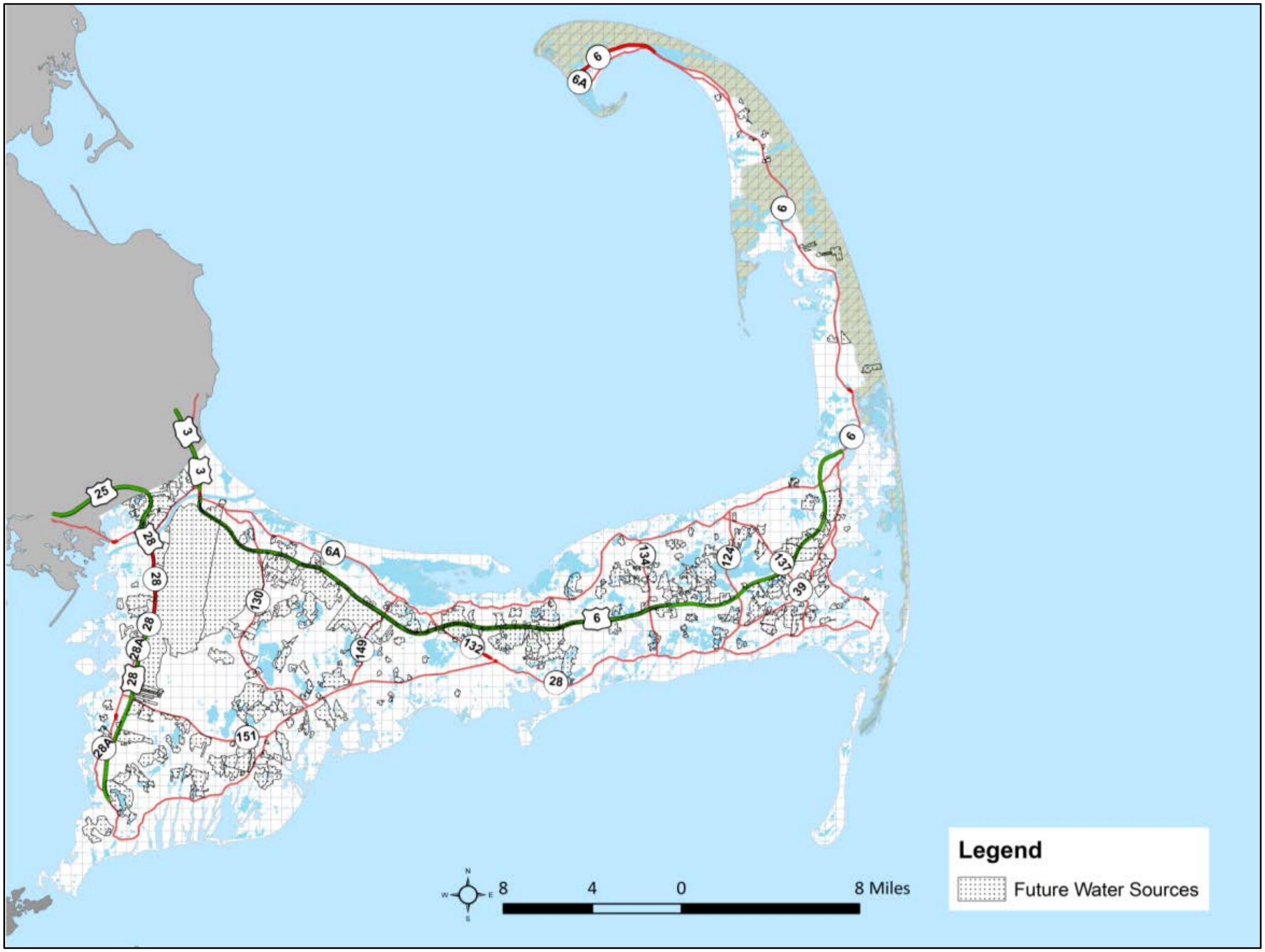


Figure 58 Map of historic preservation areas

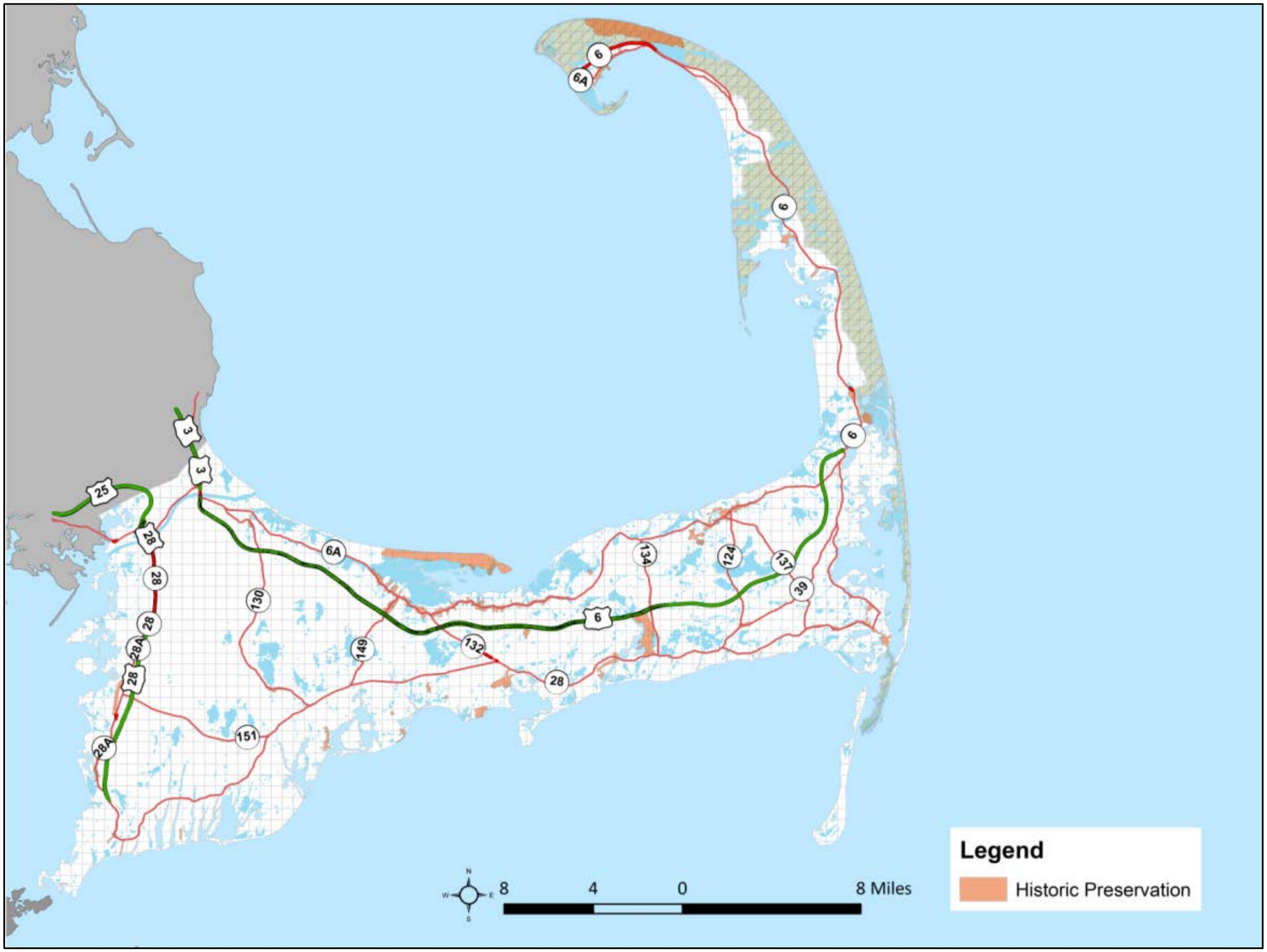


Figure 59 Map of National Seashore

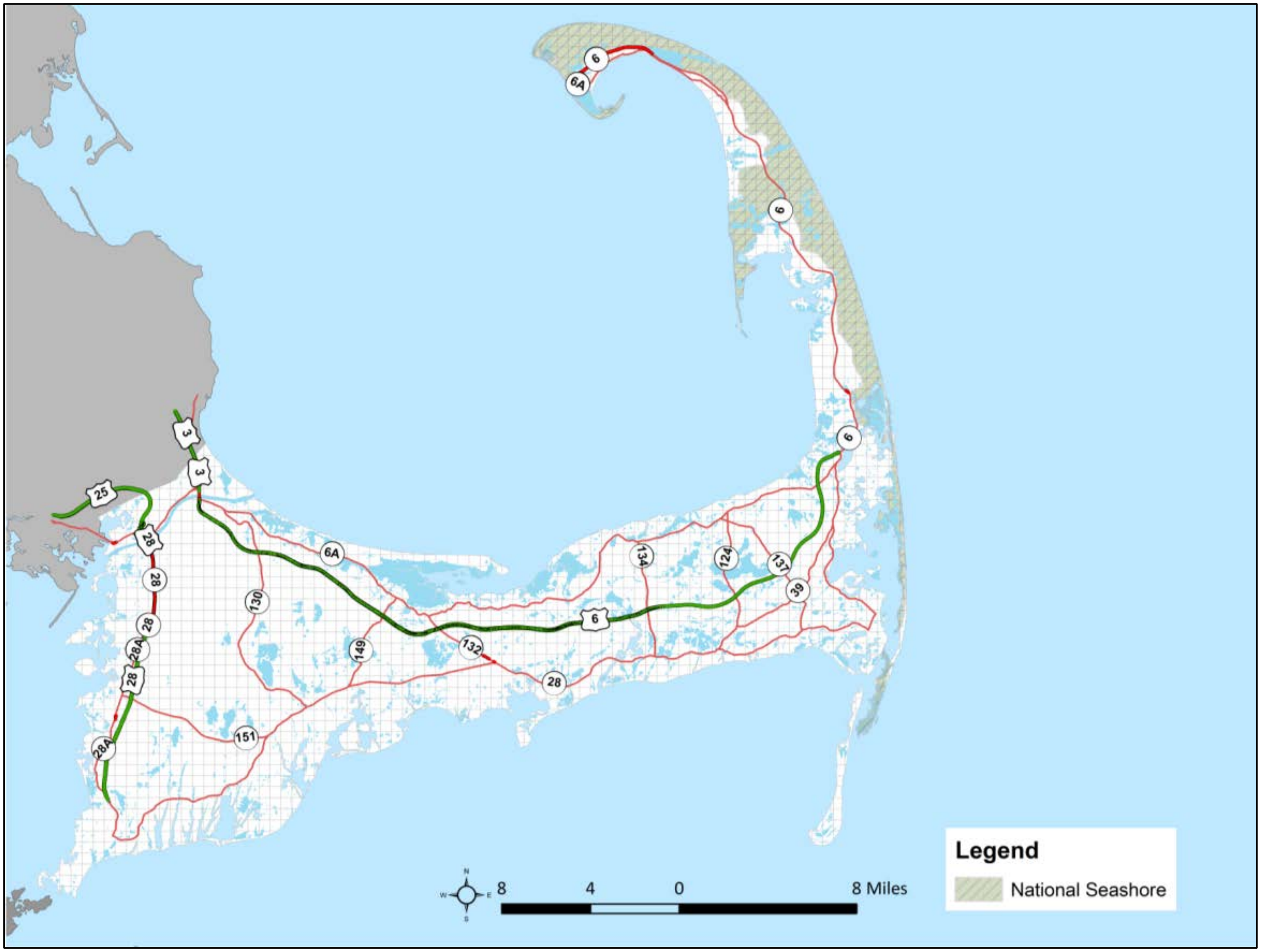
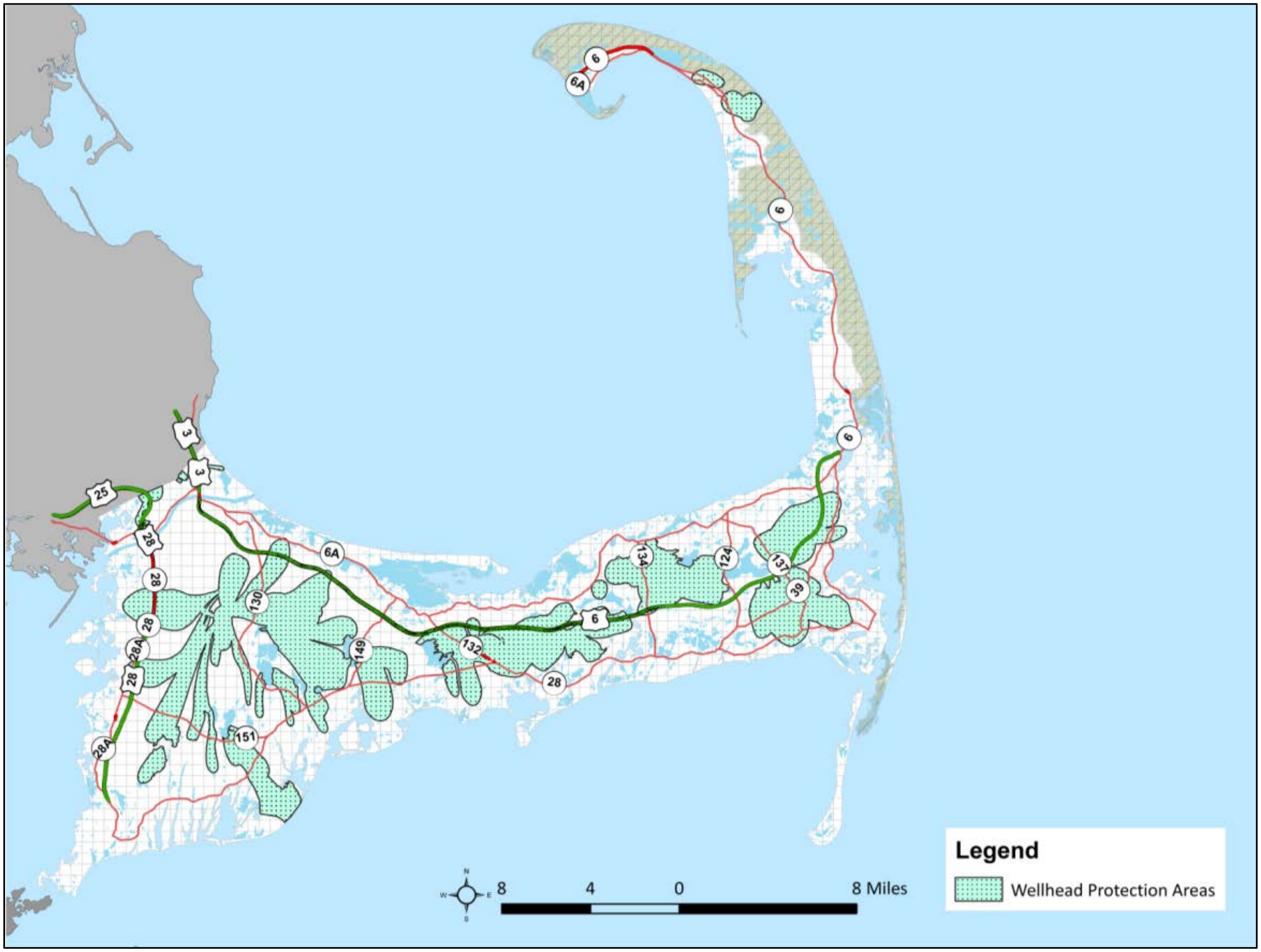


Figure 60 Map of wellhead protection areas



Appendix D

Table 9 Indicators across all scenarios

Indicator	Trend	Dispersed - Standard	Dispersed - Enhanced	Targeted - Standard	Targeted - Enhanced	Table A	Table B	Table C	Table D	Refined
15 minute capture	0	0	0	0	0	27588	0	27542	0	0
30 minute capture	0	0	6889	0	5239	51011	31868	36379	56268	86187
60 minute capture	73922	79442	158884	100045	100045	29764	48407	22805	34527	0
Percent of New Jobs Served by Transit	24.7%	21.7%	44.0%	46.3%	50.8%	47.1%	11.6%	13.9%	26.4%	33.3%
Percent of New Population Served by Transit	7.2%	16.7%	38.1%	43.1%	50.1%	44.9%	18.0%	24.1%	31.1%	24.7%
Regional Percent Change from Trend in VMT	0.0%	-0.8%	-3.3%	-6.2%	-6.8%	-7.8%	-5.6%	-6.6%	-5.8%	-5.3%
Percent Change in GHG	0.0%	-0.8%	-3.3%	-6.2%	-6.8%	-7.8%	-5.6%	-6.6%	-5.8%	-5.3%

Table 10 Indicators across all scenarios except Dispersed – Enhanced and Targeted - Enhanced

Indicator	Trend	Dispersed - Standard	Targeted - Standard	Table A	Table B	Table C	Table D	Refined
Percent Undeveloped or Rural Land Converted to Developed Land	12.7%	16.9%	2.8%	0.7%	3.2%	1.4%	2.0%	1.7%
Percent of New Jobs Served by Transit	24.7%	21.7%	46.3%	47.1%	11.6%	13.9%	26.8%	33.3%
Percent of New Population in Critical Habitat Areas	49.6%	47.5%	20.9%	25.7%	40.6%	31.6%	20.7%	14.2%
Percent of New Population in Undeveloped Areas	41.1%	32.7%	31.1%	15.1%	35.7%	28.6%	15.6%	12.4%
Percent of New Population in Wellhead Areas	33.4%	31.3%	36.4%	15.5%	32.6%	32.9%	28.1%	42.0%
Percent of New Population Served by Transit	7.2%	16.7%	43.1%	44.9%	18.0%	24.1%	31.3%	24.7%
Percent of New Population in Conservation Areas	64.4%	60.0%	31.4%	31.5%	54.0%	38.2%	29.9%	25.2%
Percent of New Population in Historic Preservation	4.8%	2.9%	6.4%	8.0%	0.4%	0.2%	1.7%	0.1%
Percent of New Population in Vulnerable Areas	28.3%	28.5%	44.0%	37.5%	19.1%	15.0%	24.9%	20.4%
Percent of New Population in Water Resource Areas	47.9%	43.0%	39.9%	21.5%	52.4%	43.1%	32.0%	47.8%

Indicator	Trend	Dispersed - Standard	Targeted - Standard	Table A	Table B	Table C	Table D	Refined
Percent of New Population in Water Resource at Low Den	47.7%	42.9%	0.3%	2.5%	2.3%	0.0%	3.8%	5.3%
Percent of New Population in Wellhead at Low Den	33.3%	31.1%	0.0%	1.9%	1.7%	0.0%	2.8%	4.5%